Water and Agriculture

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Foreword

The OECD Workshop on *Water and Agriculture: Sustainability, Markets and Policies* was hosted by the Australian authorities on 14-18 November 2005 in Adelaide. The Workshop was part of the OECD work programme on agriculture and the environment under the auspices of the Joint Working Party on Agriculture and the Environment (JWP). Under the overarching issue of the extent to which water used in agriculture is sustainable, it offered an opportunity to share knowledge and experiences on a range of policy issues regarding water and agriculture. In particular the Workshop:

- *examined the sustainability – economic, social, environmental, institutional – dimensions of agriculture's use and impact on water resources;*
- *reviewed current policy and market approaches used by countries to address agricultural water issues;*
- *explored possible policy and market approaches to ensure further progress in agriculture's sustainable use of water resources; and*
- *identified issues that could be further examined by decision makers, researchers and the OECD.*

The Workshop brought together 120 participants from 17 OECD governments as well as China and South Africa, and a wide range of representation from the academic community, agricultural, environmental, water and business interests, and international and non-governmental organisations.

The focus of the Workshop was on two broad themes: the linkages between the quantity and quality of water and agriculture; and the policies, management, and institutions influencing the sustainability of water in agriculture. Each theme was explored in depth supported by country examples, with background to the discussions provided by general overview papers. An integral part of the Workshop were two study visits, which enabled participants to see in practice the way in which water is managed in farming enterprises in the South Australian Riverland region.

In this collection of papers, the reader will find a wealth of material relating to agriculture's impact on water use and quality. It is hoped this book will contribute to the important debates on how agriculture can better manage scarce water resources, enhance water quality and provide ecosystem services, particularly in the context of agricultural policy reform, progress in advancing sustainable development, and the potential effects of climate change. While it is not an exhaustive analysis of all of the issues and many questions remain, it does point to the need for further multi-disciplined analysis.

ACKNOWLEDGEMENTS

These proceedings bring together papers from the OECD Workshop on *Water and Agriculture Sustainability, Markets and Policies*, held on 14-18 November 2005 in Adelaide, Australia. The Secretariat gratefully acknowledges the voluntary financial contribution from the host country, Australia, as well as Spain, which made this Workshop possible.

The Workshop was organised by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF), the Government of South Australia Department of Water, Land and Biodiversity Conservation and the Australian Central Irrigation Trust, in close collaboration with the OECD. For the OECD Kevin Parris was responsible for the structure and content of the Workshop, assisted by Wilfrid Legg. Theresa Poincet provided secretarial assistance. Ross Dalton, Fiona Bartlett, Angela Robinson and Damien Victorsen from DAFF, co-ordinated the Australian input, with the help of Richard Sisson and Roland Pittar in the Australian Delegation to the OECD in Paris. The OECD wishes to thank all those who provided papers and contributed to the success of the discussions, including all the Workshop Chairs and Discussants. DAFF edited the papers with OECD input from Kevin Parris and Theresa Poincet, who also prepared the final publication.

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HIGHLIGHTS

Agriculture's use and impact on water resources involves complex trade-offs between economic, social and environmental demands under a wide range of institutional structures. Irrigated farming accounts for a major and growing share of farm production and rural employment in some OECD countries, but overuse of often scarce water resources is an increasing concern. Agriculture is a major source of water pollution but also contributes to ecosystem services (*e.g.* provision of habitat for some wildlife), for certain regions within some OECD countries. Agricultural production support and subsidies for variable inputs, especially for water and energy, continue to misalign farmer incentives and aggravate overuse and pollution of water across many OECD countries.

The major challenge is to ensure that water resources used by agriculture are best allocated among competing demands to efficiently produce food and fibre, minimise pollution and support ecosystems, while meeting social aspirations under different property right arrangements and institutional systems and structures.

Policies and actions are beginning to shift toward more sustainable agricultural water management in OECD countries as policy makers are giving higher priority to water issues in agriculture and are using a mix of market-based, voluntary and regulatory approaches to address these issues. There is a widespread recognition of the need for greater use of market based instruments, such as better pricing structures and tradable permits, accompanied by government regulations, as well as co-operative efforts among water users. But the adoption of these measures should take into account the frequent regional imbalances of water resources within countries and the negative and positive environmental externalities arising from agriculture's use of water. A growing concern is the impact of agricultural policy on opportunities to mitigate or adapt to climate change and climate variability as they affect the water sector.

Countries are at different stages in reforming their water policies, partly reflecting the varying importance of water related issues in agriculture across OECD countries and current systems of property rights and management structures. But all countries need to reinforce the monitoring and evaluation of current water policy reform initiatives to ensure that these reforms are moving toward sustainable agricultural water management.

There are gaps in knowledge about both the science and data concerning the linkages between agriculture and water resources, which are an impediment to the flow of information to help improve policy decision making and actions at various spatial levels from the watershed, regional, national to international levels, but improving the science and collection of information is costly.

The Workshop recommended a number of issues that could be addressed by policy decision makers, ranging from decision makers at the watershed through to national levels, including:

- using an appropriate mix of instruments and tools aimed at addressing agriculture resource management issues to ensure the achievement of coherent agricultural, environmental and water policy goals as well as cost effective implementation (*e.g.* integrated policy treatment of water and energy input use by agriculture), including co-ordinated policy responsibilities and structures at different levels from the watershed to national level;
- integrating and expanding current scientific research and data collection capacity to underpin improved policy making, including better water accounts;
- identifying property rights attached to water withdrawals, water discharges and ecosystem provision;
- establishing clear lines of responsibility in the institutional framework to manage water – who does what, who pays for what, who monitors and evaluates – underpinned by a long term commitment from governments to resource the necessary actions, especially with the growing concerns related to climate change and climate variability;
- strengthening water policy reforms to provide a robust regulatory framework to allow, for example, for water pricing and trading, and water service competition or benchmarking performance where competition is limited, and nutrient trading for pollution abatement; and,
- raising the capacity for stakeholders (farmers, industry and community groups) to participate in the design and delivery of policy responses for integrated water management.

Conclusions and Recommendations[1]

1. Objectives of the Workshop

The OECD Workshop was hosted by the Australian government and held in Adelaide, on 14-18 November, 2005, drawing together a wide range of stakeholders representing agricultural, environmental, agro-food and water industry interests from government, the private sector, International Governmental Organisations and Non-Governmental Organisations. The focus was to:

- examine the sustainability – economic, social, environmental, institutional – dimensions of agriculture's use and impact on water resources;
- review current policy and market approaches used by countries to address agricultural water issues;
- explore possible policy and market approaches to ensure further progress in agriculture's sustainable use of water resources; and
- identify issues that could be further examined by decision-makers, researchers and the OECD.

2. Background: Why are the linkages between agriculture and water important?

The major challenge for the sustainable use of water resources in agriculture is to manage community expectations to meet social and environmental aspirations, while ensuring that food and fibre is produced competitively and profitability.

Agriculture's use and impact on water resources are complex and dynamic, especially in the context of the impacts of climate change and variability on agricultural systems, and involve trade-offs between economic, social and environmental demands. While agriculture is one among many different demands for water (*i.e.* urban, industrial, recreational uses, and for maintaining aquatic ecosystems), for many countries it is the major user of water resources (for irrigated farming and the livestock sector), while its impact on water quality is also significant in many cases. On the other hand, improvements in water productivity by agriculture over the past 40 years have played an important role in helping to expand food production and provide employment in rural areas, while pollutant discharges from agriculture have been declining in recent years for many regions within OECD countries.

1. These Conclusions and Recommendations have been prepared by the OECD Secretariat and do not necessarily reflect the views of the OECD member countries and participants at the Workshop.

Irrigated farming accounts for a major and increasing share of agricultural production, farm exports and rural employment for some OECD countries, but overuse of water resources is an increasing concern. In addition, the growing incidence and severity of droughts linked to climate variability and climate change is placing pressure on farming and water resources. Overexploitation of water resources by agriculture, within some regions across certain OECD countries, is leading to:

- reduced environmental flows in rivers and lakes;
- natural recharge rates of aquifers being exceeded;
- increased competition for water resources between farmers and other demands for water, including the maintenance of aquatic ecosystems; and,
- higher agricultural energy intensity, as the expansion of irrigated farming usually leads to an increase in the energy requirements to support this system of farming.

Over recent years, there has been a shift by farmers and policy makers in most OECD countries from water resource exploitation to water resource and environmental management. This is associated with changing societal demands, as farmers seek to both improve their efficiency in the use of water resources and also address the growing societal interest in the conservation of aquatic ecosystems.

There is also a greater public awareness that water used by agriculture is not a "free" good for personal benefit, but one that imposes costs and generates benefits. Although water application rates per hectare irrigated have been improving in many cases, wastage and inefficiency in water use remain high, associated with poor maintenance of irrigation infrastructure and a low rate of adoption of efficient irrigation technologies, such as drip emitters. Under some farm management practices and farming systems agriculture maintains and enhances certain ecosystem services related to water, such as maintaining water meadows and facilitating groundwater recharge.

Agricultural water pollution is also a focus of attention for many OECD countries due to the:

- reduction in pollution by non-agricultural polluters which has been more rapid than for agriculture, with farming mainly responsible for nitrate and phosphorus water pollution;
- increase in point pollution from agriculture linked to the intensification of livestock farming, especially in the pig, poultry and dairy sectors;
- greater public awareness of the damage to aquatic ecosystems from certain agricultural practices;
- growing concerns related to groundwater and coastal pollution, especially from the leaching of phosphorus and pesticides; and,
- uncertainty over the extent and severity of those water pollutants derived from farming that are in general poorly monitored (*e.g.* pathogens, salts, heavy metals and soil sediment).

Agricultural production support and subsidies for variable inputs, especially for water and energy**,** continue to misalign farmer incentives and aggravate overuse and pollution of water across many OECD countries. Market price support provides incentives to intensify agricultural production, while support for irrigation systems infrastructure capital (depreciation costs), operation and maintenance costs (including institutional costs) together with support to lower water supply charges, for many OECD countries discourages the more efficient use of water resources. Energy subsidies to agriculture in some countries, by lowering pumping costs, are aggravating the depletion of aquifers and increasing the energy intensity of irrigated agriculture. While agricultural support varies greatly between OECD countries and across different commodities, the provision of support for water and energy use by agriculture is common to many countries.

3. Main points from the Workshop papers and discussion

Some 50 papers were presented at the Workshop, covering the two central themes of agriculture's linkage to water quantity and water quality, over the four dimensions of sustainability – economic, social, environmental and institutional. This section provides a brief summary of the main points that emerged from the Workshop papers and discussion.

Knowledge – Science and data gaps

The Workshop highlighted a number of areas where gaps in knowledge of both the science and data concerning the linkages between agriculture and water resources are an impediment to the flow of information to help improve policy decision making and actions at various spatial levels from the watershed, regional, national to international levels (*i.e.* 'if you cannot measure it you cannot manage it'), but recognised that improving the science and collecting relevant information is costly, including:

- measuring and improving scientific understanding of the transmission and fate of farm pollutants into water bodies (rivers, lakes, aquifers, coastal waters), especially nutrients, pesticides, pathogens, salts, heavy metals and soil sediment;

- developing water accounting systems to better understand the science of water resources (*e.g.* stocks and flows in the system, aquifer dynamics) and practices (irrigation management and technologies) and how much water is being used, and how efficiently (in both physical and economic terms);

- understanding and measuring social capital in the context of agriculture and watershed management, so as to more clearly target social issues, institutions and main stakeholders;

- examining the merits of using the 'virtual water' concept (*i.e.* water required to produce a unit of crop or livestock output) as a tool to assist policy makers in helping to improve the efficiency of water use in agriculture;

- exploring the effects of climate change, variability and uncertainty on agriculture and water resources, including the institutional and policy responses, the distributional consequences, and the need to examine the linkages between one environmental area – water resources – and the consequences for other areas such as greenhouse gas emissions, energy and chemical input use; and,

- analysing the effects of existing policy distortions and policy reforms on agricultural water use and water quality, including the measurement of subsidies and prices for irrigation water.

Water management

The need for improving the management of water resources by agriculture is now widely recognised (*e.g.* in the Global Millennium Assessment) in view of the global pressure on water resources associated with growing populations and food and fibre demand, and in the context of increasing concerns related to climate change and climate variability.

Better management of water resources in agriculture requires identifying the reference levels that determines when farmers should pay for the pollution they generate (polluter pays principle), such as where the quality of drinking water is affected, and when society should assist farmers to enhance the provision of ecosystem services, such as the conservation of wetlands and groundwater recharge. This also involves better defining the property rights attached to water withdrawals and the rights attached to allowing discharges into water bodies from agricultural activities.

Water quantity trading has been established in some countries to increase the flexibility and efficiency in water resource management linked to agriculture, but government regulation has also helped in establishing markets for water allocation. For water pollution abatement, ***nutrient trading*** has two key advantages: as a means of providing incentives to reduce nutrient pollution; and as a way of achieving flexibility of land use in the face of regulatory restrictions. More widespread use of nutrient trading to reduce pollution abatement requires improved knowledge of mitigation strategies and best management practices, as well as government regulation to develop nutrient trading.

In some OECD countries the moves toward ***cost recovery, water pricing and water trading,*** have led to improvements in water management by farmers, through water resource saving, inducing technological innovation, shifting to higher value agricultural commodity production, and providing incentives to reduce pollution. But moving towards cost recovery for water will need to take into account the negative and positive environmental externalities arising from agriculture's use of water, and recognise that the importance of water resource issues in agriculture varies, reflecting, in particular, different ecological conditions across OECD regions and countries, from one of water abundance to one of water scarcity.

Policies and governance

Water reform programmes are being implemented across the range of national to watershed scales in many OECD countries, while these programmes usually involve, but are not specific to, the agricultural sector. There is a growing recognition that water policies should be coherent across different scales of decision-making - from the farm through to water catchment, national and international levels, and also between the different users (*e.g.* urban, industry) and uses of water (*e.g.* aquatic ecosystems, recreational uses). The need for policy coherence is also important across agricultural, environmental and water policies, especially to avoid conflicting signals and incentives to farmers in achieving sustainable water management.

Policy responses to address water quality and quantity issues in agriculture need to be part of a policy package that encompasses a range of policy instruments, institutional reforms and broader community engagement. Water policies and institutions need to focus on the public good (*e.g.* maintaining aquatic ecosystems) and market failure aspects of water resources (*e.g.* resource depletion and pollution), by facilitating stakeholder involvement, developing information (data) and knowledge (science), and enabling public access to this information. Moreover, given the high level of vulnerability of agricultural systems and water resources to climate change and climate variability, policies will need to be increasingly responsive and flexible in adapting to these changes.

There is a diversity of approaches to water management policies across OECD countries with different emphasis on water pricing and cost recovery, property rights, quasi water markets, taxing pollutants, payments and other policy approaches to achieve water policy goals. There is also increasing emphasis being placed in many countries in establishing decision support tools and risk management strategies to improve water management by farmers. Policy focus, however, tends to be on surface water (visible) so attention to the overuse and pollution of groundwater (invisible) also needs to be strengthened.

Understanding the links between agriculture, water use and water quality can help target the appropriate policy responses (Figure 1). Pressure on water quality from agricultural activities can be caused by poor land management practices (*e.g.* poorly timed manure spreading, dryland salinity through tree felling, tillage practices exacerbating soil sedimentation run-off). While pressure on water resources (quantity) is largely the result of excessive extractions, modification of flow regimes through storage, the poor management of irrigation infrastructure and inadequate uptake of efficient water application technologies by irrigators leading to water wastage and inefficiencies.

For countries where water scarcity or problems of water pollution linked to agriculture have been acute, this has prompted them to take action earlier than other countries. Some countries are building on and adapting existing institutional structures to implement water reform programmes and others, at an earlier stage with their reform programmes, are in the process of creating the required institutions.

Some countries are refining, developing and introducing market based approaches for water resource allocation and pollution, but little evaluation of their economic efficiency and environmental and social effectiveness has been undertaken. Moreover, clearer identification and enforcement of property rights is required if water markets are to be developed.

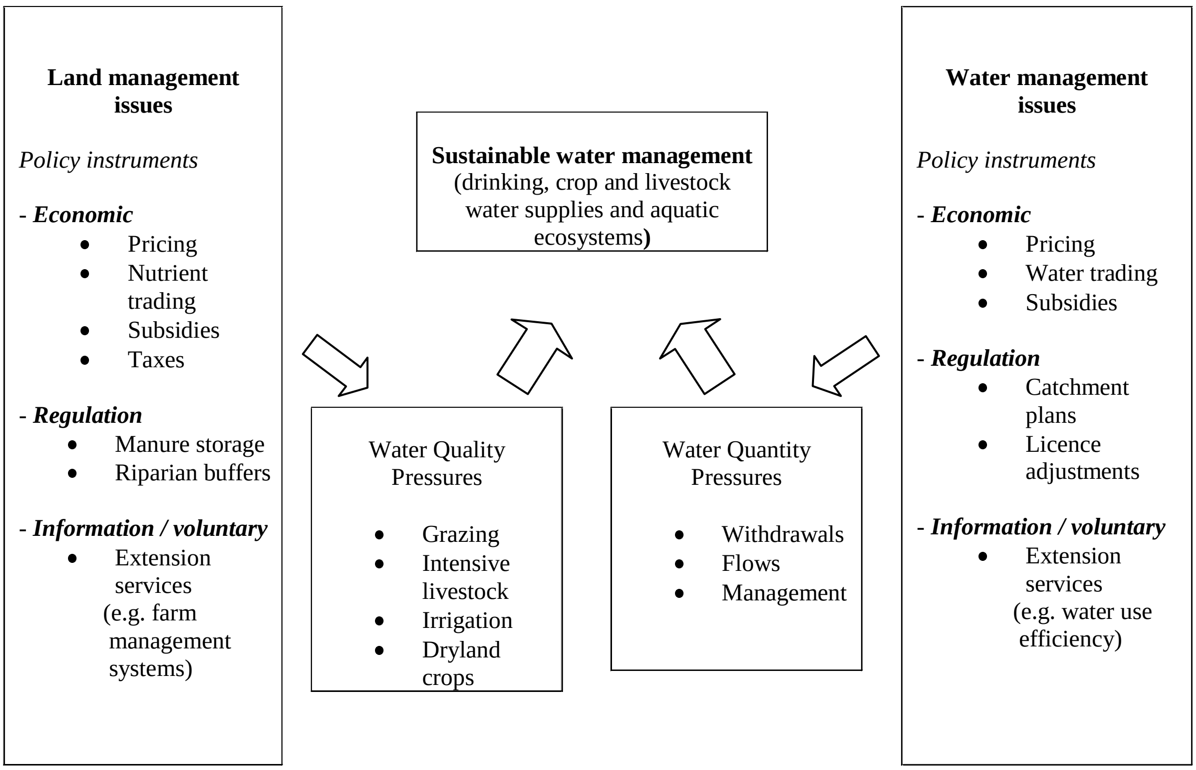
Well defined and enforceable property rights are the cornerstone of democratic and economic systems in all OECD countries, with most water rights relating to a right to use water or allow discharges into water, both of which provide the foundations of a water trading system. But limits are usually imposed on this right (*e.g.* drawing water or discharging waste into water bodies), and some countries are now engaged in the process of separating water entitlements from land title rights.

Developing stakeholder involvement is crucial to improve water and watershed management, but this can take time. Targeting communities, rather than individuals, seems a preferred solution to water governance issues. But transaction costs for stakeholder involvement are high, especially in the initial phase of pilot programmes, which points to the need to translate these pilots to a broader adoption or implementation at a larger scale so as to streamline the stakeholder engagement process. In this context, governments also need to monitor the equity and distributional effects of water reform policies on different stakeholders, and introduce appropriate safeguards and mechanisms to address these effects where they may be detrimental to both the farmer and wider community welfare.

4. Workshop recommendations of issues that could be addressed

The Workshop recommended a number of issues that could be addressed by OECD member countries, researchers and the OECD Secretariat, building on the issues and responses identified at the FAO and the Government of The Netherlands, which jointly organised the International Conference on Water for Food and Ecosystems (The Hague, The Netherlands, February 2005), as well as issues identified in other recent international fora related to water (*e.g.* the United Nations Commission on Sustainable Development, the World Water Forum, and Sweden International Water Week). The issues outlined here are not listed in order of importance.

Figure 1. Sustainable water management



Source: OECD Secretariat, adapted from Seamus Parker's Rapporteur's presentation at the Workshop.

Policy decision makers in OECD member countries

Issues that could be addressed by policy decision makers, ranging from decision makers at the watershed through to national levels, include:

- using an appropriate mix of instruments and tools aimed at addressing agriculture resource management issues to ensure the achievement of coherent agricultural, environmental and water policy goals as well as cost effective implementation (*e.g.* integrated policy treatment of water and energy input use by agriculture), including co-ordinated policy responsibilities and structures at different levels from the watershed to national level;
- integrating and expanding current scientific research and data collection capacity to underpin improved policy making, including better water accounts;
- identifying property rights attached to water withdrawals, water discharges and ecosystem provision;
- establishing clear lines of responsibility in the institutional framework to manage water – who does what, who pays for what, who monitors and evaluates – underpinned by a long term commitment from governments to resource the necessary actions, especially with the growing concerns related to climate change and climate variability;
- strengthening water policy reforms to provide a robust regulatory framework to allow, for example, for water pricing and trading, and water service competition or benchmarking performance where competition is limited, and nutrient trading for pollution abatement; and,
- raising the capacity for stakeholders (farmers, industry and community groups) to participate in the design and delivery of policy responses for integrated water management.

Researchers

Issues that could be addressed by researchers – ranging from government research institutes, the agro-food industry, environmental groups, and international governmental organisations – to help drive the research agenda toward supporting sustainable agricultural water management include:

- developing decision support tools that integrate cause-effect linkages and facilitate integrated water management at the farm and catchment levels;
- calculating the 'true' price of supplying irrigation water, taking into account the infrastructure costs as well as other costs, including the costs of planning and managing the resource, scarcity value, and the environmental and social externalities (positive and negative) associated with agricultural use of water resources, especially consideration of the economies of scale of different irrigation systems, and the equity and distributional effects on communities in watersheds as a result of water policy reforms;
- developing technologies and farm practices that improve agricultural management of water;
- assessing and comparing property rights and institutional regimes for integrated water management;

- undertaking research to better understand the impacts of climate change on water availability for agriculture and to identify adaptation strategies and policies; and,
- developing methodologies for water information and monitoring systems to support agricultural water management.

OECD Secretariat

Issues that could be explored by the OECD Secretariat include the:

- monitoring and evaluating policies and policy reforms that address water quantity and quality issues in agriculture, building on inventories of different policy approaches and data on water use, pollution and management trends (especially groundwater) across OECD countries, so as to document 'success stories' as well as the lessons learned;
- identifying ways of measuring the costs and benefits of agriculture's use and impact on water resources, taking account of the economic, environmental and social elements;
- examining the effects of different institutional arrangements on water management to develop a common set of principles to help countries improve the institutional framework for water management, with social (watershed stakeholders/community) learning and engagement a prominent theme in such analysis; and,
- analysing the impact of alternative policies and market solutions in developing agriculture's ability to mitigate and adjust to climate change and variability, taking into account differences across countries.

Address by Senator Ian Macdonald

Australian Government Minister for Fisheries, Forestry and Conservation

to the OECD Workshop on
Agriculture and Water: Sustainability Markets and Policies
14 November 2005, Adelaide Convention Centre

Good morning, ladies and gentlemen, and welcome to Adelaide.

I doubt you could find a more suitable setting for your workshop on agriculture and water. Adelaide is the capital city of the driest state in Australia, which — in turn — is the world's driest inhabited continent.

While you are here, I hope you will find time to sample some of South Australia's superb agricultural produce including its wines, which are of exceptional quality.

Water trading has proved important in providing secure water to underpin the growth in vine plantings in recent years. Sampling our local wines will give you the chance to appreciate one of the benefits of a functioning water market.

Water quality and water availability have been regular topics for conversation at the yearly meetings of the leaders of Australia's governments in the past decade. Over that time, we have agreed on three major reform programmes that I will discuss briefly today.

However, before focusing on Australia's circumstances, I would like, briefly, to take a more global view. For this I refer you to recent comments from Kofi Annan, the Secretary General of the United Nations.

In March this year, when introducing the International Water for Life Decade, he said:

> *…(M)any millions of people around the world face water shortages and a daily struggle to secure safe water for their basic needs…*
>
> *Providing access to water and sanitation is … fundamental for achieving the other Millennium Development Goals, such as alleviating poverty, hunger and malnutrition; reducing child mortality; increasing gender equality; providing more opportunity for education; and ensuring environmental sustainability. …*
>
> *Water is also necessary for agriculture and for many industrial processes. With improved scientific understanding, the international community has also come to appreciate more fully the valuable services provided by water-related ecosystems, from flood control to storm protection and water purification.*

(Kofi Annan, Secretary-General of the United Nations,
introducing the International Water for Life Decade, 22 March 2005)

Global view

We face enormous challenges if we are to meet the needs of the next generations.

Although water covers 70 per cent of the world's surface, only 2.5 per cent of it is fresh. And less than 1 per cent is accessible for human use.

Water use grew at more than twice the rate of population during the 20th century and water tables are falling in every continent. In 2000, at least 1.1 billion people — or 18 per cent of the world's population — lacked access to safe water. If present water consumption trends continue, the number will have more than doubled by 2050.

The developing world faces the most significant challenges and they come in two parts. The first is water availability and the second water quality.

For many of us here today, water policy issues are more about quality and managing the impact of farming on rivers, wetlands and supplies of drinking water. In Australia, water quality is an issue, but we are preoccupied with its availability.

I ask you to keep this wider context in mind during the next few days. Clean water is a scarce commodity for all of us, and there are many stakeholders with an interest in how well it is being used.

Water availability, water quality and lifting the environmental performance of agriculture are not new issues in the OECD's forums. In 2001, the report, *Improving the Environmental Performance of Agriculture, Policy Options and Market Approaches*, canvassed many of the issues that I see being further developed in papers for this workshop.

Last November's OECD Report on *Agriculture and the Environment, Lessons Learned from a Decade of OECD Work* also provides some useful guidance for your discussions. The report notes, in particular, that there is unlikely to be a general 'one-size-fits-all' formula to achieve the best possible policy mix, including market approaches, because ecological conditions and public preferences vary across countries.

And while there have been some reforms, the OECD noted many member countries continue to provide commodity production-linked support measures that are also incentives to adopt environmentally harmful practices. Among them are more intensive use of chemicals and expanding commodity production on environmentally sensitive land, which increases the cost to the environment.

More recently, some member countries have linked environmental cross-compliance conditions to commodity production subsidies. As the OECD noted, these conditions may mitigate some environmental pressures, but there are other ways of effectively reducing the inconsistencies between agricultural and environmental policy objectives.

The OECD report also calls for a clearer definition of property rights in agriculture. Australia's experience has shown this can be a particular focus with water entitlements.

Clarity of entitlements and responsibilities are critical to give farmers the confidence they need to invest in their properties. They will also help policy makers decide who should be liable for the cost of measures to move towards sustainability.

In your discussions, do not lose sight of the significance of clean water supplies for our communities as a whole, and the many communities not represented here. Water is a community asset and we need to be able to report we are using this valuable asset wisely.

Water in Australia

And now, ladies and gentlemen, I would like to look briefly at Australia's use of water in agriculture and our recent water reform initiatives.

Agriculture is a vital element of Australia's well being. It only makes up about 3 per cent of our gross domestic product. However, it represents around 18 per cent of our exports and provides the economic foundation for many of our rural communities.

The population density across much of rural Australia is such that communities would not exist if we did not have a viable agricultural sector. Commuting to regional centres to take up other employment is not an option when those centres are hundreds of kilometres away.

Consequently, when we talk of 'sustainable agriculture', the stakes for us are high. We are talking about the sustainability of entire rural communities.

Water use in agriculture is a major factor of sustainability. Agriculture uses about 70 per cent of the water harvested in Australia. Irrigated land takes up less than 1 per cent of our farming land and produces 30 per cent of the value of our farm production.

Irrigation water use in Australia has risen by 70 per cent since the early 1980s. More than half the total water Australian agriculture uses each year goes on pastures, with the dairy industry using most of it. The remainder is spread among cereal crops, grape vines, vegetables and other crops.

However, Australia's dependence on irrigation water has come at a cost. About 95 per cent of the river length assessed in the Murray-Darling Basin — home to much of our agriculture and two thirds of our irrigated industry — is environmentally degraded. Many of the key river systems there are now assessed as over-allocated.

This is a major concern for all Australian governments.

We used to think we had plenty of water, and saw it as a prime tool to promote regional economic development. Developing irrigation schemes and providing low-cost water were seen as the means to 'open the land'.

However, community attitudes changed as the environmental impacts became evident, and governments heeded the call for action. Since 1994, Australian governments have agreed on and implemented major initiatives to return the level of water extracted to a sustainable level. Importantly, we have put in place processes to ensure wiser use of water.

Over the decade since 1994, we made significant achievements. We brought water prices into line with the cost of supply and made progress on reducing the over-allocation of water from some systems. But more needed to be done!

In June last year, the leaders of all Australian governments again considered water reform priorities. The resulting 2004 National Water Initiative builds on the water reform programme they agreed to in 1994. The key outcomes sought from the National Water Initiative are:

- First, ***improved investment certainty***, by providing water users with secure water access entitlements, the ability to trade water, and a clear and fair assignment of risk.

- Second, ***improved environmental outcomes***, by defining specific environmental goals and recognising the environment as a legitimate user of water.

- Third, ***comprehensive water planning and improved reliability of water supply***.

- And fourth, ***efficient management of water in urban environments***.

In 2004, the Australian Government announced a $2 billion investment programme for water infrastructure, improved water management and better water stewardship.

The Australian Government Water Fund will support practical on-ground water projects that improve our water efficiency and provide better environmental results. The projects that help achieve the National Water Initiative’s objectives, outcomes and actions will be eligible for assistance from the fund.

While the 1994 and 2004 water reform agreements represent our key policy initiatives, we have introduced other measures to support them.

The introduction of a ‘cap’ on water extractions from the Murray-Darling Basin system in 1997 is one of them. The Living Murray Initiative in 2002 — to provide water to six significant ecological sites along the Murray River — is another.

These and other initiatives show how Australian governments can work together to enhance industries, communities, and natural and cultural values.

Salinity

In Australia, we cannot discuss water without acknowledging salinity as one of the major external costs associated with its use.

Salinity has long been a major challenge in the Australian landscape. Changes to land use and land clearing that followed European settlement have altered some surface water and groundwater flows. They have also increased the volume of salt entering our rivers.

In November 2000, the leaders of Australia’s governments agreed to the Australian Government's proposal for a National Action Plan on Salinity and Water Quality to tackle salinity, particularly dryland salinity, and deteriorating water quality. The National Action Plan built on the Australian Government’s Natural Heritage Trust, which was set up in 1997 to help restore and conserve Australia's environment and natural resources.

The $1.4 billion National Action Plan has two main goals.

One is to motivate and enable regional communities to prevent and reverse trends in dryland salinity that affect the sustainability of agricultural production, the conservation of biological diversity and the viability of our infrastructure.

The other is to improve water quality and security for human uses, industry and the environment.

The National Action Plan and the $3 billion Natural Heritage Trust are the biggest financial commitment to environmental action by Australian governments in the nation's history. The programmes play an important role in protecting and enhancing our unique biodiversity, the viability of rural and regional communities and the future of our agricultural industries.

The National Action Plan and the Natural Heritage Trust are partnerships between all levels of community and governments. Through them, we are working together to protect our environment and natural resources, and sustain our agricultural industries and regional communities.

Conclusion

Access to water underpins our agricultural production. Water and water quality are matters of regional and national significance. They don't just apply to our agricultural industries. Our towns and cities depend on clean, reliable water.

Water shapes the environment in which we live. And we are acutely aware of that in Australia, where water is so scarce.

The Australian Government supports the work the OECD is doing in this area and is pleased to host this workshop. We look forward to sharing our experiences with other countries. We have already chalked up some successes through our major programme of reform, but still face many difficult challenges.

Countries across the globe are realising that future supplies of clean water will not be sufficient for their needs unless they take action.

But I wonder if the first — and most important — question we must answer is: ***Who should do what?***

What is the role of governments, the business sector, farmers and regional communities, and environmental and other non-government organisations?

The first step towards a solution is accepting that governments cannot act alone. Each stakeholder group has an interest and each will need to be part of any lasting solution.

We have to adopt and enforce laws, agree on visions for the future and create enabling environments. And this is obviously a role for governments.

But when politicians and government officials become involved in micromanaging the allocation of water entitlements, you can rest assured you are headed for second or third best outcomes.

Governments also have an important role in facilitating change and supporting individuals and communities significantly disadvantaged by change. But this support should not prevent or delay change. Governments must ensure communities have access to the skills and information they need to understand the choices and their consequences.

Agriculture is a significant user of water and has a significant impact on water quality in virtually every country.

I am looking to this workshop to provide guidance on how we can best make a contribution to sustainably using our precious — and limited — water resource.

Thank you.

An Australian Perspective on Water Reform

Daryl Quinlivan[1]

Over much of the last 150 years, governments in Australia issued water entitlements primarily to support economic development. Regional communities flourished with the development of those water resources. However, over the last 20 years, there has been a growing number of questions raised about water, especially regarding its availability, its complex interactions with the environment and its importance in achieving social and economic objectives.

Irrigated agriculture accounts for nearly 70% of the water used in Australia. Economically, agriculture contributes 3% of Australia's gross domestic product and contributes 22% of the value of Australia's exports. Irrigated agriculture contributes over a quarter of the total value of agricultural production in Australia, on less than 1% of land used for agriculture. Socially, agriculture is an industry of enormous importance as it forms the basis for rural employment and income in many regional areas.

This paper provides an overview of water resource management reform in Australia, outlining the successes of the last decade and providing some thoughts on the shape of water reform in the future. Given its high level of water usage, these reforms have impacted on – and have the potential to further significantly benefit – the viability of Australian agricultural industries and the communities that depend on them.

The 1994 Council of Australian Governments agreement on water reform was the first attempt at a comprehensive national framework for improving water resource management. Since then, there has been progress, particularly in the areas of improved water planning and water use efficiency, water industry performance, providing environmental water, urban water pricing, accountability and community engagement in water resource management issues. However, it was largely left to individual jurisdictions to decide how to implement these reforms.

The 2004 Council of Australian Government agreement on a National Water Initiative is the next step in progressing water reform. It aims to achieve a national approach to secure water entitlements, open water trading markets and assigning risks in sharing water resources between the environment and consumptive uses, including agricultural production.

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In conjunction with the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust, the National Water Initiative brings together communities and all levels of government (local, state and federal) in protecting our environment and natural resources and sustaining our agricultural industries and regional communities. Further, the Australian Government's $2 billion Australian Water Fund provides a major support to water reform. It funds practical, on-the-ground water solutions and supports improved water management.

Improving water management is an ongoing task. Immediate challenges include allocations to environmental water, the transition to a free and open water trading market, the role of new technology and the need for complementary institutional frameworks.

Background

Historically, land and water management has been a significant social issue. Water is essential to human settlement and, historically, access to water has been critical for economic development in Australia. Competition for water is a feature of Australia's social, economic and political history. Under the Constitution, management of natural resources rests with state and territory governments. However, water traverses state boundaries, industries that use it operate nationally and water dependent ecosystems ignore administrative divisions. Consequently, the economic, social and environmental importance of water has made water a national issue requiring national leadership and co-ordination.

The level of development in Australia's water resources ranges from heavily regulated working rivers and groundwater resources, through to rivers and aquifers in almost pristine condition. Over much of the last 150 years, governments issued water entitlements primarily to support economic development and regional population growth. Water was allocated to support domestic needs and, as in the case of agriculture and industry, for productive use to contribute to the economic growth of the state and the nation. However, obligations for the responsible use of water were not transparent and often ill-defined.

Irrigated agriculture accounts for nearly 70% of the water used in Australia. Economically, agriculture contributes 3% of Australia's gross domestic product and contributes 22% of the value of Australia's exports. Irrigated agriculture contributes over a quarter of the total value of agricultural production in Australia, on less than 1% of land used for agriculture. Socially, agriculture is an industry of enormous importance as it forms the basis for rural employment and income in many regional areas.

During the 1980s, issues of environmental health, sustainability, water availability and water quality for consumptive uses emerged as significant issues in Australia. By the 1990s, state governments had begun to adjust their water resource policies and management arrangements to take account of these issues. At this time, water also became an issue on the national agenda. Symptoms of resource degradation such as declining water quality, increasing salinity, toxic algae outbreaks and the loss of biodiversity – key issues for Australian agriculture – came to the fore in the public arena. At the same time, irrigators were facing reduced security of supply as competing demands for water increased. The potential costs of enhancing or refurbishing water supply and wastewater management infrastructure also loomed large in government budget considerations.

Knowledge of Australia's water resources was also poor. Groundwater systems were poorly understood and the environmental impacts of largely unregulated water use, including salinity and over-extraction, were unknown.

Achievements

Against this background, a national agreement on water reform was reached in 1994 through the Council of Australian Governments (COAG), comprising First Ministers of Australian, State and Territory governments. COAG agreed to a comprehensive water reform agenda that explicitly linked, for the first time, economic and environmental issues with a package of reform measures. The agreement focused on establishing water allocations and entitlements separate from land tenure, backed by secure access to water. It also provided for trading in water entitlements, making water available for ecosystems, as well as institutional reform, public consultation and education, and research.

In 1995, COAG agreed to include water reform within the reforms associated with the National Competition Policy. Since then, the National Competition Council has progressively assessed all jurisdictions to determine if reforms to major sectors, including the water sector, are being carried out.

Based on the 1994 COAG agenda, there has been some progress across all jurisdictions as follows:

- pricing reforms have begun (for example, the introduction of two part tariffs);
- separation of government regulatory and management functions and commercialisation of government water businesses has begun;
- water trading, particularly temporary water trading, has expanded;
- water management arrangements have been developed to take account of the range of water uses including: extractive uses, environmental needs and the needs of stressed and over-allocated river systems;
- better arrangements for examining proposals for new rural water infrastructure (against the tests of economic viability and ecological sustainability) are now applied;
- water legislation to underpin these reforms has been enacted;
- greater levels of accountability, transparency and reporting have been instituted;
- stakeholder consultation and community engagement have been improved; and
- water access entitlements are being separated from land titles – an almost revolutionary achievement in the context of Australia's historical treatment of water.

In rural areas, potential water scarcity and resource access competition was (and remains) the driving force for reform. Over-allocation and overuse of water resources was a significant issue. For example, an audit of water use in the Murray-Darling Basin in 1995 showed that if the volume of water diversions continued to increase it would exacerbate river health problems, reduce the security of water supply for existing irrigators, and reduce the reliability of water supply during long droughts. In that year, the Murray-Darling Basin Ministerial Council agreed to 'cap' the volume of water that could be diverted from the rivers for consumptive uses at 1994 levels. The cap has proven to be an essential first step towards achieving the objective of a sustainable Basin, the major region for agricultural production in Australia.

Complementing the water reform agreement, in November 2000, COAG agreed to provide $1.4 billion for a National Action Plan on Salinity and Water Quality to address dryland salinity, improve water quality and secure reliable allocations of water for human uses, industry and the environment.

The National Action Plan involves the following key elements to manage dryland salinity and improve deteriorating water quality, taking into account the following principles.

- The roles of the Australian, state/territory and local governments and communities are clearly defined.
- Management plans have been developed by the community in each of 21 priority catchments and have been accredited jointly by governments.
- These management plans include explicit targets and standards for salinity, water quality and associated water flows, and stream and terrestrial biodiversity.
- In developing their management plans, communities are supported through the provision of technical and scientific support.

The National Action Plan provides further support for improved governance frameworks. It builds upon the work started with the Natural Heritage Trust, with both programmes now jointly administered by the Agriculture and Environment portfolios within the Australian Government, with most decisions about the programmes made jointly by the Australian and State governments. This holistic approach to resource management, with management plans produced by communities at a regional/ catchment level, has been an important factor in the success of these programmes.

Unfinished business

However, despite the progress, we have a long way to go. Key issues to resolve include:

- Wide variation in the progress of reforms between regions and jurisdictions
- Uncertainty over the long-term access to water
- Uncertainty over the legal security of water entitlements
- Complexities of different water product specifications

- Divergent administrative arrangements for water trading
- Lack of up-to-date market information on water trading
- Policies of some water corporations restricting license holders from permanently trading water to other users outside the district
- Slow progress in securing adequate water for environmental purposes and for applying adaptive management arrangements to ensure the health of river systems.

In 2002, the Murray-Darling Basin Ministerial Council agreed to the Living Murray Initiative, committing $500 million to reduce the level of water overallocation and to achieve specific environmental outcomes for six significant ecological assets of the Murray River: the Barmah-Millewa Forest; Gunbower and Koondrook-Perricoota Forests; Hattah Lakes; Chowilla Floodplain (including Lindsay-Wallpolla); the Murray Mouth, Coorong and Lower Lakes; and the River Murray channel. Environmental water management is now on an equivalent basis to water managed for other uses and objectives.

Importantly, COAG agreed to 'refresh' the 1994 water reform framework through an Intergovernmental Agreement on a National Water Initiative in 2004. The Initiative recognises the continuing national imperative to increase the productivity and efficiency of Australia's water use, the need to service rural and urban communities and to ensure the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction. It builds on the achievements of the 1994 COAG water reform framework and contains a number of actions that governments will implement over the next 10 years.

The National Water Initiative seeks to achieve secure water entitlements, thereby encouraging increased investment in infrastructure and planning and reducing over-allocations. This will be achieved through establishing:

- clear and nationally-compatible characteristics for secure water access entitlements;
- transparent, statutory-based water planning;
- statutory provision for environmental and other public benefit outcomes, and improved environmental management practices;
- the return of all currently overallocated or overused systems to environmentally-sustainable levels of extraction; and
- recognition of the connectivity between surface and groundwater resources and the management of these connected systems as a single resource.

The National Water Initiative also seeks to move away from government administration of water entitlements, in order to enable individuals to choose how best to use their entitlements through:

- progressive removal of barriers to trade in water and meeting other requirements to facilitate the broadening and deepening of the water market, with an open trading market to be in place;

- clarity around the assignment of risk arising from future changes in the availability of water for the consumptive pool;

- water accounting, metering and pricing that is able to meet the information needs of different water systems in respect to planning, monitoring, trading, environmental management and on-farm management;

- policy settings that facilitate water use efficiency and innovation in urban and rural areas; and

- addressing adjustment issues that may impact on water users and communities as a result of these reforms.

The Australian Government also has provided $2 billion over 5 years to the Australian Water Fund, to assist in implementation of innovative water proposals that support the National Water Initiative. This commitment funds practical, on-the-ground water solutions and supports improved water management.

The recently established National Water Commission will facilitate co-operation between the States and Territories to help progress the water reform agenda and to implement programmes under the Australian Water Fund.

Key issues

Institutional frameworks

One of the key issues yet to be finally addressed is whether the changes already made to our institutional frameworks (i.e. our regulatory, planning and water resource assessment institutions) are sufficient to drive Australia's water reform objectives. The National Water Initiative recognises the importance of clarity with regard to obligations and entitlements, and avoiding institutions with internally conflicting objectives in water resource management, standard setting, regulatory enforcement and service provision. In particular, the 2004 National Water Initiative calls for water allocated for the environment and other public benefits to be backed by legislation, consideration of land use changes that may cause significant water interception, and provisions for indigenous access to water resources as well as indigenous representation in water planning.

Environmental water

Sustainable management of land and water resources and ongoing farm viability are inseparably linked. The National Water Initiative recognises that there is a continued need to increase the productivity and efficiency of Australia's water use and to ensure the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction. As a result, irrigators will benefit from greater certainty of supply.

Issues requiring resolution are ensuring there is enough water to maintain the resource base, dealing with overallocated systems and maintaining significant environmental assets. Maximising the value of investments in environmental water will be important. In so doing, where necessary, the environment will be better able to compete with other users in securing water for environmental purposes.

The Living Murray Initiative is an example of what the future might hold. The first step decision on this Initiative focuses on achieving significant environmental benefits for six key ecological assets. It is less about environmental 'flows' *per se* and more about securing and managing environmental water to meet the differing needs of particular riverine assets and to ensure healthy working rivers. The focus is on finding measurable outcomes. It involves 'learning by doing', or adaptive management, in several key areas – developing flexible management techniques that can change with improving knowledge; refining community engagement and consultation; and integrating social, economic, scientific and cultural analysis.

The first step requires a 'whole of river' approach to matters such as water allocation, operational management and monitoring of trends in river health. At the same time, this approach needs to be co-ordinated with regional bodies responsible for natural resource management. It includes a commitment to an accounting framework for environmental water and includes monitoring and reporting arrangements that will enable the evaluation of impacts and benefits by all parties.

Water entitlements

Debate on the 'unbundling' of water entitlements has now moved beyond the issue of the separation of water from land into the issue of separate rights for each of the components of the water entitlement (including water allocations, site-use licences, and delivery capacity rights). The aims of the move to 'unbundling' are to further enhance the 'liquidity' of water assets and then for the capacity of markets to operate efficiently, with a more transparent market easily accessed by buyers and sellers with minimal transaction costs. A number of factors – including the extent to which systems for registering the new components and accounting for transactions can be put in place and their attendant costs – will determine the extent to which 'unbundling' and trading of water entitlement components is implemented

Water trading

Under the National Water Initiative, governments have agreed to establish by 2007 compatible institutional and regulatory arrangements to facilitate intra and interstate trade and manage differences in entitlement reliability, supply losses, supply source constraints, trading between systems, and cap requirements. Water trading aims to create open and competitive markets where water use is demand-driven rather than administered by governments. This enables water to flow to its highest value uses. It should also provide more cost effective and flexible water recovery options for delivering environmental outcomes.

An expanded market that facilitates permanent and temporary trade in water entitlements, annual allocations and delivery capacity (together with the development of new water products) will present great opportunities for irrigators to diversify, streamline and strengthen their businesses into the future.

However, expanding the water trading environment will also generate new challenges, particularly for the agricultural sector. For example, issues concerning social and regional impacts of permanent trade of water out of irrigation districts and economic costs of stranded assets require further examination. There also will be continuing policy debate about the development and use of access and exit fees to manage impacts on water infrastructure, as well as the use of exchange rates verus tagged trading to manage differences in water reliability.

Also, as water markets move towards maturity, there will be increasing potential for the development of various derivative products of value to water users. For example, there may be forward options that allow future sale or purchase of water at an agreed price or that allow for the future sale of the right to buy water on an agreed basis (where the buyer has the discretion to exercise the option at the time).

Better knowledge and monitoring of water resources

There remains a critical need for better knowledge and understanding of water resources including basic data, particularly in the areas of groundwater systems and interconnected surface/groundwater systems. Better information on Australia's water resources, based on agreed scientific assessment and targeted research, and the development of nationally compatible water resource accounts will help to underpin better water resource management. Development of water balances at a variety of geographic scales and monitoring the factors influence water balances over time will be important for managing the risks to water resources and changes in supply and demand. Changes to water balances over time will result from changes in land use, climate, demography, industry and water policies.

Water quality

Salt is endemic in the Australian landscape. The age of the Australian continent and its geological history has resulted in depleted soils with high salt concentrations in many places. Changes in vegetation cover or land use can alter groundwater conditions, releasing salt into streams and reducing the quality of available water.

Therefore, natural resource management and its impact on water quality will remain an ongoing issue. The current National Action Plan and Natural Heritage Trust programmes are scheduled to end in 2008, however the Australian Government is already considering the direction of future natural resource management programmes.

Technology

With the right investment climate, there is scope for developing and implementing a wide range of technologies for improving water use, including improved metering and water measurement systems, better piping and channel systems and more water-efficient irrigation systems. There is also scope for developing technologies that provide real-time monitoring and application of water to suit the requirements of individual crops, with possible extension to the paddock and catchment scale.

The National Water Initiative provides a basis for a much improved investment climate for the water industry, particularly with provisions for more secure water access entitlements and for a substantially improved framework for managing the risks of any future reduction in water availability. Potential therefore exists for the water reform agenda to drive greater investment in water smart technologies and infrastructure.

However, issues will continue to emerge around the possible negative impacts of greater water use efficiency on groundwater accessions and return flows to rivers and streams. Clarity about ownership of water saved by the new technologies and the availability of the water for consumptive or environmental uses will be important.

Conclusion

Water is a key part of Australia’s natural capital, serving a number of important productive, environmental and social objectives. Decisions about water management involve balancing sets of economic, environmental and other interests. Governments have a responsibility to ensure that water is allocated and used to achieve socially and economically beneficial outcomes in a manner that is environmentally sustainable.

Australia’s water resources are highly variable, reflecting the range of climatic and geographic conditions. The last decade has seen a focus on adaptively managing water resources for economic and environmental purposes, securing water access entitlements for users, expanding water markets and introducing more effective pricing policies and organisational arrangements.

The National Water Initiative process for resolving economic and environmental issues surrounding the use of water is of critical importance to the agricultural sector in Australia. In particular, the National Water Initiative provides irrigators with increased investment security and flexibility to respond to market conditions through water trading, while achieving greater security of supply through protecting the environment.

The reform programme has had some success, but much remains to be done if we are to meet the reasonable expectations of future generations of Australians. A strong commitment and ongoing co-operation of governments and stakeholders will be a key factor in sustaining and driving the momentum of water reform. Continuing efforts on integrated water management, cross-border co-operation, improving irrigation practices and water use efficiency will be necessary to ensure improved productivity and environmental sustainability of water resources and secure access to water for all Australians.

Using Good Economic Principles to make Irrigators become True Partners in Water and Environmental Policies[1]

Alberto Garrido[2]

Abstract

Water for irrigation is a production input that is used in farms jointly with other inputs — land, capital and managerial skills. Farmers respond to both market and policies incentives, but need time to adapt their production systems in response to policy changes. The literature shows that irrigators' water demand is fairly inelastic in the short run and for moderate water price increases. Yet, large differences across regions and even irrigation schemes can be found in water productivity, technologies and resource use efficiency in general. This shows that water productivity could be enhanced significantly. Yet this paper argues that pricing water to meet full cost-recovery is a necessary but not sufficient condition to ensure more efficient and sustainable water use. Capital adjustments, both within and beyond the farm boundaries, are also required to help farmers be able to respond to innovative water management. In contexts where water is scarce, ensuring efficient resource allocation must be added to the equation. The same applies to the environmental damage and benefits functions. Water markets, or similar instruments, are essential to distribute resource scarcity signals. In sum, balanced policy mixes are required to deliver socially desirable objectives, none of which can be achieved making farmers less competitive or eroding their profitability. There are large social and environmental benefits that can be gained from more efficient water use for irrigation. Yet farmers will not deliver them following their own interest. It is the role of government policies to lead the transformation of millions of hectares of irrigated land, working closely with farmers in order to take advantage of all technological and scientific possibilities.

1. Work carried out while on sabbatical at the Department of Agricultural and Resource Economics, University of California at Berkeley. Funding from the Spanish Ministry of Education and Science (Programa de Movilidad de Profesores, 2004) and from the Universidad Politécnica de Madrid (Programa de Sabáticos, 2004) is greatly appreciated.

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1. Introduction

OECD has supported influential work in the area of water, environmental and agricultural policies (OECD, 1998; 1999; 2001). Significant policy reforms have been reviewed in detail by past conferences, giving rise to widely cited publications. OECD has provided important venues for policy discussion and dissemination within and beyond the community of OECD countries.

Despite this important effort, most countries still suffer the consequences of:

- water scarcity and vulnerability to drought cycles;
- environmental pollution and buildup of toxic matters, and
- unsatisfactory technology adoption rates of more environmentally-friendly production and irrigation technologies.

On top of these serious concerns, the irrigation agricultural sector around the world faces serious competition and the uncertainties of agricultural policies and trade negotiations. In the European Union the number of farmers has gone down by 15 to 20% in the last ten years. Similar trends are occurring in other OECD countries as well. Less than a fourth of the registered farmers in the EU get most of their income from farming.

Yet in the EU at least, irrigation does not seem to be in retreat, maintaining its position as a major water user in the Southern countries (see Table 1). Irrigation technology, added to the modernisation of off-farm capital infrastructures, is silently transforming the way agricultural production is carried out in irrigation farms. The demand for more quality consistent products is a market driven process occurring in regard to basic products, like cereals, forages and feedstuff; and all the more so in edible and specialty crops. Product differentiation and traceability are major driving forces in the agri-food sector. Irrigation ensures that soil moisture is kept at adequate levels, enabling irrigating farms to meet the quality standards that markets are demanding.

Irrigation technologies, GIS decision support systems, and more intense water controlling mechanisms are being adopted at basin, district and farm levels. The traditional grouping of flood, sprinkler and drip irrigation technologies is now obsolete, although statistical services in FAO and the EU do not offer more detailed data. These processes take place at a more rapid pace with groundwater irrigation.

On the production side, thus, we have numerous opportunities to improve water use efficiencies, reduce water pollution and toxic buildup and even increase farms' profitability. The know-how and the technology are available at market costs to be applied and deliver the expected benefits.

Recent research on agricultural water management suggests multiple avenues to increase water/land productivity that conserves scarce resources and do not come necessarily with lower yields. We will review below some extant examples.

At the policy level progress is still disappointing. Although the ground is prepared to deliver significant results, not a lot is being accomplished in the area of water resources and pollution reduction. The reasons for this will be discussed in the fourth section of the paper.

Table 1. Water and irrigation basic figures of European countries (compiled from FAO's databases)

Country & Year	Arable & permanent crops, 2000, FAOSTAT	Average precipitation 1961-90	Total renewable water resources, AQUASTAT	Total renewable water resources AQUASTAT	Full/partial control irrigation, AQUASTAT	% of irrig/ arable land
	(ha)	(mm/year)	(Km^3/year)	(m^3/capita)	(ha)	
Albania (98)	699000	996	41.70	13306	340000	48.6
Austria (98)	1470000	1110	77.70	9616	4000	0.3
Belarus (93)	6257000	618	58.00	5694	131000	2.1
Belgium–Lux. (98)	837000	853	21.40	2003	40000	4.8
Bosnia & Herz. (98)	650000	1028	37.50	9429	2000	0.3
Bulgaria (98)	4636000	608	21.30	2680	800000	17.3
Croatia (98)	1586000	1113	105.50	22669	3000	0.2
Cyprus (94)	143000	498	0.78	995	39545	27.7
Czech Rep (98)	3318000	677	13.15	1280	154000	4.6
Denmark (98)	2289000	703	6.00	1128	447000	19.5
Estonia (95)	1134000	626	12.81	9195	4000	0.4
Finland (98)	2191000	537	110.00	21268	64000	2.9
France (98)	19582000	867	203.70	3439	2600000	13.3
Germany (98)	12020000	700	154.00	1878	485000	4.0
Greece (98)	3854000	652	74.25	6998	1431000	37.1
Hungary (98)	4803000	589	104.00	10433	230000	4.8
Italy (98)	10825000	832	191.30	3325	2750000	25.4
Latvia (95)	1874000	641	35.45	14642	20000	1.1
Lithuania (95)	2992000	656	24.90	6737	7000	0.2
Macedonia (98)	599000	619	6.40	3147	55000	9.2
Moldova (94)	2190000	553	11.65	2712	312000	14.2
Netherlands (98)	944000	778	91.00	5736	565000	59.9
Norway (98)	883000	1120	382.00	85478	127000	14.4
Poland (98)	14330000	600	61.60	1596	100000	0.7
Portugal (98)	2705000	855	68.70	6859	650000	24.0
Romania (98)	9865000	637	211.93	9445	2880000	29.2
Russian Fed (90)	126820000	460	4507.25	30980	6124000	4.8
Slovakia (98)	1576000	824	50.10	9279	183000	11.6
Slovenia (98)	204000	1162	31.87	16031	3000	1.5
Spain (98)	18217000	636	111.50	2794	3370000	18.5
Sweden (98)	2706000	624	174.00	19679	115000	4.2
Switzerland (98)	437000	1537	53.50	7462	25000	5.7
U.K. (98)	5928000	1220	147.00	2465	170000	2.9
Yugoslavia (98)	3736000	795	208.50	19759	57000	1.5

This paper reviews the factors that impede more rapid political accomplishments. It seeks to distil applicable policy conclusions in the area of water and environmental policies. The paper is structured in five sections. Next section briefly reviews a number of key economic principles that seem to drive major trends in capital intensive irrigated agriculture. The reason to briefly review them is because they are often ignored when plans and policies are designed. In the third section, we review the most recent literature with special emphasis on water and environmental policies as applied to the irrigation sector. The fourth section attempts to summarise the main policy conclusions that can be drawn from the most recent literature. The fifth section suggests a number of designing principles that may increase the chances of more policy deliverance. The sixth section summarises the paper's conclusions.

2. Key principles in irrigation economics

Water is used jointly with other variable inputs, and capital goods, using the managerial skills and the information available to farmers. It is fair to assume that farmers respond to market and policy incentives maximising their benefits, subject to resource, technological and management constraints. Although less vulnerable to non-controlled factors, irrigation agriculture is vulnerable to climate, pests, mechanic failures, policy and market risks. Irrigation is performed to increase farm yields, improve products' quality, and reduce dependency from climatic variability. Increasingly, irrigated agriculture is practiced in closed technological packages, allowing little input substitution but requiring significant managing skills and capital investments. Lastly, in many countries irrigation is managed collectively through irrigation districts or schemes.

Three management layers can often be identified in many semi-arid regions, namely, the farm level, the district level and the basin/regional/catchment level. Water is abstracted from the source and conveyed to the district and farms, but a fraction is returned to the natural water bodies with a different chemical composition. Along the whole utilisation cycle, engineers identified several efficiency or efficacy ratios, which depend on technology, natural and managerial factors. These ratios provide approximations about water losses along the system, though their betterment does not necessarily imply lesser water use. Any water demand and welfare analysis must

In the following sections we will discuss 1) technology adoption processes, 2) the role of land and water quality in irrigation technology, 3) the 'derived demand' nature of farmers' water demand, and 4) the incentives for farmers to exit or entry the irrigation sector.

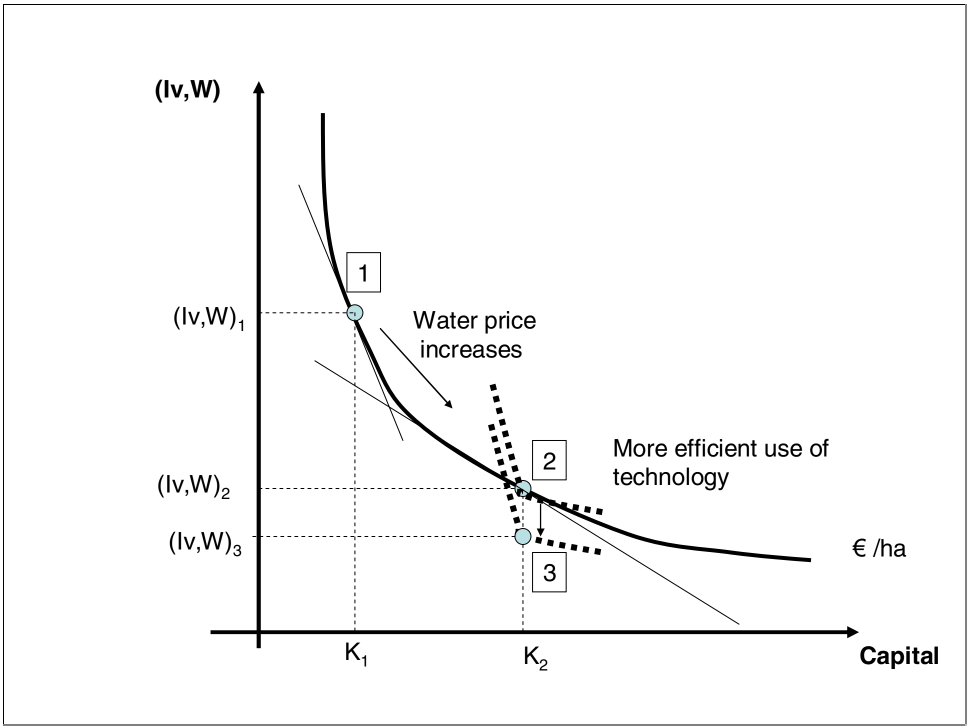
2.1. The process of technology adoption

Figure 1 attempts to describe the process of technology adoption. The large curve represents an isoquant measured in farm output (€) per irrigated hectare, and X-axis measures capital in irrigation technology and equipment, whereas Y-axis measures the variable inputs, including irrigation water. Point 1 is traditional technology, and point 2 is modern technology. A farmer may move from 1 to 2, provided the relative price of water and technology (represented by the tangential lines) provides enough incentives to do so.

Yet it is unlikely that point 2 will be the final production point, because under a different technology we would have a different map of isoquants (represented by the dotted curves). In the end and once adaptation process is finished, farmers may eventually move to point 3 requiring less inputs to produce the same output value. Moving from 1 to 2, and eventually to 3, requires adjustment time and clear incentives. In general, more capital intensive technologies will allow for less flexibility to substitute inputs (including water), and less sensitivity to water prices. The extreme case would be an orchard of a particular variety of citrus, irrigated with dripped systems. In such a context, water demand is at the short term completely inelastic up to the point where variable cost is greater than product prices, so demand would be choked off.

The main lesson is that, as water price become more expensive relative to the price of capital, and farms move to more capital intensive production systems, isoquants tend be more kinked. As a result, water price would not influence water use levels and farmers would tend to farm at the point where capital utilisation is optimal. Eventually, the options to further water conservation can only come with large benefits downfalls.

Figure 1. Moving from old to modern irrigation technologies



2.2. The role of land/soil quality in water demand and technology adoption

Another important theoretical result is that land and water quality affect crucially the quasirents of two irrigation technologies, modern and old. Figure 2 is taken from Boggess et al. (1993), and depicts the benefits (quasirents) of both technologies for different land and soil quality. The figure conveys the following important result: in general, modern technologies (land/water augmenting technologies) will be more profitable with low land/water quality (qualities lower than point C). Furthermore, for very low water/land quality (at the left of point B), irrigated agriculture may be viable only with modern technologies).

Water market incentives have been shown to provide strong incentives for technology adoption, primarily because water sales' revenues increase the revenue gains reached by the more efficient technology (Peterson and Ding 2005). Caswell and Zilberman (1986) and Caswell et al. (1990) obtained seminal results on water savings and technology adoption.

In my view, one of the most relevant results is that new technology adoption does tend to save water if price is low, whereas under expensive water resources new technology may actually increase water and other inputs' use. This result has key implications in areas where serious problems of water ground quality deterioration and lowering water tables. If policies seek farmers to adopt more efficient technologies, this may result in farmers using more water, exacerbating the problem.

Figure 2. Quasirents from traditional and modern technologies as affected by land/water quality

Source: Boggess et al. (1993).

2.3. Water demand as a 'derived demand'

The third important factor is that water demand for irrigation is a 'derived' demand, because farmers use water as a production input. Under general, albeit limiting assumptions, the elasticity of water demand can be expressed as (Layard and Walters, 1978, cited by Boggess et al. 1993):

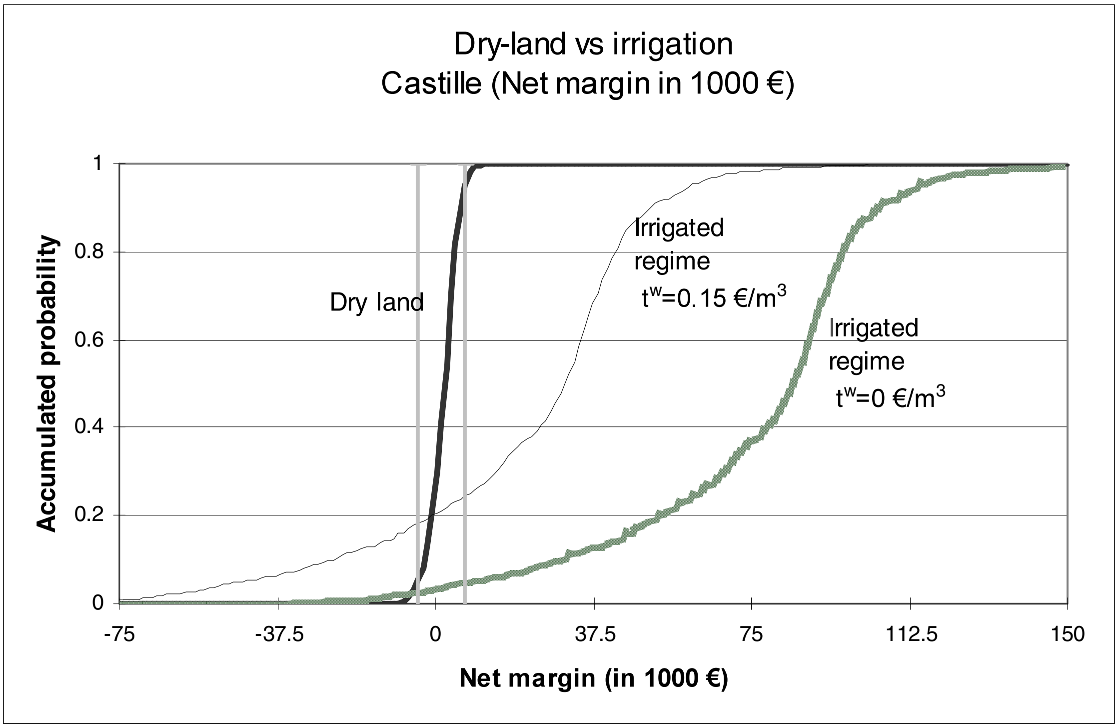
$$e_{ii} = v_i \eta_0 - (1 - v_i) s_{ij}$$

Where e_{ii} is the price elasticity of water demand; v_i is the relative share of water in production costs; η_0 is the demand of the food products; and s_{ij} is the elasticity of substitution between water and other inputs. With new technologies (low s_{ij}) and very efficient water uses (in which water costs are relatively low), water demand will tend to be inelastic; conversely, with traditional technologies, and large relative water costs, water demand will be more elastic. The implication is that once the irrigation sector reaches a certain level of modernisation (at any of the three layers mentioned above), water demand will be become less responsive to water price increases (and as a result to water costs increases).

2.4. Factors that influence exit/entry in the irrigation sector

The fourth aspect in understanding irrigators' responses to changing water and agricultural policies is related to the entry/exit processes. When and why does an irrigator decide to switch to dry-land farming? Many empirical studies that will be reviewed predict that above water price levels farms would prefer dry-land farming or no farming at all. In my view, risk is a decisive element that has not been paid sufficient attention. Risk reduction effects are shown in Figure 3, which provides stochastic simulation results for two Castillian farms under various hypotheses (Garrido et al. 2005). Random variables include crop and price yields, with density functions estimated from real observed data. Figure 3 represents the cumulative distribution functions of farmers' net margin. It shows that farming with irrigation water is still more preferred than farming under a rainfed regime, even if water prices are raised to meet full cost recovery criteria. Even if subsidised water price were priced at full, or nearly full, cost recovery rates, farmers would prefer to keep their irrigation operations than to convert their farms into rainfed agriculture.

Figure 3. Net margin measures of dryland and irrigated Castillian farms (cumulative distribution functions)



Source: Garrido et al. (2005).

3. Most recent findings on economics of irrigation

3.1. Water conservation via management and technological innovations

The evidence supporting the beneficial effects of innovative irrigation management and technologies is overwhelming. Water savings in the range of 30 to 40%, just by better managing the application schedules, with no yield reductions have been reported by Causape et al. (2004), and Luquet et al. (2005). In addition, technology shifts both on-farm and within district levels shows that significant water conservation provides economic returns (Peterson and Ding, 2005; Cetin, Yazgan and Tipi, 2004). In most cases, just controlling for key management factors such as soil moisture along the phenological stages is sufficient to accomplish consumption reductions. Shani et al. (2004) have shown that in many cases the most efficient irrigation schedule is not the one that yields the maximum production.

Economic models generally envision various management options within farmers' choice options, including 'supplemental irrigation' (Oweis, Hachum and Pala 2004; Pereira, Oweis and Zairi 2002), and water-conserving irrigation technologies (Varela-Ortega et al., 1998). These models show that investing in more efficient irrigation technologies is just of the set of responses that farmers can pursue to respond to more expensive water. Sometimes, fallowing the least efficient crops or moving to rainfed irrigation may be more beneficial than investing in new technologies.

GIS support systems provide as well valuable information to farmers who decide to save money and water on farms (Martin de Santa Olalla et al. 2003; Satti and Jacobs 2004).

This wealth of literature demonstrates that significant water conservation levels are accessible to hundreds of thousands of farmers in OECD countries.

3.2. The demand inelasticity hypothesis and the role of irrigation water pricing

In areas where water is scarce, it is essential to distinguish at which point in the continuum source-plant water demand is measured and evaluated. Thus, demand analyses have also looked at the differences between consumptive demands and delivery demands. As explained earlier, consumptive and delivery demands differ because of the discrepancies between actual deliveries and on-farm water uses. Scheierling et al. (2004) found that consumptive use demand tends to be significantly less price-responsive than delivery demand. Thus price incentives are likely to have only limited impacts on basin-wide water consumption and would not make much additional water available for emerging demands.

Bontemps and Couture (2002) show that water demand in southern France is inelastic for low available volumes, and depends crucially on the weather conditions.

Table 2 reports a number of studies compiled by Garrido and Calatrava (2005). Most studies carried out in Spain tend to support the hypothesis that water demand is inelastic, at least in the range of prices up to what would be considered full cost recovery prices.

Table 2. The effects of the WFD on the irrigation sector

	Present rate		Tariff increase		Results			
RBA	Type	Levels[1] (€ per cm)	Medium	FCR[2]	Farm income	Water demand	Other	Sources
Duero	Per ha	0.01	0.04	0.06	-40% to -50%	-27% to 52%	Great influence of agricultural policies	Gómez-Limón and Riesgo (2004)
Guadal-quivir	Per ha & Vol	0.01-0.05	0.05	0.1	-10% to -19%	0 to -10%	Same	Berbel et al. (2004)
Duero	Per ha &Vol	0.01	0.04	0.1	-10% to 49%	-5% to -50%	Technical response	Sumpsi et al. (1998)
Guadal-quivir	Per ha & Vol	0.01-0.05	0.06	0.12	-10% to 40%	-1% to -35%	Technical and crop response	Sumpsi et al. (1998)
Guadal-quivir	Per ha & Vol	0.01-0.05	0.03	0.09	-16% to 35%	-26% to -32%	Technical and crop response	Iglesias et al. (2004)
Guadiana	Per ha	0.005	0.03	0.06	-15% to 20%	-30% to -50%	Technical and crop response	Iglesias et al. (2004)
Júcar	Per ha, Vol & hourly rates	0.03-0.15	0.06	0.15	-10% to -40%	0 to -40%	Technical response	Sumpsi et al. (1998)
Segura	Per ha, Vol & hourly rates	0.05-0.30	0.10	0.25	-10% to -30%	0 to -10%	Very inelastic demand	Sumpsi et al. (1998)

1. Equivalent measure; 2. Full cost recovery rates.

Source: Compiled by Garrido and Calatrava (2005).

Berbel et al. (2005) look in detail at irrigation pricing policies around Europe, paying special attention to the likely effects of the EU Water Framework Directive. Their main conclusions are summarised in the following points (p.29):

- Even if ‘full-cost recovery principles’ are loosely applied on irrigation charges, the gap between costs and charges will be transparent because they must be defined against sound evaluations of water costs.

- EU member states will eventually need to justify on the grounds of cost and benefit analyses any dispensation to meet the WFD objectives. Thus, member states are accountable to the European Commission for setting full-cost recovery rates and for taking into account the polluter-pays principle.

- There are doubts about the effectiveness of FCR pricing policy. First, the EU encompasses widely different irrigation sectors and economies, but policy objectives are inspired on fairly similar tenets. In some countries of the Mediterranean regions, land-planning and rural development are inextricably linked to the irrigation sector. The transition to full-cost recovery prices will not be easy in many of these regions. Second, water quality issues and more efficient allocation are still the most pressing problems in some of the water-stressed regions. If society is in need of more environmentally-friendly, and more frugal, irrigation systems, it may pay to stress other factors before squeezing farmers' profitability with higher charges. Large impacts produced by equivalent pricing policies have been found by many authors (see Gomez Limon and Riesgo 2004, p. 47)

Calatrava Leyva and Sayadi (2005) examine the productive, technological and resource management characteristics that determine the growers' expressed willingness to pay (WTP) for the water they use, as well as their attitude towards the use of alternative sources (such as residual water). They show that average WTP for water expressed by the tropical fruit growers in the area was €0.27 per m^3, while the estimated marginal value of water was €1.52 per m^3.

Bazzani et al. (2005) found cereal and fruit industries in Italy would be impacted very differently by the implementation of 'reasonable' FCR prices. In the cereals industry, water prices would reduce water use, associated with a sharp decrease of farm income, a relatively high reduction of employment and an environmental improvement. In the fruit industry they found rather rigid behavior. The impact of the WFD may be identified in a decrease of farm income, associated with minor impacts on employment and environmental parameters.

3.3. How do conveyance losses affect evaluations and pricing policies?

The fact that discrepancies between consumed and delivered volumes can be significant led Kim and Schaible (2000) to show the welfare implications when irrigation benefits are based on consumed water demands. In fact, they show that, since water is a farm input, welfare estimates of water used in agriculture using demand functions can be severely biased, the bias being proportional to the rate of irrigation water losses through leaching, runoff and evaporation.

Conveyance losses along the whole water system, from abstraction point to the plant, pose political economy problems in large irrigation schemes that are served by canals. In general, flat-based pricing would induce farmers at the tail reaches to use more water than would be efficient. Yet differential pricing based on conveyance losses goes against equity perceptions, and it is hardly used in irrigation districts.

3.4. Toxic buildup, technology and water policies

Soil toxic or salinity buildup has recently been investigated by a number of authors, reaching relevant conclusions. Martínez and Albiac (2004) show that in many cases nitrate leach responds to dynamic soil processes, rendering static analyses of alternative environmental policies useless to discriminate between options. Some of the conclusions of these authors deserve to be highlighted.

The use of water pricing policies as a means to abate the pollution process has been considered by many authors (Helfand and House, 1995; Martinez and Albiac, 2004).

Since irrigation water is strongly correlated with nitrate leaching, there would be reasons to think that taxing water would provide second-best results to reduce nitrates contamination. Yet, when the dynamic of the soil's stock of nitrogen in the analysis, as Martínez and Albiac do, nitrate based instruments are more efficient instruments.

In a study of 11 irrigated farms in Australia (Gang and Felmingham, 2004) show that the potential reduction of the environmentally detrimental salt emissions resulting from the improvement of environmental inefficiency can be substantial. Their results suggest that differences in the management performance of the salt emission problem across individual schemes show that there are management avenues to reduce irrigation externalities.

4. Drawing policy conclusions from the most recent literature

Caution against subsidising on-farm irrigation efficiency

On-farm irrigation efficiency is not synonymous to water conservation in all cases and circumstances. Huffaker and Whittlesey (2003) developed a conceptual model to analyze economic policies to increase the irrigator's cost of applied water and to subsidise the irrigator's cost of investing in improved on-farm irrigation efficiency. Comparative static results demonstrate that increasing the cost of applied water may be a more effectual water conservation policy than subsidising the cost of improved on-farm irrigation efficiency. Technology is one clear way to increase productivity, but a broad social view of its consequences would advise to keep close control of the actual levels of water consumed, all the more so if irrigation modernisation is supported by subsidies. It is instructive to take into account the definition of water savings in the Central Valley Project Improvement Act (California, explained in OCDE, 2001) and the qualifications made in the Spanish Water Law to establish the amounts of water that farmers can actually sell to another user (detailed by Garrido, 2005).

Favourable economic conditions are needed to achieve the best policy results

Farmers around the OECD countries are fully aware of the need to conserve water. However, survey data show that the economics to implement the management and technologies must be based on favourable economic conditions (Johnston et al. 2001; Federacion Nacional de Comunidades de Regantes – *Spanish Federation of Irrigation Districts*[3]).

Schaible and Aillery (2003) demonstrate that conservation-incentive water policy, when integrated within balanced policy reform, can produce upwards of 1.7 million acre-feet of on-farm conserved water for the region, while also significantly increasing economic returns to farmers. Producer willingness to accept water-policy change is lowest for regulatory policy (US$4-$18 per acre-foot of conserved water), but highest for conservation-incentive policy that increases both irrigation efficiency and crop productivity ($67-$208 per acre-foot of conserved water). Conservation-incentive water policy also enhances decision-maker flexibility in meeting multiple regional policy goals

3. FENACORE (http://medioambiente.geoscopio.com/escaparate/verpagina.cgi?idpagina=3148).

Interlinkages between agricultural and water policies

First, the more choice farmers have in selecting the crops the most efficient is water use and the least income-reduction effects resulting from water conservation policies (Mejias et al., 2004). Upon the reform of agricultural policy in the EU, a number of analysts have explored whether the incentives to use water would change as a result of more decoupled measures of agricultural income support. It is shown that more decoupled measures of support may make pricing policies more effective and less negative for farmers' benefits.

Gómez Limón et al. (2002) show that agricultural and water policies can have conflicting objectives. Yet the trend towards more decoupled measures of support will likely ease the tension that, at least in the EU, have been found in many studies.

The role of irrigation reforms within basin management plans

Gomez and Garrido (2004) show that the least expensive measure to achieve good water quality status in a typical stressed Spanish catchment is to invest in rehabilitation of irrigation districts. This is by far the most cost effective way to meet good water bodies' ecological status. If conserved water is valued at true opportunity cost, and farmers can benefit from their water conservation initiatives, the incentives would be made much more transparent.

The expectations from FCR water tariffs

Water administrators should reduce their expectations about the benefits of implementing FCR prices, especially in stressed basins and catchments. Most analyses show that under moderate water pricing policies, farmers would not reduce consumption significantly, invest in more efficient technologies nor change their observed behaviour. While well-financed irrigation districts and basin agencies are signs of good water governance, they are insufficient to tackle the most serious problems of water pollution and scarcity.

The special case of groundwater irrigation

Llamas and Garrido (2005) warn that aquifer overexploitation is a complex concept that needs to be understood in terms of a comparison of the social, economic, and environmental benefits and costs that derive from a certain level of water abstraction. It is meaningless and misleading to define overexploitation in purely hydrogeological terms given uncertainties in recharge and abstraction values and the fact that the amount of available resources in a catchment area is variable and can be influenced by human actions and management decisions. The assumption that a long trend (10 years, for example) of decline in groundwater levels implies real overexploitation or overdraft may be too simplistic and misleading. This concept has been used in Spain to provide grounds for public action, igniting a top-down sort of policy that has failed to deliver significant benefits. It is unlikely that water prices will deliver them, too.

5. Designing sound irrigation and environmental policies

Before venturing into offering policy advice, it's instructive to recap the major findings reviewed above. Among them, in my view, the more relevant are:

- More economic and technically efficient water use offers less flexibility to substitute among different farm inputs. In addition, farmers who invest in more efficient technologies may increase actual effective levels of water.

- Actual water consumption levels differ from deliveries or abstraction. Hence water prices may have differential effects, depending on the discrepancies among them.

- The groundwater irrigation responds to widely different incentives to those driving surface water farmers'. The price signal in most cases has not been sufficient to deter irrigation, nor reverse the impacts caused to intensively used aquifers.

- Water pricing policies are worse policies to address water pollution and contamination caused by irrigation practices than policies that target either the polluting source or the ambient standard.

- Available technologies and management can significantly reduce water use, chemical use and runoff and, thus, make irrigated agriculture more sustainable.

These five points, in my view, summarise the main research findings that should be taken into account to develop policies that are cost effective and deliver social benefits.

In previous work for OECD (2001), one can read:

> *"… [T]here are a number of gaps and challenges that demand further work in the field of rural water pricing policies:*
>
> *1. To better evaluate cost and benefit evaluations.*
>
> *2. Full cost recovery prices is a necessary condition to clear the way for further policies in water allocation and in furthering the use of economic instruments.*
>
> *3. In many arid and semi-arid regions, moving towards more efficient water allocation may provide society more dividends than ensuring that taxpayers' contribution covering part of water projects' investments costs is completely eliminated. Society as a whole may experience larger benefits from water reallocation than from reducing the cost of water subsidies.*
>
> *4. Another area which deserves more attention is the evaluation of the costs and benefits of new irrigation projects. Countries in all continents still subsidise new irrigation projects, realising negative financial returns, although claiming to generate other economic or social benefits.*
>
> *5. Benchmarks are needed to ensure that comparisons are meaningful, realistic and usable to increase accountability. Similarly to the environmental indicators for agriculture, benchmarks on cost recovery rates and costs*

definition will become essential elements to track progress and have a better idea of subsidisation levels. OECD can help the exchange of experiences in areas such as costs evaluation.

6. Any comparison of water cost and charges across OECD countries should be based on sound and complete data.

Looked at in retrospective, one can see a lot of progress on points 1), 2), 4) and 6), but less progress on points 3) and 5). In OECD arid and semi-arid countries, we have seen significant policy realignments with respect to water and irrigation policies. Spain and Australia are among those showing more radical changes, perhaps because their water problems are among the direst between OECD countries, except for Mexico and the Western US.

We know from numerous academic and official sources, at least in the EU, the extent to which irrigators pay full water service costs. While this wealth of information seems to indicate that farmers are paying near to full cost recovery prices (Maestu, 2005), cost accounting assumptions with respect to capital investments may bias downwards the costs evaluations against which water tariffs are compared. Historical cost accounting is mostly used, so any infra-structure older than 30-35 years is by all means already amortised. In my view, whether accounting costs are based on historical costs or actual costs is not the most relevant issue. If anything, increasing transparency about the true costs of irrigation projects served the purpose to provide valuable information about how taxpayers' money should be allocated to solve water problems.

If farmers already pay 100% of the O&M costs, what else can be done? As we will see, the challenges are even more daunting than implementing full cost recovery prices.

Next steps require solid alliances with irrigators. The objective is to ensure that less water is consumed in irrigation and pollution is reduced, but irrigators maintain their viable and profitable farming businesses.

A necessary but not sufficient condition for this to happen is to have benchmarking methodologies that can be applied to real world irrigation systems. This requires large capital investments in ITs to control for water flows, soils and crop variables, drainage and runoffs, and numerous others parameters that permit a characterisation of the complete system. It is the era of nanotechnlogies and electronics applied to manage irrigation systems. One can only expect responsible use of water resources and more sustainable irrigation practices if measurement devices and gadgets are installed to track down in real time the system's key parameters.

Unfortunately, this is not going to happen: i) if farmers experience financial severe distress and face a sombre future; ii) just as a response to water pricing policies; iii) by voluntary efforts within standard irrigation districts; or iv) by initiatives of individual farmers relying on groundwater. This implies that policy action is needed, though progress must be made on a catchment basis, and ideally district by district.

The policy action is sketched in Figure 4.

The components of this policy model are detailed here:

a) Financial needs

Multi-staged projects would be financed by the districts and the farmers, perhaps by means of long-term loans with privilege arrangements. This may pose difficulties in the financial markets because collective infrastructure can hardly serve as collateral. When most of the improvements are made beyond the farm gate, farmers' property does not provide collateral. At the end, famers' organisations may need support from the government, long-term loans and a social recognition for conserving valuable water, which can be translated into further revenue. Experience in New Zealand, Mexico, and Spain shows that, without the support of government, this kind of reform is hardly viable.

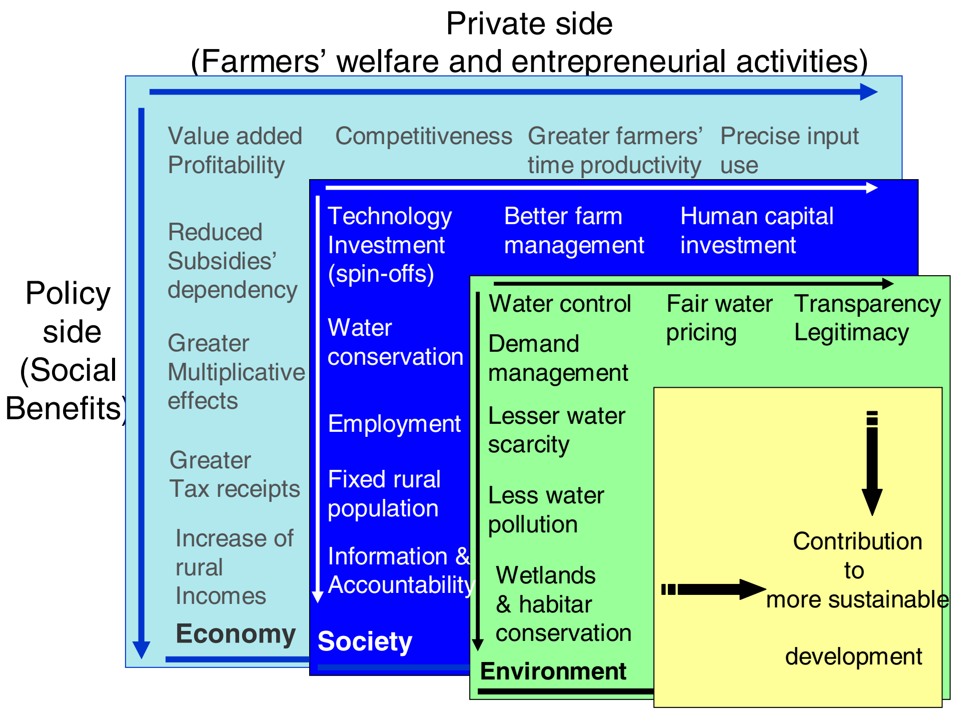
b) Technical design

Irrigators would participate in drafting the projects, together with engineers and environmental consulting firms.

c) Institutional reform

Multi-layered institutions are encountered in many successful examples of sustainable management of natural resources (See Dietz et al., 2003). Within our framework, institutional reform means changing the process of decision making, taking full advantage of the opportunities for better control of water and nutrients applications and plant development. As taxpayers bear most of the costs, it makes sense to request that these key variables are recorded and made available to the general public. In due time, benchmark studies will be possible, allowing for ex-post evaluations and increasing accountability.

Figure 4. The socio-economic and environmental dimensions



d) Water rights redefinition

In return for the public co-financing, the irrigation district would need to relinquish a certain amount of their water rights. Actual water conservation gains would need to be measured at various points of the conveyance system. The saved units can be evaluated at their true opportunity costs to highlight the social rationale of the project, and permit cost-benefit analysis evaluations.

In most cases, water rights do not need to be surrendered in full. Gómez-Ramos and Garrido (2004) show that water rights can be decomposed into their main attributes, including location, time, exclusivity, quality and access reliability. These authors show that in Mediterranean climatic patterns the most valuable resources are those needed in one out of 5-7 years.

e) Complete environmental impact assessment

Life-cycle analyses and environmental assessments would ensure that the technical and managerial improvements do deliver the expected environmental benefits. In cases where wetlands and natural habitats are improved as a result of the project, full documentation of the likely effects should be gathered.

f) Ensuring farms' profitability in the medium and long-term range

Financial evaluations and profitability analysis would ensure that farms are equipped with better means to control the ecology of their cropping systems and increase the harvests' quality.

g) Co-responsibility in project development and running

Farmers' organisations must be fully responsible for the investments made within their farms and beyond their farm gates.

6. Concluding remarks

Decades of economic studies about the irrigation sector show that incentives and policies can deliver unexpectedly negative results. We know that irrigated agriculture in almost all OECD countries is under attack by many socio-economic processes, including environmental and agricultural policies, and urban consumers' demands. Technologies are now available to put into practice the wealth of knowledge accumulated in the last decades about crops' ecology, climate and soil processes. Real time information about all crucial variables can be distributed at no cost to all control and managing centres in districts and basin agencies. This allows for gathering very disaggregate data that can be used to evaluate all sorts of efficiency and performance indicators.

All these opportunities are not going to be taken unilaterally by districts or farmers, saving a few exceptions. The public sector must put out the resources and the leadership to bring about the response of farmers and their collective irrigation entities. Large benefits can accrue to society in the form of reduced water consumption, lesser water and soils' pollution and significantly productivity gains.

Main policies have already being enacted in useful legislations around OECD countries. Liberalisation of food markets and more ambitious environmental and water policies are unavoidably reframing the role of irrigated agriculture. It is the time to work on specific projects, apply sound and environmentally-friendly engineering and see whether information technologies permit more sophisticated management — one that keeps the production of market goods, provides a decent livelihood to irrigators and minimises significantly the environmental impacts.

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The Future of Agriculture and Water: Market and Policy-based Strategies for Sustainability – What Can the Developing World Learn from North America?

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As global projections for water availability and the demand for water in agriculture point towards increasing scarcity and supply variability, more attention is being paid to the role that policies can play in enhancing the management and sustainability of water – in terms of both quantity and quality. Drawing some lessons from the North American experience, this paper discusses some best practices that can be learned by developing countries, and highlights some pitfalls that should be avoided. We discuss the role that assigning water rights can play in creating the necessary incentives for market-based mechanisms of re-allocation to work for both water quantity and quality management. We also emphasise the role that remains for centralised regulatory authority, and the need for collective action to ensure that essential eco-system requirements are met. Among the examples we draw from are those of inter-sectoral transfers, conjunctive use of surface and groundwater and tradable permit mechanisms – for which we also highlight the enabling institutional requirements.

1. Introduction

As global projections for water demand and availability point towards increasing scarcity, water resource managers and policy makers are looking for more innovative strategies to increase water use and allocative efficiency, as well as to manage demand through provision of efficiency-enhancing incentives. In response to these pressures, many developed and developing countries have experienced increases in the area of rain-fed agricultural land for food production, in order to meet the ever-growing demand for food (Figure 1). Nonetheless, there remains a clear need to enhance the efficiency and effectiveness of irrigation water delivery, as a large share of food production continues to rely on irrigation – especially in critical grain-growing regions of Northern China (Crook, 1999; Heilig *et al.*, 2000).

While the quantity problems of irrigation water have been long-recognised and discussed and studied by researchers, the quality issues that surround the agricultural use of water have also been coming increasingly to the fore of resource management policy agendas. Some of the main water quality concerns in developed countries today include trace chemicals and pharmaceuticals, as well as non-point sources of pollution from

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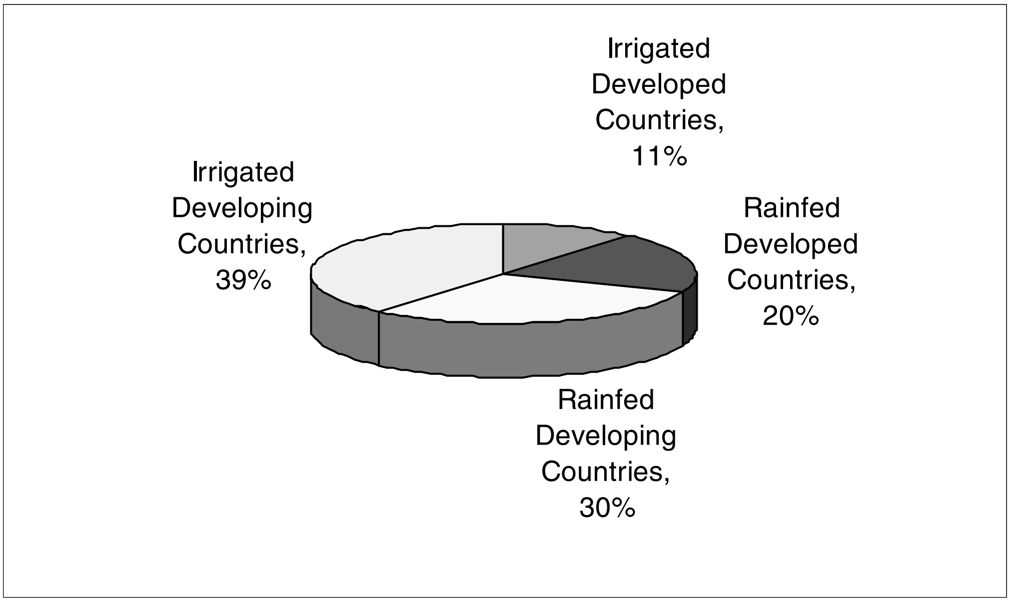
agriculture, such as runoff from fertiliser, pesticides and siltation (Davis and Hirji, 2003). These non-point sources are more difficult to regulate than point sources and thus most countries have only recently begun to deal with them. Both researchers and policy makers have come to the understanding that problems of water quality are equally as pressing as those relating to quantity scarcity, and have continued to pay increasing attention towards its management and regulation. For the case of developing countries, the issue of quality may be even more important than that of quantity, given the incidence of water-borne disease and the sheer number of rural poor who find themselves without access to clean water sources. In these countries, grave problems of water pollution are allowed to go unchecked, due to inattention or sheer lack of government regulatory institutions (Markandya, 2000).

Figure 1. Increase in share of irrigated and rainfed cereal production, 1995-2025



Source: IFPRI projections, Rosegrant *et al.* (2002).

While the policies that govern water quality and quantity are distinct in their nature, the types of institutions that govern their management within the context of water resource use have similar requirements and enabling conditions for their successful operation. In particular, the allocation of property rights to the water-consuming or polluting agents has been shown to greatly affect the outcome of agent decisions and to pre-determine the proper functioning of the governing institutions that oversee and regulate their actions. The role that water rights has played in enhancing the effectiveness of Water User Associations (WUA) has been well-documented, and has been shown to operate within a variety of settings, ranging from developing country contexts such as China (Diemer, 2001; Wang *et al.*, 2003a), Mexico (Dayton-Johnson, 2000) and India (Meinzen-Dick *et al.*, 1997). Within the wider literature of pollution control, property rights play a central role in enabling the operation of the trading and permit schemes that are designed to be both incentive-compatible and allocatively efficient. The lessons that have been learned from air quality pollution regulation are directly applicable to the case of water pollution, and are actively used by regulatory agencies and environmental policy makers in developed countries with a high degree of success.

In order to better illuminate the role that institutions and policies can play in the successful management of water quality and quantity in developing countries, we draw upon examples from the developed world – in particular, North America. The applications of regulatory instruments to the management of water quality and quantity in North America have been varied, given the heterogeneous nature of the institutions that exist among the various states. Given that the American West and Southwest rely so heavily on irrigation water for agricultural production – ranging from the Central Valley of California to the agricultural flats of Texas and New Mexico – they provide a particularly wide array of examples and institutional settings to draw from.

The lessons that we draw from cover both the management of groundwater and surface water resources, and discuss the various policy instruments that have been used to govern the availability and quality of these resources, within the North American context. The broad range of applications and policy examples referred to will give a broader perspective to our discussion, and illuminate some critical facets of institutional design that must be considered when trying to implement policies regulating water quality or quantity within a developing country context. Both the positive and negative experiences of water policy implementation in the North America will be of equal use in helping researchers and policy makers to better understand the challenges in implementing effective, long-term measures to enhance the efficiency of water resource usage and the sustainability of the resource base itself, in terms of both its quantity and quality.

The rest of this paper is designed as follows. Following a brief description of water policy in North America, we discuss the application of both market-based and non-market approaches to the management of water quantity, and refer to several specific examples for illustration. This is then followed by a discussion of the various policy instruments used to regulate water quality, in order to illustrate particular institutional features of importance and note. The section which follows draws upon these examples in order to make recommendations for sustainability-enhancing policies that can be applied within the context of developing countries, and the paper concludes with a section which discusses the implications of these policies and summarises the lessons for regulatory best-practices.

2. Water quantity management

2.1 Introduction

In this section we will explore some of the mechanisms for water quantity management that have been put into practice, and how they fit into the North American context and the water laws that exist there. Many of these mechanisms extend into the management of water quality as well, given the close connection between the demand for water of sufficient quantity as well as quality. Nonetheless, our focus will remain on quantity issues, so as to more clearly describe the mechanisms at play and draw out the lessons to be learned.

2.2 Surface water management mechanisms and institutions

Legal doctrines

Given that surface water sources are the most easily accessible, divertible and exploitable, many of the water laws and institutions in North America were initiated for the purpose of adjudicating surface streamflow and diversions from above-ground sources. The American West, in particular, was populated for the purposes of establishing farming and mining settlements, and the surface water resources that were found there were quickly adjudicated in tandem with the land titles that were being granted. This is the primary reason why the legal structure surrounding water regulation in the American West is so complicated and heterogeneous in nature. Compared to the riparian type of water laws that ruled in the eastern parts of the country, the American West saw the introduction of prior appropriation, which grants more senior rights to those who were ‘first-in-use’ compared to the holders of more junior rights. While some economists agree that appropriative rights have some positive aspects that promote water use efficiency, there can be inefficiencies that result from the fact that risks are not equally allocated among the appropriators, or that the incentives to invest in storage capacity are weak (Kanazawa, 1991).

The factors behind the differences in legal regimes governing water in the American east and west lie in the fact that riparian rights are less suited to the highly variable streamflow conditions of the western United States, where most agricultural and municipal consumption of water occurs at a considerable distance from the riparian streambank (Howe, 1998). In the case of California, there is a mix of legal regimes that exist – some riparian in nature, while others are appropriative in origin – which creates difficulties when trying to set up allocative mechanisms or institutions that cover a large spatial area across the state.

Texas is another ‘dual doctrine’ state that has both riparian and appropriative regimes for water rights – resulting from a ‘layering of law’ imposed by successive Spanish and English common law regimes in the history of that states transition from colonial rule to independence and statehood within the larger union. Despite the attempts of the Texas legislature to adapt its laws to changing pressures on the state’s water resources, so as to allow for more appropriative allocations while protecting previously-held riparian rights, the coincidence of these two regimes has been at the root of many conflicts over water in the state (Griffin, 1998).

Transfers of surface water

The majority of surface water transfers that occurred in the Western United States, during the early to middle parts of the 20th century, were for the purpose of fueling urban grown and the accompanying growth in demand for domestic and industrial use. The bulk of those transfers came from agriculture and from the acquisitions of irrigated lands in those areas, to facilitate the growth of Los Angeles in the 1920s, that of Denver in the 1930s, and even as recently as the 1980s saw the purchase of thousands of acres by cities and developers in Arizona (Colby, 1998).

Within California, itself, the psychological scars inflicted through the unscrupulous sale of water rights in the Owens Valley to the Metropolitan Water District in the 1920s has made many farmers suspicious of water transfers, and dampens the enthusiasm that would otherwise exist for such re-allocation mechanisms which have clear economic merit (Moore and Howitt, 1984). These ‘ghosts’ which still haunt Owens Valley make the promotion of market-based mechanisms difficult among farmers who would rather put their water to less-profitable uses than risk losing it through temporary transfers or leases (Thomas, 1991; Haddad, 2000).

Besides the heterogeneity of water rights doctrines mentioned previously, other obstacles to the implementation of transfers between water users can be placed by individual city governments, water districts or state legislatures. These administrative or legislative bodies can mount legal challenges to block the occurrence of transfers either within the state or across state boundaries, on the grounds of possible adverse effects that might result from them (Howe, 1998). While the presence of mechanisms that prevent damage is necessary, it might result in the placement of undue burden of water resource administration in the hands of judges within the legal system, and open the possibility of creating a contradictory patchwork of institutional restrictions and enforcement mechanisms, rather than a more unitary and comprehensive approach to resource management.

In the case of Colorado, any proposed transfer can be challenged by a third party which perceives the possibility of injury from the transfer of flow – leaving the system open to numerous challenges, as there is no later recourse once the transfer is approved. This system, which imposes tremendous costs on all parties to have both legal representation in court as well as evidence supported by rigorous engineering analysis, raises the transactions cost of effecting transfers tremendously, and makes it difficult for smaller parties to lodge legitimate claims (Howe, 1998). By contrast to Colorado, states like Utah and New Mexico handle all proposed transfers through a central agency – that of the State Engineer – whose adjudications seldom go challenged in legal appeals. These states also base transfers and appropriations on the ‘reliable’ flow – that flow which is realised over 80 percent of the time – which avoids much of the administrative burden borne by Colorado, which does not follow this rule, and must decide which rights to curtail first when the ‘volume’ of water rights held exceeds the volume of actual water in the realised streamflow (Howe, 1998).

Yet another feature of the legal landscape that presents a challenge to water transfers in the American West is that of “sleeper” rights held by native peoples and indigenous nations, which are not lost from lack of use, unlike other water rights (Livingstone, 1998). There have been a number of contentious and intensely litigious disputes over water rights that have arisen when the holders of these rights ‘awoke’ to contest their interests and historical claims in courts of law. While the dispute over water rights in the Wind River Basin of Wyoming has continued over time, despite the award of the senior-most water rights to the Wind River tribes by the Wyoming Supreme Court in 1989, an act of Congress in 1990 provided for the protection of Pyramid Lake and Truckee River fisheries in the Sierra Nevada that the local Paiute tribe had been advocating for, and channeled the interests of both federal agencies, local constituents and environmental groups towards an agreeable outcome.

Water banking

Despite the occurrence of historical disputes over water, successful transfers have been realised through the creation of novel institutions to adjudicate beneficial re-allocations in times of scarcity. Among the best known examples is that of the State Drought Water Bank which operated in California in both 1991 and 1994, during a severe drought period (Howitt and Sunding, 2003). Even though the water bank was not an entirely 'free-market' phenomenon, due to the fact that it was instigated and administered by the state legislature and state Department of Water Resources, it managed to achieve its objective in transferring water to more economically beneficial uses across the state (Livingston, 1998). This type of re-allocation seems almost inevitable in California, given that roughly three-quarters of the precipitation falls on the northern half of the state, while three-quarters of its residents live in the southern portion of the state (Thilmany and Gardner, 1992). This fact was reflected clearly in the outcome of the State Drought Water Bank's operations, which saw most of the purchases being made by farmers with permanent crops and the urban users of Southern California, while the bulk of the volume sold was obtained from farmers in the northern part of the Central Valley (Livingston, 1998).

Managing environmental flows

One of the biggest challenges that water policy makers face is balancing the needs of agricultural users, municipal and industrial water uses and the instream requirements that are necessary to preserve various necessary eco-system functions. This 'third' sector of the water use is often represented by environmental groups or local, state or federal agencies that are mandated to protect the interests of wildlife and their aquatic habitats.

A good example of this kind of policy challenge can be found in the example of the California Bay Delta, which is the most productive estuary on the Pacific coast, supporting over 120 fish species while draining 40% of California's land area (Sunding *et al.*, 1997). When the Delta smelt and Chinook salmon species were perceived to be under threat, however, three legislative acts were quickly brought to bear to remedy the situation – the Clean Water Act; Endangered Species Act; and the Central Valley Project Improvement Act – which all mandated an increase of flows through the estuary, and implicated the largest cuts for the agricultural sector. As Sunding *et al.* (1997) showed in their multi-model analysis, the most important factors that determine the social cost of protecting flows to the Bay Delta region are (1) the extent to which the cuts are shared among the growers and (2) the extent to which water trading is allowed between users. Despite these challenges, however, California has managed to maintain an ongoing dialogue between the three competing water use sectors, which has resulted in favorable policy outcomes.

2.3 Ground water management mechanisms and institutions

Legal doctrines

Similarly to the legal regimes that govern the ownership of rights to surface water, as described in the previous section, those that prescribe the allocation of rights to are varied in nature, although somewhat more spatially homogeneous within regions. In addition to the doctrine of prior appropriation, which also exists for groundwater rights, there also absolute rights which can be assigned to users of groundwater resources. Absolute ownership, which also finds its origins in English common law, essentially equates the transfer of land ownership with the transfer of rights to the water which lies underneath it, although transfers can also be effected through the direct pumping of the underlying water to the surface and conveying it by conduits (Griffin, 1998). The fact that groundwater resources are fugitive in nature, and cannot be restricted by the will of the overlying landowner, means there is no absolute means of laying claim to the entire stock of water underlying a piece of land – making it a common-property resource which no one can exploit exclusively.

In addition to the absolute and prior appropriation doctrines there is a doctrine of correlative rights that exists in California – leading it to sometimes be called the "California Rule" (Bogess *et al*., 1993). Under this doctrine, land owners are given equal rights to make 'reasonable use' of common groundwater pools, and that water is prorated among all the overlying land owners, so as to prevent a level of resource usage that could cause 'injury' to any one of them. Despite the ideals of this doctrine, some see correlative rights in unadjudicated basins as being a significant inhibitor to water trades (Howitt, 1998).

Institutional innovations

In order to prevent some of the problems associated with common-property resource exploitation, as described by Hardin (1968) and Coase (1960), innovative schemes for allocating groundwater rights have been proposed – such as that of assigning rights to the aquifer recharge (Provencher, 1993; Provencher and Burt, 1994) – but rarely implemented, due to the complex nature of sub-surface flow, and the fact that it's much less observable than surface water flow. The analysis that Gisser and Sanchez (1980) and Gisser (1983) did of the common-pool groundwater problems within the Los Pecos Basin of New Mexico, was rather pessimistic in its conclusions with regard to the potential gains that centralised management and administration of groundwater resources could achieve, and has colored the view that many have had with regard to this problem since then.

In the case of Texas, however, some efforts have been made to introduce innovations into the management of groundwater, such that rights can be more easily transferable, and made available to higher-valued uses within the state. The changes that have taken place in that state, with regard to the adjudication of rights over groundwater, can be seen principally in the management of the Edwards Aquifer, which supplies large cities such as San Antonio, and which displays remarkably rapid responses to recharge and pumping – making it behave more like the stochastic flow in a river, compared to most slow-reacting aquifers (Griffin, 1998).

The particular innovations that have taken place in Texas groundwater law, so as to gradually extinguish the absolute ownership of groundwater in the Edwards Aquifer and to break the link between land ownership and water rights, are described by Griffin (1998) as: (1) the establishment of a Water Authority to provide oversight, (2) the mandatory metering of water at the expense of this Authority, (3) the adjudication of rights based on proven use, (4) the gradual decline of total rights in the aquifer in order to improve the protection of flow from springs over time, (4) allowing the sale of rights by those owners who have installed water conservation equipment and (5) allowing the lease of water rights, up to a limit of 50% of an irrigation water right. While laudable in its move away from a seniority system and towards correlative rights – as paralleled in the evolution of surface water law – the Texas water law also places considerable administrative burden upon the central authority, which runs a high risk of executing inefficient transfers if it fails to exercise them on strictly economic principles.

The role of groundwater in transfers and banking

Like California, Texas also established a water bank, by an act of the legislature in 1993 (Griffin, 1998). While it hasn't seen the level of activity that the California State Drought Water Bank experienced during 1991 and 1994, it still represents an institutionalised mechanism that is in place to facilitate potentially beneficial transfers of water entitlements within the state (MacDonnell *et al.*, 1994). Many economists, such as Howitt (1993), support the idea that groundwater aquifers have an important role to play in effecting beneficial transfers between two parties, and can play a complementary role with that of surface water transfers – as long as the effects on third parties is taken into account.

It is precisely this issue of 'Third Party Effects' that has drawn the concern of many hydrologists, policy makers and user associations after observing the unintended impacts on return flows and natural recharge processes that were created by large scale transfer of surface water in state-sanctioned operations. Hanak (2003) has outlined many of these issues in connection with transfer and water-banking related operations in California, so as to focus on the institutional safeguards that must be in place to protect the interests of those who might be adversely impacted by market-driven water reallocations. In Thomas' study of Groundwater and Groundwater Banking in California (2001), he cites the case of Butte County, California, in which the upland farmers in the 'Cherokee Strip' area claimed damages due to falling water tables caused by the sale of surface water rights of lowland rice farmers to the Drought Water Bank in 1994. McBean (1993) also cites adverse impacts on groundwater levels in Yolo County, California, created by operations during the 1991 operation of the Drought Water Bank.

Despite these problems, however, the fact that surface water flows are highly variable in nature, in states like California, and given the highly spatially differentiated nature of supply and demand within the state, the need for both long-distance and local transfers will remain, through the use of innovative such instruments as banks, as well as spot and option markets for water (Howitt, 1998).

2.4 Mechanisms for conjunctive use of surface and ground water

In the cases that we've discussed previously, the interconnection between ground and surface water has been apparent, and often the complicating factor in the operation of transfers, trades or other re-allocative mechanisms for water. While considering surface and groundwater interactions adds a layer of complexity to the resource management problem, it also opens new avenues for exploiting the 'system' to optimise available storage capacity and to better handle issues of quality, that we will address in more detail later on in the paper.

The management conjunctive surface and groundwater usage has a long history in the natural resource economics literature, beginning with the seminal articles of Burt (1964a, 1964b), and the numerical analyses of Young and Bredehoeft (1972) and Bredehoeft and Young (1983), and followed by more recent literature which emphasises the buffer value of groundwater, when the stochastic nature of surface water cause uncertainties in supply (Tsur, 1990; Tsur and Graham-Tomasi, 1990; Provencher, 1995).

One of the best examples of conjunctive surface and groundwater use management in North America is that of the Arvin Edison Water District in Kern County, California. The way in which water is managed within this system has implications for how both quantity and quality issues can best be managed within an inter-linked surface and groundwater resource system (Tsur, 1991). This Water District, which began its groundwater recharge programme in 1964, obtains a yearly entitlement from the US Bureau of Reclamation which varies in accordance with the statewide availability of water, and which can result in shortfalls being made up through groundwater withdrawals, or with surplus being put back into the aquifer through spreading pools. Tsur (1997) shows that the stabilisation value of groundwater, in the Arvin Edison system can amount to up to 50% of the total value of groundwater

In terms of the management of water quality – especially salinity control – optimising conjunctive surface and groundwater usage can be crucial in maintaining the necessary salt and water balance, which can be especially critical for coastal aquifer systems. We will explore these aspects more fully in the next section when we discuss water quality management.

3. Water quality management

In this section we will examine various aspects of water quality management and discuss examples in North America that illustrate innovative applications of policy instruments, as well as the challenges facing regulators and policy makers who deal with water quality issues. In addition to pollution, we will also consider the issue of salinity management, which is a critical constraint to irrigated agricultural productivity in many regions of the world. The institutional examples we will examine from North America will also provide useful insight and valuable lessons towards the proper design of agricultural drainage and salinity management schemes.

3.1 Market-based approaches and the role of water rights

Market-Based approaches to water quality and other environmental problems are often considered to increase cost-effectiveness and to provide incentives for technology innovation compared to the command-and-control approaches to environmental regulation traditionally used in many countries (Stavins, 2000). The goal of these approaches is generally to reduce the environmental damage in question at the lowest possible social cost, by aligning private and social costs. While many types of market-based instruments exist, some of those considered for water pollution control include pollution charges, tradable pollution permits, and increasing the price of environmentally damaging inputs (by either taxing or removing subsidies) (Davis and Hirji, 2003; Sterner, 2003). Another innovative approach to enhance water quality is environmental service payments, where stakeholders interested in improved water quality pay for watershed conservation and management activities.

Water Rights are most often discussed in terms of water quantity issues and some system of water rights is found to operate in virtually any setting where water is scarce. The use and discussion of water rights in the context of water quality issues, however, has been mostly overlooked. The various market-based approaches to water quality issues are grounded, to a large extent, on the recognition of secure rights to water. The use and trading of effluent permits, for example, gives polluters a right to pollute a water source at a permitted level, which in turn can influence the availability of clean water available for other users. In fact, the idea of a "right to pollute" is a major concern that some environmentalists raise with market-based instruments.

Although water rights are not commonly used to deal explicitly with water quality, there is some scope for their use in areas where water rights have been defined for water quantity. For example, government authorities or conservation groups in the US have, in some instances, purchased irrigation use rights from farmers in order to increase environmental flows, such as in the previously mentioned case of the California Bay Delta Accord (Sunding *et al.*, 1997). This could lead to decreased non-point source pollution from agricultural sources as well as increasing overall water quality through dilution of pollutants due to the increased environmental flows.

3.2 Pollution charge systems and tradable permits

Pollution taxes

Pollution charge systems assess a certain tax per amount of pollutant emitted by a given firm. Different firms will reduce pollution by varying amounts depending upon their marginal costs of abatement. This type of system ideally reaches a given level of pollution at the most efficient cost by allowing firms with high control costs to pollute more, while those firms with low control costs will pollute less. Effluent tax systems are also appealing because of their potential to promote pollution control innovations and their ability to generate revenues (Boyd, 2003). The revenue-generating aspect can be particularly important to many regions since the investments required for water pollution control infrastructure are typically high.

The difficulty with this type of system is determining the appropriate level of tax to charge in order to obtain the most efficient level of pollution reductions. In addition, pollution tax systems are often hard to sell politically. Polluters are often against this type of regulation as they are responsible for the cost of implementing the control technologies as well as for taxes on uncontrolled emissions (Boyd, 2003). Moreover, new firms are often held to higher standards than existing firms under such a system, leading to disincentives for entry of new firms. Environmentalists also often oppose pollution tax systems on ethical grounds since all firms are not required to abate the same amount. Other difficulties include the fact that these systems are harder to implement than traditional command-and-control approaches. Monitoring of sources also generates problems that become much more complex when non-point sources are considered, which are generally much smaller and harder to monitor than point sources. Due to these difficulties, taxes on inputs (such as pesticides and fertilisers in the case of agriculture) rather than on outputs may be more reasonable for non-point sources of pollution.

Market-based trading mechanisms

Trading mechanisms have become fairly well-established in the management of certain types of air pollutants, particularly in the US. The seminal works of McGartland and Oates (1985) and Tietenberg (1985) were the first to discuss a decentralised system of tradable permits that could be bought and sold within a transparent market structure that could be used to improve the environment.

While market-based approaches have become relatively accepted for air quality regulations, they have not traditionally been as widely used for water quality. The use of markets for water pollution has been gaining popularity in recent years, however, particularly in the US, where many tradable permit programmes have been developed since the mid-1990s. Pollution trading programmes generally seek to achieve a certain level of environmental quality while minimising the abatement costs incurred by polluters. These programmes have appealed to policy-makers in many areas not only as a means to decrease the costs of pollution reduction, but also to help meet current environmental standards that were not being met through traditional regulatory means.

Woodward and Kaiser (2002) suggest five possible agency goals for a water quality trading programme: 1) reaching environmental goals defined by laws or regulations, 2) minimising the social costs of reaching a proposed environmental goal, 3) allowing the agency to maintain control over the programme while minimising legal risks and effort put into day-to-day programme operation, 4) minimising transaction costs by the participants, and 5) minimising the costs of initiating the programme for agencies and participants. Some authors suggest that significant cost savings can be realised from water pollution or nutrient trading programmes, as in a Michigan-based study which estimated costs of $2.90 per pound of phosphorus removed, while conventional regulations were estimated to cost around $24 per pound (Faeth, 2000). As mentioned above, it should be noted that these programmes might also have additional administrative costs that can be significant.

Challenges for implementation

When initiating a water quality trading programme, several legal issues must be considered with respect to the legal and institutional setting of the country where the regulations are to be implemented. First of all, it must be determined if such a programme is authorised under the current water quality regulations that are in force in a certain jurisdiction. The implementation of any trading programme must not violate current water quality regulations. It is also crucial that polluters monitor and report their emissions so that the agency with oversight authority will be able to determine if water quality standards are being met. In addition, as with other types of pollution trading programmes, there must be a legal entitlement for the pollution discharge. These entitlements must be transferable and enforceable in order for an effluent trading programme to work properly. Finally, the issue of enforcement is critical to ensure that the market functions effectively and that water quality standards are met (Woodward and Kaiser, 2002; Woodward *et al.*, 2002).

An added element of complexity of water pollution trading systems involves the type of pollution source that is being regulated. Trades can occur between point sources, between non-point sources or between point and non-point sources. Trading between the same type of pollution source (i.e., point/point trading or non-point/non-point trading) is generally simpler to deal with than trading between different types of sources. When trading between point and non-point sources, it is generally recommended that a trading ratio be applied since non-point source reductions are considered to be more uncertain than those for point sources. Some have suggested that a trading ratio of greater than 2:1 be used (indicating that a reduction of two units of pollution from a non-point source is required to offset one unit of production for a point source) when trading between point and non-point sources (NWF, 1999).

3.3 Salinity control and drainage management

While agricultural activity does generate water quality pollutants in the form of fertiliser nutrients that run off into surface streams and groundwater drinking supplies, another important externality generated by irrigated agriculture comes from the drainage water that is collected, and the build-up of saline waters in the substratum of the soil profile. While agriculture flourished in the Californian Central Valley with the large scale application of irrigation, the shallow clay lens that underlies the valley promotes the rapid accumulation of saline waters that must be dealt with. Parallels with the irrigation and drainage management problems in California can be found as far away as the North China Plain.

Among the options that can be considered in the management of agricultural drainage water is that of re-use, in which drainage water can be intercepted and isolated for later re-use on salt-tolerant crops. As Rhoades and Dinar (1991) point out, this could be a better strategy then 'blending' waters of high and low quality, provided that the secondary drainage water that is generated after re-application can be disposed of in a suitable manner. In his examination of the San Joaquin Valley Drainage Program, Stroh (1991) lays out a variety of possibilities for managing drainage in an area where the shallow groundwater tables contain high levels of selenium. Among the options he mentions are those of drainage water treatment; evaporation; dilution and control through groundwater pumping. He also points out that retirement of agricultural land is also a viable option for dealing with the problem, and can actually turn out to be a least-cost option under certain circumstances. In order to properly asses the impacts of land retirement, however, it is necessary to consider all the economy-wide effects that could result from the loss of agricultural production (and labour) in such a situation. For this kind of analysis, a computable general equilibrium analysis framework could be useful as is demonstrated by Berck *et al.* (1991) in their analysis of water policies in the southern San Joaquin Valley.

Suggested methods for managing salinity and drainage that parallel those used in addressing water quantity issues could be that of applying block-rate pricing instruments, as suggested by Wichelns (1991) within the context of Broadview Irrigation District in California, or the conjunctive use of surface and groundwater as suggested by Tsur (1991). Not all methods, however, are applicable to the case of water quality, however. As Randal (1991) points out, for the case of in-stream flows and provision of water for maintaining wetland functions, some degree of collective action is needed to account fully for the public benefits that cannot be internalised if one simply assigns rights in order to facilitate the creation of water markets.

3.4 Market-based approaches in North America

Market-based instruments, in particular pollution charges, have been used to deal with water pollution in the Americas with varying degrees of success. The United States has traditionally used command-and-control policies to deal with water pollution, although the role of market-based approaches, particularly effluent trading programmes, has been increasing. These programmes are often used along with current regulations to help improve the efficiency of water quality policies. While pollution trading programmes have been very successful for other media, success so far in water quality trading has been less notable, even in the United States where most of the programmes have been initiated (Faeth, 2000). Although many programmes have initiated only a few trades so far, the potential for efficiency improvements seems to exist. Many state and local governments have recognised this potential as 11 additional demonstration programmes were initiated in 2003 alone. In the following, we discuss the application and results of some market-based programmes implemented to date.

In 1989 the state Environmental Management Commission ascertained that the Tar-Pamlico River basin in North Carolina was nutrient sensitive, due to low dissolved oxygen and algae blooms caused by excess nitrogen and phosphorous in the river. The excess nutrients were found to come primarily from non-point agricultural sources, with additional contributions made by wastewater treatment plants, industrial discharge and mining operations. A programme was initiated in the Tar-Pamlico basin that allows point-source polluters to trade with one another under a cap. If they are unable to keep their emissions below the cap, they can pay into a fund that supports a government sponsored non-point source reduction programme (Easter and Johansson, 2005). The efficiency of polluters was found to increase in the first phase of the programme and discharge levels were met. A second phase will gradually reduce the allowable discharges (Faeth, 2000).

One of the most successful water quality trading programmes in the US to date has been the Long Island Sound Nitrogen Credit Trading Program in Connecticut. This programme allows point sources to trade with other point sources with the goal of reducing nitrogen levels and resolving the hypoxia problem in the Long Island Sound. The programme was passed by the state legislature in 2001 and began operations in 2002. Trading is allowed between 79 publicly owned treatment works, with the Connecticut Department of Environmental Protection (DEP) acting as a broker for the trading. This involves the treatment works operators selling and buying credits to the DEP, reducing transaction costs and allowing the DEP to have control over the market. Early estimates project cost savings over a command-and-control programme of $200 million (Kieser and Fang, 2004).

The final example is a notable example because it employs trading between point and non-point sources. A programme was developed in 1997 in the Minnesota River Basin to allow trading of nitrogen and phosphorous between two point sources and non-point sources in the watershed. The point sources have set up a trust fund, which provides funding for the programme to ensure that wastewater discharges are offset by reductions in non-point source pollution (Easter and Johansson, 2005). The trading scheme utilises a trading ratio of at least 2:1 to take into account uncertainty of the non-point pollution control measures (Fang and Easter, 2003). The Minnesota Pollution Control Agency closely monitors the programme to assure accountability. There have been five major trades and many smaller trades since the programme began. Estimates have shown this programme to increase cost efficiency, although the results vary depending on the non-point pollution control method used (Kieser and Fang, 2004).

4. Implications for water use sustainability

At this juncture, we can now draw some important lessons that might be learned from the examples of water quantity and quality management that we have examined, so far, within the North American context. Each of the lessons learned will have important implications for where policy makers in developing countries should focus their attention on in designing institutions and policies that will enhance the sustainability of water use patterns within their countries.

4.1 Some lessons for quantity management

The first lesson to be drawn from the experience of the western United States is the importance of homogeneity of legal doctrines which determine the regime of rights under which users appropriate and use water. The difficulties experienced in ‘dual doctrine’ states such as California and Texas show that where heterogeneity exists, conflicts are like to arise, which must be settled in courts of law – which leads to a situation where policy is decided on a case-by-case basis, creating a patchwork of legal strictures and administrative domains for localised adjudication of court-mandated provisions. This is a difficult environment in which to create statewide (or even multi-regional) agreements and institutions for management, which can facilitate trade or transfer of water to higher-valued uses. This underlies the contrast between California and countries with long traditions of water markets like Chile, which enjoy a more unified system of water rights within the country (Rosegrant and Gazmuri, 1994; Livingstone, 1998).

Related to the issue of harmonisation of water rights regimes is that of unified management structure at either the river basin, or for some other appropriate command area that encompasses the resource that is to be managed itself. This lowers the transactions costs that would otherwise be incurred in having to overcome the various kinds of legal challenges that are seen in Colorado, or in between the various irrigation districts and urban water supply districts in California. If a river or groundwater basin authority could evaluate and adjudicate all existing claims and undertake a comprehensive analysis of the potential impacts that might result to the parties that depend upon the flow of the resource, and if it could be multi-district, or even multi-regional in nature, then the possibilities for costly interventions by legal courts or individual city councils or state legislatures could be lessened. As some authors have noted, the lack of transboundary, river basin-level administrative bodies which adjudicate and regulate the allocation of water from transboundary water resources leads to litigious and inefficient diversions from those resources, and hinders efficient re-allocations across space (Howe, 1998). The use of the river basin authority model in China is an example of how a surface water resource that crosses multiple provincial boundaries could be managed by a unified oversight body – although even that model is not entirely free of problems of both a financial and political nature (Lohmar *et al.*, 2003). While central authorities can remove some of the transaction costs that more individualised bodies would otherwise have to incur, the choice of criterion that such an administrative authority uses in making allocations is crucial, as it can lead to outcomes that are far from the economically-efficient optimum, if based solely on considerations of parity or political ‘satisficing’.

Another useful lesson to take away from the comparative experience of Colorado, Utah and New Mexico is that it is best to assign water rights on the basis of the volume of ‘reliable’ flow, rather than based on the total flow in the river. The latter approach to rights allocation results in situations where one might have more ‘paper’ water than ‘wet’ water in a dry year (Howitt, 1998), which places a heavy administrative burden on the management authority, which must decide where to begin curtail the existing rights. This is a situation in which banking could assist, in helping to facilitate transfers between willing buyers and sellers, provided that the management authority is also up to the task of looking out for the interests of third parties. In such a situation, assignments of allocations should be made taking care to ‘net out’ that which is needed for recharge of the aquifer, so as to minimise impacts on unintended parties.

Another major lesson to be learned from the examples we have seen is that allowing for flexibility in the re-allocation of rights is important to maintaining efficiency – whether it be in the management of groundwater or surface water. The Texas model of transferable groundwater rights is far preferable to forcing farmers to over-pump in order to hedge against the risk of shortage later, or as a means of transferring water to other willing buyers. Granted that the observability of groundwater pumping and diversions is greatly reduced, as compared to the case of surface water, there is still scope for management if the proper ‘indirect’ policy instruments are applied.

4.2 Some lessons for quality management

An important lesson to be drawn from the experience of applying market-based trading mechanisms for regulating water quality in North America is the importance of accounting for uncertainty in the design of policy instruments. As pointed out by Easter and Johansson (2005), the various ways in which uncertainty can present itself – in terms of the source of the pollutant, the effects of policy, the behavior of users or the way effects might manifest themselves over time – each presents a set of challenges that must be taken into account in policy design. For that reason, the application of a trading ratio between point and non-point sources of pollution can serve to compensate for the uncertainty that a reduction in emissions from non-point source involves.

Another lesson to be gained from the experiences of water quality regulation in North America is that enforceability is just as important as maintaining the transferability of rights between polluters. As mechanisms for managing water quality move away from command-and-control regimes to ones which rely on market-based incentives, it must still be recognised that a considerable burden still remains on the regulator to monitor pollution levels and to enforce penalties or taxes on those who exceed allowable standards. While market-based mechanisms can be designed to overcome the incentive-compatibility problems that might otherwise exist in a decentralised trading system, there still remain the challenges of observability that the regulator must face when trying to assess the ambient levels of pollutant, and the extent to which they exceed defined standards of environmental quality.

In many of the policy settings examined in North America, it is evident that the creation of market-based incentives cannot, by themselves, create the conditions for environmentally sustainable resource usage. Given that many aspects of environmental quality correspond to public goods, whose total benefits cannot be fully appropriated or internalised by an individual, there needs to be a level of centralised intervention or some other type of collective action that ensures these public benefits are generated to the fullest extent possible. While it is desirable to maintain flexibility and transferability of rights for the pollutants, it should also be an objective of policy makers to ensure that the institutional mechanisms for mobilising collective action are also in place, so as to meet the goals of resource longevity and sustainability of use.

4.3 Designing water resource management for sustainability

In our examination of water resource management practices in North America, we have considered a wide variety of examples from which we can draw valuable lessons. Nonetheless, it remains a fact that the institutional settings from which we drew our examples are vastly different from the socio- and political-economic environments and realities that face many of the developing-country policy makers that we are addressing ourselves to. Therefore, some guidance must be given as to how to adapt the lessons learned from the North American experience to the developing-country setting.

One of the closest parallels to the California setting is that of China, which grows similar agricultural products, and which also has a heavy dependence on irrigation from both surface and groundwater sources to support production – especially in the North China Plain. While the majority of California’s water is in the North and the bulk of its population is in the southern part of the state – the reverse is true for China, which has propelled the momentum to realise a 'South-to-North' transfer of water (World Bank, 2002). The salinity problems in the North China Plain are also similar to those of California, and call for the same menu of options to be considered, such as improved conjunctive use management of surface and groundwater (Huang, 1988; Cai, 1988). Perhaps the most striking difference between North America and China is the structure of agricultural production and the system of land tenure that exists in rural China – which, though different from that which existed before the introduction of the Household Responsibility System in the mid-80s, is still not fully privatised and is subject to the periodic re-allocations imposed by village leaders and party officials (Lohmar *et al.*, 2003; Nyberg and Rozelle, 1999). This, combined with the fact that the average agricultural holding of a farm household is much smaller than would be seen in North America, makes the allocation of individual rights to land or water more complicated than it would be within the California setting.

The presence of village-level water user associations in rural areas, however, opens the possibility that some of the rights that would otherwise be assigned to an individual within a North American setting could be assigned to a group of farmers or a group that represents their interests, so that the collective benefits of improved management could be internalised within the group. Some evidence from China has already shown that property rights innovations centered around farmer-based groups and even individual households are already taking place in tubewell ownership (Wang *et al.,* 2003b) and in the management of village surface water systems (Wang *et al.,* 2003a) that seem to be improving the efficiency of water resource allocation in those villages.

In contrast to China – where the average land holdings of household farms are fairly small, although fairly evenly distributed within the village – the setting of Latin America presents a different set of challenges, given the fairly large landholdings and high degree of inequality in land distribution and tenure. In this kind of setting, the central authority clearly has a role to play in ensuring that the interests of smaller resource users are protected, as market-driven transactions of resource allocations are carried out, and the incentives internalised by the larger market players will most likely exclude the interests of smaller third parties. Nonetheless, some examples from India – which also has a large disparity in rural landholding sizes – have shown that properly designed schemes for assigning rights can still lead to positive outcomes for resource management (Meinzen-Dick *et al.*, 1997). But other authors warn that enforcement is more important in these settings than the assignment of tradable rights, as in the case of irrigation canal management (Ray, 2001).

While we cannot exhaust the list of possible adaptations that can be made to fit the policy lessons of North America into the varied institutional settings that are observed in many developing countries, we can emphasise some key principles that policy makers can follow. Foremost among these is the need to maintain flexibility in the assignment of quotas, initial allocations or assigned rights, so that necessary re-allocations can occur smoothly, efficiently and without the excessive involvement of central authority. Secondly, it should be recognised that while decentralisation of resource allocations may be desirable, the maintenance of central regulatory oversight is critical to ensuring the proper provision of public benefits and maintenance of essential eco-system services and streamflow requirements. The means for mobilising collective action, where needed, should also be kept in mind – and might be easier to implement in a setting like China, where the village leaders have considerable influence and control over local resource allocations (Oi and Rozelle, 2000), compared to other settings.

Lastly, it should be noted that the gradual settlement of the North American continent – starting from the East and spreading West – created a unique pattern of institutions across the country that were often rooted in English Common Law, but were also overlaid with the Spanish- or French-colonial legal doctrines that were encountered further west, as new states were created and new waves of westward migration were accommodated. This contrasts sharply with the institutional dynamics of most developing countries, which might have had a single colonial experience (at most) to contend with and adapt its systems of land tenure and legal rights to. This accounts for the relative homogeneity of legal doctrines in countries such as Mexico and Chile, and the relative ease with which these countries were able to establish market-based systems of resource allocation (Livingstone, 1998). Therefore, many of the difficulties of institutional implementation arising from the heterogeneity of water rights doctrines in the Western US need not present themselves in developing countries with more unitary legal doctrines in force, but might still serve to illustrate the 'worst-case' outcomes that could arise.

5. Conclusions

In this paper, we have examined the important policy lessons that can be gained from the experience of water resource management policy in North America. Both the policy successes and failures have provided useful lessons that developing countries can learn from in order to better understand how to design market-based incentive systems that allow for flexibility in the allocation of water and pollution rights, but which also need to be supported by mechanisms to ensure that collective action is taken, where it is necessary.

The lessons that are to be learnt from the North American experience of water resources management are both positive and negative in nature, and illustrate the importance of institutional design and how a positive or negative legal or political environment can affect the success of policy implementation. Among some of the positive lessons that come from North America are the successful implementation of regulatory instruments in the design of water banks – such as that which functioned during the 1991 and 1994 drought periods in California – and the water quality 'districts' which also operate in that state, and constitute the administrative command areas for water quality regulation (Thomas, 1991). Some negative experiences which could be drawn upon as lessons for the developing world might include the complicated legal structure that underlies the implementation of water resource planning in the American West, which has prevented the widespread use of market-based mechanisms for water allocation, as has been observed in Chile (Rosegrant and Gazmuri, 1994).

The need to account for all the public benefits derived from higher environmental quality, and the need to closely monitor environmental conditions and adequately enforce environmental quality standards both argue in favor of the continued importance of central regulatory bodies that are able to lower the transactions costs that would otherwise prevent individuals from behaving optimally, even when driven by market-based incentives. The central regulatory authority also bears the responsibility of accounting for all of the unintended third-party effects that might arise when market-driven transfers occur, and for basing the initial allocation of rights on a 'reliable' quantity of streamflow, so as to minimise the need for adjudicated reductions and cut-backs when inevitable fluctuations in resource availability occur.

While the nature of agriculture is vastly different in many developing countries, when compared to the large-scale farming enterprises of much of North America's agricultural economy, there are still underlying principles that could be applied to induce efficiency. While most developing country policy is aimed at alleviating poverty and boosting productivity through technological means, adequate attention must also be given to institutional mechanisms that enhance resource use sustainability. While it might sometimes be necessary to relax the principles of economic efficiency in order to promote equity in resource allocation, it must not be forgotten that long-term growth and productivity gains will depend on resource sustainability, which can only be maintained through a consistent application of efficiency-enhancing and waste-minimising policies.

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Part I.

The Economics of Water and Agriculture

Chapter 1.

National Water Initiative – The Economics of Water Management in Australia – An Overview

Malcolm Thompson[1]

The major economic issues facing agriculture and water in Australia involve the continued transition to using and managing water under the influence of more mature market conditions. This includes clearer specification of water property rights, assigning risk of changes in water allocation to improve investment certainty, proper accounting for water, extending the scope for efficient water markets, and pricing which seeks to better reflect the true economic cost of the resource. Each of these elements is pursued by Australia's blueprint for water reform, the National Water Initiative. Amongst other things, the transition will involve making careful judgements in order to optimise the mix of markets, planning and regulation for water management in Australia.

Background

There are a number of ways of describing water management in Australia, for example historically, legislatively, institutionally, or in hydrological or ecological terms.

By way of background, this paper begins by illustrating some of the challenges for water management in Australia through some prominent tensions which currently characterise water use and management in this country. The notion of 'tensions' is not used here as a negative term – it simply reflects the competing interests, incentives, methods and understandings which lie at the heart of managing a natural resource such as water.

Some of the more notable tensions for water in Australia include the following:

- Water is vested in the state and territory governments, but there are national imperatives for water management – including the sharing of physical water resources between states, nationally significant environmental assets, the emergence of interstate water markets, the cross-border flow of capital to water-based investments. All this is

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complicated by different legislative and administrative arrangements between states, and by the different character of hydrological systems and water dependent ecosystems between states (and within states).

- Water is used predominantly by the private sector, while ownership and service provision for water is predominantly in public hands – hence a clash between public stewardship and private extraction. Historically in Australia, public and private interests have coalesced around a common desire to develop the water resource for economic return. However, the absence of scarcity pricing for water in rural settings (for historic and practical reasons), combined with the immaturity of water markets, leaves unanswered questions about water moving to its highest value uses, and whether governments are extracting adequate rents from water as a scarce resource.

- There is a need for adaptive management of a highly variable resource versus the need for entitlement security for those investing in the resource for production.

- Policy settings which are possibly ahead of the scientific understanding of the resource. In Australia, policy has largely moved from a 'develop the water resource' through to a 'manage for the environment' mindset. However, the science and practice of managing for freshwater dependent ecosystems is not as sophisticated as the policy requires, or that the scientific understanding has not answered important policy questions. Hence there is a risk that the policy will be inadequately implemented, for example that productive values will continue to dominate over ecosystem needs because commercial imperatives can be articulated in practice more readily than ecological needs.

- The disparity in water management practices between urban and rural sectors, and the emerging competition between these sectors for water. It is true that such competition could have some significant local effects, although the effect will be small in aggregate. The increasing reuse of waste water in rural and industrial settings as a substitute for potable supply will also mean that competition between urban and rural use is unlikely to be a zero sum gain for rural uses. Competition for the resource is complicated by disparate approaches to water management in rural Australia compared with the cities, in areas such as pricing, water accounting (almost universal metering in cities versus less accurate/comprehensive measurement for rural uses), and differing notions of integrated water cycle management.

- Catchment scale planning and water management versus centralised policy setting and regulation. There is an undeniable need for engagement at catchment level (through water planning and, in some states, managing water for the environment), combined with a sizeable need to grow people's and institutions' capacity at this scale to understand and manage water resources. At the same time, governments are seeking to ensure consistent policy settings and regulatory compliance across the state, across large-scale river/artesian basins, or even nationally.

- The use of markets, planning and regulation to manage water. The mix of these three types of instruments will be discussed further in this paper as one of the major issues facing Australia's water management at present.

The National Water Initiative (NWI)

The NWI is Australia's blueprint for national water reform. The NWI Agreement was signed by all governments at the 29 June 2004 Council of Australian Governments meeting (with the exception of Tasmania, which signed the Agreement on 3 June 2005, and Western Australia, which is yet to sign).

The NWI builds on the previous Council of Australian Governments (COAG) framework for water reform signed by the Australian Government and all state and territory governments in 1994.

Since 1994, national reform agreements of this kind have proved important in Australia for guiding the **shape** of water reform and maintaining the **pace** of water reform.

The NWI represents a shared commitment by the Australian Government and state/territory governments to water reform in recognition of:

- the continuing national imperative to increase the productivity and efficiency of Australia's water use;
- the need to service rural and urban communities; and
- ensuring the health of river and groundwater systems, including by establishing clear pathways to return all systems to environmentally sustainable levels of extraction (paragraph 5, NWI).

The NWI is a comprehensive reform agreement containing objectives, outcomes and agreed actions to be undertaken by governments across eight inter-related elements of water management:

1. water access entitlements and planning;
2. water markets and trading;
3. best practice water pricing;
4. integrated management of water for environmental and other public benefit outcomes;
5. water resource accounting;
6. urban water reform;
7. knowledge and capacity building; and
8. community partnerships and adjustment.

It is important to note that action in each of these areas is necessary to achieve comprehensive and lasting water reform; and that action in any one or just a few of these areas is not sufficient to achieve that reform.

The overall objective of the NWI (paragraph 23, NWI) is to achieve a nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes. At the highest level, implementation of the NWI will achieve:

- clear and nationally-compatible characteristics for secure *water access entitlements*;
- transparent, statutory-based water planning;
- statutory provision for *environmental and other public benefit outcomes*, and improved environmental management practices;
- complete the return of all currently over-allocated or over-used systems to *environmentally-sustainable levels of extraction*;
- progressive removal of barriers to trade in water and meeting other requirements to facilitate the broadening and deepening of the water market, with an open trading market to be in place;
- clarity around the assignment of risk arising from future changes in the availability of water for the *consumptive* pool;
- water accounting which is able to meet the information needs of different water systems in respect to planning, monitoring, trading, environmental management and on-farm management;
- policy settings which facilitate water use efficiency and innovation in urban and rural areas;
- addressing future adjustment issues that may impact on water users and communities; and
- recognition of the connectivity between surface and groundwater resources and connected systems managed as a single resource.

Just under half of the NWI's 70 or so actions involve national actions or other action by governments working together. This reflects not just the emphasis in the Agreement on greater national **compatibility** in the way Australia measures, plans for, prices, and trades water. It also represents a greater level of **co-operation** between governments to achieve this end.

The need for national outcomes and greater partnership to achieve the outcomes is further illustrated by the establishment of the National Water Commission, and by the Australian Government's investment through the $2 billion ($U 1.48 billion) over six years Australian Government Water Fund (Figure 1).

The National Water Commission is established under Australian Government legislation (the *National Water Commission Act 2004*). It is an independent statutory authority reporting to the Prime Minister and, on some water reform matters, through the Prime Minister to the COAG.

The Commission consists of seven Commissioners – four (including the chairman) nominated by the Australian Government, and three nominated jointly by the states and territories. Unique among Australian intergovernmental institutions, Commissioners are appointed for their expertise in a range of water-related fields (including freshwater ecology, hydrology, resource economics, and public sector management) rather than as representatives of sectoral or government interests. The Commission is supported by a small staff of just over 40.

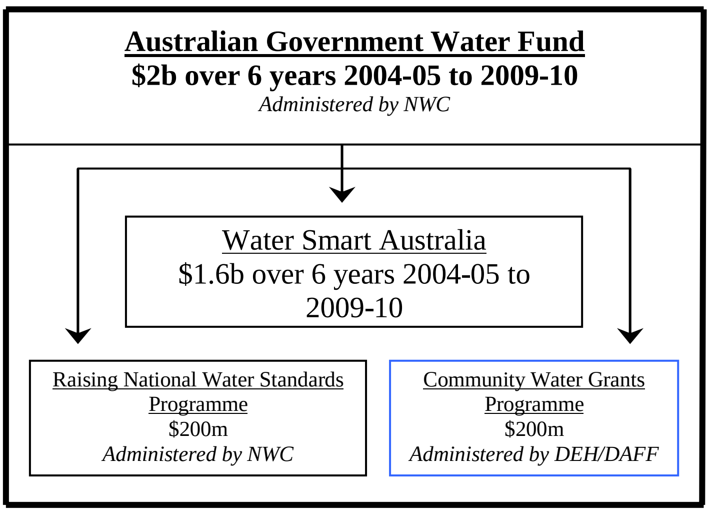
The National Water Commission has three main functions:

- assess governments' progress in implementing the NWI (e.g. through biennial assessments of progress commencing in 2006-07);

- help governments to implement the NWI (e.g. by acting as lead facilitator on certain actions under the NWI such as nationally compatible registers of water entitlements and trades, and nationally consistent approaches to pricing); and

- administer two programmes under the Australian Government Water Fund (including recommending projects for decision by the Australian Government on financial assistance from the Water Smart Australia programme and the Raising National Water Standards programme).

Figure 1. The Australian Government Water Fund (AGWF)



Further detail on the roles of the National Water Commission and the Australian Government Water Fund can be found at www.nwc.gov.au.

Market, regulatory and planning based systems for water management

As noted above, the NWI recognises that water in Australia is managed through a combination of instruments including market, regulatory and planning based systems. Any discussion of the economics of water management in Australia needs to recognise these complementary and competing instruments. To illustrate, examples of each of these types of instrument follow.

Market-based instruments

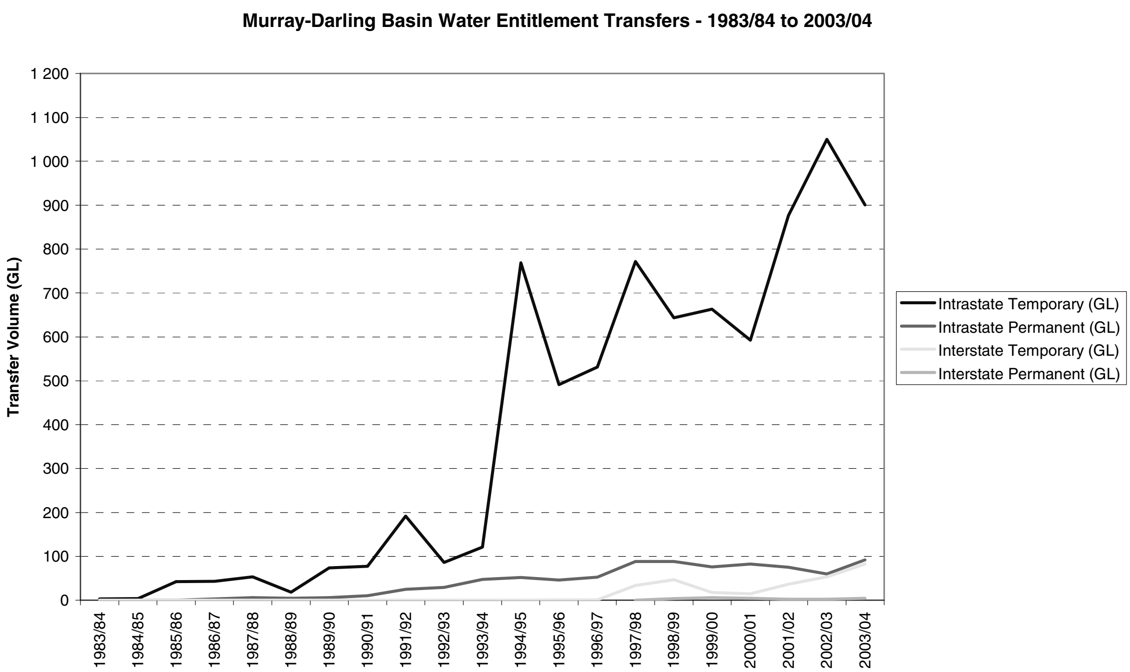
Market-based instruments include pricing for cost recovery of water service provision, consumption-based pricing, cost recovery for water resource planning and management, and pricing for externalities. Typically in Australia, such prices are set by state/territory governments or independent pricing regulators. Pricing is discussed further below.

The NWI commits governments also to use, as far as practicable, market-based mechanisms to allocate releases of unallocated water (NWI paragraph 72). Such releases are not common in Australia, but a recent release in the Burnett River in Queensland occurred using a tender scheme (www.sunwater.com.gov.au).

Water markets have been active in Australia for some time and there has been considerable growth in trading activity over the last ten years. Most trade occurs in seasonal allocations (temporary trade) rather than in entitlements (permanent trade). It is common for 10–20 per cent of allocations to be traded within an irrigation district in an irrigation season (Peterson et al. 2004).

To illustrate, Figure 2 summarises the volume of water traded on a temporary and permanent basis in the Murray Darling Basin over the last two decades. While temporary trade has increased over recent years, the permanent trade in water entitlements remains small, at less than 1 per cent of diversions in 2003-04.

Figure 2. Murray-Darling Basin Water Entitlement Transfers in the southern connected basin (provided by MDBC, November 2005**)**



Source: Courtesy of Murray Darling Basin Commission.

The increase in temporary trade in the Murray Darling Basin since the early 1990s has been due to a number of factors, including:

- a widening of trading rules in 1994 to allow trade for the first time out of irrigation districts;
- the decision in 1995 to cap diversions in the Basin;
- irrigators becoming more accustomed to the 'culture' of trading and gaining confidence in the market; and
- a long period of relatively dry years since 1994-95.

Temporary trade was an important factor in ameliorating the effects of recent drought conditions experienced in the Basin. Irrigators who could have faced large economic losses because of reduced water allocations could trade with those with more flexible production systems.

Peterson et al. (2004) estimated that allowing intra- and interregional trade in annual allocations more than halves the economic cost of reduced water allocations in the southern MDB.

Markets have also been used to purchase water to meet environmental needs. The Murray Darling Basin Ministerial Council recently agreed to explore options to obtain entitlements from the water market to help meet the recovery of 500 gigalitres of water for the six significant ecological assets under the Living Murray initiative (30 September 2005, www.mdbc.gov.au).

Regulatory-based instruments

The regulatory framework underpinning water management in Australia ranges from licensing regimes for water access, water infrastructure and water use; environmental rules governing water extraction in catchments (such as cease-to-pump rules when streamflow reaches a certain level); rules for seasonal allocation of water; and trading rules within and between water systems. Regulatory mechanisms rely heavily on the legislative and administrative architecture which give them authority, and on the institutional arrangements which give them effect on the ground (e.g., agencies to undertake licence approvals, approvals for trades, and enforcement). It is also worth recognising that many regulatory requirements – once established – rely heavily on self-regulation by water users across the vast expanse of rural Australia. Improved water measurement, metering and monitoring is expected to help to improve governments' capacity to achieve compliance with regulations.

Planning-based instruments

In most states and territories, water resource planning is the primary vehicle for describing the resource in a water system, and addressing the competing needs and values of water users (including the environment) in that water system.

The NWI commits governments to develop statutory water plans as a means to assist governments and the community to determine water management and allocation decisions to meet productive, environmental and social objectives (NWI paragraph 36).

Plans are intended to be living documents – their performance monitored, knowledge improvements included, and outcomes regularly reported to the public (NWI paragraph 40). Water plans of this kind are already a common feature in most states, although plans are yet to be developed for many priority systems.

Importantly, the NWI also commits governments to use best available scientific knowledge, socio-economic analysis, and consultation with stakeholders in the development of water plans. This will not obviate the competition between uses. However, it should help create a shared understanding of the resource, and greater acceptance of the management regime (including regulatory means) required to achieve the productive and environmental outcomes for the system which are specified in the water plan.

Creating the conditions for market-based systems for managing water resources

A major objective of the water reform agenda in Australia is to enable a measured increase in the use of market-based systems for managing water. This is seen as critical to realising gains in the allocative and technical efficiency of water use. The commitments which governments have entered into in the NWI underscore this direction by advancing some of the preconditions for market-based management of water in a number of areas.

Clear specification water access entitlements

Separation of land title and water title has been pursued by state and territory governments since the 1994 COAG water reform framework.

The NWI further specifies that consumptive use of water requires a water access entitlement to be described in legislation as a perpetual share of the consumptive pool of a water resource (NWI paragraph 28). Water access entitlements are to be separate from regulatory approvals for water use on a particular site or purpose (NWI paragraph 29). The NWI also specifies the characteristics that water access entitlements should have (NWI paragraph 31), including that they: be exclusive; are able to be traded; are able to be subdivided or amalgamated; are able to be mortgaged to access finance; and are recorded in public water registers.

Creating certainty and public confidence around water access entitlements is a fundamental precondition for the investment to underpin use of the water resource. It is also a precondition for trade in water entitlements. In most states and territories, the conversion of existing water entitlements into share-based entitlements as required under the NWI is still under way. For example, in Queensland and New South Wales, conversion of entitlements is occurring only when water plans are completed for catchments and groundwater management areas – these water plans establish the available consumptive pool of the water resource.

The NWI also requires that water provided to meet environmental and other public benefits is to have statutory recognition, and have at least the same degree of security as water access entitlements for consumptive use (NWI paragraph 35). This is to ensure that water for environmental outcomes is not made less secure in the wake of greater security for consumptive water entitlements.

A step change improvement in water accounting

Along with secure property rights, most market instruments require an agreed standard of measuring the commodity as a precondition for their operation.

The National Water Commission sees proper measurement, monitoring and reporting systems for water as among the highest priorities for the NWI.

In the NWI, governments have committed to a series of actions to improve Australia's water resource accounting (NWI paragraphs 80-89).

In particular, the outcome for these actions is to "ensure that adequate measurement, monitoring and reporting systems are in place in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for *environmental and other public benefit outcomes*" (NWI paragraph 80).

Most states are currently in the process of expanding metering of water used for irrigation. Australia has almost universal metering of water used in residential and business settings in major metropolitan areas.

Adequate metering practices and accounting systems for water are, of course, necessary for effective charging for water use, and to support water trading (e.g., to ensure that water which is traded is available to be traded, is delivered to the buyer, and that information about water trades is made available to inform the market).

Less sophisticated measurement and monitoring of water may be entirely appropriate in catchments where the resource is relatively undeveloped and there are few production pressures. In such cases the need to improve monitoring is driven by the need to better understand the resource so as to better manage its environmental values. For example, Land and Water Australia (an Australian Government natural resource management knowledge broker) has a current call for projects to better understand northern Australian rivers (www.lwa.gov.au).

Clear assignment of risk for changes in water allocation

As noted above, the creation of share-based water access entitlements establishes a secure right to access the water resource. In the NWI, governments have also committed to establish a level of security around the size of the consumptive pool of water which entitlement holders can access. To this end, the NWI establishes a framework for assigning the risks of future reductions in the availability of water for consumptive use (NWI paragraphs 46-51).

The risk assignment framework only operates on the premise that existing over-allocation of the resource is being addressed. It also operates in the context that share-based water access entitlements have been established, effective water plans have determined the water allocation, and regular reporting of progress on plans is occurring. In part, to enable time to create this context, the NWI risk assignment framework becomes operational after 2014.

The NWI framework seeks to assign risks for reductions in water allocations based on the **cause** of the reduction. Risk is to be assigned along the following lines:

- holders of water access entitlements bear the risk of any reduction in water allocation which arises from climatic changes or natural events (such as bushfires);

- governments bear the risks of any reduction in water allocation which arises from changes in government policy – in such cases governments are to recover this water from entitlement holders in the most cost effective manner;

- governments and water access entitlement holders **share** the risk of any reduction in water allocation which arises from a change in knowledge of a water systems' capacity to sustain a particular extraction level.

Apart from providing a foundation for greater security for entitlement holders, the NWI risk assignment framework helps to create the conditions for more efficient use and management of water through: clearer conditions around when governments will bear and share the risks of reduced water allocations; explicitly providing for governments to recover water for environmental or other policy goals (including through market purchase of water); and creating a shared stake in reductions in available water, therefore potentially reducing the incentive for gaming by governments or entitlement holders when reductions in allocations are required.

Efficient water markets

As noted above, temporary trade of water allocations (i.e., on a seasonal basis) has been occurring in Australia for some time. In the NWI, governments have committed to further reducing barriers to trade in temporary water allocations, and to trade in permanent water entitlements.

At present, there are a range of institutional barriers to the trade of permanent water entitlements out of many irrigation districts in Australia – either in the form of trading rules, policies governing public irrigation authorities, or policies contained in the memoranda and articles of association of some private irrigation corporations (notably in New South Wales). Governments – including those in the southern Murray Darling Basin (New South Wales, Victoria and South Australia) – are taking steps to free up trade out of their irrigation areas.

Initially, trade out of each irrigation area is intended to be enabled up to four percent of each area's total water entitlement. This measured step is provided in the NWI in order to help manage concerns about the adjustment of regions to trade, and to enable the National Water Commission to monitor the socio-economic impacts of trade.

Expansion of water trade will also rely heavily on reducing the transaction costs of trades. In particular, the NWI requires compatible water registers between states and other compatible institutional arrangements in order to enhance trading opportunities.

There is still a way to go to build not only the efficiency of water markets in Australia, but also the community acceptance of, and confidence in, water market outcomes. For example, other commonly held concerns about water trading centre on:

- the scope for trade out of irrigation areas to result in stranded irrigation assets, and a higher cost burden for maintaining infrastructure on remaining users;

- the potential for trade from rural to urban settings – indirect trade in this direction has already occurred in Adelaide and Perth to improve the security of those cities' water supplies, however, rural use of water will always dwarf urban demand in aggregate terms;

- the scope for governments to adversely affect the price for water by purchasing water for the environment directly from entitlement holders; and
- the potential for 'water barons' to buy up water, and subsequently distort both water use (by withholding water from agricultural production), and water markets (by manipulating price).

Overall, the desired outcome is efficient water markets, within and between states and territories, and between rural and urban sectors, which recognises and protects the needs of the environment and of third parties.

Improved water pricing

There have been significant improvements in water pricing arrangements since the 1994 COAG water reform framework. These include:

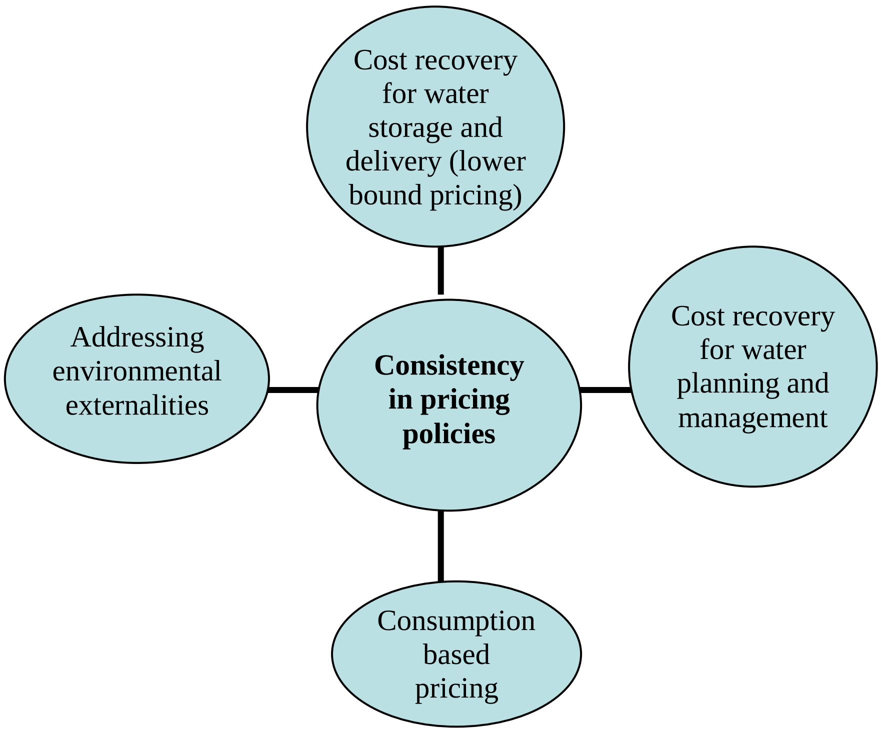
- institutional separation of water service providers (e.g., urban and rural water suppliers) from water regulation and planning bodies;
- establishment of independent bodies for reviewing water pricing or price-setting processes in every state and territory; and
- a move to consumption-based pricing aimed at full cost recovery in almost all major metropolitan centres.

In the NWI, governments have committed to continue with pricing reform, in particular:

- to continue movement to pricing which recovers the full costs of water storage and delivery for rural and regional systems;
- to continue movement to pricing which achieves a commercial return on assets (while avoiding monopoly rents) for metropolitan, rural and regional water storage and delivery;
- pricing which recovers a proportion of the costs of water resource management and planning – cost recovery for such activities to manage the consequences of commercial water extraction has become a legitimate proxy for more direct externality pricing in rural areas;
- nationally consistent benchmark reporting on the service quality and pricing of all water service providers Figure 3 illustrates some of the major components of cost recovery and pricing); and
- moving towards more nationally consistent approaches to pricing across all these areas.

Water pricing reform is currently a very active area for most state and territory governments. The overall intent is to ensure that prices set by mechanisms other than the market (i.e., by governments, public/private water service providers, and/or independent pricing bodies) do not lead to perverse outcomes either in secondary water markets or for water-related investment activity. This is critical to facilitating market based instruments as more prominent mechanisms for managing water in Australia.

Figure 3. Elements of water pricing reform



Conclusion

The National Water Initiative is the national blueprint for ongoing water reform by governments. Through it, governments have committed to a range of actions designed to achieve a nationally compatible market, regulatory and planning based system of managing water resources. This paper has demonstrated how the National Water Initiative is designed to create many of the conditions for market based mechanisms to become more prominent in managing Australia's water resources.

In practice, how well governments make this transition to market based mechanisms will depend in part on how successfully they optimise the mix of all policy instruments. This will, of course, also involve getting the sequence of policy instruments right (e.g., improved water accounting to support water trading; trading to promote greater transparency for pricing arrangements; etc).

Getting the mix of policy instruments – regulation, planning and markets – right will also depend on adaptive institutions for managing water – both in the public and private sector. Following good governance principles such as institutional separation between regulatory and policy making roles will make a contribution to this adaptability. So will a higher level of institutional accountability and transparency. In practice this means arrangements where institutions are regularly required to answer questions such as: how is water being used; are infrastructure investments cost effective; is water provided for the environment achieving the outcomes set out in water plans, how much is water management costing, and who is paying; and are monopoly water service providers operating efficiently?

This is the dynamic which water reform creates. Of course, governments will need to continue to make careful judgements in order to optimise the mix of markets, regulation and planning for water management. And this will be necessary also in order to creatively address the tensions which lie at the heart of water resource management in Australia.

Reference

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Chapter 2.

Water Pricing for Agriculture between Cost Recovery and Water Conservation: Where do we Stand in France?

Thierry Rieu[1]

Based on concrete case studies this communication presents the French experience in water pricing for various regions and irrigated schemes and over time. It shows a large range of ways for charging for water that could be analysed in light of the main objectives that are dedicated to it by policymakers and water managers: cost recovery, income redistribution among users and water conservation. This last issue will give us the opportunity to discuss the incentives to save water they provide in order to evaluate the consistency of these economic instruments with the European Water Framework Directive.

Introduction

The last few years have recorded an increase in competition over water resources in France as in many parts of the world — competition over quantities of water, its quality or the ecological status of water ecosystems. In response to this, the Water Framework Directive[2] (European Communities, 2000), and consequently the next French water law, are taking into account scarcity and the environmental aspects. In particular, Annex 9 of the WFD recommends the setting up of economic instruments, based on the polluter-pays principle in order to insure incentive pricing to water savings and "adequate" cost recovery. By the way, this European directive is the first one to recommend the implementation of economic principles.

When looking at the economic instruments in question, the incentive to save water remains weak, as the level for water abstraction fees remains low and water pricing is often designed to reach budget, even in the Mediterranean countries (Chohin-Kuper, 2002) where pressure on water is high. In France, although a draft law on water proposes an increase in taxes, a drastic change in water pricing is not really expected. This is somewhat contradictory to the present French water law of 3 January 1992, whose main objective is to ensure the protection of water quality and quantity and aquatic ecosystems.

1. École Nationale du Génie Rural des Eaux et des Forêts, Montpellier, France.

2. "The principle of cost recovery for water services, including environmental and resource costs […] should be taken into account in accordance with, in particular, the polluter-pays principle."

Based on selected case studies this communication presents the French experience in pricing water for agriculture in various irrigated schemes over time. Considering that pricing results are from a trade-off between water demand and supply, the first economic instruments to be analysed will be those that are built from a cost recovery perspective and in the second section those that are derived from the demand side. The large range for charging for water that can be analysed is seen in light of the main objectives for policymakers and water managers including cost recovery, income redistribution among users and water conservation. Finally, the evolution of tariffs over time will be addressed in order to show the close relation between the management's objectives and the choice of a tariff. Some recommendations will be then derived.

The French context

In order to give an overview of a pricing system in a given country, two main elements have to be described: the legal framework that defines the range of instruments that can be implemented and, secondly, the main characteristics of water resources and its use. Information about the farming systems and their heterogeneity in terms of access to water will also be crucial in order to evaluate what would be the impacts of a change in tariffs and pricing.

The legal framework

In France the main legal framework is represented by the law of January 1992 on water management. Its main objective is to protect water resources and the aquatic environment and to value water as an economic good. Since this law, all waters and aquatic ecosystems have become "national heritage" (–patrimoine commun de la nation–) and it provides communities and institutions with the tool to reach comprehensive water resources management. This means that water belongs to nobody including the state itself. Water rights are not defined and this is the reason why water markets are not encountered in France. In practice the water policy service allocates annual allowances for water withdrawals. Only some informal transactions on use of water have been heard.

This law also sets priorities between the various uses: conservation for aquatic ecosystems through the enforcement of minimum summer flows in the rivers; drinking water; and finally economic use, which includes irrigation. Furthermore, these issues will be reinforced by the WFD that emphasises both the "adequate" cost recovery and the setting of water pricing that are incentives for water savings.

Irrigation in France

During the last decade, irrigation has been growing quite steadily from 1.1 million hectares of irrigated crops in 1988 to 1.6 million hectares in 2000 (Table 1). Such an increase is mainly explained by the development of irrigated maize and wheat, whose water valuation is weak compared to those of other main irrigated crops (industrial crops, fruits and vegetables). This development depends heavily on the crop market conditions and on financial support coming from the EC through the Common Agricultural Policy.

From Table 2, we can see this increase mainly concerns farmers who have an individual access to surface water or groundwater and that they are located in the following regions: South West, Atlantic coast, Centre and Alsace Plain, where large hydraulic infrastructures have not been built to increase the water supply for the peak season and where irrigation needs are stochastic as irrigation is only a complement to rain. Furthermore, these individual withdrawals that are made in rivers and aquifers, imply often water conflicts between agriculture and environment during the summer period, when river flows are low, or between agriculture and other uses such as drinking water, when the aquifers are overexploited.

Table 1. Evolution of irrigated areas (ha) from 1970 to 2000

	1970	1979	1988	2000
Irrigated area (ha)	538 537	800 533	1 146 988	1 575 625
Potential irrigated area (ha)	767 200	1 325 227	1 796 769	2 633 682

Source: Service Central des Études et Enquêtes Statistiques — recensement agricole, 1970, 1979, 1988, 2000.

Table 2. Access to water in France

Access to water resource	**Irrigated acreage** (ha)	**Acreage** (%)
Collective	371 137	23.6
Individual	887 912	56.4
Both collective and individual	316 577	20.0
Total	**1 575 616**	**100.0**

Source: Service Central des Études et Enquêtes Statistiques — recensement agricole, 2000.

In order to regulate individual access to water resources and taking into account the difficulty of the enforcement of legal rules (Flory, 2003), the only economic instrument in place is tax on water withdrawal by the basin agencies following the polluter-pays principle. Charges are derived from the withdrawn water volume or lump sums on the basis of the irrigated surface when no metering system has been yet installed. Through these charges users internalise some of the negative impacts on environment and third parties are provoked. But, the low level of these charges compared to the cost of water (individual or collective) services, implies they don't have any incentive to save water (Table 3).

Table 3. Water basin authorities: abstraction charges for irrigation

Water basin authorities	**Average tax** (2002, €/m3)	**Minimum & maximum taxes amount** (2003–2006, €/m3)	**Abstracted volume** (millions m3, 2002)
Adour Garonne	0.0047	0.0026 – 0.0057	758
Artois Picardie	0.0134	0.0120 – 0.0609	15
Loire Bretagne	0.0066	0.0044 – 0.0175	495
Rhin Meuse	0.0014	0.0013 – 0.0015	77
Rhone Méditerranée	0.0015	0 – 0.0027	1643
Seine Normandie	0.0171	0.0051 – 0.0192	95

Source: Agences de l'Eau.

As these individual water services are not, by definition, subject to any charge, except the charges we see in Table 3, or in very specific conditions where water is withdrawn from a re-supplied river, this paper addresses collective services for irrigation that are managed through dedicated institutions like water user associations called – Associations Syndicales Autorisées d'irrigation (ASA) – and regional water companies called – Sociétés d'Aménagement Régional (SAR). We should notice that there is an increasing number of farmers who have both individual and collective access to water through wells that are drilled in large collective schemes. This phenomenon is recognised all over the world (Shah, 2000) and has had a number of (negative) consequences for the design of water charging in irrigated schemes. Furthermore, conflicts around water are less frequent in those collective irrigation systems than in basins where irrigation has been developed on an individual basis. The new water law is supposed to lower the charges for those who are in collective systems.

Tariffs

Principles

A water charging system has to be designed in accordance with the general objectives that are defined by the public authority and with the specific objectives of the water service. That means that the manager will be in charge of the design of the pricing system in co-ordination with users and representatives of the agriculture and environment departments. This pricing system is implemented by the water service manager. In France, the charging system is merged within a legal framework, i.e., mainly the water law and now the WFD. The main objectives to be reached are the following :

- balance the budget in order to maintain a good quality of service and to ensure the sustainability of hydraulic infrastructures,
- provide users with information about water scarcity through its price and avoid wastage,
- support the agricultural sector through local subsidies and the consent of the farmers. The normal way for reaching this is to negotiate and obtain public support from national or local authorities, for the investments linked to large infrastructures (dams, canals, pumping stations).

As a result price is discussed between three main actors: the state (including the basin agency), the project manager and representatives of farmers (Tardieu, 2000). The outcome of this negotiation process, that is frequently bilateral, is a design from the demand side or the supply side; i.e., what the users are willing to pay. The main pricing structure in France is established along these lines even though in reality supply and demand are combined.

Supply

The price of water is derived normally from the cost, namely for projects that are managed by water users' associations. Using an average cost is the usual way to establish the rate of subsidy for an investment for public and /or local authorities. From the total financial cost and the life duration of the infrastructure, an annual average cost per hectare is derived and compared to the willingness to pay from farmers, taking into account cropping patterns and some market conditions. Secondly, the water users' association keeps this rationale of average cost and defines a water price in light of the different situations. This type of pricing is really easy to understand and to present to the members.

Average cost

A recent study from Cemagref (Gleyses, 2004) for the Department of Environment dealing with water tariffs in the Charentes river basin provides an in-depth and up-to-date overview. On the basis of a sample of 75 associations, the average price is estimated at 0.11 € per m3 with a confidence interval at 95 per cent ranging from 0.09 to 0.12 €/m3. Tariffs (Table 4) are mainly binomial with a fixed part based either on the irrigated acreage or the subscribed flow and with a variable part proportional to the water volume. Flat tariffs are mainly based on the irrigated acreage.

Table 4. Water pricing for collective irrigation schemes in the Charente river basin

Water pricing structure	**Fixed** (€)	**Variable** (€/m3)	**Size of association members questioned**
Binomial (Irrig. acreage, Vol.)	81	0.06	33
Binomial (Flow, Vol.)	38	0.06	8
Lump sum (Irrig. acreage)	198	-	23
Monomial (Vol.)	-	0.10	11

Source: Cemagref, 2004.

The most remarkable point is that despite the breakdown of water tariffs, the average price is quite homogenous. This reinforces the previous hypothesis of setting water price with the consideration of water value that is derived from the irrigation of the common crop, maize, and this evens out the financial support for investment.

Marginal cost

Marginal costing for water supply derives from the Pareto's optimum. According to this principle it ensures efficient water allocation and avoids economic distortions. If we consider a large regional water service, a monopoly which balances its budget, it brings us to the Ramsey-Boiteux water pricing method. This type of tariff is used by the Regional development Company SCP – Société du canal de Provence – located in the South-East of France. This tariff has been designed for long term marginal cost pricing (Jean, 2001) as the hydraulic works have been built over several decades. The company supplies raw water to a diversified panel of uses from irrigation to drinking and industrial water (Table 5).

For the implementation of these water pricing principles, SCP defines what is called the "development cost" as follows. It is the sum of:

- cost related to building new infrastructure (dams, canals and main distribution works) to satisfy an additional unit of water demand when works are beyond capacity, and
- proportional cost including the value of water and operational costs (energy, wages ...).

Finally, the total cost depends on the discounting rate used for the investments and on estimation of the date when demand will meet the available water resources. This means that this approach is not only based on supply analysis but also takes into consideration the demand side.

What is more interesting is the way this economic analysis is used: this tarification is considered as a reference for negotiation by the stakeholders. For each use, the output is a price defined as a rate applied to the long-term marginal cost. Social considerations and the economic situation forecast for the next period are main arguments in the negotiation process.

Table 5. SCP water tariffs

	Upstream command area	Intermediate command area	Coastal command area
Fixed part (€ per m3/h)	14	12	9
Variable part (€/m3)	0.09	0.07	0.04

Source : Association Française d'Étude des Irrigations et du Drainage, 2001.

For all uses except irrigation, pricing is trinomial with (i) a fixed part depending on the maximum subscribed flow, (ii) a volumetric part depending both on the consumption in the peak period (4 months in the summer period) and outside the peak period. For irrigation, this mainly occurs in summer, and the water pricing is, as a consequence, binomial. Some specific tariffs are offered for protection against frost, or when SCP has to deliver water at a higher pressure than the nominal one.

Demand

Price sensitivity and the demand for agricultural water

Water pricing will not always be a sufficient incentive for users to enhance water use efficiency. This is the case when price elasticity for water demand is close to nil, e.g., when the water bill accounts for only a small proportion of the farmers' total production costs or income; when alternative ways of growing crops or water resources are not available, due to technical, social or economic constraints; or when the bulk of the total water charge consists of fixed costs. Beyond these factors influencing the sensitivity of demand for water which have been well documented in the literature, we come back to the trade-off position where farmers are faced with the decision to irrigate or not. Three levels of decision-making can be distinguished:

1. The decision to invest in irrigation equipment and to have access to water resources. This is a medium-term decision between rainfed and irrigated agriculture.

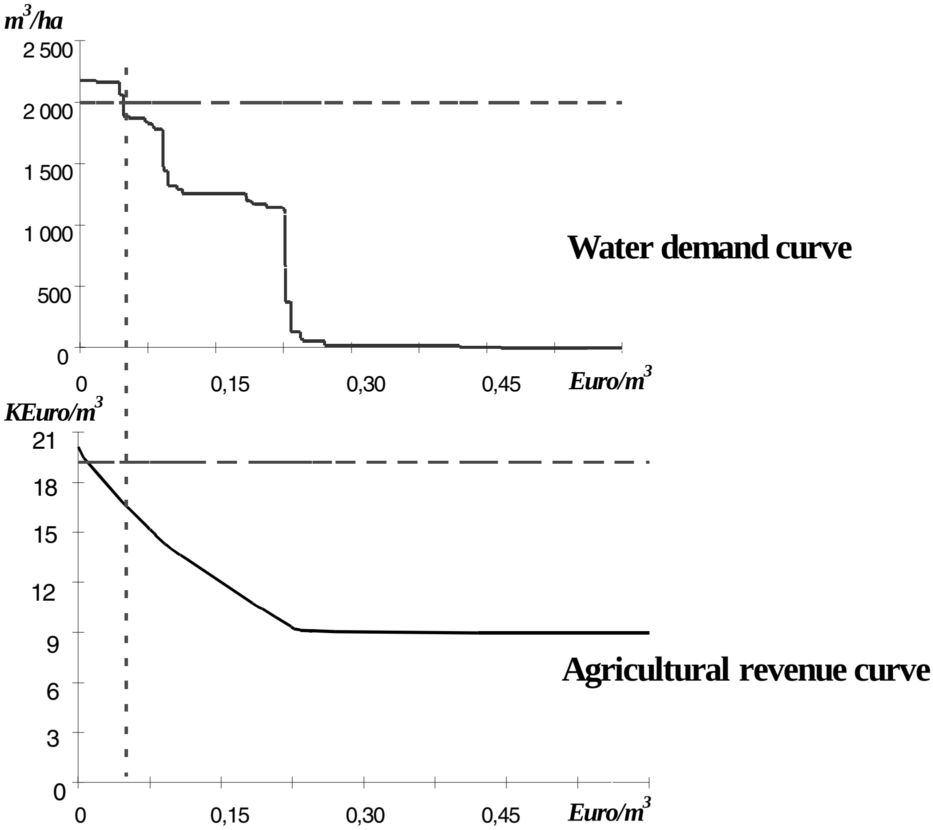
2. The choice of an irrigation cropping pattern with more or less irrigated crops or with crops that consume more or less water. Except in perennial crops like orchards, this is a yearly decision.

3. The choice of irrigation practices: irrigation scheduling and level of restriction for different crops. This is a very short term decision.

The resulting elasticity of water demand depends on the elasticity at each level and is derived from the rigidity of the farming systems that are directly linked to structural constraints, such as the financial potential and the time horizon that is to be considered by the farmer. This mechanism determines the magnitude of impact of pricing on water demand and the heterogeneity that could be found within an irrigation scheme. This is well illustrated in the following literature.

In the Charente river basin (Montginoul & Rieu, 2001), pricing water appears to be a convenient instrument for water demand management Figure 1) as an increase in water price lowers significantly the irrigation water use due to high price elasticity of demand. Nevertheless, even the very first increase in prices has a significant impact on farmers' revenues which is unacceptable. This led the local authorities and the water agency to abandon the pricing instrument and shift to a quota system.

Figure 1. Water demand and farmers revenue in Charentes river basin (France)



Source: Cemagref.

Towards a balanced budget

In many situations the first objective of the water manager is to balance its budget through water pricing. This is particularly true when there large hydraulic works that induce high fixed costs as they have been designed to meet long-term water demands. The implementation of the Water Framework Directive and the cost recovery principle could make this situation more frequent, depending on the interpretation of the term "adequate cost recovery".

In these conditions and when water valuation among farmers is more heterogeneous, a menu of optional tariffs can be proposed to users in order that the rent extracted by the manager from users could be maximised (Chohin, et al. ii). Farmers with low water elasticity of demand to price will be offered a higher price, and inversely. This type of pricing is intended to increase the manager's revenue and to ensure that the various users have an adapted quality of service. This situation can be illustrated through the case of BRL.

BRL — company for the development of the Languedoc Roussillon Region, (South-East of France) — is a Regional development Company (SAR), i.e., a commercial company with a majority of public shareholders, run under the special control of the Agriculture Department. Due to the objective to promote regional development, large hydraulic works have been built and are now largely oversized compared to the present water demand (Nicol, 2001). When farmers want to irrigate, they apply for a water contract and have to choose among different tariffs (Table 6) that are roughly of the two following types:

- Tariff "Pro": This tariff is aimed at farmers who practice each year a regular irrigation on crops like orchards and vegetables. Tariffs are binomial with (i) a fixed part based on the subscribed flow, that is the maximum instantaneous flow the farmer is allowed to use. This flow is chosen by the farmer according to the characteristics of the plots, cropping pattern and irrigation equipment, and (ii) a proportional part, based on the water volume.

- Tariff "Appoint": Supplemental tariffs are aimed at farmers who don't need much water and sometimes not every year. It is well suited for vineyards and some cereals like durum wheat, which is a drought-resistant crop. The fixed part is lower than for regular irrigation and the proportional part higher, so that if the farmer uses a greater water volume, they will be introduced to an incentive to turn to a regular irrigation contract.

Table 6. BRL optional water pricing

	Tarif "Pro"	Tarif "Appoint"
Basis	Subscribed flow (m3/h)	Volume (m3)
Fixed part (€ per m3/h)	54	36
Variable part (€/m3)	0.076	0.184

Source: BRL, 2001.

Furthermore, the subscription fee, the fixed part of the tariff, varies according to the duration of the contract (1 year versus 5 years), as an incentive to long-term contracts that secure the manager's revenue. At the same time, farmers with vineyards are reluctant to sign long-term contracts because of their low and variable water use. All these prices are indexed on price evolution according to an index representative of BRL's costs (mainly hydraulic work operations, energy and wages).

So BRL has not faced any water resources concern during recent droughts and its water pricing system is not designed to promote water savings, although the volume charge is an incentive to avoid any waste of water. Due to concerns of balancing its budget, BRL has proposed contracts that are more closely adapted to different situations and farmer strategies.

From a general perspective, the design of water pricing systems is generally a compromise between the two approaches: from the demand side versus the supply side and costs. Combining various water pricing structures and being applied in very different situations, a large range of types of tariffs is to be achieved from classical average cost pricing to more sophisticated as a long run marginal cost pricing or optional tariffs. What is important is to be convinced that the toolbox is rich enough that it is certainly possible to find an instrument that will be in accordance with the selected case in question.

Conjunctive use of water pricing and quotas

When the pressure on water resources is high and the available resources are scarce, French water managers are more likely to choose to implement water quotas. This is illustrated by two cases; the Charentes river basin and the Neste canal system. In both, a water pricing instrument is imposed, as charging for water remains essential to cover all the costs needed to maintain the quality of the water service.

The Neste system is part of a river basin with upstream dams that re-supply rivers from which farmers directly withdraw water for irrigation. CACG –Company for the development of the Coteaux de Gascogne Region– (South-West France) is a Regional Development Company (SAR) and has been managing this system since 1991. In this basin water resources are not able to meet all the demands and the pressure on water resources is high in summer during the low flow period.

In order to be allowed to withdraw water from the re-supplied rivers, farmers are able to apply for contracts, called convention de restitution, with CACG. These contracts allocate quotas among farmers. They subscribe for a volume according the characteristics of their irrigation equipment and plot characteristics. This allocated amount is at maximum 4 000 m3 per l/s with a frequency of 8 years out of 10 and could be lowered by 2 years when drought periods occur. This quota ensures that the total water delivered will not exceed the available volume of the dams and the minimum flow in rivers to be maintained.

A pricing system (Table 7) is implemented with two objectives: (i) reinforce the quota system by charging the water volumes exceeding the amount of the quota; (ii) charge the average supply costs to the users. The design is rather closed to an increased bloc rate tariff.

Table 7. Water pricing of the Neste canal system

Basis	**Pricing structure**	**Amount** (€, 2005)
Subscribed flow (l/s)	Fixed part	60*p
Metering fee (l/s)	Fixed part	40*p
Exceeding volumes over the quota (m3)	Volumetric part	.120*p
"p" value (€, 2005)		**0.901**

Source: CACG, 2005.

These prices are indexed on price evolution according to an index “p”, representative of both CACG’s (hydraulic works, energy, and wages) and farmers’ (maize and beef cattle) costs. The nature of this index is the result of a negotiation process between representatives of the farmers and CACG.

Historical perspective

When looking at the design of the tariff of an irrigated scheme, it’s essential to keep in mind that tariffs — both prices and structure — will evolve greatly over time. In some cases the evolution could be seen as a cycle beginning with an expanding phase due to the political will to demonstrate the utility of the large investment that has been made; the following phase could be a more steady period looking to balance the budget with higher water prices; and finally a mature system where economic instruments and objectives are more consistent and negotiated between the different stakeholders. The historical perspective of the tariffs evolution at BRL (Table 8) provides such an illustration.

Table 8. Historic review of BRL’s water pricing policies

Period	Objectives	Tariffs / prices[1] € (1960)	Impacts
1960–1965	Balance fixed costs and annual revenue.	Binomial (flow and volume) *21Q(l/s) + 0.006V (m3)*	Low level of contacts subscription and unbalanced budget.
1965–1970	Expand the irrigated acreage	Block rate decreasing (volume) *V < 1500 m3/ha : 0.02V (m3)* *V< 3000 m3/ha : 0.01V (m3)* *V> 3000:ha : 0.008V (m3).*	High increase in irrigated acreage, Earnings highly dependent on climatic conditions. Difficulties in controlling the real irrigated acreage of farmers.
1970–1993	Balance the budget even in wet years.	Binomial (flow and volume) + free allowance (300 m3 /l/s) 45*Q(l/s) + 0.05V (m3)*	Robust system. Budget more and more unbalanced due to the index formula for price revision don’t depend on BRL costs.
1993–2004	Balance the budget and protect against prices evolution.	Binomial (flow and volume) *45Q(l/s) + 0.06V (m3)*	Due to high water prices, irrigated maize disappears in the scheme.

All prices of this table are derived from French Francs from year 1960 with a change rate of 1 euro = 6.567 FRF.

Source: BRL, 2004.

Conclusions

Pricing experiences in France are first oriented towards cost recovery objectives and have contributed to the reduction of public financing at least with respect to operation and maintenance costs for irrigation schemes. In addition a part of the capital cost, ranging from 60 per cent to 15 per cent is charged to farmers. Is this cost recovery “adequate”? This has to be restudied with the implementation of the European Water Framework Directive and the new Common Agricultural Policy in order to ensure the sustainability of water infrastructures. Consequently, a large part of water companies’ and water users’ water pricing systems avoid any waste of water. This characteristic is reinforced by the fact that a lot of them have volumetric or other variable rate systems.

From the diversity of selected cases, we can derive that a water pricing system is always needed even if quotas systems are implemented. Secondly, it makes very little sense to speak about the design of water pricing in general because a tariff has to be defined according to an objective that has to be shared among the main stakeholders. Thirdly, as irrigation tariffs have their own life cycle, a pricing system will evolve over time depending on the economic situation and, once again, the objectives of public authorities and water managers.

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Chapter 3.

Allocation of Costs and Benefits in the Water Framework Directive: A Dutch Exploration

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Different sectors in the Netherlands, not least agriculture, have a steep hill to climb to meet the requirements for implementation of the Water Framework Directive (WFD). Considerable investments in water (quality) management are expected in the coming decade. The search for sustainable development possibilities for all sectors involved in this process dominates the discussion in the process of an economic analysis within the WFD implementation. The Netherlands strives for providing possibilities and perspective for many different activities within a small area. To prevent a disproportionate burden being placed on a particular sector it is important to strike the best possible balance between the various interests in rural areas, such as nature management and agriculture, and divide the costs associated with implementation of the WFD proportionally between the different players. A Social Cost Benefit Analysis (SCBA) where nature and environment are included illustrates the consequences for wealth in the Netherlands of implementing the measures to realise the goals of the WFD, but does not illustrate consequences for cost allocation. Via analyses of the separate items, it will be possible to gain insight into this matter. Ultimately, determining which measures are best suited to the implementation of the WFD and decisions on cost allocation, based on the results of a Social Cost Benefit Analysis and a Cost Effectiveness Analysis (CEA), is a matter of political choice.

Introduction

In this paper the implementation of the Water Framework Directive (WFD) in the Netherlands is discussed. The Dutch ministry of Agriculture, Nature and Food Quality (LNV) is intensively involved in the process of implementation, although the Ministry of Transport, Public Works and Water Management (V&W) bears prime responsibility for the implementation of the Directive. From this point of view, the issues on a balance in water for nature and environment in the implementation trajectory are considered concerning the economic analysis, which has to be carried out for the WFD. Challenges and particular points of interest are identified at the different stages of the process.

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Ultimately the objective is to realise a proper and realistic implementation of an enormous exercise, where all relevant actors contribute and play their own role, and where separate sectors contribute financially in a proportionate way.

1. The Dutch situation

The Netherlands is a small country with a total surface area of 41,500 sq kilometres, of which 7,500 sq km is water, including estuaries, sea, major rivers and lakes. It is a typical delta area where land meets water. Much of this area consists of artificial land created by man. The lowest point in the Netherlands lies at 6.74 metres below sea level. In the absence of dunes, dikes and other defences, 66% of the Netherlands would be flooded on a regular basis. There are hundreds of polders in the Netherlands — sea polders, river polders and the drained and reclaimed lakes and ponds. An extensive and complex system of ditches (over 400,000 kilometres) and waterways serves to manage the groundwater level in these polders round the clock. Every drop of rain that falls in the polders must be pumped out (Ministry of Transport, Public Works and Water Management, 2004a). Because of the effects of climate change and the fact that in the western part of the country the ground level is descending, the Netherlands changed its water policy to keep water manageable, from fighting against water to living with water. This means that water will be able to follow a more natural course and further reduce the risk of flooding (source: Water in the Netherlands, 2004– 2005). The total management costs of the water system (water quantity management of surface and groundwater) are approximately 1.6 billion Euros per year. Costs for water quality management are estimated at 3.2 billion euros per year (Raad voor financiele verhoudingen, 2005). Because of the autonomous developments, and to meet the objectives of a European ambition to improve water quality, considerably more investments in water management are expected.

At the same time the Netherlands is a very densely populated area with 452 inhabitants per sq kilometre (EU-25: 114). Hence there is a high intensity of land use and therefore pressure on the rural area is considerable. People have to live, work and relax there. Space is also needed for agricultural production and transport, while valuable nature areas and unique landscapes must be conserved for future generations. A balance must continually be struck between the various uses of the rural areas. Some two thirds of the land is used for agriculture. Woodland and nature reserves make up approximately 12% of the total area (Ministry of LNV, 2005). The Netherlands, with France and the US, is one of the largest net exporters of agricultural products and foods in the world. This is remarkable in view of its small area and high population density. The agri-complex is significant for the Dutch economy and accounts for 10% of our national income. The development of Dutch agriculture and horticulture in recent decades can be characterised in terms of expansion, intensification, increased productivity and farm enlargement. (Ministry of LNV, 2005). Clearly agriculture plays an important role in the Netherlands, in economic terms but also for the many other contributions of agriculture like its role in shaping and maintaining the landscape.

Looking at the relationship between agriculture and water in the Netherlands, the search for sustainable development possibilities for Dutch agriculture within this crowded country is at the forefront. Sustainable in the sense of people, profit and planet, and taking account of the ambitions and objectives of the EU Water policy, while also providing space for other interests such as housing, nature, recreation, industry and mobility. The Netherlands is aware of the interconnected nature of these aspects and hence also of the need to examine developments as an interrelated whole. The ministry of Agriculture, Nature and Food Quality strives constantly for harmony between the sometimes contrasting interests of nature and agriculture, and therefore for a balance between water for food and ecosystems.

2. Water policy in the European Union — The EU Water Framework Directive (WFD)

The Water Framework Directive (WFD) is a European instrument to promote integrated water management at the level of river basins. The aim of the Directive is to achieve and maintain good water quality in European waters. The starting point is water management at river basin level, with objectives and measures being incorporated into river basin management plans. The ultimate aim for the member states is to introduce cost-effective measures to reach the objective of good water quality in Europe by 2015, in terms of good ecological and chemical status (Ministry of Transport, Public Works and Water Management, 2004b). The European Directive offers member states scope to formulate actual (ecological and chemical) goals. Of course environment quality must not be allowed to deteriorate, even in the event of economic or population growth. Thus the WFD is an ambitious piece of legislation. It is an incitement to use pricing policy as an instrument to achieve sustainable use of water. As a result the economy is now taken far more explicitly into account in water management. (Ministry of Transport, Public Works and Water Management, 2003.)

To comply with the requirements of the WFD, a combination of source-and-effect oriented measures are necessary to reduce the deficits of present policies. The efforts of the Netherlands also depend on the efforts of upstream countries. The EU member states work together on management plans within the international river basins. The Netherlands makes river basin management plans for the river basin districts of the Eems, Meuse, Rhine and Scheldt. The integrated approach of the WFD with designated river basin districts ties in with Dutch philosophy for integrated policy. The source of our water quality problems often lies outside our borders. The river basin management plans provide us with an opportunity to reach agreements with countries upstream of us about achieving the objectives in a particular river basin district. However, measures taken in other countries can only go so far towards solving Dutch problems. Action also has to be taken within the Netherlands. The WFD adds new impetus to existing Dutch water quality management. If it is not possible to achieve the objectives with cost-effective measures, the deadline may be extended so that the objectives can still be met or objectives may be revised downwards (derogation).

The components of an economic analysis within the WFD include a characterisation of the river basin in terms of economics of water uses, trends in supply and demand and current levels of recovery of costs of water services. A selection has to be made of what set of measures will be least costly to ensure a good water status (cost-effectiveness analysis). This way it can be determined whether the costs of achieving the goals are considered to be disproportionate so that derogation and the setting of lower environmental objectives may be appropriate. This highlights the importance of economic analysis in the WFD. Finally the question is who pays for the costs — in other words, what impact do the proposed programmes of measures have on current levels of cost-recovery.

2.1 WFD in the Netherlands

Good water quality is essential for agriculture and nature, but also for the production of drinking water. More than 30% of our drinking water is extracted from surface water (www.minvrom.nl). Clean water is also important in other industries for sustainable development in the Netherlands. The quality of the water system is not yet up to standard. We anticipate that supreme efforts will be needed in a number of areas to achieve the goals. In the Netherlands, there are several topics where the goals will be difficult or hardly possible to achieve. These subjects are dangerous substances, eutrophication, heavy metals and PCBs (Ministry of Transport, Public Works and Water Management, 2004). The pollution of the surface waters by eutrophicating substances like phosphate and nitrate originates from agriculture, industry and sewage works, and for a certain part from other countries. Also for heavy metals and PCBs agriculture is, next to construction industry and traffic, a source of pollution. The introduction of the WFD will affect practically every Dutch citizen and many business sectors and it is clear that the costs for water management will rise. Technical work is needed to improve water mains and sewers, but we also need to reduce the phosphate and nitrate burden on the environment and clean up polluted sediments. Physical planning measures may also have to be used to provide some of the solutions. Realistic goals and packages of measures need to be formulated, in which regard public support and financial feasibility are vital factors. The Netherlands is deliberately following a cautious strategy which leads to a pragmatic implementation. Even then, the Netherlands will have a substantial extra task in relation to current policies.

2.2 Organisation, communication and the WFD

The abundance of water in the Netherlands not only determines the issues we face in the coming decade but has also shaped our attitude and our approach to these issues. In the Netherlands, we call this striving for consensus between all parties ‘poldering’, and not without reason. Implementation of the Directive is a major challenge both administratively and organisationally. Given the substantive issues, existing responsibilities and multitude of organisations, it is a complex process. The consultations in the Netherlands are taking place at national level, with the provinces, with the Association of Water Boards and with the Association of Netherlands Municipalities. At national level the Ministry of Transport, Public Works and Water Management bears prime responsibility for the implementation of the Directive. Because of many related interests, the ministry of Agriculture, Nature and Food Quality (LNV) is also involved in the process. Needless to say there are also tensions: these are only normal and arise from the seriousness and nature of the task and the interests at stake for the various parties. The decision-making process has been broken down into stages and filtered (from coarse to fine). A decision-making structure has also been put in place. This is partly a bottom-up and partly a top-down process, and results in annual policy documents that are adopted by the Government and Parliament. This is considered to provide sufficient public support for the implementation of the Water Framework Directive as laid down in the river basin management plans. As for the involvement of private parties, the Netherlands has actively invited interested parties to participate in the decision-making process. At national level this consists of a stakeholder platform, representing a wide range of interests from nature conservation to housing and infrastructure. The input of these organisations is appreciated and may lead to changes in the final product. At river basin district level, sounding-board groups are now in place. Next to the national decision making process, also at international level consensus has to be found about the interpretation of the tasks of the WFD.

Because of the issues at stake, there is large public and political concern for the implementation of the WFD. As is made clear, various parties are involved and at many different levels specific parts of the WFD have to be resolved and managers have to take decisions. To create the necessary public support, communication about process and contents is very important, in spite of the complexity of the material. This does have implications for the feasibility of the parts of the economic analysis. Clear arrangements have to be made in the decision-making process. At the same time, information has to be delivered on time to be able to make decisions and establish a clear focus. A difficulty is the fact that in many fields the information is still missing. Therefore the process is an iterative process where all actors try to fill the puzzle back and forth. In practice communication leaves much to be desired on all kinds of aspects.

2.3 Economic analysis and WFD

To achieve its environmental objectives in the most effective manner, promote integrated river basin management and stimulate the sustainable use of water, the WFD calls for the application of economic principles (e.g. the polluter/user pays principle), approaches and tools (e.g., cost-effectiveness analysis) and for the consideration of economic instruments (e.g., water pricing) (Wateco, 2003). The process of an economic analysis provides valuable information to support decision-making in order to be able to develop river basin management plans by 2009, in which a selection of measures is made. The economic analysis does not make the decisions! (Wateco, 2003). Within the economic analysis, current levels of cost recovery have to be assessed as well as the potential role of pricing of the programmes of measures, including the implications for cost recovery.

2.4 Cost effective analysis (CEA)

After going through the various steps in the process of the economic analysis, the idea is ultimately to use cost-effective programmes of measures to achieve the given objectives. In the Netherlands cost-effectiveness analyses (CEAs) are carried out at regional level, as measures often have to be taken at regional level (as well as some at national level). Cost-effectiveness is expressed in terms of the effect of a measure per Euro, and on this basis can be used as a prioritising principle so that the measure with the greatest effect per euro will be deployed first. If the most cost-effective programme of measures is chosen, there is an opportunity to determine whether a particular sector is disproportionately disadvantaged within that programme to achieve the given objective. The costs can then be distributed over the various players and/or sectors.

3. The social cost benefit analysis (SCBA)

For the Netherlands a pragmatic implementation is very important, considering the expected costs that have to be made. Box 1 explains about the start of the process how the Netherlands became aware of the fact that more clarity about the social impact of the introduction of the WFD was needed. The government therefore opted, in addition to the CEA that is being executed for the WFD, to carry out a Social Cost-Benefit Analysis (SCBA) at national level as a way to achieve a pragmatic implementation. It reveals the relationship between the benefits and costs associated with the implementation of the WFD and the ultimate effect on societal welfare. A broad welfare concept is handled, in which social aspects as well as environmental aspects are included. The SCBA determines what is feasible and affordable, so that can be focused on these elements, and by doing so create more public support for the WFD analysis and the results. The SCBA focuses particularly on establishing the values attached by society to the impact of measures taken within the framework of the FWD.

Box 1. Agriculture and the WFD in the Netherlands

A scenario study, conducted under the authority of the ministry of Agriculture, Nature and Food Quality, presents, despite its limitations, a picture of the huge task facing agriculture to achieve improvement in the ecological status of water in the Netherlands. It concluded that the ecological objectives of the WFD would not be met even if all arable land were to be taken out of production. The environmental impact of source-specific measures will be limited, because of the accumulation of phosphate in soils, which contributes to phosphate losses to surface waters. Effect-specific measures provide better prospects, although the effects of such measures have not been recorded for Dutch circumstances. Generally, the consequences of implementation of the WFD for nature, recreation and fisheries will be positive. Implementation of effect-specific measures to achieve the environmental objectives can simultaneously contribute positively to the recovery of morphology, nature restoration, landscape and recreation as well as fisheries. Thus, an integrated approach to the design and the implementation of measures is highly recommendable, the study concludes.

This information contributed to a national discussion that resulted in the political decision that the implementation of the Water Framework Directive in the Netherlands should be implemented as well as possible, with emphasis on technical and financial feasibility, in other words a pragmatic implementation. The task is ultimately to strike a good balance between the chosen goals and associated costs, with consideration for those who will ultimately have to bear the costs.

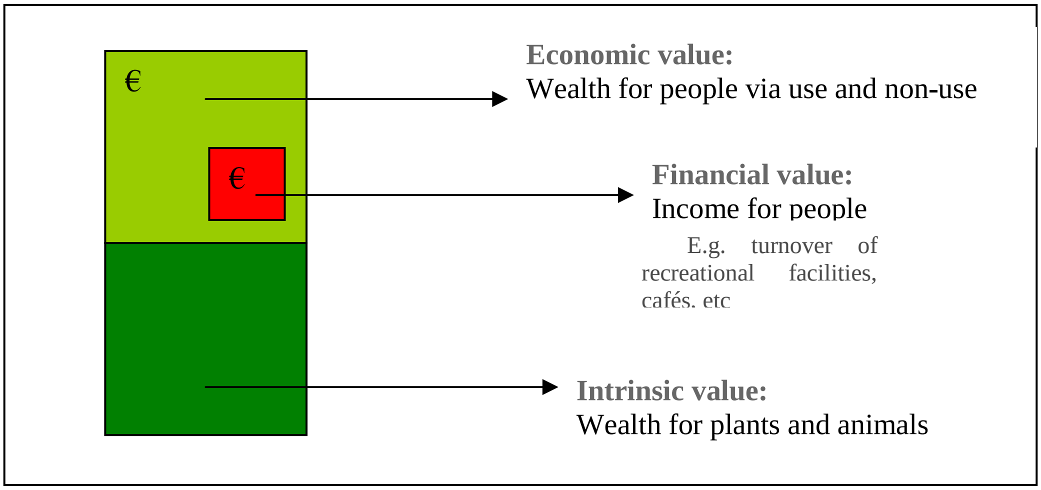
Could this ´OEI´ guide and the supplement for nature and the environment be used to carry out an SCBA for the WFD (see Box 2)? In a general sense such a supplementary guide can provide greater transparency about nature and environment policy, as there are clear benefits to set against the costs, so that ecology can be taken into account as well as possible in wealth assessment. With this information, managers and politicians have to decide how the SCBA balance is weighed against issues that are not taken into account in an SCBA, like the intrinsic value of nature (see later) or the issue of cost allocation.

Box 2. The Social Cost Benefit Analysis in the Netherlands

An SCBA is an instrument that can be used to assess all current and future social advantages and disadvantages, or the effects on wealth of a physical planning intervention, by expressing it in financial terms. Because it looks at the pros and cons for *all* those concerned, the SCBA spans more than a single sector. If the benefits outweigh the costs a project is socially justified (Witteveen + Bos, 2004). Unlike an analysis of the business economics, an SCBA takes no account of the tax burden or how the costs are to be defrayed. However, it does show how the costs and benefits are distributed among different social groupings.

The Social Cost-Benefit Analysis is increasingly important in the Netherlands in discussions concerning the use of evaluation instruments to support decision-making processes (Bos, 2003). A guide (called OEI: Overzicht Effecten Infrastructuur) is available for carrying out SCBAs in relation to infrastructure in the Netherlands (Eijgenraam et al., 2000). An evaluation of this guide showed that drawing up statements of effects based on cost-benefit analyses contributed to a greater transparency and professionalisation of policy information on infrastructure. This guide does not include the quantitative effects on nature and environment, since it maintained that these could not be expressed in monetary terms. Witteveen and Bos (2004) subsequently wrote, under the authority of the Ministry of Agriculture, Nature and Food Quality, a supplement to the guide to take account of the impact on nature and the environment.

The report by Witteveen and Bos (2004) acknowledges that the economic value of nature is not self-explanatory. Most people interpret ‘nature value’ as an ecological concept rather than an economic one. Yet a nature reserve can have an economic value even if it does not earn any money. For example, the area can produce wealth for society in many ways without this being linked to any concrete profit. For this reason it is important to be aware of the financial and economic value of an ecosystem, as well the ecological or intrinsic value (this last is beyond the scope of the economic domain and of the SCBA). The three different values of nature are represented below: socio-economic, financial and ecological/intrinsic value.



Source: *www.fsd/naturevaluation.nl*

Financial values reflect concrete profits or income (or expenditure). The financial value is a component of the economic value.

Economic values comprise not only profits, but also other flows of welfare, which are detached from the market, such as recreational enjoyment, or clean air which positively influences the well-being of people. 'Wealth' here means a contribution to both the material and immaterial amenity of the individual concerned. For example it may include obtaining a welfare benefit through the use of a natural area (e.g. recreational use), but 'wealth' can also be generated by non-use. This last relates to the fact that people can also derive benefits from nature and the environment without making use of them.

The intrinsic value relates not to human wealth or income, but to the welfare of animals and plants. This value is therefore beyond the scope of the economic domain and the SCBA.

To put it another way: economic value covers more than financial value, but it does not include the intrinsic value. Some nature reserves have little if any financial value, as no-one makes any money from them. Yet the economic value of the same area may be considerable. Thus in terms of the financial value, only exploited areas have a value. However, in terms of economic value, areas that are not exploited can also have a value, depending on the wealth functions they fulfil. For cost-benefit purposes both financial and socio-economic values are in principle expressed in monetary terms. Various economic valuation methods can be used to express socio-economic values in euros (Witteveen + Bos, 2004). This approach can of course also be applied to other environmental objectives as well as nature management. Thus, in a SCBA it is possible, to a certain extent, to include nature when making use of an appropriate guidance. This makes it possible to create a complete and better understanding of all kinds of aspects related to a broad interpretation of welfare, to aid decision-making.

3.1 Social cost benefit analysis and WFD

The costs and benefits of the implementation of the WFD are central to the SCBA that is being executed in the Netherlands to aid WFD implementation. Where possible the benefits should be expressed in monetary terms to facilitate comparison and balancing of the costs. There are benefits that are difficult to express in money, such as nature and landscape values (see above), but also benefits that are not expressed in money at all in SCBAs like progressiveness, equal distribution of burdens, etc. Insight in the distribution of the burden between sectors is, however, an important aspect. When considering major trends in local charges at national level or maintaining a level playing field for business sectors throughout the country, it is important that the decisions taken by regions and the provided information is to some extent comparable. The selection and balancing of measures based on cost-effectiveness (giving priority to the most cost-effective), as required by the WFD, means that the cost-effectiveness of regional measures is in part determined by local or regional circumstances.

To determine which measures are required to achieve the objectives of the WFD, a suitable approach would be to combine various measures into policy scenarios. The measures in the policy scenarios are subsequently evaluated in the SCBA for their effectiveness per euro (in the cost-effectiveness analysis) and the social costs and benefits (in the SCBA). The most cost-effective measures end up in programmes of measures. The elaboration reveals how far the different programmes of measures go towards achieving the objectives in a certain policy scenario. The elaboration and analysis of these policy scenarios would provide insight into the extent to which the objectives are met, and the total costs. In an SCBA the social impact is made visible. Policy scenarios thus offer the basic information required to determine which line of policy is preferable and what political decisions have to be made. This step is necessary to come to a pragmatic implementation of the WFD and is preferred by the ministry of Agriculture, Nature and Food Quality. A number of policy scenarios have to be compared in terms of achieving objectives and social consequences (feasibility and affordability). This analysis is meant as an exploration in which the present situation (= current situation including established measures in current policy) is compared with a situation in which a maximum of WFD objectives is achieved (100% realisation), not focussing directly on (regional/personal/sectoral) desirable outcomes. It should be prevented that some sectors are discarded beforehand because measures would be too expensive.

The measures included in the policy scenarios must, according to the WFD, be based on the prioritising criterion of cost-effectiveness. When working out the costs and benefits for the SCBA at national level, the state makes use of the (cost-effective) programmes of measures drawn up by the regions. This is so that it can adequately evaluate and weigh up the effects of generic and regional measures in relation to each other, and also to facilitate analysis at national level in an SCBA. This gave rise to the idea of elaborating a number of matters clearly at national level and using the results universally as the basis for regional explorations. At the same time it is important to ensure that there is proper scope for regional diversity. Each policy scenario would have to consist of generic and region-specific measures. A national framework with generic measures at regional level can have varying results for different themes and target groups. For example, generic manure policy has different effects at regional level depending on land use, soil properties, hydrology etc.

The process of the policy analysis is focussed on strong interaction between national and regional level. This means a cautious balance between national uniformity and regional freedom. Uniformity is of great importance to make an unambiguous national assessment as part of the SCBA on the basis of regional input. However there has to be sufficient freedom for interpretation on regional preferences, choices and assessments, within the framework of the regional management responsibility. Communication on steps to take, related decisions and consequences is very important. At this moment, interest groups and regional and local managers block the exploration of significant sets of measures. By doing so, not an exploration but a pre-sort on a preferential scenario is made. Resistance against the exploration of a range of solutions originates from fear to be committed to several explored but less attractive measures. The Dutch approach, close interaction between national and regional level for an optimal result, seems in practice to be less realistic than in theory. Communication on underlying principles is behind, which causes practical problems.

Testing the measures within a policy option occurs on the basis of to what extent the objectives are reached — in other words, testing the effects of the complete set of measures in relation to the task (reaching objectives). However, next to the measures, autonomous (demographic and economic) and technological developments influence the objectives. These autonomous developments are described in different national scenarios, which have to be included in the analysis. The effect of the measures is considered compared to autonomous developments. Choosing a scenario as an autonomous development can have enormous consequences for the sets of measures to be selected, and has to be discussed explicitly and decided on.

4. Cost recovery

Cost recovery is a separate task in the WFD. The WFD is based on the polluter/user-pays principle. The costs of defined water services have to be covered by the users of these services. Civilians, for example, have to pay all the costs that are being made for their drinking water, to the water supply company. No subsidies are allowed for providing drinking water.

The analysis of the current levels of cost-recovery of water services is very important for assessing the final implications of the chosen programme of measures. To investigate costs of water services, financial costs, environmental costs and resource costs have to be taken into account (Wateco, 2003). Environmental costs are defined as representing the costs of damage that water uses impose on the environment and ecosystems and those who use the environment. Resource costs are defined as the costs of forgone opportunities, which other uses suffer due to the depletion of the resource being its natural rate of recharge or recovery (Wateco, 2003).

Environmental costs should be taken into account in the costs of providing water services such as, for example, waste water collection and treatment. In order to be able to assess the level of cost recovery, one therefore has to know the total costs, including environmental costs, and the way these costs are paid for by the different users of the water service through existing pricing and financing mechanisms. This allows us to assess the extent to which the ‘polluter pays principle’ applies. Including in this assessment an analysis of the level of compensation received by different water users for any damage caused by a specific water use gives us an idea to what extent environmental costs are internalised. Hence, the role of environmental costs in the context of water pricing policies is to signal to what extent they are internalised through existing pricing mechanisms in society. A number of steps can be distinguished when trying to estimate the environmental costs associated with water use and services:

- environmental Impact Assessment to qualify and quantify the environmental damage involved;
- economic valuation of the physical environmental damage; and
- the institutional and financial assessment of the extent to which the estimated environmental costs are internalised or not through existing price and/or finance mechanisms and the application of the polluter and/or beneficiary pays principle.

(Brouwer and Strosser, 2004).

Cost recovery makes transparent that within the polluter/user pays principle, the causer of environmental damage (for instance specific sectors), has to pay to counterbalance the damage.

The economic value of the environment can be estimated with the help of direct and indirect economic valuation methods. Based on the estimation of the environmental damage costs (avoided), through direct or indirect valuation methods, existing pricing and financing mechanisms can be reviewed to assess to what extent the estimated damage costs are internalised. Brouwer and Strosser (2004) conclude that there is an important relationship between environmental and resource costs and the assessment of what has been labelled ‘financial costs’ for the purpose of cost recovery. In some cases, these financial costs are equal to (part of) the environmental and resource costs, namely when they have actually been internalised through existing pricing or financing mechanisms. For the purpose of cost recovery, the challenge is to identify and quantify the extent to which environmental and resource costs are internal or external costs, i.e., actually being paid and compensated-for or not, by those who have caused the environmental and resource costs involved.

5. Balancing the costs and benefits within the WFD

Because of the intensive use of the land and the sometimes contrastive interests which occur in different areas in the Netherlands, it is important to decide on how to deal with the distribution of costs for water services, after carrying out the CEA and the SCBA.

To find out what the economic consequences of the WFD are on agriculture, nature, recreation and fisheries, Reinhard (2005) analysed the process of the cost-effectiveness analysis within the WFD. In this analysis the most important decisions in the CEA are illustrated for these areas of interest.

At national level decisions have to be made on which measures are considered disproportionate. Adequate information is necessary to make these decisions. Hence the selection of relevant information affects the way this decision is made. To decide whether a measure is disproportionate, information of the costs and the distribution of these costs is necessary. Decisions on the methods used to gather and present this information are very important — for instance, in choosing the scenario for autonomous development, against which the effect of the measures will be compared. The exact specification of costs is important: is an increase in quality of landscape considered as a (monetary) benefit? (Reinhard, 2005). Also the decision about which methods are used to calculate environmental benefits is important. Therefore the economic analysis needs to be integrated with the decision making process; it has to provide information and knowledge to aid decision-making (Wateco, 2003).

When identifying possible measures, it is important to realise that not all possible instruments are suitable for regional implementation. Many instruments can be more efficiently and effectively implemented at national (or EU) level. Choosing a spatial scale and also a time period for analysing costs, benefits and cost-effectiveness influences to a certain extent the cost-effectiveness of the measures.

To enhance a level playing field for European agriculture, regional differences in WFD policy instruments should be related to the variation in, for instance, regional emissions of agriculture. Also it is important that all relevant measures are taken into account. In the Netherlands measures affecting traffic guard-rails and zinc roofs were not seriously considered in the preliminary analysis. They were assumed to be too costly, while special attention was give to agriculture. If these measures are indeed disproportionate it will be revealed by the CEA. When measures per sector are analysed, it is important to be aware of investments made in the past, to prevent certain sectors from benefiting from 'low hanging fruit' (no prior investments made), while other sectors which had to make previous investments can only contribute to the goals of the WFD by finally implementing the least cost-effective investments. Past investments by different sectors must somehow be incorporated into this analysis: for example, the efforts made by the agriculture sector in the field of nitrate regulation. This also applies to distribution of costs between different countries in the same river basin. Agreement at the international level is important in this aspect. Also here a decision on methodology will have major consequences for different sectors and different countries.

Regional water managers (provinces and water-boards) have to perform a cost-effectiveness analysis (CEA) to select the most effective and efficient measures to achieve the objectives of the WFD. It is not clear at which aggregation level the analysis will be done. If the CEA will be performed at the water body level (a water body could be (part of) a river, lake, groundwater), approximately 1000 CEA analyses have to be done for different objectives and various measures. It will be clear that the optimal aggregation level of the CEA will be a weighing between a low level which allows more local expertise to be put in the analysis but will cost a lot of money and a high level in which a lot of general information is used, but which will cost less. Another disadvantage of performing CEA at water body level is that only benefits are included that exist within that water body. It will be clear that for an efficient CEA, national information on the average effectiveness and impact of measures will be provided. For point-source pollution (sewage-clean installations) this average information will be suitable. However, for the diffuse agricultural emissions of nutrients, average effectiveness and costs information can be far from realised effectiveness and costs. A simple analysis based on fact sheets of measures will not provide all this relevant information about impacts of measures for diffuse agricultural emissions. Hence, model-based analysis at a higher aggregation level (to capture also market equilibrium) is essential to capture all relevant agricultural effects.

A cost-effectiveness analysis determines the costs necessary to achieve the given objective. The bundle of measures with minimum costs is preferred. At the same time it is useful to identify measures that serve multiple goals — for instance, have an effect on agriculture but also affect nature policy or landscape policy objectives positively, to make sure a balance is found between the different sectors in rural areas. A relevant question is therefore which costs (and benefits) are explicitly included in the CEA. For agriculture it is important that positive side-effects of measures are included in the CEA. For instance, if buffer strips are implemented to avoid the emission of pesticides into the surface water, these buffer strips will have a positive effect on landscape and nature. Valuation of these secondary benefits of WFD measures will prioritise those measures that contribute to reaching a balance between agriculture and ecosystems and to multifunctional agriculture.

The exact definition of disproportion is important to direct the economic analysis. Economics is only there to inform decision makers; economics can provide information for the political balancing process to establish whether a measure has disproportionate effects. Will disproportion be judged at the level of sectors or regions? If it is judged at sector level, are subsectors considered within agriculture or will agriculture be treated as one sector: how many subsectors will be distinguished? What is the carrying capacity of a sector, how many firms may be bankrupted? It is important to make a decision on which subsectors or regions need to be analysed separately in the 'disproportion' analysis.

It is clear that before even starting to explore possible measures, certain agreement has to be made on several basic principles. When finally making decisions on the allocation of costs and benefits, it is important to realise what methodological steps on what subjects, sometimes implicitly discussed, have been taken to acquire insight into the different costs and benefits.

6. Conclusions

The Netherlands is a unique country with an abundance of water, where water quality issues are more at the forefront than water quantity issues. The EU Water Framework Directive (WFD) offers opportunities, but it also has far-reaching effects for the Netherlands. Therefore a pragmatic implementation (feasible and affordable) is important. It is a great mission to find the right balance in the implementation for different subjects and at different levels and subjects: at international, national and regional level, between the different sectors, and between the costs and benefits of the WFD. Especially, the apparent discrepancy between agriculture and nature is the biggest challenge for the ministry of Agriculture, Nature and Food Quality in the Netherlands in search of a pragmatic implementation.

The Netherlands notes that a number of decisions need to be taken at different levels, which will affect the ability to make balanced decisions later about cost-effective programmes of measures to comply with the Directive. To be able to make balanced decisions at national level, uniformity to a certain extent in information about costs and benefits, partly delivered by the regions, is necessary. To a degree, direction of the state therefore is necessary for methodological decisions and to attain sufficient insight at different levels about, for instance, consequences for allocation of costs and benefits. However, at the same time it is necessary to ensure a proper scope for regional diversity. An important issue, which is easily underestimated, is achieving public support from the numerous actors involved. Only this way an extensive exploration of programmes of measures can be made, to realise a pragmatic implementation, instead of directly focussing on (regional/personal/sectoral) desirable outcomes. Communication therefore is an essential part of the complex and often technical process.

The economic analysis is an important part of the process to identify realistic goals and find the appropriate measures. If we want the economic analysis to take account of the relationship between agriculture and nature management it is important to decide in advance what assumptions and principles are selected within the analysis. It will be possible to distribute the costs within the programmes of measures eventually selected as the most cost-effective. The Social Cost Benefit Analysis (SCBA) can be used to clarify the benefits that will be derived from achieving the objectives, where environmental objectives should be included. In order to strike the best possible balance between the various interests in rural areas, such as nature management and agriculture, it is important to realise that the principles referred to in the Cost Effective Analysis (CEA) and the SCBA will have impact on the results. Decisions made now will influence the degrees of freedom for decisions further in the implementation trajectory. The decision whether or not the monetary value of nature is included in the analysis, for instance, determines the distribution of costs and benefits of measures. This influences the decision whether a measure is disproportionate or not. The final decision whether costs and benefits are disproportional is not an economic question but a political one.

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Chapter 4.

Japanese Water Management Systems from an Economic Perspective: The Agricultural Sector

Hiroaki Kobayashi[1]

Japanese water management is characterised as that of a property rights regime. Several instruments have had decisive roles in improving economic efficiencies, securing effective and equitable cost recoveries, and abating conflicts between non-agricultural sectors, under the legislative framework that prohibits explicit trading in water rights. Each LID (voluntary farmers' group) is entitled with water rights and is responsible for the management of its irrigation water. More than the marginal cost recovery is secured and effective water use is expected at the same time. The area pricing commonly applied in the LID management is supported, taking into considerations the technical aspects and transaction costs. The LIDs, in some cases, conserve watershed areas for the purpose of stable water flow to be extracted. Facing the occasions of serious water shortage the government provides quasi-markets in water, realising intersectoral transfers between non-agricultural sectors, and among LIDs, to improve economic efficiencies. Serious water shortages take place only once every ten years on average, in limited areas and during limited periods. The community-like decision making of water allocation in the quasi-markets would help to abate the social conflicts. The permanent transfer of water rights is also managed. The Japanese systems of agricultural water management could be leading examples for developing countries in the monsoon climate, where small holdings of paddy field agriculture dominate.

1. Introduction

Efficient water use is studied throughout the world for the purpose of expanding agricultural productivity to cope with increasing population and for poverty alleviation. The lack of environmental concerns in groundwater use, irrigation in arid/semi-arid areas causing soil degradation such as salinity, inefficient uses of irrigation water, etc. all require effective countermeasures for sustainable development. Conservation of watershed areas and groundwater recharge enhancement are also important (Reddy, 2005). Particularly in the case of surface water use, conservation and proper management of forests are essential for stable supply and better quality of water.

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Not only investments in irrigation facilities and technological progress for an efficient water use, but also the conservation of watershed areas and improvement of economic efficiency are needed particularly in developing countries. Food production should catch up with the increase in domestic demand. Although the situation in most OECD countries seems to be improving, water pollution, soil salinity in agricultural areas and decreasing groundwater levels in several countries, and other environment-related problems excluding deforestation, are relatively important. Challenges to improving water-use efficiency and equitable cost recovery are yet to be solved. Both require effective and pragmatic instruments in government policy and social infrastructure.

This paper aims at evaluating agricultural water use in Japan from economic perspectives, focusing on paddy field irrigation that demands vast amounts of water and requires collective management and allocation among a number of farmers with small holdings. Infrastructure development in the post-war period has attained stable water supply for rice production, at the same time avoiding serious stress on the environment and conflicts between non-agricultural sectors. Japan's experience could be a good example for many developing countries depending heavily on paddy production under a monsoon climate to establish management systems for sustainable, efficient and socially acceptable water uses.

In the following section, we show the history and overall situation of agricultural water use in Japan. Section 3 summarises an economic theory and recommended policy measures for effective use of irrigation water. The Japanese case of agricultural water use is discussed from the standpoint of economic efficiency in Section 4, and finally we conclude the paper and give some recommendations to developing countries for economically, environmentally, socially and politically sustainable sound managements of irrigation water uses.

2. Agricultural water use in Japan: situation and historical background

2.1 History of agricultural water use

Paddy field agriculture and rice production have had, for more than a millennium, an essential role in Japanese society. That is the case in many other Asian countries under the conditions of warmer climate and higher precipitation. Paddy field agriculture is resistant to continuous planting of rice in the same ground, and has higher carrying capacity of population. In some cases, the facts reflect a clear contrast among populations in Asian countries and some European countries based on grassland farming or extensive use of upland. For example, the population density in Viet Nam and the Philippines was about one person per hectare (ha) of total land area while that in Ireland and France was 0.4 and 0.8 persons, respectively, in the early 1960s, despite the fact that the former countries were still covered with forests by 44% and 58% respectively in that period. Ireland and France had considerable forest loss by hundreds years ago (*FAOSTAT*, FAO, http://www.fao.org & Westoby, 1989).

In most parts of Japan, rice production is restricted by geological and climatic conditions. Cultivation should be completed during the period from April to October due to low temperatures in the other months. The land is mountainous and seasonal rainfalls run very fast along with short rivers into the seas. These features make it easy for floods and droughts to take place. Controlling water supply and irrigation management have been necessary for Japanese rice production, because depending solely on rainfall or natural river streams causes serious uncertainties compared with tropical/semi-tropical countries. Irrigation systems both in terms of physical and social infrastructures have been continuously developed for hundreds of years.

The irrigation systems are comprised mainly of canals to deliver water from rivers to the rice production site and to allocate the water inside. From 50 to 500 farmers at the most belong to each production site and make up a community or village. Though water allocation in the community had been managed based on the principle of equal usage among farmers, water battles frequently took place among villages in years of low precipitation. Many efforts were made for efficient use of irrigation water in each community and among villages. Areas that have relatively low precipitation or extremely short rivers often constructed irrigation ponds for supplementary uses. Groundwater use has been very limited in agricultural production in Japan.

The roles of forests both in villages and upstream areas should not be neglected in agricultural production. Forests, well managed ones in particular, have a high potential to buffer rainfalls, stabilise river flows and prevent or mitigate disasters caused by floods, landslides and drought, as well as provide forestry products such as timbers and fertiliser. Japanese society has placed more importance on the roles of forests. The principle of 'replant when cutting' has been widely accepted and the forest cover in 2000 was maintained at 64% of the total land area, while many of the village forests have been converted into golf courses and other non-agricultural uses in recent years.

2.2 States of water use and water rights

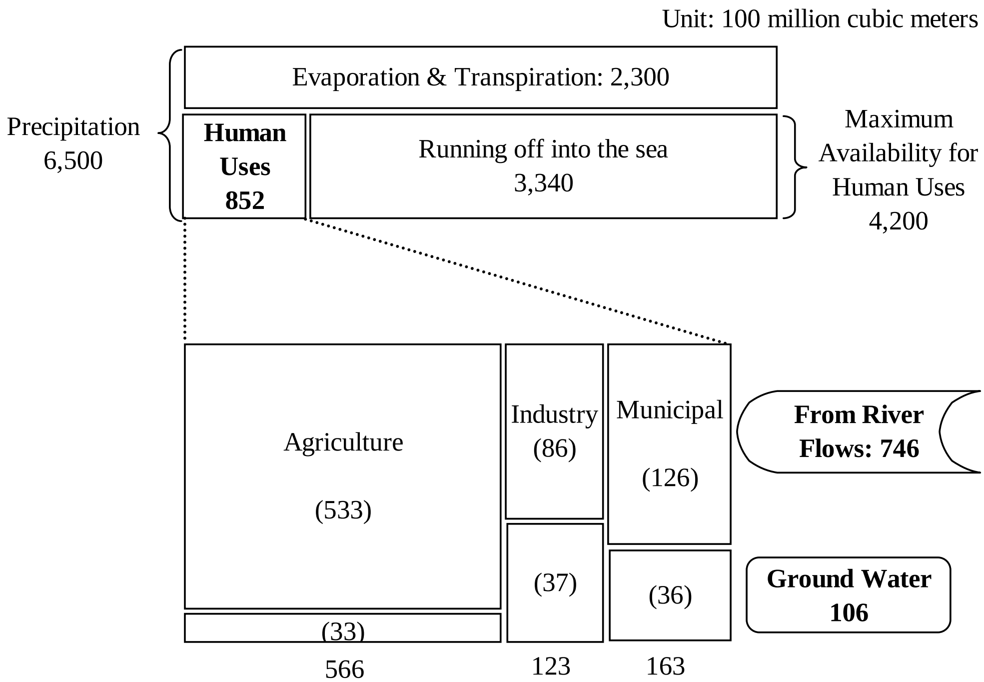
Around 420 billion cubic meters (m^3) of water a year is available for human activities in Japan, of which 85.2 billion m^3, or 20%, is actually utilised. The annual average precipitation is 1,718 millimetres (mm). Depending heavily on annual rainfall, Japan often faces problems of shortage due to annual and seasonal fluctuations, as well as frequent occurrences of disastrous floods. Agriculture is the primary user of water (Figure 1).

Property rights to water, i.e., water rights, were traditionally established by community according to customs based on prior occupation. Although rainfall and natural water flows from rivers fulfill most of the basic demand for agricultural production in years of normal precipitation, water rights become meaningful mainly when the precipitation is lower than average.

Competition with non-agricultural sectors has taken place since the Meiji Era (since 1868). Industrialisation and the population increase in urban districts expanded the demand for water. Legislation on water rights has been gradually drafted along with capital investment in water resources development to meet increasing demand from hydropower generation and industrial, municipal and agricultural sectors. Water rights to be newly issued should be connected to the construction of facilities so as to protect historically entitled rights. Water rights have not been free in this sense. They are not considered to be normal private properties from a legal perspective, although they may seem to be private properties that are excludable in consumption from an economic point of view. Economies of scale in water management have enhanced multi-sectoral investments. Water rights are to be revised by the water authority every ten years, and commercial trading has been legally banned because of the public nature of water.

In the agricultural sector, community-based water rights are usually issued. The Land Improvement Districts (LIDs), many of which have a historical background as voluntary farmers' associations, are in most cases required by legislation to be established, endowed with water rights, and responsible for the management of their water use. Each water right, which is a useful tool for protecting the right to use water mainly during years of lower precipitation as stated before, is issued to an LID operating and maintaining a single irrigation scheme comprising dams, head gates, pumping systems, canals and other facilities. The volume of water available for agriculture is set out, assuming the year of serious shortage with a probability of occurrence of once every ten years, with careful consideration to minimise impacts on the environment, to protect the rights of other users as well as local traditions and customs related to the use of water. Water rights are also assigned in detail for each half month and the minimum river flow should always (defined under legislation as at least 355 days a year) be maintained from the perspective of environmental concerns.

Figure 1. Water Resources and Utilisation in Japan



Source: *Water Resources in Japan*, Ministry of Land, Construction and Transportation, 2004.

Note (1) Precipitation; an average of 1971-2000.

(2) Agricultural uses in 2000 (from river flows) and 1996-98 (groundwater), and industrial and municipal uses in 2002.

For the purpose of utilising possible economies of scale, the area that each LID covers usually includes several, or in some cases hundreds, of community-based irrigation systems. Since many LIDs have merged, their number has decreased from 13,163 in 1961 to 7,004 in 2000, and the average area under management has increased from 245 hectares (ha) to 507 ha in the same period. Roughly speaking, each LID manages one or two head gates, and the dam is shared by several LIDs and sometimes used for other non-agricultural purposes. A farmer should be a member of an LID if he/she would like to have water delivered through the facilities of the LID. The principle of the present regime was established under the River Law promulgated in 1896 followed by the Land Improvement Law enacted in 1949 and other related legislation. Some statistical figures are listed below.

Table 1. States of Land Improvement District (LID)

No. of respondents	Area under Management ('000 ha)				Number of Membership
	Paddy field	Upland	Orchard	Total	
5,431	2,221	425	109	2,755	3.9 million
Average	409 ha	78 ha	20 ha	507 ha	726

Source: A survey by the MAFF in 1998.

3. Economic theory of water management: A brief overview

3.1 Efficient and sustainable use of natural resources

Water management has both positive and negative impacts on the environment (OECD, 2001). In general, possible impacts harmful to the environment and natural resources would be (i) overexploitation of groundwater, (ii) salinity and other soil degradation (not reported in Japan), (iii) capital investments harmful to the natural habitat, (iv) water pollution, and so forth. Paddy field cultivation combined with its water managements is considered to be environmentally friendly and to have some positive impacts on the environment. Paddy field agriculture, which dominates in Japan, is known not to emit nitrous oxides into river flows and aquifers due to the technical reasons. Biodiversity is larger in the areas of paddy fields/forests combinations than in the areas of only forests. Other facts of such positive aspects will be shown in another report in this workshop.

Ground water: In Japan land subsidence has taken places in several areas due to groundwater extraction. The major cause has been industrial use. The agricultural sector has mainly extracted shallower aquifers that are recharged quickly with annual precipitation. For industrial and municipal use, extraction of groundwater from deeper aquifers is regulated so as not to decrease the water level. The land subsidence was considerably improved in most areas by the 1980s (States of the Environment 2004, Ministry of the Environment).

Economic theory clearly distinguishes between water resources that cannot be easily recharged (e.g., groundwater with a smaller rate of recharge) and those that can be recharged such as surface water from annual precipitation. The latter is classified as a replenishable or renewable resource, and the former as a depletable resource (Tietenberg, 2000). Pollution could also be conceptualised in the same way. We define the cleanness or safety of water as a kind of resource and polluting activities could be redefined as exploitation of that resource. When the pollution is purified relatively fast through the natural assimilation process, temporary pollution can be analogised with exploitation of a renewable resource, and persistent pollution with that of the depletable resource. If the exploitable resource is abundant, we can take as much as we like and no economic challenges would be raised. That is not true for water in most cases, because the final consumption requires many activities that employ other resources which are not abundant.

Overexploitation and degradation of natural resources such as forests and water usually happen under the so-called open access situation, in which excludability in consumption is not established and congestion occurs, leading to deterioration of economic efficiency and sustainability. The failure of users to incorporate into their decision making the impacts of their uses on the resource in question is the source of this "market failure" (or tragedy of commons). How we could convert open access resources into common property resources, in which formal or informal rules among users are established so as to achieve sustainable use of resources, is a major challenge for policy makers.

Proposed remedies from economists' views are those based on market orientation such as internalisation of environmental costs and benefits into decision making and employing market mechanisms to make economic water cost explicit to all stakeholders. Market-based instruments require: first well-defined property rights; second, appropriate pricing that reflects social costs including scarcity rents and environmental burden; and third, establishment of effective markets and institutions. Policy measures to internalise environmental costs, i.e., externalities, involve application of the Polluters Pay Principle for environmental damage and levies on the extraction of groundwater that is in some cases classified as a depletable natural resource like petroleum.

Another source of market failure in the case of irrigation water use is the economies of scale in capital investments. Particularly in the developing countries where paddy field agriculture is dominated by a large number of small holdings, the governments may have to play a significant role in enhancing agricultural productivity by means of infrastructure development, even if that requires a significant amount of financial assistance.

Other problems caused by economies of scale, the analysis of which is a major purpose of this paper, are discussed in the following sections.

3.2 Criteria in the evaluation of agricultural water management

The Japanese systems of water management stand on intrinsic common property systems with the support of the government as a kind of property rights regime. In the next section, we will evaluate the systems according to the following interrelated questions: first, whether or not the allocation of water is economically efficient, and second, whether or not the governance is appropriate for securing institutional sustainability. Focus is placed on the agricultural sector, paddy field agriculture in particular. Other than the conventional costs of managing the water supply, economic efficiencies should take into account opportunity costs reflecting the scarcity of resource endowments and social costs associated with the burden on the environment, and the costs related to institutional management. Because groundwater use in the Japanese agricultural sector is very limited as explained above in Section 2, we do not have to consider the intergenerational allocation of this depletable resource.

The following criteria are the factors that policy makers would have to consider when they establish strategies for sustainable and economically efficient use of water resources:

1. ***Marginal cost bearing***: If the farmer faces a water price (i.e., the actual payment in any form) that is lower than the unit marginal cost, he/she will waste water, because the marginal benefit of water will be lower than the social cost, and an economic efficiency will deteriorate.
2. ***Average cost bearing****:* Due to the economies of scale associated with the capital investments required for developing water resources, the average cost, which stands for financial cost, is usually greater than the marginal cost. If priority were given to satisfying the first criterion, a financial deficit would therefore be inevitable. On the other hand, when financial stability or income distribution is given a higher priority and users bear the financial costs, it would be likely to violate the first criterion. In other words, there would be a tradeoff between efficient pricing and financial pricing. Economic theory could not provide clear-cut solutions to this problem and who should bear the deficit and to what extent, and how the budgetary allocations should be made are the questions that policy makers would have to face (Lipsey & Lancaster, 1956, Baumol & Bradford, 1970).
3. ***Marginal benefit equalisation****:* If the marginal benefit of one user exceeds that of another user, a transfer of a part of consumption from the latter to the former will improve the economic efficiency in the society. This point is essential for considering the allocation of water between agricultural and non-agricultural sectors in Japanese water management.
4. ***Transaction costs of the management****:* It takes costs to manage the systems themselves, to collect technical, social and economic information necessary for efficient water use, and to change the present institutions.
5. ***Equity and other social justice****:* This criterion also relates to the public nature of water and the historical background.

4. Water management in the Japanese agriculture: An evaluation

4.1 The property rights regime

First of all, we evaluate the most fundamental framework of the property rights regime in Japanese water management, compared with a hypothetical arrangement in which centralised institutions, such as the government as the representative of society, manage water resources and charge appropriate prices on users (authority regime). Particularly in the case of surface water use, the latter systems in many cases are not realistic based on the fourth criterion above. Availability, on which the marginal (social) costs of diversion are partly dependent, fluctuates according to the changes in precipitation and other natural conditions. The scarcity rent is very likely to change yearly and monthly, and varies by region and by site.

Appropriate pricing to equilibrate the marginal cost to the marginal benefit is operationally impossible (Sampath, 1992). Another difficulty is pointed out by the World Bank (2004, p. 23): i.e., farmers do not intend to pay the price from scarcity value, namely the opportunity cost, because that is invisible and because the general understanding would be that the water is a common-pooled resource in the society. Farmers resist paying even for the sunk costs from capital investments, because that is beyond their scope as well. In the real world, the government or some other public agencies in many countries often fail to charge even marginal (O&M) costs, which are visible to farmers (Tsur et al., 2004). The last problem is that of sustainable governance of irrigation water managements.

In the context of Japanese history, the centralised supply of water by the government would imply a drastic change in the institution. Confiscation of existing water rights formally issued or even those based on traditions and customs would be politically difficult and cause serious questions as to social equity. As a basic framework, the current property rights regime operated by users' associations and associated with capital investments would be the correct solution.

Actually, the property rights regime, by and large, is common in many other countries. The important question is how it works in terms of the criteria listed above. The following parts are some examples of such consideration in the Japanese case.

4.2 Normal years of normal precipitations

By virtue of higher precipitations and depending on the capital investment to stabilise water flows, water is rarely scarce in years of normal precipitation. Economic costs of water consist mainly of actual payments for service rendered, operation, repair and maintenance of facilities, and sunk costs of infrastructures. In a normal year water use in agriculture is not seriously restricted under the water rights bounds, and the allocation between non-agricultural sectors and even among neighbouring LIDs need not be taken into consideration.

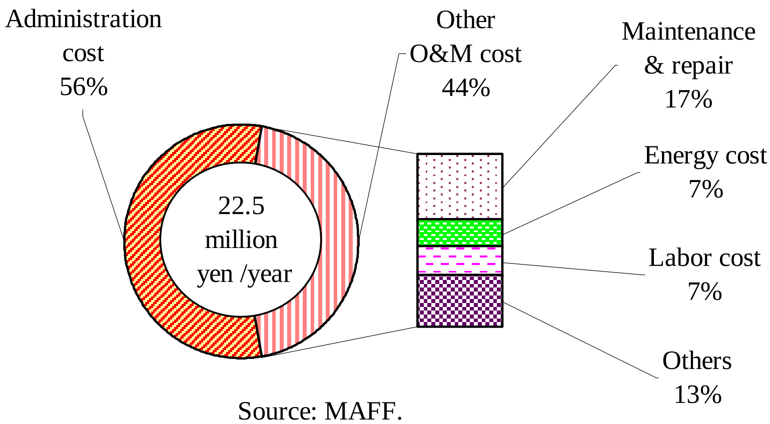
The LID that is entitled to the water rights is totally responsible for managing all facilities ranging from dams and head works to lateral canals. LIDs as farmers' organisations are in the best position to efficiently carry out these activities, since they have the most knowledge of local and specific conditions (the fourth criterion above). On-farm watercourses are maintained by farmers or village communities.

All farmers eligible for obtaining irrigation water through the facilities operated by an LID should have a membership in the LID, and they should bear the related costs. According to the classification by the World Bank (2004, pp. 22-25), farmers in Japan are considered to pay all of the O&M costs because LIDs are in principle autonomous as far as O&M costs are concerned. In addition, LIDs bear most of the costs for repairing equipment as well as some portion of the investment costs (Figure 2). This implies that the farmers are sharing a substantial part of the average costs. LIDs usually collect fees from member farmers for repaying loans payments required for initial investments (Table 2). Scarcity rents, which originated mainly from the capital investments, are incorporated in the entitled water rights.

LIDs do not allocate water rights for each member or each field under the current legal framework of the River Law. The LID acts as an authorised supplier of water in the corresponding irrigation unit and flat rates per cultivated area are charged to member farmers to recover O&M costs and part of the investments costs (area pricing by flat rates). The basic principle of this charging system lies in preserving equity among members (Nakashima, 1998). How about the economic efficiencies, which mainly reflect the first, second and third criteria above, of the allocation or pricing by the LID (Tsur & Dinar, 1997, Shobayashi, 1988)? To answer this question, we have to reconsider the characteristics of cost components for supplying water and the technical conditions in the paddy field irrigation:

First, the O&M costs would not necessarily be characterised as marginal costs, because most of them, once actually operated, are required regardless of the volume of the water to be delivered in the case of the gravity irrigation system, which is dominant in paddy irrigation. In the normal precipitation situation, increasing a marginal unit of water supply is nearly costless, and its marginal value in the agricultural production is also very small. Marginal cost pricing, therefore, implies very low levels of charges, and a large part of the O&M costs should be covered by charges not related to the volume of water.

Figure 2. Average Expenditures by LID, 2000



Source: MAFF.

Table 2. Payments for water uses in rice production, 2003

Payment to	(yen/0.1ha)	%
LID	3,808	59.5
Subordinate body	798	12.5
Capital investment loan	2,402	37.5
Individual management	114	1.8
Others	74	1.2
Total payment	6,398	100.0
Percentage of the total production cost		4.2

Source: *Production Cost Survey on Paddy Rice*, MAFF.

Second, strict control of water supply by individual paddy field is difficult due to the technical reasons: the paddy fields are separated into hundreds/thousands of patches by ridges, the water to be supplied to a specific patch must use the canals running through neighbouring upper fields and the water might percolate into the neighbouring fields (or the neighbouring farmer might break a part of the dyke to extract water). Considering the nature of small holdings, it is obvious that volumetric pricing, which requires strict monitoring and metering of the actual water use, even if it is combined with some multi-tiered pricing, is not realistic (the fourth criterion above).

Third, Nakashima analyses other important factors that would help to alleviate the inefficiencies sometimes pointed out by theory, i.e., most farmers (i) are uniform in terms of crop (rice) and (small) land holding, (ii) voluntarily save water as traditional community members, and (iii) incur additional marginal costs for effective water use required under the condition of equitable water allocation by the LID.

Therefore, we can conclude that the present scheme of area pricing contributes to achieving economic efficiency while the financial autonomy of LIDs is also preserved.

4.3 Capital investments and average cost bearing

In years of normal precipitations, we can recognise that a kind of scarcity rent is incorporated in the entitled water rights that originated mainly from the capital investments enabling stable water supply, as pointed out above. However in the general understanding, the related costs, which should be financed over a longer term anyway, are counted in the average cost. The Japanese government has subsidised the construction of irrigation facilities, such as dams, head gates, canals, and so forth, as would be the case in most countries. The financial support to each project has been at around 60% and 50% in the case of that under the central government and the prefectural government, respectively.

The government commitments to these capital investments are based on the following considerations (Nakashima, 1998):

- The basic nature of economies of scale in the investments (the second criterion above).
- Collectivity in paddy field irrigation: To exhibit the economies of scale in the investments, many projects should be relatively large and involve all the farmers in the territory. Financial support to some extent is essential to persuade passive farmers to join the project (the second and fourth criteria above).
- Food security concerns: The nation's support in raising agricultural production can be legitimated to benefit consumers especially in the early stage of economic development.
- Enhancement of externality: Water facilities and users' activities generate various environmental benefits and land conservation services.
- Stabilisation purpose: Irrigation water acts as a buffer to cope with the curious needs from the municipal sector during a period of serious droughts (see the following section).

4.4 Water shortages in the years of lower precipitations

4.4.1 Inside of the LID

The equitable allocation of irrigation water to farmers in the territory of each LID and charging based on area pricing are kept unchanged. Major instruments carried out collectively and traditionally by LIDs to achieve efficient water use are: (i) Bansui, strict rotation of water sharing by intensive monitoring, (ii) enhancing repeated uses, (iii) supplementary irrigation from groundwater or reservoirs, and (vi) sacrifice of fields that abandon rice cultivation (Irrigation Water Use in Agriculture in Japan The Japanese

Institute of Irrigation and Drainage, 2004). The numbering reflects the priority of the application. The last instruments have seldom been adopted because of the difficulty in controlling water by individual patch of paddy field. The LIDs and farmers in conclusion incur extensive costs for these operations.

The economic theory suggests that there might be ex ante deals to make farmers better off. However, water shortages take place in July/August after the paddy is already planted. The marginal productivity of water, or equivalently the marginal cost of missing water is very high for every farmer on such occasions (the third criterion above). In conclusion, few water exchanges occur among farmers regardless of the emphasis on equity.

4.4.2 Among LIDs

Water exchange, normally without monetary payment, has traditionally been carried out among communal irrigation units. Similar customs remain informally in the present day. Programmes have been provided under the transfer scheme of agricultural water, though the primary purpose is aiming at intersectoral transfers between non-agricultural sectors as explained in the next part. Transfer or exchange of agricultural water among LIDs has not been officially registered up to the present date. The reason why such transfers hardly occur may be the same as the above-mentioned accounts inside each LID.

4.5 Intersectoral transfers of water, and water rights in quasi-markets

Although droughts have not taken place very often recently, water shortage should invariably be taken into consideration as the social (opportunity) cost of water. Because drought generally hit the municipal sector more seriously, transfers of water from the agricultural and industrial sectors to the municipal sector will be significantly appreciated. According to the economic theory, the perfect property rights regime could naturally lead to an efficient allocation of water through trading in a manner to equilibrate the marginal benefits of water in every place and for every stakeholder (the third criterion above). But the other measures work in reality.

Explicit trading of water rights is prohibited by the River Law in Japan, but the government has established compensatory measures to realise temporary and permanent water transfers, which in conclusion help to raise economic efficiency in terms of the third criterion above, the marginal benefit equalisation. The systems could be called quasi-markets in water, and in water rights in cases of permanent ones, which work as the following:

Facing occasional cases of serious droughts, which take place unexpectedly in some regions during the July-August normally, the Water Utilisation Adjustment Councils, under the recommendation of the government, are summoned in the concerned regions. A total of 186 Councils have been established according to the 1991 survey by the MAFF. Chaired by the river administrative agencies, negotiations are carried out among representatives of user groups, and the target of water-saving rate from the entitled water rights in each sector and some intersectoral water transfers in conclusion at the same time are to be agreed upon. Although the agencies are responsible for making the final decisions, a consensus has been achieved in every case without any compensatory payments.

Among the sectors of municipal, power generation, manufacturing industry and agriculture, the latter two, the agricultural sector in particular, have actually incurred heavier burdens of water savings in many cases, and concluding transfers to municipal sectors should have improved economic efficiencies. Table 2 shows the agreed percentages of water extraction reductions from river flows by sector in competing cases of the 2005 droughts.

The community-like consensuses above might be based on the commonly shared considerations of priorities (larger marginal benefits) of municipal water use, and on the fact that such droughts do not take place very often. Only a few regions are damaged during limited periods and the serious droughts of 2005 were the first ones since 1994. Taking into considerations of the above conditions and the public nature of water, ad hoc negotiations like the above, compared with fully market-oriented trading, will rather help to minimise transaction costs for efficiency gains and to mitigate social contradictions (the fourth and fifth criteria above).

Table 2. Rate in restriction of water extraction: 14 cases of drought in 2005

Name of river	Subregion	Percentage of water saving by:		
		Agriculture	Industry	Municipality
Kiso	I	40	40	20
	II	40	40	20
Miya	I	45	(d)	(a)
Yahagi	I	76	(d)	40
	II	30	30	10
	III	30	30	10
Kushida		> 40 (b)	20	5 - 20 (c)
Toyo		10	10	10
Kino		10	10	10
Yoshino	I	15.9	15.9	15.9
	II	35.0	35.0	35.0
Niyodo		20	(d)	20
Shigenobu		11	(d)	5
Yamakuni		0 - 30 (c)	67	10
Simple average		31	30	17

Note: (a) voluntary saving.
(b) counted as 40.
(c) counted as 20 and 30 in calculation of the average, considering the acceptance levels.
(d) no extraction before.

Source: MAFF, http://www.maff.go.jp.

Permanent transfers, namely the transfer of water rights, have been also carried out in a form of implicit trading under the provision of the Ministry of Agriculture since 1972. The transfer in this case is connected to capital investments to improve efficiencies of water use in a partner LID's territory. The project is managed by the Ministry, but the municipalities concerning to the water rights should pay a part of the investment costs. While demand for water in municipal use has not been increased significantly in recent years, 11 cases of such 'trading', which is equivalent to the demand of 3.3 million people, have been realised up to 2005.

4.6 Conservation of watershed areas by the LIDs

Conserving watershed areas stabilises river flows and stimulates the groundwater recharge. Some of the LIDs join voluntary activities to manage the upstream watershed areas. A famous example is that by Meiji-Yosui Land Improvement District, located at the basin of the Yahagi River. People in the basin have been continuously working on effective water management; a large-scale paddy field development was launched in the 14th century, and it took about 300 years to complete the irrigation systems for agricultural production and industrialisation. A significant increase in population expanded water demand since the Meiji Era (1868–1912), the new water management systems including multi-purposed dams were constructed in 1963, and 28 municipalities established a joint organisation to achieve stable and safe water supply in 1971. While the Meiji-Yosui LID, the major user of water from the river flows, has joined the organisation, similar activities had already been carried out by farmers and fishermen. The LID has independently owned 520 ha of forests in the watershed area under its conserving management since the Meiji Era.

Many of the LIDs seem to have some role in improving the total system of water management and conserving watershed areas covered by forests. Some typical examples are summarised in Table 3.

Table 3. Conservation of forests in watershed areas by LIDs: Examples

Name of LID	Prefecture	Collaborating organisation	Features
Nanataki	Akita	None	Facing persistent water shortages in the early 20th century, the LID owned 251 ha of upstream forests. Reforestation and managements. Conservation activities since 17th century.
Kawashima-Cho	Saitama	The forestry cooperative	An exchange program. The LID manages the marketing of forestry products and has contributed 100 kg of rice as a gift since 2002.
Meiji-Yosui	Aichi	28 Municipalities & Fishery cooperatives	Continuous activities since the Meiji Era. The LID now owns 520 ha of conservation forests. Research and publicity.
Edashita-Yosui	Aichi	Toyoda-City & the fishery cooperative	Research activities on the environment and cultures related to forest and river, and publicity of environmental conservation.
Kawanishi-	Gifu	A volunteer group	Planting broad-leaved trees and publicity.
Takahashigawa-Yosui	Okayama	Owners of forests	A profit-sharing forestry operation and conservation activities since 1960.
Konomizo	Miyazaki	The forestry cooperative	The LID has owned 125 ha of upstream forests since the Edo Era (1603-1868) and had managed until 1993, and then the management was entrusted to the forestry cooperative. A collaborative activity on education and publicity of the forestry.

Source: Prepared by Mr. Akihisa Nakano (MAFF) from various materials.

Note: Translated and summarised by the author.

5. Conclusions and recommendations for developing countries

5.1 Conclusions of this paper

Overall, the Japanese systems of water management can be characterised as a kind of property rights regime. In the agricultural sector, several instruments have had decisive roles in improving economic efficiencies, securing effective and equitable cost recoveries, and abating conflicts between non-agricultural sectors, under the current legislative framework that prohibits explicit trading in water rights is prohibited:

The LIDs, voluntary farmers' groups, are entitled to the water rights and responsible for the management of all irrigation water in the corresponding territory. Based on the independency of the organisation and easier access to the necessary information, the marginal (O&M) cost recovery, at the least, is assured and effective water use in terms of both technical and economic efficiencies is mostly expected at the same time.

The area pricing commonly applied in LID management is supported compared with other systems like volumetric pricing, taking into considerations the technical aspects and transaction costs under the conditions of uniform, collective and small-scale paddy farming in Japanese agriculture.

The LIDs, in some cases, have conserved watershed areas for the primary purpose of stable water flow to be extracted. The whole system of agricultural water management in this context realises positive impacts on the environment.

Facing the occasions of serious water shortage, the government provides quasi-markets in water implementing transfers between non-agricultural sectors, and among LIDs, to improve economic efficiencies. Recently, serious water shortages take place only once every ten years on average, in limited areas and during limited periods. Explicit trading is prohibited, but the community-like decision making of water allocation in the quasi-markets would help abate social conflicts. The permanent transfer of water rights is also managed under the authorisation of the government.

5.2 Recommendations for developing countries

The Japanese systems of agricultural water management will be leading examples for developing countries under the monsoon climate, where small holdings of paddy field agriculture dominate.

Some form of farmers' organisation should be responsible for irrigation water management. Once well-defined property rights to access irrigation water are entitled to the organisation, securing the marginal (O&M) cost recoveries at the least and efficient water use will be mostly expected regardless of pricing systems actually applied inside. Uniform pricing by any governmental organisation would be inferior. Economic instruments to improve efficiencies can be considered after this kind of institutional problem concerning effective and sustainable governance is solved.

For economies of scale, which will benefit the economy as a whole, be revealed, capital investments may have to be subsidised to some extent. The benefits from productivity enhancement will accrue mainly to consumers in many developing countries. Where the property rights of water use are connected to these investments, farmers might intend to pay part of the sunk costs from the investments (average cost recovery).

Other than the infrastructure developments, the government may have to carry out significant roles facing competitions among different sectors and inside the agricultural sector, taking into considerations of economic efficiencies, equities, the environment and other social interests. Total permissions for trading in water or water rights will contradict the above instruments under the systems in the property rights regime.

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Chapter 5.

Water Quantity and Quality Issues in Mediterranean Agriculture

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The high demand of water resources for irrigation purposes is the cause of significant water quantity and quality problems in Mediterranean countries. The reliance of the Water Framework Directive on water pricing may fail in these countries, since water pricing is quite complex to implement in irrigated agriculture, efficiency of water pricing is questionable, and its political acceptability remains to be seen. This calls for alternative Directive instruments, such as the re-allocation of water from off-stream use by agricultural, urban and industrial users to environmental uses both in aquifers and streams, and also in the coastal wetlands. Pollution control instruments such as ambient quality standards and pollution emission limits are also needed.

The heated policy debate that has been taking place in Spain over ways to solve water scarcity and resource degradation highlights the difficulties involved in achieving sustainable management of water resources, because of the conflicting interests of diverse stakeholders, such as regions, economic sectors and political and environmental groups. This study presents empirical results on the assessment of alternatives to overcome water scarcity in south-eastern Spain, and also a ranking of abatement measures for agricultural pollution control. These empirical results question water pricing as an efficient or even feasible instrument to allocate irrigation water or to curb pollution. Government water authorities, environmental NGOs and international organisations should look carefully at the implications of sound empirical research that takes into account the underlying biophysical processes and the complex spatial, dynamic and social issues involved in the design of water policies. Water and pollution markets, while difficult to implement, appear to be a much more efficient and feasible policy approach than water pricing. Even the current command and control water policies that most countries have in place seem to be more appropriate for irrigation management than water pricing.

1. Introduction

Irrigation is an essential factor in the agricultural production of Mediterranean countries, while water is used only marginally in central and northern European agriculture. There is significant pressure on water resources and fluvial ecosystems in

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Portugal and Greece, because of the large share of water extractions used in irrigation. However, pressure on water resources is much greater in Spain, Italy and Turkey, where the acreage under irrigation is very large, with a combined water demand exceeding 80.000 hm^3 (Table 1). Irrigation development in these three countries has been driven by heavy, sustained public investments in waterworks to store, transport and distribute water to irrigation fields.

Table 1. European countries with high levels of water use for irrigation (2001)

Country	Total water extractions (hm^3)	Irrigated land (1000 ha)	Irrigation water (hm^3)
France	33,500	2,200	4,800
Germany	40,400	490	620
Greece	8,900	1,450	7,700
Hungary	5,600	210	500
Italy	56,200	2,700	25,850
Poland	11,600	100	1,030
Portugal	9,900	650	8,770
Spain	37,700	3,650	24,600
United Kingdom	15,900	110	1,900
Bulgaria	5,800	800	870
Romania	7,300	2,670	1,020
Turkey	39,800	4,500	31,000
Total Europe	291,900	21,170	109,470

Source: EEA (2005), INE (2005), IFEN (2005).

Another aspect to be considered in the case of Italy and Spain is the development of groundwater extraction in the second half of the twentieth century, driven by the falling costs of pumping technologies in areas with high-profit irrigated crops. In contrast to the large collective irrigation systems, these private groundwater extractions are largely outside the control of the water administration.

In Italy, pervasive aquifer overdraft and water quality problems exist in the Po basin, Romagna and Puglia, and in the coastal plains of Campania, Calabria, Sicily and Sardinia. Highly profitable fruit and vegetable production, based on individual pumping from aquifers, takes place mainly in the Po basin and in Emilia-Romagna. In these regions, the problem is not so much water scarcity as water quality. Surprisingly, fruit and vegetable production has not developed in the south of Italy, largely because traditional marketing channels cannot be restructured, preventing investments by farmers. Irrigation in the south of Italy depends on collective systems with low-value crops. In Sicily, irrigation is based on individual aquifer pumping, with an unprofitable citrus sector in need of modernisation.

In Spain, the most severe water scarcity and quality problems are found in the Júcar, Segura and Sur basins in south-eastern Spain. A dual situation holds for irrigation water resources in Spain. The irrigation districts of inland Spain are based on collective surface irrigation systems and low profit crops, and the degradation of water resources is moderate. The reason is that basin authorities regulate water extractions, and fluvial ecosystems are protected by the enforcement of minimum flows. High-profit crops, such as fruits and vegetables, concentrate in the Mediterranean coastal areas, which rely on individual pumping from aquifers. There is a lack of effective control on aquifer extractions, both on the number of legal and illegal wells and on the volume of water extracted. Decades of water resource mismanagement have created pervasive pressures on water media, resulting in severe scarcity and degradation of water resources.

There are two general policy approaches when dealing with the quantity problems faced by Mediterranean irrigated agriculture. One is the traditional water policy approach based on expanding water supply, and the other is the newly emerging approach based on water management initiatives. These emerging initiatives rely on measures such as water pricing, revision of water rights, abstraction limits on surface and subsurface waters, development of regulated water markets, and re-use and regeneration of water resources.[3] These management initiatives appear to be better suited to solving irrigation scarcity than new supply technologies, such as desalination (FAO, 2005).

A highly illustrative example of the conflict between these two approaches is to be found in the type of solutions that have been considered for solving water scarcity and degradation in south-eastern Spain. Two projects have been presented in the last four years by the central government, both of them aimed at quantity rather than quality problems. The first was the Ebro inter-basin transfer, which was subsequently replaced by the new AGUA project. Both of these projects follow the traditional approach of expanding supply with subsidised public investments, and both are questionable on economic and environmental grounds.

Measures based on the new approach of water management initiatives require careful application and a reliable information base, since the implementation of demand management measures is a complex process that meets with resistance from farmers. Banning aquifer overdraft is very difficult to achieve, since aquifers are a common pool resource posing significant managerial challenges. Water pricing is also difficult to implement because of farmers' opposition to price increases, lack of administrative control on aquifer pumping costs, and non-response of water demand to water pricing in aquifer areas with high-profit crops. Creation of water markets is another difficult task, because institutional reforms require huge and persistent efforts, and because farmers distrust such schemes.

Augmenting water supply in Mediterranean coastal areas by publicly financed desalination is much more straightforward, but entails the problem of ensuring an effective irrigation demand if water is not subsidised and farmers are obliged to face high desalination prices. The impediment for the effective demand to materialise is that farmers are extracting water from aquifers at pumping costs much lower than desalination costs, so farmers will not buy desalinated water. Public investments in desalination plants are only reasonable under a strict enforcement of an aquifer overdraft ban by the water authority, which would force farmers to buy desalinated water.

The quality problems faced by Mediterranean agriculture are illustrated in the second example presented here, which deals with agricultural nonpoint pollution abatement. This example shows that nonpoint pollution control instruments cannot be accurately assessed without a correct understanding of the key underlying biophysical processes. Neglect of these processes may lead to adoption of incorrect policy measures.

The paper examines water quantity and quality issues in Mediterranean irrigated agriculture, presenting empirical evidence from Spain on alternative policy options and measures. We approach the quantity issue by evaluating alternative measures to solve water scarcity in south-eastern Spanish basins, and the quality issue by ranking

3. Goetz et al. (2005) present an example of water allocation among farmers with heterogeneous yields, by using both uniform and sequential allocation rules developed from social choice theory.

agricultural pollution control instruments by their cost efficiency. The implications and findings are summarised in the concluding section.

2. The Water Framework Directive and Mediterranean irrigated agriculture

The European Union's Water Framework Directive is intended to protect all continental, subsurface and coastal waters. Its objectives are to improve water quality and the status of ecosystems, promote a sustainable use of water, and reduce emissions and discharges to water media. In order to increase water use efficiency, water pricing should approximate full recovery costs, including extraction, distribution and treatment costs, environmental costs, and resource value costs. There are also a combination of emission limits and water quality standards, with deadlines to achieve good status for all waters.

The European Water Directive has a great potential to solve water scarcity and nonpoint pollution in Mediterranean countries, and this initiative is supported by the findings of the European Environmental Agency, which point to agricultural nonpoint pollution as the primary cause of water quality deterioration in many European watersheds (EEA, 1999 and 2003). However, the reliance of the Directive on water pricing to curb demand may fail in Mediterranean countries such as Spain and Italy, which are characterised by high irrigation demand and quality problems compounded by water scarcity.

Water pricing will not solve scarcity or improve quality in the more degraded areas. Price increases would no doubt reduce consumption in large irrigation districts of inland Spain or southern Italy, which are based on collective systems and low-profit crops, and where degradation problems are moderate. However, water demand will not respond to higher prices in areas based on individual aquifer extractions with Mediterranean high-profit crops, where pressure on water resources is pervasive and degradation is severe (Massarutto, 2003).

Water pricing fails as a workable policy for curbing demand for several reasons. The first is the lack of control by the water administration on private wells and on volume pumped, which makes taxing water extraction from aquifers unfeasible. A second reason is the water price level needed to curb demand. In Spain, shadow prices of water in coastal areas under greenhouse production can be as high as 3 to 5 €/m^3, against 10-20 cents €/m^3 in inland Spain, while current water prices in coastal areas are between 6 and 21 cents €/m^3 compared to 2-5 cents €/m^3 in inland collective irrigation systems (Albiac et al., 2003 and 2006). With urban prices in Spain close to or below 1 €/m^3, and seawater desalination at around 50 cents €/m^3, it would seem unacceptable to set agricultural prices in water scarcity areas above urban and desalination prices. Though a policy designed to control aquifer overdraft would be quite difficult to implement, a water pricing policy that were to drive prices above the 3 to 5 €/m^3 shadow price for private extractions would be impossible to implement, both because of its technical and administrative unfeasibility and the daunting prospect of social opposition from farmers. These more degraded areas therefore require other Directive instruments, such as controlling aquifer overdraft by reducing concessions, and enforcing ambient quality standards and pollution emissions limits.

All this appears to suggest that the Water Framework Directive would be difficult to implement in Mediterranean countries. The situation can be summed up as follows: a water pricing policy could be *technically* (but not *politically*) feasible at least in collective irrigation systems managed by the basin water authorities, but measures to control aquifers are much more difficult to implement. Policy-makers in countries with significant irrigated agriculture such as Spain, Italy, Portugal and Greece do not have the necessary information on aquifer recharge and pumping by farmers, pollution emissions from activities using both surface or subsurface water, pollution transport and fate processes, ambient pollution, or damage costs to ecosystems.[4] Without such an information base, it is impossible to design reasonable control mechanisms to prevent water resources overdraft and to abate nonpoint pollution. As a consequence, water pricing measures suited to reduce industrial and urban demand, which are paramount in northern and central European countries, would also be implemented for irrigation in Mediterranean countries instead of the measures that are really needed.[5]

Water pricing is questioned as an instrument to curb irrigation demand by Cornish and Perry (2003) and Bosworth et al. (2002), who use impelling evidence from the literature and from case studies. In developing countries, water charges do not usually cover operation and maintenance costs, and capital costs are recovered only in private schemes based on aquifer pumping. In developed countries, charges for irrigation water also fall short of capital costs, because farmers would be unable to afford them.[6] Cornish and Perry (2003) indicate that introducing water rights and markets is more reasonable than trying to allocate demand through water pricing. They also recognise that introducing water markets is not an easy task, because the necessary institutional reforms require enormous and persistent efforts.[7]

4. Northern and central European countries confront the same information problems. In the UK, for example, the DEFRA is hampered in its attempt to estimate the cost efficiency of measures to abate nonpoint pollution, by a lack of information on pollution loads, transport and fate processes leading to ambient pollution, and economic valuation of damages to ecosystems.

5. In Spain, the Ministry of Environment is trying to introduce a water tax on irrigation, but at the same time there is no work being done to generate the information base needed for subsurface and surface water conservation, involving extractions, emission and ambient loads, and damages to ecosystems. The information problem is severe, and it could not be solved before the 2009 deadline of the WFD Program of Measures, to be implemented by 2012. In Italy, information on water resources is also far from satisfactory. The likely outcome could be a less than poor implementation of the Water Framework Directive, mirroring the outcome of the Nitrates Directive in most European countries.

6. As indicated by the fact that last century the federal US government spent 21.8 billion dollars on 133 water projects in western states, assigning 7.1 billion dollars to be paid by irrigation users, who have in fact repaid less than 1 billion dollars (Wahl, 1989; Wilson, 1997). Cost recovery in large collective systems in Spain, Italy, France, Greece and Portugal barely covers operation and maintenance costs, and capital costs are only recovered in private aquifer schemes (Massarutto, 2003).

7. An example of successful implementation of water markets is the Murray-Darling basin in Australia, accounting for 90 per cent of irrigation demand in the country. Before the Water Reform and the National Water Initiative policies of the mid nineties, there was practically no control on water extractions by water authorities in Australia. Irrigation demand climbed from 11.000 to 18.000 hm^3 between 1984 and 1994, and forced the water policy measures. The Australian case is quite interesting, because they have chosen to implement control through water rights and water markets, and also because they are now in the process of implementing tradable pollution permits to abate salinity.

Even under the currently binding Water Framework Directive, policy developments in Spain show that water policy initiatives continue to be based essentially on the traditional approach of expanding water supply. The recent Ebro water transfer project and the new AGUA project highlight the weaknesses of this traditional approach.

3. The rise and fall of the Ebro water transfer

The Ebro inter-basin project was intended to solve the acute water scarcity and resource degradation of south-eastern Spanish basins. The nominal costs of this project came close to 5 billion euro for transferring 800 hm^3 a distance of up to 750 km, from the Ebro basin to the Júcar, Segura and Sur basins of south-eastern Spain.[8] The Ebro transfer met with strong opposition from water resource experts, environmental and social organisations, and the Aragón and Cataluña regions located in the Ebro basin.[9] The main argument raised against the Ebro transfer was the need for new policy initiatives based on reasonable management measures.

Research was undertaken by our team to evaluate alternatives to the Ebro water transfer.[10] The evaluation is based on a model that incorporates a large quantity of technical and economic information specified at the county level. The model is used to simulate several water supply and demand policy scenarios. Details on the model specification, parameter estimation procedures, and simulation results are presented in Albiac et al. (2002a, 2002b, 2003 and 2006).

The study covers thirty-five counties of the south-eastern Iberian Peninsula, all of which receive water from the Ebro transfer in the Júcar, Segura and Sur basins (Figure 1). The objective function maximises quasi-rent from irrigated cultivation activities, and the constraints represent land, water and labour resource availability, considering irrigation and labour by month, and irrigation acreage by type of crop and irrigation technology (fruit-trees, vegetables and cereals, under surface or drip irrigation). The year of reference for all technical and economic data is 2001, and the baseline data on acreage, water use and revenue are presented in Table 2.

Water management scenarios

Several water management alternatives are examined to solve water scarcity in south-eastern basins. In the first scenario, groundwater overdraft is forbidden and there are no additions to the existing water supply. The second scenario involves increasing water prices to the level required to balance demand with available resources. This scenario follows the "close to full cost recovery" principle of the Water Framework Directive. The third alternative is to expand water supply with water transferred from the Ebro, linked to

8. An additional volume of 200 hm^3 was planned to be sent 180 km north to Barcelona.

9. Economic and environmental arguments on the transfer can be found at www.mma.es/agua/informes.htm, with the opinions provided by a large number of experts at the request of the Spanish Ministry of Environment. A comprehensive assessment of the degradation of the Ebro Delta and the fluvial and marine ecosystems, as a result of the transfer, can be found in Ibañez and Prat (2003) and Prat and Ibañez (2003).

10. The research effort was supported by both the former central government, which proposed the transfer (contract 21.803-480/8511), and the government of Aragón, which opposed it (contracts OTRI-UZ 2003/0206-0374).

water subsidies to maintain the present low irrigation water prices. The fourth alternative combines water trading between counties with an aquifer overdraft ban. Water trading may be conducted along the existing conveying facilities of main rivers and canals, allowing for an additional supply of desalinated water in coastal counties where shadow prices of water are very high.

The *aquifer overdraft ban* reduces the amount of water available for agriculture by more than 400 hm^3, the highest impact being felt in the counties where aquifers are located. In the Júcar and Segura basins, the reduction of available water involves low profit crops. In the Sur basin, however, the water reduction affects high-profit greenhouse crops, since there are few low profit crops to be given up (Table 2). Losses are quite substantial in Sur where farmers' revenue and quasi-rent fall by almost 50 per cent, while losses in Segura and Júcar are moderate.

Table 2. Acreage, water use and revenue in south-eastern basins (2001)

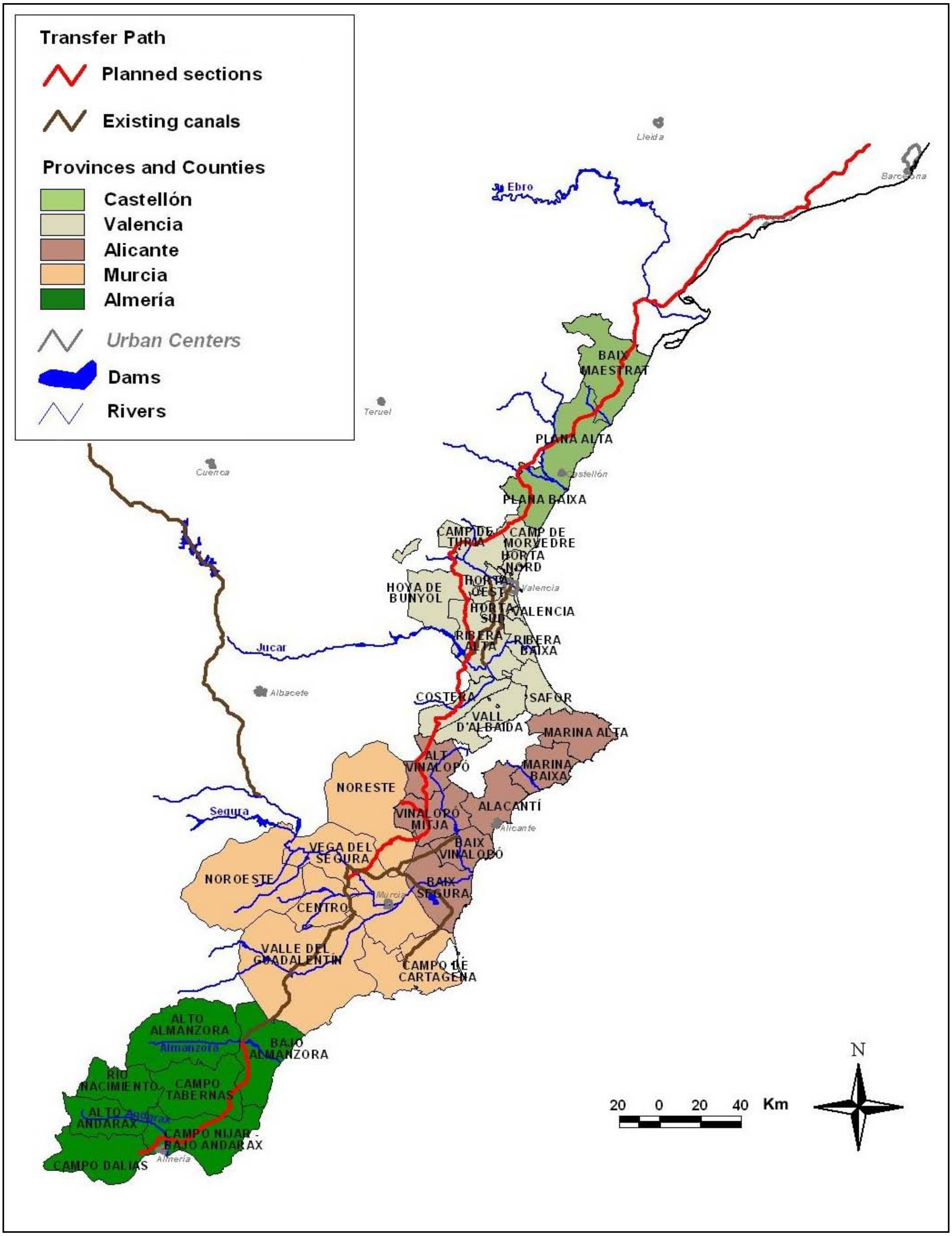
Basins	Total	Cereals, alfalfa and sunflower	Fruit trees	Open air vegetables	Greenhouse vegetables
Júcar					
Acreage (1,000 ha)	212.7	18.5	173.6	19.5	1.1
Irrigation water (hm^3)	1,450	242	1,081	121	6
Revenue (million €)	1,196	39	957	167	33
Segura					
Acreage (1,000 ha)	154.9	8.1	107.7	34.2	4.9
Irrigation water (hm^3)	863	62	654	125	22
Revenue (million €)	1,070	6	485	336	243
Sur					
Acreage (1,000 ha)	54.5	1.1	18.7	6.5	28.1
Irrigation water (hm^3)	232	10	96	24	102
Revenue (million €)	1,124	1	67	87	969

Source: Albiac et al. (2006).

The *increase in water prices* for irrigation is a demand management instrument advocated by the Water Framework Directive. A 0.12 €/m^3 increase in water prices reduces agricultural water demand by more than 500 hm^3, with a fall in farmers' revenue and quasi-rent due to the decline in the acreage of the less profitable cereals and woody crops. The impact on quasi-rent is much greater in the Júcar and Segura basins than in Sur. The loss of 287 million € in annual quasi-rent is a measure of the compensation that could be offered by the administration, or other water user groups, to encourage farmers' voluntary acceptance of water-price increases (Tables 3 and 4).

An increase of 0.18 €/m^3 in water prices reduces water demand by more than 600 hm^3, as a consequence of abandonment of cereal cultivation and reduction in cultivation of woody crops. The cost to farmers is given by the decline in quasi-rent, which amounts to a sizeable 24 per cent. The compensation that would be required to ensure that farmers voluntarily accept this price increase equals their 400 million € yearly loss of quasi-rent.

Figure 1. Map of the water transfer path and counties in the receiving basins



Source: Trasagua (2003) for the latest water transfer path.

Desalination of seawater is a measure that complements demand management measures, by expanding supply in order to balance it with demand. The cost of desalination is 0.52 €/m^3 (Uche, 2003), and the effective water demand at this price in the coastal counties from Safor to Campo Dalías is 387 hm^3. Desalination is less costly than transferring water from the Ebro in the counties south of Safor. The effective demand for desalination is 387 hm^3, and water demand reduction if water prices are increased by 0.12 €/m^3 is 408 hm^3. Together they amount to 795 hm^3, a quantity very close to the Ebro water transfer allocation of 820 hm^3 for all uses (Table 3).

Table 3. Water demand scenarios in South-eastern basins and Ebro project allocation (hm^3)

	Júcar basin	Segura basin	Sur basin	Total south-east
Current Water Demand	1,450	863	232	2,545
Water Demand Reduction for Agricultural Use…				
...through a groundwater overdraft ban	139	213	70	422
...through a 0.12 €/m^3 water price increase	313	142	54	509
...through a 0.18 €/m^3 water price increase	350	181	74	605
...through the combined alternative (overdraft ban, water markets, desalination)	139	213	10	362
Ebro Project Allocation				
All uses	300	420	100	820
agricultural and environmental use	141	362	58	561
urban and industrial use	159	58	42	259
Effective Demand of Water for Agricultural Use				
...at transferred water prices (0.20 to 1.05 €/m^3)	761	294	132	1,187

Source: Albiac et al. (2006).

Table 4. Quasi-rent losses under alternative scenarios and subsidies (million € per year)

	Júcar basin	Segura basin	Sur basin	Total south-east
Current Quasi-Rent	586	536	589	1,711
Quasi-Rent Losses to Farmers...				
... through a groundwater overdraft ban	46	101	261	408
... through a 0.12 €/m^3 water price increase	166	94	27	287
... through a 0.18 €/m^3 water price increase	232	136	37	405
... through the combined alternative (overdraft ban, water markets, desalination)	39	49	-5	83
Subsidies Needed by the Ebro Project…				
… to cover gap between costs of transferred water (0.20 to 1.05 €/m^3) and present low water prices	54	187	60	301

Source: Albiac et al. (2006).

Table 5. Water demand and prices in south-eastern basins, by county

County	Water use (hm³)	Prices of water (€/m³)			Value of water (€/m³)		
		Current	Costs of Ebro transfer	Sea-water de-salination	Average revenue	Average quasi-rent	Marginal value of water (shadow price)
Baix Maestrat	29	0.09	0.20		1.80	0.81	0.34
Plana Alta	45	0.09	0.23		1.44	0.67	0.42
Plana Baixa	120	0.09	0.29		1.23	0.58	0.56
Camp de Morvedre	48	0.09	0.30		0.95	0.46	0.34
Camp de Turia	127	0.09	0.31		0.98	0.45	0.40
Horta Nord	50	0.06	0.31		0.82	0.37	0.18
Valencia	25	0.06	0.32		0.58	0.26	0.13
Hoya de Bunyol	13	0.06	0.32		1.40	0.69	0.15
Horta Oest	39	0.06	0.32		0.80	0.38	0.16
Horta Sud	65	0.06	0.33		0.66	0.33	0.19
Ribera Alta	272	0.06	0.35		0.68	0.34	0.31
Ribera Baixa	227	0.06	0.35		0.32	0.18	0.13
Safor	99	0.06	0.46	0.52	0.83	0.40	0.37
Vall d'Albaida	12	0.06	0.46		1.42	0.58	0.14
Costera	30	0.06	0.46		1.01	0.49	0.25
Marina Alta	47	0.09	0.56	0.52	1.04	0.51	0.34
Marina Baixa	17	0.12	0.56	0.52	0.84	0.42	0.20
Alacantí	27	0.12	0.56	0.52	1.54	0.80	0.14
Alt Vinalopó	37	0.12	0.56		0.33	0.17	0.15
Vinalopó Mitja	65	0.15	0.56		1.10	0.67	0.20
Baix Vinalopó	55	0.12	0.57	0.52	0.63	0.30	0.13
Baix Segura	247	0.12	0.57	0.52	0.76	0.37	0.16
Noreste	57	0.12	0.72		0.93	0.53	0.21
Vega del Segura	273	0.12	0.57		0.75	0.42	0.24
Centro	20	0.06	0.57		0.86	0.44	0.18
Noroeste	40	0.06	0.57		0.89	0.43	0.11
Campo de Cartagena	64	0.12	0.61	0.52	3.12	1.40	0.19
Valle del Guadalentín	163	0.12	0.67	0.52	2.29	1.14	0.19
Bajo Almanzora	33	0.15	0.78	0.52	3.61	2.08	0.23
Alto Almanzora	34	0.06	0.92		0.65	0.29	0.08
Campo Tabernas	20	0.06	0.92		0.66	0.30	0.07
Río Nacimiento	11	0.06	1.05		0.72	0.29	0.13
Campo Níjar	47	0.18	1.05	0.52	6.22	3.52	0.29
Alto Andarax	16	0.06	1.05		1.13	0.54	0.15
Campo Dalías	72	0.21	1.05	0.52	9.14	4.59	3.43

Source: Albiac et al. (2006).

Transferring water from the Ebro was the alternative of the National Hydrological Plan of 2001, which was cancelled when the Spanish government changed hands. Diverted water would have high costs, with prices varying according to the distance from the Ebro river (Uche 2003), and ranging between 0.20 and 1.05 €/m³ (Table 5). These prices are well above the low 0.06-0.21 €/m³ price range currently paid by farmers, and at these prices, the project water will only pay for itself in counties with high-profit crops. The volume of imported water that counties can absorb at the prices of transferred water is 761 hm³ in Júcar, 294 hm³ in Segura and 132 hm³ in Sur (Table 3). These quantities contrast with the planned water transfer targets of 141 hm³ in Júcar, 362 hm³ in Segura and 58 hm³ in Sur. Thus, there is a significant problem of inconsistency in the Ebro project for the Segura basin, which can only absorb 294 hm³ at the water transfer price, which falls short of the 362 hm³ assigned in the Ebro project to put an end to groundwater overdraft. Farmers in these regions will therefore be unwilling to pay for the same quantity of imported project water as the amount currently being overdrawn, which means that overdraft will continue to occur.

The former central government intended to resolve the inconsistency in transfer allocation targets by subsidising the price of transferred water allocated to agriculture, and by charging higher prices to urban and industrial water users. The subsidy needed to maintain the whole 561 hm^3 of transferred water for agriculture, at the low water prices currently paid by farmers in the south-east, amounts to 301 million € per year (Table 4). This option could have turned out to be politically untenable, because urban users of imported water might have opposed excessive subsidies for agricultural users.

Finally, an *alternative combining both demand and supply measures* is considered. This alternative combines a groundwater overdraft ban, allowing water trading between counties, and the supply of desalinated seawater to selected coastal counties. Water trading between counties is conducted along the existing conveying facilities of main rivers and canals. It takes water to where it is most valued according to water shadow prices in each county, which suggest that water transfers can be expected along the Vinalopó, Segura (including Argos and Quipar tributaries), Guadalentín, Almanzora and Andarax rivers, and along the Canal Margen Izquierda and Canal Campo de Cartagena.

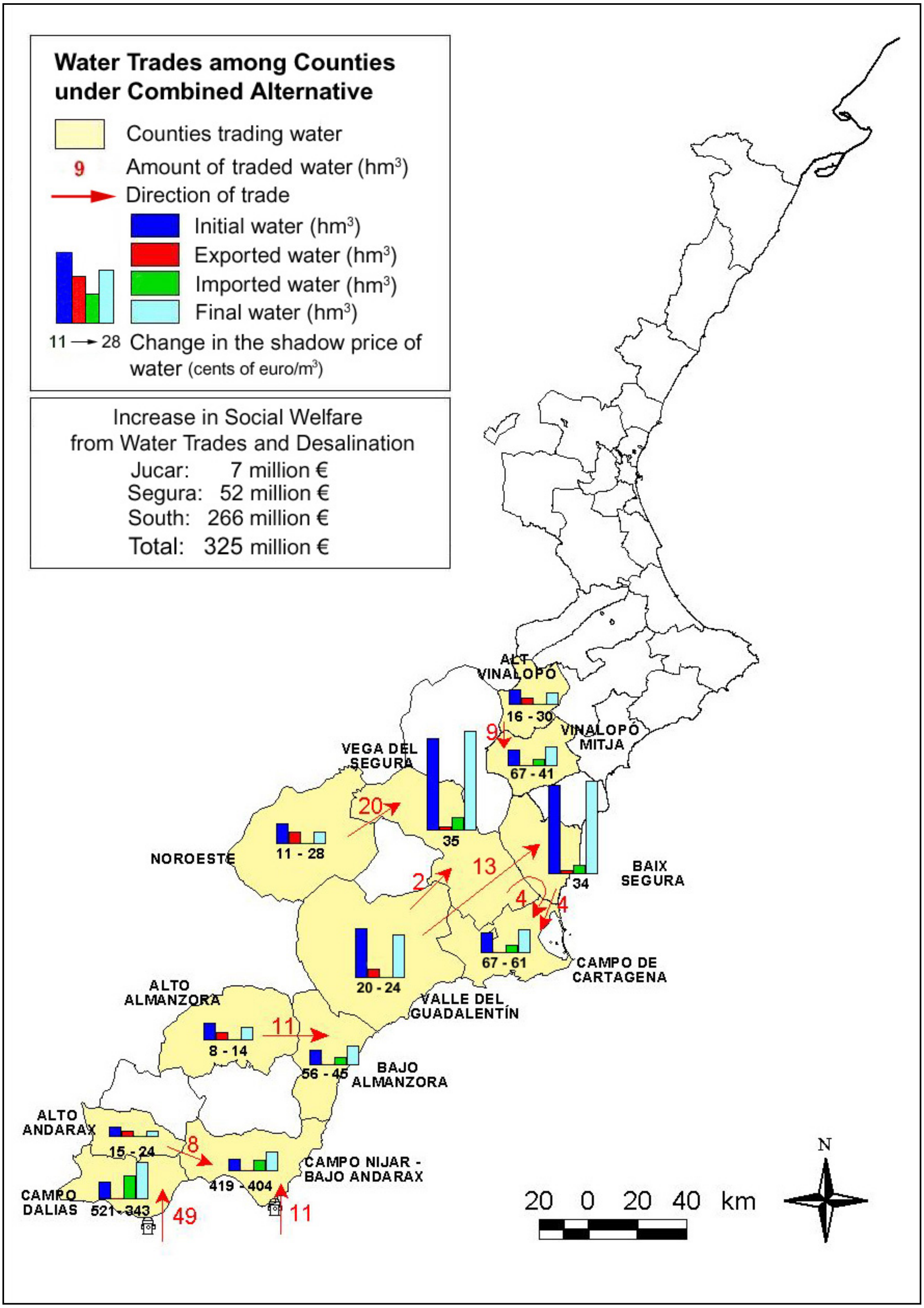
Results from the combined scenario show a significant reduction of 362 hm^3 in water use and moderate losses of 83 million € in quasi-rent (Tables 3 and 4). The gain in quasi-rent when shifting from the overdraft ban (-408 mill. €) to the combined alternative (-83 mill. €) is 325 million €. This gain in welfare from water trading and desalination is measured by the economic surplus, or area between the counties' excess supply and excess demand curves (Figure 2). These optimal trade and desalination flows are calculated by maximising welfare.

Ranking of water management alternatives

The results for each water management alternative are summarised in Tables 3 and 4. Table 3 presents water demand scenarios under each alternative, and also the planned allocation of water under the Ebro project. Table 4 shows farmers' quasi-rent losses under each alternative, and therefore the subsidies needed in order to maintain farmers' quasi-rent.

Farmers' quasi-rent losses are obtained by comparing the proposed alternative with the current situation. Under the present baseline scenario, quasi-rent is above 1,700 million €, which is reduced to around 1,400 million € by rising water prices by 0.12 €/m^3, and to 1,300 million € by rising water prices by 0.18 €/m^3. A groundwater overdraft ban reduces quasi-rent to 1,300 million €. Under the combined alternative, quasi-rent exceeds 1,600 million € which is higher than under any other demand measure. The Ebro transfer project maintains current quasi-rent, but requires 300 million € in subsidies to maintain the low water prices currently charged to farmers.

Figure 2. Water exports and imports by county under the combined alternative



A sharp reduction in water demand is achieved by water price increases in the range 0.12-0.18 €/m^3. The current 2,550 hm^3 of water demand for irrigation falls by 500-600 hm^3, but the costs to farmers in quasi-rent losses are also quite high in the range 300-400 million €. Prohibition of groundwater overdraft is the worst solution because the fall in water demand is only 400 hm^3, which is considerably less than the reduction achieved by increasing prices, whereas costs to farmers are higher than under water pricing. The combined alternative of banning overdraft, water markets and desalination, reduces demand by almost 400 hm^3 at a much lower cost of less than 100 million € in terms of farmers' quasi-rent. This is a very good alternative that improves upon any other demand management measure, and is superior in outcome to the Ebro transfer project.

Some important caveats should be emphasised concerning the difficulties of implementing demand management measures. Decades of water resources mismanagement in the south-eastern basins of the Iberian peninsula have created pervasive pressures on water resources and a severe degradation problem. An aquifer overdraft ban would be very difficult to achieve since there is at present no effective control on the number of wells or the volume of abstractions.

Water pricing measures are also difficult to implement because farmers will oppose price increases. An additional reason is that basin authorities may modify the water prices charged to collective irrigation systems using surface water, but they have no control over the costs faced by individual farmers pumping from aquifers. Even if water pricing could be implemented on individual abstractions, price increases will not reduce demand in irrigation areas based on greenhouse production of high-profit crops. The example is the shadow price of water in Campo Dalías, where prices would need to rise from the current 0.21 €/m^3 to over 3 €/m^3, in order to curb demand.

The creation of water markets is also a difficult task. Although there are informal water transactions, the possibility of formal water markets introduced by the 1999 water law reform has not spurred any significant trading in the last six years, due to farmers' mistrust of formal water markets.

Augmenting water supply by publicly financed desalination is much more straightforward. The problem arises with effective irrigation demand if water is not subsidised and farmers have to face the high desalination prices. The potential of desalination is given by the effective demand for desalinated seawater, which reaches a volume of almost 400 hm^3 in coastal counties from Safor to Campo Dalías, at the 0.52 €/m^3 cost of desalinated seawater. What prevents this effective demand from materialising is that farmers are extracting water from aquifers at pumping costs of 0.09-0.18 cents €/m^3. Since pumping costs are considerably below desalination, farmers will not buy desalinated water. Public investments in desalination plants would become reasonable only under strict enforcement by the water authority of an aquifer overdraft prohibition, that would force farmers to buy desalinated water.

This last point sums up the problem facing the new AGUA project, which is supposed to replace the Ebro transfer. The AGUA project involves investing 1,200 million € to achieve a desalination capacity of 600 hm^3, including around 300 hm^3 for irrigation between Campo Dalías and Marina Alta coastal counties. As indicated above, effective demand in these counties could hypothetically amount to 400 hm^3, but implementation of the AGUA project requires the strict enforcement of an aquifer overdraft prohibition, which is a daunting challenge for the water authority.

4. Nonpoint pollution control instruments in agriculture

Agricultural nonpoint pollution is a complex issue requiring information on pollution emissions at the source, transport and fate of pollutants, ambient pollution loads and their damage costs. Moreover, the physical, economic and social dimensions of the problem are such that they require multi-disciplinary and multi-scale approaches. In the case of Spain, nonpoint pollution is currently being addressed by both domestic and European agricultural and environmental policies. The main current policies are the domestic National Hydrological Plan and National Irrigation Plan, and the European Union's Common Agricultural Policy, Water Framework Directive and Nitrates Directive. The consistency of these policies is far from evident and difficult to assess. An example of their inconsistency is the nonpoint pollution impact of higher water prices advocated by the Water Directive, which is discussed below.

The results presented here are limited and do not cover the whole range of factors affecting agricultural nonpoint pollution. The CAP reform of 2003 and further trade liberalisation by the EU will change land use patterns in irrigated agriculture at the extensive and intensive margins. Both abandonment and more intensive use of irrigation are expected, depending basically on the availability of human and capital resources in agricultural regions. Thus, more intensive irrigated agriculture is likely in Mediterranean coastal areas of Spain, while inland collective irrigation areas are expected to stagnate. Another limitation relates to the range of pollution instruments considered. This is the case of wetland creation or recovery, which is an efficient instrument for large nitrogen abatement reductions (Ribaudo el al., 2001). Among the different nonpoint pollution issues, the information presented here tackles the question of the appropriate base instrument for nitrogen pollution abatement, which requires accurate information on the underlying biophysical processes. This is a key question for the design of policy measures, particularly for the design of the Program of Measures of the Water Directive. The acute scarcity of information regarding the biophysical processes involved in pollution and the associated damage costs in Mediterranean agriculture mean that measures cannot be reliably assessed.

Evaluation of the efficiency of alternative nitrogen abatement measures requires examination of the biophysical aspects of soil nitrogen dynamics, taking into account crop type and soil class (Martínez and Albiac, 2004 and 2006). The effects of selected abatement measures are examined using a dynamic model that includes six crops and one representative soil, in the Flumen-Monegros irrigation district located in the Ebro basin of Spain (Table 6). A ranking of nitrogen control instruments by their cost efficiency contributes to the information needed in the policy decision process. The results are consistent with previous literature, in suggesting a fertiliser standard as the more efficient second best measure to control nitrogen pollution (Table 7).

Table 6. Values of key variables under the baseline scenario, by crop

	Production (tons/ha)	Water use (m^3/ha)	Nitrogen use (kg/ha)	Nitrogen leaching (kg/ha)	Quasi-rent (€/ha)
Corn	14.1	6,220	325	140	1,180
Barley	6.0	2,200	180	29	375
Wheat	6.6	3,500	140	32	550
Sunflower	2.9	3,100	70	20	470
Alfalfa	17.3	7,800	70	15	740
Rice	5.6	12,000	170	57	797

Source: Martínez and Albiac (2004).

Table 7. Results of alternative policy measures in the district

		Welfare (10^6 €)	Quasi-rent (10^6 €)	Water (hm^3)	Nitrogen (tons)	Percolation (hm^3)	**Nitrogen leaching** (tons)
Base Scenario		22.3	24.1	190.7	4,525	66.1	1 459
Water price	0.06 €/m^3	21.2	18.8	86.4	4,367	43.3	1 381
	0.09 €/m^3	19.6	12.6	109.1	4,039	20.2	1 346
Nitrogen price	0.90 €/kg	22.4	22.6	200.6	4,265	45.3	1 222
	1.20 €/kg	22.7	21.5	186.6	3,976	56.2	990
Nitrogen standard		23.7	23.8	98.1	4,134	14.1	634
Emission tax		23.9	23.8	185.4	3,596	43.4	697

Source: Martínez and Albiac (2004).

An increase in water prices only slightly reduces nitrogen discharges at very high costs to farmers and society. A tax on nitrogen fertilisation results in more significant pollution reduction at much lower costs. A standard on nitrogen application curbs emissions by more than half, with a very moderate impact on quasi-rent and gains in welfare.

The fact that higher water prices are found to be very inefficient in abating emissions questions the reliance of the European Water Framework Directive on water pricing as a pollution control instrument to reach the "good status" target for all waters. The implication is that other instruments included in the Directive, such as ambient quality standards and emissions limits, need to be applied in order to curb pollution.

Turning to Spanish domestic policies, the main piece of legislation affecting nonpoint pollution is the National Irrigation Plan, which promotes irrigation modernisation through public subsidies. The National Irrigation Plan is a good instrument in irrigation areas with relatively high-profit crops such as fruits and vegetables, or when farmers change the crop mix to these more profitable crops. In large inland collective irrigation systems based on low profit crops, yields increase and pollution is substantially reduced with the renovation of secondary canals and plot irrigation systems. The problem is that the required investments are not financially sustainable, even when public subsidies are accounted for (Uku, 2003). The consequence is that nitrogen pollution in irrigated areas based on low profit crops, such as the Flumen-Monegros district examined here, could be controlled by the abatement measures being considered, but not by the National Irrigation Plan.

In addition, the results contribute further evidence to the discussion on the choice of instrument base for nitrogen control. Horan and Shortle (2001), using the empirical results by Helfand and House (1995) and Larson et al. (1996), claim that instruments based on irrigation water are more cost-efficient than those based on nitrogen fertilisation. The reason given is that irrigation water is more highly correlated with nitrate leaching, implying that the appropriate instrument base is not the nutrient responsible for pollution but rather the input most highly correlated with pollution. This interpretation appears inaccurate, however, because soil nitrogen dynamics are ignored. Neglect of the dynamic aspects of nonpoint pollution may have serious consequences for the design of policy measures.

An issue requiring close attention when choosing between pollution control instruments is that of implementation costs. Measures that appear to be suitable may nevertheless be associated with implementation problems relating to their political acceptability or transaction costs. Policy-makers should therefore evaluate the trade-off between cost-efficiency and ease of implementation.

5. Conclusions

High demand for irrigation water resources in Mediterranean countries results in significant water quality problems compounded by water scarcity. The heated policy debate that has been taking place in Spain over ways to solve water scarcity and resource degradation in south-eastern basins highlights the difficulty of achieving sustainable water resource management because of the conflicting interests of diverse stakeholders, including regions, economic sectors and political and environmental groups.

Two distinct general policy approaches for dealing with water quantity and quality problems in the Mediterranean, are the traditional approach of expanding water supply and the newly emerging water management initiatives. Examples of the traditional approach are inter-basin transfers and seawater desalination. The newly emerging initiatives rely on measures such as water pricing, revision of water rights, surface and subsurface water abstraction limits, development of regulated water markets, water resources reuse and regeneration, and subsidies to upgrade irrigation systems.

The effects of these measures on water quantity and quality are difficult to ascertain. For example, increasing water supply appears to have negative effects on nonpoint agricultural pollution, by encouraging the expansion of high-profit irrigation by farmers in Mediterranean coastal areas, who are able to pay for this additional water supply. Another example is upgrading irrigation systems that reduce drainage returns and pollution loads. However, farmers may use the water thus saved to introduce water demanding crops or expand irrigation acreage. This could reduce river streams in watersheds because of the reduction in irrigation return flows. In order to avoid this, public subsidies to upgrade irrigation systems need to be coupled with cutbacks in concession volumes to irrigation districts.

Several water quantity and quality issues in Mediterranean irrigated agriculture have been examined by presenting empirical evidence from Spain on alternative policy options and measures. The water policy measures examined cover two cases: the evaluation of alternatives to solve water scarcity in the basins of south-eastern Spain, and the ranking of agricultural pollution control instruments by their cost efficiency.

The first case involves the recent Ebro transfer project and the new AGUA project designed to replace the Ebro transfer. Both projects are highly illustrative examples that highlight the failure of approaches based on expanding water supply. Results from analysing the Ebro transfer show that an alternative combining an aquifer overdraft ban, water trading, and a small volume of desalination is by far a better alternative than building the Ebro transfer. This combined alternative reduces farmers' quasi-rent by a smaller amount than the subsidies required by the Ebro project, and this alternative can be coupled with compensations to prevent losses to farmers.

Augmenting water supply by publicly financed desalination is politically appealing for the new Spanish government after the cancellation of the Ebro transfer, and its AGUA project seems a straightforward measure. But the problem with the AGUA project is finding the effective irrigation demand if water is not subsidised, because farmers will have to face high desalination costs. Farmers are extracting water from aquifers at pumping costs considerably below those of desalination, and they will avoid buying desalinated water. Only strict enforcement of an aquifer overdraft ban by the water authority would force farmers to buy desalinated water. This is a daunting challenge for the water authority, and the risk of the AGUA project is that public funds are invested in desalination plants, but then the irrigation demand does not materialise.

The second case examined, compares several measures to abate agricultural nonpoint pollution. Selecting the right policy measures requires knowledge on the underlying biophysical processes involved in pollution, and the associated damage costs to fluvial ecosystems. Ranking nitrogen control instruments by their cost efficiency shows that a fertiliser standard is a good abatement measure, in accordance with previous literature. In contrast, raising water prices is very inefficient and this finding questions the reliance of the Water Framework Directive on water pricing as a pollution control instrument.[11]

One issue deserving special attention is the acute lack of knowledge that exists in Mediterranean (and non-Mediterranean) European countries regarding aquifer dynamics, pollution loads in surface and subsurface waters, soils, pollutants transport and fate processes, ambient pollution, and economic valuation of damage costs to aquatic ecosystems. This lack of knowledge precludes the design of reasonable policy measures to solve water quantity and quality problems in Mediterranean countries. The consequence is that the popular water pricing measures suited to reduce industrial and urban demand in northern and central European countries, would be implemented for irrigation in Mediterranean countries instead of the measures that are really needed.

The empirical findings presented here indicate that water pricing does not appear to be a good measure for solving water quantity and quality problems. Nevertheless, some minimum price of water is required to make farmers understand that water is not a free good. The Spanish example shows water pricing to be ineffective not only as a means to reduce water demand in coastal areas with high-profit crops and severe pollution problems, but also as a pollution abatement instrument in inland areas with low profit crops. The introduction of water rights and markets appears more reasonable than trying to allocate water through water pricing. However, the development of water markets is not easy, since institutional reforms require enormous and persistent efforts.

Further measures to curb demand and abate pollution need to be implemented, such as re-allocating water from off-stream use by agricultural, urban and industrial users to environmental uses both in aquifers and streams, and also in the coastal wetlands. Pollution control instruments such as ambient quality standards and pollution emission limits at the source are also needed. Water pricing in irrigation can not fulfil these water conservation targets, and therefore water pricing advocated by some government advisors and environmentalists starts to look like “armchair economics”.

11. Mema (2006) has studied several abatement measures to control salinity pollution from the 400 000 ha of irrigation in the mid Ebro Valley in Spain, which amounts to 1 million metric tons (not including gypsum). Because salinity pollution is driven by percolation, the efficiency of measures is linked to reductions in water use. Standards or taxes on water use are good measures to abate salinity, and water pricing is more cost efficient than in the case of nutrient pollution abatement.

Government water authorities, environmental NGOs and international organisations should look carefully at the results of sound empirical research that takes into account the underlying biophysical processes and the complex spatial, dynamic and social dimensions involved in the design of water policies. The findings of Cornish and Perry (2003) and Bosworth et al. (2002) on water pricing, together with the recent experience in Australia, provide further evidence. They suggest that, although water and pollution markets are difficult to implement, they are a much more efficient and feasible policy approach than water pricing to allocate water for agriculture and to curb pollution. Even the current command and control water policies that are in place in most countries seem to be more appropriate than water pricing for irrigation management.

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Chapter 6.

Assessing the Feasibility of Water Quality Trading to Address Agricultural Sources of Pollution in Canada

Bernard Cantin,[1] Sarah Kalff[2] and Ian Campbell[2]

This paper reports on a study exploring the feasibility of water quality trading to address pollution from agricultural non-point sources in Canada and the potential role of Agriculture and Agri-Food Canada in such initiatives. The paper provides brief background material on water quality trading and presents the main findings organised around biogeochemical considerations, regulatory/policy considerations, and key design aspects of trading programmes, including roles of stakeholders and government. Preliminary findings indicate that there are no strong legal or regulatory barriers at the provincial or federal level to the development of trading systems in Canada.

Introduction

Like many OECD countries, Canada is assessing market-based instruments to manage natural resources efficiently. This paper explores the use of water quality trading to address water pollution from agricultural non-point sources (NPS) in a Canadian context.[3]

Water quality trading (WQT) can achieve water quality objectives at reduced costs compared to command and control approaches. Despite its theoretical potential, there are few examples of water quality trading involving non-point sources of pollution worldwide. Existing programmes have not been very successful, judging by the limited number of trades that have occurred (Breetz et al. 2004, King 2005). Authors have advanced a number of explanations, including the low supply and demand for pollution reduction credits, the fact that non-point sources are not regulated (King and Kuch 2003, King 2005); high transaction costs (Woodward et al. 2002); and lack of trust among stakeholders (Breetz et al. 2005).

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3. The study was undertaken in collaboration with Policy Research Initiative, a federal government think tank, Environment Canada and the Canadian Water Network. This paper presents preliminary results from an AAFC perspective. Additional analysis will be available in 2006 on Policy Research Initiative's website (www.policyresearch.gc.ca).

The purposes of this study were to explore the feasibility and necessary conditions for water quality trading to address water pollution from agriculture in Canada, including the potential role of Agriculture and Agri-Food Canada (AAFC).

AAFC has no regulatory powers vis-à-vis water in Canada. AAFC promotes the needs of producers for water and the reduction of risks posed by agriculture to water. Through the Agricultural Policy Framework – a federal-provincial agreement signed in 2002 – AAFC is working with the provinces to achieve a wide range of goals, including several related to water.

Methodology

This project examined the following components of trading systems: 1) the biogeochemical considerations necessary for trading to be environmentally effective; 2) the regulatory/policy frameworks dischargers face for the development of water quality trading programmes in Canada; and finally; 3) the main design aspects of trading programmes, including roles of stakeholders and government.

The research included a literature review, commissioned research on the Canadian regulatory framework (Sauvé et al. 2005, Tri-Star Environmental Consulting 2005), and two workshops involving presentations, brainstorming and discussions among experts from Canada (De Barros 2005, Campbell 2005, Fortin 2005, Nolet et al. 2005, O'Grady 2005, Weersink 2005) the United States (Breetz 2005, Kieser 2005, Schary 2005), the Netherlands (Hubeek 2005) and Australia (Collins 2005). The workshops included academics, consultants, and public servants with expertise in the biological sciences, economics, and political studies.

Background: What is water quality trading?

Water quality trading[4] is a market-based system using economic incentives to improve water quality. There are basically two types of trading systems, tradable permits and environmental offsets. The first establishes individual rights – through permits – to input levels, output levels or performance standards. In the case of water pollution, individuals are allowed to exceed their authorisation to discharge if they purchase an appropriate number of permits from another individual. Offsets are actions to meet a standard at a site away from where the pollution occurs (MacDonald et al. 2004). Water quality trading systems involving agricultural sources of pollution are in general of the offset type.

Water quality trading has been implemented between point sources such as wastewater treatment plants (WWTP) discharging nutrients, or between mining enterprises discharging salt. These trading schemes usually address a specific water quality parameter such as phosphorus, nitrates, salinity or biological oxygen demand. It can also control effluents indirectly through an output, as, for example, the Netherlands did with manure. The schemes can involve several thousand dischargers, or only two. It

4. Water quality trading can also be referred to as effluent trading, the trading of pollution credits or of pollution rights.

can cover part of a watershed, or a whole nation (Netherlands). Trading can take place through bilateral trades, brokered contracts between agents that do not contact each other, or other means.

How does WQT that includes agricultural sources work?

The classic example is a watershed where municipal wastewater treatment plants (WWTP) and farming operations are emitting regulated contaminants, such as phosphorus. Under a traditional regulatory approach, municipalities have to reduce nutrient discharge to meet a regulatory requirement in milligrams of phosphorus per litre (mg/L). After a certain point, expensive investments are required to control additional phosphorus discharges (due to city growth, for example). There is a large economic advantage in looking for lower cost options to reduce loadings, such as other sources discharging phosphorus within the same watershed. If farming operations in the watershed can reduce phosphorus discharges at lower cost, it is cheaper for the municipality to pay those dischargers to reduce pollution than to reduce emissions itself.

For such trades to be effective from the regulator's (and society's) perspective, the environmental effect of reducing farm discharges has to be equivalent to or better than what the municipality could have achieved through investing in a new (or renovated) WWTP. In addition, there are usually provisions to ensure no local degradation of the environment (hot spots).

Trading can occur if there is a large enough difference in the cost of reducing discharges between different sources. This is a necessary but not a sufficient condition. Overall, the cost-effectiveness of a trading system will depend on the size of transaction costs, implementation costs and administrative costs.

To summarise, trading requires:

- an environmental objective for a specified water body;
- a clear definition of the commodity, i.e. the form of pollution that is to be traded as well as measures of pollution reduction;
- appropriate incentives for agents to trade, which generally consist of differences in abatement costs and a binding environmental regulation that limits emissions for some or all parties;
- appropriate trading mechanisms and rules to ensure trades can actually reduce costs and lead to the desired environmental objectives; and
- measurement of the results of the actions taken, with some form of monitoring.

Biogeochemical considerations to water quality trading

A WQT programme requires understanding of the sources, behaviour and abatement of the pollutant and of the watershed it affects.[5]

5. This section is a summary of Morin (2005).

Pollutant sources and potential trading partners

WQT is suitable for pollutants for which there is a potential to create supply and demand for pollution reduction credits. There are several potential trading partners for agricultural phosphorus, nitrogen, and sediment, and fewer for bacteria and pesticides (Table 1).

Phosphorus, nitrogen, and sediment can enter a waterway from several potential trading partners with which agricultural producers could exchange credits, particularly municipal wastewater and industrial facilities that are regulated. The ubiquity of nutrient and sediment sources, both agricultural and non-agricultural, contributes to their suitability as candidates for WQT.

Table 1. Main agricultural pollutants, potential trading partners, and major science considerations

	Potential Trading Partners						Science Considerations	
Agricultural Pollutants	Municipal Waste-water	Industry	Septic systems	Forestry	Mining	Urban storm run-off	Behaviour known	Quantifi-able reductions from NPSs
Phosphorus	–	–	–			–	–	–
Nitrogen	–	–	–			–	–	–
Sediment	–	–		–	–	–	–	–
Bacteria*			–			–	–	
Pesticides*				–		–	–	
Trace Elements					–			
Salts		–			–	–	–	–

* Depends on the type of bacteria or pesticide.

– Not typically a problem in Canada.

Bacteria from septic systems and urban storm water are often unmeasured and unpredictable. Pesticide use varies and their fate is not well understood. Salinity trading occurs in other countries, such as Australia, but concerns regarding salts and trace elements are not widespread in Canada. For these reasons, it is more difficult to implement water quality trading for these pollutants than for nutrients and sediment.[6]

6. Note that a trading system in pesticide use rights could be envisaged on a national basis. Such a system would probably be similar to the manure quota trading system implemented in the Netherlands.

Pollutant fate and transport – determination of the critical load

Pollutant fate and transport of a contaminant in the natural environment are important for determining the critical load, which is necessary for the design of a water quality trading programme.

The behaviours of phosphorus, nitrogen, and sediment are well understood, which allows the prediction of nutrient behaviour if the watershed itself is well understood. The behaviour of sediment depends almost entirely on water flow and particle size that will determine if and when the particles settle or become suspended.

Beneficial management practices

The ability to confidently quantify the effect beneficial management practices (BMP) or other pollution abatement technologies is crucial to creating a supply of pollution reduction credits. Quantification is significant, as the likely range of pollution reduction achieved through the implementation of a BMP on a particular farm will be converted to credits for trading purposes.

It is not practical to directly measure changes in the amount of pollutant that is emitted from most farms. Rather, the reduction due to a BMP is derived from scientific research, and may be a function of characteristics such as the type of tillage, crop, soil and slope where the BMP is being used.

A wide range of agricultural BMPs for managing sediment and nutrient loss have accepted methods for estimating pollution reduction. Other agricultural pollutants can be reduced using BMPs designed to manage nutrients and/or sediment. As an example, methods for reducing surface run-off and soil erosion may reduce the amount of any pollutant that is water soluble or sediment-bound, including certain pesticides and pathogens. Such positive side effects could only generate additional pollution reduction credits if those reductions were quantifiable.

Trading ratios, hot spots and scientific uncertainties

"Trading ratios" may be used to deal with scientific uncertainty regarding the behaviour of a pollutant and to avoid the possibility of creating a localised environmental degradation or hot spot. Formulas for pollution reductions can express a probable range of pollution reduction as opposed to a specific value. An appropriate trading ratio accounts for the range in values. For example, a purchaser who needs to reduce emissions by 100 kg of phosphorus may have to buy pollution reduction credits worth two to four times this amount to take into account uncertainties. The higher the trading ratio, the greater the expense for the purchaser of the pollution reduction credits, underscoring the importance of science in reducing trading ratios.

Trading ratios can be used to ensure the equivalence of trades by accounting for the influence of the landowner's locations (e.g. upstream, downstream, on a tributary), as is proposed for the Lower Boise River Trading system in the United States (Schary and Fischer-Vanden 2005). Another possibility is to define trading zones, restricting the direction of trades into predefined zones of a river system or its tributaries (Tietenberg 2001).

Trading rations can also be used to allow inter-pollutant trading by establishing environmental equivalency between different pollutants on water quality or ecological integrity.

Regulatory conditions for WQT in Canada

In both permit trading and offset regimes, a regulatory driver is necessary to compel the participants (or a subset of them) to be involved in trading. The regulatory driver for permit trading is a performance-based standard derived from the environmental goal established for the watershed. This watershed-based objective needs to be translated to the level of the appropriate point sources. For offsets, there can be different types of regulatory drivers, but at a minimum one is needed for the firms wishing to offset their increased discharges by reducing those of others.

In Canada, water quality is a shared jurisdiction where provinces are the principal regulator. There are some important federal responsibilities with respect to fisheries management and navigation. Provinces have adopted different approaches with respect to water quality regulation.

Given this context, we examined if provincial and federal water quality regulations would hinder or promote water quality trading. It was found that five provinces had authorising provisions supporting the development of tradable permit systems. The other five provinces have the means, through existing advisory boards, to consider the development of tradable systems and make recommendations to the responsible minister to that effect. Only one province has adopted regulations concerning the development of tradable systems. All provinces have provisions concerning the measure and declaration of discharges in water bodies, and can establish ambient water quality standards.

The majority of provinces are developing watershed-based management systems, and all have the means to initiate a trading programme through a watershed management process, a nutrient management plan or some other planning process.

The federal government would be in a position to implement a water quality trading programme for coastal and estuarine waters and for those waters deemed by the federal government and a province to be of national significance.

Important limits affecting a few provinces include: the lack of flexibility to relax standards to allow offsets or permits; the lack of clarity on assimilative capacity; continued reliance on command-and-control regulation; and by the slow movement towards ambient-based approaches.

Policy coherence

Existing AAFC policy and programmes were briefly examined to evaluate the compatibility of existing approaches with water quality trading. Under the Agricultural Policy Framework, AAFC has established a number of programmes related to on-farm action, knowledge and information development, and performance measurement. Although not designed with water quality trading in mind, these programmes could support the establishment of water quality trading programmes. For example, the research programmes could assist efforts to establish water quality trading programmes by characterising watersheds, understanding the fate and transport of pollutants, assisting in the development of equivalency ratios, and undertaking economic valuation of water resources.

Results from one study indicate some possible compatibility issues, such as overlap and potential double support between subsidy programmes and a water quality programme (Sauvé et al. 2005). A possible option is to build the trading programme within existing cost share programmes (not in addition to it), where there is only one payment to farmers for each BMP implemented.

Key design elements of trading systems

The trading system has to be designed to minimise transaction, implementation, and administrative costs. This involves ensuring that:

- trades are easily recognised by regulators as a means for buyers to meet their environmental responsibilities;
- potential buyers will easily connect with sellers and contracting can proceed;
- these requirements are achieved at least cost; and
- there is limited uncertainty with programme elements, including liability.

The Lower Boise trading pilot in the Northwest of the United States and the South Nation pilot in Ontario, Canada, highlight some general lessons.

Recognising trades as valid means to meet environmental obligations

One of the main goals of most of these initiatives is to provide flexibility to the regulated in achieving discharge levels and providing certainty on pollution reduction credits.

The trade approval process in the case of the Lower Boise pilot is made relatively simple by establishing in advance a list of acceptable BMPs, and includes a process to revise or add to the list. Once a BMP makes it through the list, there is no need to establish a trade-by-trade approval process, thus reducing uncertainty for all actors. Added flexibility is provided by ensuring new BMPs can make it through the list.

It is crucial to establish where liability lies in the case when the expected environmental benefits are not realised or when BMPs are not implemented as planned. In the Lower Boise, the regulated point source must ensure the credit is valid. In the South Nation, the South Nation Conservation Authority (SNACK),[7] the institution managing the programme and acting as broker, incurs the risks since it buys and sells the credits and must guarantee the credit's validity to the provincial department of the environment.

In both these examples, the regulator's role is limited to evaluating whether the regulated are in compliance. This involves verifying that dischargers are at or below their limit or, if not, they have enough credits.

7. Ontario Conservation Authorities are watershed-based organisations created by the province of Ontario in the 1940s. They are autonomous organisations developed to promote the protection and wise use of water resources. While a number of other provinces have recently begun the development of watershed-based organisations, the Ontario experience is unique by its longevity.

Connecting potential buyers and sellers

Information ensures potential buyers and sellers can make transactions by knowing what is being offered and at what cost. In both cases reviewed, coordinating committees of government departments and stakeholders ensure that these signals are passed, and that roles and responsibilities are well defined and understood.

In the South Nation system, the SNACK acts as a broker in a trading programme that has been built around an existing cost-share programme (O'Grady and Wilson n.d.). In fact, the trading element of the programme is not highlighted to farmers seeking funding to implement a selection of BMPs according to their needs. For the SNACK, municipalities who buy pollution reduction credits instead of investing in new treatment technologies provide a supplementary source of funding for the cost-share programme.

Reducing costs

Apart from the financial savings from lower abatement costs, the administration costs are expected to be lower than under a traditional regulatory approach. Lessons from non-water trading programmes suggest that the transitional or start-up costs can be high (OECD 2004). However, it is likely that as the role of government decreases over time, public costs would become lower than under the traditional regulatory approach.

The Lower Boise system plans to limit administrative costs through a self-reporting verification system. The South Nation system used an existing cost-share programme as a delivery mechanism and an existing peer-monitoring system to lower the administrative burden.

Providing increased certainty through policy guidance

Policy guidance can clarify to the regulated entities that trading will meet environmental obligations. Several states in the United States as well as the Environmental Protection Agency at the federal level have adopted such a policy (US EPA 2003). In Ontario, the province adopted the Total Phosphorus Management policy to allow trading (Birt et al 2004). In the United States, guidelines were also drafted to provide stakeholders with basic tools to help assess the appropriateness of a WQT system for their watershed.

Stakeholder involvement and the role of farmers

An important lesson of water quality trading systems is that all important stakeholders must be included in the development phase. This includes both those directly involved in trading and those with doubts about the environmental effectiveness of trading.

The problem of including the farming community in trading has been summarised as follows by Kramer (2003:6-7): "Agricultural nonpoint sources were very reluctant to get involved with trading discussions and agreements because they perceived that they had little to gain and much to lose. This group of sources has enjoyed near immunity from regulations regarding runoff to surface waters … Also, having a long history of being subject to market and production factors that are beyond their control … farmers have been understandably reluctant to voluntarily expose themselves to yet another –

involvement with a discharge permit. Most agricultural non point sources wanted to see good evidence that trading would benefit their bottom line before they would risk a trading agreement. Also, these sources were very reluctant to draw any public attention to themselves because of a perceived potential for negative publicity".

Our study found significant support for this statement. In addition, the rural/urban divide can limit the development of such programmes. Farmers were sometimes reluctant to indirectly fund urban growth while, on the other hand, some municipalities hesitated to be perceived as paying for pollution reductions outside of their communities (Kramer, 2003).

Addressing the question of farmers' participation and buy-in appears to be one of the most difficult issues in implementing water quality trading, requiring a substantial length of set-up time to develop common language, concepts and trust through a transparent process with legitimate representatives of farmers.

Breetz et al (2005) stressed that strategies to address the initial reluctance of farmers to participate in water quality trading systems have to be developed if such programmes are to be effective. Social factors are an essential element in the development of policy tools, even those that are market-based.

Implications for agri-environmental policy in Canada

Based on this preliminary research on the feasibility of using WQT to address water pollution from agricultural sources in Canada, the following initial conclusions can be put forward:

- There appear to be no strong legal or regulatory barriers to the development of trading systems in Canada. Some provinces have already the basic tools available to go forward.

- While trading rations can overcome significant site-specific uncertainties, the existence of well developed data sets for a particular watershed is required. This will undoubtedly reduce the number of potential watersheds in Canada where water quality trading can be easily implemented.

- Provinces are increasingly establishing organisations responsible for the management of watersheds, thereby establishing at least one obvious design and implementation mechanism. Nonetheless, it appears that policy direction and design advice could be useful to promote the use of WQT and, at the same time, help avoid the tendency of stakeholders to engage in strategic behaviour geared towards anticipating the regulator's next move(s). While policy guidance can be useful, each water quality initiative must have the flexibility to reflect conditions particular to each watershed.

- Further analysis of the links between cost-sharing for BMPs and water quality trading in Canada is required. Attached to this issue is the question of to what extent Canadian society will push for cleaner farming operations and the extent to which the urban population is willing to pay to support this objective.

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Chapter 7.

Nutrient Trading – A Water Quality Solution?

Suzie Greenhalgh and Mindy Selman[1]

The over-enrichment of rivers and estuaries by excessive levels of nutrients, such as nitrogen and phosphorus, is a persistent and growing water quality problem around the world. Even though there have been significant improvements in water quality, most of these improvements have resulted from regulating point sources – industrial and municipal wastewater treatment facilities; today the predominant source of nutrients is non-point sources, especially agricultural and urban runoff.

Innovative solutions are needed to provide incentives for non-point sources, whose nutrient discharges are difficult to regulate, to reduce their nutrient contributions. One such solution is nutrient trading. Trading involves setting a goal for the total amount of nutrients entering streams and rivers within a watershed and allowing sources, both point and non-point, to trade nutrient reduction credits in order to meet the local and regional water quality goals.

Nutrient trading is being explored and implemented as a viable mechanism to reduce nutrient pollution in a number of areas in the U.S. and internationally. To facilitate the establishment of these markets, we have developed an on-line marketplace, NutrientNet, for point and non-point sources to estimate their nutrient loads and achievable reductions, and provide a marketplace for trades to occur and a registry that allows trades to be tracked.

Setting the scene

Water quality is rapidly becoming one of the most pressing environmental concerns facing many parts of the world today. In the U.S. alone, 39 per cent of assessed rivers and streams, 45 per cent of assessed lakes, reservoirs and ponds, and 51 per cent of assessed estuaries were threatened or impaired for their designated uses in 2000 (USEPA, 2002).

Nutrient over-enrichment — one of the leading causes of water quality impairments in the U.S. — has led to the eutrophication of many of the nation's rivers and streams, and to the formation of hypoxic zones in the Gulf of Mexico and Chesapeake Bay. A majority of these nutrients come from non-point sources, principally agricultural sources. Approximately 82 per cent of the nitrogen and 84 per cent of the phosphorus in

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U.S. lakes, rivers and estuaries come from non-point sources (Carpenter et al., 1998). The nutrient pollution from non-point sources, such as agricultural or urban runoff, is typically diffuse in nature. Its precise origin cannot be identified, and because of this, non-point sources are frequently not regulated. The other source of nutrients is point sources, such as wastewater treatment facilities. Point source pollutants can be pinpointed to a specific source of origin, e.g., discharge from a pipe into a water body, and therefore are typically regulated.

This paper takes a closer look at policy instruments to improve water quality, comparing the traditional command-and-control approaches to the more innovative performance-based instruments. Given the apparent cost-effectiveness of performance-based instruments, it goes on to outline some of the challenges and issues with establishing successful nutrient trading programmes, one type of performance-based instrument. Finally, the paper describes an on-line marketplace, NutrientNet, which we have developed to facilitate the implementation of these programmes. The paper also recognises some of the significant synergies between the efforts undertaken to reduce nutrient losses and a number of other environmental problems, such as climate change and soil erosion, highlighting the need to start addressing environmental problems more holistically.

Policy approaches for improving water quality

There are a number of policy instruments that can be used to address environmental problems — traditional policy instruments such as regulations, taxes and subsides, and the more innovative performance-based instruments. All of these instruments can be applied directly or indirectly to water quality concerns.

Traditional policy instruments

Regulations

One popular policy instrument for addressing water quality problems (as well as many other environmental problems) is the use of regulations, also referred to as a command-and-control approach. Regulations are typically technology-based or performance-based standards aimed at point sources such as wastewater treatment and industrial facilities. Non-point source pollution—whose source is more difficult to identify than point-source discharges—cannot be as easily controlled through regulation.

Technology-based standards specify the type of equipment or processes that each facility needs to adopt to meet a water quality target, while a performance standard specifies a target and gives facilities greater flexibility in how they meet that target. Performance standards are often in the form of limits placed on the amount of a pollutant discharged into a waterway (e.g., USEPA NPDES programme[2]).

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2. The National Pollution Discharge Elimination System (NPDES) programme of the U.S. Environmental Protection Agency (USEPA) sets specific pollutant discharge limits for all point sources discharging into U.S. waters. The programme was developed in 1974 and has been expanded to include dischargers such as large concentrated animal feeding operations (CAFOs), municipal wastewater treatment facilities, and commercial and industrial facilities.

Even though regulatory approaches frequently achieve initial success in improving water quality, it does place heavy financial burdens on facilities to continually upgrade their equipment, and regulators to keep abreast of new technological advances, and provides little opportunity or incentive for facilities to be innovative.

In the U.S., between 1974 and 1994, local governments and the federal construction grants programme spent approximately $213 billion for the construction or upgrades of municipal wastewater treatment facilities to control point-source pollution. During the next 20 years, it was anticipated that an additional $330 billion would likely be required to construct new plants and replace aging facilities to meet the water quality levels and treatment demands of a growing U.S. population using this policy approach (Association of Metropolitan Sewage Agencies and the Water Environment Federation, 1999). Regulatory approaches become expensive once the initial ‘low-hanging fruit’ (or least expensive treatment options) have been exploited.

Taxes and subsidies

Another set of policy instruments used to address pollution includes taxes and subsidies. Taxes place a penalty on polluters, providing the ‘stick’ in the carrot-and-stick analogy, while subsidies are the ‘carrot’, providing incentives (usually financial) for polluters to reduce their discharges. These instruments are often used to provide incentives for non-point sources of pollution. In the U.S., taxes are rarely used in the agricultural sector to change behaviour, while in some OECD countries taxes have been more widely used, especially where pollution sources can be tied to inputs, such as fertilisers and pesticides, in the production process. Fertiliser taxes have been introduced in Finland, Norway, and Sweden with this tax revenue frequently earmarked for various environmental uses. Sweden, for instance, uses its fertiliser and pesticide tax to finance environmental research and improvements (O’Riordan, 1997).

Subsidies are common instruments used to provide incentives to implement agricultural best management practices (BMPs) aimed at providing environmental benefits. In the U.S., some examples include the Conservation Reserve Program—which pays farmers to take agricultural land out of production—and subsidies to increase the use of conservation tillage practices on cropland; both are aimed at reducing soil loss from agricultural land. Subsidies target a prescribed set of practices, rather than allowing farmers to choose the most effective way for them to address the specific problem at hand.

Performance-based policy instruments

Performance-based policy instruments target an environmental outcome rather than the sources of pollution and are frequently market-based, i.e., kilograms of nutrient pollution reduced is the commodity of interest, not the implementation of a BMP that results in a reduction in nutrient losses. Two performance-based mechanisms that can be applied to improve water quality are nutrient trading and reverse auctions.

Nutrient trading

Nutrient trading is an example of a performance-based instrument that is gaining popularity as a mechanism to cost-effectively meet water quality goals. Nutrient trading is premised on the fact that compliance costs differ between individual industrial and wastewater treatment facilities depending upon their size, scale, age, and overall efficiency. This means that the cost of meeting a water quality standard (or regulation) may be less for one facility than for another. Trading between point sources provides an opportunity for those facilities whose costs are lower to make additional reductions beyond their obligation, and sell these additional reductions to facilities whose costs are higher.

Similarly, trading can also occur between point sources and non-point sources. Point sources with high compliance costs can purchase nutrient reduction credits from non-point sources, whose nutrient reduction costs are much lower. In most instances point source facilities are controlled by regulatory discharge permits (e.g., USEPA NPDES programme), while non-point sources are generally not controlled by regulatory limits. Trading gives both point sources and non-point sources the flexibility of achieving an environmental target using the most cost-effective option available to them. There are a number of nutrient trading programmes currently in operation in North America. The Long Island Sound trading programme administered by the Connecticut Department of Environmental Protection, for example, addresses the problem of low oxygen levels in Long Island Sound by trading nitrogen credits between point sources, which are the main cause of excessive nitrogen levels in the Sound. The South Nation watershed in Ontario, Canada, also has a trading programme in operation that targets phosphorus discharged from both point and non-point sources.

Reverse auctions

Reverse auctions are another example of performance-based policy instruments. They are competitive bidding systems where sellers compete to supply buyers with a specified good or service, enabling buyers to locate the most competitive sellers. The key difference between reverse auctions and conventional auctions is that in reverse auctions sellers bid to sell goods and services at lower prices than their competitors, whereas in a conventional auction buyers compete with each other to purchase goods and services from sellers. Thus, in a reverse auction sellers bid prices down while in a conventional auction buyers bid prices up. Reverse auctions are used in a variety of markets and are particularly suited to markets with multiple sellers and only a single buyer. The reverse auction concept has been used in the Conestoga watershed in Pennsylvania, U.S. to purchase phosphorus reductions from farmers. In this instance, an environmental organisation with funding from the U.S. Department of Agriculture (USDA) acted as the buyer for these reductions.

How do performance-based mechanisms compare?

The World Resources Institute has undertaken two analyses to compare a variety of policy instruments for improving water quality—one addresses the hypoxic zone in the Gulf of Mexico and the other looking at phosphorus reductions in three watersheds in the Upper Midwest of the U.S.

Analysis of nitrogen water quality impairments

A 2003 study by WRI (Greenhalgh and Sauer, 2003) assessed a variety of agricultural policy options to mitigate the hypoxic — oxygen-depleted — zone in the Gulf of Mexico and found that nutrient trading was the most cost-effective solution. The hypoxic zone results from excessive amounts of nitrogen entering the Gulf of Mexico from the Mississippi River (Goolsby et al., 1999). By the summer of 2002 the hypoxic zone, which has been consistently monitored since 1985, reached a height of 22,000 km^2 or 8,500 square miles in size (Rabalais et al., 1999; Dunne, 2002; LUMCON, 2002). A majority of the nitrogen in the Mississippi River Basin comes from agricultural non-point sources,[3] prompting us to explore several agricultural policy options as a mitigation strategy.

This study compared policy options that directly affected nitrogen losses in the Mississippi River Basin, as well as a number of options that focused on other environmental problems such as soil loss, phosphorus runoff and climate change. By comparing a wide range of policies and their impacts, we were able to look more broadly at the environmental benefits of the various options.

The policy options assessed included:

- taxing nitrogen fertiliser applications;
- subsidising a change to conservation tillage practices;
- extending Conservation Reserve Program (CRP) acreage;
- trading greenhouse gas (GHG) reductions at both $5/t carbon and $14/t carbon;
- trading nitrogen reductions to meet either a 3 or 8 mg/l/day N discharge limit[4] for wastewater treatment facilities;
- trading phosphorus reductions to meet either 1 or <1 mg/l/day P discharge limit[5] for wastewater treatment facilities, and
- trading nitrogen reductions (to meet 3mg/l/day N discharge limit for wastewater treatment facilities) with an additional payment for the associated GHG reductions achieved with any implemented BMP.

These policies were evaluated using an agro-environmental model of U.S. agriculture, the U.S. Regional Agricultural Sector Model (USMP). This model was developed and is maintained by the U.S. Department of Agriculture/Economic Research Service (USDA/ERS). WRI has worked with USDA/ERS to improve the spatial delineation of USMP, increase the diversity of cropping rotations included in the model, and simulate the environmental impacts of various cropping production practices and the Conservation Reserve Program.

3. Fifty per cent of nitrogen reaching the Gulf of Mexico comes from fertiliser and soil organic nitrogen; 24% from atmospheric deposition, groundwater discharge and soil erosion; 15% from animal wastes; and 11% from municipal and industrial facilities (Goolsby et al., 1999).

4. These discharge limits are based on the limits the Chesapeake Bay are discussing to deal with their nitrogen pollution problem.

5. The 1 mg/l/day discharge limit represents a transition point in technology and capital expenditure for phosphorus removal.

Only a short synopsis of the results of this study is outlined in this paper. A more detailed explanation of the findings and recommendations of the study and a description of the model used can be found in Greenhalgh and Sauer (2003).

Taking a broader look at the environmental impacts of the various policy options, nutrient trading performed better than the other options assessed (Annex Figures A.1a through A.1f). Nutrient trading provided the largest decreases in nitrogen reaching the Gulf of Mexico and the greatest improvements in farm income. In addition, nutrient trading demonstrated improvements in local water quality as well as reductions in GHG emissions and soil losses. Other policy options performed well for some environmental parameters but not for others. For instance, conservation tillage subsidies gave the largest reductions in soil loss and reasonable reductions in nitrogen delivered to the Gulf of Mexico, but resulted in decreases in farm income. This decrease comes from an increase in farm acreage which led to increased crop production, and a subsequent decline in crop prices.

The other important aspect of assessing different policy options is how cost-effective they are at meeting the goal of interest, in this case reducing the amount of nitrogen reaching the Gulf of Mexico from the Mississippi River Basin. In other words, which policy gives the 'biggest bang for your buck'. The lowest-cost mechanisms in our study were the performance-based options, such as nutrient and GHG trading (Annex Figure A.2). However, the most cost-effective solutions were the options based on nutrient trading, which achieved large reductions in the amount of nitrogen delivered to the Gulf of Mexico at low prices.

Our conclusion at the end of this study was that nutrient trading was indeed a worthwhile policy solution for helping meet water quality targets, and for providing other environmental benefits.

Analysis of phosphorus water quality impairments

Similarly, in an analysis of policy options to improve phosphorus-impaired waters in Wisconsin, Michigan and Minnesota, performance-based mechanisms were the most cost-effective (Faeth, 2000).

This study tested four policy options:

- a point source performance standard where point sources had to meet more stringent regulatory requirements;
- conventional agricultural subsidies for mulch tillage, no-till and nutrient management;
- a point source performance requirement coupled with trading which allowed point sources to trade with other point and non-point sources to meet the new regulatory requirement; and
- a trading programme coupled with performance-based conservation subsidies where point sources and non-point sources shared the nutrient reduction obligations, and non-point sources were allowed to meet their obligation using their least-cost option rather than the adoption of a particular BMP.

In all three watersheds, tightening the point source regulatory requirements was the most expensive option, and a trading programme coupled with performance-based conservation subsidies was the least-cost option (Table 1).

Table 1. Cost of phosphorus control under different policy options

U.S. $/pound P removed / Case Study Watersheds	Point source performance standard	Conventional agricultural subsidies	Point source performance standard with trading	Trading programme with performance-based conservation subsidies	Least-cost Solution
Minnesota River, Minnesota	19.57	16.29	6.84	4.45	4.36
Saginaw Bay, Michigan	23.89	5.76	4.04	2.90	1.75
Rock River, Wisconsin	10.38	9.53	5.95	3.82	3.22

Source: Faeth, 2000.

Giving point sources the flexibility to meet their performance requirements by either upgrading their facilities or by trading with other point sources or non-point sources considerably lowers the cost of meeting regulatory requirements. Annex Figure A.3 illustrates the costs associated with achieving different levels of phosphorus reductions for the Michigan case study.

Challenges to implementing nutrient trading

Based on the comparative assessment of various policy options for improving water quality, nutrient trading emerged as the most cost-effective solution. However, while the concept of water quality trading has found favour with many in the environmental, agricultural and policymaking communities, the application of water quality trading has achieved only limited success in the few watersheds where it has been applied. Water quality trading faces some unique challenges given that it includes both regulated and unregulated sources, must address nutrient fate and transport, and must be able to quantify reductions from non-point sources that are not directly measurable. Outlined below are some of the challenges and issues that face organisations or government agencies in implementing nutrient trading programmes.

Establishing the rules

There are a number of issues that need to be considered when establishing the rules of a trading programme. Some of these issues are briefly discussed below.

Market design

The design of the market for trading programmes is important for establishing who can trade, how the trading mechanism would work, and the rules that would sanction a trade. Trading programmes can be designed in a number of different ways including:

- traditional market structures where individual regulated sources (e.g., point sources) can purchase credits from non-regulated (e.g., many non-point sources) or other regulated sources to meet their compliance obligations. The Dillon Reservoir and Cherry Creek trading programmes in Colorado, U.S. are examples of these markets;

- a market where an aggregate cap is established for regulated sources and trading with sources outside of the cap is allowed for compliance purposes. The Tar-Pamlico and Long Island Sound trading programmes in the U.S. are characterised as being this type of market structure;

- using a bank to aggregate credits from non-regulated sources. Reductions from non-regulated sources are often small compared to the reductions needed by the regulated sources. A bank can serve three roles—to bundle credits into larger trading lots, potentially reduce the liability for these small sources (see liability discussion below), and to help stimulate markets that are not yet fully functioning. This structure is being discussed widely in the U.S. as a way to more successfully incorporate non-point agricultural sources into these trading markets. The South Nation trading programme in Ontario, Canada, is structured similar to a bank model. Regulated dischargers purchase phosphorus reduction credits from South Nation Conservation (SNC), a community-based watershed organisation. In turn, the SNC uses this money to pay farmers to reduce phosphorus through implementation of BMPs.

Ensuring fungibility

Because non-point source nutrient reductions are difficult to measure and quantify, there is real concern in any nutrient trading programme about the fungibility of credits: how does a trading programme quantify non-point source reductions and ensure that a credit from a non-point source is equal to that of a point source?

Most of these fungibility concerns are addressed through the use of discount factors. For instance,

1. The uncertainties involved with non-point source reductions can be addressed through the establishment of sound and consistent estimation tools. Using the same method to calculate all non-point source reductions will ensure that they are all comparable (see NutrientNet discussion below). Uncertainties within the estimation method itself can then be addressed through the application of trading ratios. Trading ratios are discount factors related to the uncertainty associated with the actual measurement of reductions, e.g., the uncertainty associated with the effectiveness of an agricultural BMP in achieving nutrient reductions. Applying a 2:1 trading ratio means that a point source whose nutrient discharge is known with certainty has to purchase two units of nutrient reduction from a non-point source whose actual achieved reduction is more uncertain for every unit of reduction they require.

2. Another factor with credit fungibility is the variability in nutrient fate and transport depending on the location of the source within the basin. Nutrient trading programmes can be designed to address the variability in nutrient delivery by using location-specific attenuation factors or spatial delivery ratios. For non-point sources this means estimating the delivery of nutrients from the source to the stream as well as the attenuation of the nutrient from where it enters the stream to the point of interest within the watershed. Spatial delivery ratios are frequently determined from existing bio-

physical models. For instance, the Revised Soil Loss Equation (RUSLE) (Renard et al., 1991) estimates nutrient loss to the edge of a farm field for sediment-bound phosphorus. Other models, e.g., SEDMOD (Fraser et al., 1996), can then be used to assess how much of the sediment-bound phosphorus reaches the nearest water body. Similarly, nitrogen models such as the Chesapeake Bay Model (Cerco et al., 2002) provide estimates for both the attenuation of nitrogen within river segments and from various river segments to different points of interest within a watershed.

3. Some nutrient trading programmes allow trading between pollutants. An equivalence ratio, which refers to how much of one pollutant should be reduced compared to another, can be used in these situations. For example, in Minnesota a trading permit requires eight units of phosphorus to be reduced for every unit of BOD discharged.

Establishing baselines

Baselines are important for ensuring the integrity of nutrient trading programmes. Similar to the concept of 'additionality' in the GHG trading world, baselines are established to prohibit unregulated sources from selling reductions from management practices that are already required or have already been implemented. To avoid the difficulties associated with operationalising the concept of additionality in the GHG world, baselines can be set by the trading programme. In many instances for water quality trading, non-point source baselines are a minimum set of baseline practices, e.g., a nutrient management plan, which must be in place before the non-point source can generate reductions to sell. Establishing a required set of baseline practices for non-point sources ensures that "bad actors" are not rewarded for their ability to generate low-cost reductions by implementing basic good steward practices that should have been implemented in the first place, and that most other non-point sources may have already implemented. Baselines for point sources are typically straightforward, as many have permitted nutrient discharge limits that can be used to form the baseline.

Who holds compliance liability

Liability issues — who holds liability and how liability is determined — often pose significant challenges to the implementation of nutrient trading programmes. Liability for credit malfeasance could potentially rest with either the buyer or the seller of credits. What frequently occurs with buyer liability is that it fails to foster market development. If a buyer cannot be assured that the purchased credits are viable reductions, it is difficult for the buyer to effectively manage the cost of their exposure, making them more unlikely to participate in a trading programme. Therefore, seller liability is often an important element to achieving well-functioning environmental commodity markets. Small sources wishing to sell reductions, however, may find this a deterrent to participating in nutrient trading markets.

One approach to addressing liability issues is using a bank to aggregate non-point source credits. Credit buyers purchase credits from the bank, which in turn guarantees the creditworthiness of the credit. The bank is responsible for ensuring that non-point sources comply with their contracts and providing the agreed-upon reductions. The bank may also keep a 'credit reserve' to mitigate any risk of non-point sources failing to implement a BMP or when a BMP fails to function properly, therefore assuming liability for the creditworthiness of the reductions.

Stakeholder engagement

One of the often overlooked components of nutrient trading programmes is stakeholder engagement during the establishment phase. As there is still some skepticism surrounding nutrient trading programmes, this raises the importance of including stakeholders in the formation and rule discussions of these programmes. Early stakeholder engagement will help create trust between potential buyers and sellers, and the administrators of the trading programme; and help promote an active trading programme.

Providing the infrastructure

A successful water quality trading programme needs to provide the appropriate infrastructure. Some basic infrastructure elements for water quality trading programmes include:

1. An administrative agency (or agencies) to manage the programme, certify reductions and trades, and monitor compliance. A water quality trading programme which involves unregulated agricultural non-point sources may face several logistical and administrative hurdles that can be mitigated by working closely with the agricultural community and agricultural agencies to ensure programme support.
2. A trading registry to track the nutrient reductions, credits and trades, and facilitate compliance monitoring. A registry is simply a database that stores information on the entities which generate and use credits.
3. A forum where buyers and sellers can meet. Many point and non-point source trades have involved a single point source locating non-point sources such as farmers one by one and negotiating individual contracts with each farmer to provide a specified number of nutrient reductions. For example, the Southern Minnesota Beet Sugar Cooperative contracted with over 100 farmers to purchase phosphorus reductions to allow them to expand their capacity and still meet their phosphorus discharge limit. This process can be significantly streamlined through the establishment of a central marketplace that allows buyers to easily identify sellers and vice-versa.

Evaluating success

Monitoring is an important component of any nutrient trading programme and is used to assess the success of the programme. Regulated sources typically have some form of monitoring already in place as monitoring is required to prove regulatory compliance. However, unregulated sources, commonly non-point sources, do not have any monitoring requirements. As a proxy for the direct monitoring of non-point source nutrient losses, the BMPs implemented to reduce nutrient losses can be monitored to ensure they are installed and properly functioning. Similarly, water quality at the watershed level should also be monitored to determine whether the watershed's water quality goal is being attained. As there is typically a lag time between programme implementation and any improvement in water quality, this should be a long-term commitment. In many trading programmes, watershed monitoring is often only cursory and ensuring BMP implementation is frequently left to the buyers of the associated nutrient reductions.

NutrientNet: providing a trading infrastructure and facilitating implementation

Recognising that nutrient trading had the potential to play a significant role in meeting U.S. water quality goals, WRI and partners from the Michigan Department of Environmental Quality started to think about how to efficiently implement these markets. Furthermore, we recognised that nutrient trading faced a number of obstacles that made its widespread implementation complicated, including high transaction costs, initially thin markets, and no actual marketplace for trades to occur.

Our solution was to develop an on-line marketplace, NutrientNet (www.nutrientnet.org), to overcome these obstacles. There are two prototype versions of NutrientNet currently available—one for phosphorus in the Kalamazoo watershed in Michigan and the other for nitrogen in the Potomac watershed in the Chesapeake Bay. In addition there are three other sites currently under development:

- A water quality trading market (involving both point and non-point sources) for nitrogen in the Susquehanna watershed, Pennsylvania

- A reserve auction pilot programme in the Conestoga watershed in Pennsylvania

- An updated Kalamazoo watershed market with improved BMP estimation algorithms for nutrient losses.

The NutrientNet site comprises two key components:

1. Standardised tools for estimating point and non-point source nutrient contributions to surface waters, exploring nutrient reduction options, and estimating the cost of achieving reductions.

NutrientNet currently incorporates on-line calculation tools that enable farmers and wastewater treatment facility managers to estimate nutrient loads from their operations and the cost of reducing nutrient loads through various mitigation options. The rules for converting reductions into tradable credits are also incorporated into the calculation tools. This includes the discount factors used to ensure fungibility, such as trading ratios, spatial delivery ratios, and equivalence ratios.

The NutrientNet estimation tool utilises a Geographical Information System (GIS) interface that allows the users to identify the geographical location of their operation. The GIS interface retrieves the relevant information for each type of discharge from a geographic database which is used to estimate baseline phosphorus and nitrogen loads. The types of GIS information used include aerial photographs delineating roads, streams and land uses, distance to streams, topography and soil type.

In addition to the geographical data, NutrientNet requires specific information relevant to each operation to estimate baseline nutrient loads. For point sources users provide information about their specific facility, such as current flow rates, nutrient concentration and regulatory nutrient discharge limits. Using the total annual permitted load as a baseline, NutrientNet calculates the total credits needed for compliance (for those who exceed their regulatory limit), or the total credits generated (for those who are under their regulatory limit). Generated credits are calculated by subtracting the actual load from the baseline limit and applying the appropriate attenuation factor or spatial delivery ratio.

For non-point sources, users provide information on their location, field area and physical characteristics (e.g., slope), phosphorus content in the soil (when calculating phosphorus reductions), current and previous crops, current tillage practices, and currently installed BMPs. With this information plus the underlying GIS information, NutrientNet estimates phosphorus or nitrogen loads based on a series of algorithms.[6] NutrientNet provides users with nutrient loads from their particular farm, the effectiveness of various mitigation options available to reduce nutrient losses, the cost of implementing these options on their farm, and number of credits available to sell (based on the rules of the nutrient trading programme).

2. A marketplace where potential trading partners can meet and enact trades.

NutrientNet's market section provides a virtual marketplace for users to contact buyers or sellers and post their offers. Information about who is selling or buying credits is listed, as well as a means for potential traders to contact each other.

NutrientNet can also be modified to accommodate a reverse auction. For example, in the Conestoga watershed of Pennsylvania, NutrientNet was used to conduct a reverse auction for farmers in Lancaster County. Farmers used NutrientNet's on-line estimation tool to estimate their phosphorus reductions associated with implementing certain BMPs. The farmer then bid a price he was willing to accept to implement a specific BMP. The market section of NutrientNet was modified to rank farmer's bids from most cost-effective to the least cost-effective in terms of dollars per unit of phosphorus reduced (instead of ranking bids based on total BMP implementation cost). A purchasing committee reviewed bids on-line, issuing contracts to the lowest bidders until the earmarked money was exhausted.

One unique advantage to an on-line estimation tool and marketplace is the ability for such a system to interface with a trading registry. A tool like NutrientNet can allow for the automated update of a registry with records of credit generation and credit purchases. Once a user has estimated their nutrient reductions, they may submit a notice to the registry electronically where it would be reviewed and approved by the administering agency. Likewise, once a trade is completed using NutrientNet, the parties to the trade could electronically submit a notice of the trade to the registry which in turn could be reviewed and approved by the administering agency.

Our final word

With the traditional policy instruments struggling to achieve environmental targets or becoming increasingly costly solutions to our water quality problems, performance-based instruments such as nutrient trading are becoming increasingly attractive instruments to use. Many studies have pointed to the use of performance-based mechanisms as cost-effective solutions to water quality problems (Faeth, 2000; Faeth and Greenhalgh, 2000;

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6. Phosphorus losses are calculated using the Revised Universal Soil Loss Equation (RUSLE) to estimate losses to the edge of the field (Renard et al., 1991) and the Spatially Explicit Delivery Model (SEDMOD) to estimate how much is delivered to the stream (Fraser et al., 1996). Nitrogen losses (for Chesapeake Bay) are calculated using the Nutrient Management Yardstick to estimate losses to the edge of the field (IATP, 1999) and the USEPA Chesapeake Bay Program's Chesapeake Bay Model to estimate how much is delivered to the mouth of Chesapeake Bay (Cerco et al., 2002).

Greenhalgh and Sauer 2003). As an adjunct to regulatory policy, nutrient trading provides the flexibility for regulated sources to achieve their regulatory requirements more cost-effectively, while achieving overall water quality improvements.

In the U.S., these instruments are gaining popularity. Currently there are approximately 40 trading initiatives involving 17 states and one regional effort, and six statewide trading policies and programmes in existence. There are a further 27 proposed trading initiatives under development (Breetz et al., 2004). The release of the USEPA Water Quality Trading Policy in January 2003 has also provided certainty to many regions and states that would like to use trading to achieve water quality targets that these reductions will be recognised, spurring even greater interest in nutrient markets.

The often overlooked beauty of these instruments is the synergistic benefits for other environmental problems. For instance, a nutrient trading policy for nitrogen aimed at reducing the size of the hypoxic zone in the Gulf of Mexico also leads to improvements in local water quality, reductions in GHG emissions and reductions in soil loss. Policies that address a diversity of environmental issues are becoming increasingly attractive in many areas that are facing a myriad of environmental concerns. This awareness, tied with the evolution of on-line nutrient trading markets like NutrientNet will help pave the way for a new era that focuses on performance-based instruments to meet environmental goals.

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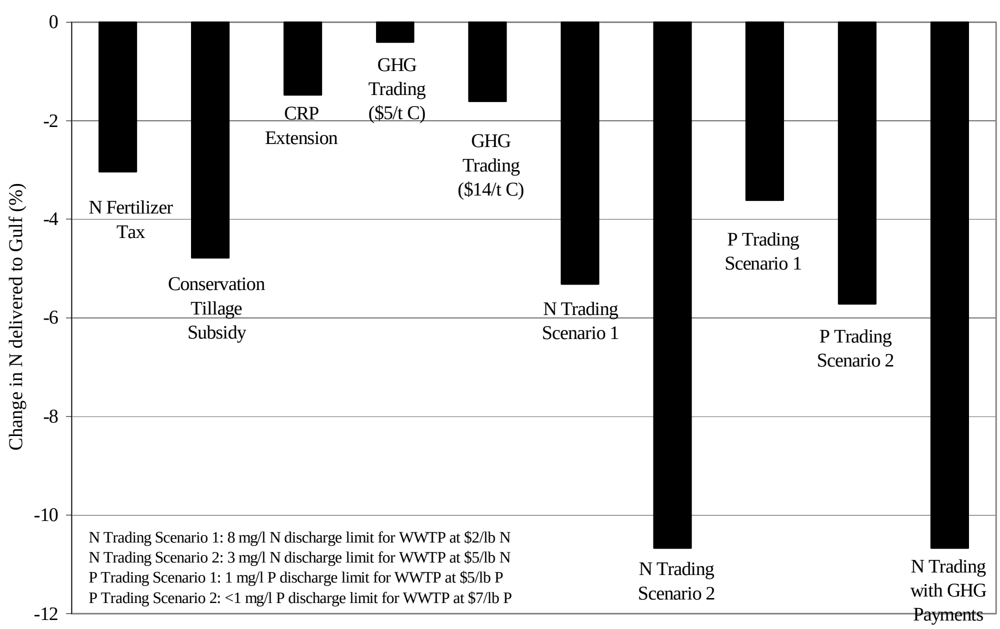
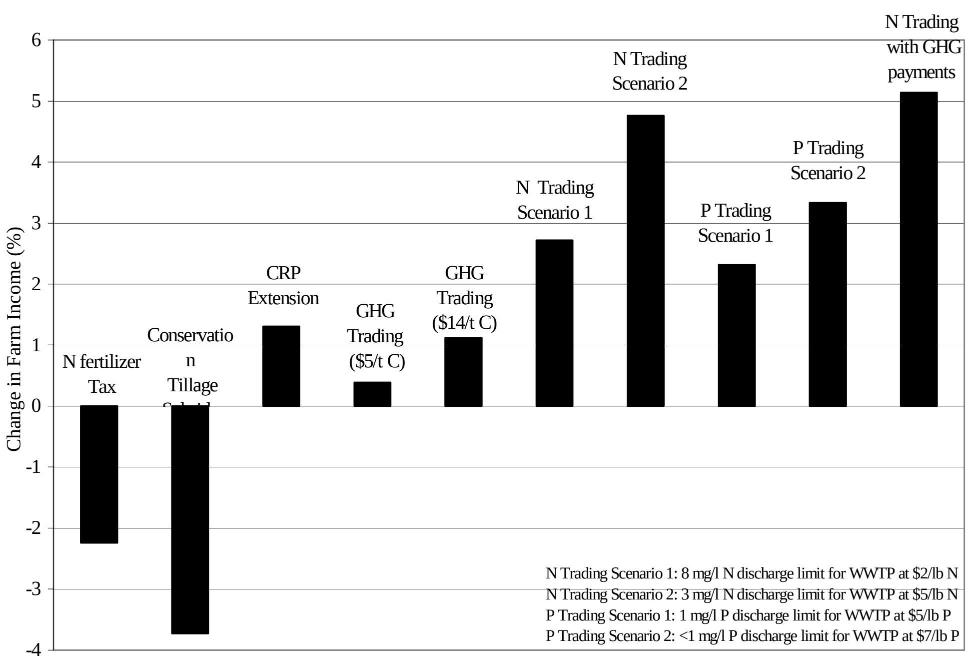
Annex

Figure A. 1. Impact of various policy options on the environment and farm income

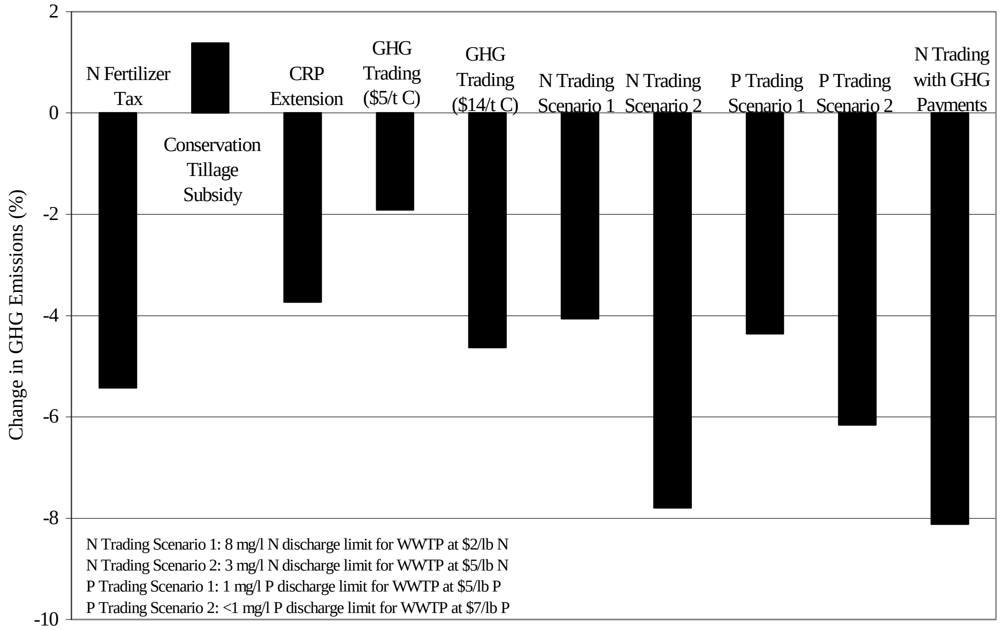
a) Nitrogen delivered to the Gulf of Mexico



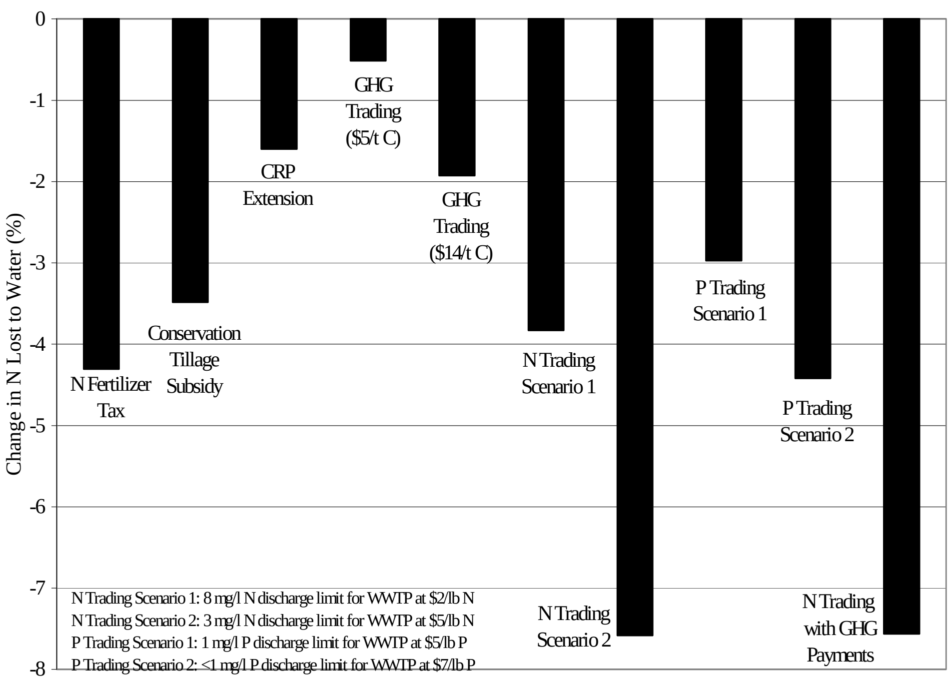
b) Farm Income



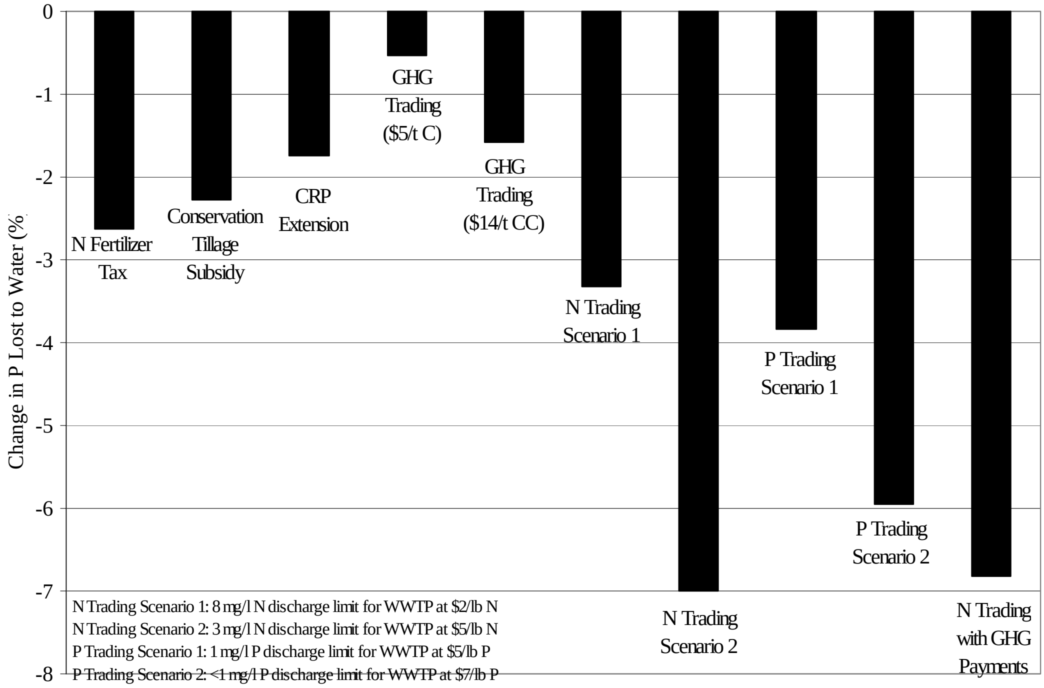
c) Greenhouse Gas Emissions



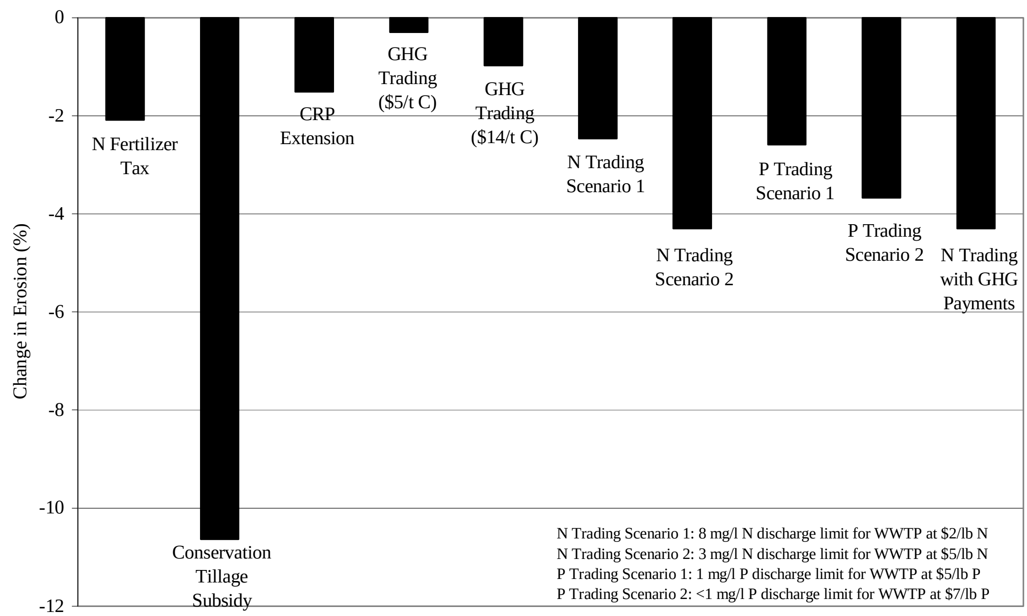
d) Nitrogen lost to waterways



e) Phosphorus lost to waterways

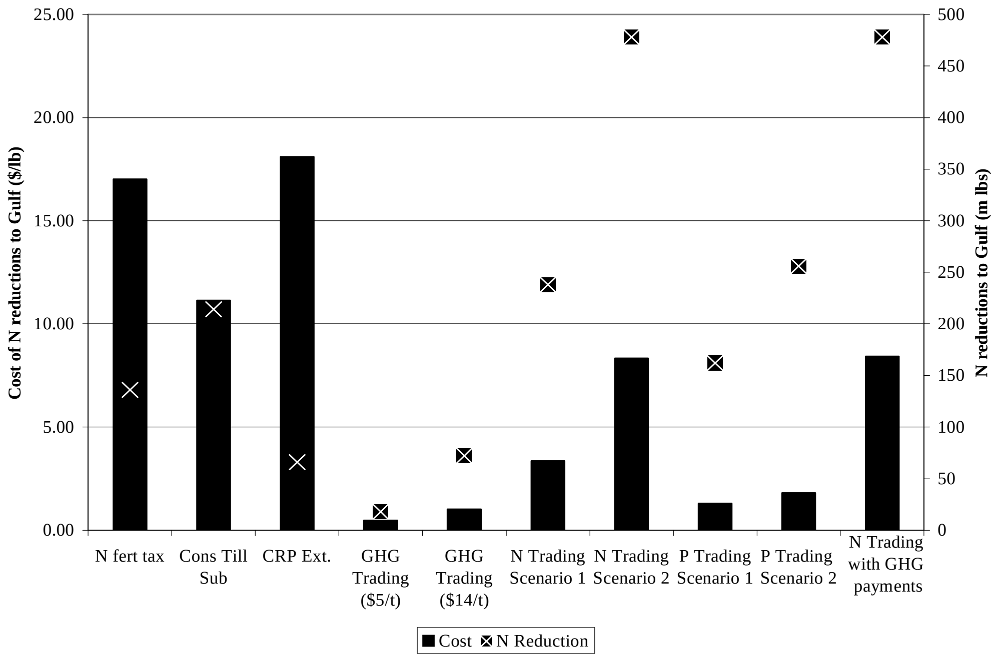


f) Soil erosion



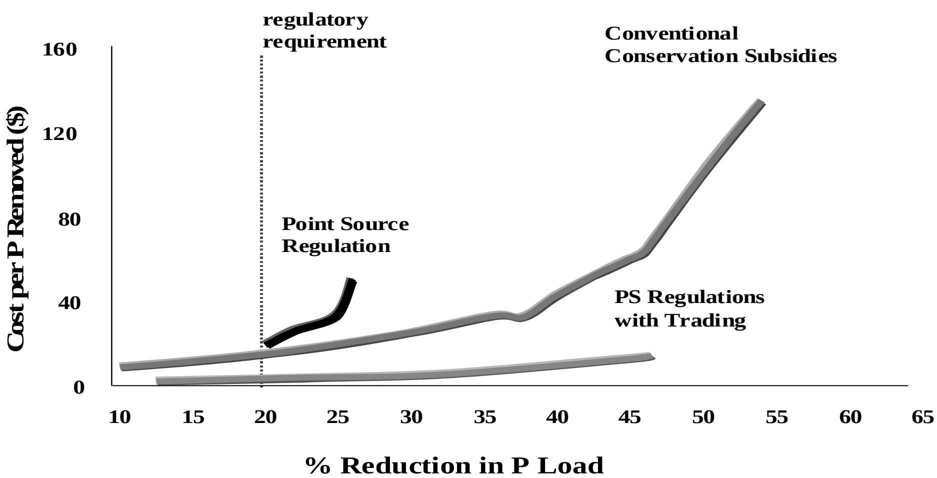
Source: Greenhalgh and Sauer, 2003.

Figure A. 2. Cost-effectiveness of policy options tested at reducing the amount of nitrogen delivered to the Gulf of Mexico



Source: Greenhalgh and Sauer, 2003.

Figure A.3. Cost-effective of nutrient trading: Michigan case study for phosphorus (in US dollars)



Source: Faeth, 2000.

Part II.

Social Issues Related to Agriculture’s Use and Impact on Water Resources

Chapter 8.

Can Water Allocation Buyback Schemes be Equitable for Impacted Communities?

Rob Freeman[1]

Some communities are being impacted by reductions in the access to water resources through market place water trade or through statutory water planning processes. This is often complicated by emotional issues as water moves from agriculture to the industrial or urban sectors or to the environment. Popular wisdom suggests that structural adjustment will occur if water allocations are purchased, and while this might adequately compensate the holder of the water licence, does it adequately deal with the broader community impacts?

Background

In 1987 the World Commission on Environment and Development released *Our Common Future*, in which the commission identified that current patterns of economic growth could not be sustained without changing attitudes and action to align with ecologically sustainable development. Two years later the Australian Government embarked on a process of public discussion that culminated in the development of the National Strategy for Ecologically Sustainable Development in 1992. This strategy complements and fulfils the 1992 United Nations Conference on Environment and Development plan known as *Agenda 21*.

Australia's largest river system, the River Murray, is in distress. After years of denial and debate, a decision has been made to return 500 GL of flow annually to the river as environmental flow, to improve its health. The best available science indicates that a minimum of 1 500 GL is required to have a reasonable chance of returning ecological health to the river and floodplain. Some ecologists argue that returns of the order of 2 500 to 3 000 GL are necessary to ensure a return to the status of a healthy working river. Whilst there is not total agreement between the jurisdictions on the volume required to achieve the necessary environmental outcome, governments recognise that 500 GL as a

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critical first step only, to be achieved by 2009.[2] There is visible evidence of its poor state of health; river red gums in wetlands and on flood plains are in decline and dying, and an ongoing dredging programme has now been in place for about three years to keep its mouth to the ocean open; so poor is the outflow that the mouth has sanded up.

Over the last 80 years, the river has been highly modified, all in the name of economic development, but with little consideration to its ongoing health and sustainability, both environmentally and economically. Weirs and locks were installed to allow a river boat industry to ply its water ways in earlier times, dams have been constructed to ensure summer water for irrigation, and a barrage was constructed at the mouth to prevent the ingress of saline water into the lower lake system.

Its hydrology is complex and highly modified; its interaction with local groundwater systems adds a further complexity. In some areas, the riverbed is a recharge zone for local groundwater systems. Exploitation of the river fed aquifers has added a further complication as groundwater extractions for economic purposes has led to some double-counting of water allocations, or a 'double loss' to the river. In other regions, saline groundwater naturally discharges into the main river channel; this discharge is in addition to the drainage discharges induced by irrigation activity.

With governments now agreeing that 500 GL should be returned as environmental flows to the river as a first step, the decision on how this is to occur is still the subject of much debate and the purchase of water allocations is considered by many to be necessary to recover the required volumes. The mechanics of how this should occur is unclear, but it is generally considered that it would simply be a purchase of the water direct from irrigators at a fair market price. Whilst irrigators may receive 'fair' and 'just' value for 'their' property right, the impacts for the communities that service the irrigators and that have been built up, in response to market signals, around the economic activity of that water allocation, need to also be considered.

Is there a more equitable approach to diverting water from one clearly defined economic activity to an environmental benefit, one which supports the social and economic fabric of small irrigation communities in making the necessary changes? This problem is not peculiar to the River Murray, but could equally apply to other over-allocated water resources.

Water as a property right

From a policy standpoint, Australian governments have been developing management strategies and water markets to achieve the outcomes Australians need to reach social, environmental and economic goals. Since 1994, the Australian state governments have separated water property rights from the land and acknowledged the environment as a legitimate user of water resources, and therefore potentially an important participant in water markets/[3] While this system is not yet ideal, with inconsistencies between

2. Beyond that point, the SA Government has urged for a target of 1 500 GL by 2018.

3. South Australia separated water property rights from land in 1983.

jurisdictions with respect to clarity or security[4] of water property rights, policy-makers are working towards some national policy consistencies and water markets through the National Water Initiative.[5]

However, the creation of a healthy, competitive, working water market faces certain challenges:

- Allocations have generally been made on the basis of historical use, creating significant over-allocation issues, which need to be addressed. Water management policies until recently have tended to be reactive.

- Over-allocation has resulted in detrimental impacts for downstream third parties, including the environment.

Policy-makers have been tasked with changing the economic value of water to more accurately reflect the environmental and social costs of water use, which has implications for future land use. Given the time frames required to "save the river" and avoid larger environmental costs in the future, governments need to create policies around water use that will foster rapid structural change or adjustment. The challenge will be to do so in a way that allows the structure of rural communities to adjust with a minimum of social, economic and environmental casualties.

It is not intended to convey an impression that the River Murray is the sole focus of Australian water policy, but it is one of the most important resources in Australia, and collectively one of the most managed, albeit still requiring considerable policy alignment between the different jurisdictions. The River Murray and its main tributaries, the Murrumbidgee and the Darling, are collectively known as the Murray-Darling catchment, or basin. In addition to the Australian Government, four state jurisdictions and one territory government all have a direct interest in the basin, as it covers about one-seventh of Australia's land mass. It is home to about 11 per cent of Australia's population and provides in excess of 40 per cent of the nation's gross agricultural production. With many jurisdictions having an interest, its management is complex.

Being a relatively dry continent, and sometimes referred to as the driest inhabited continent, water resources are important for economic development in Australia. Many water resources present management challenges because of climate variability, many streams are ephemeral or episodic, and much of the groundwater is of poor quality. However, many of the management problems and principles are common to all water resources, and particularly the management environment of competing interest, and consideration of the natural environment as a legitimate user of water resources.

4. Some surface or river water is regarded as high security, whereas other property rights relate to high flow water and are dependent upon prevailing seasonal conditions and or the storage level of dams.

5. An Intergovernmental Agreement signed on 25 June 2004 between the Australian Government and most mainland states. Details on the NWI and the National Water Commission, which administers the NWI, can be found at www.nwc.gov.au.

What the government intended

It is generally agreed that water resource allocations are to be managed within sustainable limits of the natural resource.

The Council of Australian Governments[6] (COAG), an organisation of federal, state and local governments, agreed to act on this in 1994. This led to a 'cap'[7] on Murray-Darling diversions, provision of water for the environment, and a separation of water from land right. It was the first official national step in creating water markets.

Ten years later, at the June 2004 COAG meeting, the council reaffirmed its support for the development of sustainable water policies. An Intergovernmental Agreement on a National Water Initiative was completed and extended that affirmation.

The intent of the agreement is to create water policies that enhance and protect social outcomes as well as economic and environmental ones. The preamble of this agreement states:

> *Water may be viewed as part of Australia's natural capital, serving a number of important productive, environmental and social objectives…. Likewise, governments have a responsibility to ensure that water is allocated and used to achieve socially and economically beneficial outcomes in a manner that is environmentally sustainable.*

The agreement also intends for policy-makers to take the impact on society as a whole into consideration when designing water policies. Further into the agreement, there is a requirement for policy-makers to:

- *"[settle] the trade-offs between competing outcomes for water systems [involving] judgements informed by best available science, socio-economic analysis and community input…" (para. 36); and*
- *"[assess] the socio-economic costs and benefits of the most prospective options, including on downstream users, and the implications for wider natural resource management outcomes." (para. 79).*

The signatories to the agreement intend for policy-makers to create a water management system that protects social capital as well as environmental and economic capital during a period of reform and adjustment. Furthermore, the Australian Government has set up a National Water Commission to measure the social as well as the economic and environmental impacts of these policies. That Commission is required to "review the NWI comprehensively, including assessing… the impact of the implementation of the NWI on regional, rural and urban communities." (Sect. 7:2:i)

6. For further details on COAG, visit www.coag.gov.au.

7. For further details on the Murray Darling Basin Commission and the 'cap', visit www.mdbc.gov.au.

Rural adjustment policy tools

A great deal of effort has been invested in negotiations between key stakeholders in the exploration of options to develop a range of policy tools needed to create a sustainable water market that takes the needs of the environment into account, whilst allowing and encouraging industry development. Much of the discussion has centred on structuring the current water market into a cohesive and completely national market. However, in the natural resource management context, there are few instances where a pure system of private property rights will guarantee the outcomes the Australian community desires, because of the ongoing tensions between competing commercial and environmental interests.

The policy-makers' aim is to assist with adjustment at the community as well as the individual level, so that all members of the community are able to adjust to the new economic, social and environmental structure brought about through policy changes, to ensure all water resources are used within sustainable limits; and to foster the development of a national water market where the environment is a stakeholder. To date most structural change has focussed on acknowledging the environment as a legitimate water user and on improving operational efficiency of water transport and management systems, to release more water to the environment and for further economic development.

Many water management discussions, particularly those related to the Murray-Darling Basin, are currently about the purchase, by governments, of water entitlements to surrender back to the environment. The literature generally acknowledges that in many cases, structural change will occur faster than the 'natural' flow on effect of any adjustment, and that this might cause hardships that would unjustly afflict members of a wider rural community. In the case of irrigation areas, much of the rural community has evolved around servicing the irrigators, who are the beneficiaries of any significant water allocation buyback scheme. Given such changes would be driven by government policy changes, should government play a role in easing the adjustment of the impacted rural economies, enabling them to survive essentially what is a water reallocation process?

There are, however, some gaps between the policy tools suggested and designed in literature, and the intentions of COAG and the National Water Initiative.

First of all, the term "socio-economic" is generally limited in literature to irrigators themselves and their social welfare. The language of COAG, the NWI Agreement and the NWC Act[8] reflects a broader view of social capital, one that embraces not only other irrigators, but also the support structures such as irrigation manufacturers, food processing plants and other businesses along the agricultural supply chain. Rural adjustment policy discussions should broaden to include these businesses.

Second, the literature considering the impact of water policy changes also discusses the issue of "stranded assets" and proposes models to compensate those who have invested in assets such as dams and irrigation channels that will no longer be required. In this context, stranded assets refers to the infrastructure that becomes redundant when the water that it was developed for has been transferred away to another use or location, thus rendering the infrastructure unnecessary or of a utilisation level well below its designed capacity.

8. National Water Commission Act 2004.

Generally, the rest of the support community is not considered as a *stranded asset*, even though this infrastructure might fit the definition. In this context, the social capital and support services developed around an irrigation industry could also become 'stranded' if the irrigation activity is removed, or the water is converted to other uses. In a free market environment, these services generally develop in response to demand signals from the irrigation activity. An exogenous shock to a regional community, such as a government buying significant water allocations, could negatively impact upon the services that have evolved to support the irrigation industry during the peak of its activity.

- Historically, financial benefit from a restructuring, such as a water allocation buyback, is likely to accrue only to the holder of water allocations. They in turn will likely make business investments outside of their local irrigation community, thus 'stranding' local social capital.

- Reducing water allocations results in a number of restructuring issues for licensed water users. The impact of stranded infrastructure and financial compensation, often expressed as restructuring assistance for holders of water allocations, is generally the focus, and considerable political and academic effort has already been invested in this aspect.

- Literature, in general, looks at the positive and negative social impacts on the individual direct recipient businesses and families, and treats this as a flow-on from economic change. But what happens when you have a positive economic (and therefore social) outcome for the farming families directly involved in transactions, but a negative impact on the community as a whole during a period of structural adjustment?

    - For example, if irrigators are compensated through the purchase of their water allocations or through another policy decision, they might decide to leave their rural community. The farmers and their families would have been adequately compensated, but with their removal from the rural supply chains, sometimes all at once, those supply chains could collapse before the other businesses in them have time to react, innovate and adjust to their new customer base, if one emerges.

- The literature largely ignores the direct economic third party impacts on the support community servicing the licensed water users all along the agri-business supply chain. This group is made up of the providers of goods and services supporting irrigation communities; suppliers of fuel, fertiliser, farm chemicals, seed, freight services, machinery, and specialist services such as those of agronomists.

- The multiplier effect can take this to the next level of tertiary providers such as medical, education, financial, and retailing. At these levels, policy decisions to buy out water allocations can impact the wider social capital of rural communities.

    - Community health and social welfare are also "outside the market" as water rights were 20 years ago. Is it possible to develop economic models which assign value to these stranded assets, in order to ensure the social capital of the broader irrigation communities that have been developed around the use of water is given due consideration?

Conclusion

There is a need to develop comprehensive policies to enable an equitable adjustment in impacted rural communities, not just irrigators, and to provide support mechanisms that will allow communities to survive the rapid adjustment associated with water policy changes. This may include being giving an opportunity for businesses in the agricultural supply chain to adapt to new land uses, populations and economies.

While policy tools should not attempt to interfere with the direction of structural adjustment, they should expand the abilities of rural communities to take advantage of the opportunities opened up through structural adjustment. For example, policy tools should not prop up farm businesses that are no longer profitable, but they should enable businesses affected by structural changes to access resources needed to shift their operations accordingly, say from servicing an irrigation industry to servicing a forestry industry, potentially in another location.

Policy instruments can be designed to "adjust" the rest of the non-irrigator community that supports the irrigator, who is the initial restructuring target.

- Is there a better method of allocating a restructuring package?
- Are there economic models for mitigating the temporary negative effects of water policies on third party businesses in the agri-business demand chain? If not, can we build them, and would they be useful in developing policies that protect water resources and the environments that are water-dependant?

In order to encourage thought and discussion, it is suggested that any model designed to provide a more equitable distribution of restructuring funding should take into account the following:

- Adjustment assistance would only apply to permanent water entitlements, not opportunistic water access.
- Impact on the third party business would have to be demonstrable and immediate, with a view to providing assistance that aims at enabling the business to make permanent adjustments, for example grants for new plant to service a new industry in the area, or to expand operations to cover a larger geographic area, which now has fewer irrigators per acre.
- Adjustment assistance aimed at easing the adjustment needed in social capital would have to demonstrably assist communities in ways that increased their economic adjustment to their new environment. For example, assistance might be available to retrain the local labour force, previously available to harvest irrigated crops, to now manage tourism or other local growth areas.

Chapter 9.

China's Agricultural Water Policy Reforms

Bin Lui[1]

The population, food, resources and the environment have been under high pressure for a long period of time in China. The water supply and demand situation is serious. It is estimated that China's population will peak at 1.6 billion in 2030, and this will increase demand for agricultural products, and for agricultural water as well. Increasing industrial and domestic water use will further affect agricultural water supplies. So China's agricultural water system is facing great challenges. In such a severe situation, the Chinese government actively tests agricultural water use policy reforms to guarantee the basic agricultural water supplies and farmers' benefits, in order to support sustainable agricultural development and secure grain production with limited water resources.

1. China's agricultural water circumstances

Water resources in China total 2800 billion cubic meters, but per capita consumption is only 2200 cubic meters and per hectare consumption 6200 cubic meters, which are 50% and one-third of world averages respectively. The per capita consumption will decrease to 1760 cubic meters in 2030, when China's population reaches 1.6 billion. At the same time, the temporal and spatial distribution of water resources is uneven, and does not match with the distribution of industrial and other resources. Some 60%–80% of rainfall and runoff are concentrated in the flood season. The areas north of the Yangtze have 65.4% of the cultivated land, 46.1% of population and 45.8% of the GDP of the country, but only 19% of the water resources. The Yellow, Huai and Hai river basins especially, with 34% of the population and 33.3% of the GDP of China, have only 7.7% of the water resources.

These circumstances result in severe conflict between water supply and demand, heavy water pollution and water and soil erosion. It is estimated that, according to normal demand without over-drafting groundwater resources, the average water shortage in China is 30-40 billion cubic meters. A total of 400 cities out of 669 are short of water. Between 1980–2020, water usage was continuously increasing, resulting in water conflicts between industry and agriculture and urban and rural areas, and between regions, severely compromising of ecological water use.

1. Department of Water Resources, Ministry of Water Resources, Beijing, China.

1.1 Agriculture is the biggest water user in China

Agriculture has a significant role in China. At all times, more than two-thirds of total water use is agricultural water use. Water resources development has a very important role in China’s economy, especially in relation to agriculture. At present, agricultural water use is 400 billion cubic meters, with irrigation water use 360 billion cubic meters, 65% of the total water use of the country.

1.2 The high pressure of agricultural water supply to secure the grain production

Agricultural irrigation greatly contributes to China’s domestic grain supply. The irrigation area makes up one-third of total cultivated fields, providing two-thirds of total grain products. It is estimated that grain production must reach 575 million tons and 650 million tons in 2010 and 2030 respectively. Facing a decrease in cultivated land areas and current high unit output, in order to increase grain production to secure the supply of grain and other agricultural products, it is necessary to enlarge the effective irrigation areas and to strongly promote agricultural water saving.

It is projected that the total demand for agricultural water will be 418.6 billion cubic meters in 2010 and 463.4 billion cubic meters in 2030, while agricultural water availability will be 398 billion cubic meters in 2010 and 420 billion cubic meters in 2030, allowing for sustainable development, effective protection and efficient reuse of water resources. Thus, the shortfall in agricultural water would be 20.7 billion cubic meters in 2010 and 43.4 billion cubic meters in 2030. The irrigation water shortfall will be 15.9 billion cubic meters in 2010 and 39.1 billion cubic meters in 2030.

1.3 The intensified conflict between agriculture and industry, urban areas and the ecology

During rapid social and economic development, with increasing use of industrial and domestic water, many water sources of good quality and high security are diverted to industrial and domestic use, with a decrease in agricultural water supply security. At the same time, with the consumption of agricultural water, agriculture begins to encroach on ecological water use, which causes the environment to deteriorate in some regions. It is necessary to return water to the environment. Therefore, conflicts over water will be more and more severe.

1.4 Low efficiency of agricultural water use

The efficiency of agricultural water use is lower in China. The average efficiency of channel water use is 0.4–0.6. The efficiency of field water use is 0.6–0.7. Irrigation water production is about 1.0 kg/m^3. In the 80 million hectares of fields without irrigation, the field water production ratio is about 0.6–0.75 kg/m^3. The North China Plain is the area of higher agricultural water use in the country, but still with great variance between regions.

1.5 Unclear agricultural water use rights

According to the 2002 Water Law, water resources belong to the state. Due to the lack of integrated management, the definition of water resources rights is unclear. The water drawing permit system has been implemented since 1994. But the super-small scale of China's farms would make it very costly to manage water resources on an individual farmer basis. So in China, agricultural water resources are public resources. Due to unclear water rights, it is easy to have a lack of a compensation mechanism when water use rights are violated.

1.6 The irrational agricultural water tariff structure

At present, there are three problems in agricultural water pricing: one is that the water tariff cannot reflect the water supply cost; the second is that there are too many collecting levels, with the accompanying risk of free-riders; the third is that the current water tariff level results in a financial burden on the government budget.

Investigation shows that the current water tariff level is less than 50% of water supply cost. Due to the lower price level of agricultural products, and the heavy burden on and limited affordability for farmers, the regulation of an agricultural water tariff is very difficult. At the same time, due to the lack of a constraining mechanism on revenue collecting and too many management levels, the real revenue of the water supply unit was much less than the supply cost.

2. Policy reforms in China's agricultural water use

In the last 20 years, with 9% of the cultivated land and 6% of the fresh water resources of the world, as well as uneven spatial and temporal distribution and lack of correlation with land resources, China supports 22% of the population of the world. With the decrease in the percentage of irrigation water use in total water use, the effective irrigation area continues increasing, to support agricultural and economic development. In the new century, under a market economy, agricultural water use must be reformed to achieve the state's agricultural development aims, and to support sustainable social and economic development with sustainable use of water resources.

2.1 Clarifying and guaranteeing basic agricultural water rights

Article 35 of the Water Law states that construction projects which utilise agricultural irrigation water sources and irrigation facilities, or have a bad effect on original irrigation water and water supply sources, should implement relevant compensation methods. Those who suffer loss shall be compensated according to law.

The water administrative department in China is actively pushing for the clarification of agricultural water use rights. According to the water rights and water market theory, with the development of a new water resources management institution, significant progress has been achieved in clarification of agricultural water use rights, which guarantees the rational allocation of water resources among sectors together with basic agricultural water use rights and farmers' benefits.

As a result of the water rights reform in Zhangye, Gansu province, each farmer has a water right card, which clearly indicates the annual water usage for the farmer. This legally protects the farmer's water use rights and relevant benefits while, at the same time, limiting the farmer's water use. In the water rights transfer pilot case study area in the Inner Mongolia Autonomous Region, the government defines the agricultural water use rights with legal documents, and allocates agricultural water use rights to the water user associations (WUAs) in the irrigation zone. Under the guarantee of agricultural water use rights, water rights were transferred through compensation from industry to agriculture.

2.2 Strongly promoting agricultural water saving

In order to secure grain production under circumstances of increasing population, it is necessary to develop irrigation areas rationally. Under conditions of increasing water demand and increasing industrial and domestic water use, the Chinese government keeps agricultural water usage rates unchanged to stabilise agricultural production. So promoting agricultural water saving to increase overall agricultural production capacity is a long-term task.

Under conditions of severe water shortage and with a high percentage total water usage being for irrigation, there is great scope for saving irrigation water. So irrigation water conservation must be considered a revolutionary development. A sustainable irrigation water saving mechanism, with reforms in irrigation management systems, the application of economic techniques and legal, administrative and technological methods, must be developed.

Since 1998, the central government has arranged special capital to maintain and build water saving facilities in major irrigation districts. Until 2004, 255 of a total of 402 major irrigation districts have implemented water saving structures, which increased, recovered and improved an irrigation area of 3.87 million hectares. Irrigation efficiency increased from 0.42 to 0.48, and water saving capacity increased by 7 billion cubic meters.

2.3 Encouraging agricultural water users to participate in irrigation management, to strengthen agricultural water use management

The WUA is an effective organisational method to enable water users to participate in irrigation management and co-ordinate water use. Due to an emphasis by governments, a push by the water administrative departments, support by the relevant agencies and active participation by the farmers, the WUA system is rapidly developing in China. At present, there are more than 7000 WUAs in China. The WUAs implement democratic negotiation and self-management, with good results.

The characteristics of participatory irrigation management in China are as follows:

- Participation improves water use management. The decentralisation of field water use decision rights and rights to use irrigation facilities fully encourage the farmers to maintain irrigation facilities, collect water tariffs and reasonably allocate water.

- The participation strengthens farmers' self-management and promotes agricultural water saving. The WUA development clarifies the relationship between water supply and use. The irrigation management units are based on voluntary service by the water users. At the same time, the farmers value the water and promote agricultural water saving.

- Negotiation on an equal basis reduces conflict over water use. Previously, the government spent too much time resolving water use conflict. Now WUAs can deal with this issue and reduce the burden on the governments.

2.4 Trialling market mechanisms to improve water use efficiency

During the implementation of several agricultural water use policy reforms, the Chinese government trialled a market mechanism to improve water use efficiency and promote efficient allocation of water resources, while increasing the agricultural water use level.

In Zhangye, Gansu Province, after receiving water rights, the farmers can buy water tickets from water departments. The tickets could be traded. This form of water rights trading stimulated the development of an agricultural economic structure and irrigation pattern reforms.

In the cross-sector water transfer in the Inner Mongolia Autonomous Region with the characteristic of "investing in water saving and transferring water rights", the water market and water rights institution realised the optimal allocation of water resources, and increased the efficiency of the use of water resources.

China is promoting and improving agricultural pricing mechanisms too. In the consideration of affordability to farmers, and through the development of a scientific and rational water pricing mechanism, the reforms are implementing field water tariff structures and increasing farmers' water-saving awareness, while promoting changes in the irrigation pattern to save water. At the same time, a public notice mechanism is implemented to publicise water tariffs and water usage, in order to reduce the number of collecting levels and abuses, and to reduce the burdens on farmers.

Chapter 10.

Developing Economic Arrangements for Water Resources Management — The Potential of Stakeholder-oriented Water Valuation

Leon Hermans, Gerardo van Halsema, Daniel Renault[1]

As water is increasingly recognised as a scarce resource, the use of economic arrangements for water resources management seems increasingly promising. Experiences show that economic arrangements can contribute to a more efficient use of water resources, but only if specific conditions are met, related to a well-functioning institutional framework and regulations that ensure that the use of economic arrangements is balanced with broader societal objectives. One of the remaining questions is how to replicate the existing cases where economic arrangements are successfully used in water resources management, in other areas where the conditions seem promising. Therefore, this paper reviews three cases in the USA, Ecuador and Australia where economic arrangements have been successfully applied, focusing on the processes that have characterised their evolution. Based on these cases, it is concluded that stakeholder-oriented valuation can offer useful support for the development of economic arrangements for water resources management, and an approach for such stakeholder-oriented water valuation is briefly outlined and illustrated.

Introduction

Water is increasingly recognised as a scarce resource in a growing number of regions. Numerous countries are expected to experience structural water stress, whereas numerous others are facing problems in securing sufficient water resources during occasional periods of drought. Also, polluting activities and deteriorating water quality threaten the reliability of water supplies and contribute to the scarcity of freshwater resources of sufficient quality. Water scarcity may be related to physical scarcity of water resources, it may be due to scarcity in financial means to develop infrastructure to access and distribute water resources, it may be induced by poor management of existing infrastructure, or it may be caused by inadequate (enforcement of) institutional arrangements for the allocation of access rights to water resources and inadequate arrangements for pollution control.

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The increasing awareness of the scarcity of water resources has led to the adoption of the principle that 'water is an economic good' as one of the four Dublin principles in 1992, which are widely accepted as the basis for integrated water resources management (IWRM). Economics deals with the allocation of scarce goods over various competing demands, and therefore this view of (scarce) water resources as economic goods seems to make good sense. The focus of various OECD studies on 'making markets work for water management' and on the use of water pricing is in line with this (OECD, 1999, 2002, 2003), as well as the focus of the FAO/Netherlands Conference on Water for Food and Ecosystems on the 'new economy' as one of its main themes (FAO/Netherlands, 2005).

Using economic arrangements for water resources management seems promising, but is by no means easy. Experiences show that economic arrangements need to be embedded within an appropriate institutional framework and that the objective of economic efficiency needs to be balanced with broader societal objectives. As the interest in market instruments has grown, more insight has been gained in the conditions within which they may or may not be successfully applied for water resources management. However, the question remains: how to replicate the existing cases where economic arrangements are successfully used in water resources management in other areas where the conditions seem promising. Therefore, this paper sets out to review some of existing cases where economic arrangements have been successfully applied, focusing on the processes that have characterised their evolution.

Economic arrangements for water resources management

Water as an economic good

Water is a valuable resource, but its value is rarely reflected in monetary terms. Using economic arrangements in water management can be useful as a means to capture certain important values in cash flows and to allow economic exchange mechanisms to support the allocation of water resources and the associated costs and benefits among stakeholders. Examples of such economic arrangements are, for instance, payment schemes for environmental services (FAO, 2002, 2004c), water quality trading schemes (EPA, 2004), green water credits (Dent, 2005) and water markets for the trading of water rights or entitlements (Kloezen, 1998; World Bank, 1999). The use of such economic arrangements and market approaches is expected to lead to a more economically efficient allocation of water resources as compared to more administrative allocation mechanisms. Especially, market arrangements are believed to provide a more flexible allocation mechanism that also provides economic incentives to water users to use water resources in an economically efficient way (Briscoe, 1996; Kloezen, 1998; World Bank, 1999; Bjornlund and McKay, 2002).

Although the available examples show that economic arrangements can be successfully applied to deal with scarcity issues in water resources management, various authors have convincingly argued that water is not an ordinary economic good (Perry *et al.*., 1997; Savenije, 2001). One should recognise that property and user rights may be complex, that physical characteristics often hinder transfers of large water volumes from one place to another, and that water is a non-substitutable resource. Although these complexities may be less present in certain parts of the drinking water industry, they certainly do apply to agricultural water uses (Savenije, 2001). In economic terms, water resources are neither purely public nor purely private goods and they are mostly non-excludable but rivalrous in consumption; in principle, everyone is able to withdraw water resources from a shared base, or everyone is able to degrade the resource base through polluting activities, and when one person has used or degraded a given quantity of water, this water is no longer available in this quality for other users. This means that water resources are more appropriately classified as common pool resources (Kaul *et al.*, 1999).

Balancing economy and institutions

The fact that water is a common pool resource implies that market failures are likely to occur when using economic arrangements for water management, which means that these arrangements might lead to outcomes that are undesirable from a societal perspective (Hellegers and Perry, 2004). Broader societal interests require that other values be taken into account beyond mere market values, such as food security, conservation of ecosystems, employment, balanced rural-urban development, protection of vulnerable groups, etc. Thus, the successful application of economic arrangements for agricultural water management is not straightforward but needs to be balanced with the use of institutional arrangements to safeguard broader societal interests and to reduce or mitigate the negative impacts of market failures (Bjornlund and McKay, 2002; Hellegers and Perry, 2004). In other words, water markets are, by default, *regulated* markets.

A review of institutional frameworks in successful water markets confirm the need to combine economic and institutional arrangements, and indicates some of the institutional factors that are likely to support successful and sustainable application of economic arrangements in water resources management. These include factors that are equally important for both the introduction of market arrangements and for other administrative allocation systems, such as active water user participation, with structures that provide transparency and accountability among users, an administrative system that registers and enforces timely water deliveries and a well-maintained water delivery infrastructure (World Bank, 1999). This implies not only that the lack of well-functioning institutions cannot simply be bypassed by the introduction of market arrangements, but also that the lack of well-functioning institutions should not necessarily be a reason to refrain from the use of economic instruments altogether. When functioning institutions are absent, institutional strengthening is needed in any case for improved water resources management.

Nevertheless, there are some additional requirements when one prefers an economic over a more administrative approach. These include the need for transferable water property rights and water allocations (in the case of water markets), for information and transaction mechanisms to facilitate economic transfers, and for a mechanism to deal with externalities, to negate the effect of third party interests or to mitigate negative impacts which might occur (Perry et al., 1997; WorldBank, 1999; Bjornlund and McKay, 2002; Hellegers and Perry, 2004).

The process leading up to the successful introduction of economic arrangements in water management

Although some knowledge is now available on the institutional requirements for the use of economic arrangements in water management, still little seems to be known about the processes that precede the successful introduction of such economic arrangements – successful here meaning that the introduced arrangements promote a more economically efficient allocation of water resources, in a sustainable way, and without compromising important social, cultural and ecological values. A better understanding of the processes behind the success stories will help to draw some lessons on what is needed to improve the development of successful and sustainable economic arrangements in other places. What is the process that leads towards the successful introduction of such arrangements, and how can it be supported?

Without pretending to be exhaustive, three fairly recent cases are discussed where economic arrangements have been introduced for water resources management: the New York City Watershed Agreement in the USA, the 'fondo ambiental del agua' in Quito, Ecuador and water rights trading in the Murray-Darling Basin in Australia. These cases are generally considered to be successful, as illustrated by their inclusion in the recent Millennium Ecosystem Assessment Water report (MA, 2005) and by citations in various other international publications as good examples, as the coming sections will illustrate. They show that economic arrangements can be successfully applied to water resources management, linking the provision of good quality water resources to financial flows between beneficiaries and providers. In all three cases economic arrangements were introduced fairly recently, which is likely to increase the relevance for future replications of insights into the processes that led to their adoption.

The processes behind the introduction of economic arrangements in water management in cases in the US, Ecuador and Australia

The New York City Watershed Agreement

Description of the NYC Watershed Agreement

New York City (NYC) relies on the provision of clean water from upstate watersheds for the water supply of about nine million people. In order to protect the source and to maintain the quality of its drinking water, the city has reached an agreement with the upstream watershed communities to finance the implementation of measures that will help control pollution from agricultural and domestic sources. Under this agreement, New York City makes funds available to the watershed residents for the implementation of best management practices on farms, the upgrade of wastewater treatment facilities, the rehabilitation of septic systems, the improvement of storm water runoff systems and the acquisition of land from upstate landowners on a voluntary basis (NRC, 2000; Platt et al., 2000). This agreement costs New York City approximately US$1.5 billion over ten years (NRC, 2000).

The funds are administered by the Catskill Watershed Corporation, which is a non-for-profit corporation established under the agreement to administer programmes for the watersheds. It includes members from the watershed communities, as well as representatives of state and city government. A Watershed Agricultural Program has been incorporated into the agreement, administered by a council composed of farm, agribusiness and environmental leaders, to review, approve and support efforts on individual farms to improve the water quality of surface and groundwater resources (Platt et al., 2000).

This New York City Watershed Agreement has received considerable attention as an 'innovative set of economic alternatives for protecting water quality for one of the world's largest public water systems' (WWAP, 2003), a 'turning point' for valuing ecosystems services (Economist, 2005), and 'a prototype of the utmost importance to all water supply managers' (NRC, 2000). It can be regarded as one of the first payment schemes for environmental services (PES) and thus is of considerable importance. Currently, there is much interest in the use of such PES schemes to support water resources management. PES schemes are flexible compensation mechanisms by which the providers of environmental services are compensated by users that benefit from these services. PES schemes in watersheds usually involve the implementation of financial mechanisms to compensate upstream communities for activities that are expected to maintain or improve the availability and/or quality of water resources for downstream uses (Kiersch et al., 2005).

Process leading to the Watershed Agreement

The process leading to the New York City Watershed Agreement was triggered by the Surface Water Treatment Rules that were issued by the federal Environmental Protection Agency (EPA) in 1989. These rules were meant to ensure the safety of drinking water by requiring filtration of water from surface water sources, unless it could be proven and guaranteed that the surface water sources met very high water quality standards. As New York City was relying on surface water reservoirs for its drinking water, which was currently not filtered before distribution, the new federal rules implied that the city would possibly have to build a filtration plant for its drinking water in order to safeguard public health. This would costs some US$ 6-8 billion, as well as some US$ 300 million in operating costs annually, according to 1993 New York City estimates (Platt et al., 2000; NRC, 2000).

In order to avoid filtration, New York City had to show that the high quality of the water from the watersheds could also be guaranteed for the year to come. Therefore, New York City started co-operative efforts to protect its watershed together with the local governments and farmers. In 1992 the Watershed Agricultural Program started as a co-operative programme between the city's Department of Environmental Protection and farmers in the watershed. Also in 1992, 'whole community planning' was started as a platform for negotiations between NYC and the communities on maintenance of water quality standards.

However, by the end of 1993 the co-operation between New York City and the watershed communities ended abruptly when New York City presented its proposal for meeting the filtration avoidance requirements. These plans consisted of new watershed rules and regulations[2] and the large-scale purchase of lands to prevent further degradation of water resources in the watershed. These plans were considered unacceptable by the watershed communities, who feared the plans would impair economic development and reduce property values. In December 1993 the Coalition of Watershed Towns filed a lawsuit against New York City to prevent it from executing its plans. This led to an impasse in efforts to reach an agreement about a watershed management plan which lasted for over a year, until the Governor of New York State intervened in April 1995

2. Based on the State Public Health Law, NYC has the authorisation to make watershed rules and regulations to protect its drinking water supply from contamination, although these rules are subject to the approval of the State of New York.

(Platt et al., 2000). The negotiations that started in 1995 resulted in an agreement in principle later that year: "There were more than 200 meetings, many of them bitter and unproductive. But in the end – the last details were worked out at 4:20 yesterday morning – the combatants agreed on a plan." (*New York Times*, 1995). In January 1997 the final Memorandum of Agreement (MOA) was signed and formally executed.

Conclusions from the case

In the case of the New York City Watershed Agreement, the establishment of an economic payment scheme was the result of a difficult negotiation process, which eventually led to an agreement on specific types of activities to be included in the payment scheme. New York City was a key player in this process, combining significant economic and political weight in the region with a clear motivation to avoid an enormous investment in a filtration plant for its drinking water.

Fondo ambiental del agua (FONAG) in Quito

Description of the FONAG

The Quito valley is one of the most densely populated areas in Ecuador, and includes the Quito metropolis with more than 2 million inhabitants. It faces large water related problems because of high water demands combined with contamination of limited water resources. In Quito, a water protection fund, 'fondo ambiental del agua' (FONAG), has been established to collect money from the downstream beneficiaries of water-related services in the Quito metropolis, to provide donations to the national park administrations and to support local programmes of interest to FONAG in the watersheds that supply water to Quito. These activities include reforestation, environmental education, surveillance and monitoring of water quality, and investigation of sustainable community production alternatives. Although at this point it remains difficult to quantify the impacts of these projects, some conditions have been laid out to ensure that funds are spent wisely, including limits in the amounts of money that can be spent on the management of the fund and on studies (Lloret, 2005). The FONAG should help to safeguard downstream interests, consisting of water sources for the city of Quito, including drinking water for households and water for industry, and power generation in a hydropower reservoir.

Membership of FONAG is on a voluntary basis and consists of both public and private organisations, who entered into a long-term agreement. The diversity of members and their long-term commitment is considered to be one of the strong features of the fund. It means that FONAG is not constrained by the many rules and regulations that apply to public agencies, making it, for instance, easier to attract foreign donor investments, while the fund's (semi) public members and its constitution provide safeguards that the fund's activities are beneficial to public interest.

FONAG is, like the New York City Watershed Agreement, another example of a PES scheme, and during recent years, many similar payment schemes for environmental services have been implemented in the Latin American region (FAO, 2004c; Kiersch et al., 2005). The FONAG features in many of the recent overviews of payment schemes for environmental services, from an article in the Economist (2005), to the Millennium Ecosystem Assessment (MA, 2005), the Katoomba Marketplace (Katoomba, 2005), recent work by FAO (2002, 2004c) and the FAO/Netherlands Conference on Water for Food and Ecosystems (Lloret, 2005).

Process leading to the establishment of FONAG

The water supply of the city of Quito originates mainly from two watersheds located in the Cayambe-Coca (4 000 km²) and Antisana Ecological Reserve (1 200 km²) in the Andes mountains. Although both areas are under environmental protection, the watersheds are threatened through several land uses such as agricultural production, extensive livestock grazing (with impacts on both water quality and quantity for drinking and irrigation water use), power generation, and recreation. Destruction of forests and grassland (*páramo*) which contributes to the degradation of the high plateau is assumed to affect the stream flow, causing floods in winter and drought in summer (Kiersch et al., 2005).

To ensure the conservation of the water resources in the watersheds for the drinking water supply of Quito, the Nature Conservancy (TNC) and the Fundación Antisana, a local NGO, launched the idea in 1997 of establishing a fund that would make an explicit link between the use of water and the conservation of the watershed (Katoomba, 2005). With the support of USAID and the Quito Metropolitan Area Sewage and Potable Water Agency (EMAAP-Q), this led to the creation of the FONAG water protection fund in January 2000. In May 2001, the Quito power company (Empresa Eléctrica Quito) entered as a constituent, as did the private company Cervecería Andina in March 2003. Recently, the Swiss Development Co-operation has joined the fund, as well as the Ministry of Environment, which has an observer status. The constituents contribute to the fund, varying from 1 percent of drinking water revenues by EMAAP-Q to an annual fixed amount by others, with written agreements for the 80 years of the fund's constitution. At the start of 2005, the fund had close to US$2 million, and investment bonds for the year 2005 were estimated at close to 500,000 dollars (Lloret, 2005).

Although this may appear to have been a straightforward process, in fact 'the process has been slow and painstaking' (Katoomba, 2005). Initially, the city mayor and the boards of directors of the water utility and the power company had to be convinced of the potential benefits of the fund (Katoomba, 2005). Once established, field activities financed by FONAG did not start until 2004, years after the establishment of the fund, because FONAG works with the interest, not the capital, on the money in the fund (Katoomba, 2005; Lloret, 2005). In fact, the fund still has to prove that it is really contributing to improved availability of water resources. The lack of understanding of linkages between specific watershed protection activities and water flow and quality makes it difficult to assess how much of the desired service actually reaches the users. As yet, statements concerning outcomes in terms of environmental improvement or hydrological returns are not available (Kiersch et al., 2005).

Conclusion from the case

The FONAG payment scheme is based largely on a 'virtual' market for activities that are expected, but not yet proven, to contribute to the sustained availability of good quality water resources. It is the result of a process initiated by non-governmental organisations that lasted several years and that gradually gained more momentum, after its participants were sufficiently convinced of the value of the services and activities supported by the fund.

Water rights trading in the Murray-Darling Basin

Introduction to the case

The Murray-Darling river basin spans several states in the south-east of Australia and some three million people inside and outside the basin heavily depend on its water resources. The development of the basin's water resources has enabled the expansion of agricultural activity, and currently the agricultural produce of the basin exceeds AU$ 10 billion (MDBC, 2004). Since the 1950s, the growing water demands have caused declining water quality, rising water tables and increased salinity. To help prevent further degradation of the water resources, a cap has been put on diversion, limiting annual diversions, effective from July 1997.

Within the cap, water entitlements may be traded and prices are determined by the market. The trading arrangements that are in place for the Murray-Darling river basin in Australia are an often cited example for river basin management and well-functioning water markets (e.g. Tarlock, 2001; Bjornlund and McKay, 2002; Moss et al., 2003, FAO, 2004b). Trading arrangements have first been put in place at state level and, although a pilot has been started on interstate water trading, the state level experiences are more advanced. The specific trading arrangements are illustrated here for the state of New South Wales (NSW).

Water trading arrangements in New South Wales

Water trading in New South Wales is based on the trading of water rights, which are separated from land titles. Individual water rights are vested in water licences that define a share in the available water resources, expressed as a unit share rather than as a fixed volume per year. The actual volume that a licence-holder is entitled to differs per year, based on water availability, and is called the annual water allocation. Water licences as well as annual water allocations can be traded, and water licences can be split and consolidated (DIPNR, 2005).

Generally, at the start of the water year government officials make an available water determination (AWD), specifying the water volumes per unit (e.g. 0.8 megalitres per unit), taking into account aspects such as climate, storage, flow levels and historic usage. This provides the basis for the annual water allocations to individual licence holders, which is calculated as *units in the licence* x *water volume per unit*. This annual water allocation is credited to the water allocation account of the licence holder, which, similar to a bank account, specifies how much units of water a licence holder is entitled to. For some licence categories, AWDs may be made throughout the year if more water becomes available (DIPNR, 2005).

The system of tradable water licences and water allocations deals mainly with water diversions for commercial purposes, such as irrigation of crops. The overall extraction limits for the source, specific environmental water rules and the rules under which the available water determinations are made available, are determined in the water sharing plans, which are mandatory for all water sources in NSW. Rural landholders are entitled to basic rights to water without a licence and there also is a provision that recognises the cultural and spiritual importance of water to Aboriginal people in NSW (DIPNR, 2005). In dry periods, priority is given to the environment, urban water supply, rural drinking water supply and finally irrigation (Huckell, 2005). This means that in dry years, the volumes of water needed for the environment and for drinking water supply (priority allocations) are first abstracted from the total available volume, before calculating the water volumes per unit for commercial water licences.

Process leading to the establishment of water trading arrangements in New South Wales

The serious problems related to overexploitation of the water resources in the Murray-Darling river basin triggered the involved states' ministers to limit annual water diversions in each of the basins states to the volume of water that would have been diverted under 1993/94 levels of development (MDBC, 2004). In New South Wales, enforcing this cap proved especially difficult, as in 1996 and 1997 three major sub-basins in this State exceeded the cap (Tarlock, 2001). The Government of New South Wales announced a comprehensive water reform package in 1997, initiating a participatory stakeholder process through the establishment of community based Water Management Committees (WMCs). The outcome of this process was consolidated in the 2000 Water Management Act, which consolidated previous legislation.

The Water Management Act required the development of water sharing plans for all water sources in NSW by local water management committees, which should give directions for water allocations between competing users, including between the environment and extractive users (ACIL, 2002). Furthermore, the Water Management Act provided a framework for these water sharing plans, determining the conditions for water rights and the duration of the water sharing plans. However, the duration of the water sharing plans and of the water rights proved an important source of disagreement. Initially, the state government of NSW announced plans for water sharing plans to have five year tenure (NFA, 2005) and to confirm existing rights for only ten years (Moran, 2003). For farmers, a longer tenure for water sharing and perpetuity of water rights was important to allow security for their investments. If water sharing arrangements could change regularly and if water rights could be lost, risks of investment would become too high and obtaining credits from financing institutions would be almost impossible (Huckell, 2005).

Eventually, the framework for most water management provisions in New South Wales evolved largely from agreements on water made between the Commonwealth and the states in the Council of Australian Governments, which resulted in the National Water Initiative, signed on 25 June 2004 (Hamstead & Gill, 2004; DIPNR, 2005). The 2004 NSW Water Management Amendment Act gave effect to aspects of the National Water Initiative, including the creation of perpetual water rights and the provision for the term of a water sharing plan to be extended beyond its ten years. This development was in parallel to the agreement reached in NSW that existing rights were to be converted into *perpetual* water access licenses, in return for agreed cuts in agricultural water use of a further 3%, in addition to the basin cap, over a period of 10 years, from 2004 to 2014 (Huckell, 2005). In the agreed trading scheme, there is a phased transition towards full trading to protect farmers in existing irrigation systems. To ensure that tail-end farmers within an irrigation system do not, all of a sudden, find themselves alone within a system, facing a much higher burden of operation and maintenance costs for irrigation infrastructure, only 4% of a water licence can be traded annually. This will eventually be phased out (Huckell, 2005).

Conclusions from the case

The water trading schemes in place in New South Wales in the Murray-Darling river basin resulted from a long process of political negotiations and legislative reform, triggered by increasing water scarcity and influenced by external pressures from the interstate basin level and the national level. Water trading is embedded in a complex system of rules and regulation that has been established through this political process and that include various safeguards, such as the rules for the establishment of water availability determinations and a phased transition towards full trading. Within this legislative framework, further conditions for water allocations are determined by the local water management committees, through the development of water sharing plans.

Key conclusions from the cases

Although the three cases covered two very different types of economic arrangements, namely water protection funds or payment for environmental service schemes in New York City and Quito and water markets in New South Wales, one key aspect clearly emerges from the descriptions of the processes that preceded the described arrangements: economic arrangements are the result of a (long) negotiation process among stakeholders. The arrangements were put in place only when the stakeholders agreed on the adoption of trading mechanisms or payment schemes. This was the result of a stakeholder process which had its own pace and rationale and was not imposed by an external (government) actor, but that was initiated after years of profound problems, causing stakeholders to unite for action. Conflict and distrust among stakeholders was often part of this process, but also a joint realisation that sound water management required a co-operative approach and a joint recognition of the value of water.

A negotiated agreement among stakeholders is key, because the successful economic arrangements in the described cases operate within well-defined boundaries. They are part of a larger package of economic, administrative and institutional arrangements to ensure that a broad range of societal values are included. Particularly, the rules and regulations that shaped the administrative and institutional arrangements were the subject of negotiations among stakeholders, before they trusted the 'invisible hand' of the market to play its role. The agreements for the New York City Watershed and for the FONAG in Quito are basically agreements on the way in which the economic funds are regulated: how much funding is to be made available or how funds are to be collected, and what guidelines and procedures apply for financing projects and activities with these funds. Although much closer to a free market, the trade in water rights in the Murray-Darling basin is also constrained by various licenses and trading rules and is embedded in an institutional and regulatory system that safeguards environmental baseflows as well as social fairness. The importance of the regulatory arrangements in the last case is further underlined by the fact that existing laws were changed to enable the use of market mechanisms.

Although previous studies on existing economic and market mechanisms in water management did not focus on the process leading up to those mechanisms, the findings here are very much in line with the findings from previous studies. As was mentioned in an earlier section, those studies point out the need to balance economic arrangements with institutional, regulatory and administrative arrangements, but they also point out the importance of active stakeholder participation for the proper functioning of the resulting hybrid economic/administrative/regulatory systems (Briscoe, 1996; World Bank, 1999).

Thus, stakeholder processes are important throughout the lifecycle of these hybrid systems, from their early conception to their sustained use.

Stakeholder-oriented water valuation to support the development of economic arrangements

The potential of water valuation to support the development of economic arrangements

Stakeholder processes determine the success of economic arrangements in water resources management. As transparency and accountability are known success factors for existing economic arrangements (World Bank, 1999), they are also likely to be important for the stakeholder processes leading up to those arrangements. Offering stakeholders a mechanism for the transparent assessment of important water values is potentially very useful in helping them reach an agreement on those values, and on the ways to manage them through the use of regulated economic arrangements.

So far, an explicit and transparent assessment of water values and the way they are impacted is often absent in the process leading up to economic arrangements. In the case of New York City, the costs of building a filtration plant were very clear and high enough to trigger action, but even here, the agreed package of US$ 1.5 billion does not offer a guarantee that the activities under the agreement will be sufficient to meet official water quality standards within the time frame of the filtration avoidance granted by the EPA (NRC, 2000; Hermans et al. 2003). In Quito, the contributions to the fund by the constituents are set rather arbitrarily, based on their individual willingness and ability to pay, and the eventual impacts of projects funded by the FONAG on water availability downstream remain, as yet, largely unknown.

Nevertheless, a certain common understanding on the value of water resources is necessary to reach an agreement on the design of economic arrangements. Eventually, an accurate valuation is important to ensure sustainability of these economic arrangements. In the case of New York City and Quito, those who pay for the activities in watersheds want to ensure that the money they spend is actually contributing to the provision of water resources. In the Murray-Darling basin, direct costs of purchasing a certain volume of water is set in the market place, but the societal transaction costs to enable this market to function should also be taken into account. Registration of licences, water accounts and trade, and monitoring of water diversions are all required for a well-functioning market. The costs of maintaining this institutional and administrative support infrastructure should be reasonable in relation to the contribution of the markets to improved water resources management.

In general, valuation is a prerequisite for addressing the question of whether or not economic arrangements contribute to the sustainability of agricultural water use and quality. Limits in technical knowledge limit the extent to which the costs and benefits associated with economic arrangements can be assessed, but nevertheless, some sort of assessment or valuation needs to be done, both in deciding about new arrangements and in monitoring progress in using existing ones. But then, how does one help stakeholders to decide on the appropriate rules and regulations for well-functioning economic arrangements?

The need for a new approach to water valuation

Economic valuation methods such as market-based approaches, contingent valuation, hedonic pricing and the travel-cost method help to express environmental values in monetary terms, incorporating externalities in a total or full economic value of water resources (FAO, 2004a). This offers a logical starting point to translate water values into financial flows through market arrangements and to 'internalise the externalities'. Nevertheless, the three cases have shown that in the success stories, calculations of full economic values have not played a decisive role in the development of economic arrangements. Several explanations for this can be found:

1. Specific costs and benefits associated with watershed protection and water uses are difficult to quantify and to capture in monetary terms, not only in developing countries, but also for instance in the case of New York City and Australia. The limited accuracy reduces the usefulness of economic valuation methods in practice.

2. Stakeholders may value other things in addition to narrowly defined economic values expressed in dollars, such as social stability and environmental sustainability. Of course these values can somehow be translated into monetary values, but, apart from the methodological constraints involved in conducting such translations, this ignores the fact that trade-offs between such values are within the realm of politics rather than economics (cf. Hellegers and Perry, 2004).

3. Economic valuation is a tool for researchers and analysts and as such it is disconnected from stakeholder processes. The pace of stakeholder negotiations may not fit the timeframes needed for proper analytic valuation exercises, or, when external experts are consulted by one or more stakeholders, their advice may simply be overruled by the client, as was the case for an expert panel consulted by EPA in the New York City case (Okun et al., 1997).

Thus, although in principle the existing methods for economic water valuation can offer useful support for the design of economic arrangements for water resources management, their application in practice is limited. There is a need to complement the existing suite of economic valuation methods with an approach that is specifically oriented towards the stakeholders and their negotiation processes that determine the design and implementation of economic schemes. Rather than regarding valuation as an external input, it is to be recognised as an intrinsic part of the stakeholder process – throughout their negotiation process, stakeholders are making various choices, which implies that they value one thing over another. Valuation should help stakeholders to gain more insight into the values affecting their choices, so as to take them more consciously into account when making their choices. However, these values are not always strictly economic. This means that the established economic valuation tools and methods can be part of a stakeholder-oriented approach, but they are not the sole focus and they are only to be used if they can usefully contribute to clarifying values and reaching agreements among stakeholders.

A general process for stakeholder-oriented water valuation

Stakeholder-oriented valuation approaches have been explored in several cases for local water resources management, for instance in Tanzania (FAO, 2005), Sri Lanka and Lao PDR (Nguyen et al., 2005a, b) and Cambodia (IUCN, 2005). A forthcoming publication by FAO, IWMI, IUCN and Imperial College capitalises on the experiences and insights gained so far with this new approach by these organisations. From this, a generic process for stakeholder-oriented water valuation is emerging to more firmly link water valuation to stakeholder processes. This stakeholder-oriented valuation process is based on the IWRM process as conceptualised by GWP (2004), but focusing specifically on the implications of linking valuation to stakeholders as part of water management processes. Essentially, the process consists of seven elements that are linked to one another as a logical sequence of activities:

1. Identify the main triggers for the process, problems to be addressed and stakeholders involved
2. Identify and structure the objectives that are at stake, covering each involved stakeholder, to ensure that the full range of values is considered
3. Value the existing situation, using indicators that are linked to the identified objectives
4. Identify possible measures that can help improve the situation, including economic instruments
5. Assess the expected impacts of possible measures, covering the full range of identified objectives
6. Evaluate, refine and choose a set of measures / economic arrangements to implement
7. Implement, monitor and evaluate the impacts of the implemented (economic) arrangements.

The structure of the seven elements outlined above suggests a linear process, but often reality is different; this is the case for IWRM processes generally (GWP, 2004) and also for stakeholder-oriented valuation. Water management processes may move from problem to solutions, from solutions to other solutions or even from one problem to the next. Also, the group of stakeholders involved is likely to change over the course of the process, as some stakeholders may disengage themselves and new stakeholders may enter the process in a later stage, changing the range and priority of the values, problems and solutions that are considered in the process. Whatever the exact sequence of activities in a stakeholder process, the role of stakeholder-oriented water valuation should be to support stakeholders by explicating the problems and the values involved, sharing the different perspectives and positions, and through this process, identifying solutions that can form an agreeable basis for action. The seven elements outlined above are considered essential for a sound stakeholder-oriented valuation process, be it as a direct sequence or in a more haphazard way.

Illustrating the stakeholder-oriented valuation process for the case of New York City

The use of the stakeholder-oriented valuation process is illustrated for one of the cases discussed before: the New York City Watershed Agreement. Table 1 shows how the process in the NYC watershed can be described in terms of the procedure for stakeholder-oriented water valuation. It illustrates that the seven elements in the stakeholder-oriented water valuation process should be used in an iterative way and that sometimes certain steps need to be repeated whereas others can be skipped.

Table 1. Illustration of the stakeholder-oriented water valuation process for the NYC Watershed Agreement

Element in the process	Explanation for the NYC Watershed case
Triggers and key stakeholders	EPA Surface Water Treatment Rules issued in 1989 require NYC to protect water sources or build filtration plants for its drinking water. Key stakeholders are NYC, EPA, watershed communities
Main objectives and associated stakeholders	Safe and reliable drinking water supply – EPA and NYC Financial costs within reasonable limits for drinking water supply – NYC Local economic development opportunities – watershed communities
Values – current practices (current values here taken as 1996 values)	Current drinking water supply meets health criteria, but fear is that increased human activity in watersheds threatens ability to meet standards in future, especially for pathogens and phosphorus (ref: NRC, 2000) Costs for NYC drinking water supply: US$ 450 million for water supply and wastewater collection in 2002, so presumably less in the 1990s (ref: NYC, 2002) Economic development in watersheds: local economic indicators score low in comparison to NYC and national averages. For instance, 1996 per capita personal income (PCPI) was US$ 18 743 for the non-metropolitan areas in New York State, which include the NYC watershed area; PCPI was US$ 29 320 for metropolitan area; for US as a whole it was US$ 24 175 (ref: BEA, 2005).
Possible measures	Build filtration plant (option for NYC) Request filtration avoidance based on unilaterally imposed watershed rules (option for NYC) Request filtration avoidance based on agreement NYC and watershed communities to control pollution on voluntary basis (joint option for NYC & watershed communities)
Impacts of measures	Filtration plant: reliable and safe drinking water supply, investment of US$ 6-8 billion and annual operating costs of US$ 300 million (costs for NYC) (ref: NRC, 2000) Filtration avoidance based on strict watershed rules: impaired economic development (economic impact: local counties to remain at bottom end of state and national lists, affected stakeholders: watershed communities); reliable and safe drinking water supply, with possibly some remaining risk of pathogen outbreaks (impacts relevant for NYC and EPA) Filtration avoidance based on agreement and compensation payments: slightly reduced range of options for economic development but compensation and support for certain types of economic activities (such as best practices for farms) (watershed communities); reliable and safe drinking water supply, with some remaining risk of pathogen outbreaks (impacts relevant for NYC and EPA); investment of US$ 1.5 billion over 10 year period by NYC (ref: NRC, 2000)
Choice	Request filtration avoidance based on strict watershed rules and regulations, together with some voluntary activities with watershed communities (unilateral decision by NYC)
Implementation - Trigger round 2	New watershed rules announced by NYC, appealed by watershed communities in lawsuit. Impasse, need for external intervention by a new stakeholder: the Governor of New York State
Key objectives	As above plus the objective of New York State for healthy regional development, balancing the urban and rural interests in the state
Measures	As above but minus the option of unilateral imposition of stricter rules by NYC
Choice	Filtration avoidance based on agreement among NYC and watershed communities (i.e. payment for environmental service scheme)
Implementation, monitoring and evaluation	Agreement under implementation since 1999, through various watershed programmes. Impacts are improved management practices on farms, upgrading of wastewater treatment plants in watershed towns, rehabilitation of numerous septic tanks (ref: Brown, 2000) A first evaluation of the agreement has been executed by the National Research Council in 2000 upon request of NYC (source: NRC, 2000) Monitoring water quality in reservoirs is done continuously and will determine whether or not additional activities are required to meet the objectives of safe and reliable drinking water supply.

Although it is a hypothetical example, Table 1 illustrates the general thinking behind stakeholder-oriented water valuation and demonstrates how a stakeholder-oriented valuation approach fits the (negotiation) processes by which economic instruments for water resources management are developed. Stakeholder-oriented valuation features a pragmatic use of analytic tools, including some 'straightforward' economic analyses, which are relatively easy to incorporate in a participatory process. For instance, the main value driving the process in New York was the financial costs of filtration. This was relatively easy to estimate and, although the estimate had a considerable margin of uncertainty, it effectively triggered New York City to search for alternative solutions.

Conclusions

The available experiences show that economic arrangements can offer useful tools for efficient, equitable and sustainable water resources management, but that they need to be accompanied by adequate administrative arrangements and embedded in an appropriate institutional framework. Apart from knowledge about the economic, administrative and institutional arrangements, a proper understanding of the mechanisms that determine success of failure of economic arrangements also requires knowledge about the processes through which they are developed. A review of three cases where economic arrangements have been successfully implemented shows that the economic arrangements have been the result of a negotiation process among multiple stakeholders. The stakeholder process was especially important to reach an agreement about the administrative and regulatory arrangements that set the boundaries within which economic arrangements were confined to ensure that societal goals were not jeopardised. This means that new economic arrangements need to be carefully designed, with the involvement of multiple stakeholders.

More insight is needed into these multi-stakeholder processes, to identify certain commonalities that can help support future negotiations among stakeholders about the regulations and conditions required to put in place sustainable economic arrangements for water resources management. Nevertheless, one thing that is clear already from the three described cases is that a transparent assessment of the value that water resources represent to the involved stakeholders, as well as to society as a whole, will be helpful to support this process. For this, traditional economic valuation methods need to be complemented by stakeholder-oriented approaches that help to facilitate dialogue among stakeholders and that can effectively incorporate the broader societal concerns related to social equity and environmental sustainability, beyond mere monetary values. Further work in this area is needed, building on the experiences that have already been gained and from which a process for stakeholder-oriented valuation emerges. This needs to be further developed into sound operational methodologies that link water valuation to the stakeholder processes by which economic arrangements are developed. Specific attention is needed for the participatory aspects in such valuation methodologies, as well as for the assessment of the broader societal values associated with water resources management.

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Chapter 11.

Challenges of Water for Food, People and Environment – ICID's[1] Initiative on 'Country Policy Support Programme' (CPSP)

Mukuteswara Gopalakrishnan[2]

Introduction

Water is increasingly becoming scarce with ever rising and unabated growth rates of population, especially in developing and least-developed countries. Global food security can be assured only when a sizeable number of countries with a large population in these parts of the world can address to a meaningful extent their own national food security, if there is enough scope with available land and water.

The water challenge, though, apparently focusses more on the bi-polar aspects of water required for food production and water required for environmental security. It is important to recognise the role of water for the people sector. This includes the avowed water needs for drinking and other uses besides industrial needs. Both urban and rural requirements form part of them.

In the first phase of CPSP studies, detailed assessments in two countries, viz. China and India, were undertaken. Egypt, Mexico and Pakistan were also studied in a preliminary manner. One basin each in Mexico and Pakistan were also subsequently added using a similar approach; an intensive study of these basins and others was deferred for a future plan. These five countries were specifically chosen for the ICID studies because of the fact that they together cover 51% of irrigated area globally, and affect directly about 43% of the world population.

The study undertaken looks at the development and management of water, land and related resources, integrating the needs of various uses including vital needs of terrestrial and aquatic ecosystems.

In order to enable a rapid examination of the impacts of various future scenarios, a land and water use model, introduced with the acronym BHIWA, "Basin-wide Holistic Integrated Water Management", was developed. The aim was to handle an integrated computational framework for a basin-level assessment of water resources, keeping in view existing and other desirable options of water sector polices. This model was developed to consider the entire land phase of the hydrologic cycle; it is capable of

1. International Commission on Irrigation and Drainage – please visit the web page www.icid.org for more details of ICID, its mission and goals and other details.

2. International Commission on Irrigation and Drainage, New Delhi, India.

depicting human impacts such as changes in land and water use; also the impacts of water storage and depletion through withdrawals for various water uses, and inter basin water transfers. The model takes into consideration complex interaction between numerous factors including surface and groundwater, land use and natural water supply, storage and water withdrawals and returns, through separate water balances for surface and groundwater as well as an overall water balance.

To support the 'decision making', several scenarios were examined by a multifaceted hydrologic modeling which brings on board not only the hydrologic cycle, but also factors that are relevant for irrigated and rainfed agriculture, forestry and desirable flows in streams for the aquatic ecosystem.

The approach through modelling the entire land and water use of the basin, as developed, was found to be useful especially for understanding existing as well as future water availability; also for assessing future water needs under different scenarios, and for analysing the impact of different policy options for an integrated and sustainable development of resources. In a dynamic situation, one sees in the developing nations like India the conversion of barren lands either into forests or into irrigated or rain fed agriculture. Such actions tend to increase the evapo-transpiration, and in turn impact the river or stream flows adversely. Similarly, rainwater harvesting and soil and water conservation practices were also seen to influence the total as well as the inter-distribution of surface and groundwater. An impact of internal changes in land use invariably occurs in the long run. The changes in policies and programmes in regard to soil and water conservation can be properly tested only when the overall water balance for the entire land phase of the hydrologic cycle is studied. Dry season flow in rivers is contributed-to by shallow aquifers. Large-scale groundwater use for agriculture is becoming more common in some basins, particularly in India and Pakistan. Such use severely affects environmental interests and the sustenance of ecosystems, as the base flow in rivers vanishes, apart from depletion of the water table. The separate water accounts for the river-surface and groundwater systems enable a study of this in order to achieve integration of supply sources and to consider the natural and human-induced interaction between the surface and groundwater components. Nevertheless, one also sees that several hydrologic modelling solution techniques are available to study any basin in a detailed manner; but these are seen to be rigorous, and hence are more apt to evolve the best operational policies of existing systems that are developed fully. A quick and easier approach is to study the dynamics of different options where development actions are still being contemplated, as in India (and other developing countries). The impacts of such actions were required to help decision-making processes, and CPSP is one such attempt.

India was chosen for the detailed study alongside China, and this paper restricts its coverage to Indian studies only. Two typical basins were taken up. A water deficit basin in the west coast, namely the Sabarmati river basin, and a water rich basin in the east coast, namely the Brahmani river basin, were the candidates for this study. The location of these basins is shown in the India country map – (Annex Map 1).

For depicting the type of results emerging out of the CPSP, the example of Sabarmati is dealt with broadly in what follows.

Sabarmati River Basin

Sabarmati River Basin (Annex Map – 2) is one of the 24 river basins of India. This water deficit basin lies on the west coast of India between latitudes 22° N to 25° N and longitudes 71° E to 73° 30' E, and is spread across the States of Rajasthan and Gujarat. The river outfalls into the Arabian Sea (more specifically in the Gulf of Cambay, or Khambhat as it is well known locally). The basin has a total drainage area of 21,565 km^2. The basin has a tropical monsoon climate. The average annual temperature varies between 25 and 27°C. The rainfall occurs almost entirely during the monsoon months. The average rainfall of the entire basin is 749 mm. The rate of evaporation is maximum during April to June due to the rise in temperature and increase in wind speed. The average annual evaporation losses in the basin are in the order of 1500–2000 mm.

The total population in the basin (2001) is 11.75 million, of which 5.99 million is urban and 5.76 million is rural. The projected population of the basin for the year 2025 is 19.86 million, of which 10.81 million is urban and 9.05 million is rural.

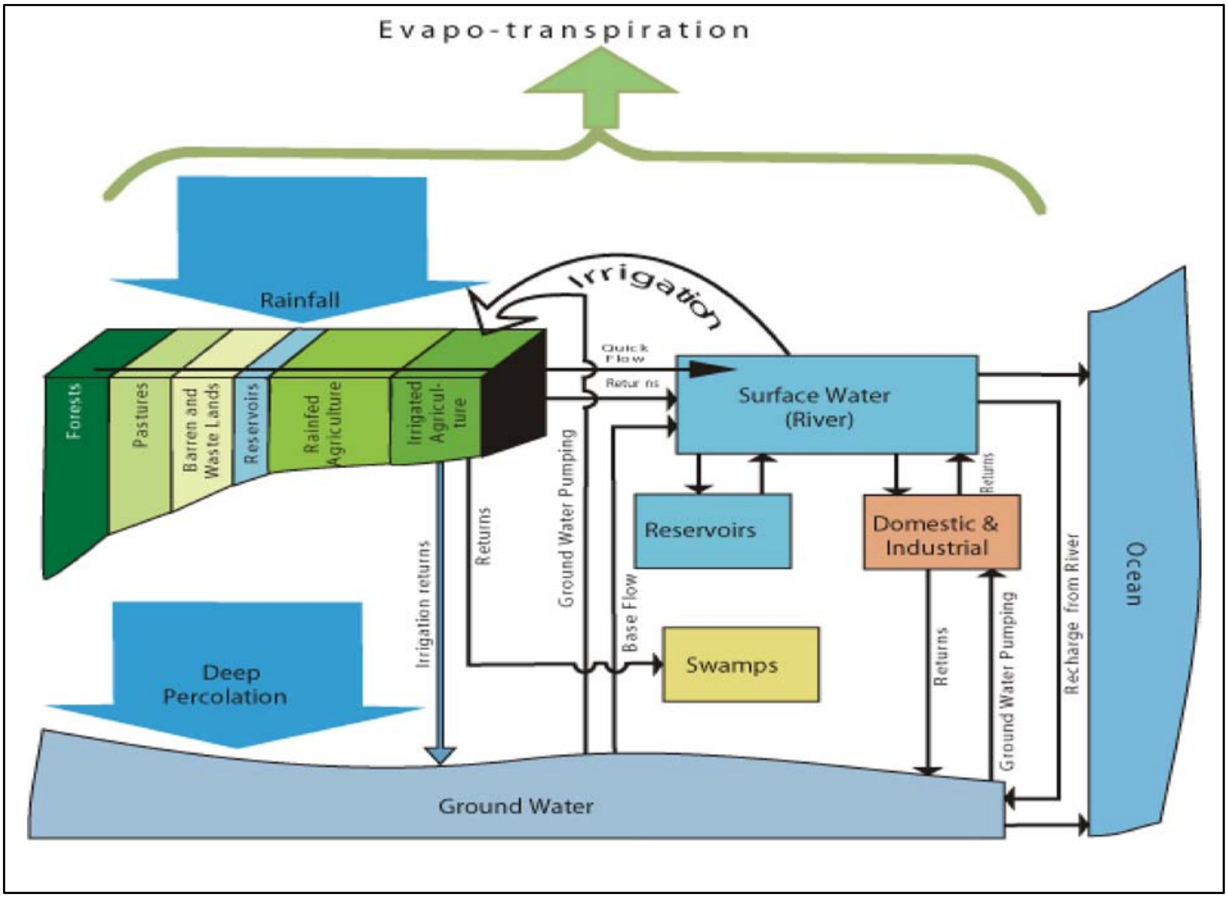
The annual mean water resource in the basin is estimated as 3,810 million m^3. Water consumption of surface water for irrigation has been estimated to be 3,465 million m^3 per year, including the Mahi command within the Sabarmati basin (1,663 million m^3). The groundwater contribution to agricultural use is estimated as 2,279 million m^3. The total demand for the year 2001 was in the order of 5,744 million m^3. The irrigation demands, considering the future expansion of areas and development of additional possible irrigable areas (with infrastructure like main canals ready), is about 4,554 million m^3. These are considered in some scenarios studied, which take into account inter-basin water transfer which has already been in place with an increasing provision in future. These include imports from the Mahi and Narmada rivers, which adjoin the study basin in its southern part. Since the basin suffers from overexploitation of groundwater, the groundwater demand for irrigation in the study has been restricted to the present use of 2,279 million m^3. Water requirements for humans and livestock in 2001 were 510 million m^3, which will increase by 2025 to 898 million m^3. The water requirement for the existing 20 industrial estates in the basin is 99.64 million m^3, and the demand is likely to be 245 million m^3 in 2025.

Basin-wide Holistic Integrated Water Management (BHIWA) Model

Figure 1 shows the schematic of the BHIWA model. The model covers the entire land phase of the hydrologic cycle, right from precipitation, and various water uses, river flow, groundwater recharge, returns, and outflow to the sea. The BHIWA model approach asks for a division of the entire river basin into sub basins and several homogeneous land parcels; depicting different land use categories such as forest land, pasture, waste land, wet land, land under infrastructure, land under reservoirs, rain-fed agricultural land, irrigated agricultural land, etc. is also necessary. The agricultural land can further be subdivided into parcels to represent broad seasonal cropping patterns (such as perennial crops, land with a single crop in two four-monthly seasons and not cropped in the third season, land under two different crops in two seasons and fallow in the third season, and land that is cropped only in one season and remains fallow in two seasons, etc.). The main inputs to the model include hydrological data, crop parameters, land use and land parcel areas, soil moisture capacity for each type of land parcel, irrigation system efficiencies, coefficients for return flow accounts, changes in reservoir storages, etc.

Giving due consideration to all the affecting parameters, such as monthly rainfall and the initial soil moisture content, soil moisture capacity, potential crop evapo-transpiration (etc.), quick runoff including interflow, ground water recharge, irrigation withdrawal and return, evapo-transpiration for nature and for agriculture sectors in each land parcel were worked out. The domestic and industrial withdrawals, use and returns were also accounted for.

Figure 1. Schematic Diagram of BHIWA model



The scenarios studied considered emerging possibilities, the developmental plans, and improved water and soil management plans etc. In Sabarmati River Basin, there is little possibility of additional dams and structures across the river, and there is no possibility of increasing the storage capacity. The available storage capacity in SB1 and SB2 is not fully utilised. There are plans for large imports from the Narmada River by inter-basin water transfer schemes. The Gujarat State Government, under whose jurisdiction the harnessing of Sabarmati River lies as per the Indian constitutional provisions, has evolved a plan for using monsoon (Indian rainy seasonal flows in rivers are from monsoons, as is well known) surpluses from the Narmada River, for pumping and filling up of the high level storages, including those in Sub Basin 1 and Sub Basin 2. Although there could be various pros and cons about these plans, their possibilities needed a quick evaluation. Similarly the possibility of constraints on imports due to inter-state issues (water, in a broader sense, being a state subject, as per the Indian Constitutions) also exists, and this needed a study. The present irrigation, with stress on post wet season (Rabi crops November-March) irrigation, was found to be causing a large reduction in river flows, and hence the idea of changing the emphasis and having increased irrigation in the wet season (Kharif crops: June-October) instead of post wet season, needed to be studied. Similarly, at present, groundwater is the predominant source of irrigation, and is already overexploited. If this trend continues, the situation may become totally unsustainable. Hence, a comparative reduction in groundwater use was studied in various scenarios. Improved water management through improving irrigation system efficiency and evaporation control, by adopting measures like mulching, weeding of barren areas and increasing the area under micro-irrigation, were also important strategies, which needed a study. The various scenarios are listed in Table 1.

Table 1. Scenarios studied in respect of Sabarmati Basin, India, in CPSP

No.	Scenarios	Description
1	Past (1960)	No water development
2	Present (1995)	Considerable storage, ground water and surface irrigation, and
3	Future I(2025)	Business as usual. Irrigation expansion with similar composition.
4	Future II (2025)	Business as usual. No Narmada import
5	Future III (2025)	Gujarat Plan. Large imports and exports, pumping imported water in
6	Future IV (2025)	Less expert and less import, to recognise competition amongst
7	Future V (2025)	Agriculture seasonal shift. Irrigation expansion mostly in wet season
8	Future VI (2035)	Similar to Future V, but ground water irrigation reduced. Reduced
9	Future VII (2025)	Similar to V, less irrigation expansion. Less ground water irrigation.
10	Future VIII (2025)	Smaller seasonal shift and improvements in water management

The types of policy support decisions that emerged out of these studies for future basin planning are quite revealing. The specific and overall lessons learned relate to issues of water use sectors, especially in the context of Integrated Water Resources Management. Given the fact that there are many water users and cross-cutting interests, any suggested action should not only be sustainable but also be attractive in a socio-politico-economic context (with a pro-poor and pro-woman leaning, a cherished goal in India). The study kept in view these aspects, which also came to the fore in the stakeholders' consultations and dialogues. A few such indicators are:

- Maintenance of water accounts, in terms of withdrawals, consumption and returns, separately for the requirements of food, the people and the nature sector, leads to a better understanding of water uses.

- The consumption levels of individual sectors (water for agriculture, people and nature) need to be assessed and integrated in order to understand the real impacts of land and water use and management policies. Consumption management is to be treated as an integral part of water and land related resources management.

- Nature sector water use needs to be accounted-for carefully, as it affects water availability in the rivers and aquifers and is important for maintaining the terrestrial as well as the aquatic ecology.

- The return flows from both point and non-point sources constitute a sizeable water resource. These could be of different qualities, depending on how the water is managed by each use sector. The return flows out of the withdrawals from surface and groundwater are available for re-use, subject to proper treatment to ensure the required water quality standard.

- Inter-basin surface water transfer is in some cases an inevitable option to meet the water needs of the basin for agriculture and for allowing restoration of the groundwater regime, and also for providing environmental flows required for the riverine ecosystem, besides improving river water quality through the re-use of effluents from domestic and industrial needs.

- Though watershed development/management enables more equitable use of land and water, and often involves harvesting of rain water where it occurs, watershed development upstream of the existing reservoirs could result, in some cases, in a considerable reduction in water availability, and should therefore be carefully analysed.

- Water requirements of the nature sector need to include both the requirements (mostly consumptive) of the terrestrial ecosystems like forests, grasslands, wetlands etc. and the water requirements (mostly non-consumptive) of the aquatic ecosystems. Both of these have to be decided through demand estimation, management, and tradeoffs.

- EFRs need to be recognised as a valid requirement. However, the stipulation of a desirable environment flow requirement for riverine eco-systems in water deficit basins needs more investigation and proper substantiation. Their estimation methods could be initially on an ad hoc basis, if rigorous methods are not available from Ecologists, and perhaps hydrology based. Better methods based on water regimes required by different species, also based on the tradeoffs between environmental flow and uses, as preferred by society, need to be evolved.

Brahmani Basin

The Brahmani River (Annex Map – 3) is one of the east-flowing rivers of India. The basin has a total drainage area of about 39,268 km² lying in different states of the Indian Union. The river has two main tributaries, namely the Sankh and Koel. The basin has a sub-humid tropical climate, with an average rainfall of 1305 mm, most of which is concentrated in the Indian southwest monsoon season of June to October. Rainfed agriculture is predominant, except in lower deltaic parts, where irrigation plays a major role. Compared to the national average, the basin has a higher proportion of both land under forests and cultivable wastelands. In contrast to Sabarmati, the basin is almost double its size, with a much smaller population (about 8.5 million total habitants in 2001) and an even smaller percentage of urban to total population. Relatively (in comparison to Sabarmati Basin) much less land is under irrigation. The irrigated area in recent years has averaged only about 1.23 million ha against a total cropped area of 1.57 million ha.

The basin has an abundance of mineral resources such as iron ore, coal and limestone. The Rourkela steel plant, built in 1960, is one of the large steel plants with substantial ancillary industries in the Angul-Talcher area. There are two large thermal plants established by the National Thermal Power Corporation and the National Aluminium Company, besides coal-based fertiliser plants set up by the Fertilizer Corporation of India. Industrial activity in the basin is picking up substantially.

The basin is rich in forests which occupy as much as 37% of the basin's total area. Near the Brahmani-Baitarani delta are located mangrove ecosystems, including the famous Bhitarkanika National Park and a wildlife sanctuary. About 215 km^2 of the mangroves in this region was listed as one of the RAMSAR sites in November 2002. The basin has considerable potential for development of inland fisheries in reservoirs, ponds, tanks and canals. The occurrence of floods, particularly in the deltaic region, is a common feature, and on average a population of about 0.6 million and crop production of over 50,000 ha is affected annually. A large multi-purpose dam, the Rengali project, was completed in the year 1985, and has provided some relief to the lower flood plains in this regard, but its canal systems are not yet fully ready. Pollution of surface water of the Brahmani, and some of its tributaries below Rengali, on account of discharge of industrial effluents continues to be a cause of concern, despite some recent measures by the Orissa State Pollution Control Board to improve the situation.

Water assessments

The initial basin-level consultations were held based on preliminary studies, primarily to help identify issues concerning water use for the food, people and environmental sectors. The BHIWA model was applied to derive responses to

1. past,
2. present and
3. four future alternative scenarios using long-term average rainfall. These include:
    a) Business as usual (B as U) Scenario (F-I)
    b) Large expansion of agriculture and irrigation (F-II) to harness much of the water and land potential
    c) More industrialisation, considering the present base and its future growth (F-III)
    d) Lesser agriculture and industrial expansion with increased allocation of water to nature sector needs and navigation (F-IV).

In all three future cases (3b, c and d), better water management by best practices was presumed, and irrigation system efficiencies increased for the future scenarios; as well, recycling and reuse are also assumed.

The total water input (rainfall and imports) to the basin is 51,586 million m^3. The major water outflow from the basin comprises consumptive use (69%) and river flows (31%). The total consumptive use (in terms of evapo-transpiration — ET) at present (2000) is 34,138 million m^3 comprising about 64% by the nature sector (forests, pastures and barren lands), 35% by the agriculture sector (rainfed and irrigated agriculture) and 1% by the people sector (domestic and industrial). The non-beneficial ET is about 28% of the total consumptive use.

Major findings

The major findings of the assessment are:

- The nature sector is by far the largest consumer of water.
- The contribution of groundwater to base flow is increasing, indicating risk of waterlogging.
- Future withdrawal requirements would need full use of Rengali Dam storage, as well as creation of additional storage in the basin.
- Considerable land would remain rain-fed, and productivity increases may require watershed management of upper regions.
- The basin would not have overall water shortages, even in the projected scenario of increased agricultural and industrial water use.

Policy-related issues emerging out of Brahmani Basin studies

Some important policy-related choices emerging from the Brahmani river basin assessments are:

- A shift in the concept of "water resources": in order to consider the impacts of nature sector use, both terrestrial as well as the needs of aquatic eco-systems, impacts of rainfall harvesting, artificial recharge and, above all, for integration across the three sectors, precipitation is to be considered as the primary renewable water resource.
- The need to account for return flows as additional water available for use.
- The need to account for water use by sectors, and their integration.
- The need for recognising EFR and mainstreaming such requirements into basin water management;.
- The need for a more balanced use of surface and ground water and provision of adequate drainage and relief from floods.

- Improving water distribution and on-farm efficiencies through participation of beneficiaries
  - improved designs and O&M of structures, agricultural practices, waste water treatment technologies, etc.
- The need to adopt a participatory approach in regard to the choice of a strategy for flood control.
- The need for exploring the possibilities of 'inland navigation' in and near the delta, and the need for integrating water needs for navigation (which may be compatible with EFR and hydropower), and consumptive uses.
- Multipurpose reservoirs like Rengali, generating hydropower, play a great role in maintaining or even improving low season river flows. However, the effects of any changes in the hydrologic regime, including improvement of flows, on the aquatic ecology needs to be studied and understood.
- There is a need for the integrated management of land and water resources and the integration of rural livelihoods.

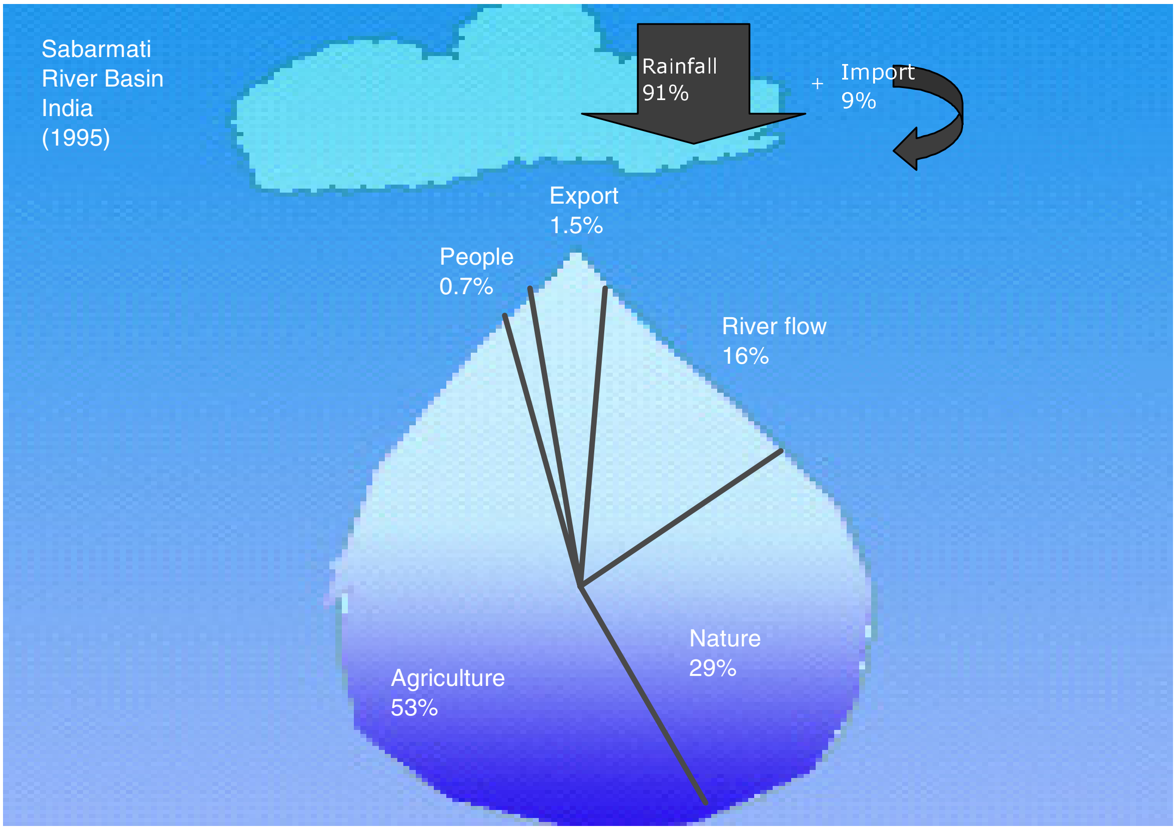
Allocation of available water in the respective basins

The types of studies carried out in respect of both Sabarmati and Brahmani basins in India yielded good insights on the sectoral allocation of water, and a scenario for each case is depicted in the text (Figure 2 and Figure 3).

These studies gave an insight into inter-allocation stress, if any, between different water users; essentially the people sector (both drinking and industrial), food sector (essentially agriculture) and the nature sector (terrestrial and aquatic ecosystem needs). In our study, forests were classified as of interest to the nature sector, and the allocations shown against them are depicted accordingly.

Water stress indicators were also evolved in an independent manner in the process, essentially in terms of withdrawals of surface water and groundwater (abstractions by pumping). Return flows were accounted for, which also gave an insight into the impacts on water quality. Having done this at basin scale, an extrapolation of a preliminary nature for all the basins was attempted, so as to sequentially order further detailed studies to investigate the possibility of severe stress, and the scope for inter-basin water diversions as a solution strategy. These are explained in what follows:

Figure 2. Water allocation for people sector, food sector (agriculture) and nature sector in respect of Sabarmati basin



Water situation indicators (WSI)

The following four indicators are proposed for the modelling framework used in detailed assessments for the purposes of describing pressure on resources due to withdrawals and threat to water quality:

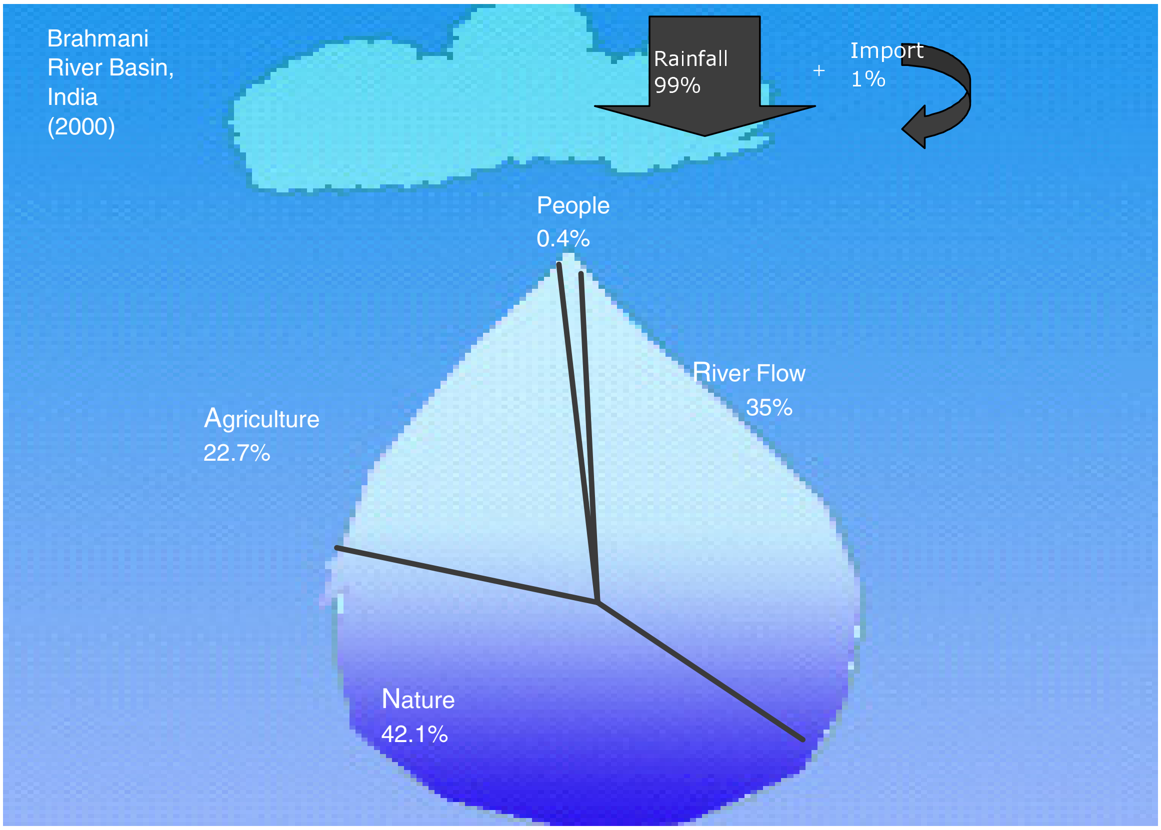
Indicator 1: Withdrawals/ total input to surface water

Indicator 2: Returns/ total input to surface water

Indicator 3: Withdrawals/ total input to groundwater

Indicator 4: Returns/ total input to groundwater.

Figure 3. Water allocation for people sector, food sector (agriculture) and nature sector in respect of Brahmani basin



These indicators have been considered more relevant to situations in developing countries like China, India and Pakistan for the following reasons:

1. A large amount of groundwater is used in India and Pakistan as well as China. One needs indicators which reflect water uses from both surface and groundwater sources.

2. The WSI, as defined based on 'withdrawals' by some authors earlier, does not account for the 'substantial part of the withdrawal' which would return (to surface or underground sources). Either one needs to consider the returns as an additional resource, adding to the natural runoff, or one needs to consider the 'net consumptive use' rather than withdrawals.

3. All use for terrestrial natural eco-systems, food or people is accounted-for on an equal footing, as it is desirable to have a prima facie look at what each such sector is drawing from the sources of water. For many basins that are water-deficit, or at a threshold level, a competing situation between such sectors arises and tradeoffs have to be looked into critically, and this approach is superior (to begin with such a review process in

allocation). The in stream environmental uses are not consumptive and can be considered as one of the requirements competing with others. It remains un-consumed, supporting aquatic ecosystems till it reaches the ocean.

4. Since large land use changes can also affect the natural supply, any other type of single prescription based on quantity ceilings may not be desirable. Either a 'natural' land use, which does not allow for human interventions through agriculture, or a 'pseudo-natural' condition, where agriculture is allowed but irrigation is not, would have to be defined for this purpose.

The proposed indicators depict the water situations in the basins in quantitative as well as qualitative terms. Indicators 1 and 3 depict the level of withdrawals as fractions of total water available in the surface and groundwater system, respectively. Indicators 2 and 4 depict the potential hazards to water quality in surface and groundwater systems respectively. These indicators are subdivided into four categories each to represent the degree of water stress (Table 2).

Table 2. Categories of surface and groundwater indicators

Indicator 1 – surface water quantity	1. Very high stress – value of indicator more than 0.8 2. High stress – value of indicator between 0.4 and 0.8 3. Moderate stress – value of indicator between 0.2 and 0.4 4. Low stress – value of indicator less than 0.2
Indicator 2 – surface water quality	1. Very high threat – value of indicator more than 0.8 2. High threat value – value of indicator between 0.2 to 0.8 3. Moderate threat – value of indicator between 0.05 and 0.2 4. Low or no threat – value of indicator less than 0.05
Indicator 3 – groundwater withdrawals	1. Very high stress – value of indicator more than 0.8 2. High stress – value of indicator between 0.4 and 0.8 3. Moderate stress – value of indicator between 0.2 and 0.4 4. Low stress – value of indicator less than 0.2
Indicator 4 – groundwater return flows (quality indicator)	1. Very high threat – value of indicator more than 0.8 2. High threat – value of indicator between 0.4 and 0.8 3. Moderate threat – value of indicator between 0.2 and 0.4 4. Low threat – value of indicator less than 0.2

Assessment for India in general by an extrapolation of Sabarmati and Brahmani Basin studies to understand water stress

The various rivers and river basins of India are seen in Annex 1.

After an assessment of indicators as above in respect of Sabarmati and Brahmani Basins, an upscaling was attempted.

On an analogy, the results of the Sabarmati River basin (water stressed basin) could be of relevance to the other Indian river basins of Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi in regard to surface water.

In regard to groundwater quality, the problems of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery could be similar to Sabarmati.

On the other hand, some problems of the Brahmani River basin (water rich basin) are attributable to high river flows and low use of groundwater. Brahmaputra, Godavari, Mahanadi, Tapi, Narmada and Mahi river basins in India could have similar groundwater-related problems, and therefore policies to increase groundwater withdrawals in future may be desirable.

The water resources availability both in respect of surface and groundwater are shown in Table 3.

An approximate insight for the present conditions in respect of other Indian basins

Grouping of various Indian river basins based on the foregoing criteria and values of water situation indicators are presented in Table 4.

Estimation of environmental flow needs

Fair and reasonable assessments of the riverine ecosystem needs posed difficulty throughout the exercise, in the absence of expert study inputs, and were largely based on consultations with stakeholders with some degree of arbitrariness.

Brahmani River has a considerable lean season flow, and sizeable fish numbers, particularly in lower reaches, supporting many livelihoods. Although the water development structures like Jenapur Dam (early 20th century) and Rengali Dam (late 20th century) caused some obstruction to free movement, fish catches and species are so considerable that an adverse impact situation does not currently appear.

Considerable areas of mangroves cover the mouths of the Brahmani, and other rivers have a common delta. The mangrove around Bhitarkanika is a well-known area of interest, especially for ecological interests. Migration of people from within and outside the basin and new settlements in the mangrove areas were identified as the main reason for the progressive and apparent reduction of mangrove areas. The mangrove species prevalent in any area are likely to depend on the tidal range, the salinity levels in the estuary, and the salinity in the root zone soil and moisture/groundwater. Unfortunately, no correlation between headwater discharge and estuarial salinity is available, nor could one be established from the available sparse data.

Of primary importance in the future would be a good response-based objective analysis, or studies projecting the realistic demand of minimum flows in different stretches of the rivers, not only for the Sabarmati and Brahmani, but also for all the riverine eco systems of India.

People sector requirements can be the first charge on fresh water. The study is a pointer to demonstrate that return flows after withdrawal for agriculture could also help (if duly treated, even for industrial and other uses) and sustains other aquatic ecosystems. Such an approach would ensure a win-win situation in both sectors, i.e. water for food and water for environment. Policy support suggestions are considered valuable if they are based on basin studies and bring in cross-cutting issues and interests.

Table 3. Water Potential of India by basin (Basin Map of India at Annex 1)

(Values are in Cubic Km/Year. A basin map of India is at Annex 1)

Sl No.	Name of river basin	Average annual potential in river	Total replenishable GW resources
1.	Indus (up to border)	73.31	26.49
2.	a) Ganga	525.02	170.99
	b) Brahmaputra Barak & others	585.60	26.55, 8.55[1], 10.83[2]
3.	Godavari	110.54	40.65
4.	Krishna	78.12	26.41
5.	Cauvery	21.36	12.30
6.	Pennar	6.32	4.93
7.	East Flowing Rivers Between Mahanadi & Pennar	22.52	
8.	East flowing rivers between Pennar and Kanyakumari	16.46	18.22[3]
9.	Mahanadi	66.88	16.46
10.	Brahmani & Baitarni	28.48	4.05
11.	Subernarekha	12.37	1.82
12.	Sabarmati	3.81	
13.	Mahi	11.02	
14.	West flowing rivers of Kutch, Sabarmati including Luni	15.10	11.23+ 7.19[4,5]
15.	Narmada	45.64	10.83
16.	Tapi	14.88	8.27
17.	West flowing rivers from Tapi to Tadri	87.41	
18.	West flowing rivers from Tadri to Kanyakumari	113.53	17.29[6]
19.	Area of inland drainage in Rajasthan desert	NEG.	
20.	Minor river basins drainage into Bangladesh & Burma	31.00	
	Total	**1869.35[7]**	**431.42[8]**

1. Meghna value assessment.

2. North East: a composite value

3. Madras and south of Tamilnadu

4. Kutch and Saurashtra composite

5. Cambai composite.

6. Western Ghat all-inclusive.

7. Official web site statistics of the Government of India 2005 (Surface Water Resources data). These data, given independently for surface and groundwater, have some differences in the basin categories and hence some readjustments have been made in the table to put GW under the corresponding row of a river basin in the table.

8. Official web site statistics of the Government of India 2005 (Ground Water Resources data).

Table 4. Water situation indicators of river basins in India

Class description	Value of indicator as proposed in the paper	River basin(s) of India (Annex 1 shows an 'India basin map' for reference)
	Indicator 1	
Very highly stressed through surface withdrawal	>0.8	Pennar
Highly stressed, through surface withdrawal	0.4 – 0.8	Cauvery
Moderately stressed, through surface withdrawal	0.2 – 0.4	Indus, Ganga, Subarnarekha, Mahanadi, Tapi, Sabarmati
Low stress, in regard to surface withdrawal	<0.2	Brahmaputra, Godavari, Brahmani
	Indicator 2	
Surface water quality, low stress	< 0.05	All basins
Surface water quality, moderate stress	0.05 – 0.2	Cauvery, Tapi, Sabarmati, Pennar
	Indicator 3	
Groundwater very highly stressed through withdrawals	>0.8	Sabarmati
Groundwater highly stressed through withdrawals	0.4 – 0.8	Indus, Ganga, Subarnarekha
Groundwater moderately stressed through withdrawals	0.2 – 0.4	Mahanadi, Godavari, Krishna, Pennar, Cauvery,Tapi, Narmada, Mahi
Ground water low stressed	<0.2	All other basins including Brahmani
	Indicator 4	
Groundwater quality under very high threat	>0.8	None
Groundwater quality under high threat	0.4 – 0.8	Indus, Ganga, Subarnarekha, Krishna, Pennar, Cauvery, Sabarmati
Groundwater quality under moderate threat	0.2 – 0.4	Brahmaputra, Mahanadi, Godavari, Tapi, Narmada, Mahi, Brahmani

Conclusions

Some of the interventions thrown up through by ICID's CPSP studies in India are of interest, though they are country specific. They relate to how best some of the provisions in the existing Country Water Policy could be reviewed in the context of individual basins. A few suggestions are listed below for the facilitation of the decision-making processes and mechanisms available in the region:

- Identify a time-bound programme for investments needed in the five year plans to meet the needs of 2025.
- Integrate surface water and groundwater.
- Aim for attaining equity, efficiency, economy and efficacy in all aspects of water resources development.
- Identify basin-wise contemplated storage schemes and undertake and complete them by 2025. Enhance useable waters simultaneously through special means, such as inter-basin transfers.
- Undertake watershed development and management in rain-fed areas through ample provisions.
- Maintain food security through 'sufficiency plus buffer stocks' and through governance towards 2025. Divert areas to cash crops if and when food production exceeds this threshold level.
- Collect, evacuate, treat and recycle all wastewater. Do not allow release of polluted water directly into rivers. Industry should only use make-up water.
- Implement drainage schemes to allow irrigated agriculture to convert non-point sources of pollution to point sources of collected drainage water, to enable treatment and re-use.
- Water resource development redistributes terrestrial waters to land from which it can run off, and hence can be considered as eco-friendly. Maximise the productivity of terrestrial eco-systems consuming significant quantities of waters. Quantify it.
- Assess the lengths of river systems presently supporting aquatic eco-systems. Try to sustain them. Assess goods and services provided by eco-systems for humans. Where possible, shift fisheries to reservoirs from flow systems.
- Stop encroachments on mangroves, assess freshwater need and provide it by pipelines, rather than through river channel, terming it environmental flow requirements (EFR). Dispassionately examine EFRs and minimum flow needs (MFN) based on realistic studies/needs. They are expensive, and do not reach targets if the needs of en-route human systems are left unattended.
- Assess and promote public awareness of flood amelioration provided by dams, including drought proofing and avoiding desertification.
- Adopt all science and technological interventions on a priority basis to bring about realisation of the objectives of Integrated Water Resources Development and management.
- Investment for addressing water needs for food, people and nature has many tacit returns. Quantify them independently and collectively, to help generate a propensity by policy makers and national governments to allocate these.[3]

3. The views expressed in this paper are the author's impression, and are not necessarily the opinion of the organisations which he serves, or has served in the past.

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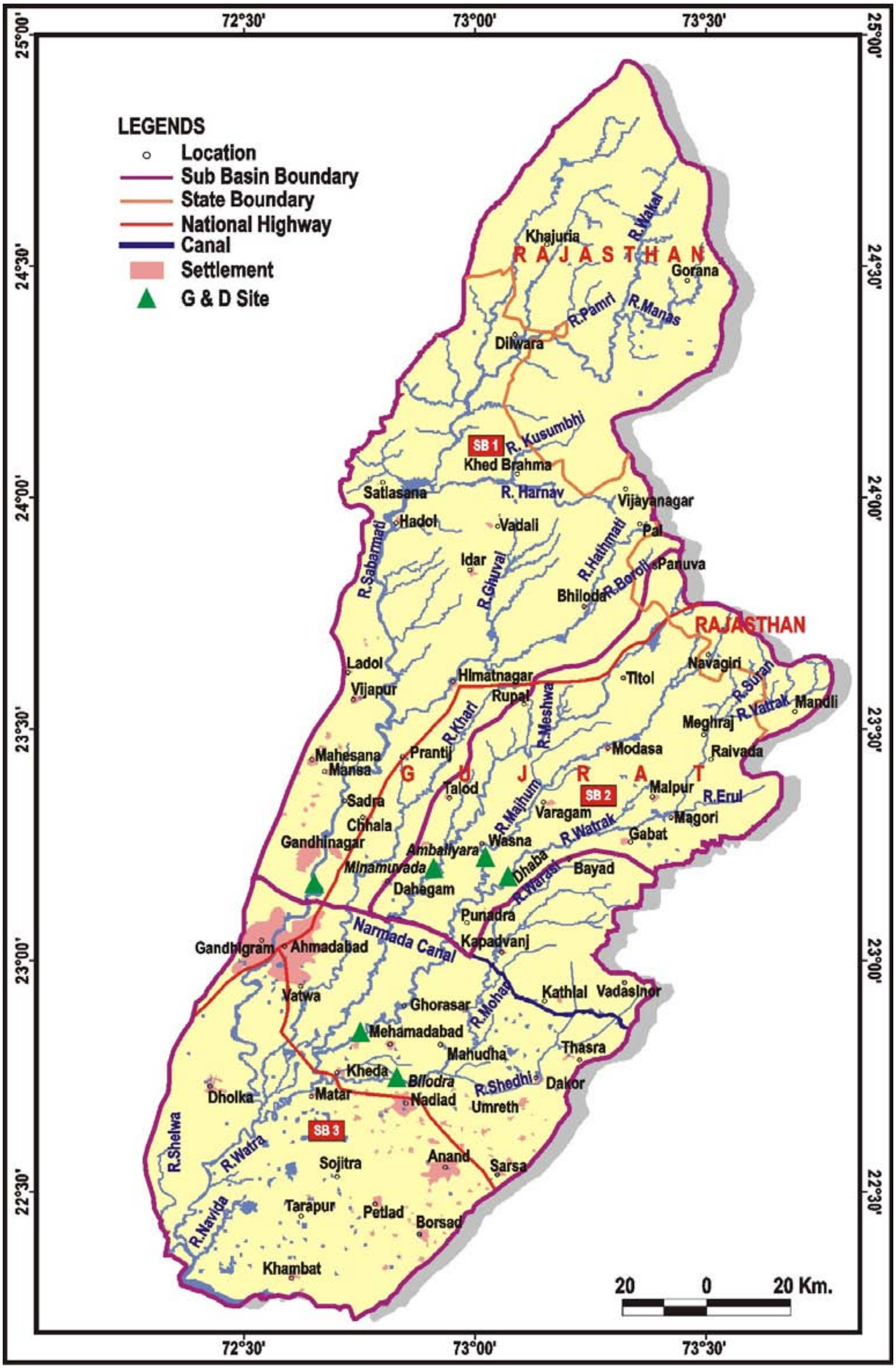
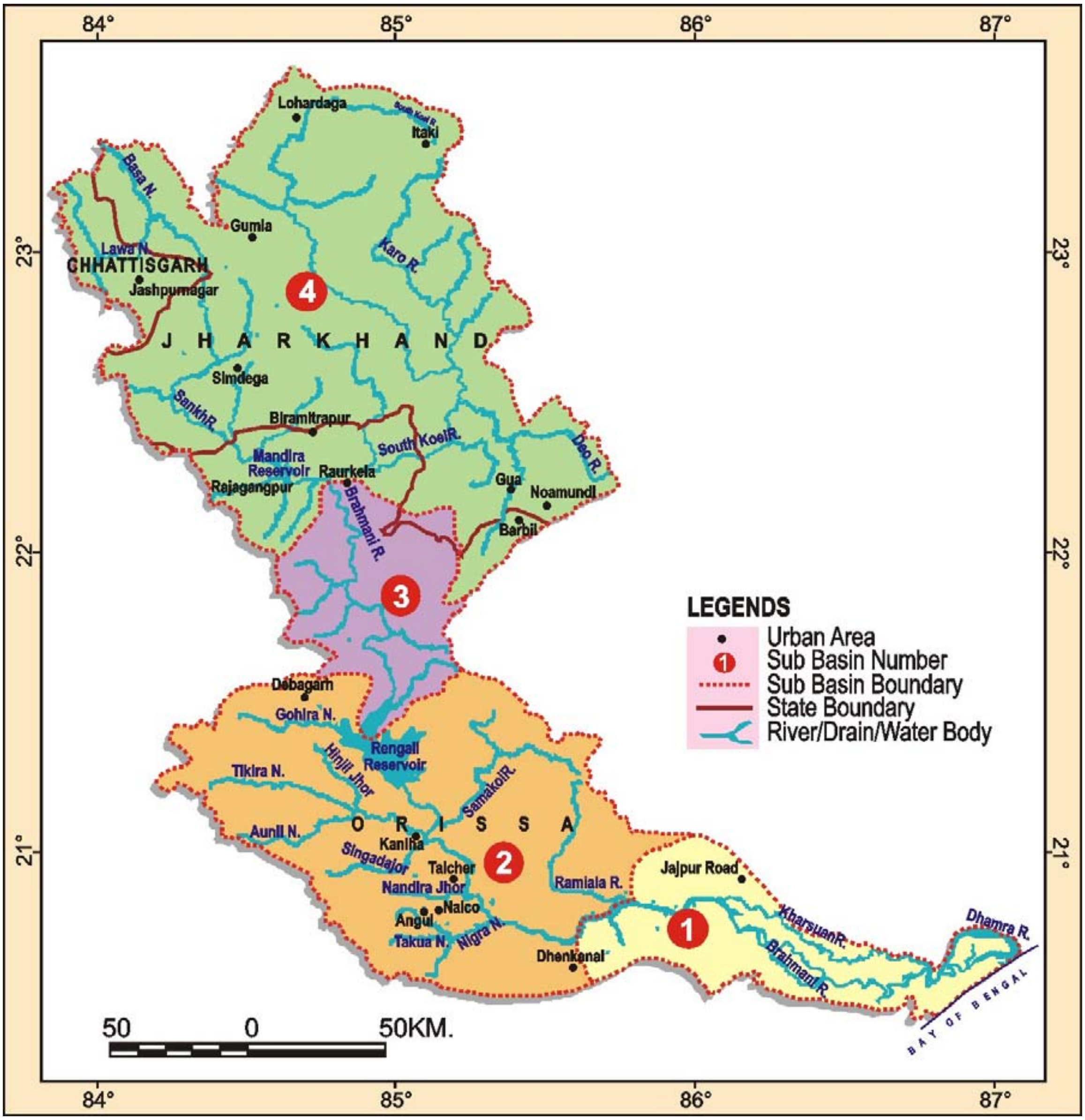
Annex 1.

1. Indus
2. Ganga
3. Brahmaputra
4. Subarnarekha
5. Brahmani-Baitarani
6. Mahanadi
7. Godavari
8. Krishna
9. Pennar
10. Cauvery
11. Tapi
12. Narmada
13. Mahi
14. Sabarmati
15. West Flowing Rivers of Kachchh and Saurashtra Including Luni.
16. West Flowing Rivers South of Tapi.
17. East Flowing Rivers between Mahanadi and Godavari
18. East Flowing River between Godavari and Krishna
19. East Flowing Rivers between Krishna and Pennar
20. East Flowing Rivers between Pennar and Cauvery
21. East Flowing Rivers South of Cauvery
22. Area of North Ladakh Not draining into Indus
23. Rivers draining into Bangladesh
24. Rivers draining into Mayanmar
25. Drainage Area of Andaman and Nicobar and Lakshadweep

Annex 2. Sabarmati Basin



Annex 3. Brahmani Basin



Chapter 12.

The Spanish Programme of Improvement and Modernisation of Traditional Irrigation Systems

Pablo Pindado[1]

The need for the improvement and modernisation of Spanish irrigated areas is easily understood when some of their technical characteristics are taken into account. One of them gives a good idea of the problem: one third of the Spanish irrigated area is more than a century old. The improvement and modernisation programme attempts to correct this situation, which burdens the competitiveness of the irrigated agriculture and causes environmental concerns, and this programme aims to upgrade irrigation schemes and increase the irrigation efficiency up to 70%. Other objectives are water savings, upgrading technologies, decreasing diffuse pollution, improving farmers' quality of life … To carry out such a programme, a great effort of co-ordination and co-operation among public administrations and stakeholders has been expended. This effort has led to a high state of implementation at present.

Introduction

Irrigation is the main user of water in Spain: 23 000 hm^3/year. This represents nearly 70% of the water used in the state and 50% of the water kept in reservoirs and dams. The Spanish area with irrigation infrastructure is nearly 4 million ha (9.88 million acres). Approximately 3.3 million ha (8.2 million acres) of that is irrigated on average each year, this is roughly 1% of the arable area, and this produces about 60% of the whole agricultural output. This means that the Spanish irrigated agriculture provides six times more income than dry-land agriculture.

The Spanish programme of "Improvement and Modernisation of the Traditional Irrigation Systems" is one of the five[2] programmes included in the National Irrigation Plan. This plan, carried out by the Spanish Ministry of Agriculture, Fisheries and Food, analysed[3] the situation (water demand, water supply, conveyance systems, irrigation

1. Ministry of Agriculture, Fisheries and Food, Madrid, Spain.

2. Improvement and Modernisation, Infrastructure in Irrigation Bodies into Execution, New Infrastructure for Social Purposes, New Infrastructure in Private Irrigators Communities, Support Programme.

3. Sixty-three per cent of the irrigated land was studied.

networks, water management schemes…) of the irrigation areas. The analysis showed that several of their technical characteristics constrain the irrigated agriculture in a lot of these areas. One important characteristic can explain various problems of the Spanish irrigation systems: one third of the Spanish irrigated area is more than a century old.

A result is, for example, the fact that one third of the irrigation area in Spain[4] gets its water via channels which waste water through leakage (700 000 ha are irrigated using ditches; and where concrete channels are used, 400 000 ha are irrigated with these in bad conditions). 420 000 ha extract water from aquifers that are over-exploited or are in danger of saltwater intrusion.

Sixty per cent of irrigated areas are irrigated by flooding, but more than a third of irrigation lands do not have their water supplies ensured[5]. Farmers work in shifts in nearly 50% of the irrigated land, and Spanish irrigation efficiency is 60%.

The total area affected by one or more of these problems is assessed at 2 269 781 ha. So, this represents 65% of the irrigated land in Spain. This huge dimension of the problem means that it cannot be resolved in one step. The Spanish programme of improvement and modernisation of the traditional irrigation system hopes to remedy problems in half of that area by 2008. This means that 1 134 891 ha of Spanish irrigation area should be improved or upgraded by this date.

Objectives and actions

To improve the general situation of Spanish irrigation it is necessary to design actions aimed at resolving problems in two main areas: firstly, to save water by reducing leaks and secondly, to increase efficiency rates all along the waterways (conveyance, irrigation network, application system on farms). These water savings lead to ensuring water availability and competitive irrigation agriculture.

The programme aims to:

- Optimise the agricultural irrigation by increasing by ten percentage points the efficiency of the whole system (to reach 70%), which would make possible **water savings** in all the irrigation areas. These water savings could be very important in volume in areas without supply problems, or in those with more water supply than demand. This is already an environmental improvement (less water abstractions), but also, it allows for extra water resources for environmental purposes (wetlands, aquifers) or, in some cases, these water savings could be allocated to under-supplied water irrigation areas.

- Improve the **water management**, by promoting new technologies, lowering production costs, increasing the value-added and upgrading manpower efficiency, which leads to a strengthened competitiveness of farms and of the rural economy. Also, this improves the quality of life of workers, farmers and their families.

4. 3 760 000 ha with irrigation systems; 3 344 637 ha irrigated on average (9 291 000 acres; 8 264 485 acres)

5. An irrigated plot of land is considered "under-supplied" when water supply is less than 70% of the demand.

- Achieve a technological shift, by using **new technologies** in irrigation, in order to upgrade farm management and increase productivity as a main objective. This is a horizontal need linked to other objectives of the Programme, as well.

- Use of sewage **water**, as an additional resource of water.

Some specific actions that are carried out include:

- Replacement of conveyance **systems**: from channels to pressured or low-pressured pipelines. This will save water, reduce wasted water through leakage and allow a better water distribution.

- Replacement of **application systems** in farms. Of course, this action needs to be taken by the farmers, but what the Programme of Improvement and Modernisation does is to improve the irrigation networks of irrigation districts so that they provide enough water (water resources reliability) and in optimum conditions of pressure. This way, every farmer will take advantage of this situation and will replace their application systems from flood irrigation to sprinklers or drippers. Please note that 60% of irrigated land uses flood irrigation, whereas sprinklers and drippers are used only in 24% and 17% of the irrigated land respectively.

- Improvement of conveyance **management**. More control of water distribution (canals) in irrigation districts leads to lower water return flows and to an optimal supply-demand balance between basin authorities and users associations. This is not only a consequence of the two above-mentioned actions, but it implies the use of new technologies and an overall rationalisation.

- Similarly, a better control of water in irrigation districts is achieved by **metering** the water consumed by farmers. New technologies can help, not only in metering but also in management, at the irrigation district level, of water demands and real water use on farms.

- It is clear that **new technologies** are a key issue. Examples are: automation of the irrigation networks (improving working conditions and quality of life), geographical information systems implemented in irrigation district centres (where the management of the irrigation associations is carried out) and linked with automatic devices of the network …

- **Other actions** are complementary, so they do not directly affect irrigation systems. For example: pathway improvement and land consolidation (necessary in some areas, otherwise this will affect competitiveness through aged infrastructure and it will be impossible to take advantage of the upgraded irrigation system), improvement of drain systems, repairing of channels …

The goals of the programme are socio-economic and environmental. At the socio-economic level, the programme strives to increase and ensure farm income by upgrading crop-market adaptability and by lowering the outcome risk, which improves quality of work and rural life in general and prevents depopulation. Among the environmental goals, the programme will achieve water savings or the reduction of diffuse pollution by decreasing run-off and leaching.

Environment

There are two main water sources for irrigation purposes in Spain: surface water (75% of the volume) and groundwater (25%). There are other sources, but they are not relevant in terms of volume: water transfers between basins, return flows, water depuration, and desalination. The last two sources are not important in volume, but very important as new ways to provide irrigation water. In specific zones like the east of Spain (arid) or the Spanish islands, these sources become more important.

Regarding the aquifers, some are over-exploited, so it is necessary to improve the efficiency of the irrigated areas that abstract water from them.

It is expected that in 2008 the water saving will be around 1 250 hm^3/year. This is 10% of the water used in irrigation agriculture.

The rationalisation in the water used on-farm will reduce the use of inputs like fertilisers or pesticides, and in the long-term, reduce diffuse pollution.

Implementation of the Programme

The Spanish Programme of Improvement and Modernisation of Irrigation Systems is implemented by the Ministry of Agriculture, Fisheries and Food, the regional governments and the farmers (grouped in irrigation districts).

Two of the main characteristics of the National Irrigation Plan are **co-ordination** and **co-operation**. In the first phase, the ministry and the regional governments worked together drawing up this plan, taking farmers' demands into account. With regard to the Improvement and Modernisation Programme, the farmers, who are grouped in irrigation districts, are fully involved in the programme at different levels: they are the target, they design improved irrigation projects and they co-finance the investment.

This point, the co-financing of the investment, is a key factor in terms of involving the farmers in the modernisation of their irrigation districts and farms. It is agreed that 50% of the investment (the project budget) is financed by public administrations (Ministry or Regional Governments, and also EU funds) and farmers pay[6] the remaining 50%. It is important to note that the Improvement and Modernisation Programme does not affect farms, but is focussed on the different parts of the irrigation district owned by the farmer association as a corporate body. This means that farmers must invest also in their irrigation application systems, to be able to take advantage of the improved irrigation conveyance and network. The farmers' co-responsibility is a main goal in the programme.

To manage this programme, four state-owned companies have been created, each one working in a specific area of the Country (south, middle and east, northeast, northwest). These companies work at several levels: they conclude agreements with irrigation districts, they design irrigation projects[7] based on these contracts, they are in charge of the construction of the projects, they recover the investment from farmers, and they provide technical support and advice to the irrigation districts.

6. Using long-term loans and other facilities.

7. In some cases, the irrigation project is designed by farmers' associations.

Achievements

The state of implementation to 31 December 2004 of the Improvement and Modernisation Programme was very satisfactory. This can be seen from Table 1.

Table 1. Execution degree of the programme

Area involved			Investment		
Planned by 2008 (ha)	Carried out[1] (ha)	Execution rate (%)	Planned by 2008 (€)	Invested[2] (€)	Execution rate (%)
1 134 891	1 384 696	122,01	3 056 591 302	1 504 487 055	49,22 [(3)]

1. Works finished or in execution.

2. Paid.

3. The rate rises to 84,83 % if we only take only account the planned public administrations investment and their execution degree: € 1 527 494 651 and € 1 295 746 286, respectively.

Conclusions

The Improvement and Modernisation Programme aims to save 1 250 hm^3 of water resources, which can then be used for other purposes (environment, re-allocation in other irrigation areas).

The execution degree of the Improvement and Modernisation Programme is fully satisfactory, because the figures shown in Table 1 correspond to 2000–2004 in terms of execution, but to 2000–2008 in terms of planning. These rates show the high interest of farmers in the programme.

The National Irrigation Plan showed that 2 269 781 ha need improving or modernisation. Fifty per cent of this target was planned for completion by 2008, so there is further work to accomplish for the period from 2008 onwards.

Part III.

Environmental Issues Related to Agriculture's Impact on Water Quality, Quantity and Ecosystem Functions

Chapter 13.

Balancing Consumptive and Environmental Water Use – An Australian Perspective

Christine Schweizer and Judy Lai[1]

Australia is the driest permanently inhabited continent. With annual rainfall of less than 600 millimetres across 80 per cent of the land and drought a regular feature of the Australian climate, the development of water resources in regional Australia has made a significant contribution to national wealth, underpinning the development of primary industries as well as cities and towns. Settlement and economic growth has relied upon large-scale damming, diversion, pumping and drainage of surface waters, reclamation and loss of wetlands and extraction of groundwater for irrigation, stock, domestic and industrial use. Many of Australia's waters and water-dependent ecosystems have suffered degradation, including declining water quality, habitat loss, salinisation and loss of biodiversity. Balancing the needs of the environment — including the flows required to maintain and restore healthy rivers — with water allocation for consumptive users, is a major task facing Australian governments and communities. This paper reflects on the co-operative, intergovernmental responses in Australia to increase the efficiency of water use and improve the sustainability and productivity of the agricultural sector, while promoting the health of river and groundwater systems. Case studies, including from the Murray-Darling Basin and Great Barrier Reef catchment, illustrate approaches taken by Australian policymakers for policy setting and programme delivery to achieve these multiple objectives.

1. Water — A key driver to achieving national growth in the sunburnt country

The Australian continent of 7.6 million square kilometres is the driest permanently inhabited continent, facing extreme irregularity in water availability. Its rainfall level is low and volatile. The average rainfall is only 469 millimetres per year (DAFF, 2004), with 80 per cent of the land receiving less than 600 millimetres. Rain, when it does fall, is unreliable compared to Europe and North America — recurring droughts are a regular feature of the Australian climate. Extremely high evaporation rates compound the water problem Australia faces with low and irregular rainfall — only 12 per cent of rainfall is collected in rivers, compared with a world average of 65 per cent (DAFF, 2004).

1. Land, Water and Coasts Division, Department of the Environment and Heritage, Australian Government, Canberra.

Australian rivers have the least amount of water in the world and have the second highest flow variability (DAFF, 2004). It is justifiably named, by one pioneering Australian poet, a "sunburnt country".

In Australia, the development of water resources in regional areas has made a significant contribution to national wealth, underpinning the development of primary industries as well as cities and towns. Settlement and economic growth have relied upon the manipulation of natural water courses to satisfy production and domestic demands.

Despite being the driest inhabited continent, Australians and Australian industries consume a lot of water. Australia's rate of water consumption is the highest per capita in the world, surpassing North America (Parliament of Australia, 2005). In 2000-01 a total of 24,909 gigalitres (GL) was consumed in the Australian economy. The three highest consumption sectors were agriculture, electricity and gas supply and households (ABS, 2004).

In light of Australia's climatic characteristics and the water-demanding nature of some of its primary industries, it is not surprising that water is a key natural resource management concern in Australia. However, in the past, concerns raised by water shortages focused on the needs for human consumption and driving economic growth. The heavy reliance on large-scale damming, diversion, pumping and drainage of surface waters, reclamation and loss of wetlands and extraction of groundwater for irrigation, stock, domestic and industrial use has meant that many of Australia's waters and water-dependent ecosystems have suffered degradation. This includes declining water quality, salinisation, habitat loss and loss of biodiversity.

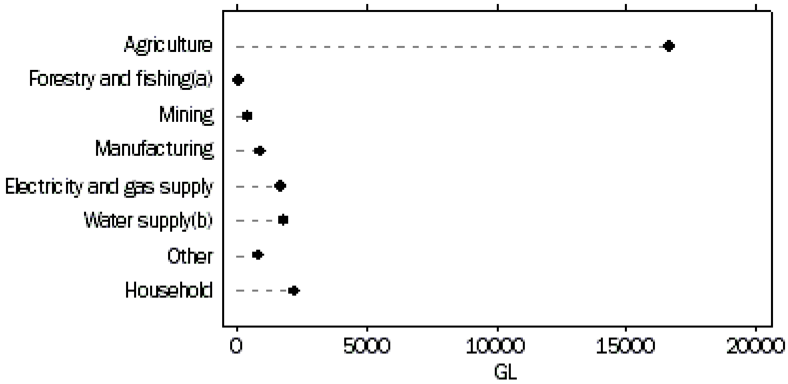
Balancing the needs of the environment — including the flows required to maintain and restore healthy rivers — with water allocation for consumptive users is a major task facing Australian governments and communities. While this paper provides a snapshot of the forms of degradation facing Australian waters and water-dependent ecosystems, its focus is a reflection on the co-operative, intergovernmental responses in Australia to increase the efficiency of water use and improve the sustainability and productivity of the agricultural sector, whilst promoting the health of river and groundwater systems. Case studies from the Murray-Darling Basin and Great Barrier Reef catchment illustrate approaches taken by Australian policymakers for policy setting and programme delivery to achieve these multiple objectives, and identify the common elements for success.

2. The agriculture-water relationship at a glance

Australia is a renowned agricultural producer, representing 3 per cent of world agricultural exports. In 2002–2003, the gross value of farm production was AUD 31.8 billion and farm exports AUD 27 billion (DAFF, 2004). In 2001-02, the agricultural sector contributed 4.2 per cent of the Australian Gross Domestic Product and 2.9 per cent in 2000-03 (ABS, 2005).

However, the sector's economic contribution is not proportional to its water demands. The agriculture industry is by far the major water user in the Australian economy. Estimates in *Water Account Australia 2000–2001*, compiled by the Australian Bureau of Statistics (ABS), the premier statistical organisation in Australia, show that agriculture accounted for 67 per cent of water consumption in 2000-01 (ABS, 2004) (Figure 1).

Figure 1. Water consumption in Australia 2000-01



(a) Includes Services to agriculture; hunting and trapping.
(b) Includes Sewerage and drainage services.

Source: ABS, 2004.

Agricultural water use is largely influenced by climatic conditions. Drought and other climatic events influence agricultural output and water demand more so than other industries. Long-term rainfall anomalies have been present since 1996 in a number of areas, resulting in persistent dry conditions. 2002–2003 saw the peak of a severe drought, which affected almost all of Australia from March 2002 onwards (ABS, 2005).

The area of irrigated agricultural land has increased by 22 per cent between 1996-97 and 2000–2001, to 2.5 million hectares (ABS, 2004). During 2003–04, 43,774 Australian agricultural establishments applied 10,404 GL of irrigation water to 2.4 million hectares of crops and pastures, an average application rate of 4.4 megalitres per irrigated hectare (ABS, 2005b). Consumption varies between crops and between states and territories. New South Wales (including the Australian Capital Territory) was the largest user of water for agriculture, accounting for 44 per cent of Australian agricultural water use.

To further understand the water requirements and management practices in the agricultural sector, the ABS conducted a study on agricultural water use and management in Australia in 2002–2003. The Water Survey – Agriculture 2002–03 was developed in response to strong demand for nationally consistent information on water use, particularly from government agencies responsible for the environment, natural resources, agriculture and related industries.

The survey found that the majority of the water used by the agriculture industry in Australia was self-extracted (9,132 GL, 55 per cent), followed by mains water (7,105 GL, 43 per cent), and then reuse water (423 GL, 3 per cent). Self-extracted water is defined as water extracted directly from the environment for use, and includes water from rivers, lakes, farm dams, groundwater and other water bodies. Mains water is water supplied to a user often through a non-natural network (piped or open channel), and where an economic transaction has occurred for the exchange of this water. Reuse water for this paper refers to wastewater that may have been treated to some extent and then used again without first being discharged to the environment. It includes only the reuse water that is supplied to a customer by a water provider.

3. Degraded waters and water-dependent ecosystems

Healthy rivers are important for water supply, irrigation and for aquatic biodiversity. Wetlands contribute to biodiversity and aid in groundwater recharge, water filtration and nutrient retention. Changes to rivers and wetlands are linked to the intensity of land use, invasive species and increases in sediment and nutrient loads. Widespread irrigation and extraction by other water users has placed the natural ecosystem under considerable pressure. Many of Australia's waters and water-dependent ecosystems are under considerable environmental stress. A snapshot of the water-related issues facing Australia and the challenges they present is provided in this section.

Loss of biodiversity

Australia is one of 17 megadiverse countries, countries with an exceptional total number of species and a high degree of endemic species found exclusively in that country (ABS, 2003). To illustrate, the Great Barrier Reef in northern Australia contains about 2,000 reef and 500 coral species, the highest concentration of the world's fish and coral species.

The loss of biodiversity is considered one of the most serious environmental problems in Australia (ABS, 2003). Key threats identified include dryland salinity, pollution, nutrient loading and sedimentation of waterways and coastal areas, and altered hydrological regimes. All can be partly attributed to agricultural activity and water management.

Australian's water resources sustain 64 wetlands of international importance and over 850 of national importance. Of these, 80 of are affected by salinity, and this figure could rise to 130 by 2050 (DEH, 2001). The number of threatened native fish species has increased substantially in recent years, with approximately 210 listed in 2001 (AFSB, 2005). Furthermore, approximately 630,000 hectares of native vegetation are at risk from salinisation (NLWRA, 2003).

Declining water availability

Increasing pressures to extract surface and groundwater for human use are leading to continuing deterioration of the health of water bodies. Approximately 26 per cent of Australia's surface water management areas are close to or have exceeded sustainable extraction limits (DEH, 2001). This pressure is particularly strong in Australia's south east, where the Australian population and agricultural industries are concentrated.

Rising land salinity

Land and water are essential for agricultural production. Currently around 456 million hectares, or 59 per cent of land mass, are used for agriculture, making it the dominant form of land use.

Salinity is the build-up of salts in the soil. While salinity is a naturally-occurring condition of Australian soils, it has been exacerbated by agricultural activities (ABS, 2003). In 2002, two million hectares of agricultural land were showing signs of salinity (ABS, 2002). Agricultural activities exacerbate both dryland and irrigated salinity. The clearing of native vegetation for planting of modern agricultural and grazing species is the major cause of dryland salinity. When deep-rooted native vegetation is replaced by crops and pastures that have shallower roots and different water use requirements, substantial rises occur in water tables due to increased recharge of groundwater. This often results in increased salt loads entering the river systems. Reduced river flows, brought about by the construction of dams, weirs and water diversions, compound the problem as the flow is insufficient to dilute saline groundwater inflows.

Salinity through irrigation resembles dryland salinity, with the exception that groundwater accession is induced through irrigation water rather than rainfall recharge. Irrigation salinity arises when the volume of irrigated water exceeds evaporation and the transpiration of agricultural plants. Contributing factors include inefficient watering systems and inadequate drainage infrastructure.

Increased nutrient loading and sediment accumulation

Agricultural practices have accelerated the leakage of nutrients and sediments from Australian landscapes (ABS, 2003). Total phosphorus loads in rivers average 2.8 times higher than estimates for pre-European settlement levels and total nitrogen loads are 2.1 times higher (NLWRA, 2001). The leakage of nutrients stems predominantly from erosion and dissolved phosphorus run-offs. Excessive nutrient levels in river systems results in eutrophication and can lead to increases in the occurrence of algal blooms.

The accumulation of sediments stresses many Australian river systems. River system stress from sediment runoffs from catchments is exacerbated by artificially-altered flow regimes. About 30,000 kilometres of river length have experienced sediment accumulation of greater than 0.3 metres since European settlement. The Murray-Darling Basin is one of the worst affected basins, with 20 per cent of river length accumulating more than 0.3 metres of sediment (ABS, 2003).

4. Balancing consumptive and environmental water use — The environmental aspects of Australian water reform

Balancing consumptive and environmental water use, striking a compromise between providing the flows required to maintain and restore healthy rivers with water allocation for consumptive users, is an important dilemma facing Australian governments and communities. In response to these pressures, Australian governments have adopted an intergovernmental and multi-stakeholder approach that emphasises co-operation, consultation and dialogue between the stakeholders.

Australia's system of government is three-tiered: commonwealth ("Australian Government"), state/territory, and local. There are six state and two territory governments, and over 730 local governments. In Australia, a multi-stakeholder approach is often adopted to maximise the viability of and support for environmental remediation activities. This process necessitates co-operation and active participation from stakeholders. The programmes and initiatives discussed in this section are negotiated outcomes between different levels of government and representatives from industry and community groups. Typically, national and interstate plans involve the Australian Government and the relevant state and territory governments, while intrastate and regional programmes involve a state/territory government and its local governments. This section highlights national land and water reforms taking place across Australia.

National Water Initiative

Ratified in 2004 at the peak Australian intergovernmental forum, the Council of Australian Governments (COAG), the National Water Initiative provides a framework for the continued improvement of the productivity and efficiency of Australian water use while maintaining healthy river and groundwater systems. It establishes the timelines, actions and monitoring programmes to implement major water reforms in Australia over the next 10 years, and builds on the previous water reform framework agreed by COAG in 1994.

As an intergovernmental agreement between the Australian and most state and territory governments, its signatories have a shared responsibility for its implementation. Many of the reforms create direct environmental benefits. For example, the governments have agreed to identify and protect surface and groundwater systems for their important conservation values and restore over-allocated river and groundwater systems to sustainable usage levels. Importantly, water allocated to meet agreed environmental and other public benefit outcomes will be given statutory recognition, enabling these allocations at least the same degree of security as water allocated to consumers.

Several commonwealth or state ministerial councils contribute to the implementation of the National Water Initiative, including the Natural Resource Management Ministerial Council, the Environment Protection and Heritage Council and the Murray–Darling Basin Ministerial Council. The use of ministerial councils provides an efficient tool to ensure reforms are delivered across relevant government agencies and departments, across different levels of government and helps ensure that the responsibility for implementation is shared.

National water reform within the National Water Initiative is driven and monitored by the National Water Commission, an Australian Government statutory body.

The Australian Water Fund

Administered by the National Water Commission, the Australian Water Fund represents a major investment by the Australian Government in water infrastructure, improved knowledge and water management, and better practices in the stewardship of Australia's scarce water resources. Investment under the Australian Water Fund will be made on the basis that it is consistent with, and helps to achieve, the objectives, outcomes and actions of the National Water Initiative. The Fund is made up of three programmes. The Water Smart Australia programme, with its objective of accelerating the development and uptake water-smart technologies and practices, is particularly relevant to increasing the efficiency of consumptive uses.

National Action Plan for Salinity and Water Quality

The AUD 1.4 billion National Action Plan for Salinity and Water Quality (the National Action Plan) represents a co-operative approach between the Australian, state and territory governments to address salinity and water quality issues. The funding, which commenced in 2001, is provided over 7 years to support the actions of communities and land managers in priority regions across Australia to implement the primary goals of the National Action Plan – managing salinity and improving water quality. This is achieved through comprehensive natural resource management plans and investment strategies.

Twenty-one regions affected by salinity and water quality were identified as priority targets under the National Action Plan.

After the introduction of the Intergovernmental Agreement on a National Action Plan for Salinity and Water Quality in 2000, bilateral agreements between the Australian and state or territory governments facilitated the development of action plans in the priority regions. These agreements provided details on the state or territory's specific arrangements for regional bodies, accountability and administrative arrangements and institutional reforms, to progress key limitations in policies and legislation. In developing action plans, government and community bodies collaborate in the search for solutions to address the salinity and water quality problems.

Funding is provided to regional groups for the development of regional plans. Specific funding is allocated to address urgent resource condition issues through priority actions. At a regional level, investments under the National Action Plan and the regional component of the Natural Heritage Trust (discussed further below) are driven by regional plans, developed by regional natural resource management bodies with the support of governments.

Natural Heritage Trust

The Natural Heritage Trust (the Trust) was set up by the Australian Government in 1997 to help restore and conserve Australia's environment and natural resources. It is the largest environmental rescue plan ever undertaken in Australia, with a strategic outlook that adopts a long term, co-ordinated approach to address natural resource management challenges. Funding for environmental activities is provided at a local level, a regional level and a national or state level. The Trust was extended in 2001 to provide funding for another five years to ensure the viability of many significant ongoing activities. As a reflection of its role in funding on ground works, funding was extended to 2007-08 in 2004, with investments since 1997 totalling AUD 3 billion.

The Trust is administered by a ministerial board comprising the Minister for the Environment and Heritage and the Minister for Agriculture, Fisheries and Forestry. There are also a number of organisations and committees which oversee and support the Trust, including members from non-government organisations (NGOs), the scientific and academic communities and officers from different levels of government.

There is considerable co-operation and dialogue between governments to maximise the effectiveness and efficiency of investments. This is formalised through bilateral agreements between the Australian Government and each state or territory to deliver the Trust, including the establishment of 56 natural resource management regions across the whole of Australia. This regional delivery framework is aligned with, and builds on, the regional delivery of the National Action Plan for Salinity and Water Quality.

The central feature of natural resource management in Australia is the active engagement of the community. Regional staff and boards consist of community members, and projects are delivered locally with strong community participation in both their planning and implementation. Investments now focus on achieving important resource condition outcomes expressed as measurable targets (set jointly by communities and governments), including for water quality, improved estuarine health, improved vegetation management and improved soil condition. Regional targets include longer term resource condition targets (10 to 15 years) and shorter management action targets (1 to 5 years).

While achieving identified environmental outcomes remains the objective of investments under the Trust, the associated benefits include skilled resource managers, communities playing a key role in their future direction, improved productivity and profitability, enhanced protection and restoration of biodiversity, and more people taking an active role in improving the management of natural resources, including those who are not directly involved in land and water management activities.

Since the inception of these programmes in 2000-01, governments have jointly approved National Action Plan and Trust investments totalling AUD 352 million. The great majority of National Action Plan funding, and around half of the Trust funding, are being invested to pursue targets and priorities developed by regional communities and articulated in plans accredited by governments (Natural Resource Management Ministerial Council, 2005). The National Action Plan and the Natural Heritage Trust are prime examples of the Australian Government and state and territory governments implementing co-ordinated, strategic and national approaches to Australia's environmental issues.

The subsequent sections present two case studies on the Murray-Darling Basin and the Great Barrier Reef Catchment to illustrate some of the specifics of the innovative and co-operative approaches Australia has taken to engage stakeholders in solving environmental problems.

5. Case Study 1: The Murray-Darling Basin

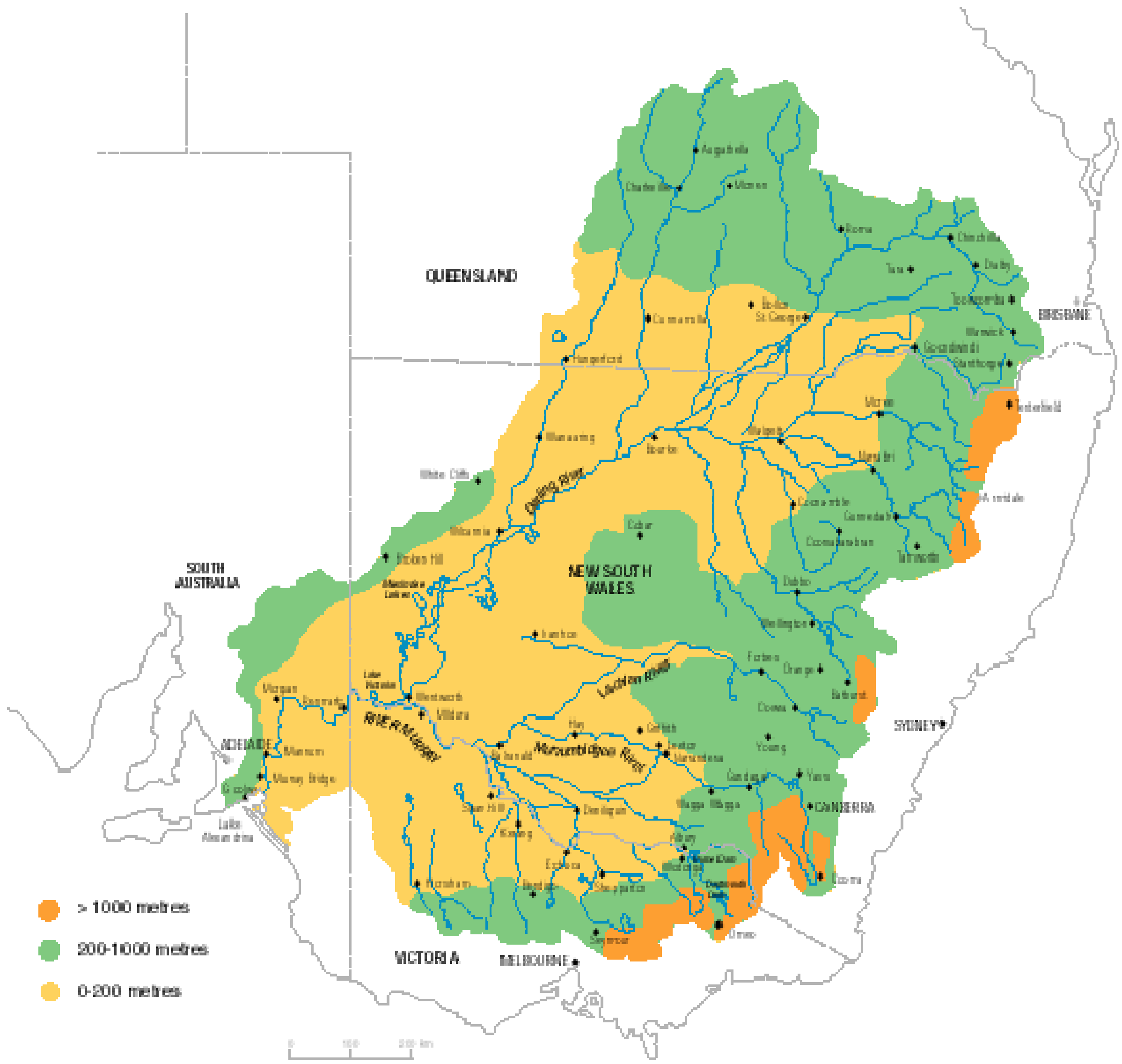
The Murray-Darling Basin (Basin) is the catchment for the Murray and Darling Rivers and their many tributaries. Extending across one-seventh of the continent, it contains more than 20 major rivers as well as important groundwater systems (Figure 2). Spanning four states and one territory, from north Queensland to South Australia and including three quarters of New South Wales and half of Victoria, it is the heartland and the economic powerhouse of rural Australia. It has a population of nearly 2 million people, with another million people outside the region depending heavily upon its resources. The Basin generates about 40 per cent of the national income derived from agriculture and grazing. It supports one quarter of the nation's cattle herd, half of the sheep flock, half of the cropland and almost three-quarters of its irrigated land. It is also an important source of freshwater for domestic consumption, agricultural production and industry (MDBC, 2005b).

Many of the Basin's natural resources are of high environmental value. A number of the Basin's 30,000 wetlands are recognised under the Convention on Wetlands of International Importance. For fish and other riverine life forms, the Basin is a vast interconnected network, stretching from the saline lakes of the Coorong estuary in South Australia, east to the alpine streams of the Snowy Mountains and north to the semi-arid and tableland streams of southern Queensland. As a large, very shallow drainage basin with only one exit flowing out of Lake Alexandrina in South Australia, the Basin is an unusually complex biophysical system.

In the last 100 years life in the Basin has been transformed by the construction of major water storages on the rivers. The total volume of water storage capacity in the Basin is just below 35,000 GL (MDBC, 2005d). However, the development that made the economic productivity of the Basin possible has also caused much biophysical degradation. The operation of the storages and the extraction of large volumes of water for consumption off-stream have reduced the annual and seasonal variability which shaped the ecology of the region. The riverine corridor supporting aquatic life is also constricted by structures such as dams and locks.

Beyond the riverine corridors extensive clearing of native vegetation has dramatically increased the volumes of rainwater leaking through the soil profile to groundwater systems. Groundwater levels are now rising in many parts of the Basin, causing widespread and serious salinity problems. Broad-scale clearing has also reduced the habitat for many native plant and animal species. In the south many rivers now have low flows in winter and spring when rain in their catchments is being captured in the storages. In the summer and autumn when flows were traditionally low, they run full to supply irrigation.

Figure 2.The Murray-Darling Basin



Source: www.mdbc.gov.au.

The Murray-Darling Basin Agreement

The Basin is administered by the Australian Government, four state and one territory governments, and more than 200 local governments. These governments manage the natural resources of the Basin in partnership with numerous catchment bodies, landcare groups and other community organisations. Management of the Murray-Darling Basin requires the balancing of many values and assets that are potentially in competition. Tensions exist between some production-orientated activities and environmental needs. There is also competition between different economic and social interests.

Intergovernmental co-operation on managing the River Murray has occurred since 1915, when the governments of Australia, New South Wales, South Australia and Victoria signed the River Murray Waters Agreement to secure minimum flows and manage navigation along the river. To address broader water and natural resource management issues, it was replaced by the Murray-Darling Basin Agreement (Agreement) in 1987.

The Agreement was first ratified by the governments of the Commonwealth, New South Wales, Victoria, and South Australia in 1987 after two years of intensive negotiations between the four governments, in appreciation of the need to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources. The Agreement provides the process and substance for the integrated management of the Basin, and is recognition of the fact that no one government or group of people was able to deal with the Basin's emerging natural resource management problems. The involvement of the community is recognition of the fact that the task was not one that governments could fulfil on their own.

The Agreement was subsequently revised in 1992. Queensland became a signatory in 1996 and the Australian Capital Territory became an informal partner in 1998. There are thus six formal partner governments in the Agreement, with many departments and agencies involved. Whilst there are a number of other inter-jurisdictional agreements in the Murray-Darling Basin which continue to operate, they are beyond the scope of this paper.

The Agreement established new institutions at the political, bureaucratic and community levels to underpin its implementation. The overarching bodies are the Murray-Darling Basin Ministerial Council, Murray-Darling Basin Commission and the Community Advisory Committee. The Murray-Darling Basin Ministerial Council is the primary body responsible for providing the policy and direction. It comprises the ministers responsible for land, water and environmental resources within the contracting governments.

An autonomous organisation equally responsible to the governments represented on the Ministerial Council as well as to the council itself, the Murray-Darling Basin Commission (Commission) is neither a government department nor a statutory body of any individual government. The Commission has a role to equitably and efficiently manage and distribute the water resources of the River Murray in accordance with the Agreement to obtain the highest achievable quality and efficiency of use of such resources. It was created out of the desire by the six governments to have an organisation that transcended the political boundaries between these jurisdictions to manage the far-reaching Murray-Darling river catchments as effectively as possible.

The Community Advisory Committee advises the Ministerial Council on critical natural resource management issues. Its role of increasing community participation in the natural resource management issues within the Basin has risen significantly in recent years, following a review of the CAC in 2002–2003.

The Murray-Darling Basin Initiative

The Murray-Darling Basin Initiative (Initiative), a partnership between the governments and the community, was established to give effect to the revised 1992 Agreement. The Initiative is the largest integrated catchment management programme in the world, covering an area of over one million square kilometres (MDBC, 2005a). It addresses the delicate balance between the goal of environmental preservation and conservation with growing and developing Basin communities. To achieve this, it draws together communities and governments, with the directions and policy for its implementation provided by the Ministerial Council.

Initially, the Initiative focused on promoting the principles of integrated catchment management (ICM) and the development of joint community and government structures which have remained key mechanisms for achieving sustainable use of the Basin's natural resources (MDBC, 2004). The Integrated Catchment Management Policy Statement 2001–2010 was made by the community, industry and governments to demonstrate the commitment towards ecological sustainable development of the Basin. The statement was based on setting targets for catchment health and building capabilities of the parties in order to achieve them. In recognition of the substantial learning curves and behavioural changes required, the timeframe was set to 10 years.

Actions under the Murray-Darling Basin Initiative

A large variety of actions and projects have been undertaken under the Initiative that addresses Basin-wide or regional issues. Table 1 provides a snapshot of activities that have taken place.

Targeting salinity through a salinity strategy

The guiding force for co-operation between community and governmental bodies in controlling salinity in the Murray-Darling Basin is the Basin Salinity Management Strategy 2005–2015 (Salinity Strategy). It establishes targets for the river salinity of each major tributary valley and the Murray-Darling system itself, which reflect the shared responsibility for action, both between valley communities and between the states.

A key feature of the fifteen-year Salinity Strategy is the adoption by the Ministerial Council of end-of-valley salinity targets for each tributary catchment and a Basin target at Morgan in South Australia. The Basin target is to maintain the salinity at Morgan at less than 800 electro-conductivity units for 95 per cent of the time (MDBC, 2005c). These targets are a way of measuring the progress towards achieving the Salinity Strategy's key objectives of:

- Maintaining the water quality of the shared water resources of the Murray and Darling Rivers;
- Controlling the rise in salt loads in all tributary rivers of the Murray-Darling Basin;

- Controlling land degradation and protecting important terrestrial ecosystems, productive farm land, cultural heritage and built infrastructure; and
- Maximise net benefits from salinity control across the Basin.

Table 1. Actions under the Murray-Darling Basin Initiative

Region	Issue	Action/ Project	Description
Basin-wide	Sustainable communities	Integrated Catchment Management Framework 2001-2010	Document outlines an approach to ICM that is based on targets for catchment health and progressive evolution of the way communities, institutions and governments are organised to meet the challenges and opportunities of the future.
	Communicating with natural resource management partners	Towards Whole of Community Engagement – a Practical Toolkit	Toolkit is designed to help Murray-Darling Basin stakeholders develop better processes to engage communities in natural resource management processes in the Basin.
Dryland	Salinity	Implementation of the Basin Salinity Management Strategy	Strategy guides communities and governments in co-operation to control salinity in the Basin and protect key natural resource values within their catchments. It establishes targets for the river salinity of each major tributary valley and the Murray-Darling system itself.
Rivers and wetlands	Competing demands for water	Review of the Operation of "the Cap" (water diversions from rivers)	A limit imposed on the volume of water which could be diverted from the rivers for consumptive uses.
	River regulation and forests	Development of a water management strategy for the Barmah-Millewa Forests	Recognises the forest as a single ecosystem by recognising appropriate economic, environmental and social factors and by adapting to knowledge advancements.
	Declining native fish	Murray-Darling Basin Fish Management programme Native Fish Strategy 2003-2013	To rehabilitate native fish communities back to 60 per cent of their estimated pre-European settlement levels after 50 years of implementation through key actions ranging from restoring fish passage to environmental flows and rehabilitation of river reaches.
Irrigated regions	Salinity	Implementation of the Basin Salinity Management Strategy	Discussed in Dryland Region

Actions under the Salinity Strategy include capacity building through communication and education, identifying and quantifying assets at risk, redesigning farm systems to improve the control on groundwater recharge, constructing salt inception works and ensuring Basin-wide accountability through the establishment of monitoring, evaluating and reporting frameworks.

The Living Murray First Step

In response to evidence that the River Murray system's health was in serious decline, and amidst concerns that the decline would threaten the Basin's industries, communities, and natural and cultural values, significant work was undertaken in 2002 and 2003 to investigate options for improving river health through the provision of additional water for the environment. The outcome was the establishment of The Living Murray Initiative (The Living Murray) by the Ministerial Council. Activities within The Living Murray relate to environmental management, communication, consultation and communications for water recovery. All work is executed in consultation with the wider community and Indigenous representatives.

As an initial plan for progress, the 'First Step' for The Living Murray was endorsed in late 2003. The First Step decision included input from communities through meetings, submissions, the Living Murray Community Reference Panel, the CAC to the Ministerial Council, and an Indigenous consultation process undertaken with Murray-Lower Darling Rivers Indigenous Nations. The First Step focuses on maximising environmental benefits for six sites along the River Murray, termed Significant Ecological Assets (SEAs) for their regional, national and international ecological significance (Figure 3). Environmental objectives include forests, floodplains and river systems.

Actions undertaken for the First Step consider environmental, social and cultural implications for the individual SEAs and include the recovery of water for environmental outcomes, an Environmental Delivery Project to develop the water application arrangements across the River Murray system, an eight-year Environmental Works and Measures Programme to provide the operational flexibility to deliver and manage environmental flow allocations, an Indigenous Partnerships Project to provide for an agreed approach for Indigenous peoples' spiritual, cultural, social and economic considerations within The Living Murray initiative, and the development of a Community Consultation and Communications Strategy.

The political and financial support for the implementation of the First Step is provided for through an intergovernmental agreement signed by the New South Wales, Victoria, South Australia, the Australian Capital Territory and the Australian governments. The "Murray-Darling Basin Intergovernmental Agreement to Address Water Overallocation and to Achieve Environmental Objectives in the Murray-Darling Basin" provides a commitment of AUD 500 million for the venture over five years, to address water over-allocation to human-related activities in the Basin to minimise adverse social and ecological impacts, with the Living Murray First Step Decision the priority investment. The AUD 500 million funding was agreed to by the COAG as part of the National Water Initiative. Additional funding of AUD 225 million is provided through other sources.

Figure 3. The Living Murray significant ecological assets

In addressing the environmental degradation of the Basin, the participating governments have invested significant resources in building a solid foundation for remediation activities. The Living Murray has been an effective model for co-ordinating and managing a wide array of water-related projects and activities across the Basin. It demonstrates the variety of issues, social, economic and environmental, that must be addressed to balance consumptive, agricultural and environmental needs in a populated area.

The commitment by governments towards intergovernmental agreements, establishment of various bodies to execute the activities, the development of strategies to direct future actions for discrete concerns, and measures to engage the community and industries all denote enthusiasm for an all-encompassing approach to addressing water issues in the Basin.

6. Case Study 2: The Great Barrier Reef Water Quality Protection Plan

The Australian Great Barrier Reef (the Reef) on the east coast of Queensland is an international tourism icon. Stretching over 2000 kilometres, comprising of approximately 3000 unconnected coral reefs, it is the largest and most complex coral and diverse reef system in the world (ABS, 2003). It is also home to extensive seagrass beds, mangrove forests, and sponge gardens. Many of the Reef's marine species rely on coastal freshwater wetlands and estuaries as breeding and nursery areas. Over the past 150 years, extensive land development in the catchments adjacent to the Reef (for urban centres, agricultural production, tourism and mining) has led to increased pollution, leading to a decline in the water quality in the catchments draining into the reef lagoon. Quantities of sediment and nutrient washing into the Reef have quadrupled since European settlement (Australian Government, 2003). This trend is consistent with the findings of the United Nations' Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, which estimates that 80 per cent of marine pollution is the result of land-based sources (Reef Water Quality Protection Plan Annual Report 2004–05, 2005).

In addressing the environmental challenges facing the Reef, it was recognised that single issue-based actions or policies by individual organisations are no longer an effective way to protect the Reef from this threat. The challenge was to change behaviour in order to reduce risks to the Reef's ecological health, calling for a societal-based involvement for policy-making.

The Reef Water Quality Protection Plan

In response to this challenge, the Australian and Queensland governments, in partnership with a wide range of industry and community groups, developed the Reef Water Quality Protection Plan (the Reef Plan). Launched in December 2003, it aims to halt and reverse the decline in water quality entering the Great Barrier Reef by 2013 through focusing on actions to address pollutants from diffuse sources via an integrated natural resource management approach. Implementation and financial responsibilities are shared between the Australian and Queensland governments and the community. Activities under the plan are funded from existing government programmes, such as the National Action Plan for Salinity and Water Quality, the Natural Heritage Trust and the Queensland Wetlands Programme.

Strategic and policy direction for the Reef Plan is provided by an Intergovernmental Steering Committee, representing a wide array of interests and organisations. From the Australian Government, it comprises the heads of agencies from the Department of Agriculture, Fisheries and Forestry, Department of the Environment and Heritage, and the Great Barrier Reef Marine Park Authority. From the State Government of Queensland, the Department of Natural Resources and Mines, Department of Premier and Cabinet, Department of Primary Industries and Fisheries, and the Environmental Protection Agency.

The Reef Plan encompasses two objectives: to reduce the load of pollutants from diffuse sources in the water entering the Reef and to rehabilitate and conserve areas of the Reef catchment that have a role in removing water-borne pollutants. It was anticipated that the realisation of the objectives relied on a co-operative partnership approach by all stakeholders (all levels of government, industry and community groups) and a commitment to align resources to the Reef Plan's objectives. Catchments were prioritised according to the most at-risk. A broad range of strategies and actions was compiled to achieve the objectives of the Reef Plan. Progress is measured against milestones set for each action, and the identification of responsibility for an action to a particular group(s) ensured a demarcation of accountability. Monitoring and evaluation activities are also included in the Reef Plan to assess its impact and effectiveness.

Progress of the Reef Plan

In the first two years of the implementation of the Reef Plan, activities centred on developing partnerships, aligning resources and providing a strong foundation of policy co-ordination to support the delivery of on-ground actions into the future. Developments towards boosting environmental and ecosystem health during 2004–2005 included the implementation of an integrated Reef Marine Monitoring Programme that benchmarked the main environmental and ecosystem variables and established the monitoring programme to measure changing trends in water quality and ecosystem health of the Reef; work on the development and implementation of water quality improvement plans in four catchments; and the accreditation of regional natural resource management plans and regional investment strategies within the catchments opposite the Great Barrier Reef. These plans identify targets for the region's natural resource management and detail catchment-wide activity in land and water management, biodiversity and agricultural practices.

As a measure of the integrated approach of the Reef Plan, 2004–2005 initiatives addressing the agricultural impacts included the rollout of the Farm Management System, the development of the AgForward programme and a trial training programme conducted under the Fertcare programme. The implementation of the Farm Management System was managed by an industry body, the Queensland Farmers' Federation. It is a voluntary property and business-level management process producers can use to identify and manage risks, particularly environmental risk, from farm operations. The AUD 8 million programme AgForward will be delivered by another industry body, AgForce, and will assist landholders within the broad-acre industries of cattle, grain, sheep and wool to improve their land management practices. The training programme under Fertcare provided participants with knowledge of environmental issues, product stewardship and food safety issues. The programme also assessed the competency of fertiliser advisers in providing nutrient recommendations to fertiliser users (Reef Water Quality Protection Plan Annual Report 2004–05, 2005).

Activity in future years will continue to build on these partnerships and closely engage all relevant stakeholders in delivery of the Reef Plan. Another targeted area for future effort is the development of better communication and more effective engagement with non-government stakeholders and the wider community to engender wider understanding of, and participation in, the Reef Plan.

7. Key lessons from the Australian experience

As the driest permanently inhabited continent with the highest water consumption rate per capita in the world, Australia has faced significant water-related issues. Since European settlement, water bodies and their surroundings, inland or coastal, have suffered marked and serious decline in condition. Adverse consequences from agricultural production include salinisation, pollution runoff, soil degradation, drainage of wetlands and the artificial control of water flow in major tributaries. Many water systems are highly stressed, with significant ramifications for the future viability of agricultural pursuits, and pose grave risks to the nation's biodiversity and ecological system health. Australia faces an extremely tough challenge in restoring the health of its water bodies while maintaining agricultural production.

Strategically balancing the needs of the environment with water allocation for consumptive users is a major task facing Australian governments and communities. This paper highlighted the major environmental challenges consequent to declining water quality and reflected on the co-operative, intergovernmental responses in Australia to increase the efficiency of water use and improve the sustainability and productivity of the agricultural sector, while promoting the health of river and groundwater systems. It drew on activities undertaken in the Murray-Darling Basin in inland Australia and Great Barrier Reef catchment along the eastern coast of Australia to illustrate approaches by Australian policymakers for policy setting and programme delivery to achieve these multiple objectives.

While located in geographically and climatically distinct regions of Australia, the case studies displayed some common characteristics that are often perceived as key ingredients for success in the Australian environmental management arena. They include strong, co-operative relationships between the Australian and state or territory governments and focus on multi-stakeholder approaches that embrace not only different government bodies, but also representatives from the wider community, such as the agricultural industry and community groups. Such co-operation and involvement is required from the outset, when the goals, objectives and implementation mechanisms are determined. Strategies and policy directions need to be negotiated amongst the parties, and agreed, to receive support, and should be readily accessible to all involved as binding agreements, such as the Murray-Darling Basin Agreement and the Reef Water Quality Protection Plan. All parties to the process should have clear roles and responsibilities to ensure accountability. Remediation activities and solutions should include measures that tackle social, economic and environmental challenges. Finally, and perhaps most importantly, goodwill needs to be matched with adequate financial support by governments in order to bring the visions, goals and ideas to fruition.

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Chapter 14.

Meeting Environmental Outcomes – A Planning Framework

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One of the main river management goals in the Murray Darling Basin is to strengthen the link between the river and wetland environments by augmenting natural high flow events with synchronised releases from storages. However, the volume, and timing of release, of water resources required to meet this goal is highly uncertain. An environmental planning framework is developed that generates well specified demand for environmental water and a set of high flow release rules. The framework provides clearly specified environmental objectives, giving rise to measurable performance, that are met at the lowest possible resource costs. The problem is specified as a constrained cost minimisation where the constraints define the characteristics of a successful high flow event. An optimal water release strategy is determined using a genetic algorithm. The approach is applied to a case study in the central reaches of the Murrumbidgee River and linked to a hydrological model of the entire river system. This link allows the systematic exploration of how alternative environmental objectives and release strategies affect the river system. The cost minimisation framework allows the costs of alternative strategies to be compared and options to reduce those costs to be explored.

Introduction

One of the main river management goals in regulated catchments in Australia is to strengthen the link between the river and wetland environments of the flood plains. The natural link between these environments was through high flow events, but such events occur much less frequently in highly regulated river systems. In a regulated system, this connection can be re-established by creating or augmenting natural high flow events with synchronised releases from storages. Supplementing existing high flows reduces the volume of water required to meet the flow objective and reduces the likelihood of failing to create the event.

Meeting both agricultural and environmental demands will place increased pressure on water resources. However, it is recognised that the timing of irrigation and environmental demands are quite different. In relatively dry years the cost of reallocating

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water from irrigated activities to meet current or future environmental demands will be greater than in wet years. This reflects the fact that the marginal cost of the last irrigated activity to which water is allocated will tend to be highest when water availability is lowest. At the same time, an extended period with low river flows is a frequent and natural phenomenon. In wetter years the cost of reallocating water from irrigation to the environment will be lower. Further, in wetter years, tributary inflows will tend to be highest, and the level of supplementary releases from storages needed to generate high flow events will tend to be lower.

Exploiting this complementarity or counterseasonal pattern in irrigation and environmental demands requires appropriately structured institutional and management arrangements. As recognised in the Australian National Water Initiative, released in 2004, trade between agricultural and environmental water uses has the potential to limit the costs of any conflicts between irrigation and environmental demands (COAG 2004). At the same time, both irrigators and environmental managers need to be able to deal with the uncertainty associated with environmental objectives that depend on high flow conditions. Uncertainty arises because neither the timing, nor the volume of water required to augment naturally high flow events to meet environmental objectives, is known with any degree of long-term predictive accuracy.

The objective in this paper is to establish a framework for defining environmental water demands to meet specific flow based objectives that characterises this inherent uncertainty in a useful way. The approach is applied to billabong and wetland management in the New South Wales Murrumbidgee River through the supplementation of natural flows using dam releases. The approach is intended to be adaptable to other river systems, and environmental objectives that can be met through altered flow management.

Background

River hydrology and the river ecosystem are interlocked in a variety of ways. The most obvious are the requirement of all life for water to support metabolic processes and the fact that aquatic organisms require water as a medium for existence. The natural link between river systems and wetland environments in a river system is through high flow events that now occur much less frequently in highly regulated river systems, where the major share of water may be stored upstream and diverted for other uses, rather than allowed to flow. As a consequence there has been a loss of connectivity, both laterally across the flood plains and longitudinally between upstream and downstream environments. Lateral connectivity provides a conduit for the movement of resources and biota to and from the flood plain. Longitudinal connectivity permits the translocation of larger aquatic organisms through, for example, fish migration. High flows also help harvest food and snags from the banks, modify internal architecture such as benches and gravel bars, and create new channels and cutoffs.

The case study river, the Murrumbidgee, rises south of Canberra in south eastern Australia and runs westerly for 1700 kilometres before entering the Murray River. The Murrumbidgee River catchment is 84 000 square kilometres, and is part of the much larger Murray Darling Basin. The Murrumbidgee River conveys approximately 4300 gigalitres of water annually, of which around 65 per cent, or 2800 gigalitres, is licensed for diversion for irrigation and other human uses (Pratt Water 2004). The Murrumbidgee River catchment is well regarded for the diversity of native flora and fauna, reflecting the variety of geology and landforms, altitudes and climates across the catchment. The Murrumbidgee River catchment is also home to sites of international ecological significance, including the Fivebough and Tuckerbil Swamps and the Lowbidgee Wetlands (Murrumbidgee Catchment Management Authority 2005).

As part of a National Land and Water Audit, Norris et al. (2001) calculated an index of hydrological disturbance for all rivers in the southern Murray Darling Basin. The index rated the rivers on a scale of 0 to 1 from extremely disturbed to undisturbed. Of the twelve river basins assessed, the Murrumbidgee River was estimated to be the most disturbed (hydrologically modified) category, with an index value of 0.41. The Murrumbidgee River is a highly regulated river, with two major storages, a number of smaller weirs and a network of irrigation delivery channels designed to meet irrigator demand. Diversions for irrigation are significant and, as a result, end-of-system flows are considerably less than they would have been under natural conditions (Crabb 1997). In addition, seasonal patterns of flow have shifted, with high releases during summer and autumn, and low flows during winter and spring while storages are replenished.

The Murrumbidgee River, as with most rivers and streams in the southern Murray Darling Basin, is a working river — a term coined by Dr Dedee Woodside to describe a river that has been harnessed for human purposes but which nonetheless should be afforded resources, including hydrological resources, to maintain its ecological 'health' indefinitely (Hillman et al. 2003). While the re-creation of natural or predevelopment high flow conditions on a working river may not be possible or desirable, the restoration of some aspects of stream ecology by more closely re-creating the frequency, timing and duration of naturally-occurring high flow events is seen as an essential element of water management (Murray-Darling Basin Commission 2005).

Data from the New South Wales Government Department of Natural Resources Integrated Quantity Quality Model (IQQM) were analysed to understand the changes that have occurred with the development of large-scale storage and delivery infrastructure to support irrigation on the Murrumbidgee River. IQQM is a daily time step hydrologic modelling tool that was developed by the New South Wales Government Department of Natural Resources, with collaborative assistance from the Queensland Government Department of Natural Resources. It is intended for use in investigating the impacts of water resource management policies or policy changes on stakeholders and environmental outcomes. IQQM is designed to be capable of addressing water quality issues as well as water quantity issues. It can also be used to investigate new water resource developments or modifications to existing developments.

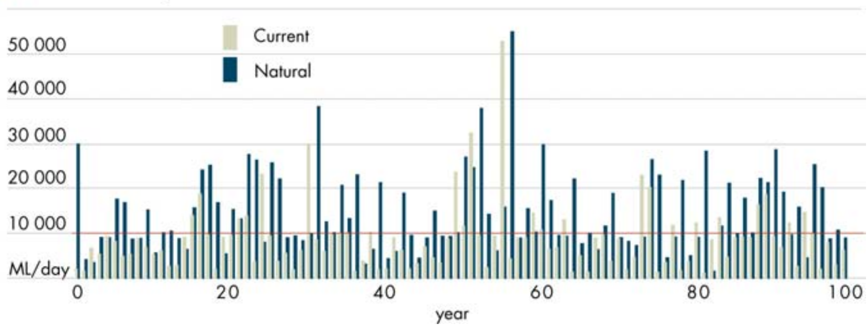
Some of the major processes that are simulated include:

- flow routing in rivers and irrigation channels, including branches, loops and tributaries;
- storage operation;
- irrigation; and
- wetland and environmental flow requirements.

In this paper, the model has been used to simulate two flow regimes from the Murrumbidgee River for the period from 1900 to 1999. The first, referred to as natural conditions, is without existing storage and delivery infrastructure and consumptive demands. The second is with current infrastructure, consumptive demands and agreed flow management rules under the Murrumbidgee Water Sharing Plans, as commenced in July 2004 (New South Wales Department of Infrastructure, Planning and Natural Resources 2004).

The maximum one-day flow in August over the period 1900–99 at Balranald on the Murrumbidgee River is indicated in Figure A for both flow regimes. The simulated data support the observation that extreme high flow events, such as those when flows are more than 30 gigalitres a day, are not greatly affected by infrastructure and flow regulation to meet irrigation demands, but that moderately high flows, between 10 and 30 gigalitres a day, are.

A Maximum flows in August over the period 1900 to 1999 using modeled current and natural daily flow data from IQQM



Maximum flows in August exceed 10 gigalitres a day in 54 of the 100 years under modeled natural conditions — an average return period or interarrival time of 1.78 years. Under current conditions, August flows are predicted to exceed 10 gigalitres a day in only 23 of the 100 years. This is equivalent to an average return period of 4.27 years but, more significantly, the maximum period between these events is 15 years compared with only four under natural conditions.

The duration as well as the frequency of these events is also important. An experiment was carried out on the Murrumbidgee River near Wagga Wagga to investigate the response of billabongs to natural inundation, with a view to exploring the likely ecological outcomes of connectivity between flood plain wetlands and the river (Hillman et al. 2003). An environmental contingency allocation was used to augment high tributary flows, and volumes exceeding 30 gigalitres a day were briefly achieved allowing connection with four billabongs. Although connection was soon lost, the research team tracked several ecological parameters in the river and billabongs for several weeks afterwards. The key results in this work that are of relevance to the current paper include the following:

- During periods when billabongs are disconnected from the river they contain significantly higher levels of particulate organic carbon, support much higher levels of bacterial activity and have zooplankton densities several orders of magnitude greater than the river.

- Connection with the river (and inundation) produces the following sequence of events:

  Day 1: Concentrations of dissolved organic carbon increase rapidly.

  Days 2–5: Levels of a range of microbial functions and therefore microbe densities, reach maximum levels.

Days 12–16: Zooplankton densities, having at first been diluted by inflowing river water, increase to equal or exceed pre-high flow event levels. As inundation can increase the volume of the billabong several fold, this represents a substantial increase in micro-invertebrate biomass.

- This sequence is triggered by the initial inundation and is independent of the duration of connection to the river. Thus, the resources that are returned to the river as flow levels recede depend on the length of time since the original inundation.

While a return to the replication of natural flow conditions is not a practical management objective in a working river such as the Murrumbidgee River, there are options to enhance or recreate conditions that will significantly improve the health of the river ecosystem, including:

- the supplementation of high tributary inflows with releases from storages, to create more frequent high flow events under moderately high flow conditions
- the lowering of river sill heights to again create more frequent high flow events
- the use of regulators to control the flow of water in and out of billabongs and wetlands, and
- the pumping of water into billabongs and wetlands.

Clearly, not all of these options will deliver the same environmental benefits. Short term high flow events and river pumping are unlikely to deliver nutrients back into the river system. While this might be achieved with the use of regulators, artificially induced inundation events not linked to appropriate cues in the river may be of reduced value. For example, for fish species that are cued to breed by an influx of freshwater to the river, artificial inputs of larval food without appropriate flow signals in the main channel may be of little benefit. However, successful recruitment for a number of waterbird species is dependent on the presence of water during breeding and chick fledging (Leslie 2001). The presence of water is probably the main criterion here — how it is delivered and the means of keeping it there are probably not important. The most important points in the context of this study are that hydrological conditions need to be linked to outcomes and that there is a preference for the flow regime that delivers that outcome at least cost.

The framework developed in this study is applied to the supplementation of high flow events from storages along the central reaches of the Murrumbidgee River. The central reaches of the Murrumbidgee River are located within two to three days travel time from the two major storage dams, Burrinjuck and Blowering. Furthermore, there are significant tributaries below the dam walls and above the wetland areas. The flow requirements to commence inundation of billabongs within the reaches are shown in Figure B, based on New South Wales Government Department of Natural Resources survey data. High flow or flood events, as they relate to individual billabongs, occur over a wide range of flow rates. However, the majority of billabongs are connected to the river system at rates between about 22 gigalitres and 32 gigalitres a day.

The frequency of natural and current flow conditions is provided in Table 1. This is again derived from IQQM simulations. High flow events are substantially reduced under current as opposed to natural conditions. The reduction is around 50 per cent for both short and extended events. The reductions are less for flow rates at or below 30 gigalitres a day.

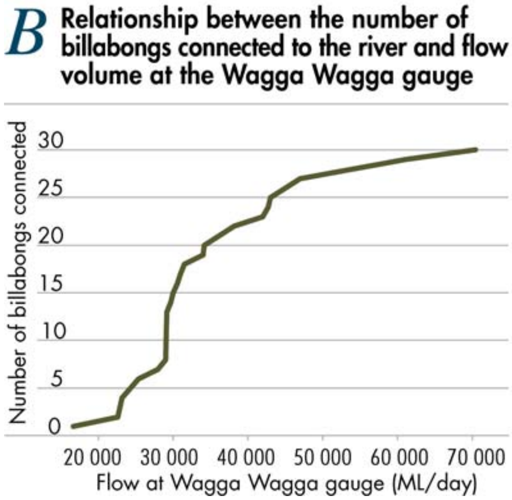


Table 1. High flow events at the Wagga Wagga gauge – current and natural modelled flow

	Number of flood events in a 100 year period for events lasting at least:			
	1 day		15 days	
Minimum flow GL/day	Current	Natural	Current	Natural
25	323	457	38	66
30	245	395	24	39
35	190	353	12	25
40	159	301	8	16
50	104	228	3	8
60	175	55	1	2
70	55	127	1	2

A planning framework

In this section an environmental planning framework that is intended to generate both a well specified demand for environmental water and an optimal set of high flow release rules is developed. Well defined demands imply that expected volumes of water required and conditions of use are known. There are three characteristics sought within the design of the framework:

- a clearly stated environmental objective or set of objectives that gives rise to measurable outcomes
- technical efficiency such that environmental goals are met at the lowest possible resource costs, where these costs reflect both productive and environmental values
- a clearly specified set of operational rules to provide planning certainty for environmental managers and consumptive water users — planning certainty is an important feature of an effective water market.

Specifying the environmental objective

There is a range of potentially complementary and competing management objectives along a river system. Some of these may be managed independently, but most will need to be managed jointly, as the supplementation of tributary flows with dam releases is likely to affect flow regimes all along the river system. From an operational perspective it is useful to consider a flow regime, and hence the environmental flow objective, at a specific reference point, remaining mindful that altering this regime will have broader consequences.

At a given location, an environmental release strategy that reconnects the river and flood plain environments at appropriate time intervals has at least three elements:

- ***timing or release window of the high flow event*** — for example, during late winter or early spring to coincide with breeding cycles;
- ***duration of the high flow event*** — the number and pattern of days that flow rates are maintained above a specified level;
- ***minimum and maximum flow requirements****;* and
- ***frequency of occurrence*** — the distribution of return or inter-arrival times between high flow events.

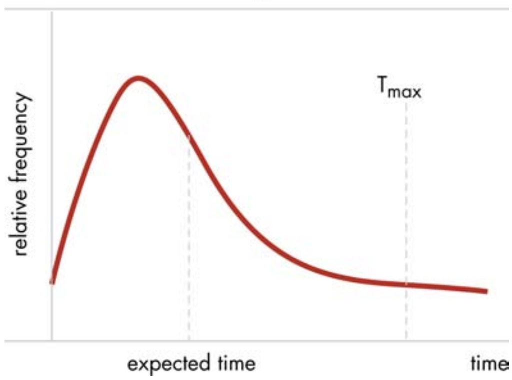
The first three elements serve to establish the criteria for a desired or successful high flow event. An environmental release strategy encompasses both access to a volume of water resources and a set of release rules, to generate a high flow event. For example, in the context of the discussion in the previous section, the environmental objective may be specified as maintaining a flow of at least 30 gigalitres a day at Wagga Wagga for a period of 15 days, commencing in the period from 1 August to 30 September. A minimum flow rate of a little over 30 gigalitres a day would fill the majority of billabongs and lagoons in the middle reach of the river, as indicated in Figure B. A maximum flow rate may also be imposed to avoid upstream flooding at Gundagai.

The criteria for success may reflect ecological imperatives that are ultimately subjective. For example, a high flow event lasting between ten and 15 days may be considered a partial success, although the incorporation of partial success into the planning framework would require the benefits of alternative flow regimes to be given relative weights. Natural high flow events are still subject to large variability in flows and the desired event may be better characterised by the processes of filling and flushing the wetland environments, as opposed to maintaining a minimum flow level. An alternative strategy may be to fill the billabongs and lagoons at the start of the cycle, allow the river to drop and then flush the billabongs at the end of the cycle. This is consistent with a point made by Hillman et al. (2003) that the connection sequence is more important than the duration of the event. Nevertheless, the duration of the event is kept as the focus here for simplicity.

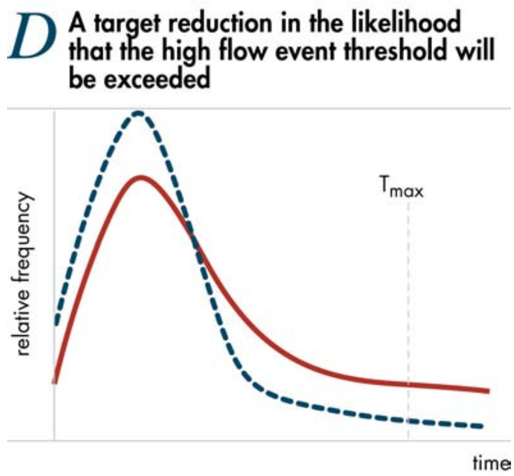
The objective here is not to design the specific features of a high flow event but to establish the concepts that underlie an environmental release strategy. The key point is that a prerequisite to the implementation of a planning framework is a well defined link between alternative hydrological flow regimes and community preferences for different environmental outcomes.

The frequency of occurrence of the event is central to the development of a release strategy. The frequency of occurrence of an event can be characterised by the distribution of return or interarrival times between events, a concept that is well established in queuing theory. A stylised distribution showing the relative frequency of the duration between events is shown in Figure C. The figure shows key aspects of the distribution that may have an impact on the underlying environmental objectives. These include the expected time between events and the likelihood that the time between events will exceed a critical threshold, Tmax. The relative importance of these or other distributional parameters is subject to debate. However, the parameters are not independent, and a flow regime designed to affect one will affect the other.

C **A stylised distribution of interarrival times between high flow events**



For illustrative purposes, the focus again is on the likelihood that the time between events will exceed the critical threshold, Tmax. A desired change in the inter-arrival time distribution is shown in Figure D, with a reduction in the probability that the time between events will exceed Tmax. That is, the area under the curve that exceeds Tmax is reduced. This reduction can be interpreted as an increased reliability, or probability, that a release strategy will achieve the targeted outcome of a high flow event occurring within the specified time frame.



While the environmental objective can be specified in terms of reliability, we can take advantage of a clear relationship between reliability and the resource costs of meeting environmental objectives.

Again there is a clear analogy to queuing theory where the waiting costs of remaining in a queue exceed a threshold that leads to reneging and a subsequent loss of business for the service provider. The problem faced by the service provider is to supply sufficient resources such that the cost of an additional service provider equals the expected cost associated with a reduction in the demand for services. There is a direct correspondence between the reliability that the service will be provided within the threshold period and the cost of failure to provide that service. In the context of the problem at hand, the desired level of reliability can be achieved by imposing a penalty for failing to meet the environmental objective.

An optimal release strategy with a well defined set of expected outcomes and resources may be determined by formalising the problem as a constrained cost minimisation problem. This set of outcomes and resources includes:

- an expected time between well specified events, and
- an expected level and distribution of the volume of water released to meet the environmental objective.

While setting a threshold and a level of reliability must be seen in the wider context of river ecology, hydrology and other assets at risk, such as farm and urban infrastructure, this underpins the development of a release strategy that takes into account the benefits and costs, and hence the efficiency, of alternative environmental flow regimes.

The cost minimisation problem

An optimisation problem is specified in terms of an objective function and constraints. The range of potential environmental objectives requires this to be done using a hypothetical example; however, the example provides some useful insights into the design of an optimal release strategy. Costs include the environmental benefits forgone if the flow objectives are not met, as well as the resource costs. The constraints set out the conditions that define the criteria that must be met for a successful high flow event.

The cost of providing environmental flows can have two components. The first is the opportunity cost of the water released. This cost will reflect the best alternative use of water held in storage. This could be an environmental release at a later point in time or the consumptive use of water in irrigation. In either case, the opportunity cost is likely to reflect the level of water in storage and expected future inflows into that storage. The second is the opportunity cost of having the water on call. This will reflect the capital cost of holding an environmental water entitlement, or of holding an option giving access to water held in storage by other entitlement holders. The latter will also depend on the salvage value of the water not used for the environmental release.

The cost of releasing water to meet an environmental flow objective will also clearly depend on the volume of supplementary water required, and this will depend on current dam releases and tributary inflows as well as current and expected climatic conditions. So a key aspect of a release strategy will be to predict release requirements to determine when the expected costs are less than the expected benefits. That is, to determine the flow and climatic conditions that will trigger an environmental release, given the time available before the maximum time between events (Tmax) is reached.

The constrained optimisation problem takes the general form:

Objective – to minimise the total economic costs associated with an environmental flow objective, including:

- the opportunity costs of acquiring and releasing water, and
- the penalty for not meeting the environmental objective.

Subject to – the event targets:

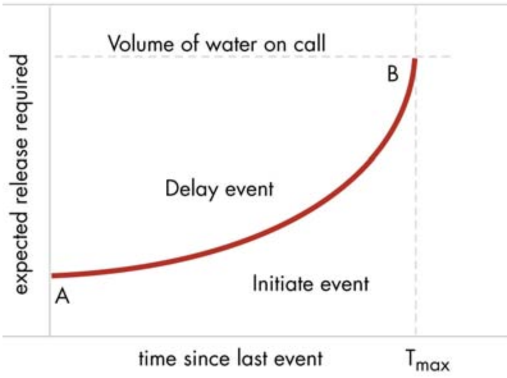
- release window
- event duration
- flow rates, and
- the frequency of events.

Given –

- the cost of holding water on call at the dam wall
- the opportunity cost of the water released, and
- the expected flow conditions or supplementary release requirements.

The release strategy that can be derived from this constrained optimisation problem is illustrated, in stylised form, in Figure E. The general structure of the release strategy is based on the fact that it is less costly to induce a high flow event when base stream flows are expected to be high. The volume on call at the dam wall constrains the maximum expected release, while the Tmax constrains the timing of the release. Above the line AB, the expected release requirements are too large and the event is delayed; below the line, the event is initiated. The curvature of the line reflects the fact that if the time since the last event is small, then initiating a high flow event will only postpone the need for a subsequent event for a short period of time. Further, the window of opportunity to create the event within the specified time horizon is relatively large. Conversely, as the time since the last event increases, the implicit value of generating an event increases as the maximum time required for a subsequent event increases, and the time remaining to avoid the penalty decreases.

E A stylised release strategy for supplementing high flow events



A more rigorous specification

A release strategy is a set of rules based on expected release requirements that determine when to trigger a decision to release environmental water holdings in an attempt to create a high flow event. There are four elements to the problem: defining the expected water requirements needed to generate the event; the state transition function; the loss function to be minimised; and the release strategy. Expected release requirements are based on forecast river flow conditions. The state transition function defines the time remaining until failure to generate a high flow event incurs a penalty. The loss function includes both resources costs and the penalty for not meeting the environmental objective. The release strategy includes the desired volume of water on call and the set of expected release requirements that, if met, initiate the high flow event.

Expected flow requirements

It is more strategic to release water to induce a high flow event when the background river flows are greater. This increases the chance that a successful high flow event will be achieved, and reduces the amount of supplementary releases that are needed. At any point in time, there is an (unknown) quantity of water that will be needed to induce a high flow event. A daily time series model was fitted using historical river flows:

$$y_t = c + \sum_{i=1}^{m} \beta_i y_{t-i} + v_t$$

$$v_t = \sum_{i=1}^{n} \alpha_i v_{t-i} + \varepsilon_t$$

where y_t is the river flow at time t; c, β and α are parameters to be estimated; and ε_t is an independent normally distributed random variable with mean 0 and a variance σ2. This was used to predict future river flows, and hence dam releases required to achieve a flood. The total predicted supplementary release P_t to achieve a high flow event, with a flow rate of F megalitres per day for a duration of Dmax days, is given by:

$$P_t = \sum_{t=1}^{D_{\max}} F - y_t$$

The state transition function

The state transition function is dependent on the specification of the environmental objective and, as a consequence, it is not possible to specify a general functional form. A simple form is used here for illustration, where the state s is given according to how many years have elapsed since a high flow event has occurred:

$$s_t = \begin{cases} s_{t-1} + 1 & \text{if no event occurs} \\ 1 & \text{otherwise} \end{cases}$$

A high flow event occurs when the minimum flow rate required, F, is achieved for a minimum of D_{min} days.

The loss function

The strategy is determined by minimising the loss function. Again, the specification of the loss function depends on the environmental objective. The illustrative loss function is the sum of the average annual cost of three components:

$$Q*(C - SV) + SV.\sum_{s=1}^{\infty} p_s.\overline{U_s} + \sum_{s=Y}^{\infty} p_s.F_s$$

where *Q** is the volume of water on call; *C* is the annualised cost of a permanent entitlement per megalitre; *SV* is the salvage value of water not released for environmental purposes. Hence

$$Q*(C - SV)$$

is the annual opportunity cost of the water on call, and

$$SV\sum_{s=1}^{\infty} p_s\overline{U_s}$$

is the opportunity cost of the released water.

Any strategy will result in a set of long-term probabilities

$$\{p_s : s = 1, 2, \ldots\}$$

of being in the various states s. If the average annual volume of water released while in state s is $\overline{U}_s$ then

$$\sum_{s=1}^{\infty} p_s.\overline{U}_s$$

is the overall average annual water release, and

$$\sum_{s=Y}^{\infty} p_s.F_s$$

is the average penalty incurred each year. F_s denotes the average penalty incurred in state s if a high flow event is not achieved. A penalty is incurred for states $Y = T_{MAX}$ or higher if the minimum flow rate required is not achieved for at least $D_{\max}$ days.

If the flow rate is maintained between $D_{\min}$ and $D_{\max}$ days, a variable penalty *F(t)* might be applied to reflect the value of a partial success discussed earlier. The penalty might decline to zero as the event approaches $D_{\max}$ at a decreasing, constant or increasing rate.

The release strategy

The release strategy is based on the curve shown in Figure E and the volume of water on call. The estimated curves define the threshold level of expected release requirements for each day of the release window in each season, below which the event is initiated and up to the volume of water on call is released. As the release windows are discontinuous between seasons, a separate curve is specified for each state *s*. An exponential functional form was selected as a compromise between flexibility and the number of parameters, a_s, b_s and c_s to be estimated:

$$f(t,s) = a_s + b_s.e^{c_s.t}$$

Whenever $P_t < f(t,s)$ then a high flow event attempt is initiated.

A solved example

The objective is to have a high flow event at least once every five years (T_{MAX} = 5). The minimum daily flow requirement at Wagga Wagga is 30 gigalitres a day (*F* = 30 gigalitres). A minimum of ten consecutive days at or above this flow rate is required to generate a high flow ($D_{\max}$ = 10) and reset the state *s* = 1. However, the expected release requirements are calculated to generate a 14 day high flow event

(D_{max} = 14). A penalty of $30 million is imposed if a high flow event lasting ten days is not achieved in the fifth and any subsequent states. The penalty is assumed to decline at a constant rate to zero as the event reaches the 14 day target. The penalty used here is arbitrary, but is ultimately related to the level of reliability achieved under the release strategy. A clear alternative is to specify the level of reliability as a constraint. However, this does add to the technical difficulty of solving the optimisation problem.

The water entitlement Q^* for environmental release is determined endogenously given the annual cost C of holding that entitlement; assumed to be $70 per megalitre a year, a value close to the annualised cost of purchasing a permanent high security entitlement in the Murrumbidgee River at a discount rate of five per cent. The salvage value or opportunity cost of the water actually released is $50 per megalitre, a value close to the average traded price in the physical allocation or temporary water market.

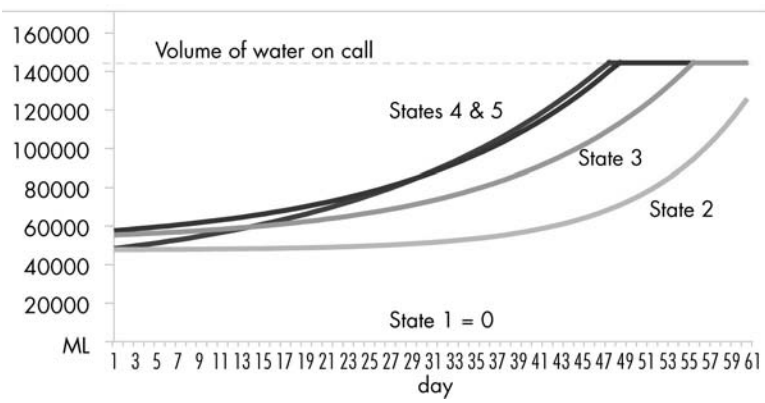
The problem as formulated is not well suited to traditional optimisation methods as the loss function is discontinuous and the state transition equation is subject to jumps. A modified genetic algorithm was used to estimate the values of a_s, b_s, c_s, and Q^* that minimised the loss function (Goldberg 1988). The algorithm was implemented in Visual Basic and is available from the authors on request. Convergence of the algorithm to an optimal solution was tested by perturbing the estimated parameters.

The hydrological link between supplementary dam releases and flow rates at Wagga Wagga was based on a simple routing model without flow attenuation or upstream overbank losses. Attenuation does generate significant variability in flows that are not accounted for in the evaluation of the criteria for a successful high flow event. The optimal release strategy was subsequently evaluated in the Murrumbidgee IQQM model to gain a more accurate assessment of the impact of the release rules on flow regimes.

The solution

The optimal release strategy is shown in Figure F. The volume of water on call is slightly above 140 gigalitres, which is substantial. This, however, reflects the relatively stringent criteria for a successful high flow event, and penalty for failure. The volume of water actually released is substantially smaller, averaging about 25 gigalitres a year. In years when a release is made, the average volume of the release is 75 gigalitres.

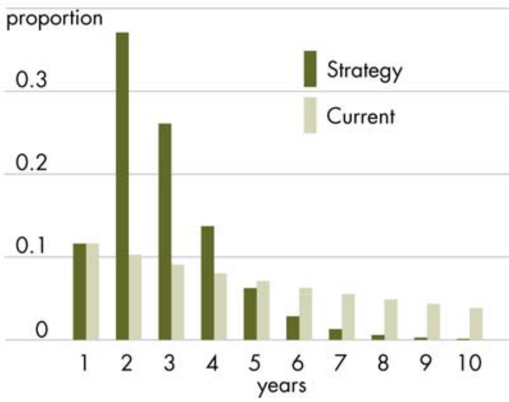
F Optimal release strategy



In state 1, corresponding to a year in which there was a successful high flow event in the preceding season, the release threshold is zero. The release curves become successively higher in states 2 through to 4. States 4 and 5 are similar, reflecting the way in which the penalty function is structured. In state 5 there is a penalty for an event lasting less than the full 14 days. No penalty is incurred in state 4 even if a high flow event lasts only ten days, creating an additional incentive to make a release in that state. It is not intended to infer that this is an appropriate environmental design, but it does highlight how the structure of the penalty function affects the release strategy.

The penalty level generates a very reliable release strategy within the simple hydrological specification used to predict flows. Under current conditions, the likelihood of achieving a high flow event within five years is approximately 46 per cent. With the supplementary releases, the likelihood of achieving a high flow event within five years increases to 95 per cent. The shift in the interarrival pattern of events is shown in Figure G. As well as reducing the likelihood of an extended period without a high flow event, there is a marked increase in the frequency of events occurring in years 2 and 3. The direct resource costs, excluding penalties, of the release strategy over the 100 year simulation period are approximately $4 million a year. This reflects the cost of holding a high security entitlement, the volume of water required to generate a continuous 14-day high flow event, and the level of reliability achieved.

G Interarrival time between high flow events



The release strategy is incorporated into the Murrumbidgee IQQM model to more closely simulate actual flows at Wagga Wagga. The IQQM modeling of loss and attenuation effects changed the profile of flows and the number of days at which the target flow rate was maintained. That is, while on average the target was maintained, fluctuations occurred between days that did not meet the relatively stringent definition of a successful event. As a consequence, there was no increase in the predicted number of 14-day events at or above 30 gigalitres per day. Nevertheless, there is a substantial shift in the flow regime with a large number of events being generated below the target threshold. A comparison with Table 1 indicates that the number of high flow events of 25 gigalitres a day restores about 50 per cent of the natural flow conditions for a 14-day event (Table 2).

Table 2. Additional high flow events at Wagga Wagga

Minimum flow per day						
	25 GL	26 GL	27 GL	28 GL	29 GL	30 GL
7 days or more	10	13	13	11	7	–3
10 days or more	17	17	12	5	8	3
14 days or more	15	13	9	2	–1	0

Sensitivity analysis

While there are many parameters to consider in the design of an optimal release strategy, the cost of failing to meet an environmental objective and the cost of the water resources required to meet that objective are central to the problem. The model is therefore solved under a set of alternative assumptions for both of these parameters.

The annual penalty for failure was reduced to $20 million and increased to $60 million. The results for the volume of water on call, the reliability of the rule and the cost of operation are shown in Table 3. The results are consistent with logical expectations of a cost minimisation model. The relationship between penalty rates and reliability is clearly illustrated. Relative changes in reliability are associated with a large change in the volume of water on call and hence the costs of the optimal release strategy. Moreover, the resource costs of adopting the release strategy decline sharply as the level of reliability falls.

Table 3. The optimal release strategy under different penalty rates

Penalty/Value	$20 million	$30 million	$60 million
Volume on call (ML)	100 408	144 111	191 098
Likelihood of success (%)	93	97	100
Cost ($million NPV)	61	86	109

The cost of a high security entitlement is reduced to $1200 per megalitre and increased to $1800 per megalitre. The salvage value is held constant so that the reduction in entitlement cost reduces the capital and opportunity costs of environmental releases. The results are shown in Table 4. Again the results are consistent with a cost minimisation model. The volume of water on call falls with entitlement prices and there is a consequent reduction in the reliability of the release strategy. Further, the percentage change in entitlement costs is roughly equal to the percentage change in the costs of adopting the strategy.

Table 4. The optimal release strategy under alternative entitlement costs

	Entitlement cost		
Value	$1200/ML	$1500/ML	$1800/ML
Volume on call (ML)	152 868	144 111	103 229
Likelihood of success (%)	97	97	94
Cost ($M NPV)	59	86	89

Discussion

The environmental objectives considered here, while set in a context of flow conditions on the Murrumbidgee River, are still hypothetical. Nevertheless, the exercise raises a wide range of conceptual and applied issues.

One advantage of adopting a formal decision framework is that it does link river hydrology to environmental objectives and the demand for water resources to meet those objectives. It places a strong focus on the hydrological aspects of an event that are important to achieving a desired or at least improved outcome. The adverse impact of attenuation on achieving the flow target in the solved example offers a good example. If maintaining constant flows is important to delivering the environmental outcome, then it might be necessary to increase the targeted flow rate, increasing both the resource requirements and cost of the strategy. If the underlying objective is to initially fill and to eventually flush the billabongs and lagoons, then it might be better to reconsider the definition of a successful event.

One potential disadvantage of this type of planning framework is that it can reduce the ability of an environmental manager to respond to unanticipated opportunities to achieve a desired environmental outcome. Hence, a release strategy should not fully preclude the discretion of the environmental manager. Further, while not a limitation, it is important to acknowledge that a planning framework will embody qualitative value judgments regarding, for example, the desired characteristics of a high flow event, as well as non-market values such as the cost of failing to meet an environmental objective.

The linking of the decision framework to a hydrological model such as IQQM allows environmental managers to more systematically explore how alternative environmental objectives and release strategies impact on the river system, not only at the point of reference but throughout the system. It allows the consideration of how targeted releases will affect subsequent storage levels, spills and end-of-system flows.

The cost of the example strategy is large when compared with current government commitments to increase environmental flows. This is largely an artefact of the design of the example, reflecting the high level of reliability imposed on the strategy and the cost of holding high security water at the dam wall. More importantly, the integration of the cost minimisation framework with river hydrology allows the costs of alternative strategies to be compared and options to reduce those costs to be explored. For example, rather than holding a high security entitlement, a general security entitlement or options contract, as discussed in Hafi et al. (2005) and Heaney et al. (2005), can substantially reduce costs, albeit at a lower level of reliability. Improved forecasting of river flows, and hence release requirements, is another avenue to reduce costs. These are all areas of ongoing research.

ACKNOWLEDGEMENT

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Chapter 15.

Paddy Field Characteristics in Water Use: Experience in Asia

Kazumi Yamaoka[1]

Typical arguments at international water fora advocate a competitive relation between agricultural water use and other water use, including for ecosystems. This premise is generally applicable to the discussion on irrigation in arid and semi-arid regions where water is constantly scarce. However, it is unsuitable for humid regions such as the Asian monsoon region where paddy rice culture has been developed for thousands of years, using ample natural water from rainfall, including flooded water and artificially irrigated water from various water sources such as streams, ponds and rivers. The inundated water in paddy fields and flowing water in irrigation and drainage canals serves as a network of wetlands and waterways to create another excellent secondary natural environment outside the river. Furthermore, paddy fields stretching along a river serve as a retardant reservoir that at once receives outflow from the mountainous hinterlands and irrigated water drawn from the river, and that gradually supplies the water to groundwater aquifers and the downstream river. This paper, in the context of the impact of irrigation on the environment, reviewing studies and reports of recent years on quantifying hydrological characteristics on a basin scale and identifying services for secondary natural environment in Japan, shows the unique natural features and cultural climate in paddy field irrigation in humid regions contrasting with those in irrigation in arid and semi-arid regions. It also describes international activities among rice growing countries, regions, international organisations and research institutions, namely the INWEPF, and the Japanese policy direction "Shifting to agriculture, thinking much of preservation of the environment", and gives recommendations for future challenges.

1. Introduction

Although Asia accounts for only 24% of the world's land area, it holds more than 60% of the world's population of about six billion. About 54% of the world's population live in a region known as humid Asia, or the Asian monsoon region, that covers only about 14% of the world's land area. Arable land in Asia, producing food to sustain this population, accounts for only about 34% of the world's arable land area of about

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1.5 billion ha. However, irrigable land in Asia occupies some 66% of the world's irrigable land area of about 270 million ha. The majority of this irrigable land is in paddy fields that extend over the whole of the Asian monsoon region. It goes without saying that the majority of Asia's massive population is supported by intensive paddy rice cultivation which offers high land productivity, based on irrigation.

Paddy rice cultivation in the Asian monsoon region is not only an excellent form of agriculture offering high land productivity and stable yields, but it could also be seen as a sustainable and environmentally friendly economic activity that suits the climatic and topographical conditions of this warm, humid region. This form of agriculture, an economic activity, has continued to evolve for hundreds to thousands of years at many sites, as witnessed by archaeological traces of 7000-year-old rice cultivation in China. And still today, it forms a unique natural feature and cultural climate by the endeavour of people living in symbiosis with water.

This unique natural feature and cultural climate, a complex amalgamation of this sustainable human activity, society and the natural environment, ranks alongside rice itself as another product of paddy rice farming. Water in paddy fields and irrigation-and-drainage system serves as a network of wetlands and waterways, and creates an excellent secondary natural environment with an enriched flora and fauna. Furthermore, it also supports the convenience of life for city dwellers through recharging groundwater, reducing peak flood flows, supporting biodiversity and so on. These functions are non-commoditised "products" provided jointly and consumed publicly.

When a given economic activity brings profit to other economic entities through non-market means, we say that it performs positive economic externality, or it has an external economy. We shall call above-mentioned functions "the multi-functional roles of paddy field irrigation" as positive economic externalities. In the Asian monsoon region, as elsewhere, the rapid modernisation of socio-economic activity and the rapid growth of cities and industries have inevitably impacted on the rural socio-economy. In many places in arid and semi-arid regions, as the socio-economy grows, improper agricultural water use has caused problems such as accumulation of soil salinity, depletion of groundwater resources and degradation of biodiversity. What impacts will the rapid modernisation of Asian-style small-scale, labour-intensive paddy rice cultivation bring to the natural environment created by rural society and paddy rice farming, and the multi-functional roles of paddy field irrigation enjoyed by city dwellers?

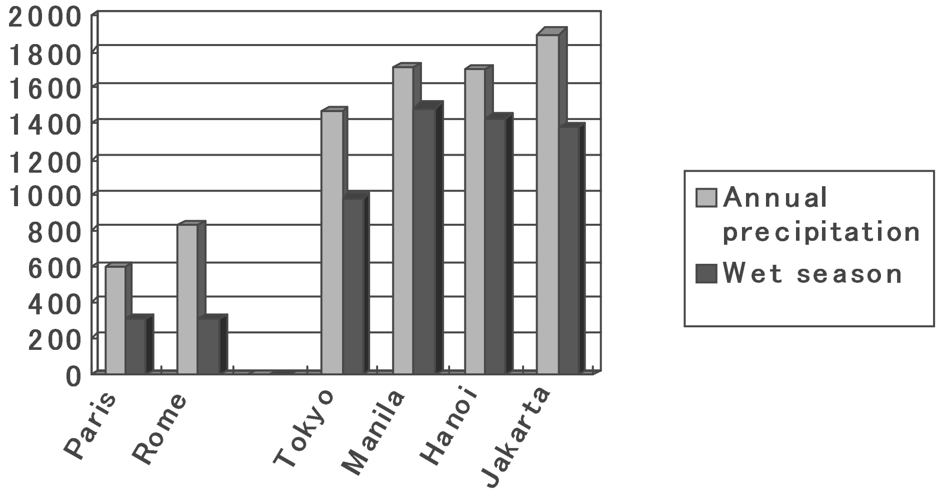
In responding to these questions, we shall illustrate the multi-functional roles of paddy field irrigation in humid regions by comparing their hydrological environment, forms of irrigation and characteristics of paddy fields with those in arid and semi-arid regions. We shall go on to examine methods of quantitatively or economically evaluating these multi-functional roles, and make policy proposals for Asian monsoon countries and the rest of the world on the problems awaiting solution.

2. Characteristics and roles of paddy rice farming in the Asian Monsoon Region

2.1 Natural conditions

The Asian monsoon region embraces the Indian Ocean to the south, the expansive region of Tibet, the Himalayan mountain mass and continental China to the north, and the Pacific Ocean to the east. Most of it consists of high-precipitation warm regions that have annual rainfall in excess of 1000–1500 mm, influenced by low pressure and monsoons accompanied by westerly winds. Moreover, the seasonal monsoon concentrates 70–90% of annual precipitation in a half year of the wet season (Figure 1).

Figure 1. Annual precipitation and precipitation in the wet season

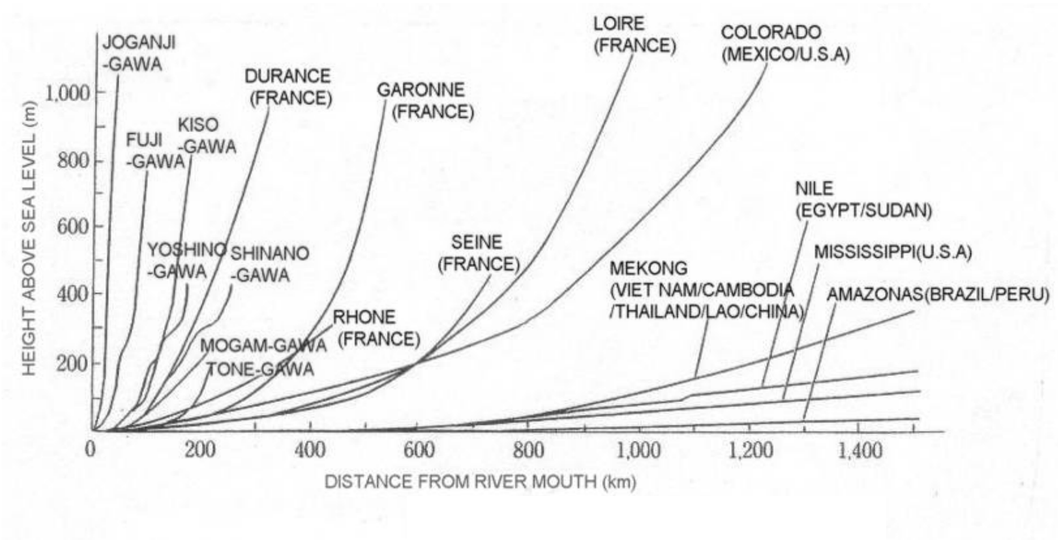


In terms of climate classification, meanwhile, it should be seen as a high-precipitation region and belongs to a warm climate zone (a climate classification encompassing temperate, subtropical and tropical zones). The water balance (calculated by subtracting annual potential evapotranspiration (ET), from annual precipitation) generally exceeds 500 mm. There are not too many regions of the world where there is a positive water balance of over 500 mm per year. Of these, the Asian monsoon region is the largest in land area and the highest in population.

The Asian monsoon region is physiographically composed of river basins that are influenced by tectonic zones, if the world's continental land is broadly divided into tectonic zones where orogenic movement is active and stable zones where the geology is older. This brings general characteristics of steep topography and fast-flowing river streams. Figure 2 contrasts the steep slope of major rivers in Japan with the gradual slope of major rivers in the continent.

The Asian monsoon region is characterised by large seasonal and short-term fluctuations in the supply of water resources, as is evident in the distinct dry and wet seasons. For this reason, the basic norm is to plant and cultivate paddy rice during seasons when water resources are abundant. When doing so, water is introduced to arable land, in excess of the moisture to be consumed by crops, with standing water, through the use of floodwater and irrigation.

Figure 2. Slope of major rivers in Japan and the world



Source: Takahashi, Yutaka (1990).

Most of the water introduced in excess of the moisture to be consumed by crops is returned to groundwater and the downstream river via percolation and surface outflow to drainage channels leading to the river. The proportion of water consumed for evapo-transpiration differs from region to region, but in the example of Japan, it is said to be 25-50% of the water introduced into paddy fields and the rest of it, 50%–75% of the water, returns again to the water cycle system in a river basin. In this manner, by repeating the cycle within a river basin of initially extracting water from rivers, temporarily inundating paddy fields via water supply channels, then slowly accumulating groundwater or returning the water to rivers and reusing it downstream, water resources can be retained on land for as long as possible and used efficiently. This use and reuse of water is important in areas with many rivers with short courses and fast currents because of steep topography, where water resources might otherwise be immediately released into the sea without realising their full potential value.

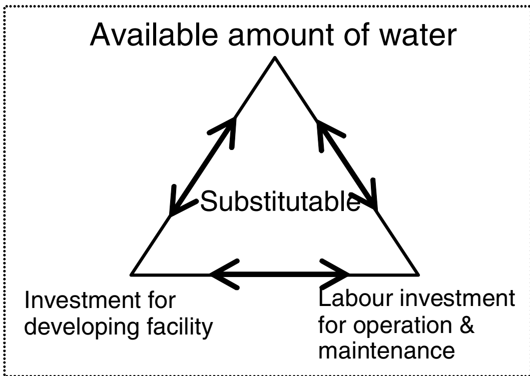
2.2 Characteristics of paddy rice agriculture — substitutability in water use

In the Asian monsoon region, paddy field irrigation is managed using the benefits of the wet environment as much as possible. "Wet environment" as used herein refers to two environmental conditions that are present during the wet season. The first condition is the fact that anybody who wishes to obtain water can ordinarily get it relatively easily and in large amounts if rain falls normally. This is because high precipitation results in a large amount of water resources available, and because the hilly terrain has many mountain streams and networks of small- and medium-sized rivers that have easier accessibility than large rivers. In economic terms, this means that, in most cases, water resources have an extremely low shadow price.

The existence of ample water enables water to be sent from higher-elevation fields to lower-elevation fields by introducing water into upstream paddy fields, cutting a part of the levees surrounding paddy plots, and letting the excess flow to downstream paddy fields. With this system, called "plot-to-plot irrigation", the fields themselves serve as irrigation canals. It does not matter if tens or hundreds of plots are involved; if there is sufficient difference in ground elevation, this method can be used to supply water to all of them, enabling the labour required for on-farm management of water, as well as investment in facilities, to be reduced. Therefore, this is widely developed, naturally in rain-fed paddy areas, and around the tips of traditional irrigation networks and also even in the periphery of modern irrigation systems.

The existence of ample water also enables water to be conveyed to the tail end of irrigable area even if poorly built canals with many leaks are used. The reason is that losses from leaks may be covered and the more water that is available in irrigation canals, the easier it is to appropriately manage the water distribution at divergence points. This means that the amount of investment in facilities and labour required for off-farm water management can be reduced. Consequently, the available amount of water use, labour investment for operation and maintenance, and investment for developing facilities can be substituted for each other. An item that is costly can be replaced by one that is less costly. If this practice is employed, it is possible to raise the economic efficiency of water use by using cheap and ample water resources (Figure 3).

Figure 3. Substitutable items for efficient irrigation management in paddy fields



The second condition is paddy rice's physiology as a water-loving plant that can perform exceedingly well in inundated fields. There are varieties of rice that do well in fields that have a very shallow depth of ponded water, and others like floating rice varieties that can adapt to areas with a ponded water depth of several metres. Because of this, cultivation known as "immersion cultivation", whereby the entire field is continuously covered with water, becomes possible. This method represents a fundamental difference from water management of dry field soil, as a standing pool of water is created by levelling out a field and building levees around it, and formulates several advantages described below. In mountainous areas with steep terrain, paddy fields that are created in this manner are terraced, forming beautiful curves along the mountain side.

Owing to the characteristics of rice, namely high tolerance to inundation and the natural and economic condition allowing ample water use, multiple effects can be expected from rice paddy irrigation, as mentioned later, including reducing labour for the work of tilling the submerged paddy soil, reducing the proliferation of weeds (except vascular plants), maintaining soil fertility (by replenishing nourishments and mineral ingredients through irrigated water), preventing soil erosion (because it is surrounded by levees), avoiding fall in yield by repeating mono-crop cultivation, and leaching (removing salinity from soil). The upshot is that, as an internal economy for farming, paddy rice cultivation in the Asian monsoon region, with ample water use, has the following advantages which allow continuous cropping of rice on the same land for hundreds to thousands of years (Table 1).

Table 1. Advantages of paddy rice agriculture with ample water use

Items of advantages	Explanation on advantages of paddy rice agriculture with ample water use
Reducing management in distributing water (off-farm)	Because ample water is available, it is possible to convey water to all parts of the field with even poorly-built canals, and it is easy to manage water distribution at divergence points. This means that the amount of investment in facilities and labour required for off-farm water management can be reduced.
Reducing management in distributing water (on-farm)	With the system called "plot-to-plot irrigation", the paddy fields themselves serve as irrigation canals. This method can be used to supply water to all of tens or hundreds of paddy plots easily. By repeatedly using water (i.e., by introducing it into paddy fields that are located in higher-elevation terrain and letting excess water flow to downstream paddy fields), labour required for on-farm management of water, as well as investment in facilities, can be reduced.
Reducing weed control	Flooding can prevent growth of weeds, except vascular plants like reeds that normally grow quickly and thickly when the soil is not submerged in the wet and warm climate.
Preventing soil erosion	Use of levees around rice fields and a standing pool of water reduce soil erosion losses even during periods of heavy rain. In fact, rice paddies act as a settling basin for suspended sediments in water.
Reducing fertilisation	Organic matter in the soil, decomposing slowly through anaerobic decomposition when the soil is flooded, maintains soil fertility. Organic nitrogen is transformed into ammonia nitrogen while the soil is under reduced conditions, and nitrogen is easily taken up by plants and attaches to soil particles. Less phosphate fertiliser is required for flooded soils because soluble, plant-available phosphates are formed while the soil is in a reduced state.
Reducing ploughing	Paddy rice cultivation in clay-rich soil involves a year-long process whereby flooding expands and softens the soil (swelling) and drying shrinks the soil, forming cracks. This process increases the pore space between grains of soil, which facilitates movement of water, improves soil leaching that occurs with rainfall and prevents the build-up of salts in the soil.
Preventing a fall in yield by repeated cropping	The soil is under reduced conditions when it is flooded and becomes oxidized when water is drained. This process promotes alternation between anaerobic and aerobic microbes, which maintains bacterial balance and soil fertility and prevents a fall in yield from repeated cultivation of the same crop on the same ground.

Source: Yamaoka, Kazumi, Naoki Horikawa and Tatsumi Tomosho (2004).

However, even in the Asian monsoon region, water is not always abundant even in the wet season, and unforeseen abnormal water shortages occasionally happen. At such times, just as in arid and semi-arid regions, the absolute volume of moisture needed for the growth of crops tends to be in short supply. Furthermore, "plot-to-plot irrigation" tends to allows upstream farmers to have a strong priority in taking water. Most of the downstream farmers with lower priority are reconciled to taking the drainage water released from upstream paddy plots.

During abnormal dry spells, all water users want additional supplies of water. The scarcity (i.e. value or shadow price) of water will temporarily soar in response to the tightness of demand and supply of water. Good governance and equitable distribution of water through Participatory Irrigation Management (PIM) is considerably important during abnormal dry spells. It may be dangerous to leave the water distribution to market mechanisms during abnormal dry spells because speculation and cornering may happen, and disturb people's access to water.

2.3 Characteristics of paddy rice agriculture — multi-functional roles of water use

Paddy field irrigation in the Asian monsoon region improves the utilisation efficiency of water resources throughout the river basin, and contributes greatly to the formation of healthy water cycles in river basins. In many instances, paddy field irrigation using this ample water also has the "knock-on effects" of recharging groundwater; mitigating floods; providing a domestic water supply and water for fish farming, shipping and other industries; passing on traditional culture; protecting biodiversity; forming aquatic landscapes; and other socio-economic effects and environmental services, in addition to its benefits for agriculture. The functions that give rise to these benefits are generally known as the "multi-functional roles of irrigation". With paddy field irrigation in the Asian monsoon region, these various socio-economic and environmental benefits are relatively large. Therefore, these multi-functional roles are also characterised in that they need to be correctly evaluated from the point of view of water use efficiency and sustainability of PIM.

Masumoto (2003, 2004) comprehensively reviewed methodologies of quantifying multi-functional roles of paddy field irrigation. He classified the multi-functional roles into four groups:

- water cycle control functions: flood prevention, groundwater recharge, prevention of soil erosion, sediment collapse and landslides
- environmental load control functions: water purification function, climate mitigation, organic waste processing
- nature formation functions: protection of biodiversity, landscape formation
- social culture formation functions: health and recreation, relaxation.

He also introduced and interpreted some recent results of studies on quantification of the multi-functional roles of paddy field irrigation more specifically. He pointed out that attempts had been made to evaluate the multi-functional roles quantitatively. The specific examples of these results were categorised as follows:

- flood mitigation functions: mountainous regions of Niigata prefecture, Tone river in Japan, Mekong river, Chao Phraya river in Thailand
- groundwater accumulation and recharge functions: the Shira river basin in Kumamoto prefecture in Japan
- soil erosion and hillside collapse prevention functions
- eco-system protection functions: the Kokai river and others in the Tone river basin in Japan
- landscape formation functions, health and recreation functions.

Moreover, he made a review on the methodologies of economic evaluation of the multi-functional roles of paddy field irrigation such as the substitution method, the contingent valuation method, the hedonic method, the travel cost method, and the direct method. Finally, he made a policy proposal to domestic policymakers and the international community.

On the other hand, the Rural Development Bureau in the Ministry of Agriculture, Forestry and Fisheries of Japan submitted a proposal document to the OECD Expert Meeting on Agricultural Water Quality and Water Use Indicators held in Gyeongju, Korea in October 2003. In the document entitled "The Relationship between Water Use in Paddy Fields and Positive Externalities —Japanese Perspective and Proposal", Yamaoka (2003) describes some examples of attempts to evaluate the multi-functional roles of paddy field irrigation and drainage, such as:

- aquatic creatures in paddy fields in Japan, paddy fields required for breeding of migratory and endangered birds in Japan;
- water returned to the river from paddy fields in the Kino river basin, balance of nitrogen in paddy and dry fields, effect of reducing peak flood runoff by water storage facilities for agriculture, provided by Dr. Kato and others, NIRE, Japan;
- example of supplying water resources for industrial needs in Youkaichi city, example of the relation between water use in paddy fields and change in recharging of groundwater in the Tedori river basin in Ishikawa prefecture in Japan.

2.4. Roles of paddy rice agriculture

The principal grain crop in the Asian monsoon region is rice. Rice supplies 31% of total food calories to people in Asia while only 3% in other areas in the world. Rice supplies more than 60% of total food calories in some countries such as Bangladesh, Cambodia, Laos, Myanmar and Viet Nam. Even in OECD member countries in Asia, Japanese and Korean people receive 23% and 31% of total food calories from rice (Table 2).

Surveying the cultivation of the "big three grains" in various regions of the world, we find that Asia accounts for nearly 90% of the world's paddy rice cultivation area. The cultivation of wheat, meanwhile, predominates in Europe, Russia, West Asia, and

Australia. Maize is the dominant crop in South America, while wheat and maize account for the majority of grain cultivation in North and Central America.

Paddy rice has a large physiological water requirement on the one hand, but is also highly tolerant to inundation. Moreover, it has a higher ratio of production for food and a lower ratio of use in international trade. Of the big three grain crops, therefore, rice could be said to offer the greatest potential for human self-sufficiency. In contrast, maize has a lower ratio of use for food, and is more important as a fodder grain (Table 3).

Table 2. Proportion of calories supplied by rice

Country/ region	Bangla-desh	Cam-bodia	Indo-nesia	Japan	Korea Rep.	Laos	Myan-mar	Viet-nam	Asia	Non-Asia	World
Proportion of calories supplied by rice (%)	72	75	50	23	31	66	71	66	31	3	20
Population (mill.)	138	13	212	127	47	5	48	78	3,680	2,391	6,071

Source: IRRI's homepage, [Atlas of Rice & World Rice Statistics], www.irri,org/science/ricestat/index.asp FAO's homepage [FAOSTAT], http://faostat.fao.org/faostat/collections?version=ext&hasbulk=0.

Table 3. Comparison of world's three major grains

Name	Area under cultivation (2000) (mill. ha)	Annual production (2000) (A) (mill. tons)	Water required to produce 1g of dried foodstuffs	Ability to withstand immersion	Consumption of A as food		Amount of A exported	
					B (mill. tons)	B/A (%)	C (mill. tons)	C/A (%)
Rice paddy	154	600	682	High	521	87	36	6
Wheat	214	585	557	Low	419	73	138	24
Maize	138	593	349	Low	115	19	85	14

Notes: Rice production is based on unhulled rice. The amount of water required to produce 1g of dried foodstuffs has a degree of latitude, depending on the reference.

Source: Statistical Databases (UN Food and Agriculture Organization) / Black, C. C., T. M. Chen and R. H. Brown, Biochemical basis for plant competition. Weed Soc. 17, 10–20, 1969.

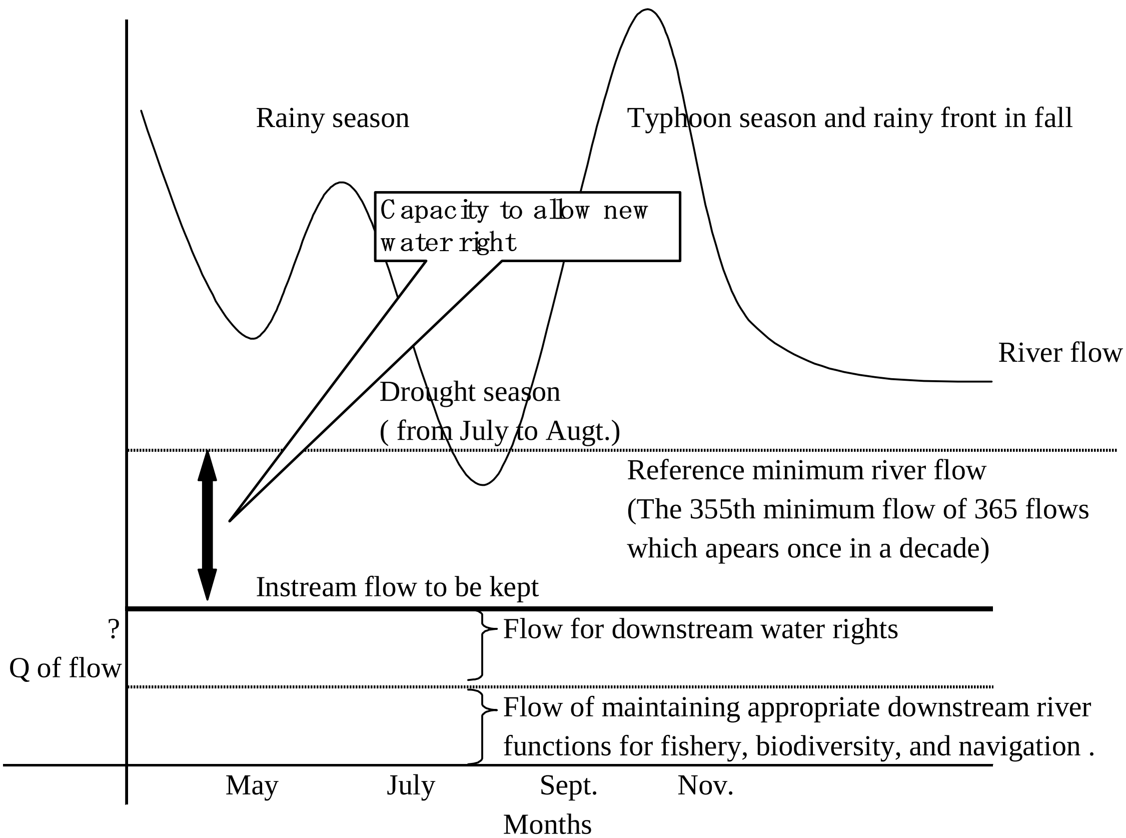
Each year, the world uses about 3,572 km^3 of fresh water (or 641 cubic metres per capita of population). About 60% of this total is used in Asia. Of the world's annual water usage, about 70% or 2,504 km^3 is used by agriculture, and of this about 70% is used in Asia alone. In Asia, the Middle East and North Africa, there are many countries in which the use of water for agriculture has reached about 90% of all water extracted. Japan's annual water use is about 88 km^3 or 691 cubic metres per capita of population, with about two-thirds taken up by agriculture.

3. Analysis on advantages of water use in paddy fields to enhancing ecosystem services: Case studies in Japan

3.1. Diverting water from rivers in harmony with downstream ecosystems

The River Act in Japan provides that a minimum river flow should be regulated when a water right is authorised to water users. Water users should release the amount of water designated as a minimum river flow to the downstream river when they take water from the river. The minimum river flow comprises flow for maintaining an appropriate downstream river flow function for fishery, bio-diversity and navigation, as well as flow for permitted water rights of the downstream water users. Figure 4 illustrates a system of conditionality for obtaining a water right. When a river authority entitles a water right to a water user for extracting water from a river, the authority strictly limits the amount of water which can be drawn from the river, with a calculation subtracting the minimum river flow from the 355th largest river flow of 365 daily flows in the drought year that statistically appears once per decade. In consequence, almost 100% of the length of rivers in Japan has respectively been assigned, under the River Act, an amount of minimum river flow for maintaining an appropriate downstream river flow function for ecosystems, including bio-diversity (Table 4).

Figure 4. Conditionality for allocating a water right in rivers in Japan



Source: River authority in Japan (2002).

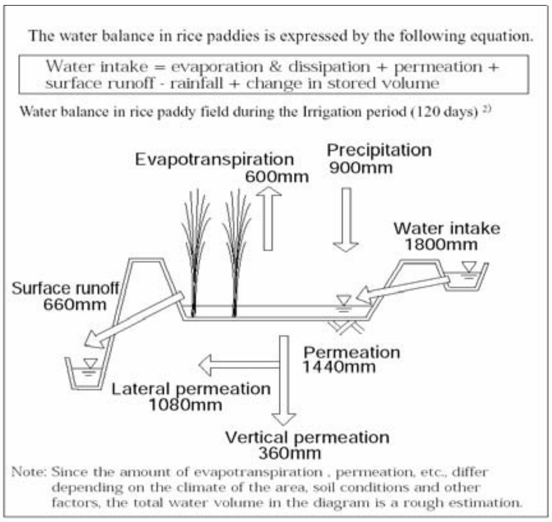
Table 4. Lines, length and authority of rivers controlled by the River Act

Class	Lines	Authority	Length	Ratio	Minimum flow
Class 1 River		National Government	10,553km	7%	Regulated
	13,979	Local Governments	77,008km	54%	Regulated
		Total	87,560km	61%	
Class 2 River	7,071	Local Governments	35,934km	25%	Regulated
Quasi-class River	14,113	Municipalities	20,032km	14%	Regulated
TOTAL			**143,528km**	**100%**	

Source: River authority in Japan (2002).

Agricultural water users are controlled by the River Act in Japan when they take water from a river. Moreover, the greater part of water taken from a river for rice paddy irrigation is not consumed, i.e. it is evapo-transpired. Figure 5 illustrates the water balance in typically irrigated rice paddies. The water taken from a river and not consumed in paddy fields contributes to enhancing ecosystem services in two ways: a) water in the total paddy irrigation and drainage system serves as a network of wetlands and water ways, and creates another excellent secondary natural environment outside the river with an enriched flora and fauna; b) water drained from paddies and returning to the river reinforces the ecosystems inside the downstream rivers and marshes.

Figure 5. Water balance in paddy (Japan)



Source: Maruyama, T., R. Nakamura et al. (1998).

Paddy fields stretching along a river serve as a retardant reservoir that receives outflow from the mountainous hinterlands and irrigated water drawn from the river, and that gradually supplies the water to groundwater aquifer and the downstream river. Figure 6 shows a schematic drawing and Figure 7 shows a diagram explaining the contribution system of rice paddy irrigation to ecosystem services. This system is widely observed in humid regions such as the Asian monsoon region. Figure 8 shows a diagram explaining the typical arguments advocating a competitive relation between agricultural water use and ecosystems where water is constantly scarce. It contrasts the contribution system in humid regions with the competitive nature of water use in arid and semi-arid regions.

Figure 6. The role of paddy fields as a reservoir promoting a sound water cycle in a basin scale

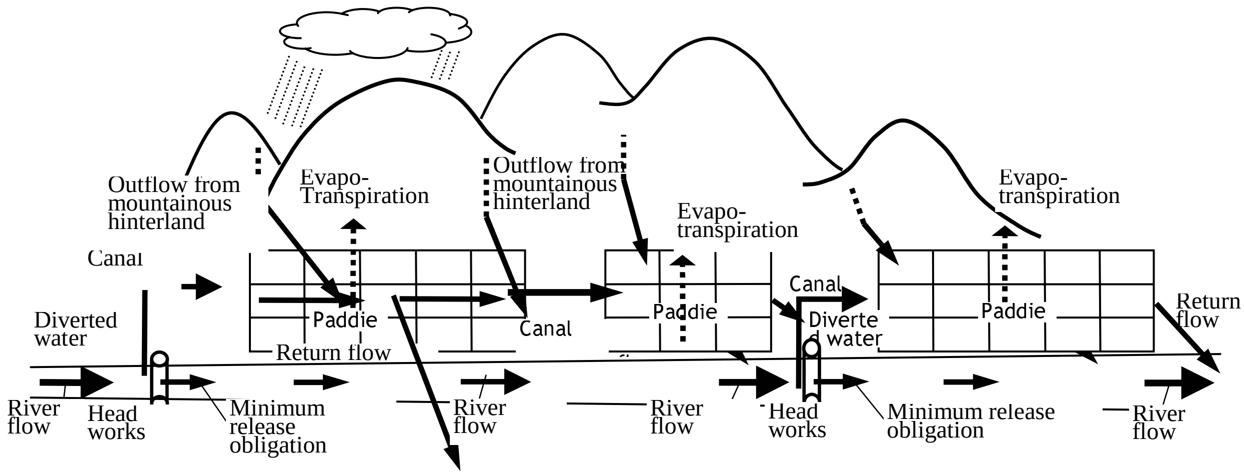


Figure 7. Contribution of paddy field irrigation to ecosystem services in humid regions

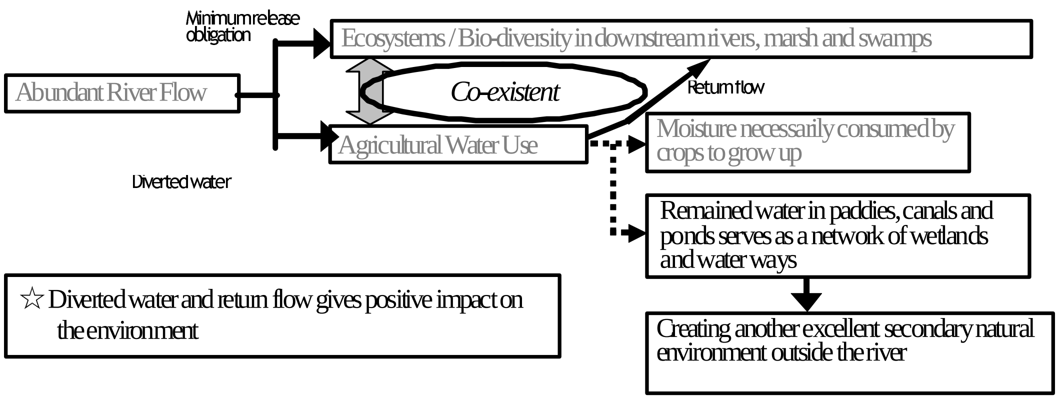
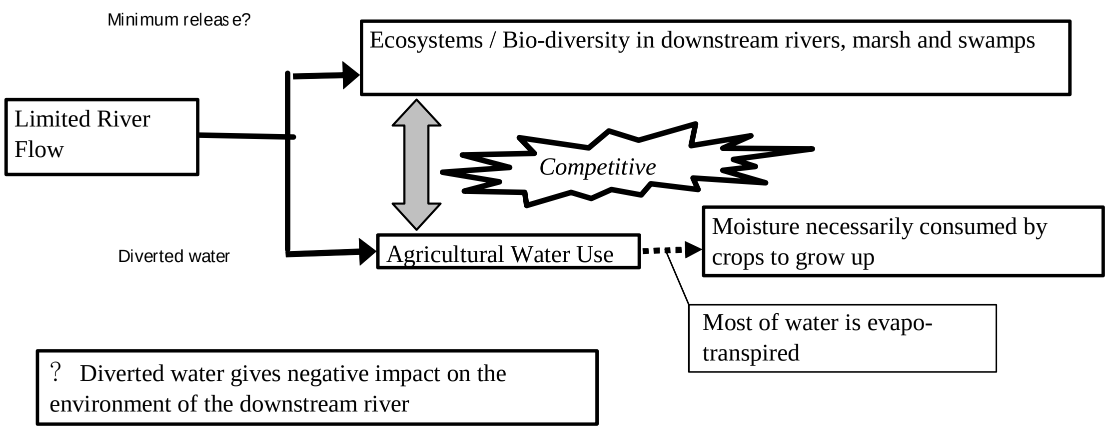


Figure 8. Competitive nature of water use in arid regions where water is constantly scarce



3.2 Stabilising downstream river flow through constant return flow to rivers

Rice paddies surrounded by levees store water from rainfall as well as irrigated water and discharge them into drainage canals. The irrigated water comprises water from rivers, irrigation ponds and streams. Some of the drained water directly returns to the downstream river while other water recharges irrigation canals in lower ground. The water is reused for irrigation in the downstream farmlands and for domestic water use. For analysing such complicated water balance in a basin scale, a water budget model divided into the sub-basin scale using the Complex Tank Model (CTM) was developed. Following two studies quantify the amount of return flow from paddy fields in basin scale using this methodology.

Nakagiri et al. (1998, 2000) studied the Kino River Basin located in the Kinki Region in the western part of Japan. It has a catchment area of 1750 km^2. The upper mountainous area has an average annual precipitation of more than 3000 mm while the lower part consists of a long and narrow plain along the main river stream with an average annual precipitation of 1350 mm. There exist three reservoirs in the mountainous area and six main diversion works in the plain, mainly for paddy irrigation. While the area of farmland is only 15% of the whole basin area, the total intake water for irrigation is about 80% of total water use. Figure 9 shows a ground plan of the Kino River Basin and division system into 25 sub-basins. Figure 10 illustrates a diagram of the irrigation and drainage network of sub-basins in the Kino River Basin. Figure 11 illustrates a diagram of CTM in a sub-basin.

Figure 9. Plan of the Kino River Basin and division into sub-basins

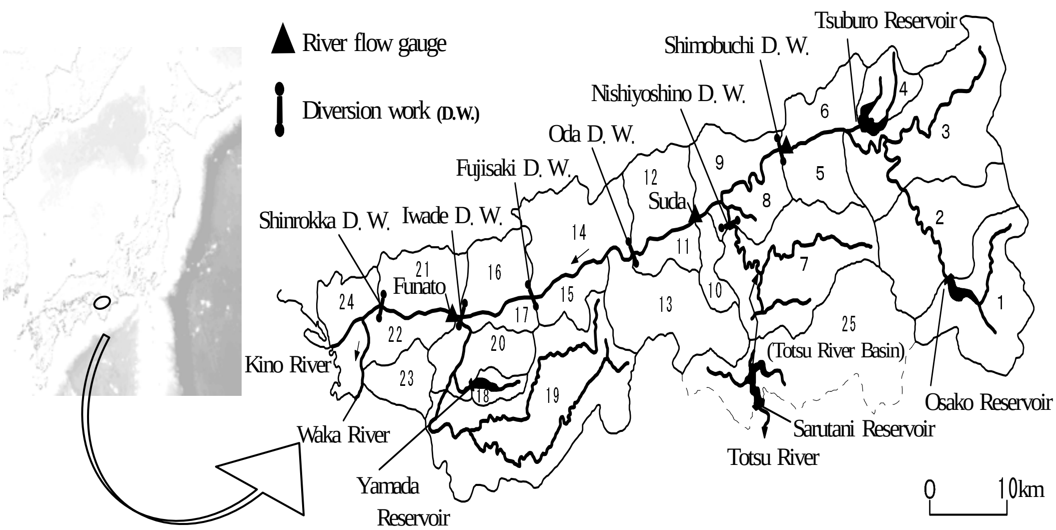


Figure 10. Diagram of irrigation and drainage network of sub-basins in the Kino River Basin

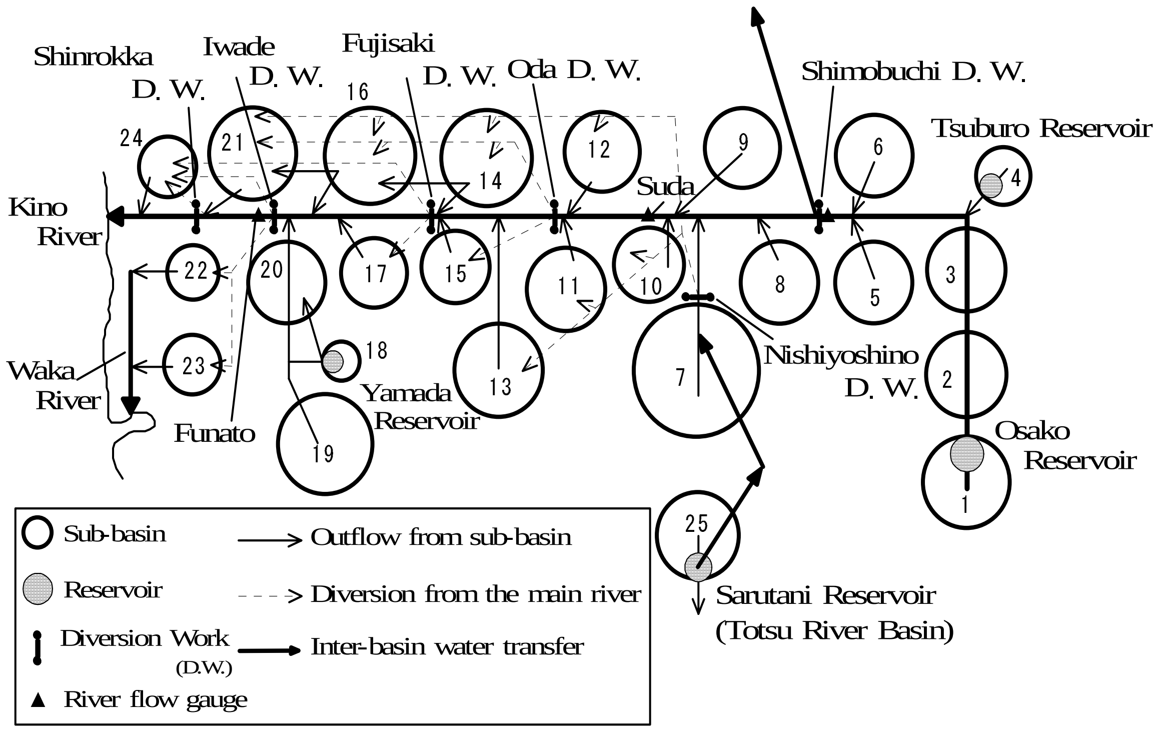


Figure 11. Composition of series tanks for each type of land use in a sub-basin

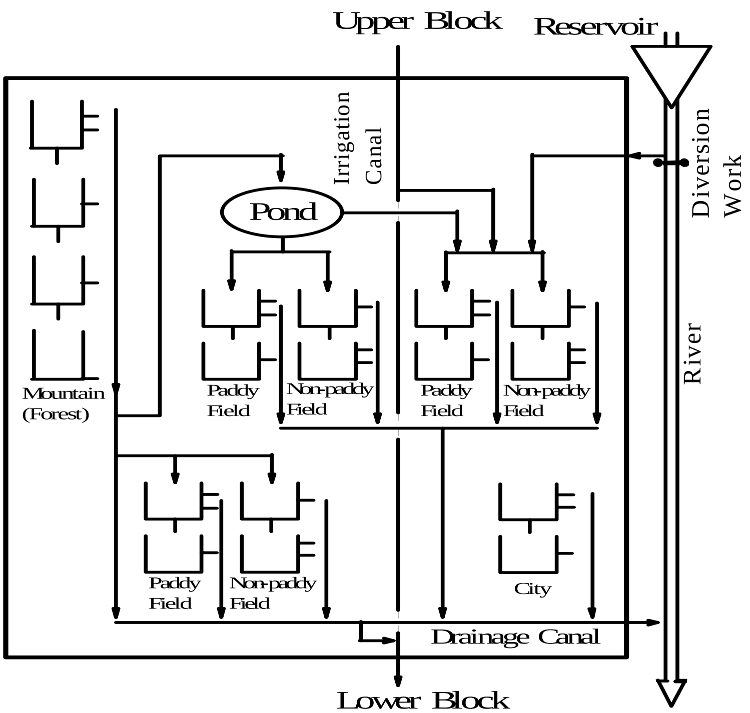


Figure 12 shows examples of the validation of the CTM comparing the simulated daily river flow discharge with the observed one at Shimobuchi, Suda and Funato in 1990. Let Q_{sim} represent amount of the simulated daily river flow (m^3/s), let Q_{obs} represent amount of the observed daily river flow (m^3/s), let N represent the number of data. The annual mean relative error of the simulated daily river flow to the observed one is defined as following equation:

$$\mathrm{Re} = \frac{1}{N}\sum^{N}\left(\left|Q_{sim} - Q_{obs}\right| / Q_{obs}\right)\times 100 \qquad \textbf{(1)}$$

Table 5 shows annual mean relative errors of simulated daily river flow to the observed flow. It shows that the model simulates, with a desirable level of accuracy at each point in most years, namely 21.9% at Shimobuchi, 24.8% at Suda, and 34.3% at Funato in an average of 8 years.

Table 5. Annual mean relative errors of simulated daily river flow to observed daily river flow (%)

Point	1983	1984	1985	1986	1987	1988	1989	1990	Ave.
Shimobuchi	30.2	24.2	20.1	15.9	24.5	17.1	18.3	25.1	21.9
Suda	23.2	29.1	21.3	24.3	25.0	24.5	24.1	27.0	24.8
Funato	43.9	40.0	34.4	28.8	33.3	22.4	27.4	43.8	34.3

Note that ρ1 is defined as the component ratio of return flow from upstream agricultural land in the diverted flow discharge at each diversion work. The return flow consists of irrigated water and rainfall in farm land. ρ2 is defined the same as ρ1 but the return flow should consist of only water irrigated in the upstream farmland. ρ2 can be regarded as the irrigation water reuse ratio (%) at each diversion work. Figure 13 and Figure 14 show the change of ρ1 and ρ2 by year and indicate that the values of both ρ1 and ρ2 increase as water flows downstream, up to 35% and 25% at the lowest reach in the river basin. The year 1987 has the lowest precipitation of 617 mm during the irrigation period; that in 1988 was 1076 mm and that in 1989 was 1335 mm. It predicts that the lower the precipitation, the higher the irrigation water reuse ratio at the lower reaches in the basin.

Figure 12. Hydrograph of river flow discharges observed and simulated by CTM

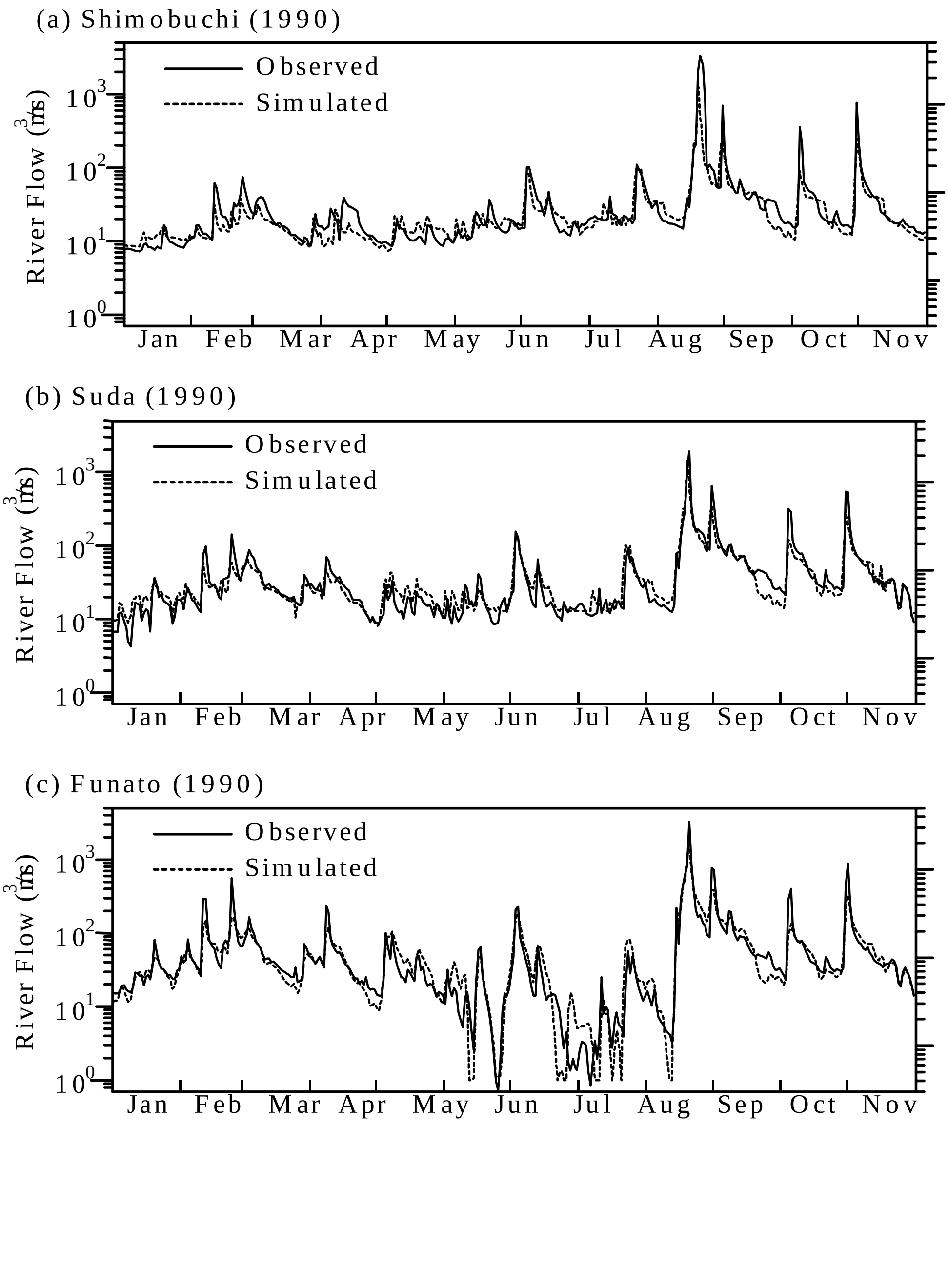


Figure 13. Component ratio of return flow from agricultural land in the diverted flow discharge at each diversion work

(by year, average for an irrigation period)

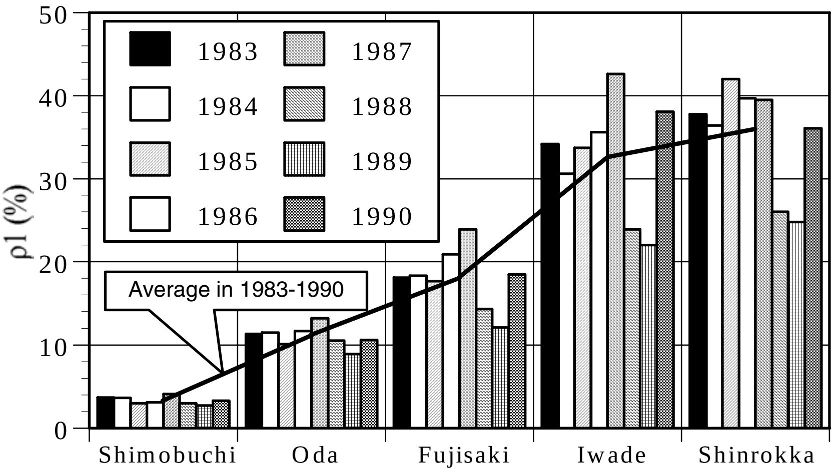


Figure 14. Irrigation water re-use ratio (%) at each diversion work

(by year, average for an irrigation period)

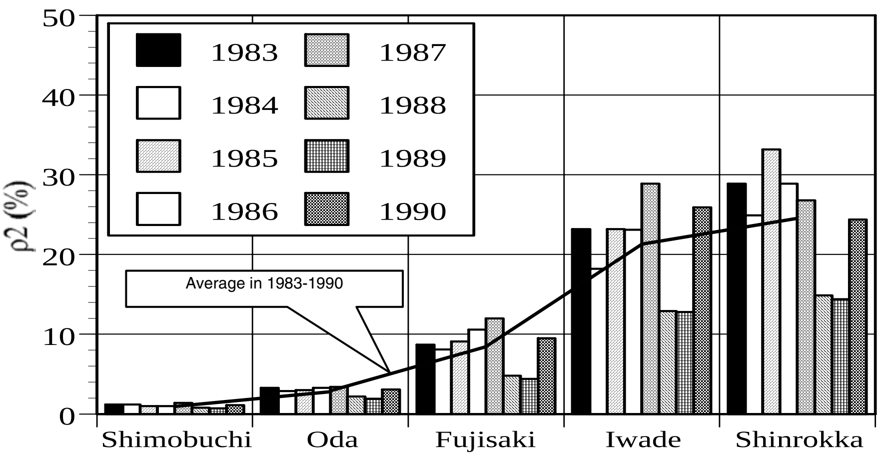


Figure 15 shows the transition of ρ1 and ρ2 at Iwade D.W. from June to September in a dry year, 1987. It indicates that ρ1 and ρ2 fluctuate widely and reach 70% and 60% respectively after a dry spell. Figure 16 shows the transition of river flow and its component corresponding to ρ1 and ρ2 at Iwade D.W. from June 20 to July 1 in 1987. It indicates that the return flow from upstream agricultural land (ρ1) and return flow of water irrigated in the upstream farmland (ρ2) plays a very important role for stabilising the river flow during the dry period.

Figure 15. Irrigation water reuse ratio (%) in intake water from D.W. in a dry year (1987, every 5 days average unit, Iwade D.W.)

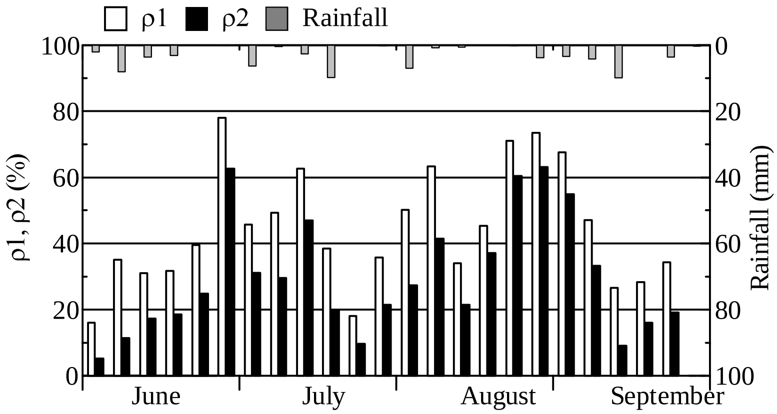
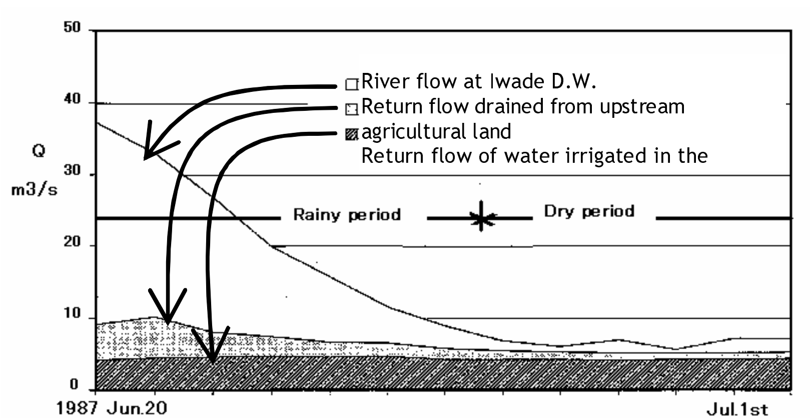


Figure 16. Transition of river flow and its component corresponding to ρ1 and ρ2 at Iwade D. W. from June 20 to July 1 in 1987



The second study basin, the Kinu and Kokai River Basin, is located in the Kanto Region in the central part of Japan. The report of the Tone River System Land Improvement Examination and Management Office in MAFF (2003) describes that the study basin area is the lower part of the basin with a catchment area of 1420 km^2. The Sanuki diversion work is located at the uppermost reach of the study basin area. Average annual precipitation in the study basin area is 1200–1600 mm. There exist three reservoirs in the upper reach of the Kinu River system and three main diversion works in the long and narrow plain in the study basin area. The plain area accounts for 80% of the study basin area. 51% of the plain area consists of 21,000 ha of paddy fields.

The study was carried out using a model with CTM, the same as in the first study basin. Figure 17 shows a ground plan of the Kino River Basin and division system into 81 sub-basins. The average of annual mean relative errors of simulated daily river flow to the observed one during 6 years, from 1998 to 2003, ranged between 11.1% and 18.7% at Okamoto, 20.1% and 36.6% at Katsuu, 18.7% and 30.5% at Hirakata, and 17.9% and 24.2% at Mitsukaido. It means that the model simulates with a good accuracy at each point in most years. Figure 18 shows the result of calculations revealing that, on average during the irrigation period in 2000 and 2001, 98% of the equivalent amount of intake water at Sanuki D.W. and 84% of the equivalent amount of intake water at Okamoto D.W. return to the Kinu and Kokai river at several downstream points.

Figure 17. Plan of the Kinu and Kokai River Basin and division into sub-basins

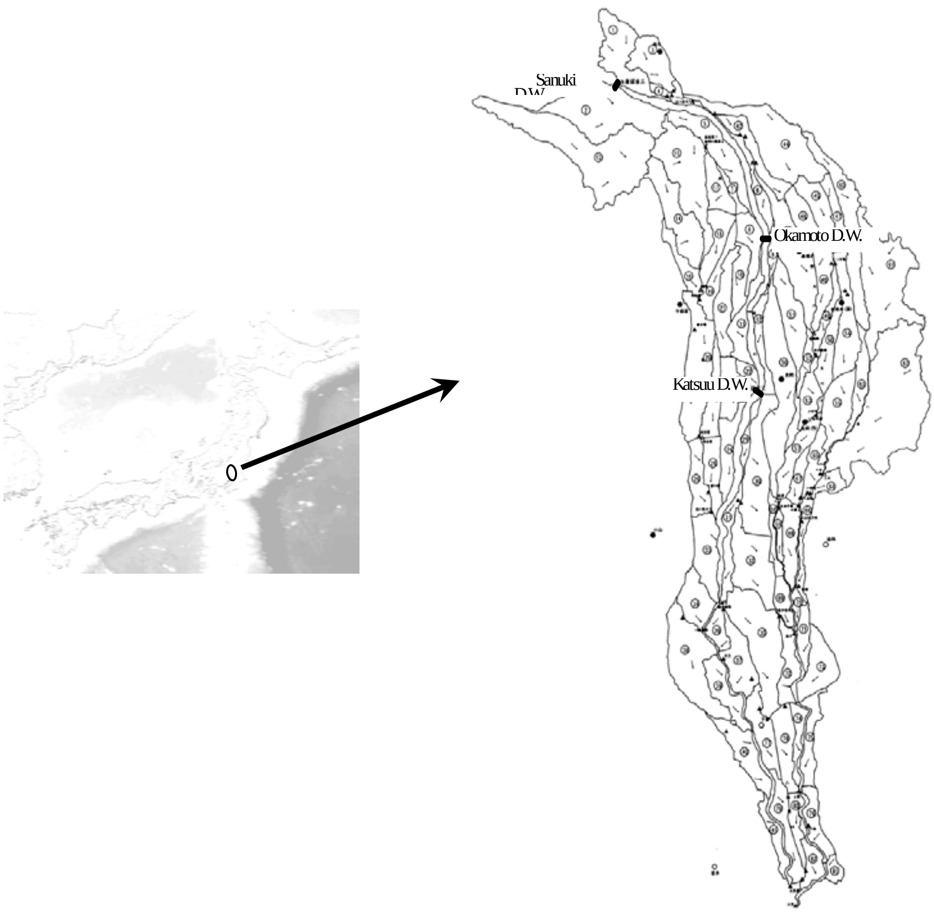
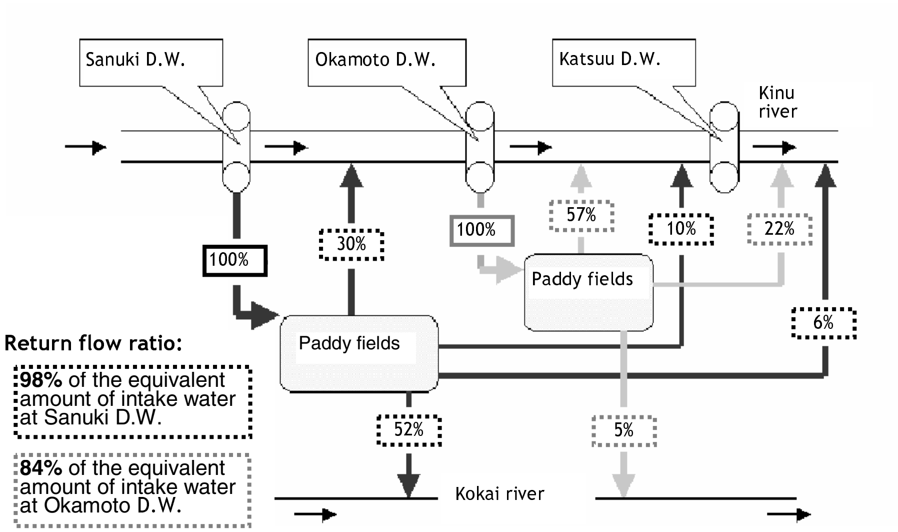


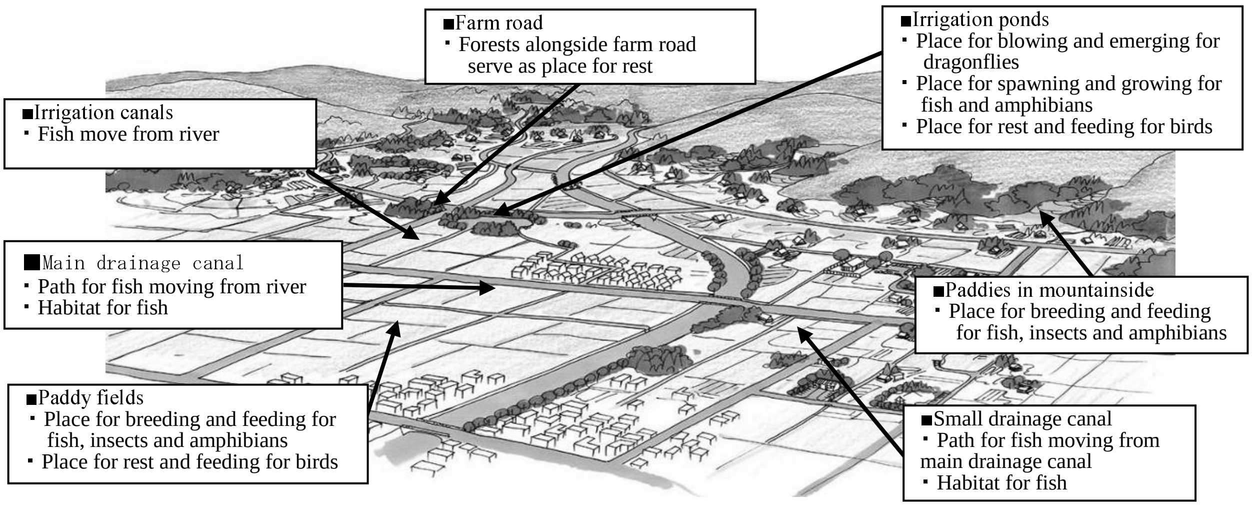
Figure 18. Ratio of calculated water amount returning to the Kinu and Kokai river during irrigation period (%)



3.3 Creating a secondary natural environment with wetlands and water networks

Paddy fields provide a valuable habitat for living creatures. Shallow ponded water over black soil easily becomes warm in summer and its combination with fertile soil serves as an incubator and fodder for creatures — from micro-organisms to higher forms of life such as amphibians, fish and birds. In addition, irrigation and drainage canals provide a network of water ways serving the same function as animal trails in a jungle. Irrigation ponds connected with paddy fields through canals provide a habitat and place of refuge for aquatic creatures during the non-irrigation period. Scattered coppices and groves in the countryside also provide a habitat and place of refuge for terrestrial creatures during the non-irrigation period. Figure 19 shows various creatures and their habitats on a typical bird's-eye picture of a countryside paddy field area in Japan.

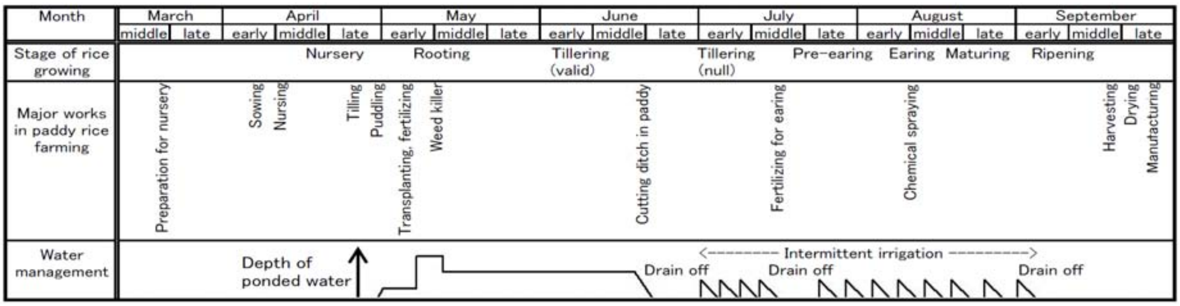
Figure 19. Various creatures and their habitats in typical countryside paddy field area in Japan



Source: MAFF, (2005).

The above-mentioned total paddy irrigation and drainage system creates an excellent secondary natural environment with a rich flora and fauna, and water taken from a river to the system preserves another and richer ecosystem outside the river. Paddy farming embraces varied on-farm water management such as for puddling, transplanting, temporary dry-up, intermittent irrigation and harvesting. This provides an ideal habitat for creatures which used to inhabit flooded plains, marshes and swamps. Note that an environment moderately intervened by human activity is actually helpful to less competitive creatures because the propagation of more competitive ones is disturbed by human intervention. Such a phenomenon is widely observed in a natural habitat intervened by occasional flood and dry-up. Figure 20 shows an example of a paddy rice cultivation calendar with typical variations of on-farm water management.

Figure 20. Example of paddy rice farming calendar with typical variation of on-farm water management



Source: Ministry of Agriculture, Forestry and Fisheries, Japan, 2005.

3.4 Enriching ecosystems and bio-diversity in and surrounding paddy fields

Suzuki (2004) reported the results of field research on fish swimming upstream and downstream in drainage canals connecting paddy fields in Japan. *Misgurunus anguillicaudatus*, a species of loach, and *Carassius* spp., i.e. crucian carp, swim up in drainage canals to paddy fields where they grow, then swim down from paddy fields after propagation. The on-site survey was conducted throughout a year. Table 6 shows the results of estimated biomass of loach in several paddy fields. It indicates that the loach increase their wet weight on average by three and half times from the time of their swimming up to nine paddies surveyed. It is also reported that the crucian carp increase their wet weight by 9.6 times from the time of their swimming up to a paddy.

Japan has about 38 million ha of national land territory of which rice paddy fields account for only about 7%, or 2.6 million ha. A large number of various animals and plants including endangered species survive in this rather small paddy area. The Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan (2003) carried out an on-site survey on fish, reptiles and amphibians, and their predators — birds, mammals, benthos, dragonflies and plants — surviving in paddy fields and canals in Japan. Table 7 shows the total number of species in 14 areas verified in "Survey for developing environmental information in agriculture and rural areas" conducted by MAFF. It indicates that more than 30% of species of fish and dragonflies in the national territory survives in paddy fields and canals in the surveyed 14 areas, and more than 20% of species of reptiles, amphibians and plants in the national territory survives there. Furthermore, large numbers of endangered species designated by the Ministry of Environment and prefectural governments are discovered in paddy fields and canals.

Table 6. Estimated biomass of *Misgurunus anguillicaudatus* from each paddy field in 2001

Site	Weight of population (g)		Amount of increase (g) (B – A)	Rate of increase (B / A)
	Swim up to paddies **A**	*Swim down from paddies* **B**		
A	841.9	856.4	14.5	1.0
B	257.8	73.7	-184.1	0.3
C	43.8	184.7	140.9	4.2
D	36.3	1019.7	983.4	28.1
E	22.8	582.7	559.9	25.5
F	9.1	20.1	11.0	2.2
G	21.7	1113.6	1091.9	51.3
H	10.4	216.2	205.8	20.8
I	41.5	472.4	430.9	11.4
TOTAL	**1285.4**	**4539.5**	**3254.2**	**3.5**

Table 7. Total number of species verified in paddy fields and canals in 14 areas in Japan

	Number of species verified in paddies A	*(Of which endangered species)*	Total number of species in Japan B	A / B (%)
Mammals	28	(5)	Approx. 200	14
Birds	136	(37)	Approx. 700	19
Reptiles and amphibians	38	(17)	161	24
Fish (sweet water)	101	(36)	Approx. 300	34
Benthos	182	(24)	Approx. 5,200	4
Dragonflies	61	(9)	204	30
Plants	1379	(67)	Approx. 7,000	20

3.5 Recharging groundwater with water used in paddy fields

Irrigated paddy fields generally possess a superior function of recharging groundwater because of the high rate of vertical and lateral permeation as described in Figure 5. To quantify the amount of water recharged from paddy fields and other lands, Ichikawa (2002) observed the amount of flowing water at nearly 300 monitoring points in the middle-stream basin of the Shira river in Kumamoto prefecture in Japan. The monitoring included the amount of water intake from six weirs in the region, the amount of return flow to rivers, and the amount of down-flow to the lower basin. He also surveyed the distribution of paddy fields and calculated the exact area for cropping among the fields.

As a result, groundwater accumulation amounting to an average of around 90 mm/day, and a maximum of 150 mm/day was observed in this region. Figure 21 shows a ground plan of the survey area and main directions of groundwater moving in the area. Figure 22 shows that paddy fields upstream of the Kumamoto city area supply 45% of the total groundwater recharge (281 million tons) of which the city requires around 226 million tons annually for drinking water, industrial water and air conditioning for buildings.

Figure 21. The ground plan and groundwater flow route in Shira River Basin area, Kumamoto, Japan

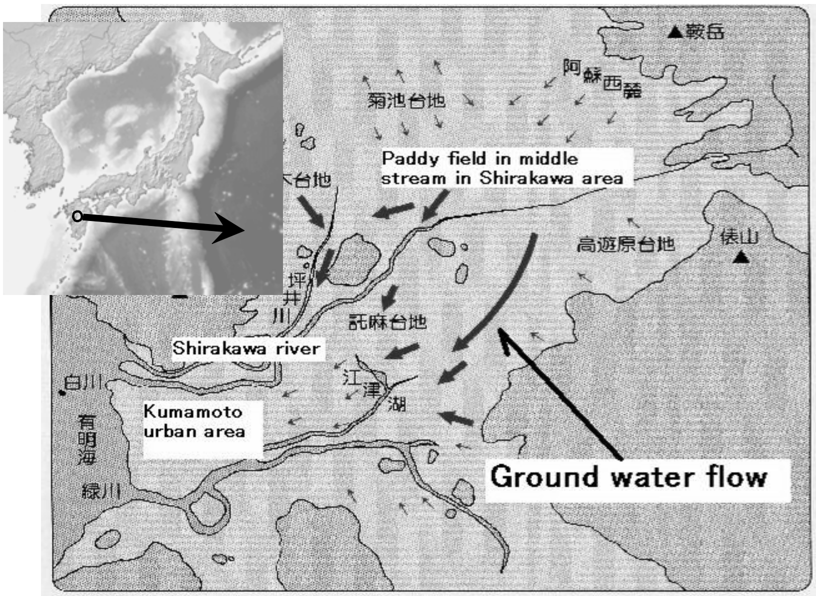
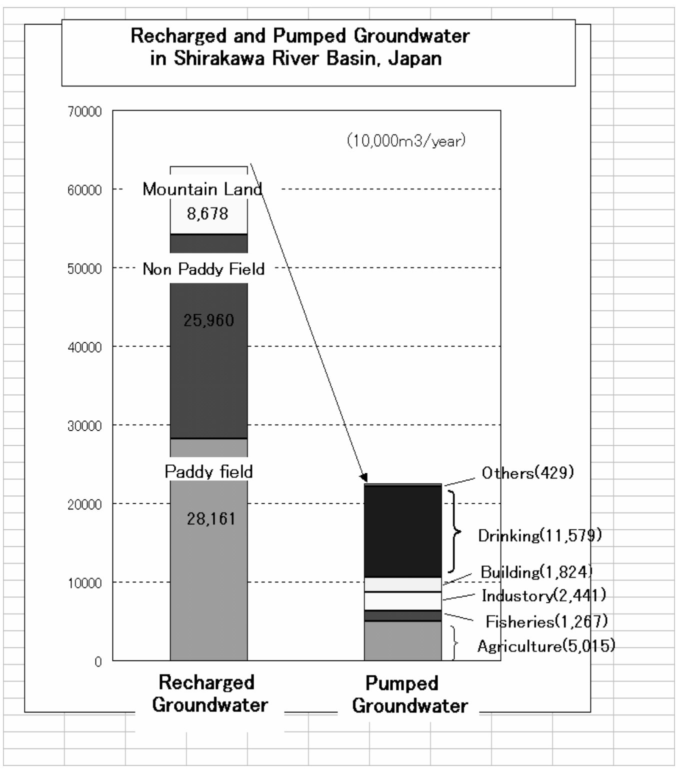


Figure 22. Recharged and pumped groundwater in Shira River Basin



The local government of Ishikawa prefecture of Japan carried out a long term monitoring and research on groundwater level in the Tedori River Basin from the 1970s to 2000. The research report concluded that the groundwater level decreased during non-irrigation periods when the water supply is cut off to paddy fields. Figure 23 shows the monthly change of the amount of water discharged by pump and that of groundwater level in the Tedori River Basin. The report also concluded that the diminishing area of cultivated paddy fields over the long term caused the gradual decrease in groundwater level and deterioration of groundwater resources from year to year. Figure 24 shows the secular change in area of arable paddy fields and groundwater level in the Tedori River Basin.

Figure 23. Monthly change of amount of water discharged by pump and ground water level in Tedori River Basin, Japan

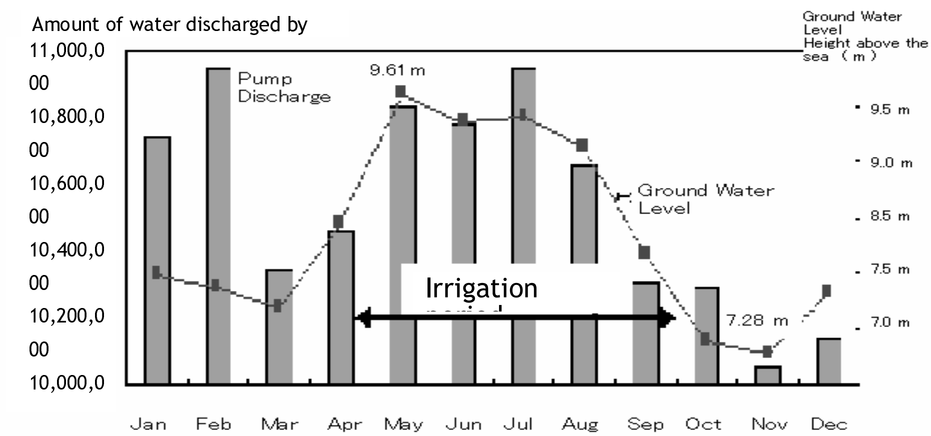
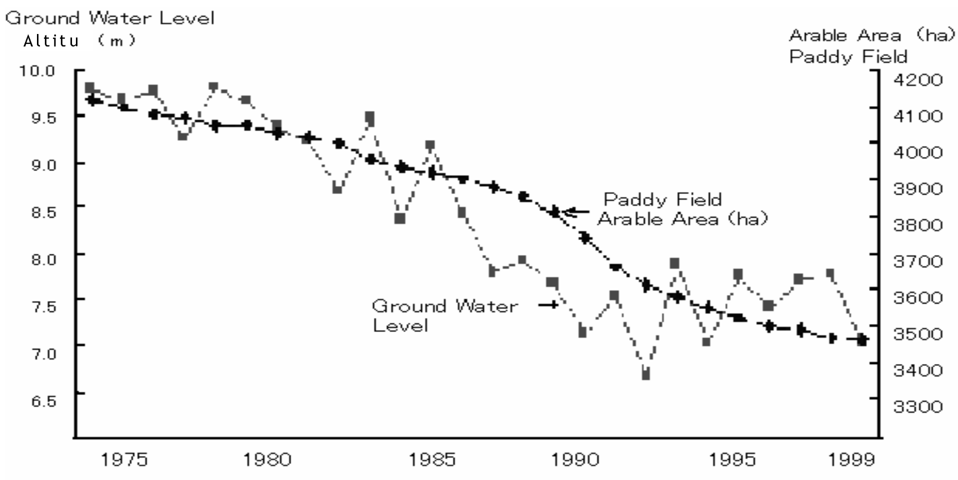


Figure 24. Secular change in area of arable paddy field and ground water level in Tedori River Basin, Japan



4. Advanced measures and activities led by Japan

4.1 Agricultural policy measures for protecting the environment in Japan

The Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan released "Basic Environmental Policy on Agriculture, Forestry and Fisheries" in December 2003. The policy document is sub-titled "Shifting to Agriculture, Forestry and Fisheries Thinking Much of Preservation of the Environment." It declares that the target of assistance by the MAFF will shift to agriculture, forestry and fisheries for the preservation of the environment. The basic environmental policy cites policy measures for the environmental issues of sound water circulation, sound atmospheric circulation, sound materials circulation and preserving a sound environment in rural areas. Concerning sound water circulation, preserving agricultural land and securing irrigation water supply functions; water purification in rural villages; inter-ministerial action for building a sound water circulation system; promoting agriculture for the preservation of the environment, and cattle manures control are stressed.

The MAFF also drew up the Basic Plan on Food, Agriculture and Rural Areas for promoting policy measures on the structural improvement of agriculture and environmentally-friendly agriculture, so as to correspond to global developments. The Cabinet of Japan endorsed it as a five-year governmental policy plan in March 2005. The Basic Plan encourages working out a model of action for promoting agricultural production harmonising with the environment, and introducing measures to support farmers who put the model into practice from 2005. It also anticipates a support programme for farmers who take drastic advanced action to reduce the impact of agriculture on the environment in an environmentally sensitive area from 2007.

Ahead of the policy plans, advanced projects for reorganising agricultural water use have been carried out since 1998. The MAFF implements 14 national projects for 48,500 ha of command area to develop systems, in parallel with renewing irrigation facilities, for realising efficient water management and enhancing multi-functional roles of irrigation such as recreation, bio-diversity, landscapes, groundwater recharge, and water purification.

4.2 International Network for Water and Ecosystem in Paddy Fields (INWEPF)

On the occasion of the Third World Water Forum, the MAFF of Japan and the Food and Agriculture Organization of the United Nations (FAO) co-organised the Ministerial Meeting on Water for Food and Agriculture in March 2003. The Ministerial Recommendation highlighted three challenges: "Food Security and Poverty Alleviation", "Sustainable Water Use" and "Partnership." The INWEPF was established in 2004, the International Year of Rice, to provide a forum to realise the three challenges by promoting dialogue, exchanging knowledge and experiences, creating synergy among existing forums and strengthening capacity-building in agricultural water management in paddy fields with due consideration for environmental aspects. Rice growing countries/regions, international organisations, research institutions and donor agencies are welcome to become members.

The INWEPF lists the members and participants, as of October 2005, including Cambodia, China, Indonesia, Japan, Korea, Laos, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Viet Nam, Asian Development Bank Institute, Asian

Productivity Organisation, Food and Agriculture Organization, International Commission on Irrigation and Drainage, International Network on Participatory Irrigation Management, International Rice Research Institute, International Society of Paddy and Water Environment Engineering, International Water Management Institute, Mekong River Commission, World Bank and others.

The INWEPF encourages members to contribute through a variety of activities including Steering Meetings (SM), Virtual Meetings (VM), workshops, symposiums and other knowledge exchange and capacity-building activities. The first SM was held in Japan in November 2004 and the second in Korea in November 2005. The third SM is expected to be held in Malaysia in 2006. The VM was held in September and October 2005 and the discussion was reported to the second SM. Officials, researchers, academics and individuals who have knowledge of and experience in water management and environmental conservation of paddy fields are expected to participate in the activities of the INWEPF.

In addition to the activities affiliated to the main body of the INWEPF, special collaboration with existing forums is ongoing, such as the International Conference "Water for Food and Ecosystems" co-organised by FAO and the Netherlands and held in the Hague in February 2005; the International Conference organised by the International Society of Paddy and Water Environment Engineering (PAWEES) in Kyoto in September 2005; and the 19th Congress hosted by the International Commission on Irrigation and Drainage in Beijing in September 2005. The INWEPF is preparing to contribute to the Fourth World Water Forum (WWF4) in Mexico in March 2006.

The INWEPF's second SM concluded that the following INWEPF recognition and recommendations should be included into a statement to be made in the Ministerial Conference in WWF4:

Water policy should be made while:

- recognising that government-oriented assistance (e.g. financial, legal and educational services) is essential for investment, rehabilitation and management of water systems for rice, in order to achieve food security, poverty alleviation and ecosystem conservation which is difficult to maintain by a market approach;

- recognising, evaluating and taking into account the multiple uses, roles and values of agricultural water for the development and management of water resources; and

- basing on, or applying to the long-term, the good experiences and wisdom of local communities, and their participation.

5. Conclusions and recommendations

5.1 Conclusions of this paper

In the Asian monsoon region, paddy field irrigation is managed using the benefits of wet environment as much as possible. Paddy rice cultivation in the region with ample water use has various advantages, which allow continuous cropping of rice on the same land for hundreds to thousands of years.

Paddy field irrigation using this ample water also has the "knock-on effects" or "multi-functional roles" of recharging groundwater; mitigating floods; providing a domestic water supply and water for fish farming, shipping and other industries; passing on traditional culture; protecting biodiversity; forming aquatic landscapes, and other socio-economic effects and environmental services.

The water taken from a river and not consumed in paddy fields contributes to enhancing ecosystem services in the Asian monsoon region in two ways: a) water in the total paddy irrigation and drainage system serves as a network of wetlands and waterways, and creates another excellent secondary natural environment outside the river with an enriched flora and fauna; b) water drained from paddies and returning to the river reinforces the ecosystems inside the downstream rivers, marshes and swamps. Almost 100% of the length of rivers in Japan has respectively been assigned, under the River Act, an amount of minimum river flow for maintaining an appropriate downstream river flow function for ecosystems, including bio-diversity.

Paddy field irrigation improves the utilisation efficiency of water resources throughout the river basin, and contributes greatly to the formation of healthy water cycles in river basins. The component ratio of return flow, embracing irrigated water and rainfall in farm land, from upstream agricultural land increases as water flows downstream, up to 35% at the lowest reach in the Kino River Basin in Japan. One the other hand, 98% of the equivalent amount of intake water at Sanuki D.W. and 84% of that at Okamoto D.W. return to the Kinu and Kokai River in Japan at several downstream points.

Paddy fields provide a valuable habitat for living creatures because a combination of shallow ponded warm water and fertile soil serves as an incubator and source of fodder for living creatures. Furthermore, irrigation ponds connected with paddy fields through canals, and scattered coppices and groves, provide another habitat and place of refuge for living creatures during the non-irrigation period. Therefore, while the area of paddy accounts for only 7% of the territory of Japan, more than 30% of all species of fish and dragonflies and more than 20% of all species of reptiles, amphibians and plants survive in paddy fields and canals in the surveyed 14 areas.

Groundwater recharge is another crucial function of paddy fields. Upstream paddy fields of Kumamoto city in Japan supply 45% of the total groundwater recharge (281 million tons) of which the city requires around 226 million tons annually for drinking water, industrial water, and air conditioning for buildings.

5.2 Recommendations

Because the value, i.e. shadow price, of water is extremely low in normal times and temporarily soars in response to tightness in the demand and supply of water, even in the wet season, instead of water use efficiency in the normal condition, water use efficiency during abnormal dry spells should be improved through promoting PIM in paddy field irrigation in the Asian monsoon region.

Multiple socio-economic benefits and environmental services should be evaluated and taken into account for designing government-oriented assistance (e.g. financial, legal, institutional and educational services) for investment, rehabilitation and management of water systems for rice, in order to achieve food security, poverty alleviation and ecosystem conservation, which is difficult to maintain by a market approach.

Because collective actions are necessary for farmers to manage the total irrigation system and water in paddy fields, the role of social capital should be studied and the mechanism for accumulating social capital among farmers should be elucidated to introduce effective measures for increasing multiple socio-economic benefits and environmental services in normal times, and promoting effective collective actions during abnormal dry spells.

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Chapter 16.

Irrigation Sustainability in the Land Use/Soil System in South Italy: Results from a GIS Simplified Approach and Future Methodological Developments

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The optimisation of water use in agriculture is a key factor in rural development and agri-environmental management. The full utilisation of the available water means the possibility of enlarging the irrigated areas and reducing the environmental impact of water use.

The irrigation sustainability evaluation in Objective 1 Italian Regions, taking into specific consideration the interaction between irrigated land use, irrigation soil suitability and three different irrigation techniques, is one of the supports to water resources management.

The methodological approach, based on the use of GIS (Geographic Information System) technology to integrate different data typologies and sources, and on the development of an irrigation efficiency index (IEff), allows estimation of the inefficiencies in m^3 of wastewater.

Introduction

Irrigated agricultural productions represent about 72 % of total agriculture's GDP (Gross Domestic Product) of Southern Italy Regions. The total area covered by irrigated crops is about 1600000 hectares. It represents the 60 % of the total water consumption, and the agricultural areas with water distribution networks are still increasing. Water networks and irrigation utilities have a low degree of efficiency, with significant losses of water (differences between sources water availability and water availability in irrigation areas) from sources to field. The full utilisation of the available water means the possibility of reducing the environmental impact of water use.

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The EU has financed, inside Reg. (CEE) n. 2081/93 – QCS 1994/99, the Operative Programme (P.O.) "Water Resource, in Objective 1 Italian Regions". This project was finalised to the realisation of a geographic information system for water resources management in agriculture (SIGRIA). INEA has collected data on irrigation infrastructure and on crop water requirements in all the Southern Italy Regions Land Reclamation and Irrigation Consortium (Italian administrative structure for irrigation water management).

Thanks to the availability (at EU and national level) of several databases related to water use and to more accessible GIS technologies and data sources, monitoring and measuring water use efficiency and sustainability is now a concrete and suitable possibility.

In this paper particularly attention is paid on the sustainability of irrigation in South Italy, taking into specific consideration the interaction between irrigated land use, irrigation soil suitability and three different irrigation techniques, to support water resources management. The methodological approach is based on the use of GIS.

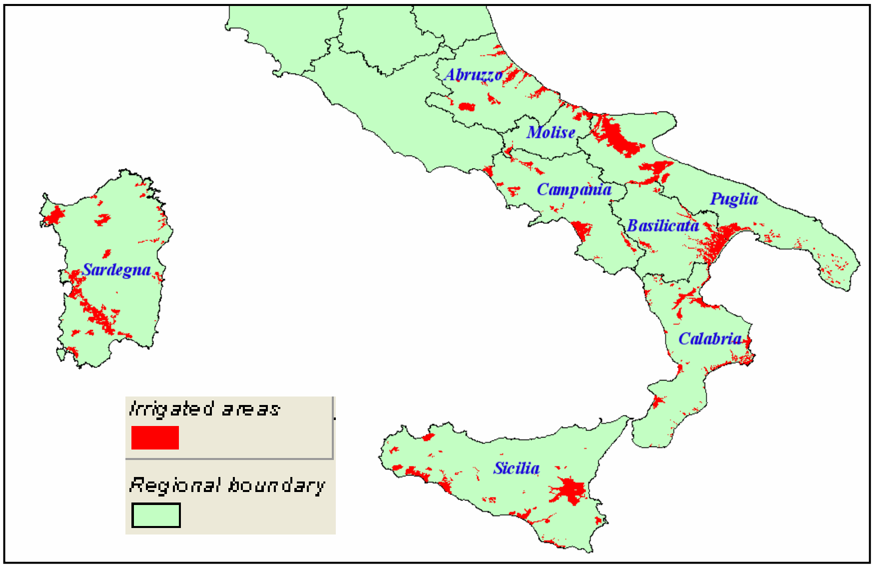
A new research project started from this experience is now developing new methodologies and quantitative methods in order to define specific indicators on water use efficiency based on the integrated soil-crop-irrigation technique system, and on the related optimal crop water requirement.

The geographic localisation, at soil/land use cross-combined poligon level, of soil irrigation sustainability is a key element to support water managers and decision makers in planning water use distribution in competitive water source use situations, and in planning water distrubution pipelines realisation. Using land use and soil maps and information on irrigation requirements, is possible to define areas suitable or not suitable to be irrigated, according to their territorial characteristics.

1. Study areas

The work covers all the irrigated areas of Objective 1 Italian Regions (Figure 1). Data were collected and organised at "Land Reclamation and Irrigation Consortium" and regional (NUTS II) level. In South Italy 66 "consortia" manage an area of 8358165 hectares. To detect all the irrigated surfaces (about 1 600 000 hectares, inside and outside administrative boundaries of the "consortium"), a land use map (Irrigation Study Areas Map CASI 3: scale 1:50000) has been realised, using remote sensing technology on three different Landsat TM images (thematic accuracy: 1:50000 scale), referring to three different years and three different seasons (autumn, spring and summer), and digital ortho-photos (greyscale with pixel of 1 m – geometric and geographic base of the whole system) for geometric accuracy (1:25000 scale). The study area (about 6 500 000 hectares) was previously mapped, thanks to the superimposition of different cartographic layers (DTM, CORINE Land Cover, irrigated areas).

Figure 1. Irrigated areas in Objective 1 Italian Regions



2. Materials and methods

The methodology applied is articulated in several steps, as in the following paragraphs.

2.1 Irrigated areas (administrative boundaries) identification

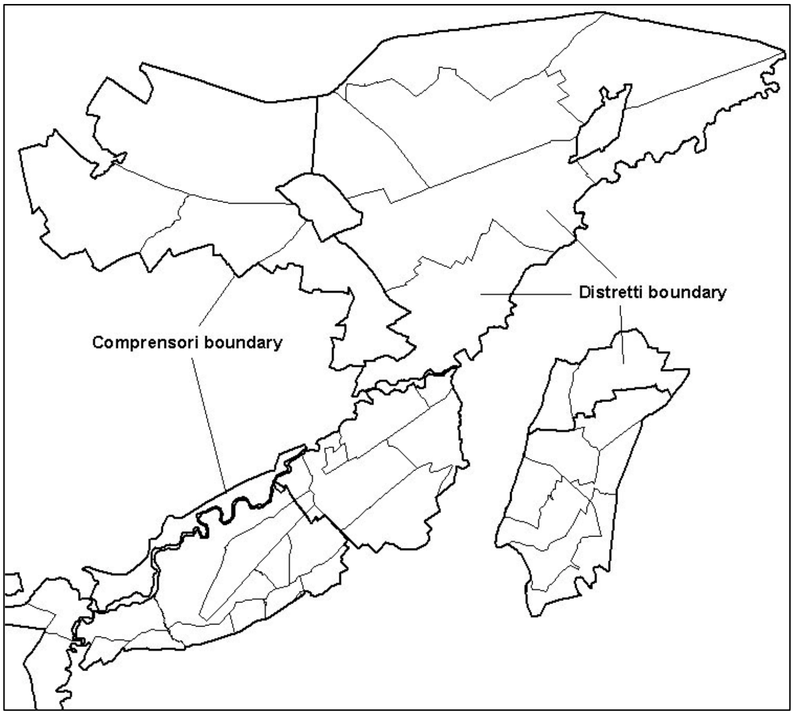
Land Reclamation and Irrigation Consortia are organised in two principal administrative and physical-territorial units: *Comprensori* and *distretti* (Figure 2). The picture). The boundaries of this administrative and physical-territorial units has been acquired throw direct inquire beside the Land Reclamation and Irrigation Consortium. The cartographic support present in the Consortia archive — normally available in hardcopy — has been acquired in digital format, georeferenced and then drawing in vector format inside a GIS system. Some alphanumeric attribute has been linked to the geometric feature regarding information on irrigation characteristics of the above-mentioned unit, such as the topographic, potentially irrigated and actually irrigated surface, types of crops present inside the units, etc. All data have been aggregated at *Comprensorio* level (256 *Comprensori* in the whole study area).

2.2 Irrigated crop georeferenced database

The evaluation of water volumes needs the following very detailed information:

- detailed land use on a level suitable to distinguish the single cultural species;
- crop water requirements for the different crops;
- irrigation techniques;
- water costs.

Figure 2. Irrigated areas in Objective 1 Italian Regions



2.2.1 Land use

The nomenclature system (Table 1) — articulated at 4th level CORINE Land Cover — adopted in CASI 3 allow us to make crop distinctions only for some permanent crops (vineyards, olives groves) while it isn’t sufficiently detailed for irrigated arable land (code 212) and irrigated fruit and berries plantations. In fact, for example, land use class 2121 — Irrigated industrial crops at spring/summer cycle — has inside different species such as maize, sunflower, sugar beet, tobacco, sorghum, etc. with different CWR.

Thus, to reconstruct the land use, different alphanumeric data (administrative and statistics information) on crop surfaces were integrated, using GIS procedures, with CASI 3 cartographic data (land use classes/polygons) inside administrative aggregations (municipalities, administrative irrigated areas).

The sources of alphanumeric data are the following:

- ISTAT data, significant at provincial level and, in some cases, at Agriculture Regions[4] level
- AGEA (Italian Payment Agency) farm subsidies data on CAP, significant at municipal level
- specific surveys Land Reclamation and Irrigation Consortium, regarding the irrigated crop type.

4. Group of contiguous municipalities with homogeneous natural (geology, climate, topography, etc) and agricultural conditions, defined by the National Institute of Statistics (ISTAT).

Table 1. CASI 3 nomenclature (agricultural areas only)

CORINE code	Land use code	Description
211	211	Not irrigated arable land
212	2121	Irrigated industrial crops at spring – summer cycle
	2122	Irrigated horticulture at summer – autumn – spring cycle
	2123	Irrigated horticulture at spring – summer cycle
	2124	Nurseries
	2125	Greenhouses
213	213	Rice field
221	2211	Irrigated vineyards
	2212	Not irrigated vineyards
222	2221	Irrigated fruit and berries plantation
	2222	Not irrigated fruit and berries plantation
223	2231	Irrigated olives groves
	2232	Not irrigated olives groves
231	231	Irrigated pastures
	232	Not irrigated pastures

The methodology developed consists of the following steps:

1. intersection between CASI 3 land use cartography and the irrigated areas layers;
2. aggregation CASI 3 and short term ISTAT data per single Agriculture Region;
3. calibration of ISTAT data with those of AGEA and land reclamation and irrigation consortia;
4. identification of the possible crop frequency classes per single CASI 3 class polygon (i.e. a polygon formed by irrigated arable land of industrial cultures — class 2121 — of 30 hectares is made by: 50% corn, 20% sugar beet, 20% sunflower, 10% sorghum = 100%);
5. clipping of the CASI 3 polygon with relative frequency class on the irrigated area boundaries.

Table 2 and Figure 3 show how, inside a Comprensorio, for each land use polygon/class every single irrigated crop is defined (4th level) and the related area calculated.

2.2.2 Crop water requirements

The CWR analysis and evaluation is based on two different values: nominal crop water requirements (N CWR) and real crop water requirements (R CWR). The first one refers to the volumes value used by the irrigation consortia to define the water cost (tariff €/ha). This is a normalised nominal water need per hectare, because it doesn't take into consideration the soil and meteorological variability, but historical data from literature and experimental parcels (coming from: Land Reclamation and Irrigation Consortium archive — see Figure 4; specific studies at parcel or irrigation districts level from Agriculture University and research Institute). These data have been collected, processed and stored in the land use database. But available data do not cover all the irrigated areas. In these cases, the evaluation of N CWR is based on the FAO methodology, applied on the main crops per area (from land use map), and the assessment of the effective rainfall.

Table 2. CASI 3 matching table — irrigated land uses classes/crop surface

ID Polygon	CASI 3 code	Database code	Description	He Polygon	%	He crop
1	2121	21211	Sugar beet	50	60	30
		21213	Maize		40	20
2	2122	21221	artichoke	70	43	30
		21222	cauliflower		7	5
		21223	lettuce		21	15
		21224	potato		29	20
3	2123	21231	tomatoes	86	17	15
		21232	aubergine		9	8
		21233	water melon		15	13
		21234	melon		12	10
		21235	asparagus		47	40

Figure 3. CASI 3 irrigated land uses polygons and classes

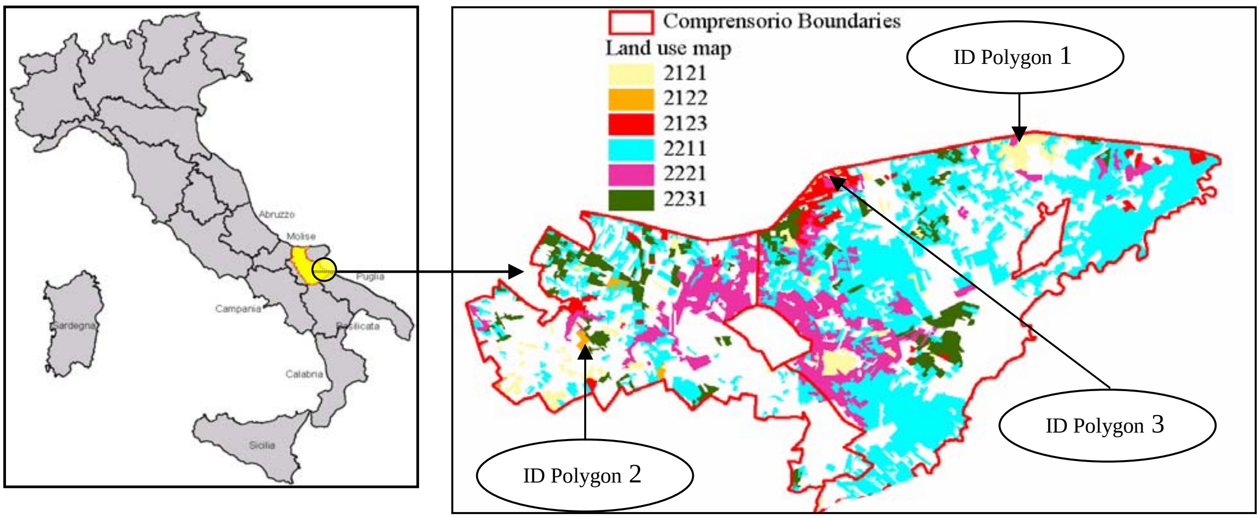


Figure 4. Consortia CWR data

Consorzio	Capitanata	
Comprensorio	Fortore	
Distretto	6A	
Anno	1998	

Colture irrigue praticate nel distretto

Coltura	Asparago	
Superficie	10	[ha]
Inizio stagione irrigua	10/04	[gg/mm]
Fine stagione irrigua	30/09	[gg/mm]
Durata	173	[gg]
Turno	17	[gg]
Volume specifico	500	[mc]
Volume stagionale	5000	[mc]

Crop evapotranspiration (ETc) calculation is based on the following FAO two step approach:

1. Reference evapotranspiration (ETo) computing;
2. Crop coefficient (Kc) application, that takes into account the differences in the crop canopy and aerodynamic resistance relative to the hypothetical reference crop. $ET_c = ETo \times K_c$

ET_0 computing is based on the following Hargreaves–Samani equation (Penman-Monteith equation is not applicable, because of the lack of solar radiation, relative humidity and wind speed data):

$$ET_0 = C \cdot \frac{R_A}{\lambda} \sqrt{\Delta T} \cdot (T + 17.8)$$

where:

C = empiric constant, normally fixed at 0.0023 value

R_a = extraterrestrial radiation [MJ m^{-2} d^{-1}]

λ = latent heat of vaporisation [MJ kg^{-1}]

ET_0 = evapotranspirative flux [mm d^{-1}]

□*t* = thermal monthly range [°C]

T = monthly average temperature [°C]

The R CWR is based on the calculation of effective water volumes, utilising a SWAP implemented application that has been validated on five consortia test sites. The final value refers to each land use polygon and, taking dynamically into account the irrigation techniques, the land use changes, the soil and the metrological variability, represents the optimal water volumes to use for each soil/crop/technique system (Table 3).

Table 3. CASI 3 matching table — Irrigated land uses classes/crop surface/unitary CWR

ID Poly	CASI 3 code	Database code	Description	He Polygon	%	He crop	CWR (m^3/ha)	Irrigation Technique	Average* CWR (m^3/ha)
1	2121	21211	Sugar beet	50	60	30	4600	Sprinkler	4550
		21213	maize		40	20	4500	Sprinkler	
2	2122	21221	artichoke	70	43	30	3200	Drop	1900
		21222	cauliflower		7	5	1500	Drop	
		21223	lettuce		21	15	700	Drop	
		21224	potato		29	20	2200	Drop	
3	2123	21231	tomatoes	86	17	15	5100	Drop	5060
		21232	aubergine		9	8	5500	Drop	
		21233	water melon		15	13	4600	Drop	
		21234	melon		12	10	4600	Drop	
		21235	asparagus		47	40	5500	Drop	

* The water use efficiency calculation is based on the average CWR per CASI 3 land use polygon/class.

2.2.3 Irrigation techniques

The information about irrigation techniques is available on 27617 he (circa 70% of the consortia irrigated surface). In synthesis the main irrigation techniques adopted in the Objective 1 Italian region are: sprinkler 58,9%; drop 27,2%; flowing 8,90% (Table 4).

Table 4. Hectares distribution of the irrigation techniques inside Consortia Comprensori

	Irrigation techniques (he)					
Region	**Flowing**	**Submersion**	**Infiltration**	**Sprinkler**	**Drop**	**Total Region**
Campania	66	65	5514	7115	362	**13122**
Puglia	506	0	0	37944	16920	**55370**
Sicilia	3645	200	500	11407	25703	**41475**
Sardegna	20	4118	23	39731	15637	**59529**
Calabria	1993	730	0	6902	681	**10306**
Abruzzo	15551	11	0	44215	89	**59866**
Molise	0	0	0	1615	311	**1925**
Basilicata	2.735	0	2527	13532	15230	**34024**
Total	***24516***	***5124***	***8564***	***162461***	***74932***	**275617**

Source: INEA 2001 (SIGRIA — Land Reclamation and Irrigation Consortium Database).

In the actual dynamic, the abandon of flowing and the constant decrement of the sprinkler techniques are both in favour of the drop system, especially on the irrigated orchards. This process tends to reduce the utilised volumes per ha, incrementing on farm irrigation investment. But it actually seems not to produce any results on the water costs.

The nominal CWR doesn't take into account the differences between the irrigation techniques inside a single irrigated land use.

2.3. Irrigation infrastructure investments and water costs

Data on water costs (as well as the information related to irrigation networks, and related areas, nominal CWR and irrigation techniques) has been collected on the 66 consortia (Land Reclamation and Irrigation) surveys, based on the Q2 SIGRIA questionnaire. Data are updated to 1997.

Water cost definition in South Italy is rarely based on the real crop consumption. This because of the scarce diffusion of water meters, and the non-profitability of water use in agriculture (farmers cannot pay the real water cost because is not economically sustainable). The cost is fixed on the basis of a fixed tariff per year/hectare, plus in some cases variable cost per crop type (on which a standard CWR is fixed). The unitary (per hectare) water tariff is based on the recover of both running and labour costs of the consortia. A significant difference in water costs depends on the relative relevance of energy costs, due to the quota of raised water in the total distributed volumes. 48/66 consortia have costs related to rising hydraulic waterworks. The irrigation scheme investments are not included into the unitary water cost, because in Italy they are totally financed by the State, as well as the extraordinary maintenance costs. Mostly of the water cost data collected on the consortia referred to a €/ha value (data on €/mc are available only on nine consortia). In 13 cases the water cost is reconstructed (per interpolation with the regional available data, and taking into account the presence of water raising hydraulic waterworks). In Tables 9 and 10 (section 3), the water costs, both at consortium and region level, are listed. Significant differences in the unitary costs between consortia of the same region, generally due to the energy costs for water raising, make the average regional value not representative.

In the water cost definition the annual public founds (generally at regional level and for extraordinary maintenance costs), and the cost per hectare of the irrigation infrastructures (both at consortium and farm irrigation waterworks level) are not taken into consideration. But the unitary cost of the irrigation infrastructures has been used to analyse the efficiency of the investments. From the graphic in Figure 5 and from the Tables 9 and 10, it's possible to see the difference between the area equipped with irrigation networks and the related irrigated area.

This significant difference is mainly due to a structural insufficient water availability to irrigate all the equipped area. In second order, 20-25 % of this difference is due to the normal rotation/crop shifts inside a *Comprensorio*. In some cases the irrigated areas are larger than the equipped one. This is principally due to the private underground water utilisation.

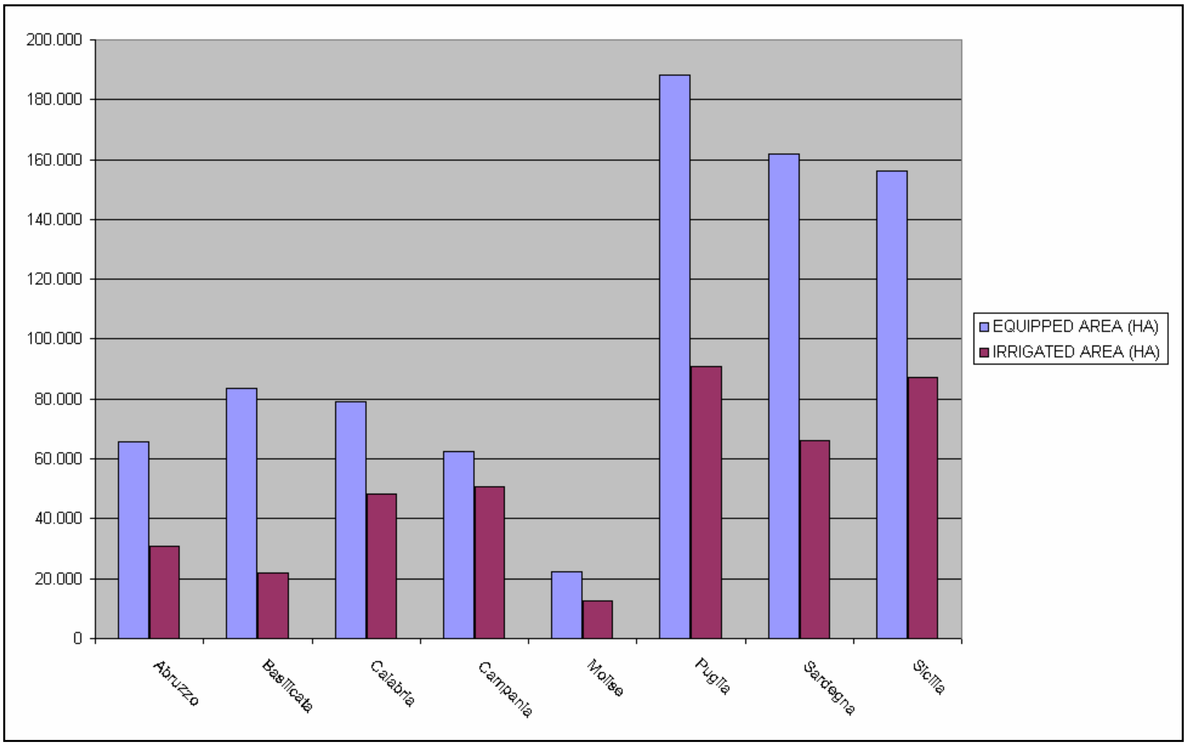
The infrastructures investments, both public and private, concern not only the yearly irrigated area, but all the area equipped with pipelines, and consequently the on-farm field water distribution equipment. The following analysis of the Irrigation Infrastructures Investments (III) shows the average cost per hectare/year of the joined public (IIIpub.: adduction and distribution pipelines, plus waterworks nodes) and private (IIIpriv.: rolls and sprinkler – III*s* - or micro-irrigation tools - III*i*) investments at Italian level[5]):

III*s* = IIIpub/ha + IIIpriv. *s* = 400 €/ha + 397 €/ha = 797 €/ha
III*i* = IIIpub/ha + IIIpriv. *i* = 400 €/ha + 788 €/ha = 1188 €/ha.

5. Both data are extracted from specialised project technical guidelines and refer to the yearly amortisation cost, based on the depreciation time of the investments: 30-40 years for pipelines; 12-15 years for water field distribution tools.

It's pretty clear that with the micro irrigation cost the farmer pays an indirect additional water cost, without any tangible direct benefits (in most cases, it doesn't correspond to a reduction of the tariff per hectare). Benefits that are instead completely for rural and urban communities, and environment, having this irrigation technique direct effects on water use savings.

Figure 5. Regional consortia area equipped with irrigation pipelines and related irrigated area



2.4. Data base on soil type, an the Irrigation Soil Suitability map

The GIS layers used for the spatial analysis, soil unit polygon and land cover polygon, have been extracted from SIGRIA database. To extract the area of interest, both layers have been clipped with the irrigated area polygon borders.

Soil suitability layer

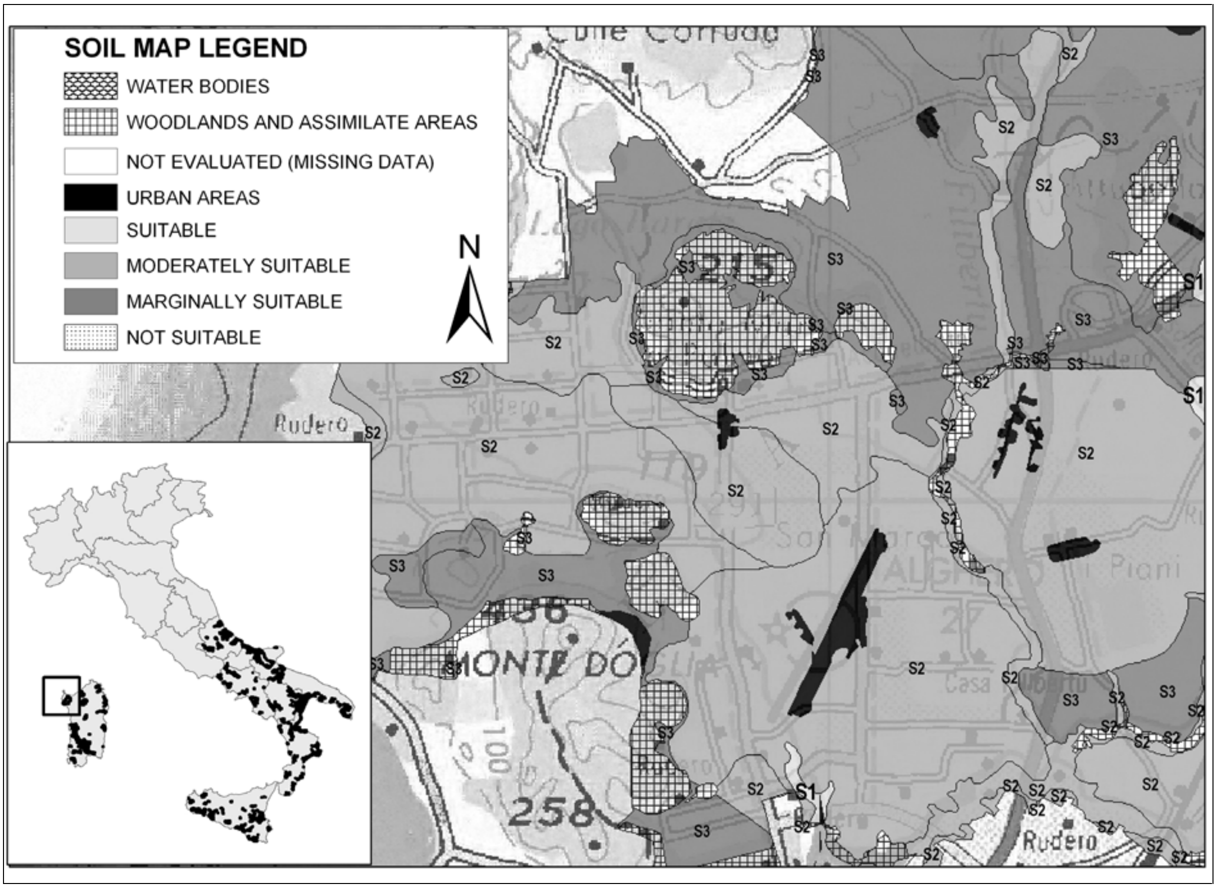
The soil map units layer has been structured as polygon, with the following info (soil and evaluation data types) table structure (see Table 5):

1. Soil Cartographic Unit Code, linked to a Soil Typological Unit in the SIGRIA soil database;
2. Irrigation suitability class codes, for the three major types of irrigation techniques (Drop, Sprinkler and Flowing/Submersion)
3. Major limitation suffix, related to the soil characteristic(s) that have been considered to establish the suitability class code (e.g.: PE = slope, T = texture, D = drainage, etc.);
4. Slope code class and related range of values.

Urban areas, Woodland areas and making like (stable grassland, Mediterranean garigue, riparian vegetation), and water bodies have been also included in the soil layer, but not evaluated because of missing or not sufficient soil data.

In the first step the Consortium area is divided in different suitable classes (see Figure 6).

Figure 6. Nurra Consortium irrigation suitability to sprinkler technique and soil map (Sardinia – about 1:75.000 scale)



The National Soil Database (from the Experimental Institute for Soil Study and Conservation – ISSDS, Costantini et alii, 2003) is the basis adopted to the irrigation suitability evaluation. The United States Bureau of Reclamation methodology, modified by the ISSDS during the project POM INEA in the southern regions (POM IRRIGAZIONE, 1998-2002), has been adopted for the evaluation procedure.

Several soil features and qualities have been taken in account to evaluate the irrigation suitability, (referred to both surface and internal soil). A matching table defines the type of limitation in rows and the suitability class in column. The maximum limitation criteria (the strongest limitation determines the suitability class) has been utilised to evaluate all the soil type. The soil characteristics/parameters, for both topsoil and subsoil, are listed in Table 6. For the slope classes, the main irrigation techniques (drop, sprinkler and flowing) thresholds have been adopted.

Table 5. Example of structure of soil data info table
(000 hectares)

SOILS_ID	CART_UNIT	FLW_CODE	FLW_LIMITA	SPR_CODE	SPR_LIMITA	DROP_CODE	DROP_LIMITA	CLASS_SLOPE	RANGE	HECTARES
1	AB08UC2203	NOT SUITABLE	PE, T	MODERATELY SUITABLE	PE T	MODERATELY SUITABLE	T	4	5-13%	897.035
2	999	URBAN AREAS		URBAN AREAS		URBAN AREAS		1	0-1%	2.739
7	AB08UC2202	MODERATELY SUITABLE	PE, T	MODERATELY SUITABLE	PE T	MODERATELY SUITABLE	T	2	1-3%	118.523
10	AB08UC2202	MODERATELY SUITABLE	PE, T	MODERATELY SUITABLE	PE T	MODERATELY SUITABLE	T	2	1-3%	5.897
12	AB08UC1101	NOT SUITABLE	D	MODERATELY SUITABLE	D	MODERATELY SUITABLE	D	3	3-5%	4.055
14	AB08UC2101	MODERATELY SUITABLE	PE	MODERATELY SUITABLE	D	MODERATELY SUITABLE	D	2	1-3%	51.196
16	AB08UC1101	NOT SUITABLE	D	MODERATELY SUITABLE	D	MODERATELY SUITABLE	D	3	3-5%	12.385

FIELD LEGEND - SOILS_ID: polygon unique id; CART_UNIT: code of Soil Cartographic Unit; FLW_CODE: soil suitability class for Flowing technique; SPR_CODE: soil suitability class for Sprinkler technique; DROP_CODE: soil suitability class for Drop technique; *_LIMITA: Soil Main Limitation codes for each technique.

Three thousand soil pedons inside the irrigated area have been evaluated with this criteria. The results have been reported in the soil cartographic units and organised in the GIS info table.

Land sustainability to irrigation practices and evaluation of the water nominal and real needs

The conceptual framework in establishing the correlation between soil suitability and irrigation is based on the FAO studies about the "Land productivity index[6] and economic measures of suitability" (*Guidelines: Land Evaluation for Irrigated Agriculture* - FAO Soils Bulletin 55, Land and Water Development Division, Rome 1985).

Starting from the FAO Land productivity index concept, the relationship between the productivity index and water volumes has been estimated, based on the assumption that the *overall agronomic efficiency of water use* (F_{ag}[7]) doesn't change in the time. On this basis, per each map unit with same soil, land use, and irrigation technique, the soil suitability reduction factors has been directly related to the nominal normalised water needs in the calculation of the real CWR (Table 7.).

6. "Land Productivity Index: this is defined as the physical productivity of land for a specific land use, relative to that of the best land. **Relative yield** can be a convenient land productivity index. This is the yield per hectare relative to that of the best land as a percentage or fraction. Thus the top yields of Class S1 land for a given Land Unit may be taken as 100% or 1.0, the top of s2 as a fraction of S1 (e.g. 80% or 0.8), S3 as 0.6, etc. as appropriate. Other standards such as absolute yields or relative production can be used as alternative measures of physical productivity. Productivity may be for a **present** or **potential** suitability classification. It would normally be necessary to use a physical land productivity index in reconnaissance studies and as a necessary preliminary to economic evaluation."

7. $F_{ag} = P/U$; the ratio of crop production (total dry matter, or the gross product) on the used water volume.

Applying the reduction factor to the optimal CWR, the lesser suitable is the soil the higher is the CWR value. At the end of this evaluation procedure, both the nominal crop water requirements (N CWR) and the real crop water requirements (R CWR) has been established. The Irrigation economical and technical Efficiency Index – **Ieff =** $\frac{Rcwr}{Ncwr}$ – is the ratio between this two values The range may be variable from 1, that is the optimal situation, to 2.5, for the not suitable soils.

Table 6. Matching table for irrigation Soil Suitability Classes (from USBR, mod. ISSDS)

	1. Suitable		**2. Moderately suitable**		**3. Marginally suitable**		**4. Not suitable**	
Soil Parameters	**Values**	**ISSDS classes**	**Values**	**ISSDS cLASSES**	**Values**	**ISSDS classes**	**Values**	**ISSDS classes**
TOPSOIL TEXTURE USDA	FA or FLA or FL or FSA		AL or F or FSV or L or A or AS or FS		SF		S	
Subsoil Texture USDA	FA or FLA or FL or FSA		AL or F or FSV or L or A or AS or FS		SF		S	
Radical Depth (cm)	>=100	5 or 4	<100 ->=50	3	-	-	<50	1 or 2
Stoniness (%)	<=0,1	0 or 1	>0,1 - <=3	2	>3% - <=15	3	>15	4 or 5
Rockness (%)	0	0	-	-	>0 and <=2	1	>2	2-5
Internal Drainage	good	3	moderate	4	Quasi-excessive or low	2 or 5	Excessive, low or blocked	1 or 6 or 7
Topsoil Reaction pH	<=9	<9	-		-		>9	9
Subsoil Reaction pH	<=9	<9	-		-		>9	9
Topsoil Carbonates %	1-20	3 or 4 or 5	<1 or 20-40	1 or 2 or 6	>40	7	-	
Subsoil Carbonates %	1-20	3 or 4 or 5	<1 or 20-40	1 or 2 or 6	>40	7	-	
Topsoil salinity mmhos	<2	0 or 1	-	-	2-4	2	>4	>2
Subsoil salinity mmhos	<2	0 or 1	-	-	2-4	2	>4	>2
Surface Water Erosion	absent	0	Moderate sheet	1	Moderate gully	2 or 4	Strong sheet and/or gully	3 or >=5
Slope for drop irrigation (%)	0-13	1-2	13-21	3	21-35	4	>35	5-6
Slope for sprinkler irrigation (%)	<=5		5-13	-	-	-	>13	
Slope for flowing/ submersion (%)	1		3	-	-	-	>3	

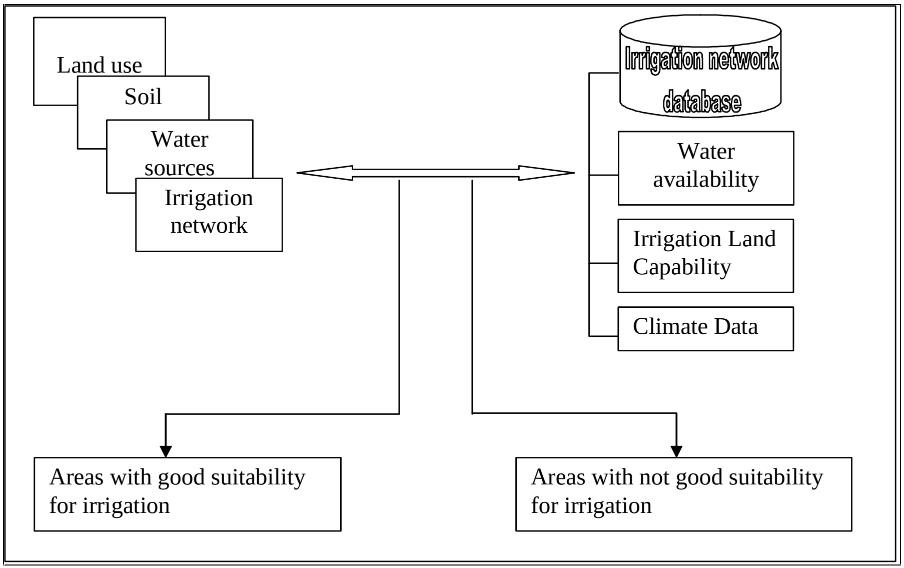
Table 7. Reduction factors for calculating the real needs in the soil/land use/irrigation technique map unit

Soil suitability class	S1. Suitable	S2. Moderately suitable	S3. Marginally suitable	N. Not suitable
Reduction factor	1.0	0.8	0.6	0.4

2.5 Data processing

Starting from SIGRIA database structure (Figure 7), the final evaluation process is based on the intersection of the soil suitability and irrigated land use layers. A new layer, with (per map unit) homogeneous data on soil suitability, land use, irrigation technique and nominal crop water requirement per hectare, has been derived.

Figure 7. General scheme of relationships inside SIGRIA database



The cumulative nominal CWR (m^3 = mc) per each homogeneous new map unit has been derived from the hectares of each soil/land use/irrigation technique systems. The real water crop requirements has been calculated from the IEff index. The cumulative real crop water requirement (RCWR) has been obtained multiplying the cumulative nominal crop water requirement (N CWR) by the IEff values (based on the criteria of soil suitability per irrigation technique - see Table 8). The validation of this index is based on the CWR calculation with SWAP, and then divided per the nominal CWR of the 5 Consortia test sites irrigated crops. These values has been correlated with the FAO index. This procedure is shown in Figure 8. The gap between real and nominal water crop requirements was defined for every map unit belonging to an irrigated area, defined a delta of crop water requirement ($\Delta\text{CWR} = R\text{CWR} - N\text{CWR}$), which represent the environmental effect due to the interaction of the irrigation techniques with the soil characteristics.

Figure 8. Procedure to Δ Crop Water Requirements calculation

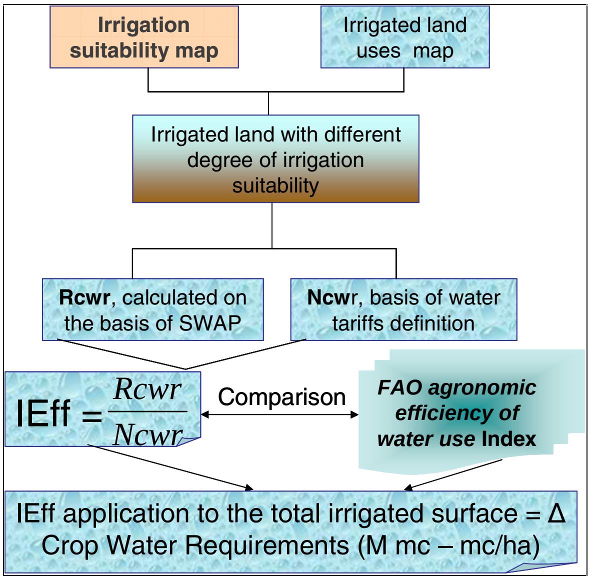


Table 8. Values of IEff for the Land Units of Italy – Southern Regions

Soil suitability class for specified irrigation techniques	S1. Suitable	S2. Moderately suitable	S3. Marginally suitable	N. Not suitable
IEff values	1.0	1.25	1.67	2.60

2.6 New methodologies and quantitative methods

The SWAP Soil-Water-Atmosphere-Plant (SWAP ver. 3.0.3., 2003 - University of Wageningen -NL) model will be also used to calculate, trough several simulation cycles, the best performance irrigation index Ip for irrigation practice for every benchmark site. The performance irrigation index Ip is defined by the minimum irrigation volume (Virr) necessary to maintain the crop productivity without stress with the same Potential Evapotrasipartion (ETp).

$$Ip = \frac{ETp}{Virr}$$

The SWAP model consists in the implementation of mathematical soil water flow descriptions, solute transport and soil temperatures, with special emphasis on soil heterogeneity.

The model will be run on about 60-70 selected benchmark sites, representative of all the variability of the system soil/crop/irrigation technique/water irrigation volumes.

SWAP model will use historical climatic series (daily average Temperature and cumulative Rain data) of almost 20 years, reference crops, benchmark soil profiles, single irrigation technique and water volumes.

The results will consist of the minimum optimal irrigation volume values per test representative_sites, that will be used for final calibration of the real water crop requirements (Rwcr), and the validation of the IEff values for all the Southern Italy.

3. Results and conclusion

Thanks to the integrated use of different cartographic layers, and on the basis of F.A.O. standard, the irrigation suitability of the soil of the South Italian Land Reclamation Consortia irrigated areas has been defined. This data are organised in a GIS data base, and are geographically linked to the irrigated land use layer , which contains information on irrigation techniques and nominal water crop requirement (NCWR).

Based on the irrigation soil suitability data an Irrigation economical and technical Efficiency Index (Ieff) has been derived. This index, defining the efficiency of irrigation water use per crop/soil/irrigation technique, allows to calculate the extra amount of water used per hectare due to an inefficient water use (in Table 9 and 10 Δ CWR mc/ha). This value has been applied on the whole irrigated surface inside the Consortia waterworks equipped area, obtaining the total extra amount water (Δ mc Crop Water Requirements) per Consortium (see an example in Table 9) and per Region (see Table10). The data of the total Δ CWR in Southern Italian Region (425228118 mc) represents about the 34 % of the total CWR, more or less the same quota of the unitary value (1039.6 mc/ha).

The Δ CWR is at present wastewater or waste money (about 22 M€, based on an average unitary irrigation water cost of 0.052/m^3), but, with appropriate rural and agricultural policies it should be considered as saveable water for irrigated area expansion, or for other uses.

Particularly attention has to be paid on the opportunity of expanding the irrigated areas already equipped with irrigation waterworks, but that are actually non irrigated for lack of water. Presently the ratio between areas equipped with irrigation waterworks and irrigated areas is very low in several Consortia (in Table 10: Pipeline use % is about 50 % in the whole area).

The average irrigation waterworks cost per hectare/year, obtained joining public (adduction and distribution pipelines, plus waterworks nodes) and private investment, estimated in 797 and 1188 €/ha, respectively for rolls and sprinkler and micro-irrigation tools. According to the lower value (the sprinkler technique is the most diffused), the total cost of the infrastructure on the total area equipped with irrigation waterworks is 653267872 €/year. But taking into consideration only the irrigated area, the unitary irrigation investments cost rise to 1597 €/year/ha.

Table 9: Example of data collected and elaborated per irrigation Consortium in Campania Region

Region	Land reclamation and irrigation Consortia	Hectares with pipelines (A)	Irrigated surface (B)	Pipeline use % (A/B)	Δ mc Crop Water Requirements (CWR)	Δ CWR mc/ha	Cwr mc/ ha	CWR mc tot	Water cost €_mc	€/ha of losses - Δ CWR based	Tot € of losses - Δ CWR based	Irrigable hecteres from ΔCWR	Total potential irrigable hecteres	Pipeline use % from ΔCWR	Pipeline use increase %
		(A)	(B)	B/A	(C)	(D)	E	B*E	(F)	D*F	C*F	(G) D/E	(H) B+G	(I) H/A	I - B/A
Campania	Agro Sarnese	2840	2.865	100,9	7.220.266	1717,1	2.348	*6.726.262*	0,110	188,84	*794.030*	3.075,1	5.939,7	209,1	108,3
	Aurunco	5495	4.514	82,2	2.567.302	757,7	2.433	*10.983.078*	0,021	16,08	*54.494*	1.055,2	5.569,4	101,4	19,2
	Bacino Volturno	8105	10.067	124,2	4.907.698	577,0	2.424	*24.402.240*	0,037	21,51	*182.976*	2.024,6	12.091,6	149,2	25,0
	Destra Sele	16375	9.018	55,1	1.860.914	359,9	3.520	*31.741.900*	0,020	7,29	*37.677*	528,7	9.546,3	58,3	3,2
	Ente Irrigazione	1080	67	6,2	111.527	1600,0	2.514	*168.070*	0,048	76,02	*5.299*	44,4	111,2	10,3	4,1
	Paestum	8537	5.871	68,8	1.898.029	791,8	3.163	*18.571.232*	0,082	64,64	*154.948*	600,1	6.471,5	75,8	7,0
	Sannio Alifano	9670	8.342	86,3	10.408.114	1710,4	2.662	*22.206.914*	0,035	60,06	*365.472*	3.909,9	12.252,1	126,7	40,4
	Ufita	1109	392	35,4	133	137,5	2.750	*1.078.191*	0,026	3,56	*3*	0,0	392,1	35,4	0,0
	Valle Telesina	4510	3.276	72,6	4.217.187	1792,2	3.033	*9.936.219*	0,068	122,07	*287.225*	1.390,4	4.666,5	103,5	30,8
	Vallo di Diano	7200	5.757	80,0	922.141	460,0	1.434	*8.255.253*	0,023	10,77	*21.586*	643,1	6.399,9	88,9	8,9
	Velia	1200	488	40,7	1.028.908	2574,5	2.671	*1.303.762*	0,012	29,87	*11.936*	385,2	873,3	72,8	32,1
Campania Totale		*62.424*	*50.657*	*81,1*	*35.142.219*	*1134,4*	*2.672*	*135.373.122*	*0,055*	44,60	*1.915.646*	13.150,3	63.807,2	102,2	21,1

In red box interpolated value

Table 10. Synthesis results per southern Italian Region

Region	Hectares with pipelines	Irrigated surface	Pipeline use %	Δ mc Crop Water Requirements (CWR)	Δ CWR mc/ha	Cwr mc/ ha	CWR mc tot	€_mc	€/ha of losses - Δ CWR based	Tot € of losses - Δ CWR based	New Irrigable hectares, with ΔCWR = extra available water	Total potential irrigable hecteres	Pipeline use/new irrigable area (%)	Pipeline use increase %
	(A)	(B)	B/A	(C)	(D)	E	B*E	(F)	D*F	C*F	(G) D/E	(H) B+G	(I) H/A	I - B/A
Abruzzo	65.826	31.004	47,1	15.584.464	1.014,8	1.622	50.276.374	0,086	68,65	1.347.745	9.610,4	40.614	61,7	14,6
Basilicata	83.428	22.077	26,5	37.055.712	1.636,4	5.014	110.702.676	0,031	71,84	1.137.298	7.389,8	29.467	35,3	8,9
Calabria	79.138	48.373	61,1	48.304.178	715,1	3.233	156.368.396	0,026	27,55	1.274.904	14.942,9	63.316	80,0	18,9
Campania	62.424	50.657	81,1	35.142.219	1.134,4	2.672	135.373.122	0,055	44,60	1.915.646	13.150,3	63.807	102,2	21,1
Molise	22.428	12.499	55,7	19.239.108	1.129,8	3.486	43.576.856	0,033	44,11	631.303	5.518,2	18.017	80,3	24,6
Puglia	188.372	90.953	48,3	78.507.047	1.037,9	3.270	297.387.475	0,112	98,84	8.815.270	24.010,5	114.963	61,0	12,7
Sardegna	161.743	66.142	40,9	124.249.091	2.336,2	2.515	166.375.742	0,041	55,92	5.089.827	49.394,4	115.536	71,4	30,5
Sicilia	156.299	87.314	55,9	67.146.298	1.263,0	3.325	290.332.655	0,029	34,77	1.972.024	20.193,5	107.508	68,8	12,9
Total	**819.659**	**409.018**	**49,9**	**425.228.118**	**1039,6**	**3057**	**1.250.393.297**	**0,052**	**54,24**	**22.184.016**	**144.210,1**	**553.228**	**67,5**	**17,6**

Considering the total Δ CWR as volumes utilisable to increase the irrigated area (G column), the total irrigated surface could rise to 553228 hectares, with an average relative increase of 17, 6 %, and the yearly infrastructure investment could decrease to 1181 €/year/ha.

In conclusion, the European Mediterranean Countries the full utilisation of the available water and the optimisation of water use in agriculture is a key factor in social-rural development and agri-environment management. The definition of an index on water use efficiency in agriculture is a key element in the optimisation of water resources management.

The present work gives the baseline information to evaluate the efficiency in irrigation water use.

The IEff index allows to determine the additional water wasted in an irrigation area, on the basis of the irrigation suitability of the land use/soil/irrigation technique system.

After a first analysis of the wastewater and infrastructures investment costs, two main considerations:

- Farmers pay a unitary water cost that is generally far away from the real cost; this also considering that infrastructural investment are completely founded by the public works and are not included in water costs; the low irrigation water cost compensates farm irrigation waterworks yearly costs, particularly significant for the drop systems;

- The low water cost contributes to an inefficient agricultural water use; the perfect evaluation of the real/optimal crop water requirement will allow the farmer to pay water at least on the basis of the real volumes of irrigation, or to reduce the unitary water volumes.

A new research project started from this experience is now developing new methodologies and quantitative methods in order to define the optimal crop water requirement.

The available data regarding the irrigated areas are structured in geographic layers, with an information system with the possibility to query and aggregate information at geographic level.

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Chapter 17.

Catchment-Sensitive Farming: Tackling Diffuse Water Pollution from Agriculture in England — Policies and Drivers

Soheila Amin-Hanjani[1] *and Russell Todd*[2]

Diffuse water pollution from agriculture (DWPA) is a significant contributor to the long-term degradation of UK rivers, lakes and groundwaters — 70 % of nitrates and 44 % of phosphorus loads in UK surface waters comes from agriculture. Within the EC, the key driver for tackling DWPA is the Water Framework Directive (WFD). The paper discusses the approach being taken in the UK to meet the challenging targets set by WFD through Catchment-Sensitive Farming (CSF). The challenge is to identify appropriate and most cost-effective measures for tackling the impact of farming on the environment while ensuring, in the long term, a sustainable farming industry. This paper details the current policies in place including action under the EC Nitrates Directive, Environmental Stewardship Schemes under CAP and activity to encourage early voluntary action by farmers (CSF Delivery project). Details of the complementary work being taken forward on the use of other policy instruments, such as regulation and analysis on development of an effective package of policy measures for tackling DWPA, is also discussed.

Background

In the UK, Agriculture covers 76% of the land area of England and Wales — total land use area for agriculture in the UK is around 18,000,000 hectares with approximately 175,000 main farm holdings (Defra Farm Census 2001). It is not surprising, therefore, that agriculture plays a key role in determining what the UK's landscape looks like, what happens on the land, and consequently, impacts of land use on the environment.

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Agricultural industry brings many benefits to society, not least of which is food production, but also through positive effects on habitat and species, and on landscape. However, there is also a negative cost of agricultural production — namely impacts on the environment. Agriculture contributes to carbon dioxide emissions (primarily through the use of fossil fuels and electricity, as in other sectors) and accounts for over 40% of methane and nearly 66% of nitrous oxide emissions in the UK. Intensive farming of monoculture has resulted in losses in biodiversity and impacts on the water quality of UK rivers, lakes and ground water. In the UK it is estimated that 60% of the nitrogen load in surface waters comes from agriculture (WRc 2004) and 43% of the phosphorus (Morse et al. 1993). Everyday activities such as the tillage and ploughing of land, the spreading of slurries and farmyard manures (FYM), use of pesticides, veterinary medicines and fertilisers can all give rise to the inadvertent contamination of water supplies. Agriculture uses large amounts of inorganic nitrogen (N), phosphate (P) and potassium (K) fertilisers.

The value of the impact of agriculture on the environment

The costs of natural resource degradation and environmental pollution due to agriculture in the UK, both in monetary and environmental terms, are difficult to quantify precisely. However estimates have been made on the total cost of the problem and agriculture's contribution to it (Table 1).

Table 1. Costs of agriculture in England and Wales in £ million per year 2004–05 prices (adapted from EA [2002])[1]

Environmental impact	Lower bound	Upper bound
Nutrients in lakes	20	34
Recreation damage	10	24
Fisheries (freshwater angling)	14	37
Bathing water	23	44
Amenity loss (property prices)	5	5
Groundwater (costs to water companies)	94	94
Ecosystem (river) damage	156	389
Total	**322**	**627**

1. The Environment Agency report (2002) estimated the costs of natural resource degradation and environmental pollution due to agriculture in the UK by estimating the total cost of the problem and agriculture's contribution to each problem. These estimates have been updated using analysis done by the Environment Agency in the context of the periodic review of the water industry in 2004, and using figures from Defra's Framework for Environmental Accounts for Agriculture (Defra 2004). A range of estimates exists because of uncertainty as to both the value of total damage and the share of the damage that stems from agriculture. The methodology is acknowledged to be simplistic, and therefore the resulting estimates are indicative. However, it should also be noted that values were not estimated for all impacts, so the quantification of agriculture's contribution is likely to be conservative.

The figures indicate that the benefits of tackling water pollution from agriculture are potentially in excess of £300m per year and can be as high as over £600m

Attributing figures to the financial cost of the damage to the water environment from agriculture is a difficult and complex process. It is not currently possible to disaggregate the figure shown in Table 1 further to attribute proportions to individual pollutants. A project currently funded by Defra is working to bring together as much information as possible on the link between farm practices, impacts on water quality and the categories of cost outlined in Table 1.

The environmental impacts of water pollution from agriculture

Over the last two decades, much effort has been put into cleaning up UK rivers and lakes. Since 1990, over £20b has been spent upgrading the sewerage infrastructure in England and Wales in order to improve the quality of discharges and hence the quality of receiving water. Limit values control the amount of pollution that industries are allowed to discharge in order to meet Environmental Quality Standards and controls have been put in place to reduce or ban the use dangerous substances. All these improvements have lead to a steady increase in the quality of our waters (for more details see http://defraweb). For example, there have been significant improvements in drinking water quality every year since 1997 (99.88% of the 2.97m drinking water test samples taken in England and Wales in 2003 met stringent quality standards) as well as in bathing waters (around 98% passing EU standards), and about 69% of rivers in England are now of good biological quality. Despite significant improvements in the water quality of our rivers (mainly as a result of a reduction in point-source pollution) there are still valuable improvements to be made, particularly to the ecological health of our rivers and other waterbodies. The main challenge we face is to address diffuse water pollution from agriculture — in the UK 60% of the nitrogen load and 43% of the phosphorus load in surface waters come from agriculture.

Excess levels of nutrients in water contribute to the process known as eutrophication, which refers to the process of nutrient enrichment of either aquatic or terrestrial ecosystems. The higher levels of nutrients stimulate plant growth, which can adversely impact the productivity and biodiversity of ecosystems leading to excessive growth, or "blooms", of algae, which causes oxygen depletion, making waters uninhabitable for fish and other animal life. In freshwater systems, phosphorus as phosphate is considered the main nutrient limiting the rate of plant growth while in coastal waters, nitrogen as nitrate or ammonia is considered the limiting nutrient. The eutrophication of water and its contamination by material with high biochemical oxygen demand (BOD), pesticides, veterinary medicines and soil all impact on the aesthetic, recreational, conservation and biodiversity value of water. Contamination by faecal microorganisms gives rise to human and animal health risks (for more details see Defra 2004a).

Long-term monitoring records, export coefficient modelling and palaeolimnological studies all indicate that nutrient concentrations in UK freshwaters are greatly enhanced above natural levels and have had considerable ecological effects, particularly in the last 50 years.

There are large regional differences in the degree to which lakes and rivers deviate from a 'natural/background' level in the UK, with less impacted sites predominating in less agriculturally-intensive (and less populated) landscapes, particularly Cumbria and the

Scottish Highlands and Islands. The greatest ecological change is found in lowland regions in Northern Ireland and England, where nutrient concentrations are often well in excess of background levels (Defra 2004a).

Catchment-Sensitive Farming and UK priorities for water and agriculture

The UK is looking to achieve reductions in diffuse water pollution from agriculture (DWPA) by promoting Catchment-Sensitive Farming (CSF). CSF is about managing land in a way that is sensitive to the ecological health of the connected water environments and helping the industry to work toward sustainability.

Governments' priorities for water in England over the longer term are:

- protecting the countryside and natural resource protection. This includes:
  - prudent use of water resources and keeping its use within the limits of its replenishment;
  - achieving better integration between water and other policies and between different aspects of water policy.
- emergency preparedness – developing, setting and overseeing delivery for reservoir safety. Continuing to take steps to protect our drinking water from accidental or deliberate contamination.

UK's water policies are grounded in the Government's commitment to sustainable development, covering economic, environmental and social aspects. Key aspects of this relevant to water quality include:

- enabling viable livelihoods to be made from sustainable land management, both through the market and through payments for public benefits
- respecting and operating within the biological limits of natural resources (especially soil, water and biodiversity)
- achieving consistently high standards of environmental performance by reducing energy consumption, by minimising resource inputs, and using renewable energy wherever possible.

Achieving reductions in DWPA by promoting CSF is a key component of delivering this commitment.

Drivers for Catchment-Sensitive Farming

Many of the important aquatic plant and animal species in England need low levels of nutrients and silt to flourish. In addition to their conservation value, healthy and robust river systems provide many direct benefits, including clean drinking water, safe bathing water, healthy fisheries, reduced flood risk and an improved living environment. Good water quality also encourages recreation and tourism, contributing to use of the countryside and the viability of rural businesses. These are all key drivers for tackling diffuse water pollution from agricultural (DWPA).

Because of these benefits we have agreed and signed up to a number of international and EU commitments. Of our commitments, the Water Framework Directive (WFD) is the principal driver for action to address DWPA, though not the only one – others include the Bathing Waters Directive and the Birds & Habitats Directives.

Water Framework Directive

The European Union (EU) Water Framework Directive (WFD) (see http://europa.eu.int/comm/environment/water/water-framework/index_en. html) aims to ensure the integrity of the water environment and its associated eco-system functions by requiring the maintenance of 'high ecological and chemical status' of surface waters where it exists, and aiming to achieve 'good ecological and chemical status' for surface waters and 'good chemical status' for ground waters. The WFD applies to all waters (rivers, lakes, estuaries, coastal waters out to one nautical mile, and ground waters). The WFD must address both point source and diffuse source pollution where it impacts on achieving WFD objectives. The details of the WFD timetable are shown in Table 2. Member states are required to split their countries into River Basin Districts (RBD) and produce a draft River Basin Management Plan for each RBD by December 2008 — and finalise these plans by 2009. The plans will bring together information relevant to each RBD, including the environmental objectives for each water body and a summary programme of measures which will be taken to achieve those objectives.

Table 2. Water Framework Directive implementation timeline
(for more details see the Defra website (http://defraweb)

Year	Requirements under WFD
March 2005	Reports to be submitted to EU Commission showing first assessment of risk (characterisation) of water bodies not meeting the environmental objectives of the WFD. This work is to be refined in a second phase of characterisation in 2005–07, and carried forward in a monitoring programme from 2006 to 2008.
2008	Draft river basin management plans (RBMPs) to be prepared at the regional (river basin district) level, with active involvement of interested parties, showing proposed environmental objectives for each water body. RBMPs must also summarise programmes of measures (POMs) to be applied, including addressing DWPA. The WFD states expressly that measures shall consist of 'for diffuse sources liable to cause pollution, measures to prevent or control the input of pollutants'.
2009	RBMPs to be published in final form.
2012	POMs summarised in the RBMPs to be made operational.
2015	Environmental objectives in RBMPs to be met (except for water bodies where an extended deadline has been set); start of second round of RBMPs to achieve outcomes in 2021.
2021	Start of third round of RBMPs to achieve outcomes in 2027.

WFD also repeal several existing and older EU water directives dating back to the 1970s. By encompassing previous water directives WFD effectively sets a strategic framework, which should ensure sustainable management of water in the long term. The repeal of the older Directives will take place in either in 2007 or in 2013 after which WFD will offer at least the same level of protection as the repealed directives. The Directives to be repealed include the Surface Water Abstraction Directive (in 2007); Freshwater Fish Directive (in 2013); Shellfish Waters Directive (in 2013); Groundwater Directive (in 2013); and the Dangerous Substances Directive (in 2013).

Implementing WFD is complex and requires new ways of working across the EU. It is also unique amongst water directives as economic analysis is also written into its requirements — cost-effective analysis (CEA) is one of the criteria for choosing the measures to be used to achieve WFD objectives. There are also a number of exemptions that may be used when defining the objectives to be met during River Basin Management planning. These include setting less stringent objectives if the water body is heavily modified (HMWB) or is an artificial water body (AWB). Instead of aiming to achieve good ecological status, the aim must be to achieve good ecological potential. Exemptions may also be used in cases where (1) costs of achieving the status are disproportionately expensive, (2) the time scale for achievement of the objectives is technically infeasible or natural conditions do not allow timely improvement of the water body. All exemptions have detailed criteria which must be met for the alternative objectives to be applied.

Bathing Water Directive

The Bathing Water Directive (76/160/EEC) (see http://europa.eu.int/water/water-bathing/index_en.html) aims to protect public health and the environment from faecal pollution in bathing waters. The Directive requires member states to identify popular beaches and monitor the bathing waters for indicators of microbiological pollution. The microbiological quality of bathing waters has improved considerably in the UK following substantial capital investment at inland and coastal sewage treatment works. Compliance with the current mandatory coliform standard of the European Bathing Water Directive at coastal waters in the UK was 98% in 2003, compared with 77% in 1990. However, proposed revisions to the Bathing Water Directive, with stricter water quality standards, will result in reduced compliance (see Defra web site for more details).

Water quality failures occur principally following times of high river flow, when there is increased runoff from diffuse agricultural sources and, potentially, releases of untreated sewage from combined sewer overflows and storm tanks. The relative contributions of diffuse agricultural and urban associated point sources depends upon the land use and hydrology of a catchment. A number of recent studies have quantified this impact in a number of UK catchments. Intensive monitoring of discharges and water quality on the Island of Jersey, the Staithes catchment (North Yorkshire), the Ayrshire beaches in south-west Scotland and the Nyfer catchment (Pembrokeshire) established that during storm flows c.60% of the FIO budget was contributed by diffuse sources from within the catchments, rather than to known sewer and storm over-flows (Defra 2004a).

Although a number of detailed catchment investigations have now been carried out, an overall picture of the agricultural contribution to bathing water quality failures has not been formed. Defra is currently funding a project to enhance an existing methodology for estimating faecal pollution arising form manure spreading on agricultural land and determining agriculture's contribution to failure of bathing waters to meet the requirements of the Directive.

Birds and Habitats Directives

At the EU level, the 1979 Birds Directive (79/409/EEC) (http://europa.eu.int/comm/environment/nature/directive/birdshome_en.htm) and 1992 Habitats Directive (92/43/EEC) (http://europa. eu.int / comm. / environment / nature / nature_conservation / eu_nature_legislation/habitats_directive / index_en.htm) have established Special Protection Areas (SPAs) and Special Areas of Conservation (SAC) that member states are committed to protect and improve.

The 1979 Birds Directive requires the maintenance of favourable conservation status of all wild bird species across their distributional range and, as already stated, the establishment of SPAs for rare or vulnerable bird species. In the UK, 237 SPAs have been classified covering 1.25m ha. Other requirements include a general scheme of wild bird protection, restrictions on the sale and keeping of wild birds and hunting restrictions.

The 1992 Habitats Directive requires member states to introduce a range of measures including the protection and surveillance of habitats and species listed in the Directive. Each member state has had to put together a list of national sites containing the 189 habitats and 788 species listed in the Directive (567 UK sites covering 2.16m ha have been listed). These sites are designated as SAC. The Directive applies the precautionary principle to SAC so development projects are only permitted in these areas if it is ascertained that there is no adverse impact.

More recently SPAs and SAC have been used to create a European-wide network of protected areas known as Natura 2000. This network of protected sites, which represent areas of the highest value for natural habitats and species of plants and animals which are rare, endangered or vulnerable in the European Community, is essentially a re-commitment to the preservation and protection of these SPA and SAC sites.

At the national level, the 1981 Wildlife and Countryside Act (see www.defra.gov.uk/wildlife-countryside/cl/) implemented the obligations of the Bern Convention and EC Birds Directive in England and Wales and established Sites of Special Scientific Interest (SSSIs) as well as making it an offence to kill wild animals and birds. There are currently 4113 SSSIs in England covering 7% of the country — all SAC, SPA and Ramsar sites are designated SSSIs. Defra has a challenging Public Service Agreement (PSA) target to get 95% of SSSIs into a favourable condition by 2010.

On an area basis, 1.5% of SSSIs (62 sites) in England are in an unfavourable condition because of water quality and DWPA. In 2003, of the 43% of SSSIs in an unfavourable condition, on rivers and streams, 70% were affected by diffuse pollution. Diffuse pollution also impacts 35% of standing water/canals, 15% of fen, marsh and swamp, as well as 5% of lowland neutral grassland.

The size of the problem in the UK

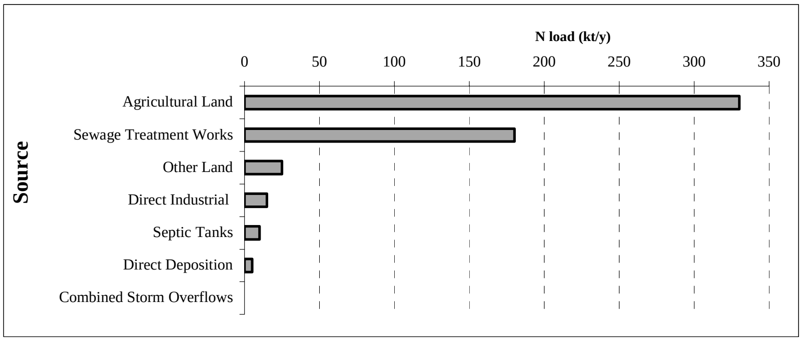
Phosphorus

Agriculture is responsible for about 43% of phosphorus inputs to surface waters in the UK. Human and household waste is responsible for some 24%. Detergents were responsible for about 19% of inputs and industry and background sources account for the remaining 14 % of phosphorus inputs in the UK (Morse et al. 1993).

Nitrogen

For nitrogen (N), agriculture's contribution is roughly 60%, while that of sewage treatment works (STW) remains at roughly 30% (Defra 2004c). The contribution of point and diffuse sources of nitrogen to both marine and inland waters in England and Wales amounted to some 558 ktN/yr. In England and Wales, N levels have increased by about 15% from 287 kt N to 330 kt N, and the estimated inputs from sewage treatment works (STW) have declined by about 15% — from 216 kt N to 184 kt N (Figure 1). This decrease has come about primarily as a result of improvements in STW discharges to the marine environment, undertaken to meet legislative requirements.

Figure 1. Nitrogen sources in England and Wales, year 2000 nominal (ktN/yr) (from WRc ([2004])



Silt

The highest proportion of suspended solid loadings to rivers derives from diffuse sources and that in rural catchments this is heavily dominated by agriculturally-derived soil erosion. However, no national source apportionment is yet available. Where arable lands are under drained, 50% and more of the silt load that leaves a catchment can be agriculturally derived. Soil loss by erosion from pastureland can also provide the dominant source of silt in streams, particularly where under drainage is present and where poaching of soils has occurred (Defra 2004a).

BOD

Livestock in the UK produce about 2.5 million tonnes of BOD every year. If just 2% of this were to escape into water it would be equivalent to the total BOD from human excrement that is discharged via sewage treatment works each year (Defra 2004a).

Faecal Indicator Organisms (FIOs)

Numerous studies (see Defra 2004b) have demonstrated the importance of diffuse agricultural sources to the faecal loadings at bathing waters. Extensive work in Scotland has shown the important role that livestock management can play in influencing the quality of bathing waters. Direct access to watercourses and poor management of livestock and slurry have all been implicated in high bacterial loads in rivers. The lack of adequate on-farm storage facilities for manures and slurries was shown to be a major contributing factor. They reported a direct positive correlation between river water bacterial loading and intensity of livestock management. In-stream concentrations of faecal indicator organisms in two areas of high livestock intensity were four to eight times higher than in two corresponding areas of low livestock intensity.

River Basin Characterisation maps

River Basin Characterisation (RBC) was the first stage in the WFD management cycle. It describes the water environment and the human pressures on it, so that the risk of failing the WFD targets or objectives can be assessed. Characterisation work for WFD in England and Wales found the following:

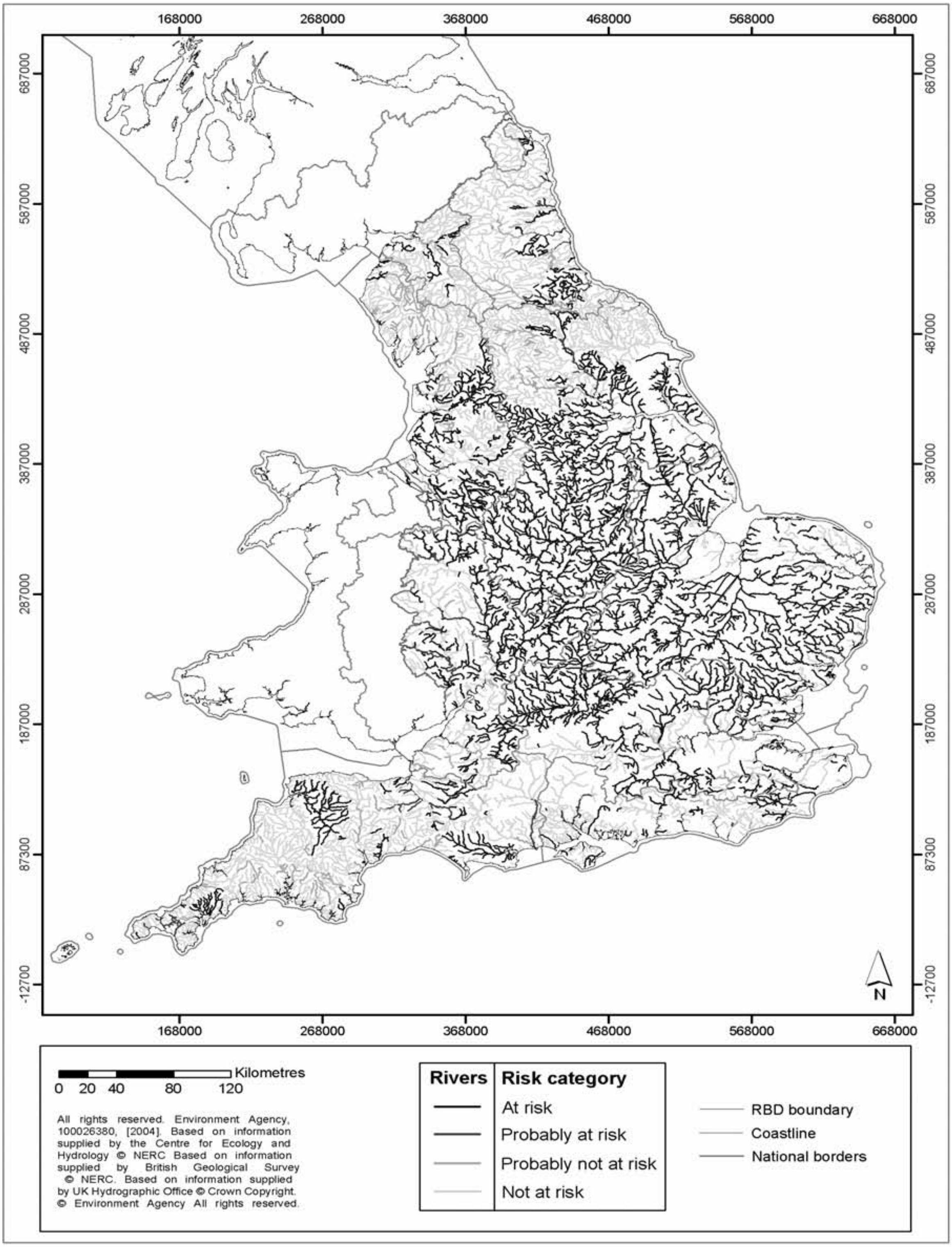
- Nitrate is a risk for drinking water supplies in 49% of rivers, particularly in England.
- Phosphate is a risk for 38% of rivers and 23% of lakes (by area).
- Sediment (from eroded soil) is a risk for 21% of rivers.
- Eighty-five per cent of groundwater boreholes monitored in 2003 show rising nitrate concentrations. Many in England are above or approaching the upper limit for nitrate in drinking water.

(For further details and information see http://defraweb/environment/water/wfd/article5/ index.htm.)

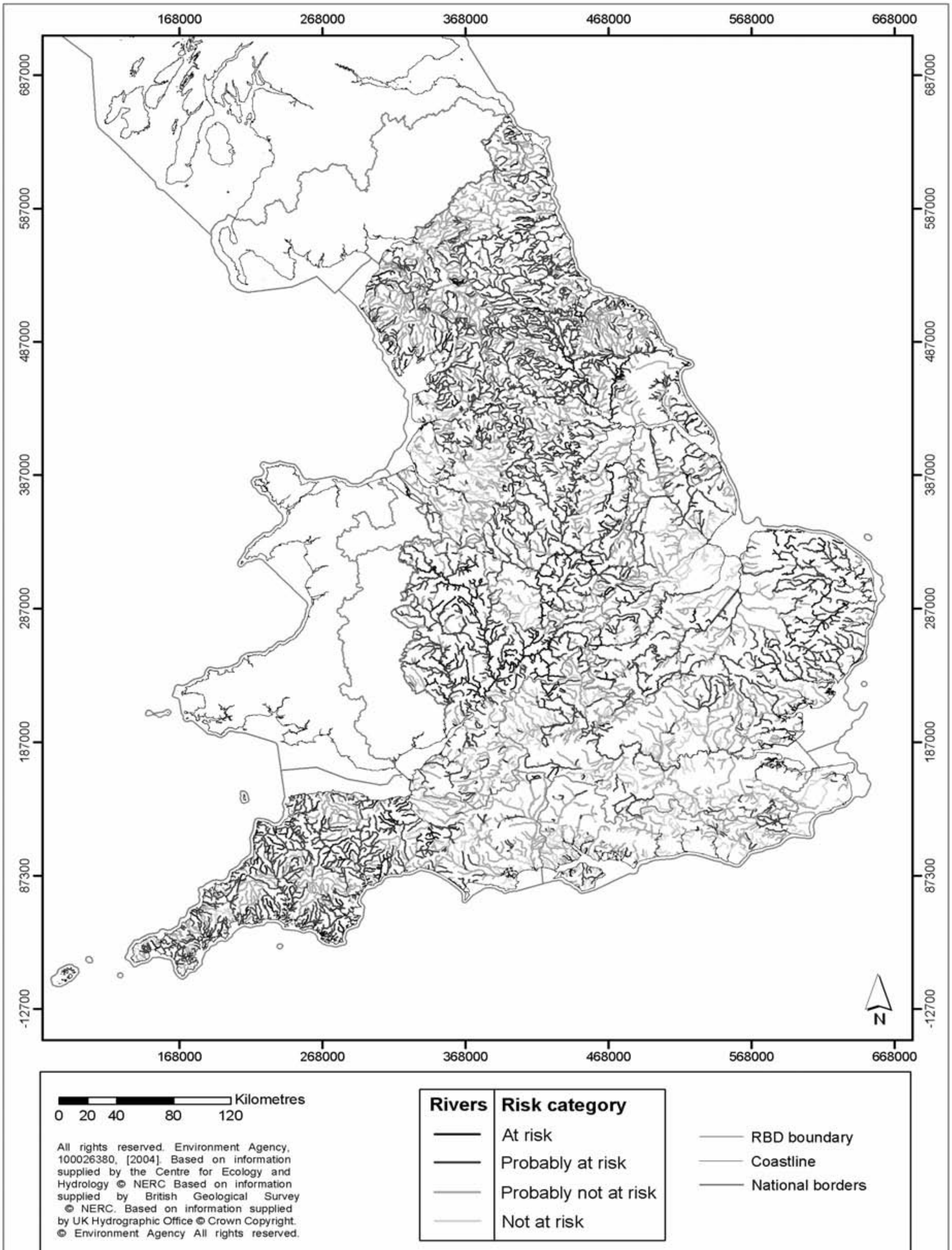
As part of this work the EA estimated the pressures contributing to these risks (see Figure 2). With regard to agriculture:

- Diffuse pollution causes a risk of not achieving WFD objectives by 2015 in 82.4% of rivers, 53% of lakes, 25% of estuaries, 24% of coastal waters and 75.3% of ground waters.
- Nutrients such as nitrogen (mainly from agriculture) put almost 40% of rivers, nearly 20% of estuaries and over 50 % of groundwaters at risk of not achieving good ecological and chemical quality by 2015.
- Phosphorus accounts for nearly 50% of rivers and 25% of lakes being at risk. Agricultural pesticides and sheep dip also put 20% of rivers and groundwaters at risk.

Figure 2. Maps of diffuse nitrogen and phosphorus pressures: rivers at risk of not meeting WFD objective of Good Ecological Status
N (mainly agriculture) pressure map



P (mainly agriculture) pressure map



Agricultural sources of DWPA

Significant resources have been committed to understanding the pathways of nutrient losses from land and the impacts of these nutrients and other pollutants on the water environment. However, although we have a good understanding of N loss pathways, our understanding of P loss is still limited. In addition, until recently little was done to understand the impact of nutrients on the ecology of receiving waters.

Pollutants can either be transported in solution or in suspension, and either in drainage water moving through the soil or in water moving across the soil. Pathways differ between pollutants. The mechanism for water movement through soils with little structure is relatively straightforward: water drains downward through the soil with a generally uniform wetting front, carrying solutes in the soil profile towards the groundwater. In more structured soils, such as clays and loams, water generally moves laterally, either across the surface as 'overland flow' (sometimes called surface runoff) or through the surface layers via cracks, channels and, ultimately if installed, drains; collectively known as 'soil water drainage'.

A generalised and simplified summary of pathways and states of solution or suspension, for the different pollutants are:

	Solution	Suspension
Overland	NH_4^+, BOD	TP, FIO, Sediment
Subsurface	NO_3^-	

Both the risk of loss and pollutant pathways vary between farming sectors. Table 3 illustrates the main practices/issues within three representative farming sectors contributing to diffuse loses of N, P and FIOs in England and Wales.

The most effective on-farm mitigation measures fall into three activity categories — nutrient management, soil erosion and runoff prevention, and farm landscape and infrastructure changes. The most effective mitigation measures for tackling N and P pollution relate to manure management. Soil management measures are shown to be comparatively less effective (Defra 2005)).

Current and planned policies for tackling DWPA

There are currently a number of policy levers in place for tackling DWPA. The most significant are the Nitrates Directive and CAP reform.

Nitrates Directive

The Nitrates Directive (91/676/EEC) (see http://europa.eu.int/comm/environment/water/water-nitrates/index_en.html) is concerned with the protection of waters against pollution caused by nitrates from agricultural sources. The directive was adopted by the Commission on 19 December 1991. It seeks to reduce or prevent the pollution of water caused by the application and storage of inorganic fertiliser and manure on farmland. It is designed both to safeguard drinking water supplies and to prevent wider ecological damage in the form of the eutrophication of freshwater and marine waters generally.

Table 3. Summary of the perceived main issues contributing to diffuse pollution of nitrates, total phosphorus, and faecal indicator organisms for the three farm system types from England and Wales
(adapted from Defra 2005)

FARM SYSTEMS	DIFFUSE POLLUTANTS		
	Nitrates	**Total Phosphorus**	**Faecal Indicator Organisms**
Intensive grassland[1]	***Nutrient overload and risk of leaching*** 1. Inappropriate fertiliser and manure management 2. Overstocking 3. Maize	***Nutrient overload, incidentals and detachment*** 1. Soil phosphorus accumulation 2. Improper manure and fertiliser management 3. Maize 4. Poaching and compaction	***Transfer of excreta and manures*** 1. Improper manure management 2. Direct defecation to steams 3. Uncontained losses from hard standings and manure heaps
Outdoor pigs[2]	***Nutrient overload*** 1. High stocking rates 2. Lack vegetative cover 3. Nutrient hotspots	***Increased runoff and detachment*** 1. Poaching and compaction 2. Lack vegetative cover 3. Foraging damaging soil structure	***Increased runoff and detachment*** 1. Poaching and compaction 2. Lack vegetative cover 3. Foraging damaging soil structure
Arable systems (heavy soils)[3]	***High nutrient inputs and high hydrological connectivity*** 1. Injudicious fertiliser applications and manure management where relevant 2. High risk crops i.e. rape 3. Preferential pathways through cracks and drains	***High runoff soils with high inputs*** 1. Soil phosphorus accumulation 2. Inappropriate fertiliser and manure management 3. Preferential pathways through cracks and drains	***Manure imports*** 1. Improper manure storage 2. Inappropriate manure application 3. Preferential pathways through cracks and drains

1. Intensive grassland — is characterised by being typically overstocked, leading to poaching, soil erosion, manure management problems and related losses to watercourses. Soils are often subject to nutrient surpluses. Where maize occurs, leaching and erosion increases.

2. Outdoor pigs — is characterised by high stocking rates and difficulty in maintaining green cover, leading to capped, poached soils. Nutrient hotspots such as feeding and defecation areas are a problem in terms of surface runoff and leaching losses through typically light soils.

3. Arable systems (heavy soils) — is characterised by drainage and surface runoff that can lead to rapid movement of pollutants to water courses by surface and preferential pathways. Surface runoff can also lead to erosion of exposed soils.

Since 2002 55% of England has been designated a Nitrate Vulnerable Zone. Farmers in this area have been required to follow an Action Programme to comply with the requirements of the Nitrates Directive. This means that farmers have to: restrict nitrogen use to crop need, observe closed periods for inorganic and organic nitrogen subject to risk of run off, observe spreading controls, use appropriate storage to match closed periods and keep records of nitrogen use.

Farmers located within the existing NVZs designated in 1996 have been required to adhere to a lower limit of 170 kg/ha total N per year for spreading manure on arable land since 19 December 2002. From 19 December 2006, farmers located in the new NVZs will also be required to adhere to this lower limit rather than the current 210 kg/ha.

The Government encourages farmers outside of the NVZs to follow voluntary Codes of Good Practice (Defra 1998) for the protection of the environment. The Code also helps to reduce other pollution, including phosphate losses, microbiological contamination of bathing waters and pesticide losses.

The UK is currently in the process of reviewing the Action Programme and possible changes include:

- extending the closed period for manures to all soils
- extending manure classification to other types of manure
- setting a 170kg N/ha
- compulsory nutrient management plans for N.

Any changes will come into effect in mid-2006 after wide consultation in late 2005 (see Defra website [http://defraweb/default.htm] for detail).

Common Agricultural Policy (CAP) Reform

The most significant policy currently impacting on the agricultural industry is the recent reform of the CAP and the de-coupling that is taking place from production-led to demand/market led (see Defra website [http://defraweb/default.htm] for detail).

Since January 2005, the Single Payment Scheme replaced most existing crop and livestock payments. The new scheme has broken the link between production and support. Instead, farmers will be asked to demonstrate that they are keeping land in Good Agricultural and Environmental Condition (GAEC) and complying with a number of specified legal requirements relating to the environment, public and plant health, animal health and welfare, and livestock identification and tracing (SMRs). Meeting these requirements is described in the CAP legislation as "cross compliance".

The CAP Regulations (Council Regulation 1782/2003) set out a framework of GAEC standards within which each member state decides its own detailed rules. The GAEC framework, and hence the standards for England, focus upon two areas: soil management and protection; and maintenance of habitats and landscape features. It is generally held that GAEC standards will contribute to raising the environmental performance of agriculture. GAEC requirements will apply to all land managers in receipt of the Single Payment.

As well as changes to the direct farm payment, in 2005 farmers in England[3] can also apply to Environmental Stewardship Schemes (ES) that pay farmers to farm in a more environmentally sensitive manner, beyond that of what is required in cross compliance. This forms part of England's funding from the EU's Rural Development Regulation

3. In Wales, Tir Gofal (like Higher Level Stewardship) and proposed new schemes such as Tir Cynnal (like Entry Level Stewardship) are available under Environmental Stewardship Schemes.

(RDR) application, which amongst other things provides funding so that environmental issues are taken into account in farming policies.

Environmental Stewardship (ES) is a new agri-environment scheme which aims to secure widespread environmental benefits. The scheme has three elements:

- ***Entry Level Stewardship*** (ELS) is a 'whole farm' scheme open to all farmers and land managers with conventional land. Acceptance will be guaranteed providing you can meet the scheme requirements. ELS aims to encourage large numbers of farmers and land managers across England to deliver simple yet effective environmental management that goes beyond the Single Payment Scheme (SPS) requirement to maintain land in Good Agricultural and Environmental Condition (GAEC). If ELS is taken up across large areas of the countryside it will help to improve water quality and reduce soil erosion.

- ***Organic Entry Level Stewardship*** (OELS) is a 'whole farm' scheme similar to ELS, open to farmers who manage all or part of their land organically.

- ***Higher Level Stewardship*** (HLS), which will be combined with ELS or OELS options, aims to deliver significant environmental benefits in high priority situations and areas. HLS is discretionary and concentrates on the more complex types of management, where land managers need advice and support and where agreements need to be tailored to local circumstances.

- The five primary objectives of Higher Level Stewardship are:

  – wildlife conservation

  – maintenance and enhancement of landscape quality and character

  – natural resource protection

  – protection of the historic environment

  – promotion of public access and understanding of the countryside.

There are two secondary objectives — flood management and conservation of genetic resources, where spin-off benefits are sought from management, designed to achieve the five primary objectives.

CSF Delivery Project

There remains a mixed response from farmers to the question of whether farming contributes to diffuse pollution. Some accept that farming practices cause pollution, others do not, or at least challenge the extent to which they do compared to other, usually fixed point, sources of pollution. Getting farmers to accept or realise that farming causes pollution — that is, by its day in and day out activities — remains a big problem, particularly if they feel they are observing best practice or if the impacts are off-farm.

The CSF Delivery Project (CSFDP) is raising awareness and promoting voluntary activity and best practice to tackle this issue. It comes in on the back of CAP reform, which at a minimum should make farmers realise that the old system of subsidised production is over, that gives CSFDP a new platform to begin its work.

As already highlighted in this paper, the cross compliance requirements and standards of the Single Payment Scheme, and numerous options of the Environmental stewardship Scheme (both Entry Level Stewardship and Higher Level Stewardship) will make an important contribution to tackling DWPA. The resource protection options of HLS are of particular importance. HLS will be particularly important in priority catchments.

The Project has so far put significant funding (£2.5 million) into a pollution minimisation advice contract being delivered by RDS/ADAS, to improve the environmental performance of farming. Most of this work is geared at DWPA.

We have also secured £10 million in 2006-07 and £15 million in 2007–08 of Government funding to spend on tackling DWPA. This is on top of agri-environment money and the ADAS advice contract. The key elements of our model for CSF delivery include the following:

- prioritisation of catchments within river basin districts
- creation of a network of Catchment-Sensitive Farming Officers within a Natural England/ Environment Agency partnership
- detailed knowledge of catchments and of farming activity within them
- shared understanding of practices which cause DWPA and of mitigating measures
- establishment of inclusive and dynamic catchment steering groups
- involvement of key stakeholders, in particular farmers
- targeting of farms for advice, including 1:1 farm visits
- support and incentives through enhanced uptake of agri-environment schemes, and possible capital grants.

Preparations to deliver these elements are well advanced.

Impact of current policies on water quality

Defra have funded studies to provide projections of estimated quantitative percentage changes in key arable and livestock activities to 2015 (Defra 2004 d, e). These scenario based studies have indicated that there are a number of uncertainties about the impact of CAP reform but the research to date indicates that CAP reform won't do enough to deliver the scale of reductions in nutrient levels required to meet our water quality targets in most catchments in England. The key findings were:

- Although a number of pressures and drivers have been identified that would affect land use up to 2015, overall land use is not projected to change dramatically. Key projected trends include an increase in cropland as land that was previously set aside returns to production; and declines in livestock numbers.

- However, projections may mask potentially significant structural changes and changes in production intensities, which could have significant economic and environmental implications.

This work is now being further refined and further analysis will be carried out on the impacts of new policies not only on land use changes but also on land management changes and their impacts on water quality. The research will revisit the considerations arrived at in previous studies, set a new policy baseline and re-examine the drivers of change as well as being able to flesh out policies that in 2004 were still in process of negotiations.

In addition to this work Defra is funding a longer term project — the Agricultural Change and Environment (ACE) Observatory — which will monitor the impact of CAP reform over a number of years, 2005–2008, in England. It will consider information on:

- farmer's intentions and any resulting changes in patterns and practices

- actual and predicted environmental outcomes which result from these changes

- to establish links between the changes observed

- extrapolate future environmental changes on the basis of what has been observed or intended behavioural changes, and the best available information on the casual links between these and longer term impacts.

Our evidence to date, therefore, indicates that current regulatory controls, including the Nitrates Directive, and softer measures such as advice, voluntary and supportive approaches (including CAP reform and funding through RDR and CSF Delivery project), although valuable instruments with real benefits, will not be sufficient, on their own, to allow us to meet WFD targets and objectives. Stronger measures will be needed to encourage farmers to take up activities which have financial implications for their business, and we are looking to identify the most cost-effective of our options.

Additional measures required and analysis of most cost-effective packages of measures for tackling DWPA

Further analysis is required to enable us to make informed decisions about the most appropriate additional measures required, and hence the most appropriate package of measures for inclusion in WFD PoMs.

We are currently in the process of identifying the most cost-effective additional policy options required to enable us to tackle DWPA effectively to meet WFD objectives. Options being considered include the extension of existing Defra policies as well as the development of brand new approaches for tackling DWPA. As part of this work we are currently examining a range of new and existing regulatory powers that could potentially tackle DWPA. Over ten existing regulatory powers were identified as having potential for tackling DWPA. A small number that could be extended or modified to address DWPA have now been identified, including provisions under the Water Resources Act 1991 and the use of Waste Regulations to control phosphorus. The Water Resources Act 1991 is a domestic policy which currently provides a framework for controlling the abstraction and impounding of water resources in England and Wales. It ensures that any existing rights to abstract water are protected, sufficient water flow remains in rivers and the water environment itself is properly protected. The Waste Framework Directive Regulations ensure that waste is recovered or disposed of without endangering human health and without using processes or methods that could harm the environment.

In addition, several possible new powers, including provisions for General Binding Rules that restrict or prohibit polluting farming activities, have also been identified and are now under consideration. General Binding Rules (GBRs) are sets of mandatory rules that can be applied to a particular activity. Authorisations under GBRs will set out the scope of the activity under the GBR and the conditions that apply to carrying out that activity.

Our overall approach is based on determining the cost-effectiveness of the various options for controlling farm practices that lead to DWPA, whether regulatory, supportive or otherwise. These will then be taken forward for consideration as components in the various packages of DWPA policy measures.

The cost-effectiveness analysis is being taken forward in two steps: first, analysis of cost-effectiveness of single policy options followed by analysis of the cost-effectiveness of a combination of policy packages (it is unlikely that one instrument alone will be sufficient, or the most cost-effective approach to tackling the issue). The analysis will consider costs both to the farmer and industry, as well as costs to the taxpayer for enforcement and other economic costs.

To determine how far various packages will take us towards meeting WFD, the most cost-effective packages will be assessed for their impact on reducing the risk across the UK (England and Wales) of failing to meet WFD objectives, by analysing the impacts of the policies on the characterisation analysis carried out by EA for WFD (see Figure 2). This work will enable us to make judgements on the impact of various policy packages on water quality objectives under WFD, i.e., it will allow us to see how effective various packages are in filling the gap between where we are now (in relation to risk to waterbodies) and where we would be if a policy package was implemented. We will also take forward cost-benefit analysis of the various packages.

This programme of work will enable us to consult with a wide range of stakeholders on a range of potential packages of policy instruments, provide the costs and benefits of each, and information on how effective the package is at helping to reduce the number of water bodies at risk of failing to meet WFD objectives. We plan to formally consult on how we will tackle DWPA in 2006. This will ensure that effective measures for tackling DWPA (including necessary powers if required) will be available for inclusion into draft River Basin Management Plans by 2008/9.

Conclusion

- Agriculture is a significant contributor to diffuse pollution and to eutrophication of UK waters.

- Our policies are aimed at a sustainable farming industry — looking to improve the environmental performance of the industry without compromising the economic and social benefits.

- It is important in the short term to make farmers aware of their contribution to the problem, and to support them in adapting their farming practices.

- Longer-term it may be necessary, and more cost-effective, to use stronger legislative measures to ensure the industry plays its part in protecting the environment.

The principal challenge is to identify appropriate and most cost-effective measures for tackling the impact of farming on the environment while ensuring, in the long term a sustainable farming industry.

ACKNOWLEDGEMENTS

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Chapter 18.

Tool for Monitoring and Evaluating the On-farm Environment Management and Nutrient Use on Finnish Cattle Farms

Elina Nikkola[1] *and Kaisa Tolonen*[2]

Nitrogen and phosphorus balances as well as the Usability Classification of Waters are used as national indicators to monitor the trends in nutrient use and their effects on the environment. In addition to national rules, regulations and actions, voluntary approaches to minimise nutrient leaching as well as more specific, farm-level indicators have been developed.

One example of such approaches is the voluntary Cattle Farm Environmental Auditing Tool (CFEAT), which helps a farmer to optimise and benchmark certain farm management activities on the farm level in order to achieve more environmentally-friendly management practices. CFEAT has been created and developed by the Association of Rural Advisory Centres (ProAgria ARAC), which is a non-governmental agricultural expert organisation in Finland. CFEAT helps farmers to classify and evaluate their normal, day-to-day cultivation activities (nutrient and manure use, tillage) and animal husbandry. More emphasis is given to activities which have the most beneficial effects on the environment and animal welfare and which go beyond the mandatory level. Evaluation is carried out together with a ProAgria ARAC adviser and the results, combined with farm-level quality or environment systems, help farmers to find concrete measures and targets for developing farm management practices.

The use of CFEAT started already in 1995. The number of dairy and cattle farms evaluated by means of CFEAT by 2005 is 1337, which is about 1% of the total number of dairy and cattle farms in Finland, but the number has been rising steadily. The results concerning nutrient leaching from arable area are promising: the nitrogen effluent has decreased, on average, by 4-15% and solid phosphorus by 5-13% as a result of the introduction of better and more efficient methods for the management of nutrients and use and handling of livestock manure. The load of soluble phosphorus is about the same as before.

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Background

Finland has abundant water resources. Using the Water Poverty Index,[3] researchers from the United Kingdom's Centre for Ecology & Hydrology and experts from the World Water Council found Finland to be the highest-ranking country in their list of the world's water-rich nations. Only 2.2% of the country's total renewable water resources are actually used each year. Water is taken mainly to meet the needs of industry and public water supply.

The role of irrigation in agriculture is quite insignificant in Finland, and in practice it is mainly used in the cultivation of vegetables. Non-point leaching of nutrients from arable lands is a far greater problem than the use of waters.

Fertilisers are used on arable land to get a higher yield of a better quality and to maintain or improve the fertility and production capacity of the soil. However, each year part of the nutrients contained in fertilisers is left in the land, because nutrients are bound, for example, to the roots of the plants which are not collected along with the crop. Nutrients left in the land are susceptible to leaching and erosion.

In Finland the use of fertilisers, tillage and handling of animal manure are regulated through various kinds of statutes and recommendations, but in certain regions the eutrophication of lakes and rivers located in farming areas is still a problem. It is estimated that 50% of the total nitrogen and 60% of phosphorus in watercourses derives from agricultural production.

The National Water Protection Programme until 2005 (MoE 1998) sets a strict minimum requirement according to which the loading from agriculture must be reduced by at least 50% from the level of 1990–1993. In the early 1990s the average loading was 1.1 kg/ha of total phosphorus and 15 kg/ha of total nitrogen per year (Vuorenmaa et al. 2002), and efforts were made to reduce this, in particular, through agri-environmental support and the Nitrates Directive of the EU (EU 1991). According to the mid-term evaluation of the Water Protection Programme, the reduction objective set for arable farming cannot be reached, even if the practical farming methods have become more environmentally-friendly.

The nutrient loss into the land is not only a threat to the state of waters but they are also an economic loss to farmers. For example, measurements carried out in Southern Finland in 1997–2003 (Marttila et al. 2005) showed that the average nitrogen surplus left in the land each year was 240,000 kg, and the phosphorus surplus was 35,000 kg (size of the catchment area was 213,71 km^2, of which 25% was arable land). The costs of the nutrients which were not utilised totalled about 155,000 €. However, it is often very difficult for the farmers to perceive where the agricultural loading of waters comes from, and how strong it is.

Nutrient balances

Nutrient balance is a good method for reducing nutrient leaching in the long term, because they show how the nutrients are being used, what the quantities are, how the nutrients move, and where losses may be created. There are several types of nutrient balances, for example, farm-gate balance, field balance, cattle balance and manure

3. World Water Council and UK's Centre for Ecology and Hydrology, 2002.

balance. Annual calculation of nutrient balances and utilisation of the information in cultivation planning and measures would very likely improve the environmental protection on farms.

Nutrient balances and utilisation of nutrients vary a great deal in different parcels of a single farm. The utilisation of nutrients depends especially on the weather conditions, but the structure, drainage and acidity of the land, arable crop and the production intensity, type and method are also important factors. The volume of the harvested crop, and thus the nutrient surpluses, vary considerably from one year to another in Finland because of the northern climate. Binding of nutrients takes place more efficiently if the land is in good condition. Almost without exception the nutrient balances are better in crop production than in livestock farming, where animal manure always causes some effluent. In crop production it would be important to plan the fertilisation according to a reasonable yield level to be harvested from the parcel.

The difference between the amount of nutrients added to the land and removed from it (nutrient balance) has been calculated in several projects in different parts of Finland. For example, in the follow-up study of the agri-environmental support, nutrient balances (field balances) have been calculated nationally and according to the territories of Rural Advisory Centres. In 1990 the national nitrogen balance was about 90 kg/ha, and by 2002 it had decreased to about 50 kg/ha. Regional balances varied between 137 and 58 kg in 1990 and 64 and 33 kg/ha in 2002. The annual phosphorus balance in 1990 was 30 kg/ha and 7.7 kg/ha in 2002. In 1990 the regional variation was from 40 to 25 kg/ha and in 2002 it was from 13.6 to 4 kg/ha. (Pyykkönen et al. 2004).

Farm-level factors may be decisive in terms of the creation of nutrient surpluses even annually, which is why the nutrient balance should be determined over a longer time period. On the farm level nutrient balances can be used for the monitoring of nutrient flows together with other long-term planning and monitoring of the production. Nutrient balance calculations have been of great practical help, especially when comparing different arable land parcels with each other. The nutrient balance calculation gives information to the farmers on the problems in the use of nutrients, and functions as a tool in the knowledge-based guidance. It also gives useful information for annual cultivation planning, sensible financial management and improving the measures to promote water protection.

Nutrient balance calculation is a highly appropriate tool for monitoring nutrient flows on the farm level, even if further indicators are needed for the general monitoring of the impacts of agriculture on waters.

Cattle Farm Environmental Assessment Tool (CFEAT)

General

Because the decisions and actions influencing the environment take place on the farm level, there was a clear need to create a practical tool to assist farmers in their everyday work and planning of best practices. The Cattle Farm Environmental Assessment Tool (CFEAT) derived from the need to help farmers to find the best ecologically and economically sustainable practices for their farms, and to build a new kind of competitiveness into the whole milk production chain. Finnish agriculture is strongly founded on practices which are environmentally friendly and respect the environment, but to assist in the marketing as well there was a need for a tool through which the realisation of the environmental objectives could be proven in practice.

The development of CFEAT was started in north-eastern Finland in Kainuu in the mid-1990s. Various experts and advisors in the field as well as the Kainuu Dairy Cooperative and the Kainuu Regional Environment Centre took part in the project. During the project in 1995–2000 assessments based on CFEAT were made on about 700 farms, and on about 350 of them the assessment was made twice. The objective of the project was to prove that farm applies an environmental friendly production practice which takes the conditions and care of the animals into account, and to use these arguments in the marketing of the milk produced on these farms.

By 2005 altogether 1337 environmental assessments had been made, of which 40% were second or third reassessments. This represents about 1% of the total number of dairy and cattle farms in Finland, but the number is steadily rising. Most of the farms are located in the strong cattle production regions in Finland (mainly central and northern parts of the country).

Today CFEAT is maintained and developed by the ProAgria Association of Rural Advisory Centres (ProAgria ARAC), whose advisers go through the farming activities together with the farmer and look for development targets. So far CFEAT has only been used on cattle and dairy farms, but the assessment is being developed further to make it applicable to farms specialising in crop production as well.

Method

CFEAT is a tool for dairy and beef cattle farms for classifying and grading activities that are significant in terms of the environment. Main emphasis is on activities with the greatest environmental impacts or which promote animal welfare or landscape management on the farm the most. The assessment is made from the perspective of plant production, care for the animals and conditions in the production building, water and waste management and landscape management. Each perspective is divided into sub-sections and graded according to the level or results of the activity. Grades are awarded only for actions which go beyond the statutory requirements, which means that farms are rewarded for undertaking additional measures.

CFEAT looks for the strengths and development needs from the perspectives of the environmental conditions and animals and related management, and development plans are drawn up for each sub-section. Progress in each development target can be measured by repeating the measurement in the following year or after 2–3 years. CFEAT comprises three main elements which can be measured either separately or together, according to the needs and wishes of the customer. These are 1) plant production, 2) water and waste management and environmental management and 3) care for the animals and conditions in the production building.

The total number of points available for all sections is 100. The conditions in each section are classified into four categories (poor, satisfactory, good, and excellent) on the basis of levels set for each category. The environmental impacts of the activities are assessed on the arable lands of the farm and production building, all the way to the farm's gate. CFEAT grades and classifies the production processes of a cattle farm by stages. The sub-sections of CFEAT constitute separate entities which can also be used alone.

The measurement starts with an assessment interview, which covers the basic information on the farm: size of the farm, type of production, average returns, location, water bodies (if the farm borders on waters) and extent of the activity. After this, the different sub-sections of the main elements referred to above are examined and the elements are graded according to CFEAT grading system. After the grading an analysis of the farm as a whole is carried out, and the strengths and development targets are identified. The assessment is compiled into the computer programme development by ProAgria ARAC, where the grading and summing up of the points takes place automatically. The programme also shows the distribution of the points of the farm as a whole, and of the different sub-sections.

The objective of the measurement is to proceed step by step to finally set the targets that are the most sensible for each farm and to which the farmer can commit. To reach the highest category the farm must take voluntary measures to enhance the environment and animal welfare. The result of the assessment can be compared with the result of the previous measurement, which shows the trend in the different elements and makes it possible to follow the realisation of the objectives in a reliable way. If the farmers wish to do so, they can also compare the results of their farm with the other farms in the reference data.

Plant production

Plant production is the most extensive and important of the three main sections. It comprises the planning of arable farming and implementation of cultivation measures, storage and handling of animal manure, storage of silage, and flow and utilisation of nutrients on the whole farm, i.e. on arable lands and in cattle. The functioning of the farm machinery and quality of the work are also assessed.

In CFEAT the ability of the different plant and animal production processes to utilise the available nutrients is assessed through the nutrient balances. Nutrient balance calculation is a central element in the environmental assessment. It is based on the assessment of the utilisation of nutrients on the farm. In the farm-gate balance the kilos of nutrients purchased for the farm are summed up, and the kilos of nutrients sold are deducted from this. Nutrients are purchased mainly in feedingstuffs and fertilisers, as well as in seed and live animals. Nutrients exit the farm along with the crop and animal products, as well as to some extent in manure. CFEAT includes the calculation of the farm-gate balance indicating the utilisation of nutrients on the whole farm, field balance showing the nutrient flow in the cultivation, and cattle balance showing the utilisation of nutrients in cattle production.

Further issues to be taken into account are the so-called manure balance and use of animal manure. Manure balance is the difference between the nutrients excreted in manure and those spread on the field. The calculation monitors nitrogen, phosphorus and potassium, and they are calculated as kilos of nutrients per farm, hectare of arable land, livestock unit of litre of milk produced. The balance shows the amount of nutrients which has not been utilised in the nutrient flow on the farm, i.e. which has evaporated, leached, or accumulated in the soil or plants.

Water and waste management and landscape management

Water and waste management and landscape management are divided into the treatment of waste and wastewater, tidiness of the farmyard and landscape management. This section is concerned with the quality of the household water and organisation of waste management, as well as the assessment of landscape management and environmental diversity on the farm. Special emphasis is on the waste treatment methods, where the highest points are awarded to the prevention of waste production. The assessment covers the treatment and storage methods of organic and problem waste, as well as waste that can be burned or recycled.

Today landscape management receives a great deal of attention in agriculture. The preservation of traditional woodland pastures and meadows is particularly important. CFEAT assesses the level and amount of measures related to landscape management, including measures to enhance biological diversity. The assessment also covers the general tidiness of the farm and the state of the buildings and roads.

Animal welfare

The care of the animals and conditions in the production building are divided into three sub-sections: care of the animals, conditions in the building and the animals' possibilities for natural behaviour, movement, access outdoors and social interaction. The professional skills of the person caring for the animals, care of the health and safety of the animals and prevention of infectious animal diseases are taken into account in the assessment. Detailed classification facilitates the assessment and reduces the differences in the grading between different evaluators.

Report

The farmer receives a report on the assessment. The report gives the grades for the activity as a whole and for the different sub-sections as both figures and descriptions. The material left on the farm includes the detailed grounds for the classification in different sections, which shows the strengths in the current activities and development needs, as well as the targets to be set for this, together with the farmer. The customer also receives further written instructions concerning the sections to be assessed according to the needs on each farm.

It is also possible to compile summary reports from several farms to get an overview of how environmental measures are carried out on farms on average, and what the biggest development targets in the future are.

Example: results based on evaluations carried out in 2000-04 (137 farms)

The average size of the farms shown in these results is 42 hectares and the average number of livestock units is 32. The farmers were very active and they participated regularly in training and advisory sessions. The age of the farmers varied between 36 and 45 years, and most of them had been educated in an agricultural school or college. 36% of the farms intended to continue the present type of milk production and 48% planned to increase the production capacity.

Nine of the farms practised organic production, while the rest were conventional cattle farms. 74% of the farms were dairy farms and 16% practised combined milk and beef production. In the handling of manure, the dry and liquid manure storage systems were about equally common. Most of the buildings were tied stall barns (104 farms), while about a quarter used free stall or cold free stall housing (33 farms). More than half of the farms engaged in machine cooperation with other farms.

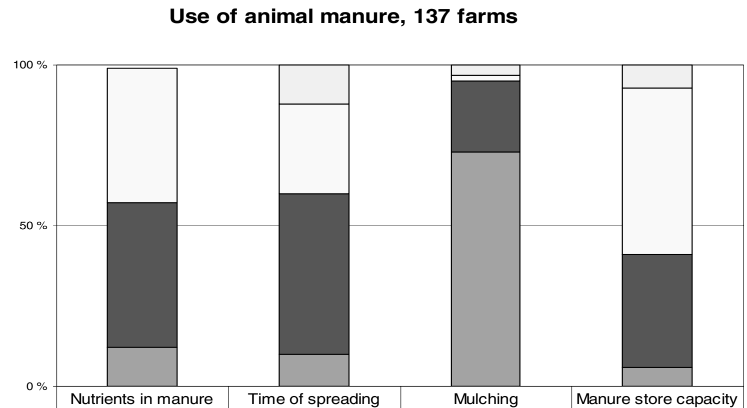
The following paragraphs deal with the results of the plant production section only.

Use of nutrients

Good balance results can be reached only by studying the whole manure handling process and the methods applied, which is why the assessment covered not only the use of animal manure but also the nutrient content in manure and time of spreading, how quickly the manure was earthed-over and the capacity of the manure storage facility.

The assessment showed that on most farms the examination of the nutrient content in manure was good or satisfactory, which means that a manure analysis was carried out every five years (Figure 1). The farms which reached the class "good" had also examined the nutrient balance of feeding, i.e. cattle balance, which shows the utilisation of nutrients in feedingstuffs: the amount of nutrients entering the cattle and exiting from them (milk, meat, animals). The rest is excreted as manure and urine.

Figure 1. Use of animal manure on farms assessed by CFEAT



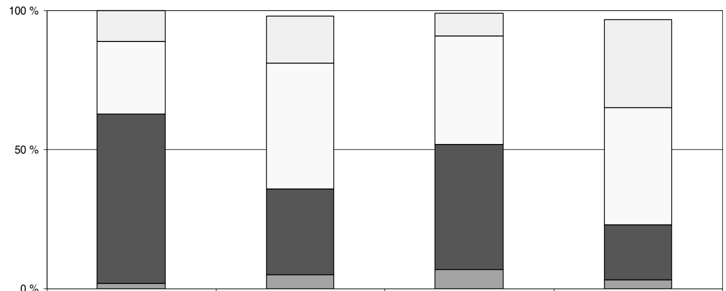
	Nutrients in manure	Time of spreading	Mulching	Manure store capacity
Excellent	0 %	12 %	3 %	7 %
Good	42 %	28 %	2 %	52 %
Satisfactory	45 %	50 %	22 %	35 %
Poor	12 %	10 %	73 %	6 %

The so-called farm-gate balance where the nutrients purchased for the farm are deducted from those sold from the farm indicates the balance of the whole farm. The assessment covers the nutrients used and their quantities relative to the arable area. The practices of most farms belonged to the classes "satisfactory" (61%) and "good" (26%). Farms where the level was satisfactory were aware of the nutrient needs of the crops they cultivated and adjusted their actions according to these. To reach the higher class the farms must also apply parcel-specific nutrient balance calculations, as well as, e.g., follow the changes in nutrient needs during the growing season and know the amounts of nutrients in each lot of animal manure.

The farm-gate balances show that there would be room for at least some improvement in the utilisation of nitrogen on Finnish farms (Figure 2). Most of the farms belong to classes "good" (nitrogen utilisation 20–29%) and "satisfactory" (nitrogen utilisation 10–19%). In terms of the loss of nitrogen the situation is not as good, because in the first class the losses were estimated at 51–80 kg/ha and in the second at 81–140 kg/ha. The classes are about the same in the cattle and manure balance so that in the class "satisfactory" the nitrogen loss in cattle balance is 121–140 kg/ha and the utilisation rate is under 60%. In the class "good" the figures are 101–120 kg/ha and 60–79%.

Figure 2. Nutrient balances on farms assessed by CFEAT

Values of nutrient balances and utilisation, 137 farms



	Nitrogen, phosphorus, potassium quantities spread	Farm-gate balance of nitrogen, utilisation % and loss, kg/ha	Assessment of cattle and manure balance	Soluble nitrogen and usable phosphorus in field balance
□ Excellent	11 %	17 %	8 %	32 %
□ Good	26 %	45 %	39 %	42 %
■ Satisfactory	61 %	31 %	45 %	20 %
▤ Poor	2 %	5 %	7 %	3 %

Discussion

As a general result we can say that on the cattle farms included in the project the level of the environmental impacts of plant production, environmental management and animal welfare is satisfactory or good. The farms take care of their environment, animals and cultivation practices better than required by the statutory obligations in almost all sections of the assessment. Development needs concern in most cases the management of the nutrient flow on cattle farms; i.e. purchases and use of nutrients and quantities sold. The care of the young cattle should also be developed.

The most important element in terms of the environment is the nutrient balances, which also give information on the impacts of the activity on waters and the environment, and the level of the activities in general. The analysis of the nutrient balance results showed that that the efficiency of the use of manure on cattle farms and estimation of the quantities of nutrients to be purchased should be improved. The results also showed that balance calculations, especially the manure balance values, are seldom used in the planning of fertilisation, even if the balances would be quite readily available to assist in planning and as basic data for the following season.

On the farms included in the assessment the field balance values were slightly lower than the manure balances. Most of the farms belonged to the classes "good" and "excellent", which shows that the average losses of nitrogen from arable lands was under 70 kg/ha and the phosphorus loss was under 20 kg/ha.

The review of the production processes together with an expert helped to find the development targets, unnecessary work and purchased inputs, and time thieves. Farmers have been highly satisfied with the assessment, because it has also identified the extra cost items due to the current level of activities, for example, in fertiliser purchases. When fertilisers and their use are raised as a development target, farmers have observed that cost savings have been achieved in the follow-up assessment. Even if CFEAT requires some concentration and paperwork from farmers, it has proven a functioning tool which gives a farmer a comprehensive view of the environmental impacts of farming activities. The development of the practices has also produced clear economic benefits.

Farmers who are interested in using CFEAT are those who have a strong business attitude to farming and who aim to continuously develop their professional skills. They are able and willing to take advantage of the available training and advisory services in their work, and are active in searching for further information on the use of the best and most cost-efficient practices.

One major challenge for advisory services and administration is how to encourage the farmers with more "traditional" attitudes and working methods to also improve their practices, especially those relating to the control of nutrient emissions. Incorporating the calculation of nutrient balances as one condition into the agri-environmental support scheme could be one way of achieving this, besides increasing the training and advice. The planning of the next programming period is now under way in Finland, and the calculation of nutrient balances has been raised strongly as one additional measure. The calculation of nutrient balances and review of the farming practices, together with an outside expert, help farmers to develop their practices further in an ecologically and economically sustainable direction.

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Chapter 19.

Water and Soil Management for Water Conservation in a Watershed

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Until now, there are no ways for sustainable water use and water resource protection from pollution applicable to all of the countries, but water conservation and sustainable use of water should be a supreme work for each country if we think of a life for descendants and a good environment for human beings. Assuming that these are the latest goals for sustainable agriculture, researchers in Korea having farms of small size and complex topography are attempting to introduce various systems for water and soil conservation.

Water retaining capacity per ha of paddy fields in Korea was 5 times larger than that of upland, 3.5 times over forest area and 2 times over grassland. The total water retaining capacity on paddy fields was estimated at 23.8 billion tons for 1146 thousand ha in total, considering the present topographical condition. This quantity of water storage was equal to 47.6 times the amount of water kept in Youngweol Dam, which can store 0.5 billion ton·year^{-1}and for whose construction one billion dollars was taken. Therefore, the most appropriate type of farming in Korea, located in the Asia monsoon belt with heavy rain, was paddy rice farming. Although water use in paddy fields was larger than in uplands, putting water into paddy land played an important role for energy equilibrium through circulation between air heated in cities and that of surrounding rural areas. In the case of water quality, a new approach and concept considering land use, including paddy fields that are covering 61% of arable lands, is required to improve water quality contaminated by agricultural pollutants in Korea. This could be possible through a pollution load evaluation system, classification of watersheds by topographical characteristics & mother rocks, sub-classification of arable lands, assessment of erosion potential and a possibility of site-specific BMP (Best Management Practice) application in the field.

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Introduction

The land in Korea consists of approximately 64% mountainous terrain. Paddy fields, as the main arable lands, are mostly located in the plains or valleys, in the form of levees or terraces that help to reduce soil erosion. As the Korean Peninsula belongs to the Asian monsoon belt, the annual precipitation is about 1500mm in the southern part of Korea and 1300mm in the central part. More than half the annual precipitation falls during the summer season, and sometimes there are severe short-term droughts during the early stage of rice growth in Korea. For the rainy season, paddy rice farming which can be resistant to floods has been developed. Because most of the water resources are derived from rainfall, techniques for the storage of rains have become the most important ones in water use. But, human life and general industry do not contribute to storing water, and just consume it differently from farmland. With an economic development, agriculture is facing increasing competition for surface and groundwater from urban and industrial demands. Also there is a growing desire to meet environmental needs through re-allocation of water resources for the protection of the environment from down-stream impacts caused by agricultural pollution. Some indicators relating to water use were proposed by the OECD, but we think that the OECD has overlooked regional differences in climate, the social and economic meanings of irrigation or water use, and water conservation in the development of these indicators. Therefore, a new recognition on the perspective of water use and water conservation will be required to understand more clearly the status of each country. It will be fruitful, in finding more efficient and effective ways of water management, to consider the issues related to water in some other aspects, through a few case studies on water resources in Korea.

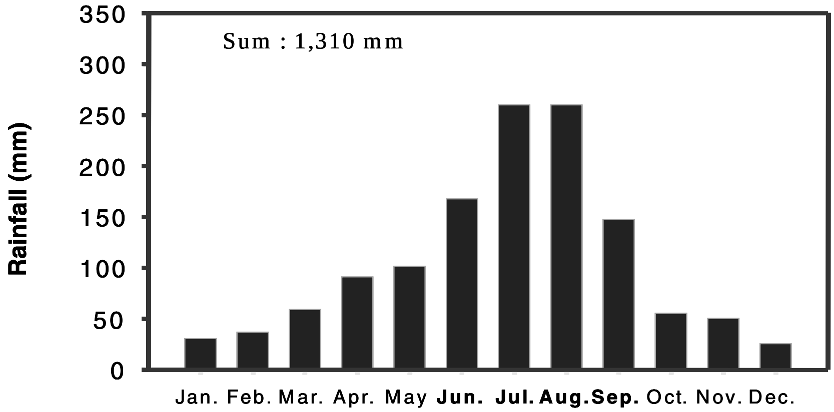
Overview of water resources in Korea

1. Characteristics of water resources in Korea

The climate in Korea is under the effect of both continental and marine climate, and variations in seasonal temperature and rainfall are therefore great. As well, there is a rainy season for about one month because the Korean Peninsula is located in the Asian monsoon belt. As an average of precipitation for 30 yrs (1971–2000) in Korea was 1310mm (Figure 1), it was 1.3 times greater than the annual average precipitation in the world. But, when the precipitation per capita in Korea, about 2,705m^3, was compared with the average amount of the world, 26,800m^3, the precipitation per capita in Korea was only 11% of the average amount of the World. Also, the range difference of annual precipitation having a width from minimum 745mm to maximum 1683mm is about 930mm. A trend of average precipitation is close to regular value, but the amplitude of change is becoming greater.

There was a great variation in precipitation depending on local areas as well as seasons. Two thirds of annual mean precipitation was concentrated in June through September, and precipitation in October through March of the next year was only one fifth of the annual average precipitation. Therefore, it is not easy to manage and use water resources efficiently since water deficits from droughts and disasters from flood or typhoon caused by the great seasonal variation of climate happen frequently. Especially, river basins in Korea having a large mountainous area, which covers 64.3% of the total land, have a small area of steep gradients and short lengths so that a large amount of water flows out at the same time during the rainy season, and the difference between the maximum and minimum flow rate during the dry season was 300–400 times, as compared with about ten times which was reported in other countries.

Figure 1. Average precipitation in Korea (1971–2000)



Source: Korea meteorological administration, 2001.

2. Utilisation of national land area

Decrease in cultivated land has begun with a rapid growth of industry since the 1970s. The main cause was the vacancy of the rural community through very poor social infrastructure, diversion of cultivated land for other uses accompanied by industrial growth, and deepened differences in living levels caused by unbalanced growth between rural areas and urban areas. Recent trends of change in cultivated land area were shown in Table 1. Total land of the whole country was increased by land reclamation, land reformation for drainage, etc., but cultivated land decreased by about 11,550 ha per one year from 2,108,812 ha in 1990 to 1,935,634 ha in 2004. The ratio of paddy fields to the total cultivated land showed little change from 63.7% in 1990 to 57.6% in 2004. The land use for other purposes increased greatly from 13.5% to 17.3%, whereas the forested area was a little reduced from 65.3% of the total area to 64.2%. The Area of paddy field irrigated by facilities was about 77% (881,228 ha) of total cultivated land area. So, the area of non-irrigated paddy field covering about 23% (264,854 ha) should be inevitably irrigated by using pumping instruments and trapped water. If enough water is not supplied into these paddy fields, rice production will be decreased severely by poor growth.

3. WRC (Water Retaining Capacity) of agricultural land when torrential rains occur

As mentioned earlier, the reduction of cultivated land means a decline not only in agricultural production, but also in multi-functionalities of agriculture including preventing flood, fostering water resources, preventing soil erosion and landslide, soil purification, etc. Flood control through paddy fields in Korea is one of the important multi-functionalities and it is thought as an important function linked to the water retaining capacity (WRC) mentioned as an indicator expressing a potential of agricultural activity in OECD. Therefore, it is very important to study on WRC in arable lands beneficial to the prevention of damages due to heavy rains during summer season in Korea, having paddy rice as the predominant crop.

Table 1. Change in land use (area: ha)

Year	Total	Cultivated land		Forest (%)	Others (%)
		Paddy field (%)	*Upland (%)*		
1990	9,927,369	1,345,280(13.5)	763,532(7.7)	6,476,030(65.3)	1,342,527(13.5)
1995	9,926,838	1,205,867(12.1)	779,390(7.9)	6,451,885(64.9)	1,489,696(15.1)
2000	9,946,074	1,149,041(11.6)	739,724(7.4)	6,422,128(64.6)	1,635,181(16.4)
2004	9,961,738	1,114,950(11.2)	720,684(7.2)	6,400,301(64.2)	1,725,803(17.3)

Source: Ministry of Government Administration and Home, Ministry of Agriculture and Forestry, Forestry Administration, 2005.

Water in soil was separated into water (Wi) coming into underground soil from rain or irrigation and water (Wo) above the soil surface. The Wi and Wo of paddy fields and non-paddy fields such as upland, grassland, and orchard were calculated by using two different methods. One was a 'water balance' method and the other a 'water rechargeable pore space' method. The results are shown in Table 2 (Jung et al. 2002). Rice paddy fields had much smaller WRC in the soil than above the soil surface under flooding conditions during the months from June through September, when torrential rains occur. But the WRC in non-paddy fields was larger in-soil than above the soil surface.

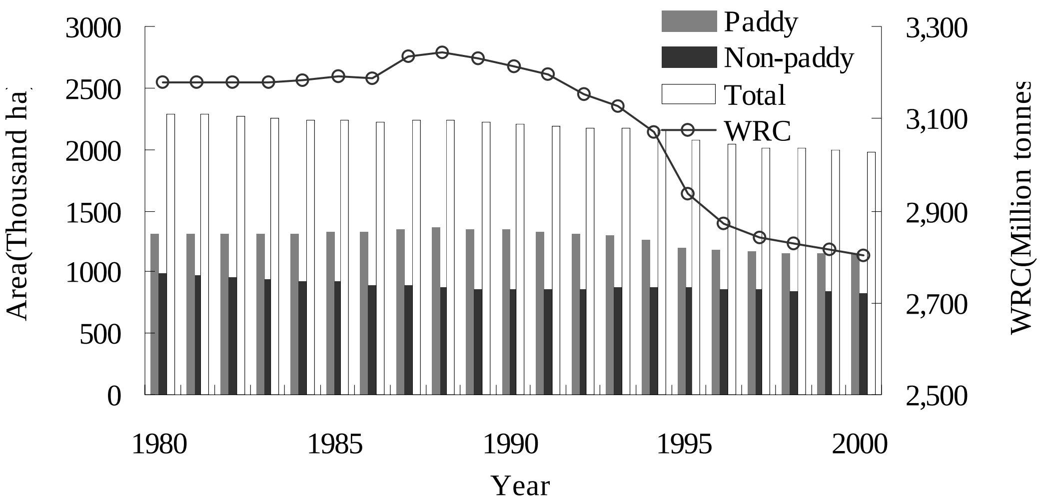
Arable land area, as mentioned earlier has decreased as a result of the expanded market opening for agricultural products, and the growth of the other industries except for agricultural sector. Thus, the reduction of cultivated land has influenced the WRC of agricultural land as in Figure 2, which shows the change in WRCs of agricultural land with a change in arable land area. WRC reached the peak in the latter half of 1980s, and it has been decreased since then. It implies that the potential risk of flooding increases with the reduction in WRC. Actually, damage by storms and floods at a similar precipitation level were observed to be greater since the early 1990s, with paddy land diminishing.

Table 2. The WRC by land use type in 2000
(million tons)

Land use	Wi	Wo	WRC (Wi+Wo)
Paddy field	-	2,378.4	2,378.4
Upland	353.4	214.9	568.3
Grassland	60.1	110.0	170.1
Orchard	123.5	113.2	236.8
Total	**537.0**	**2,816.5**	**3,353.5**

Sources: ASI, 1986 and 1991; NIAST, 2000 and 2002; MAF, 2002.

Figure 2. Changes in the WRCs of agricultural land with change in arable land area

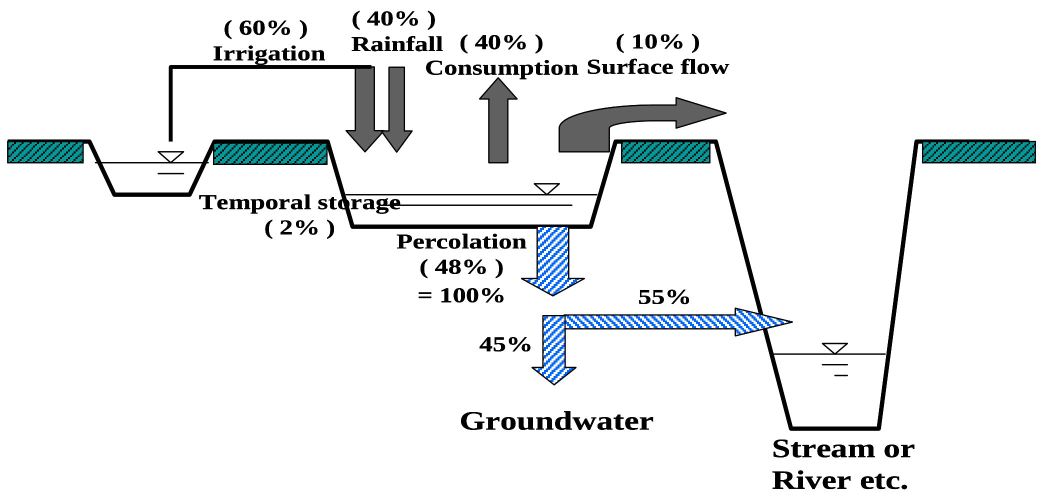


4. Water balance in paddy field

The water use indicator in the OECD report, *Environmental Indicators for Agriculture, Volume 3* did not describe fully all of the actual status of water drainage & efflux in agricultural land, especially in paddy fields. In particular, the indicator did not represent fundamental characteristics of water use in paddy fields in Korea, which belongs to the monsoon climate zone. The paddy field has a large water holding capacity. Water coming from intensive rainfall in summer can be captured by the paddy field and then be stored through a drainage into streams or underground water reservoirs. In addition, the water derived from intensive rainfall in summer in Korea amounts to approximately 2/3 of the total amount of the annual precipitation. Thus, considering the contribution of paddy fields to water holding capacity, agricultural water use characteristics of an area or a country should be reflected in order to create an indicator for genuine agricultural water use, because it has a different agricultural water use system even in countries having only non-paddy land. Water supplied into paddy fields by precipitation or irrigation can be used again, both by forming ground water through drainage of holding water by infiltration and/or by the efflux of a considerable amount of surface water to rivers or reservoirs. That is, about half of agricultural water supplied into paddy fields can be used again as household water, industrial water, or in-stream water. Therefore, it is more reasonable to consider characteristics of a water resource and its behavior in a given area including precipitation, irrigation & return flow, farming systems, etc. when we develop an environmental indicator for agricultural water use.

Oh et al. (1998) reported that runoff water in paddy fields was 10%, infiltrated water was 48%, and water consumed by evaporation was 40%, respectively (Figure 3). Eom et al (2000) reported that 55% of infiltration water flowed into rivers again by drainage and 45% was stored as ground water. If we calculate the amount of water stored in paddy fields or to be able to be reused at this rate, this will be equal to 1.5 times the amount of water to be kept in *Soyang* Dam, which can store 1.9 billion ton year^{-1}.

Figure 3. Water balance in paddy field



Concept for water resource conservation

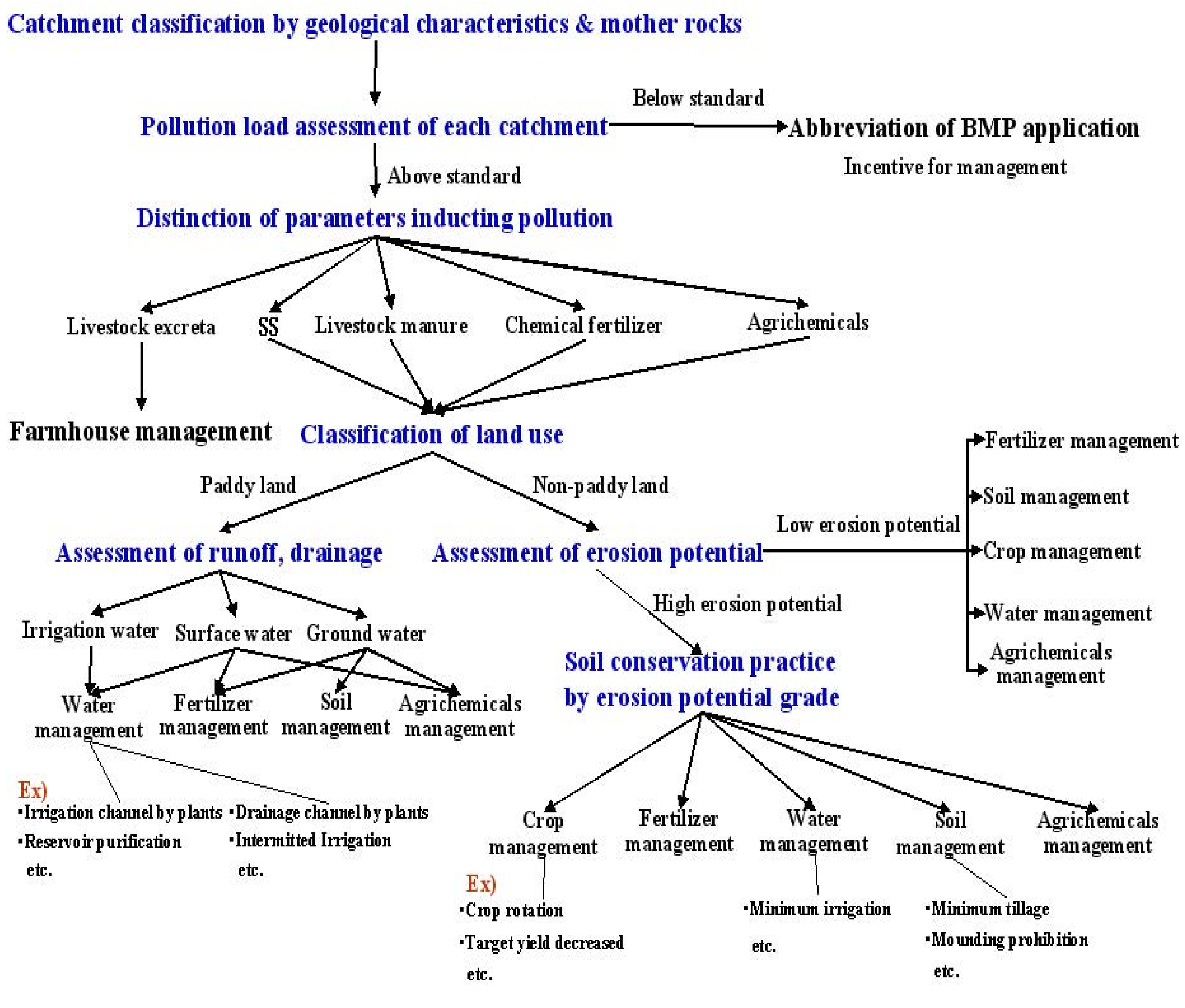
Water management for maintaining sustainability of water resources becomes more and more important as water consumption by agriculture is seriously recognised due to the shortage of water of a quality and a discrepancy between demand and supply and the environmental impacts of agriculture. Of course, some people these days have no concern about water quality, and don't know how much water we need. But, many countries are really facing serious water pollution, a decrease of water resources and growing competition for water use between countries. These situations might cause an unstable water supply, so that most countries are required to develop effective water management technologies for the stable supply of water and sustainable water use. At first, we should think what water conservation is and what 5W 1H for water conservation means. The shortest way is to know who, when, where, what, how, and why. So, the Korean Government is carrying out various works in many sectors for water conservation. Especially, these works in the agricultural field are to complete a system through which farmer can easily get information for a farmer's field on the internet, improving water quality by soil erosion prevention practices and BMP application, and water management handbooks for upland crops and crops cultivated in greenhouses, etc. BMP, which is one of these, is a practice or combination of practices that is determined by a state (or by an area-wide planning agency) — after problem assessment, examination of alternative practices and appropriate public participation — to be the most effectively practicable (including technological, economic, and institutional considerations) means of preventing, or reducing, the amount of pollution generated by non-point sources to a level compatible with water quality goals (Baily and Waddell, 1979). If each country or researcher thinks water quantity for appropriate distribution of water resources besides these meanings, a new BMP concept for water resource sustainability, considering water demand and supply, use and production or storage suitable for each country, will be made and added to the old concept on BMP focused on water quality.

Strategies for water resource conservation in Korea

1. Procedure of BMP for protecting from water pollution

The procedure for water conservation reflecting BMP for non-point pollution control can be variously described by each researcher and be expressed with policies discussed in the OECD. Also, it will be different from the situation faced by country. In Korea, various works improving water quality were attempted but the cost efficiency in the aspect of economics was not so big. It was caused by a simple input of money, time and labor without the right application of solutions to address pollution, so that a new approach for water conservation was needed different from the preexistent solution. Figure 4 is the new strategy for water conservation in Korea.

Figure 4. Procedure for water conservation reflecting water quality in Korea



2. Strategy for water production or storage in Korea

Water present in soil or above the soil surface, and in streams or rivers, comes basically from rainfall and snowfall. The formation of groundwater is also made via water flow into the soil from precipitation. Thus, soil acts as an important media for water cycling. Therefore, water in soil or above the soil surface is a very important element to be considered for sustainable water use and water conservation. If anyone or any country can develop techniques to store water in soil or above the soil surface of lands, countries that have experienced disasters or damage caused by floods or heavy rains would be free from these concerns. Korea is a happy country in that aspect, because dykes shutting in water exist in paddy rice fields. That is, paddy fields, having dykes as mentioned earlier, act as a kind of water storage facility and are the best important resource for water storage. Table 3 showed the different height of dykes and the submergence level in paddy fields formed in an area having topographically different landforms. The dykes were highest on the plain. Also, water retaining capacity of paddy fields was estimated at 23.8 billion tons for the whole paddy area of 1146 thousand ha. The amount of water storage was equal to 47.6 times of water to be kept in Youngweol Dam that can store 0.5 billion ton·year^{-1}and was constructed at an expense of one billion dollars. To maintain the shape of paddy fields can finally produce an effect equivalent to 47 units of Youngweol Dam, and so the economic value of paddy fields was estimated at 47 billion dollars, as expressed in the expense to construct 47 units of this dam.

In conclusion, it might be one of the best strategy for sustainable water use to maintain the dykes and shapes of paddy fields by preventing destruction or encroachment on farmlands caused by the construction of roads, houses and industrial complexes and not having a water storage function any more.

Table 3. Bank height and water logged level in paddy land according to geographical condition
(unit: mm)

	Valley land	Hillside land	Plain land
Dyke height	252	198	271
Water Level	45	41	45
Ratio of Area	0.46	0.11	0.42

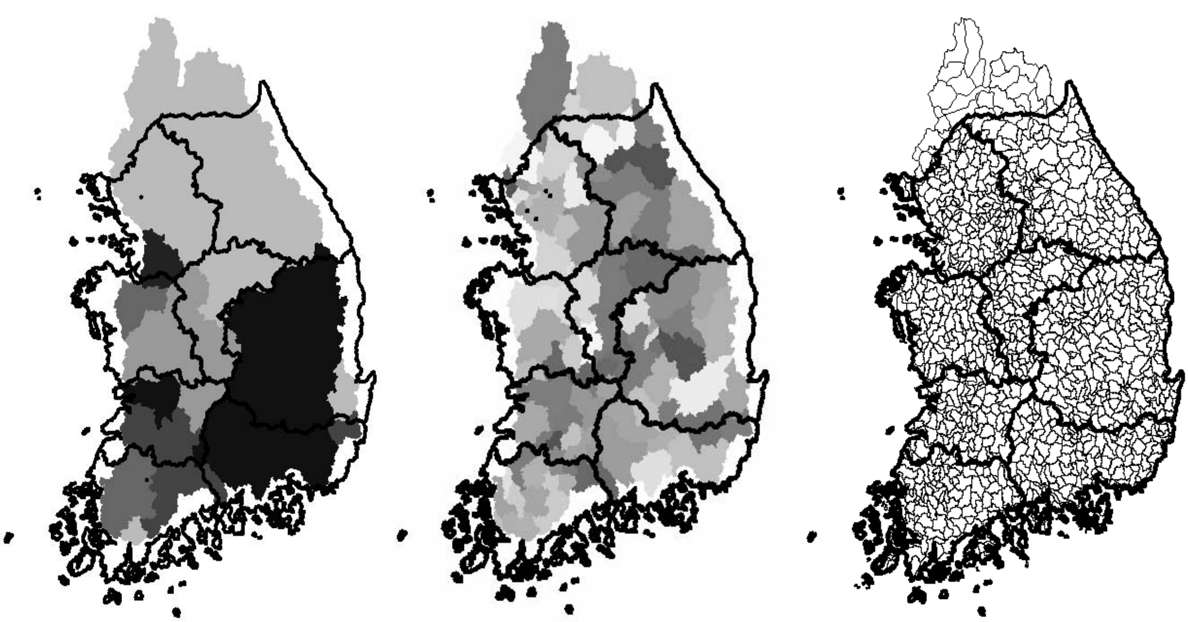
Source: NIAST, 2000.

The case study for water conservation considering water quality

1. Watershed classification by geological characteristics and mother rocks

The geological and topological characteristics of land in Korea are very complex, because the land consists of approximately 64% mountainous terrain. Because of the complexity, it is not easy to study water quality and quantity for sustainable use. The classification of agricultural fields into watersheds in an area surrounded with mountains is easier than in a plain area with a variety of irrigation sources such as rivers, streams, and reservoirs even in the same area. But we need to consider a factor such as mother rocks as a general standard for classification for an extended application from the area of a case study to another site. Figure 5 is a watershed map showing results classified by characteristics of topography and mother rocks. Digital maps used for this classification were a 25,000 index map and a standard watershed map and river map, a super-detailed soil map, and a topographic map. Using altitude and characteristics of mother rocks with granite, porphyry, shale, sandstone, conglomerate, etc, the analysis of similarity with geological characteristics was made.

Figure 5. Watershed map classified based on topographical characteristics and mother materials

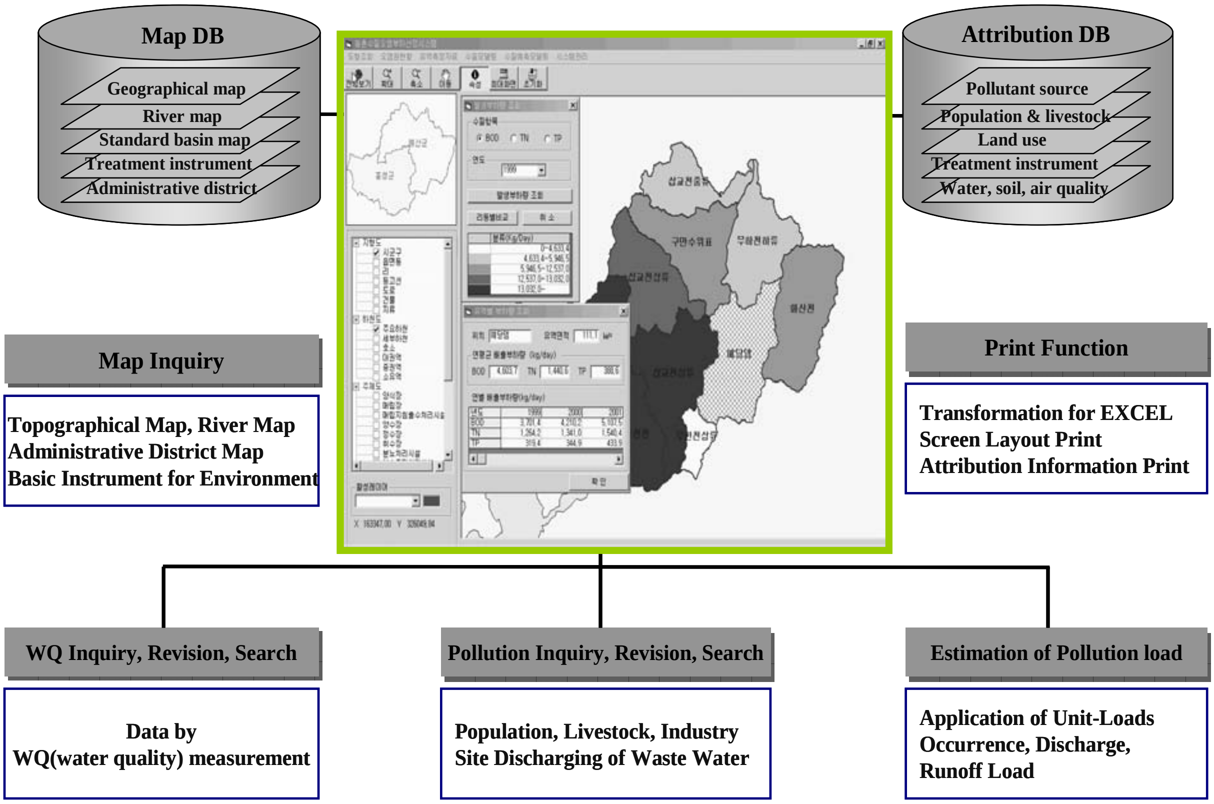


(a) Large-sized watershed (b) Middle-sized watershed (c) Small-sized watershed

2. Pollution load assessment by a watershed

Pollution from agriculture is the result of inflow of pollutants from livestock waste and living sewage of the rural community, etc. into soil or a water body in an agricultural area. Point sources can be identified and managed by law and education, etc., but the management and control of non-point sources isn't easier than that of point sources. Non-point source pollutants transported into water by rainfall is a significant contributor to water quality degradation in surface water. Two methods for monitoring and modeling can be used to assess the pollutant loads. Monitoring is a direct method to evaluate the pollution in a given site with time, but the cost is expensive and a lot of time is consumed. The evaluation model for watershed is less accurate than the direct evaluation by monitoring of pollutants at given sites, but this model can predict the status of pollution in the future and can help us better understand the relationship between water quality and farming. Figure 6 shows one system for pollution load assessment. This system was produced by watershed drawing using a digital standard watershed map, a land use map with a high resolution image, a topographic map, a river map and an administration district map. DB construction for non-point pollutants from land use and point pollutants from living, livestock, industry, etc., was completed and then the estimation of pollution loads was made with works for inquiry, revision, search and print function still remained.

Figure 6. Process and concept for pollution load assessment



3. Crop land unit mapping by classification of land use

In this pollution load assessment system, we could not classify each field into different types of land use because of the limit of programme size and image resolution. But when one watershed has a pollution problem, different management practices should be applied to each field for improving water quality in the watershed. Therefore, we tried to classify land use through on-screen digitisation using high resolution aerial images, a DEM (Digital Elevation Model) and a super-detailed soil map (1:5,000). Figure 7 shows the result. Here, each field boundary was delineated on the basis of farmland unit. This classification could be very helpful for a further study on soil erosion in each field. In research on soil erosion in Korea, having small farm fields, very complex topography and steep slope farmland at high altitude, it is not easy to get good results without classification of each field. This will be a first step for the application of site-specific BMP for the protection of the environment from non-point source pollution.

Figure 7. Classification of each farmland using high resolution aerial image

4. Assessment of soil erosion potential and BMP application

BMP is one of a number of methodological and structural practices designed to prevent or reduce water pollution and soil loss caused by runoff. The BMP in farmland deals specifically with non-point source pollutants, such as minerals, and chemicals such as pesticides. Implicit within the BMP concept is a voluntary, site-specific approach to addressing water quality problems. The site-specific approach based on this concept will provide a better management system for farm resources, especially loss of nutrients and soil particles in each field for protecting from water pollution. BMP includes information, technologies and practices based on a management system now possible owing to several technologies currently available for farming. BMP tools could be differently expressed depending on policies, GIS, GPS, pollution monitoring, soil-plant-weather characteristics, and various technologies for application of inputs. Many of these tools are already standard practices, known to be both environmentally and economically sustainable. The goal of BMP is to protect water resources from non-point pollution while maintaining the economic viability of Korean agriculture and related industries. The following figures (Figures 8 and 9) show examples of BMP for soil conservation in each field and potential grade of soil erosion in paddy fields and non-paddy fields in a watershed. The size of this site was about 4,700 ha and the mother rock of the soil was composed of 68% granite gneiss, 26% granite and 6% other. The land use in this area was 68% for forest, 11% for paddy rice farming, 12% for upland farming and 9% for other uses including villages, rivers, reservoirs, etc. Maps for soil erosion and BMP were made by using data on steepness and slope length determined by geographical maps, soil erodability (K factor) by a super-detailed soil map (1:5,000), and land cover and practice factors by image data, respectively. This result could be connected to policies such as direct payment, and it could be also used as a standard of financial support to achieve environmental goals.

Figure 8. Soil erosion potential grade in paddy and non-paddy land in a watershed

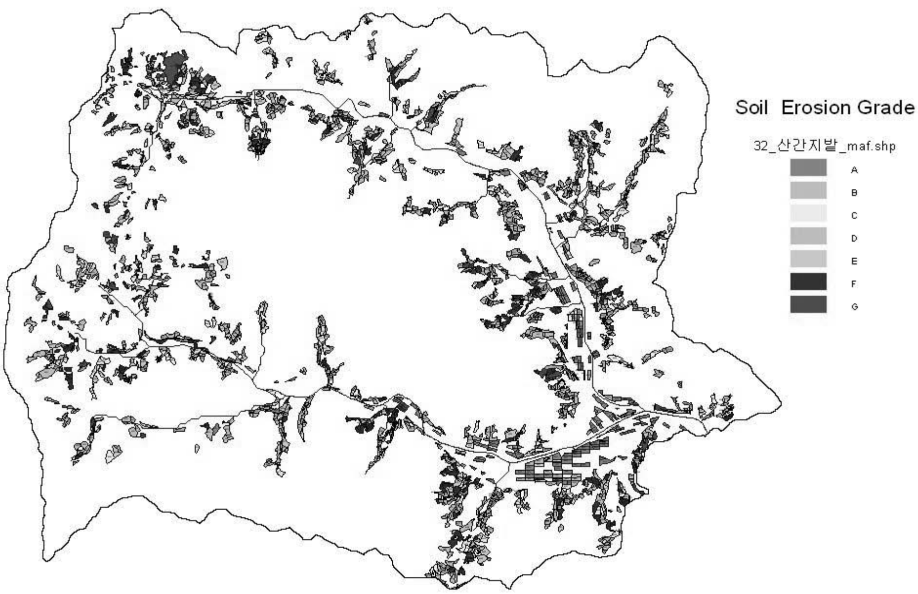
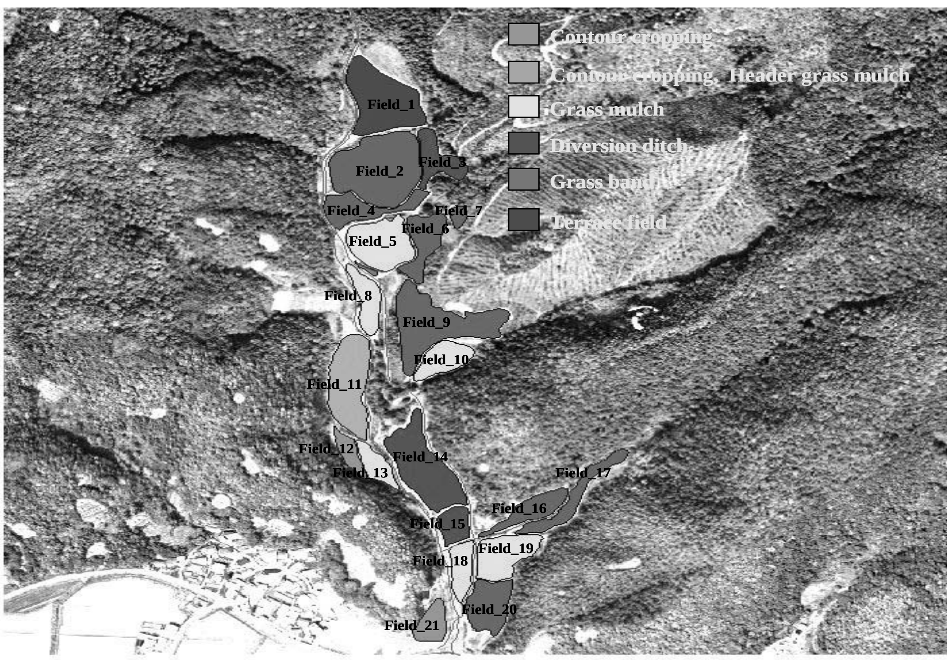


Figure 9. BMP for soil conservation management in each field



Conclusion

Water and soil management for more sustainable use of water resources should be considered in two aspects, water quality and quantity, because both farmers and consumers are concerned about environmental impacts derived from water consumption by agriculture. Therefore, it will be very important to protect water resources from pollution for the supply of water of high quality, or to go in the right direction for sustainable water use. As for water quantity, policies should be drafted to raise the WRC of agricultural land in order to reduce a potential risk of flooding. For example, it needs to encourage farmers to maintain the shape of the paddy field, even though the field is idle without cropping. A national project to promote the construction of basic facilities for conservation practices that can reduce soil erosion and run-off will be also available. One of the best strategies for sustainable use of water could be to maintain the dykes and shapes of paddy fields without the destruction of arable land for the construction of facilities not having water storage capacity, such as roads, houses and industrial complexes. As for water quality, a new approach and concept considering land use, including paddy fields which cover 61% of total arable land, is required to improve water quality by protecting water resources from pollution by farming. Conclusively, we think that the first step needed in order to minimise water pollution and to acquire water resources for sustainable use is to compartmentalise the watershed based on the topographical characteristics of land and species of mother rocks. The second is to assess pollution load from agriculture within the watershed; the third is to identify pollution source; the fourth is to categorise land use patterns into non-paddy and paddy, etc.; the fifth is to assess runoff, drainage in paddy land and soil erosion potential in non-paddy land; and the sixth is to determine soil conservation practices depending on the soil erosion grade in each field of non-paddy land. The last step is to apply appropriate management practices for water, soil, crop, fertilisers and agro-chemicals in each field.

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Part IV.

Institutions and Policies for Agricultural Water Governance

Chapter 20.

Institutional Overview from an Australian Perspective – With Particular Reference to the Murray-Darling Basin

Wendy Craik[1]

Water is especially precious in Australia, the world's driest inhabited continent. When negotiating the Australian Constitution, the states chose to secure the sovereign right 'for reasonable use of the waters of rivers for conservation or irrigation'. Each state developed its own arrangements for sharing of the waters within its jurisdiction, and then became aware of the interdependencies for shared river systems like the Murray-Darling, which spans six jurisdictions.

The Murray-Darling Basin Commission exists to facilitate and promote effective planning and management for the equitable, efficient, and sustainable use of the water, land, and other environmental resources.

In the past, the sovereign governments have chosen to progress through the commission the sharing of waters (including the implementation of the cap on diversions), salinity management, and the introduction of interstate water trade.

Current priorities (in the context of the National Water Initiative and policies within jurisdictions) include active management of water and works to achieve environmental outcomes at internationally significant sites along the River Murray, and development of policy to address emerging issues such as climate change and groundwater diversion.

In the future, the commission will continue to support the jurisdictions as they contemplate evolution of water sharing arrangements, and the development of more sophisticated integrated environmental management approaches, towards a more sustainable basin.

Introduction

Water is a scarce resource in Australia, the world's driest inhabited continent. Approximately one third of Australia is classed as arid, with an average annual rainfall of less than 250 mm, and another third as semi-arid, receiving between 250–500 mm annual rainfall. Rainfall distribution is highly variable and part of Australia is usually in drought.

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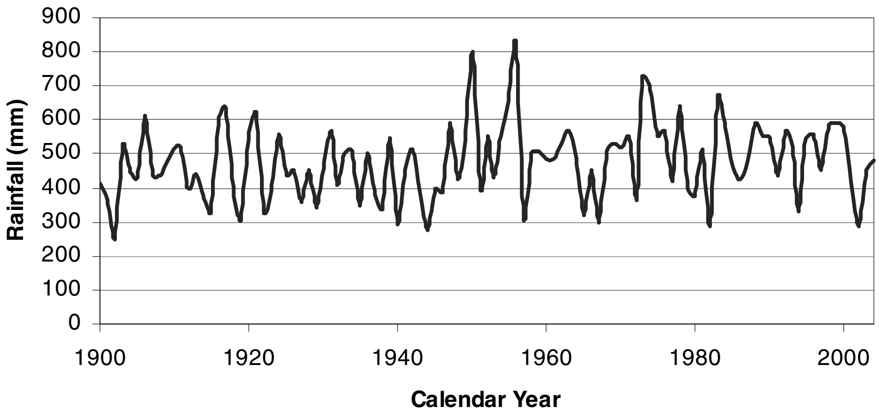
Figure 1. The Murray-Darling Basin

The Murray-Darling Basin (Figure 1) is a major catchment of 1.06 million square kilometres in south-eastern Australia, covering almost 15 per cent of the continent.

The climate of the basin is varied, with cool humid eastern uplands, temperate in the southeast Mallee, inland subtropical northern areas and hot, dry arid and semi-arid country in the far west. Temperature, precipitation (Figure 2) and evaporation are highly variable, impacting on the water resources in the basin.

The Murray-Darling Basin contains two major river systems by world standards: The Murray River is 2,530 kms in length, and the Darling River 2,740 kms. Despite their length, their river flows are globally small and extremely variable (Table 1). As a result, Australian dams are about six times larger than those of Europe for the same mean annual streamflow.

Figure 2. Rainfall in the Murray-Darling Basin



Source: Bureau of Meteorology, 2005.

Table 1. Ratio between the maximum and minimum annual flows from select rivers

Country	River	Maximum to minimum annual flows
Brazil	Amazon	1.3
Switzerland	Rhine	1.9
China	Yangtze	2.0
Sudan	White Nile	2.4
USA	Potomac	3.9
South Africa	Orange	16.9
Australia	*Murray*	15.5
Australia	Hunter	54.3
Australia	*Darling*	4 705.2

Annual runoff in the basin is about 24,000 GL/yr. Under natural conditions, about 11,000 GL /yr is consumed by wetlands and /or floodplains and about 13,000 GL/yr flows to the sea. The Murray River forms part of the New South Wales and Victorian state border and the Darling River forms part of the New South Wales and Queensland border.

This paper profiles the Murray-Darling Basin and the management of natural resources through the Murray-Darling Basin Commission. The Commission is an example of inter-jurisdictional management of rivers and catchments — a consequence of federation and state boundaries.

The Murray-Darling Basin

The Murray-Darling Basin is important economically, socially and environmentally to Australia. The basin is home to over two million people and a further million in Adelaide rely on Murray River water. Historically, the Murray River was an important navigation route and more recently, it has become the critical water supply for the basin's agriculture and communities, including capital cities, Adelaide and Canberra. Currently, the Murray-Darling Basin produces about 40 per cent of Australia's gross value of agricultural production and over 70 per cent of irrigated agricultural production. Agricultural processing and manufacturing, mining and tourism are also significant. Environmentally, there are 16 internationally important RAMSAR sites, important breeding grounds for migratory birds and at least 35 endangered birds and 16 endangered mammals in the basin.

Institutional arrangements

The development/construction phase

At the turn of the 20th century, there was significant pressure on the Murray River because of the then severe drought and agricultural expansion. The self-governing colonies in the basin were unable to reach agreement on water management, specifically for navigation and irrigation. There was a realisation that there was a need for coordinated management of navigation along the Murray River and to ensure adequate water supplies to users in New South Wales, Victoria and South Australia. At a conference in Corowa in 1902, both the Commonwealth and state governments were called on to 'cooperate in preparing and carrying out a comprehensive scheme for the utilisation of the waters of the River Murray' which would cater for both navigational and potential consumptive uses. The Australian Constitution, which was adopted in 1901, provides the framework which defines responsibilities of the Commonwealth and the states with respect to water, in sections 51, 98 and 100. Although land and water management is primarily a state responsibility, the Commonwealth powers over trade, commerce (S51), and also over navigation (S98) are limited by Section 100, which states:

> *The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a* State *or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation.*

The Corowa conference lead to the appointment of an Interstate Royal commission on the River Murray and eventually in 1914, the River Murray Waters Agreement was signed by New South Wales, Victoria, South Australia and the Commonwealth. It aimed to achieve the following:

1. Set out a series of 'joint' structures — storages, locks and weirs, to be built by a constructing authority nominated by the state in which the work was located;
2. The principle of sharing capital works equally between the parties; and
3. Sharing ongoing operation and maintenance costs between the states.

Water sharing principles were initially established under the River Murray Waters Agreement. The principles take into account the variable flow, the storage capacity and demand on the River Murray:

- Upper states equally share flow at Albury;
- Upper states retain rights to develop downstream tributaries;
- South Australia ensured a nominated set of monthly and annual flows (effectively the first commitment on available water resources);
- Continuous water accounts maintained, upper states have flexibility in annual use subject to priority of commitment to South Australia.

These water sharing principles are still fundamental to the way the waters of the River Murray and tributaries are shared.

The construction phase

From 1914 to the 1970s the focus on increasing water diversions for irrigation resulted in the building of structures to regulate the Murray River.

Hume Dam (now 3,038 GL), completed in 1936, was the second largest dam in the world at the time. The barrages between the lower lakes and the mouth of the Murray were completed in the 1940s to reduce salt water intrusion, stabilise the river level, concentrate releases in times of low flow and maintain a pool of water; and Dartmouth Dam (3,906GL) was completed in 1979 — the last major storage to be built (Figure 3). These storages meant that the Murray-Darling Basin can now store one and a half times its average annual flow.

By 1980, the Murray River was a highly regulated river with almost $2 billion of infrastructure and a complex series of rules for its operation to serve both the extensive irrigation development in each state and provide water for communities. However, questions about the health of the basin were starting to be raised at this time.

Integrated catchment management phase

By the late 1970s there was a growing awareness of water quality problems, especially with salinity, which resulted in the jurisdictions agreeing to adopt a more ‘whole of basin’ approach. In 1992 the River Murray Agreement was re-negotiated and extended to become the Murray-Darling Basin Agreement, with Queensland joining and the ACT participating through a Memorandum of Understanding. This provides the process and substance for integrated management of the Murray-Darling Basin. Each signatory jurisdiction to the agreement has passed its own complementary legislation.

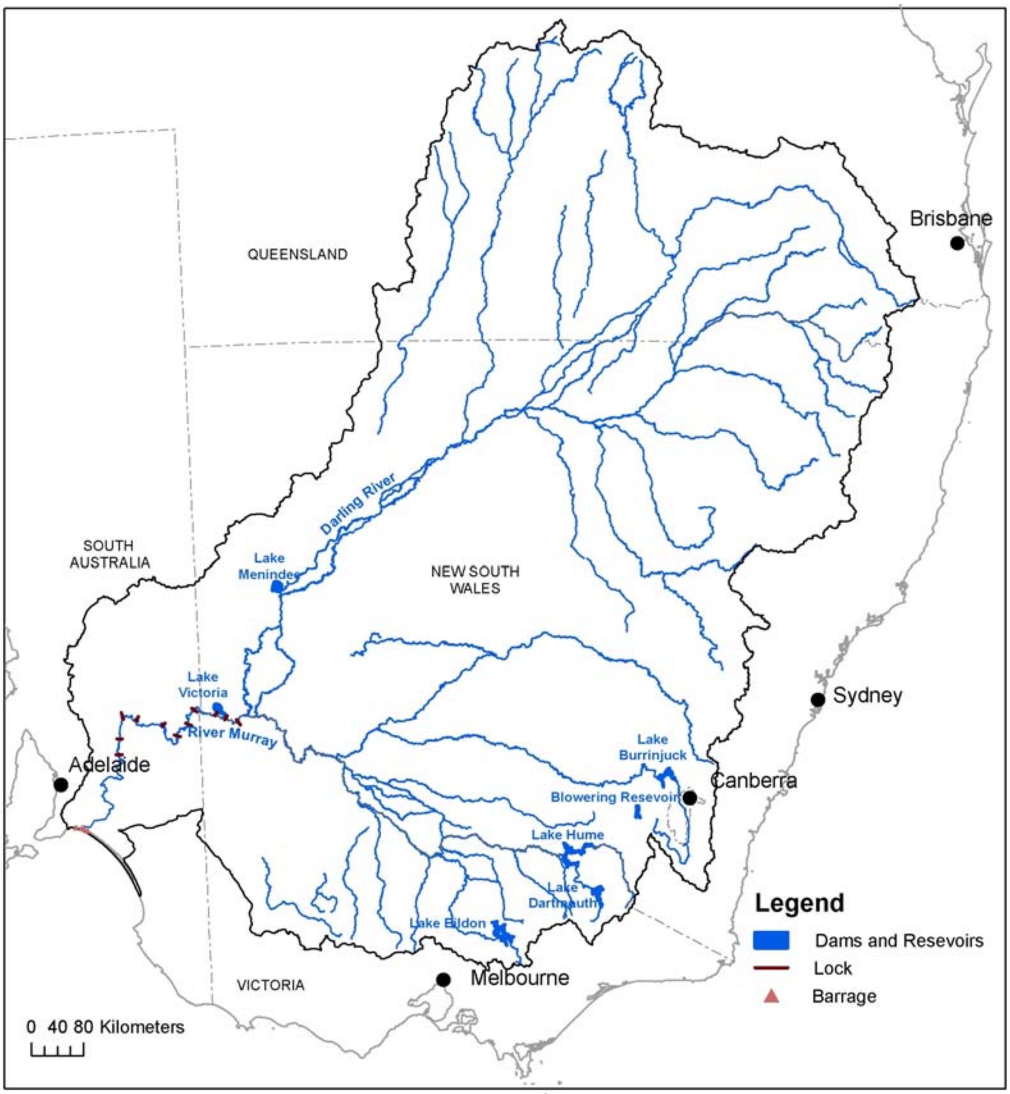
Legislative arrangements

The Murray-Darling Basin Agreement

The Murray-Darling Basin Agreement sets out the objectives, functions and composition of the new arrangements and the procedures to be followed for natural resource management, water distribution, asset management and financial contributions and disbursements. The Murray-Darling Basin Commission does not displace or replace its partner governments; it is simply a mechanism by which some of its shared business is undertaken.

Each participating jurisdiction retains its identity as a partner to the Murray-Darling Basin Agreement. Jurisdictions aim to work together to sustain water management assets and diversions and to achieve a healthy working river and managed shared resources. Each of the governments contributes an amount based on cost-sharing formulae specific to construction, operation and natural resource management in the basin.

Figure 3. Location of major dams and water infrastructure in the Murray-Darling Basin



Institutional arrangements

The MDBC is not a statutory authority, it is not subject to corporations law, nor is it a traditional government department. It is a unique unincorporated joint venture which requires unanimous agreement for significant decisions and which actively supports a government-community partnership for implementing effective natural resources planning and management in the basin. Its charter is to

Promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources.

The structure

The current framework is based on the philosophy of integrated catchment management not solely river management. The Murray-Darling Basin Agreement established a Ministerial Council and Commission, and a Community Advisory Committee to report to the Council (Figure 4). The Ministerial Council is the primary body responsible for providing policy and direction to implement the Murray-Darling Basin Initiative. It consists of ministers holding land, water and environment portfolios in each contracting government. Their main functions are to consider and determine major policy issues concerning the use of the basin's land, water and other environmental resources, and to develop, consider and authorise (as appropriate) measures to achieve the purpose of the Murray-Darling Basin Agreement. The Community Advisory Committee provides the Ministerial Council with advice and provides a two-way communication channel between the Council and the community and consists of a chair, catchment and special interest representatives. The Murray-Darling Basin Commission includes an independent president and commissioners/ deputy commissioners representing each contracting government (senior executives from land, water and environment agencies). The council, commissioners and Community Advisory Committee are also supported through the commission office which contains technical and support staff. There is a comprehensive network of supporting committees, which support and address particular issues, through jurisdictional representatives.

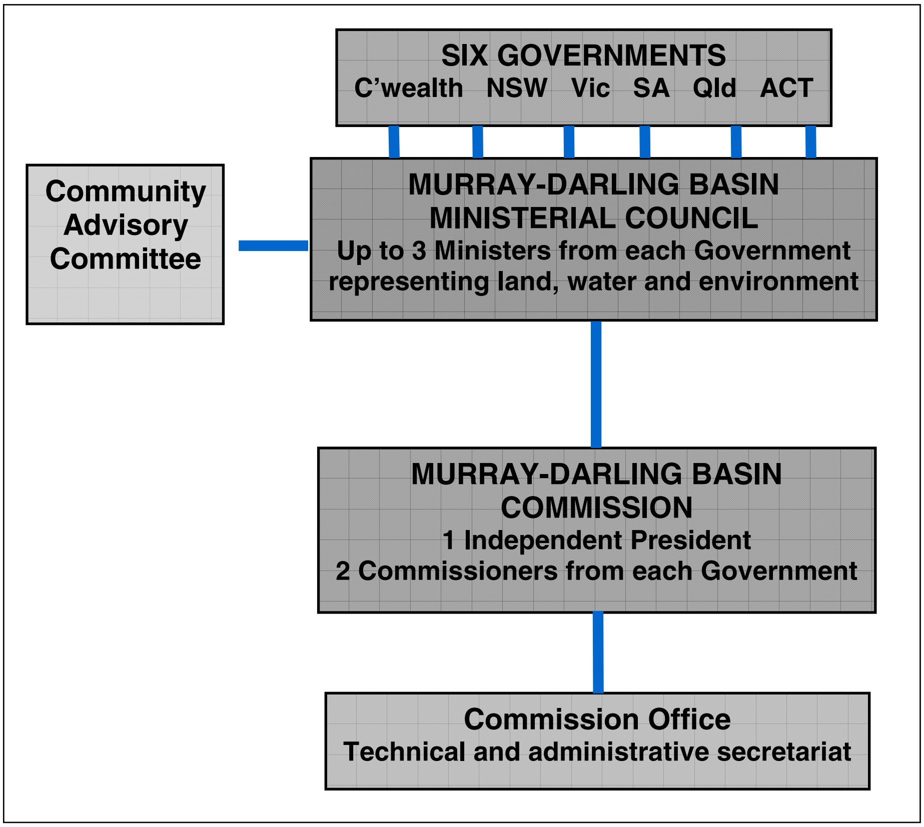
The Murray-Darling Basin Agreement requires unanimous decisions. This can be both time-consuming and challenging.

Applying this structure

Given the inter-jurisdictional nature of the issues to be resolved and the significant impacts of these, the structure of the Murray-Darling Basin Commission works well. It has survived in various forms for over 90 years, which suggests that it provides the appropriate framework for canvassing issues.

A structure loosely modelled on the Murray-Darling Basin Commission has been established by the Mekong River Commission, whose four member countries, Cambodia, Lao PDR, Thailand and Viet Nam, came together in 1995. It maintains dialogue with the two upper states of China and Myanmar. It has a structure of a Council, Joint Committee (JC) and Secretariat. The Mekong River Commission member countries agree to co-operate in all fields of sustainable development, utilisation, management and conservation of the water and related resources of the Mekong River Basin, such as navigation, flood control, fisheries, agriculture, hydropower and environmental protection.

Figure 4. Entities under the Murray-Darling Basin Agreement



History of Basin initiatives

As development of infrastructure and diversions led to increasing river regulators an increase in salinity and an observed decline in general river health. This resulted in governments and communities developing and implementing a number of strategies: the Salinity and Drainage Strategy, the cap and the Living Murray. The strategies challenge jurisdictions to meet the objectives and participate in the whole of catchment management. Progress by jurisdictions in implementing these strategies is independently audited.

Salinity and drainage strategy

The Murray-Darling Basin Agreement of 1992 recognised the importance of managing the basin as a whole. The 1988 Basin Salinity and Drainage Strategy, which was agreed when discussions towards the new Murray-Darling Basin Agreement were progressing, was implemented to minimise land degradation arising from irrigation-induced salinity and waterlogging and maximise net benefits to the basin subject to the overall objectives of the council. It provided a framework for joint action by New South Wales, Victoria, South Australia and the Commonwealth, which required a coordinated effort of monitoring government and community cooperation. It was a very significant breakthrough in the management of natural resources in Australia that brought the states together in to jointly tackle a major environmental problem. This paved the way for future strategies requiring inter-jurisdictional cooperation and in 2001 this strategy was integrated into the 15-year Basin Salinity Management Strategy. The strategy guides communities and governments in working together to control salinity in the basin and to protect key natural resource values within their catchments. It reflects the responsibility for action between valley communities and states, by targeting river salinity of each major tributary valley in the Murray-Darling Basin. Progress of jurisdictions in implementing their responsibilities with the salinity strategy is independently audited each year.

The cap

In 1995, recognising the importance of a more holistic approach to basin management, the Murray-Darling Basin Ministerial Council commissioned an audit of water use in the basin, which confirmed the increasing levels of diversions and the consequent decline in river health. The Audit found that by 1994, 11,000 GL per year was being diverted from the Murray River, out of a possible 24,000 GL per year. A cap was introduced to limit further water diversions based on the 1993–94 levels of development.

The cap has not limited development; rather it has encouraged the more efficient use of water. It has also provided a framework to support the establishment of a water trading scheme. The cap serves the dual purpose of preventing further erosion of water access reliability for existing water users and protects river systems from further reductions in flow. The cap is independently audited each year with reports to both to the Ministerial Council and the public.

The Living Murray

In response to the substantial evidence that the health of the River Murray System was declining, the Murray-Darling Basin Ministerial Council established the Living Murray Initiative. Concerns had been expressed about algal blooms, stranding of trees, drowning of trees, salinity and the possible closure of the Murray mouth.

In 2002–03, significant work was undertaken by the MDBC to investigate the options for contributing to the improvement of the health of the Murray through the provision of additional water for the environment. The work included scientific, economic and social analysis together with community consultation.

An agreement was reached in late 2003 by the Ministerial Council, and ratified by the first ministers of the Council of Australian Governments in June 2004. The agreement involves investing $500 million over five years commencing in 2004–05, to reduce the level of water over-allocation by recovering 500 GL of water. This water will be directed to achieve specific environmental outcomes at six significant ecological sites: Barmah-Millewa Forest, Gunbower, Koondrook-Perricoota Forests, Hattah Lakes, Chowilla Floodplain (including Lindsay-Wallpolla), Murray Mouth and Coorong and Lower Lakes and the River Murray Channel. The $500 million was additional to $150 million of funding for environmental works and measures (i.e., infrastructure and strategies to deliver environmental water more effectively). To date, proposals have been received to recover some 240 GL of water at a cost of $179 million. A number of feasibility studies are under way investigating other water recovery projects.

Other initiatives

Since the initial salinity and drainage strategy, additional initiatives have been developed to guide the participating governments towards achieving environmental results. The Native Fish Strategy for the basin aims to restore native fish communities in the basin to 60 per cent of their pre-European levels over 50 years. It provides the framework for community involvement, interstate coordination of management actions and policies, as well as conducting research, monitoring and reporting management activity. The Sustainable Rivers Audit aims to provide consistent, basin-wide information on the health of the basin’s rivers in order to promote sustainable land and water management. The joint monitoring effort, using consistent methods, has started across Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory.

Water reform initiatives

Council of Australian Governments

The Council of Australian Governments (CoAG) is the peak inter-governmental forum in Australia, which is chaired by the Prime Minister, and comprises state premiers, territory chief ministers and the President of the Australian Local Government Association. It first met in 1992. Its role is to initiate, develop and monitor the implementation of policy reforms that are of national significance and which require cooperative action by Australian governments.

In 1994, all state and territory governments agreed that the management and regulation of Australia’s water needed significant changes. An agreement was reached on a package of reforms including water prices, allocations and trading, environmental and water quality, and public education and that these reforms would be included under the umbrella of the National Competition Policy (NCP). With this agreement, the governments formally acknowledged that the Australian rivers, catchments and aquifers do not stop at state boundaries and that development activities can impact upon other states. Under the NCP arrangements the water reforms were assessed regularly.

The key areas of water reform include water pricing based on cost recovery and volume used, establishment of specified water entitlements and arrangements for trade, environmental allocation, the establishment of regulatory and water service institutions and public education and consultation.

In 2003, CoAG noted the continuing national imperative of increasing the productivity and efficiency of Australia's water use to sustain rural and urban communities and the need to ensure the health of river and groundwater systems. This required water reform to mover further towards arrangements that provide greater certainty for investors and the environment. In 2004, CoAG agreed to a National Water Initiative (NWI) to improve water management across Australia.

National Water Initiative

The NWI builds on the 1994 NCP water reform initiative but more clearly articulates targets and limits the coverage of reform. It focuses on establishing securely defined water access entitlements, sustainable water planning, environmental water entitlements, managing risks to water allocations, expanding water trade, improved water accounting, pricing reforms and urban water reforms. The MDBC role is mainly focused on coordinating the overarching reforms in the basin and the CoAG Inter-Governmental Agreement on implementing the Living Murray.

Water trading

With the implementation of the cap, any water to be used for new developments has to be sourced from existing uses. Water markets provide an opportunity for new investment in high value added agriculture despite resource constraints, moving the water to a higher value, more sustainable use. In enhancing water trade on an inter- and intra-state basis, governments recognise that rights to access and use water are valuable assets and that the users of those assets are best placed to decide their most productive use.

Water markets provide the opportunity for new investment in high value added agriculture despite resource constraints. Trade provides the opportunity to make the most of water availability and helps individual irrigators to manage risk. Key requirements for water trade are an agreed transfer mechanisms, a set of trading rules (to account for the varying “denominations” in differing “currencies” of water entitlements, environmental and salinity clearances), managing outlying irrigation areas and having a robust accounting mechanism.

Unofficial water trade has existed in the basin since the 1940s and it was in the early 1990s that legislative change facilitated trade. In 1995, the Murray-Darling Basin Ministerial Council agreed to establish a permanent interstate water trading trial. Arrangements were made under the Murray- Darling Agreement, with a pilot permanent interstate trading scheme beginning in 1997.

Responsibility for the use of water after it has been diverted from the river lies with the relevant jurisdiction. Each jurisdiction has different arrangements of water entitlements, management and distribution. Victoria has statutory water authorities with individual irrigator water rights and licences. New South Wales has irrigator shareholders in private irrigation companies. South Australia has irrigation trusts and irrigator licences with a separate state water plan and regional plans. Queensland has a government-owned water corporation with individual licences converted to individual water allocations. These different access rights, policies and administration can make water accounting and trading a challenge. Risk management options vary between the jurisdictions.

Risks to shared water resources

In 2004, the Murray-Darling Basin Ministerial Council considered six risks, which, if not addressed, could affect the water quantity and quality in the Murray-Darling Basin. The six identified factors are:

- increased groundwater use;
- bushfire impacts;
- climate change;
- reforestation;
- hillside farm dams, and
- reduced return flows from irrigation.

How these potential risks will affect the water in the basin is still largely unknown. In some cases, for example, climate change and bushfires, the capacity to directly reduce the impacts on the basin's surface waters is limited, but building the capacity to adapt is critical. In other cases, the Governments may have the opportunity to identify and implement management strategies to reduce the impacts. The development of policy options based on sound science and complemented by economic and social analysis will help to address these risks to our shared water resources.

Future

The MDBC has recently developed a five-year strategic plan to provide principles to guide the work of the commission, with a vision of working towards a sustainable natural resource with healthy ecosystems, which will support prosperous communities. The three objectives of the new MDBC strategic plan are:

- protection and enhancement of the basin's shared environmental assets and water resources
- efficient and equitable delivery of water for productive and sustainable domestic consumption, environmental benefit and economic use, and
- delivery of high quality advice to Council, and achievement of its endorsed priorities, through strengthened capacity of the commission and the commission office.

For the first time, we are developing an Integrated Basin Report, which will bring together and report on aspects of basin condition to guide future investment.

Key strengths of commission and Council structure

Different aspects of the Commission's activities affect jurisdictions differently and while the Commission and Council structure can result in slow decision making and tension between the ministerial council and individual ministers in taking responsibility for progressive decisions, jurisdictions have persisted with the arrangement for about a century.

Representation from each jurisdiction of water, land and environment ministers means that MDBC decisions are taken in the context of prevailing jurisdictional conditions. The requirement for unanimity in decisions is essential to the functioning of the structure. A network of inter-governmental and technical committees provides advice to the Commission and is essential to its smooth functioning.

The representative nature of the Commission is both a strength and a weakness as it ensures that state interests are considered but there is no requirement that that jurisdiction's primary focus necessarily coincides with the best interests of the basin.

A further strength of the structure is the independent audit approach to evaluate progress on critical issues. Bringing together the audited results of strategies in an integrated basin report should support the notion of basin-wide assessment.

Conclusion

The Murray-Darling Basin Commission has existed for over 90 years to focus on shared resources benefiting from joint action. It achieves its goals through the partner jurisdictions; it does not replace or displace them. It is an adaptive structure that can embrace, and has embraced challenging new initiatives.

In the future, the Commission will continue to support the jurisdictions as they contemplate evolution of water sharing arrangements, and the development of more sophisticated integrated environmental management approaches towards a more sustainable basin.

Chapter 21.

New Zealand’s Sustainable Water Programme of Action

Rebecca Martel[1]

In 2003, New Zealand commenced a Sustainable Water Programme of Action, under the umbrella of the Sustainable Development Programme of Action. New Zealand’s management of freshwater occurs within the framework of the Resource Management Act 1991, which focuses on the sustainable management of natural and physical resources. Gaps in the Act framework, and its implementation, have become apparent as New Zealand’s freshwater resource comes under pressure from competition between uses, users and the differing values New Zealanders hold for freshwater. These gaps are challenges for the Sustainable Water Programme of Action. There is also concern that diffuse agricultural discharges are inadequately addressed and are having negative impacts on lowland streams and rivers. New approaches may be needed to assist the development of water allocation frameworks that address the pressures. Public consultation on ideas for improving water management occurred between December 2004 and March 2005. A focus for the next stage of the Sustainable Water Programme of Action is to assess new tools, approaches and initiatives to better manage water allocation and quality issues.

Introduction

The sustainable development programme of action

In 2003, the New Zealand government launched a Sustainable Development Programme of Action (SDPoA). Sustainable development in New Zealand has economic, environment, social and cultural dimensions. The SDPoA seeks to better provide for New Zealand’s current and future well-being in a range of critical issues — energy, freshwater, cities, and child and youth development. The SDPoA describes the sustainable development direction for New Zealand and outlines initial actions for the government to protect the well-being of New Zealanders and the natural capital of the environment (Department of Prime Minister and Cabinet 2003).

1. Ministry of Agriculture and Forestry, Wellington, New Zealand.

The sustainable water programme of action

Freshwater is a critical issue as New Zealand needs to improve its water management framework so that it can better cope with increasing current and likely future pressures on water. The Sustainable Water Programme of Action (WPoA) was established to deliver on the water component of the SDPoA. The WPoA is co-led by the Ministry for the Environment and the Ministry of Agriculture and Forestry. The WPoA is two years through what is intended to be a three-year programme. This paper describes the problems and issues, and some of the solutions, the WPoA is considering. The WPoA vision is outlined in Figure 1.

The WPoA aims to improve management of:

- water quality — maintaining quality to meet all appropriate needs;
- water allocation — allocating and using water in a sustainable, efficient and equitable way; and
- water bodies — protecting water bodies with nationally significant natural, social or cultural heritage values.

The WPoA recognises that, given the range of peoples' interests in water, the current framework makes it difficult to establish priorities for action. New Zealand's water management framework is highly devolved to local government.[2] Central government is involved in regional and local water issues only in a reactive way. The WPoA is considering whether central government needs to be more actively involved in addressing priority issues.

The New Zealand water resource

While New Zealand has abundant rainfall, it is not evenly spread geographically or seasonally. In some regions of New Zealand demand for water cannot be met at certain times of the year. Additionally, there is significant variation between rainfall in different years and climate science indicates that the frequency of droughts and other climate extremes is likely to increase in the near-to-medium future (Ministry for the Environment 2004c).

Growing pressures on New Zealand's freshwater resource are arising from competing values as well as competing abstractive uses. The values and uses for water considered by the WPoA include:

- domestic
- hydro-electricity generation
- agriculture

2. Local government is comprised of regional councils and district councils (and unitary councils that perform the functions of both). Regional councils prepare regional plans and regional policy statements which provide an overview of the resource management issues, integrated management needs, and related functions in terms of the natural and physical resources of a region.

- health
- industrial
- recreation
- natural heritage and fisheries
- tourism
- cultural values and mahinga kai.[3]

This last value includes recognition of the relationship of Māori, the indigenous people of New Zealand, to water resources.[4]

Pressures on the freshwater resource are growing in some regions of New Zealand faster than others. Some of this pressure is linked to a growing demand for energy, as New Zealand has significant hydro-electricity generation. Abstractive uses of water include irrigation, livestock consumption, household consumption and industrial use. Agriculture is the largest abstractive user of freshwater and agricultural diffuse discharges are having significant impacts on water quality (Ministry for the Environment 2004c). These pressures on the water management framework are similar to the kinds of pressures recognised as a barrier to the implementation of sustainable development policies by New Zealand's Parliamentary Commissioner for the Environment (Parliamentary Commissioner for the Environment 2002).

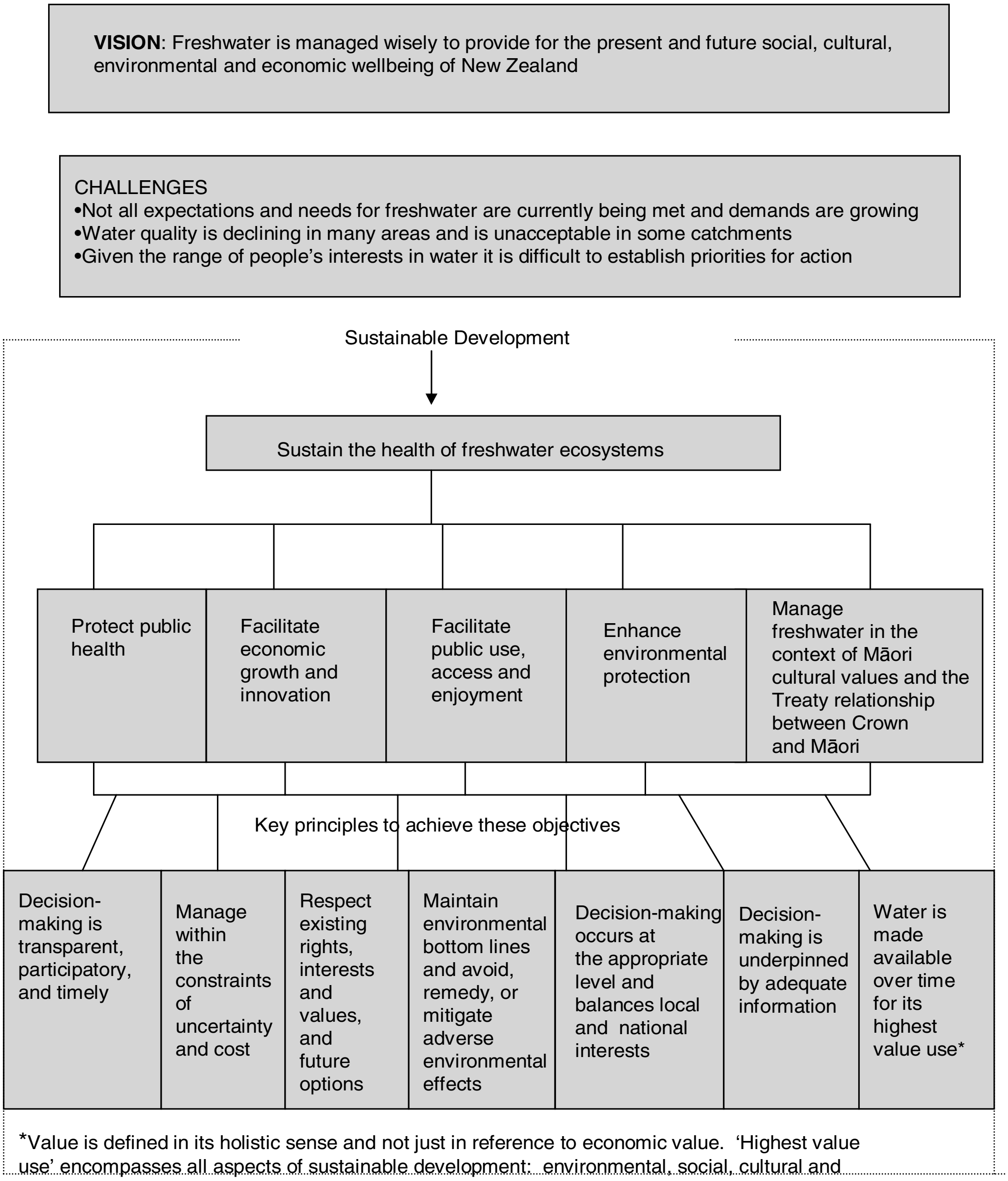
Resource Management Act 1991

The key environmental management legislation in New Zealand is the *Resource Management Act 1991* (RMA). It provides the overall policy framework for the sustainable management of New Zealand's natural and physical resources, including water and discharges to water. It devolves primary responsibility for most environmental issues to local government; regional councils are largely responsible for water management.

3. The customary gathering of food and natural materials and the places where those resources are gathered.

4. Freshwater has important cultural values. For Māori water represents the lifeblood of Papatuanuku (Earth Mother) and the tears of Ranginui (Sky Father), and is an essential ingredient of life both physically and spiritually. Water symbolises the spiritual link between the past and the present, thereby giving mana or authority to people. It is considered to be a treasure or taonga left by the ancestors for the life sustaining use of their descendants, who must guard these taonga and hand them on in a good state. In the modern environment, traditional values such as kaitiakitanga (stewardship) and the maintenance of the life-giving capacity of water, encompass and intersect with other values for water (Ministry for the Environment 2004c).

Figure 1. Sustainable water programme of action vision diagram



*Value is defined in its holistic sense and not just in reference to economic value. 'Highest value use' encompasses all aspects of sustainable development: environmental, social, cultural and economic.

Sustainable management is defined in section 5 of the RMA as the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while:

- sustaining the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations;

- safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
- avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Under the RMA the Crown reserves to itself the right to manage (but not own) water.[5] The fact that water is not 'owned' and is, therefore, a public good is a key policy consideration in managing any substantial change to New Zealand's water management framework.

The RMA states that water is a natural resource:

Water —

a. Means water in all its physical forms whether flowing or not and whether over or under the ground;

b. Includes fresh water, coastal water, and geothermal water;

c. Does not include water in any form while in any pipe, tank, or cistern.

The sustainable water programme of action

This section describes the two main components of the WPoA, water quality and water allocation.

Water quality

The WPoA is concerned with managing the impacts of rural land use and associated diffuse (non-point) discharges of contaminants[6] on freshwater quality. While both rural and urban sources of pollutants contribute to deteriorating water quality the WPoA focuses on rural land use impacts for the following reasons:

- around 60% of New Zealand's land area is under primary production and therefore, rural land uses have the ability to impact on a large number of waterways;
- agriculture is linked to declining water quality in many areas including surface waters (streams, rivers and lakes) and groundwater systems;
- urban areas affect only 3% of New Zealand's length of rivers; and
- urban discharges are largely being managed through the local government resource consent[7] process and by individual users, whereas diffuse discharges to water from rural land uses are not being addressed well (Ministry for the Environment 2004b).

5. Water is not privately owned in New Zealand except where enclosed in a pipe, tank or cistern.

6. The RMA definition of 'contaminant' covers any substance (including a gas, odorous compounds, liquid, solid or micro-organism); energy or heat that when discharged into water, or onto land, or into air, changes the physical, chemical, or biological condition of that water, land or air.

7. Individuals and businesses may seek resource consents (often known elsewhere as permits or licences) to take, use, dam or divert water, or to discharge contaminants to water. Resource consents to take water may be transferred between different users in specified circumstances, but there has been only limited use of this opportunity.

Over the last 15 years, New Zealand has made significant progress in reducing direct (point source) discharges of human and agricultural sewage and industrial waste into waterways. These discharges were easy to identify and address (relative to the difficulty of managing diffuse discharges), leading to significant and almost immediate improvements in water quality in many areas. To some degree, however, direct discharges have been reduced by converting them to diffuse discharges, for example, land disposal of urban waste and dairy shed waste. With the reduction in direct discharges, there is evidence that diffuse sources of contaminants from intensive agricultural land use[8] are now key contributors to rural water quality problems, particularly in lowland rivers.

Intensive agricultural activities put pressure on water bodies to cope with additional nutrients, micro-organisms and sediment. Agricultural land use covers over half of New Zealand, with agriculture being the main base of economic activity in most regions and provincial cities. Agriculture contributes approximately half of New Zealand's export earnings and will remain a major contributor to New Zealand's economic growth and, as a consequence, ongoing pressure to intensify is likely (Ministry for the Environment 2004b).[9]

Higher economic returns from farming are possible through either intensifying or diversifying land use activities. In the case of pastoral farming this could mean increasing pasture growth (e.g., by adding more fertiliser) and bringing more feed onto the property (e.g., silage) to enable higher stocking rates. In some cases this could change the type of farming from a less intensive activity such as sheep and cattle farming to a more intensive one such as dairy farming. In some regions, for example Canterbury and Southland, there has been a trend of conversion from sheep farming to more intensive land uses, particularly dairy farming. Dairy cattle numbers have increased nationally from about 3.2 million in 1994 to over five million today. In the same period sheep numbers dropped from 50 million to less than 40 million. The intensification of dairy farming has occurred through increasing herd sizes, increasing intensity of farming, and the expansion of dairy farming into new areas. This has been accompanied by an increased demand for irrigation in often dry parts of the country and by the increased use of fertilisers (Ministry for the Environment 2005b).

The WPoA is concerned with addressing the management of diffuse discharges especially where this is an unintended consequence of land use, such as intensive farming. Currently there are few tools for managing diffuse discharges. The WPoA will explore how the RMA can manage diffuse discharges, look at research including the use of computer modelling to assess the potential impact and sources, and whether water or nutrient trading regimes can be applied.

In most other regions local government has focused mainly on non-regulatory means for managing diffuse discharges, with an emphasis on encouraging better practice by enhancing landowner awareness of impacts of land use on water quality. Gains in on-

8. E.g., nitrogen or phosphorus from fertilisers, nitrogen/ammonia from animal urine or silage, micro-organisms from animal faeces such as campylobacter, and sediment from stock pugging.

9. Economically, the total value of agricultural exports in 2003 was $14.4 billion (equal to 51% of total mercantile exports) and the sector employs 9.6% of New Zealand's total workforce.

farm practice through this non-regulatory approach can be lost when changes in the economic climate encourage land use intensification. There are also issues with regulation of land use and water quality relating to perceived impingement on landowners' property rights. Addressing these issues can be politically contentious, leading to a reluctance to tackle them.

One catchment where diffuse discharges are being tackled through regulation is the Lake Taupo catchment in New Zealand's North Island. Lake Taupo is an example of a water body experiencing a gradual decline in water quality linked to land use. There has been a gradual decrease in Lake Taupo's water clarity due to increasing nitrogen levels from land use in the catchment, causing greater phytoplankton production. The best scientific evidence available suggests summer water clarity will decrease from an average of some 14 metres to nine metres over the next 20 years unless nitrogen inputs are held at current levels. However, some decline below current levels is inevitable as there is a lag time for nutrients to enter the lake. Some of the current decline is attributed to increased nitrogen inputs from farming in the last 50 years (Ministry for the Environment 2005b).

In July 2004, the central government agreed to fund NZ$36.7 million towards a total package of NZ$81.5 million to improve water quality in Lake Taupo. The balance is funded by local government agencies. This funding package aims to encourage pastoral farmers to diversify to low nitrogen land uses through a mix of financial incentives and advisory services over the next 15 years and is intended to reduce nitrogen levels in the lake by 20% (Ministry for the Environment 2005b). This reduction will be achieved by developing regulatory land use controls to secure the benefits gained of farmers changing to less nitrogen intensive land uses. Alongside this a fund will be used to purchase nitrogen from farmers in the Lake Taupo catchment. It will operate through a rule in a regional plan that would place a cap on nitrogen emissions, so that total emissions remain at current levels.

Water allocation

There is increasing pressure in some regions for water to be available to irrigate agricultural land. The area of irrigated land in New Zealand has approximately doubled every ten years since the 1960s and only 20% of the total area of potentially irrigable land is currently irrigated. Agriculture relies on freshwater and irrigated land consumes a large proportion of all abstracted water, accounting for nearly 80% of current allocation (Ministry for the Environment 2004b).

Irrigated agriculture and horticulture add an extra $1 billion annually above the best dry-land (non-irrigated) farming options for the same land (Department of Prime Minister and Cabinet 2003). Most water allocated for irrigation is allocated in Canterbury, a region covering approximately 17% of New Zealand's land area. Approximately 58% of the water allocated in New Zealand is from the Canterbury region and 70% of New Zealand's total irrigated land area is in this region. Between 1985 and 2002 the irrigated area in Canterbury is estimated to have increased from 150,000 to 440,000 hectares (Ministry for the Environment 2005b).

The RMA provides for councils to make regional policy statements and regional plans to provide a framework for allocation decisions.[10] Regional plans may specify such

10. Regional plans are not compulsory but nearly all regional councils either have an operative plan or are in the process of developing one.

matters as environmental baselines and how water will be shared between users. Water is allocated between uses (beyond environmental baselines) under the resource consent process which operates under a first-in first-served system.[11] In considering an application for a resource consent the focus is on avoiding, remedying or mitigating adverse environmental effects and the potential impact on existing permit holders. In circumstances where there is competition for water, there is no ability to compare the merits of different applications for resource consent.

New Zealanders increasingly understand that water has a value, and that the current system is not always able to meet all demands for water and sustain the important values of water resources. Processes for water allocation need to be able to establish an appropriate balance between the competing values society has for water. Some regional plans do not clearly specify an upper limit on the amount of water that can be allocated, with the result that there is a risk of an unacceptable loss of in-stream values. There is potential also for conflict between those wanting protection of in-stream values and those seeking further abstraction. While New Zealand has so far largely avoided the need for claw-back of allocations, this is likely to change with increasing demand.

In international and historical terms, growth and intensification has happened very quickly in New Zealand. Given New Zealand's abundant (albeit variable in location) rainfall, the current allocation and use system, and attitudes to water, have grown out of a situation where there was very little scarcity. The current allocation and use system has failed to keep up with this growth and change is required — in particular situations there will not be enough water to meet all desired uses or demands. A flexible allocation and use system would encourage more careful consideration of environmental, social, cultural and economic values and assist in achieving the difficult balance of optimising economic wealth while ensuring a quality environment for New Zealand (Ministry for the Environment 2004c).

Consultation on the sustainable water programme of action

Public discussion

To help explore these issues in greater detail the WPoA released a public discussion document for consultation on ideas for improving the freshwater management framework (Ministry for the Environment 2004d).[12] Four groups of potential actions were presented:

- providing national direction for water management;
- central government being more involved in regional water issues;
- providing more tools for regional councils; and
- working together.

11. The first-in, first-served system means that resource consent applications are considered in the order that they are received by the resource consent processing authority (typically a regional council). If someone puts in an application on Monday, and then someone else lodges an application on the Tuesday the applications will not be considered together — the Monday application is considered first, and then the Tuesday application is considered afterwards.

12. Available at www.mfe.govt.nz/issues/water/prog-action/index.html.

Action 1: Providing national direction for water management

This action explored the need for central government to provide greater direction and support to local government. The RMA provides some processes for central government to give direction to local government on issues that are nationally important. The mechanism to achieve this is a national policy statement and/or national environmental standards.[13] At the moment neither of these has been developed for freshwater. These two mechanisms could help local government agencies when developing regional policy statements and regional plans.

The WPoA is also looking at whether and how central government might need to intervene in local water issues. One step would be to identify priorities around particular values, such as tourism, ecology, energy generation, irrigation and recreation, for management.

Action 2: Central government being more involved in regional water issues generally

This action considered how central government could be more involved in working with local government. For example, supporting local government by providing information or funding, and working together on pilot projects or making whole-of-government submissions on regional plans. The Lake Taupo case, described above, is an example of central and local government working together along with others such as farmers, foresters and local Māori.

Action 3: Providing more tools for regional councils

This action explored a range of possible tools to deal with the over-allocation of water and declining water quality. It looked at improving technical efficiency, the use of market-based instruments and setting priorities.

The issue of market-based instruments received some strong responses during consultation. To the extent that any tool entails payment for access to the resource, perceptions of 'privatisation' of water arise. This may carry particular risks for Treaty of Waitangi relationships between central government and Māori, as well as raising concerns in the broader community. These risks can be managed to some degree by open consultation to increase understanding of the instruments, and by more effective engagement with Māori.

Consideration of market-based instruments included:

- modifying the first-in, first-served system using market-based approaches;
- enhancing the transferability of water resource consents;

13. The purpose of a national policy statement is to state policies on matters of national significance that are relevant to achieving the purpose of the RMA. National environmental standards are a type of central government regulation prescribing technical standards relating to the use, development and protection of natural and physical resources including contaminants, water quality, levels or flow, and soil quality in relation to the discharge of contaminants.

- emergence, as a result of water transfers, of financial incentives to improve technical efficiency in the use of water;
- establishing a resource rental for water; and
- increasing certainty in the specification of rights in water resource consents.

Two ideas that were focused on were technical efficiency and the transfer of water resource consents.

Technical efficiency

Ideas for improving the technical efficiency of water use included:

- making water meters compulsory;
- allowing charges to be made on a volumetric basis;
- separate take and use consents with take consents of limited duration;
- industry efficiency standards, codes of practice or a certification system;
- providing financial assistance for water users to shift to more efficient technology; and
- public education and measures to encourage efficiency in use of domestic water (particularly related to use of drinking-quality water).

These ideas were well-received during consultation and submitters offered many other solutions around efficiency of domestic water use.

Transfer of water resource consents

The transfer of water resource consents can happen under the RMA but few transfers occur. Enhancing the transferability of water resource consents would encourage regional councils to consider consent transfers and to remove the barriers to, or reduce the transaction costs involved in such transfers and would potentially lead to an improved overall system of water allocation and use. To the extent that trading facilitates the reallocation of water resources, the first-in first-served system for making initial allocations would be of less concern.

There is some resistance, however, to the concept, especially among some land owners who believe that the transfer of consents should only occur in the context of the transfer of ownership of land. Greater use of the transfer of consents would enable the ability to allocate and reallocate water to its highest environmental, social, cultural and economic values over time. This is a key policy issue to be considered by the WPoA. The emergence of a price for water would also provide incentives for technical efficiency in water use.

Action 4: Working together

This action recognises there are problems that are too complex or problematic for any one agency, or layer of government, to attempt to solve alone. It involved tools to raise awareness through education and communication programmes and improving Māori participation in water management. It explored the merit of establishing pilot projects between central and regional councils, scientists and communities to test new ways of doing things.

In recent years the Government has also spent significant monies on research into water issues through a range of agencies including the Ministry of Agriculture and Forestry, the Ministry for the Environment, the Department of Conservation, and the Foundation for Research, Science and Technology.

Consultation outcomes

In early 2005, WPoA officials spent some five weeks at meetings throughout New Zealand with local government, the public, stakeholder groups and Māori discussing the issues and the proposed actions raised in the discussion document. Written and verbal submissions were analysed and a report was produced for each of the consultation streams (local government, the public and stakeholder groups, Māori and written submissions) as well as a summary report.[14]

The consultation considered the role of central and local government. The view was that central government should provide guidance and support for local government and the provision of national funding where impacts of implementing national priorities have local costs. Submitters recognised value where central government involvement would lead to improved consistency between local government agencies, whether this was through central government directives or guidance. Submitters also voiced a need to recognise local differences and to retain local decision-making (Ministry for the Environment 2005a). A common theme was the need for greater involvement by communities in finding solutions to water management issues.

Māori participants in the consultation raised concerns about the Treaty of Waitangi relationship between Māori and central government, and sought greater involvement in management and decision-making. They also raised ownership issues and noted the link between this and the use of market-based instruments. Māori want increased recognition of traditional Māori values for water and were concerned about the need to restore the life-supporting capacity of water.

Support was expressed for retaining the RMA as the framework for water management. There was a desire to the see the RMA being used to best effect, rather than replacing or duplicating it, and to provide a greater emphasis and focus on consistency of implementation, enforcement and performance.

14. The reports are available at www.mfe.govt.nz/issues/water/prog-action/index.html.

Questions were raised about the use of market-based instruments and concerns about the:

- potential for monopolies;
- impact on property rights;
- privatisation of a public good;
- impact on the environment and community; and
- framework within which a market would operate.

There was also a view also that there is a need for improved integrated catchment management. This included greater recognition of the linkages between urban and rural water issues, and between different parts of the physical water resource system. Following consultation the scope of the WPoA was broadened to include urban water quality issues in response to concerns expressed by submitters.

Following consultation

Following consultation a series of studies were undertaken into specific policy areas to clarify earlier work and work through issues raised during the consultation. It included a range of sub-projects exploring lessons from other countries and other resources in terms of the balance between market-based and administrative mechanisms for managing water. Lessons from the management of natural resources, other than water, in New Zealand were also explored.

Conclusion

The WPoA is concerned with improving the way freshwater is managed in New Zealand. In particular it is concerned about water quality and water allocation issues. The impacts of agricultural activities on water are a significant part of this. To date, the WPoA has scoped issues and problems with the current management framework and has consulted publicly and extensively on a range of potential actions to improve the management framework.

The WPoA still has one year until it is complete. In the next six months the New Zealand Government is expected to signal the direction it wants the WPoA to take in determining specific changes to New Zealand's water management framework.

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Chapter 22.

Italian Policy Framework for Water in Agriculture

Raffaella Zucaro and Antonella Pontrandolfi[1]

Introduction

The paper describes the evolution of the institutional and legal context of the Italian water system during the last decade, as well as political strategies followed by the Italian Government to reach a sustainable water use according to European Union guidelines.

In particular, the first section describes Italian irrigated areas and focuses on the main problems referring to water use for irrigation.

The second section explains briefly the evolution of legislation during the last decade, the activated reforms, the new institutional framework and the actual legislation, focusing on the role of agriculture in this context.

he third section analyses applied policies, specific objectives and economic instruments used by the Italian Government. Particular attention is given to the integration with agri-environmental policies, finalised to water saving and water quality protection. Policy performance levels are also analysed with regard to the impact of agriculture on water bodies.

The fourth section points out the critical factors related to the water system and possible strategies and instruments for achieving agri-environmental objectives.

In the conclusion, some reflections are made upon future scenarios in Italian rural areas in consequence of the Common Agricultural Policy Reform, the future European Rural Development Policy (2007–2013) and the implementation of the European Water Framework Directive.

1. Irrigation in Italy

In Italy, economic-social development has greatly influenced the environment producing consequences on plants, animal and human life. Agricultural activities changed very quickly to a managerial industrial model causing a deep impact on water use and on water quality.

1. National Institute of Agricultural Economics (INEA), Rome, Italy.

Total water availability in Italy is estimated at 52 billion cubic metres,[2] 50% of which is allocated to agriculture, in line with the medium value of OECD countries[3] and with a constant tendency to reduction[4]. Water distribution for geographic areas is not homogeneous: 65% is concentrated in the North of Italy, 15% in the Centre, 12% in the South and 8% in the big islands (Sicily and Sardinia). The difference between North and South is due to climatic and historical factors: regions in the Centre and in the North are characterised by favourable climatic conditions and a tradition of irrigation and drainage. On the contrary, Southern regions, characterised by a semiarid climate, have faced water availability problems and strong public action after World War II (numerous dams were financed and built starting from 1950 onwards[5]); nevertheless, in the southern areas and in the islands remains an asymmetry between water availability and water requirements.

According to the Italian National Census of Agriculture (ISTAT, 2000), irrigated areas in Italy are approximately 2,5 million he, and 19% of Utilized Agricultural Area (UAA).[6] The main irrigated crops are grains (30% of irrigated area), concentrated especially in the Northern regions, wood crops (a greater percentage in the islands, 50%), citruses (prevailing in all of Southern Italy) and, thanks to technological progress, crops that once were not irrigated (for example, olive trees).

The relationship between agriculture and water resources is characterised by several common problems, whose relevance changes at territorial level:

a. fragmentation of irrigation services from a legal and physical point of view;

b. private irrigation and the increase of groundwater withdrawals;

c. condition of irrigation networks;

d. managerial efficiency;

e. the release of pollutants produced by agriculture into water bodies and a worsening of water quality.

With respect to fragmentation, there are many public agencies operating in the water system having different competencies that are not always well defined; sometimes agencies' competencies overlap creating coordination problems in planning and management of water use.[7] Moreover, there are a high number of agencies (several hundreds) which are very small.

In all regions, in the same areas where public agencies operate, there is irrigation operated with a private water supply (80% of farms in some areas).[8] It creates a problem because this kind of water supply cannot be planned and controlled by the authorities.

2. IRSA-CNR (1989).

3. OECD (2004).

4. National Environment Protection Agency (2004).

5. Zucaro R. and Pontrandolfi A. (2003).

6. ISTAT (2000).

7. Ubertini L. e Casadei S. (2002).

8. Zucaro, R. (ed.) (2004).

During the last years, for both private and public irrigation, there has been the problem of increasing groundwater withdrawals.[9] This is due to climate changes that have caused an increase of drought events with consequent water availability reduction.[10] In the last 20 years, the area of national territory that has suffered from drought events increased from 8% to 20%. This increase creates strong worries regarding agri-environmental problems as soil salinisation and loss of fertility, desertification and subsidence on costal areas.

Regarding the condition of infrastructures for irrigation, based on an estimation, water losses along the networks are 30–50% of water withdrawals; this is not due only to infrastructure characteristics, but an insufficient maintenance and systems' low technological level.

The efficiency level of water use management shows some points of backwardness, except in some specialised areas. In a world where efficiency represents the most important aim, a critical factor is the low incidence of water use planning.[11] In many cases, agencies do not have a deep knowledge of water requirements and consumption in the areas that they manage. Control instruments are lacking and requirements' calculation methods are not diffused.

With respect to management aspects, a critical factor is represented by the "pricing system". In Italy a pricing system does not exist, but instead there is a "contributive" system,[12] often based only on the extension of the area that farmers intend to irrigate, without consideration of the water requirements of different crops or water consumption. This system does not assure efficient water use.

Despite technical progress realised in the last few years, high water consuming irrigation methods (submersion and sliding) are still widespread, in particular in the North, where national rice production is concentrated (Table 1).

Finally, a typical characteristic of some areas is the worsening of water quality.[13] Irrigation ditches have often a wastewater drainage function; pollutants are transported to irrigated soil. This happens more in areas with elevated density of livestock and maize production. Moreover, in the last decade tourism (which is more and more important) has produced environmental pressure especially during the summer (the Mediterranean Sea is the area with the highest tourism pressure of the world.[14])

9. National Environment Protection Agency (2004).

10. National Environment Protection Agency (2004).

11. Pontrandolfi A. (edited by) (2005).

12. Farms pay a contribution to public agency for irrigation benefit.

13. Pontrandolfi, A. and Papaleo, A. (2004).

14. National Environment Protection Agency (2004).

Table 1. Irrigation methods and relative irrigated area (hectares)

Geographic area	Superficial sliding and lateral infiltration	Submersion	Sprinklers	Micro-irrigation	Drop	Other
North	723.672	213.834	599.344	17.557	51.401	27.039
Centre	20.891	556	158.225	6.058	24.403	3.146
South and Islands	105.997	3.146	293.632	51.717	214.903	23.489
ITALY	**850.560**	**217.536**	**1.051.201**	**75.332**	**290.706**	**53.674**

Source: Inea elaboration on data ISTAT;V Census of Agriculture, 2000.

Regarding the release of pollutants produced by agriculture, eutrophication events take place almost every year, and agriculture activities have surely an important role in these events. But knowledge of the specific impact of agriculture on water bodies is not yet sufficient.

The Italian National Environment Protection Agency[15] underlines that the most serious problem observed in the recent years is the increase of groundwater use, which represents the prevailing sources of irrigation supplying in Italy. This increase is due to the reduction and quality deterioration of superficial water. However, the APAT indicates that their general condition in 2004 "demands attention but is not dramatic". The groundwater quality level is not yet well known, although knowledge is improving. The available data on drinkable water quality shows some problems about chemical quality (only 37% at good or elevated level). Critical parameters include nitrates, pesticides, metals, boron and chlorides.

Water quality parameters for rivers (important sources of irrigation supplying in the North), show a situation in 2004 compared to 2002:

- similar for ecological state (37% with good or elevated ecological state);
- improved quality with regard to pollutants concentration (from 53% to 58% with good or elevated level);
- improved quality with regard to biological class (45% good or elevated).

Therefore, it seems that progressive adaptation of wastewater treatment systems and the several actions to reduce pollution created by agriculture (see paragraph 3) are attenuating or, at least, not increasing water pollution.

In conclusion, at national level the relationship between water resources and agriculture shows different situations, but also common critical points, above all structural condition and management efficiency. These are the main elements that European and Italian policies are trying to deal with.

15. National Environment Protection Agency (2004).

2. National legislation and competencies for the water system

A weak point of the Italian irrigation system is the complexity of the institutional roles of the several institutions and agencies involved. This point appears so important to slow down the necessary reform process.

First of all, it is necessary to underline that water use and water protection have always proceeded apart, considered as two separate fields until the end of 1990.[16]

The first important laws that regulated water use are from 1930. In this period, water was seen as a productive factor for increasing crop productivity and as a development factor for improving life quality (most of civil, industrial and irrigation infrastructures have been built before and after the Second World War).

This approach was unchanged until 1970–1980. After this period, new aims became important for public opinion and at the political level: water became a public and limited resource to defend.

In this context, several laws have been made from 1990 onwards, determining a new arrangement of competencies in the water system. New legislation has been passed regarding soil defence (Law 183/89) and water management (Law 36/94). These laws strongly reformed the field, but their application has had, and it still has, some difficulties in several Italian regions.

Legislation concerning water quality protection has been developed in the last two decades both at European and Italian level. From 1980 and after the Treaty on European Union (Maastricht Treaty), numerous European Directives have been passed with respect to International Conventions or to establish common quality standards for specific water uses (drinkable, human consumption, bathing, dangerous substances, nitrate pollution, etc).

Moreover, European policy has tended towards an increasing integration of productive and environmental policies. At the national level, several laws have been passed to apply these European Directives between 1980 and 1990.

In 1999, a new Water Framework Law was passed, Decree 152/99. It reassumes the evolution (directives application) and the integration between productive and environmental policies. The main aim of the decree is the "water integrated qualitative-quantitative protection": it considers excessive water withdrawals a very important factor for water environmental alteration. Therefore, the decree involves agriculture directly, in terms of pollutants release and exploitation for irrigation and livestock production.

In particular, agriculture is included in: directive 91/676/CEE, relative to water protection from nitrate pollution produced by agriculture; directives 76/464/CEE and 80/68/CEE, concerning protection from pollution generated by dangerous substances. With respect to those directives, Italian Institutions defined the areas with nitrate pollution, while the census about dangerous substances has not been completed and monitoring, has not started yet.

16. Zucaro, R. (ed.) (2001).

Another important points are contained in Decree 152/99: the obligation to apply a "code of best agricultural practice" in the areas designated as vulnerable to nitrates from agricultural sources; the definition of action Programmes for agronomic use of livestock production waste water and of olive oil production waste water; the norms for urban waste water reuse for irrigation.

With respect to water quality for irrigation, in Italy a specific law does not exist, like in the majority of the other countries. That is due to the wide variability of factors that determine water quality for irrigation (soil, crops, irrigation methods). So, there is a consequent difficulty in establishing common indicators and quality standards that would be good for all agronomic situations. Otherwise, Decree 152/99 defines that the "good" level of water will assure all water uses, so water quality classification of the decree is the legislation regarding the estimation of water quality for irrigation.

In synthesis, the Italian legislation evolution led to the definition of the so-called "Integrated Water Cycle", characterised by three levels:

1. "planning" of water resources allocation on a river basin scale. At this level, both environmental and productive aims are defined.

2. "programming", concerning the definition of the political strategies and the economic instruments to achieve the aims fixed at the planning level. At this level, Action Programmes and financial resources allocation are defined.

3. "management" of water resources, entrusted to several agencies in the territory.

Planning of water use and water protection is entrusted to the several Authorities competent in the water system, first of all:

- Italian regions;[17]

- "river basin authorities" instituted by the Law 183/89 for the government of resources at river basin level (there are 11 national, 18 interregional and several regional river basins);

- "ambit authorities" instituted by Law 34/96 for civil, industrial and purification fields (there are 89 authorities in the territory).

The ***planning*** level has to assure the integration between productive requirements and environmental aims. So, ideally, there is a unique water planning policy in a river basin.The ***programming*** level act through several investment programmes, entrusted to the competent authorities (see paragraph 4).

The water ***management*** level of water at territorial level is entrusted to:

- "integrated services" for civil and industrial uses and for the water purification field (Law 36/94); they operate on the directive of ambit authorities;

- several agencies for irrigation (see paragraph 1).

17. Italy has constituted 21 Regions as administrative units on the territory.

The institutions and agencies can have competencies in one or more of the three described levels. In particular, the competencies are shared:

- between state and regions (according to the new text of the Italian Constitution[18] and to the laws of decentralisation that have been passed from 1990);

- among the central administrations (ministries). In particular, the institutions involved are: Ministry of Agricultural and Forestry Policies, Ministry of Environment Protection, Ministry of the Economy and Ministry of Infrastructures and Transports.

The large part of the competencies has been assigned to the Ministry of Environment Protection, while the Ministry of Agricultural and Forestry Policies is competent for the greatest irrigation networks and for programming of national funds. Regions have the remaining competencies.

At the end of this brief examination, we would like to underline that in 2000 the Water Framework Directive (Directive 2000/60/CE) was passed at the European level. The main aims of the directive are: widening water protection; managing resources on a river basin scale independent from administrative units; proceeding through an arranged approach that integrates chemical water quality and environmental quality; assigning the right price to water use based on real economic costs ("full cost recovery" principle); involving citizens in the adopted choices. Although the directive still has not been applied in Italy[19] (a procedure of infraction of the European Commission is in course), under many aspects the Italian decree has already applied its principles and aims, in particular regarding the approach on a river basin scale and the integrated quali-quantitative protection. But, obviously, its application will make other modifications and integrations of the Italian water system necessary.

3. Main legislative instruments for planning and programming for the water system

As described, from a legal point of view the Italian water system is very complex and characterised by a high level of fragmentation and competencies, and functions tend to overlap. This situation creates the necessity of a strong coordination among different competent local and national administrations in making decisions regarding planning water use and choosing economic instruments.

The main legal instrument for the water use planning is the "River basin Plan" (Law 183/89), defined by the competent river basin authority. The plan is constituted by several sector extract plans, among which the more important are:

- the Ambit Plan, for civil and industrial use and purification fields; the plan is defined from the ambit authority;

- the Water Protection Plan (Decree 152/99), that indicates the environmental objectives and the prescriptions for all water uses in order to respect water quality. The Plan comprises strategies to reduce negative impacts derived from anthropic activities, included agriculture. Regarding quantitative protection, the Plan must include measures driving to a more efficient water use in agriculture, through the regulation of

18. Legge costituzionale 18 ottobre 2001 n. 3.

19. Actually, a proposal of decree has being discussing.

the water withdrawals authorisations. In relation to qualitative protection, the control of the impact of agriculture is done through: the location of nitrate vulnerable zones from agriculture; the definition of specific action programmes against the presence of dangerous substances (also pesticides); the regulation of the agronomic use of organic substances. The protection plan must contain the indications of specific field plans (agriculture, industry) and it must represent a document of communication and social information.

In the end, it is important to notice that Water Framework Directive 2000/60/CE requires the definition of an unique planning document called Management Plan, that member states must predispose for every single river basin. The plans can be supplemented by more detailed programmes and management plans (for example, water use sectors, different problems or water categories) to deal with particular aspects. In this sense, it will be necessary to evaluate, applying the directive in the Italian law arrangement, how the river basin plan and its extract plans will converge into the management plan.

Based on aims and criteria fixed in planning, institutions define the programming that includes the answers that policies choice to solve problems. The programming of investments for irrigation has shown, in the last few years, an increasing tendency to the coordination among all fields of the Water Integrated Cycle, following the "integrated" programming approach. In particular, agriculture participates directly by:

1. promoting quantitative protection through water-saving actions and the improvement of management and infrastructures for irrigation; and

2. promoting qualitative protection through the reduction of pollutant released from agriculture into water bodies.

Regarding ***quantitative protection*** and water saving, several instruments can be used at the national and the European level, like national programmes that finance irrigation infrastructures and regional programmes financed by EU (Operational Programmes and Rural Development Programmes of EU) for the improvement of management at farm level.

In the last six years, different national instruments studied irrigation and they financed investments for almost 3,6 billions euro[20] for projects finalised to (Figure 2):

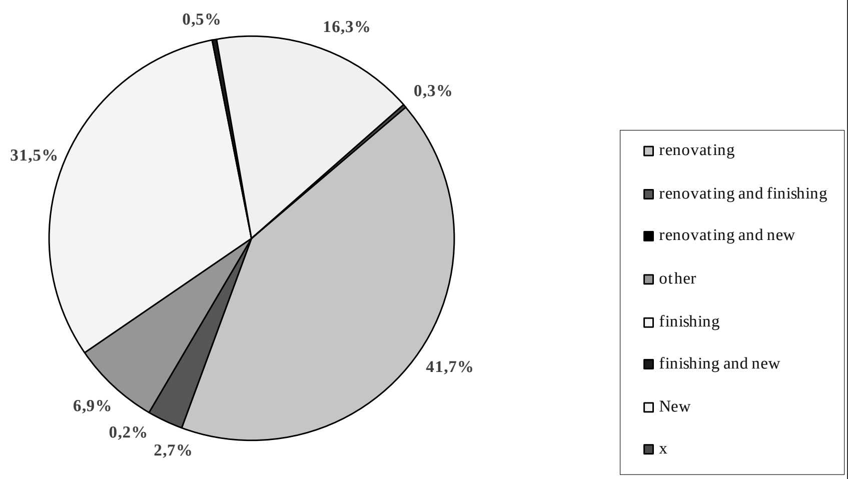
- recuperating dams' efficiency;
- completing irrigation networks;
- renovating distribution and adduction networks
- control and measure instruments, and
- wastewater reuse for irrigation.

20. Zucaro, R. (ed.) (work in progress).

Even if the economic investment has been considerable, the performance level of some of these instruments has not been high, especially when a high priority from a structural point of view was not supported by availability of financial resources. One positive element is the prevalence of demand of structural renovating, that evidences the tendency towards a more efficient use of water, in particular in the areas where irrigation is characterised by obsolete networks and open sky ditches, producing a high water loss. Nevertheless, programming choices privilege completing of the adduction and distribution networks, especially in the areas where irrigation is not still completely structured (the main worry is drainage), and irrigation systems are not efficient while water requirements are high.

The *National Water Plan* of 2004[21] seems to have made a treasure of past experiences. In fact, the plan involves the whole national territory, all water uses and all central and regional institutions. It represents one of the most important challenges in the next few years, because of the remarkable effort of coordination that has been done for its definition. Although the financial resources programmed by Ministry of Agriculture (EUR 1,1 billion), structural and financial requirements remain to satisfy; they'll be the priorities for future programming.

Figure 2 - Programmed investments for irrigation in last 6 years in relation to kind of actions (INEA, 2005)



It is important to specify that programmed investments funded by national resources do not address farms. In fact they are orientated to efficiency improvement of public networks, while programming for water management improvement and modernisation of farm irrigation systems are financed by the operational programmes and the rural development programmes of the EU. Regarding these programmes, the financial resources (for the period 2000–06, almost EUR 750 million) have been used for management improvement, irrigation methods modifications in order to reduce water consumption, research and technical innovation.

21. Comitato Interministeriale per la Programmazione Economica 2005; Legge n. 350/03.

The most important role of regional rural development programmes is the water ***qualitative protection*** aims. In effect, rural development programmes represent the only programming instrument used in order to pursue reduction of diffuse pollution produced by agriculture, because it involves farms directly, so it acts on environmental pressure levels of agricultural activities, rather than on responsibility attribution (the principle "polluters pay"), which is difficult to define for non-point pollution. This instrument is voluntary, which means that farmers can decide if they want to join it or not. Upon joining the programme, farmers receive economic support for application of the environmental prescriptions. The agri-environmental measures prescribe actions which aim to reduce the use of nutrients and pesticides. In particular, measures entitled "biological agriculture" and "integrated agriculture" are called "cross" measures because of the general environmental benefits that they produce. It is difficult to extrapolate the effective and specific contribution of every measure on water quality, especially for measures not explicitly finalised to qualitative protection (effects on water bodies derive from actions finalised to soil defence).[22]

4. Critical factors concerning water use for irrigation

Analysing the relationship between agriculture and water resources at the national level, it emerges that several critical factors characterise the national context, some of which have recently been objects of the agricultural and environmental policies.

The most important factor is that agriculture is not included, at the institutional level, in the Integrated Water Cycle, but there are specific institutions and agencies managing water for the primary sector.

Regarding ***planning*** of water use, there are delays in the application of national laws and the authorisations for water withdrawals are sometimes expired or not updated. For these reasons, planning of water use is not efficient. Moreover, in the case where the river basin plans have been defined, irrigation is often not included because of its different history in the last few decades and because of its particular requirements. However, this situation creates serious problems of coordination and of policies' effectiveness, especially considering that in many river basins water withdrawals for irrigation prevail with respect to the other water uses.

Moreover, another critical factor at the planning level is the absence of an exhaustive knowledge of water use for agriculture. There is a strong need for support instruments at the national level in order to elaborate strategies of integrated planning and to find better political answers for the territory. Therefore, it is necessary to develop a common information base to compare conditions, requirements and, consequently, choice priorities. Regarding water quality, a monitoring net already exists at a regional level, but regarding water use for irrigation a monitoring net is not yet available. Therefore, the Italian Ministry of Agriculture is working (with INEA) to realise it.

Regarding ***programming***, the complex arrangement of competencies makes hard to reach a good integration among all political actions regarding water. Anyway, during the last few years the degree of coordination between national and local competent administrations is increasing, producing positive impact on water saving and water protection.

22. Mantino, F., Monteleone, A. e Storti, D. (eds) (2005).

Water ***management*** has the same problems. In fact, the fragmentation of the water system, characterised by many management agencies (both public and private), makes difficult to operate an efficient water management. Moreover, an important issue regards the "price of water" for agriculture. As shown, in Italy there is not a pricing system and the existing contributive system, generally, is not economically efficient and it is not oriented to water saving.

Therefore, it seems necessary to simplify competencies, and to consider the problem of water costs in order to increase efficiency and effectiveness of water policies.

Conclusions

Water represents one of the main factors for agricultural production processes, because it has a great impact on quality and quantity of agricultural products. This is particularly true for the southern Italian regions, where, because of climate conditions, agriculture depends on irrigation. At the national level, irrigation has led to considerable improvements in productive techniques, lengthening production periods and promoting product standardisation, contributing to food stabilisation. ater availability constitutes, in fact, an important factor of competitiveness because irrigation increases the ability of farmers to be on the market and this encourages higher qualitative standards for productions.Furthermore, irrigation produces several environmental benefits, related in particular to groundwater recharge; it also characterises the agricultural landscape and in some areas it contributes to tourist and recreation countryside activities. However, excessive water use and pollutant released from agriculture produce a negative impact on the environment.

An insufficient water pricing system as well as a coupled agricultural policy have been blamed for having favoured an excessive exploitation of water resources. But this scenario is changing. CAP reform has, in fact, eliminated the prices protection net for the great part of agricultural productions and agricultural prices are gradually being driven at the world market level.

Therefore, farmers can receive a fully decoupled single payment and choose between not producing, assuring maintenance operations, or continuing to produce adapting their production to market demand. Several researches[23] assumed positive effects on water use in consequence of the CAP reform application, related to a reduction of production in marginal areas for a drastic re-allocation of cultivated surfaces. Nevertheless, an interesting scientific work of Massarutto (2003) has shown that in the areas where farmers have a good organisation and water management is efficient, this reduction of production should not happen. In this case, the CAP reform should not be a strong incentive to water demand reduction in consequence of irrigated areas' reduction and conversion of farms (towards afforestation and landscape-oriented agriculture, ecological farming) as irrigated land is normally also more productive. The most obvious candidates towards use reduction, if any, are those areas in which both farming practices and water efficiency are very poor because of geographic or other factors. The condition for this to happen is more likely to occur when water is used because it is very cheap, and not because it is very useful.

23. Whitby (1997), van Huylenbroek and Whitby (1999); Anania (2001).

Farmers, both for mental habitus and for economic convenience, should opt for productive use of lands, substituting productions that had a high level of subsidies, as cereals, with productions they estimate positively in a market perspective or that incorporate a greater value added.[24] In this context, water is very important because, in looking for the best factors arrangement, farmers will choose irrigated crops only in the presence of water availability — and that not very expensive — and in presence of an efficient irrigation service.

If water requirements increase, conflicts among the several water uses can also increase. In Italy, water demand for civil and industrial uses, in particular for tourism, is increasing. Tourism has become the main antagonist of agriculture because both sectors present the highest water demand in the same period (during the summer).

In the meantime, the CAP reform is strongly oriented to privilege sustainable development pushing farmers to a correct use of production factors; therefore, the access to subsidies is subordinated to the respect of best practice in agriculture (eco-conditionality), and to the respect of principles of Water Framework Directive 2000/60/CE (described in paragraph 2).

The application of the directive and the changes in the institutional system that it requires could help to contrast the high fragmentation of the national water system at the planning, programming and managing level, introducing a new and more appropriate pricing systems based on the "full-cost recovery" principle.

Therefore, the scenario designed by CAP reform and by the application of WFD offers an important opportunity with respect to the objective of a more efficient water use, in particular through management improvement and water-saving irrigation techniques.

The coming scenarios that emphasise the relationship between agriculture and water resources are one of the objects of the future European Rural Development Policy. The next programming cycle (2007–2013) aims for a closer integration between agricultural and environmental policies. All investments in agriculture and rural development (European Agricultural Fund for Rural Development) will have to contribute to environmental aims. Analysing the indications approved from the European Union Council,[25] it emerges that the main purpose of rural development policy is to help agriculture to achieve its multifunctionality and its management/control role of the territory. Resources are concentrated on the following objectives:

- increasing agriculture competitiveness;
- valuing environmental resources and natural surfaces supporting a more efficient territory management;
- improving life quality in rural areas and promoting the diversification of the economic activities.

24. Borrelli, L. and Picchi, A. (2004).

25. European Union Council (2005).

Therefore, for the water system, regions (that define the programmes) will have to find new modalities for integrating all development requirements and subsidies to the farmers will have a higher environmental valence, for example, supporting them in the application of water protection plans in nitrate or pesticide vulnerable zones.

In conclusion, in Italy the prevailing instruments in water policies are:

- policy instruments for reducing fragmentation at the institutional level with regard to planning and management water use;
- economic instruments for improving the efficiency of the water systems and irrigation networks; and
- voluntary instruments within CAP measures and rural development programmes, for reducing negative environmental effects of agriculture on water.

In this context, it is important to work on the problem of water costs. In fact, while the evaluation of pricing systems for drinkable and industrial water is a relatively simple task, it is more difficult for irrigation — first of all, because there are technical-structural limits: in Italy, consumption measurement instruments are not spread, so it is not easy to apply a water price based on water consumption. Moreover, irrigation water pricing has to consider many factors like the high average consumption for irrigation, the economic importance of agriculture production and the environmental implications of irrigation (positive and negative environmental impacts). Finally, it is important not to burden the agriculture sector, which is very important for the Italian economy, and is characterised by several weaknesses.

Also, it becomes important to encourage farmers to contribute to the common good through their voluntary participation in information and sensitisation activities about environmental protection.

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Chapter 23.

The Spanish National Irrigation Plan

Ángel Barbero[1]

The climatic conditions in the major part of the Spanish territory belong to the Mediterranean type. That means medium to high temperatures with warm and extended summer seasons in the eastern and southern regions, while in the inland, for instance in the Central "Meseta", differences between winter and summer temperatures are wider than in coastal regions. For that reason, it can be found a wide range of types of irrigation systems, conditioned by factors like their geographical situation in the national territory: not only different crops, yields and watering methods but diverse structural, economic and social aspects. Nevertheless, the common characteristic of these regions is an uncertain and low rainfall regime added to frequent and long periods of drought. Historically, in a great part of rural zones irrigation has played a critical role for rural population to avoid poverty and sometimes starvation.

Today, there are still in Spain a great number of rural zones in which no other options for development are significant except irrigation-based agriculture. The disappearance of agriculture in these rural zones will imply depopulation and the abandonment of the land with negative environmental impacts and a great imbalance in the population territorial distribution. But in many cases, this type of agriculture has negative environmental impacts too: very low efficiency of water use, due to old distribution networks and flooding irrigation methods; over-exploited aquifers and diffuse pollution.

During the last decades, agriculture in many countries has to face challenges such as: decreasing subsidies, compliance with an environmental legislation more and more restrictive, severe restrictions to the use of water and, at the same time, the need for farmers to produce competitive goods in a global market.

The implementation of the new water policy approaches and measures, e.g. water pricing, must take into account all these circumstances and its consequences to the future of the agriculture in many rural zones of Spain.

The Spanish National Irrigation Plan (PNR) aims to help the irrigation-based agriculture to face all these challenges, developing five programmes and building a new financing system tailored to the different irrigation systems and reinforcing the relationship between administrations and stakeholders, mainly the irrigating farmers' communities.

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The most important programme of PNR is "Improvement and modernisation of traditional irrigation systems" in which the four State owned companies for agricultural infrastructures called SEIASAS (in Spanish, Sociedad Estatal de Infraestructuras Agrarias, Sociedad Anónima) play a key role. There are three more action programmes less financed and affecting a more reduced area: "Works in irrigation zones with infrastructures into execution", "New infrastructures for social purposes" and "New infrastructures in private irrigation communities". The fifth programme includes supporting actions such as an environmental monitoring programme, training and educational programmes for irrigating farmers, complementary studies, knowledge and dissemination of new technologies, etc.

The expected outcomes are: water savings; increased efficiency in water management; control of inputs use and consequent improvement of water quality; extended implementation of automated irrigation technologies; increased capacity to diversify crops for a market-oriented production; increased competitiveness facing global markets; improvement of irrigating farmers work conditions; a more balanced territorial distribution of population. In short, the Spanish PNR has to contribute to an economically, socially and environmentally sustainable development of many Spanish rural zones.

Introduction

Near 3.8 million hectares in Spain are irrigable, while from 3.2 to 3.4 ha are irrigated every year, depending on the hydrological season. That is about 14 per cent per cent of the total Agricultural Used Area, but, in economic terms, this area represents 13.000 M€, more than 60 per cent of the total Agricultural Production value.

Irrigation has a great influence in the development of many rural zones in Spain. One irrigated hectare produces average 6.5 times more than one rain-fed hectare (see Table 1).

Studies developed during the PNR planning process have pointed out the next main rural development issues related to irrigation:

Economic aspects:

- increasing yields and benefits per cultivated hectare
- diversification of agricultural production
- guarantied production against climatic variability, and
- increase of agro-food industries.

Employment:

- man power generation, and
- increase of indirect employment.

Table 1. Average of productivity — economic value irrigation/rainfeed

COMUNIDAD AUTÓNOMA	RATIO OF ECONOMIC AVERAGE PRODUCTIVITY IRRIGATION/RAINFEED
ANDALUCÍA	4,6
ARAGÓN	5,4
BALEARES	4,5
CANARIAS	19,9
CANTABRIA	2,8
CASTILLA- LA MANCHA	2,0
CASTILLA y LEÓN	3,7
CATALUÑA	5,2
COMUNIDAD VALENCIANA	6,8
EXTREMADURA	4,2
GALICIA	3,7
LA RIOJA	3,4
MADRID	3,1
NAVARRA	6,0
PAÍS VASCO	5,9
REGIÓN DE MURCIA	40,4
NATIONAL	*6,5*

Source: PNR .2002.

Population evolution (1981–2001):

- population increases where irrigation exists and decreases where it does not, and
- more stable population (except in some cold irrigation zones).

But, at present, the future of agriculture in an EU member state is linked to the response given to a number of demands imposed by society and global markets such as: human health and animal welfare, decreasing subsidies, compliance with an environmental legislation more and more restrictive, severe restrictions to the use of water and, at the same time, the need for farmers to produce a competitive market-oriented production. Only modern irrigation-based farms, using automated technologies, practising efficient water management with substantive water savings and complying prescribed good agricultural practices in the framework of the European environmental directives can face these challenges with certain guaranty of future.

Water use in agriculture in Spain

The agricultural sector is the most important user of water in the country, near 68 per cent of the total consumption. Table 2 shows the gross water demand supplied, 23 298 Hm3 which is very near to the estimated water demand for irrigated crops, 23 520 Hm3. The average efficiency of the irrigation bodies is very low — 60 per cent — because of substantive water losses through old conveyance networks and extended flooding irrigation systems. Before 2002, the starting year for PNR, 700 000 ha were irrigated by ditches and there was a network of concrete channels, more than 60 years old, in bad conditions through near 400 000 ha. A surface of 420 000 ha was irrigated using groundwater from over-exploited aquifers.

Table 2. Gross demand supplied and water consumption (hm^3) of existing irrigation bodies in the main river basins

BASIN	Gross demand Supplied (m^3/ha)	Irrigated area (ha)	Gross demand supplied (hm^3)	Water returns (hm^3)	Water Consumption (hm^3)
Galicia Costa	8.337	26.371	220	44	176
Norte	7.734	74.032	573	63	510
Duero	6.801	447.576	3.044	322	2.722
Tajo	8.262	201.336	1.663	230	1.433
Guadiana	6.657	335.590	2.234	236	1.998
Guadalquivir	6.635	602.966	4.000	505	3.495
Sur	5.620	142.457	801	75	725
Segura	6.240	276.316	1.724	157	1.567
Júcar	6.122	384.802	2.356	184	2.172
Ebro	8.033	738.662	5.934	962	4.971
Cataluña CI	5.962	67.774	404	36	368
Baleares	7.804	17.376	136	25	111
Canarias	7.147	29.379	210	27	183
TOTAL	**6.965**	**3.344.637**	**23.298**	**2.866**	**20.432**

Source: PNR. 2002.

Table 3 shows the origin of irrigation water sources in the Autonomous Communities. Currently, a number of new seawater desalination plants are into execution in Andalucía, Murcia and Valencia under the AGUA project.

Table 3. Distribution of irrigated areas (ha) according to watering main source

Comunidad autónoma	Surface water	Ground water	Transfers inter-basin	Returns	Sewage	De-salination	TOTAL
Andalucia	546.703	224.670	2.783	85	5.639	0	**779.880**
Aragón	373.886	20.315	0	321	0	0	**394.522**
Asturias	4.110	232	0	0	0	0	**4.342**
Baleares	21	15.895	0	0	1.460	0	**17.376**
Canarias	2.054	26.277	0	0	775	273	**29.379**
Cantabria	2.600	3	0	0	0	0	**2.603**
Castilla y león	361.055	113.164	0	12.428	29	0	**486.676**
Castilla-la mancha	124.262	228.528	1.011	0	0	0	353.801
Cataluña	205.031	53.043	0	6.377	342	0	**264.793**
Extremadura	207.337	3.151	0	0	0	0	**210.488**
Galicia	85.061	92	337	0	0	0	**85.490**
Madrid	25.650	1.789	0	0	534	0	**27.973**
Murcia	42.553	93.810	54.104	360	1.600	271	**192.698**
Navarra	79.941	1.682	0	50	0	0	**81.673**
P. Vasco	10.167	1.208	0	0	1.751	0	**13.126**
Rioja	45.771	3.564	0	0	0		**49.335**
C. Valenciana	146.691	154.821	40.258	4.178	4.534	0	**350.482**
TOTAL	**2.262.893**	**942.244**	**98.493**	**23.799**	**16.664**	**544**	**3.344.637**

Source: "Caracterización y Tipificación de los Regadíos Existentes", 2001.

Relating to irrigation methods, Table 4 shows that flooding still shares a great part — more than 1.2 million hectares — of the total area for many crops.

Table 4. Irrigation methods according to different crops (%)

Crop	Flooding	Sprinkler	Sprinkler with pump	Drip
Cereals	61,9	22,4	15,7	0,0
Citrus	37,4	1,2	2,0	59,3
Fruit trees	35,0	2,7	1,1	61,2
Fodder	60,0	26,1	14,0	0,0
Vegetables	23,0	18,8	8,1	50,1
Industry crop	23,8	55,5	9,5	11,2
Pulse	32,5	38,7	28,7	0,0
Olive grove	8,3	0,1	0,9	90,7
Potatoes	23,3	63,1	8,3	5,3
Vineyard	7,2	8,1	2,3	82,3

PNR modernisation works developed into traditional irrigation zones are creating growing areas for sprinkling and dripping methods. It is interesting to outline the significant increase of dripping in olive grove and vineyard during the last years.

Figures 1 and 2 show the diverse distribution of irrigated crops in two different regions of the "Peninsula".

Figure 1. DISTRIBUTION OF CROPS IN THE EASTERN AND SOUTHERN REGIONS

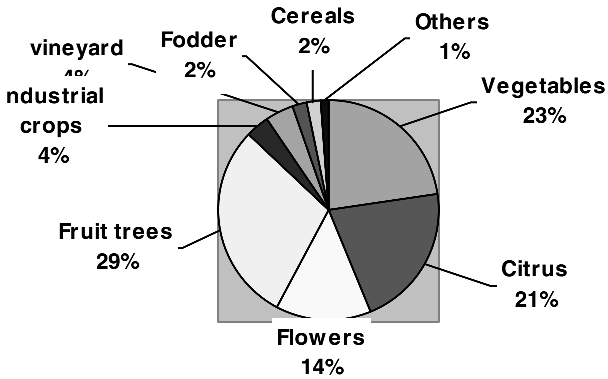
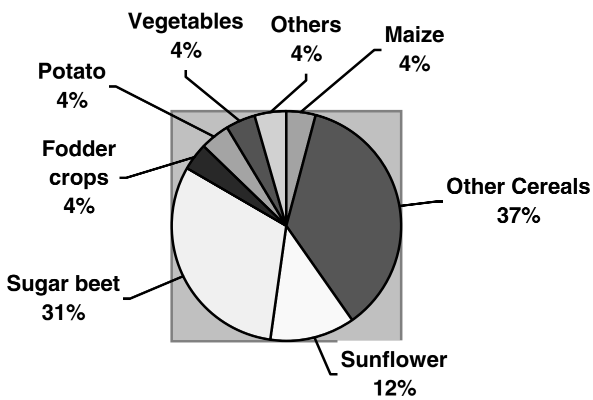


Figure2. DISTRIBUTION CROPS IN NORTHERN "MESETA"



The Spanish National Irrigation Plan — Horizon 2008

After more than seven years of studies, research and enquiries the Royal Decree 329/2002, enacted in 2002 was the starting point for the National Irrigation Plan — Horizon 2008 (in Spanish, Plan Nacional de Regadíos, PNR) as a response to the new challenges and society demands for the Spanish irrigation-based agriculture, with actions aimed at:

- saving water and rationalising water management in irrigation bodies
- contributing to consolidate the national agro-food system under the framework of the CAP and the market evolution
- improving social and economic status of farmers
- contributing to the territorial balance, maintaining population in rural zones
- controlling the inputs use, reducing diffuse pollution and water consumption, and
- incorporating other environmental aspects into the management of irrigation bodies.

The PNR implementation is based on principles of coordination and cooperation with the autonomous administrations and the stakeholders, mainly those grouped into irrigating farmer's communities.

Actions included in the PNR are implemented through agreements between the State General Administration (SGA) and the autonomous governments and between the SGA and irrigating farmers' communities.

The PNR include five action programmes:

- improvement and modernisation of traditional irrigation bodies
- infrastructures in irrigation bodies into execution, completing works in the big irrigation zones created during the twentieth century
- new infrastructures for social purposes, implemented in irrigation zones of less than 2 000 ha, in order to maintain population in rural settlements
- new infrastructures in private irrigating farmers communities, implemented in irrigation zones of less than 2 000 ha to consolidate local agricultural production, and
- supporting programme: includes monitoring and permanent assessment programmes, training, dissemination of modern technologies and complementary studies.

Table 5 shows the diverse importance of the programmes in surface and investment.

Table 5. PNR programmes

Programme	Surface (ha)	Investment (mill. EUR)
Improvement and mod.	1 134 891	3 056.5
Zones into execution	138 365	1 136.6
New infrs. social purposes	86 426	681.9
New infrs. Private IC	18 000	123.8
Support Programme		25.7
TOTAL	**1 377 682**	**5 024.5**

The investment of each participant in the total amount is in Table 6.

Table 6. PNR actors investments

Total investment	**5 024 575 385 €**
Private investment	2 007 260 227 €
Public investment (MAPA)	1 430 396 788 €
Public investment (Autonomous Comms.)	1 586 918 370 €

Financing in the PNR

Improvement and modernisation Programme through MAPA

Farmers financing	**50%**
Agriculture administration	50%

Zones into execution and infrastructures with social purposes (according to the Agricultural Reform and Development Law)

National general interest works	**100% financing**	**100% granted**
Communal interest works	100% financing	40% granted
Agricultural private interest		30% granted

Improvement and modernisation programme through SEIASAS

The SEIASAS are State-owned companies created to promote and implement irrigation modernisation works through direct agreements with irrigating farmers communities. There are four SEIASAS occupying the national territory divided into four districts: north, northeast, southern “Meseta” and south and east.

The SEIASAS finance in advance the full cost of the modernisation works but farmers have to pay 50 per cent at the starting of the works as an amortisation tariff. The remaining 50 per cent is paid from the 26th year in 25 instalments.

Current and future figures of the PNR Programmes

At the end of 2004, the situation of the works of the different programmes can be seen in Tables 7 and 8:

Table 7. Surfaces (31 December 2004)

Programmes	Surface (ha)		% Programmed execution
	Programmed	**In execution**	
Modernisation	1 134 891	1 384 696	122
Zs. into execution	138 361	136 095	98
Social purposes	86 425	35 594	41
Private comms.	18 000	7 296	40
TOTAL	**1 377 682**	**1 563 681**	**113**

Table 8. Investments (31 December 2004)

Programmes	Total investment (EUR)		% Programmed execution
	Programmed	**Executed**	
Modernisation	3 056 591 302	1 504 487 055	49
Zs. into execution	1 136 567 982	341 536 622	30
Social purposes	681 908 331	96 177 192	14
Private comms.	123 808 492	19 768 218	16
Support programme	25 699 278	28 502 612	111
TOTAL	**55 024 575 385**	**1 990 471 699**	**40**

Water saving in irrigation is the result of several actions:

- control of the existing supply
- reduction of gross demand by reducing water losses in the conveyance networks, improving efficiency in watering methods, growing less water demanding crops, and
- reducing water returns of the irrigation.

The estimated water saving achieved by the modernisation works executed during 2004 amounts to ***844 Hm^3*** and the expected water saving at the end of the 2008 could be more than ***2 100 Hm^3*.** The improvement of water management and water saving will reduce groundwater abstractions in zones with over- exploited aquifers.

With respect to the social objectives, in the new irrigation zones, more than 25 000 new jobs and 21 500 Units of work are expected. But the tendency for the next future irrigation policies is to limit new irrigation areas.

Water management in modern irrigation-based farms is conducive to a better control of the use of inputs like fertilisers and pesticides, so that diffuse pollution can be reduced.

Nevertheless, the PNR has an environmental monitoring programme which, for the moment, controls the compliance with the environmental impact assessments of the infrastructure works, and when the modernised irrigation bodies will be working, will permit knowledge of how the PNR is meeting its objectives.

Chapter 24.

Progress with Water Allocation Reform in South Africa

Ashwin R. Seetal[1]

In implementing South Africa's National Water Act (36 of 1998), the Water Allocation Reform (WAR) programme is a proactive intervention to address race and gender imbalances created in the water sector as a result of historical discriminatory legislation in the country. Its conceptualisation and implementation fits firmly within the ambit of integrated water resources management (IWRM); however, its focus is primarily socio-political, dealing with the re-distributive aspects of water allocation reform. WAR has a formally legislated political mandate and its scale is national. Although it is primarily socio-political in its focus, a wide range of specialist considerations supports it. For these reasons, the programme is multidisciplinary and complex. Success with its implementation will result in greater socio-political and socio-economic stability for the country, and support the contention that socio-centric elements of IWRM are equally, if not more, important than techno-centric ones in particular instances. The paper describes an IWRM implementation approach with socio-politics at its forefront, one that is purposeful and process-driven as a potential recipe for success. In addition, potential risks and threats are identified and their likely impacts briefly highlighted.

1. Introduction

Water Allocation Reform (WAR) in South Africa forms part of the government's overall post-apartheid programme of reform and redress of past discriminatory legislation that started with the advent of democracy in 1994. Within the water sector, reform commenced formally in 1995 with the Water Law Review process (DWAF 1995, 1997a). This legal review process culminated in the "White Paper on a National Water Policy for South Africa" (DWAF 1997b) and two sets of water legislation, namely, the Water Services Act (108 of 1997) (Anon 1997) and the National Water Act (36 of 1998) (Anon 1998). The process is described in several earlier papers (Ashton & Seetal, 2002; Ashwin R Seetal, 2002; Ashwin R Seetal, 2004; Ashwin R Seetal & Gavin Quibell, 2003a; Roland Schultze *et al*, 2004). The WAR programme is located within this broader water sector reform process.

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All elements of integrated water resources management (IWRM) are factored into the WAR programme; however, particular emphasis is given to the socio-political dimension of IWRM to help remove the perception of IWRM as a techno-centric process with the "people element" being incidental. In South Africa, the engineering, technical and scientific disciplines have traditionally featured prominently in IWRM creating and reinforcing perceptions of this exclusivity. An envisaged outcome from the WAR programme is the "socialisation" of IWRM, particularly by bringing together land- and water-use management and actively engaging people in the management of both resources. Although WAR is primarily socio-political in its focus, it is supported and informed by a wide range of specific considerations, including *inter alia* legal, technical, scientific, institutional, environmental, financial and economic issues.

The race and gender re-distributive component of the WAR programme is given specific attention because, to date, little concerted action has been taken to address this socio-political element of IWRM in South Africa. As the country enters its second decade of democracy, this lack of progress has the potential for conflagration, resulting from the impatience of the historically disadvantaged majority in the country. On the flip side, the minority historically advantaged sector are insecure regarding their historic entitlements to water use.

In the introduction to the National Water Policy (DWAF, 1997b) it is stated that "The new water policy embodies our national values of reconciliation, reconstruction and development so that water is shared on an equitable basis, so that the needs of those without access to water in their daily lives are met, so that the productive use of water in our economy is encouraged, and so that the environment which provides us with water and which sustains our life and economy is protected." Accordingly, in support of government's commitment to nation building in forging "A South Africa that truly belongs to all", the WAR programme was designed to contribute to the socio-political and economic stability of the country in its implementation, but also to tangibly engage IWRM and give substance to its ideals from a socio-centric perspective. This paper follows on earlier publications and presentations on the programme and provides an update on progress.

2. Legislative provisions and considerations — A recap

The previous water law, which was based on the Roman and Dutch riparian rights principle, gave access to the resource to those who owned land. The minority white population (3 per cent) owned approximately 87 per cent of the land and a land reform programme was established to address this anomaly (Ashwin R Seetal & Gavin Quibell, 2003a). Although the riparian rights principle and the concepts of public and private water have been abolished, their legacy still endures and all lawful water use in terms of these and other relevant statutes are recognised by the current National Water Act (NWA) and are accommodated within the WAR programme (Ashwin R Seetal & Gavin Quibell, 2003b).

Water use under the previous legislation was also allowed on the basis of the availability of water and priority of application for its use, i.e. on a first-come-first-served basis. Most of this was largely unregulated, also because of the principle of riparian rights and the concepts of "public" and "private" water and "normal" and "surplus" flows. Regulation of water use was greatest in the Government Water Control areas, i.e. areas where the previous government had developed the resource by building dams, irrigation supply canals and/or providing other infrastructure. Here, co-operative groups of agricultural water users (Irrigation Boards) had their water use scheduled and an element of self-management prevailed (Ashwin R Seetal & James Perkins, 2003).

The approach proposed by the NWA is framework-based and much more strategic, deliberate and dictated by socio-political reforms and socio-economic development needs on a programmatic basis for long-term sustainability. The approach is also more systematic, but resource intensive and demanding in the inception period (Ashwin R Seetal & James Perkins, 2003). The Act also makes specific prescriptions to ensure that there is a balance between "individual rights" and the "public interest" in allowing access to water resources, or to the benefits from the use of water resources. Proactive implementation of the reform aspects of the NWA has been slow to date.

As South Africa enters its second decade of democracy, this continued slow progress with implementation will further exacerbate the current situation of increasing unlawful and/or unsustainable use of water resources by both the historically advantaged and disadvantaged sectors of South African society. It is for these reasons that the WAR programme was formally and publicly launched in April 2005 by the Minister of Water Affairs and Forestry, to demonstrate its political importance to the country and government's commitment to its speedy implementation.

Some other legislation that directly impacts on the WAR programme includes the Constitution of South Africa, the Promotion of Administrative Justice Act and the Intergovernmental Relations Framework Bill.

3. Programme and conceptual framework

The programme is comprised of three distinct phases, briefly described as follows:

Phase 1: Vision and approaches — identifies a common vision and clarifies the principles or "rules of the game" for the programme. This is also the phase where specific processes and interventions are identified and approaches, methods and tools for implementation are developed.

Phase 2: Implementation — although this should sequentially follow on from Phase 1, much preparatory background work is undertaken to develop a coherent picture of the status of the resources in preparation for the formal engagement with stakeholders.

Phase 3: Auditing, monitoring and evaluation — the successes and failures of interventions and the attainment, or not, of envisaged outcomes is established to inform future processes.

Phase 1 has both national and catchment perspectives. The national perspective is the overarching one and guides specific catchment perspectives (the Water Allocation Frameworks) which vary around the across the country. Phases 2 and 3 relate to specific local interventions, although the approaches, methodologies and tools are developed as generic instruments for application across the country. Notwithstanding these factors, financial and other resources must be secured and mobilised in support of each of the three phases, nationally and locally.

4. Progress: Specific sub-components

The sub-components listed below were identified as specific interventions or considerations required within the programme and many were mentioned in an earlier paper (Ashwin R Seetal & Gavin Quibell, 2003a). This section of the paper describes progress with several sub-components, which may otherwise not receive adequate attention elsewhere in the paper.

Capacity development and communications

The integrated set of eight aspects of capacity development to be addressed within the programme included: mandate; policy instruments; organisational structure; technical skills; procedures; planning and problem-solving skills; financial; and capital and networking skills. A ninth, and perhaps most critical, component was added concerning willingness or desire to use the water (enthusiasm). The development of procedures and methodologies for water use reform around these nine components were recognised as a critical intervention to support sustainable water use reform.

Studies that have been completed include a sector-wide capacity gap analysis and a capacity building strategy in support of WAR. However, some difficulty has been encountered with the implementation of a Capacity Development Programme of Action specifically targeted at women and the poor.

The strategy for the communications programme has included printed materials in the form of posters, pamphlets, a newsletter, newspaper and tabloid advertisements. These have been developed and used to showcase the programme, encourage participation in aspects of the programme and for capacity development. In addition, other communications media include television interviews and discussions, and community radio stations. A range of awareness materials currently being developed, includes:

- a shorter version of the position paper, translated into the eleven official local languages
- a pamphlet on “What is Compulsory Licensing?”
- a pamphlet on “What is Verification and Validation?”; and
- a booklet on “How do you make productive use of water?”

The most resource intensive approach used to date has been one-on-one communication and capacity building with different sectors — geographic, economic or interest-based. This approach is usually the most rewarding.

Importantly in South Africa, all the relevant communication materials are translated into all eleven official languages, even though this places a substantial cost burden on the programme. The value of this exercise substantially outweighs this cost.

The water use context

According to the National Water Act, “water use” includes the consumptive use of water, the use of water to carry waste, storage of water, impeding or diverting the flow in a water course, and stream flow reduction activities (such as commercial forestry). The terms “water use” and “water use allocation” refer to water use as defined in Section 21 of the National Water Act. Water use may refer to use of either the surface or groundwater resource. All of these uses of water form part of the process of water use allocation and, therefore, part of the programme.

Much of the thinking with respect to allocation planning and compulsory licensing (a specific intervention in which water allocation plans are developed and licenses for water use issued on a catchment-wide scale) has focused on the consumptive use of water, and primarily on water for irrigation. However, other uses of the water resource are included as well. In particular, these include the challenges concerning reallocation of licenses for water used to carry waste.

The WAR programme prescribes the most beneficial use of water, which, unless demonstrated, could result in the reallocation of water between inefficient and unproductive users and sectors to more productive ones. WAR, and the methodologies developed by the programme, attempts to give effect to the goal of "beneficial use in the public interest" and preaches the slogans "more crop/rands/jobs per drop" of water used.

The current emphasis on consumptive use of water by irrigated agriculture is that use by this sector accounts for approximately 62 per cent of the water use in South Africa. Although irrigated agriculture makes a relatively small contribution to South Africa's gross domestic product (primary agriculture: 4%), it provides socioeconomic stability to rural society (DWAF, 2004). Much of the socioeconomic stability provided by agriculture in rural areas comes from providing employment to rural communities. National employment in agriculture is 11 per cent, and of this only 10–15 per cent is in irrigated agriculture. However, agriculture provides much of the country's food security. Market gardening initiatives are one of the most viable ways of securing a better life for the rural poor.

Currently, irrigation water is still primarily in the hands of a few white farmers. Clearly, this pattern must shift. Many of the existing irrigation water users feel disenfranchised by the new dispensation and may not willingly cooperate with the reallocation process, which may slow down reallocation. Willing cooperation from this sector is also important to ensure adequate cost recovery for water use, and will be critical to the sustainability of future catchment management agencies. The manner in which the programme will engage these existing water users, and the way it shifts water use patterns, is therefore critical to successful water use reform and for maintaining economic growth and investor confidence.

Current water use patterns in South Africa show not only a racial bias, but also a gender bias. Even though in many rural households women are the primary decision-makers and have the responsibility for raising crops to feed the family, land ownership is often in the hands of the male members of the household. Gender inequality may therefore be further entrenched by linking water use to property rights over land. The water reform process must recognise and correct these gender inequities in water use.

The National Water Resources Strategy (NWRS)

The first edition of the NWRS (DWAF, 2004), which outlines South Africa's current and future water situation and outlines reconciliation interventions to balance water availability with water requirements, was formally approved in September 2004.

Within this framework, the National Minister retains responsibility for:

- specifying the requirements of the Reserve;
- specifying the water required for international obligations;
- specifying a contingency to meet future needs;
- authorising transfers between water management areas; and,
- authorising water use for strategic purposes (e.g., power generation).

The national Department of Water Affairs and Forestry will administer these on behalf of the Minister. Management of water resources outside of these functions may be delegated to Catchment Management Agencies (CMAs) — when they have the required capacity (see Catchment Management Agencies below).

WAR sits at the heart of the NWRS and the NWRS highlights a number of catchments and Water Management Areas that are likely to be water stressed. The water allocation process in these catchments may require curtailing existing lawful water uses to achieve greater equity. If so, the compulsory licensing process will be used in these catchments as a tool for reallocation. Accordingly, the NWRS has outlined a programme for compulsory licensing in 100 significant surface and groundwater resources based on these reconciliation scenarios.

Water use authorisations and compulsory licensing

The National Water Act makes provision for the authorisation of water use in three ways. Schedule One use includes relatively small quantities of water mainly for domestic purposes and stock watering. General Authorisations conditionally allow limited water use without a license. Water Use Licenses control all other water uses.

Water use licensing will be the tool used to ensure equity in water use. In water-stressed catchments, all water use can be reviewed via a compulsory licensing process. Compulsory licensing may be used to:

- achieve fair allocation in stressed catchments;
- review prevailing water use to achieve equity;
- promote the beneficial use of water in the public interest; and,
- facilitate efficient management of the resource and protect resource quality.

Given that inequities in water use exist in almost every catchment, compulsory licensing will be undertaken across the country. However, the greatest challenges for reallocation will emerge in situations where there is insufficient water, or where water quality is affecting water use, and existing lawful use of water will have to be curtailed to meet the needs of equity. Cutting back on existing lawful use has complex political, legal, and economic consequences. The manner in which this is done is critical to sustainable development in South Africa.

Several mechanisms can be used to reconcile water requirements, achieving greater equity without significantly curtailing existing lawful water use. In many catchments, a doubling of water use by small-scale irrigation farmers would not require significant reductions by the large-scale users. In these cases water conservation and demand management should be used as a first option to reduce water use without affecting economic returns. Similarly, the removal of alien vegetation can increase water availability. Resource management options such as increased storage, regulation of stream flow, or interbasin transfers may also increase water availability.

More challenging circumstances could arise in situations in which these interventions will be insufficient to meet demands, and existing lawful water use will have to be reduced to ensure greater equity, to achieve certain water quality objectives, or to shift to more productive water use sectors.

Reallocation issues

The National Water Act provides for existing lawful users to claim compensation in cases where they may suffer "severe prejudice to the economic viability of the undertaking" because of water curtailments. However, water users may not claim compensation where the reduction in lawful use is required to:

- meet the needs of the Reserve (see below); or
- rectify an over-allocation; or
- rectify an unfair or disproportionate water use.

These provisions were checked for constitutionality when the Act was promulgated. However, the way in which these provisions are exercised and the way in which reallocations of water are carried out, may give rise to challenges for compensation. It is therefore important for the allocation procedures to be administratively reasonable, fair, and consistent.

Resource-directed measures

The National Water Act outlines two complementary approaches toward protecting the water resource: resource-directed measures and source-directed controls. Source-directed controls would take effect through the water use licensing process described earlier. Resource-directed measures focus on the overall health of the water resource and include mechanisms to protect the character and condition of river and riparian habitats and aquatic biota. Resource- directed measures currently under development by DWAF include the following:

- development of a National Classification System for water resources;
- determination of the class of each significant resource;
- determination of the Reserve in accordance with the class of the resource; and,
- determination of Resource Quality Objectives.

The Reserve represents that quality and quantity of water required to protect aquatic ecosystems and to meet basic human needs. It has priority over all other water uses. This portion of the available water is under the direct control of the Minister. The Act specifies that the requirements of the Reserve must be met before water can be allocated to other uses. However, where the water is already allocated to other users, requirements of the Reserve may be met progressively over time. The Reserve therefore has a significant impact on allocation planning. The NWRS indicates that the determination of the Reserve, the resource class, and the resource quality objectives will form part of the compulsory licensing process.

The basic human needs component of the Reserve provides water necessary for survival (currently set at 25 litres per person per day). Water for domestic use is regarded as a Schedule 1 use, and so does not require authorisation. All other human uses of the resource would be subject to authorisation.

Currently, the Preliminary Reserve (basic human needs and ecological) has been determined at a desk-top level for the entire country. Studies are being undertaken to determine these reserves at a comprehensive level in several catchments.

Catchment Management Agencies (CMA)

The National Water Act provides for the delegation of water resources management to the lowest possible level. The NWRS has subsequently outlined a programme for the establishment of these water management institutions.

CMAs will ultimately be responsible for water use allocation in catchments. However, the powers and functions retained at a national level specify the water that will be available for reallocation, and can therefore have a profound impact on the allocation process by the CMA. The way in which the national department interacts with the CMA in this respect is therefore critical. Methodologies for water use allocation must resolve these institutional interactions.

Currently, one CMA has been established and seven are close to establishment; these out of a total of 19 proposed CMAs for the country.

Monitoring

Chapter 14 of the National Water Act places a duty on the Minister to develop National Monitoring Systems. The purpose of these systems is to facilitate the monitoring of water resources and water resources management processes, so as to provide information to water users, water management institutions, and the public. This information is critical not only for the effective and efficient management of water resources, but also to demonstrate that management of the water resource is realising benefits for all. This is particularly important given the sensitivities about the water reallocation process, and because the ultimate success of the process will largely be determined by the extent of willing participation by all existing and potential future water users.

The application of the methods developed in other water management areas also rests on demonstrating their efficacy in the test catchments, and using these results to encourage the future CMAs to initiate implementation. Activities have been aimed at developing monitoring systems for measuring the impact of the processes, particularly in terms of improved livelihoods for the rural poor, and for linking these to the monitoring systems. This has required the inclusion of socioeconomic data into the national monitoring system. This form of monitoring is expensive, and the NWRS already indicates the need for considerable investment in water resources monitoring systems.

A number of monitoring frameworks are under development. However, many water resources managers who have little appreciation and understanding of social indicators in water resources management have resisted the use and inclusion of socioeconomic indicators and have delayed the implementation of these frameworks.

Assistance to emerging users

One of the primary goals of this programme is to ensure that the rural poor realise tangible benefits from using water. This is possible only if emerging users have the means, both financial and technical, to develop infrastructure to use the water productively. In this respect, Section 61 of the National Water Act makes provision for financial support in specific circumstances. Accordingly, a "Policy for Financial Support to Resource Poor Farmers" has been developed and is currently being implemented. This policy provides for support under six conditions — ranging from support to individual small water use to large communal irrigation schemes. In addition, the Raw Water Use Pricing Strategy indicates that water user charges for emerging farmers could be subsidised (decreasingly) over a period of five years, or waived under particular circumstances.

Assistance to emerging farmers also includes the alignment of support from other government departments, especially the Departments of Land Affairs and Agriculture.

5. Progress: Phase I — Vision and approaches

A draft Position Paper for Water Allocation Reform in South Africa, under development since October 2003, formed the basis and focal point for this phase of the programme. Its primary purpose was to provide an aligned and collective vision for the programme that all could identify with and relate to as a point of reference.

The first challenge to the programme was to converge the diversity of opinions that people, within and outside the department, had on the way water allocations and re-allocations should be dealt with. Thus, very early in the programme, and preceding the development of approaches and methods to promote race and gender equity in water allocation, the basis and mandate was derived from the Constitution, National Water Policy, National Water Act and other related legislation. The outcome of this was the draft "Position Paper for Water Allocation Reform in South Africa."

The position paper outlined the high-level "rules of the game" for allocating water to promote race and gender reform, while at the same time supporting government's programmes of poverty eradication, job creation, economic development and nation building. This included addressing the expectations of the historically disadvantaged majority South Africans and dealing with the fears and uncertainty of a historically advantaged minority, primarily by minimising the impacts on existing lawful users and the supporting the stability of the rural economy.

Early drafts of the position paper were presented to an expert panel comprised of a range of experts representing different disciplines and constituencies including the rural poor, water poverty, water law, politics, hydro-politics, as well as experts in strategic water resource management. Inputs from this group were used to refine the document, which was then presented to the Department of Water Affairs and Forestry for endorsement and a mandate to table this paper for public discussion. Permission was given to solicit comment from the department prior to its public dissemination.

Presentations were made to 17 business units within the department. Additional presentations were made to the National Water Advisory Council (NWAC), an advisory committee to the minister and to the Parliamentary Portfolio Committee, a political oversight body of government. Comments were invited from these groups, and a final draft position paper was prepared along with a consolidated comments/ response report. This was re-submitted to the governing structures of the department in November 2004, for endorsement as a formal draft DWAF discussion document to be made available for public comment.

The Minister formally launched this draft and announced the commencement of the WAR programme in April 2005. The workshop was used to introduce stakeholders to the document and to solicit their inputs on its content. Feedback from this first workshop and a further nine provincial workshops, completed in July and August 2005, will be used to update the draft position paper, which will then be presented to the department for a final decision on the way forward.

The workshops held in each of South Africa's nine provinces were organised by nominated lead agents who have been designated the "Regional WAR Champions". Their role is one of coordination, facilitation and leadership of the programme within their respective constituencies. In preparing these champions for their roles, specialised training sessions have been developed to equip them with the appropriate skills and competencies to carry out their functions. Some of the competencies included: arranging workshop logistics, preparation, presentation, facilitation and conflict resolution skills.

Workshop attendance ranged from approximately 60 to 200 delegates per workshop and documented proceedings are in the process of finalisation. Media coverage, both radio and print, of the workshops was satisfactory to good. Delegates' participation in discussions was excellent and many difficult political issues were raised.

6. Progress: Phase II — implementation

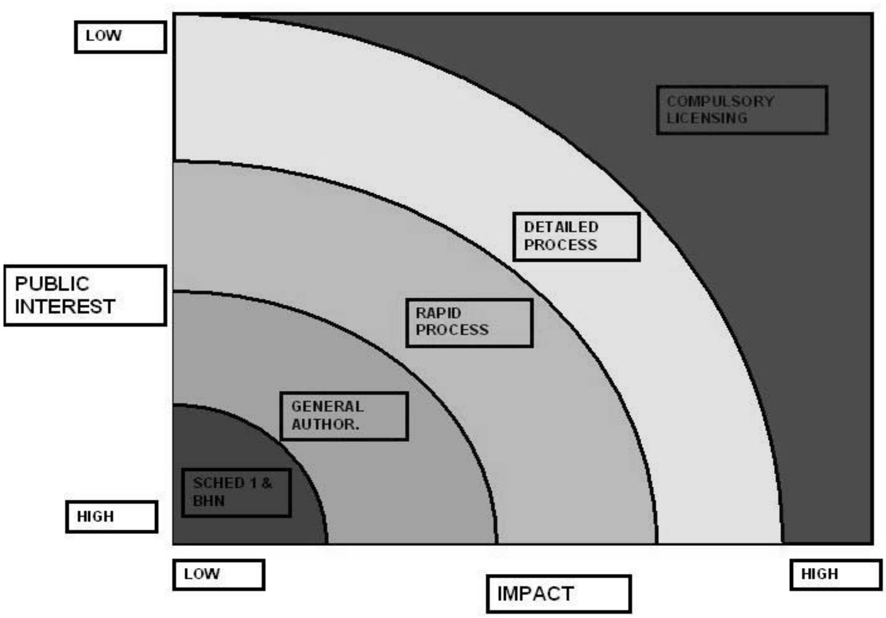
The backbone of this phase is the "Toolkit for Water Allocation Reform — A Manual to help Achieve Race and Gender Equity in Water Allocations" and the Regional WAR Champions. This phase addresses the coordinated implementation of NWA activities as a coherent approach towards achieving the goals and objectives of the programme at a local and regional level. It is also intended to ensure the effective implementation of the NWA, as articulated constitutionally and in the National Water Policy.

The Toolkit for Water Allocation Reform

Draft 4 of the "Toolkit for Water Allocation Reform" was presented to the department in July 2005, with a request for its internal roll-out, for comments, further inputs and refinement. The draft Position Paper forms the basis of the toolkit and outlines practical methods for WAR implementation. It also uses practical examples to demonstrate water allocation projects that illustrate the steps that can be followed to give effect to water allocation reform.

The toolkit is based on a Licence Streaming Concept (Figure 1) developed in consultation with the regional offices. This “expert advisory system” is based on Section 27 of the NWA, and helps regional officers determine an appropriate level of impact assessment, preliminary Reserve determination, as well as a priority rating for any individual application. The toolkit also provides support to rolling out the compulsory licensing process (DWAF, 2005).

Figure 1. The conceptual Licence Evaluation Streaming Model that gives effect to Section 27 of the National Water Act



Validation and verification guide

A draft “Guide for the Validation and Verification of Water Use”, developed in July 2004 has already been used in projects in several catchments. Its usefulness has already been demonstrated in these projects and recommendations have been made for amendments to fine tune aspects of the methodology.

What has become apparent within the department is the lack of knowledge and understanding of Sections 32 to 35 of the Act (that deal with the validation and verification of water use), and the linkages with particular administrative processes; for example registration, existing lawful use, current use and WARMS, compulsory licensing, etc. A lack of understanding of the linkages between these legal, administrative and management processes would result in unnecessarily complicated preparative processes for WAR implementation, especially where legal challenges are bound to arise. A correct understanding of the application of, and linkages between processes, will support speedy implementation and minimising the legal risks to the department and government.

Rollout of the compulsory licensing process

The compulsory licensing process will be initiated in three catchments within the following year. These processes are being initiated by undertaking *status quo* studies of water use in the catchments. The studies are used to "set the scene" with stakeholders, and an outcome of this process being the establishment of Compulsory Licensing Steering Committees or Working Groups of stakeholders in the catchments concerned. Draft catchment assessment reports (CAR) have been compiled, which are evaluated by the operational departmental staff and stakeholders prior to being tabled as an information/discussion document in support of compulsory licensing.

Improving the licence processing and allocation systems

Much of the success of the WAR programme rests on being able to rapidly respond to applications to use water. Steps are being taken to develop and/or acquire systems that expedite the efficient evaluation of licence applications during compulsory licensing. These include a CD based allocations support system that will help personnel collate and report on the current state of water allocation reform on a quaternary catchment basis. This process will also support the allocation process in these catchments, as outlined in the Toolkit.

Linkages and partnerships

The provincial WAR workshops have provided excellent opportunities for forging stronger links with civic structures, state and para-statal structures and for strengthening the involvement of the regional office staff of the department in the programme. These are being further pursued with the intention of formalising some of the partnership; for example, memoranda of understanding.

7. Progress: Phase III — auditing, monitoring and evaluation

The limitations within this phase of the programme have presented particular challenges regarding its design at the outset, and its effectiveness during and post-implementation. The absence of data regarding the extent of water use on a gender and race basis has delayed the development of a monitoring protocol for these attributes.

8. Risks and threats

Five potential risk areas have been identified and include:

- lack of committed departmental high-level support for WAR;
- an inability to effectively address human resource capacity constraints in the provincial offices of the department in a timely manner;
- performance in "bad faith" by internal and/or external partners during the WAR process resulting in obstacles to co-ordination — these include power-blocs and turf-battles;

- increased turnover in WAR-trained personnel (“Champions”); and
- possible legal challenges during compulsory licensing.

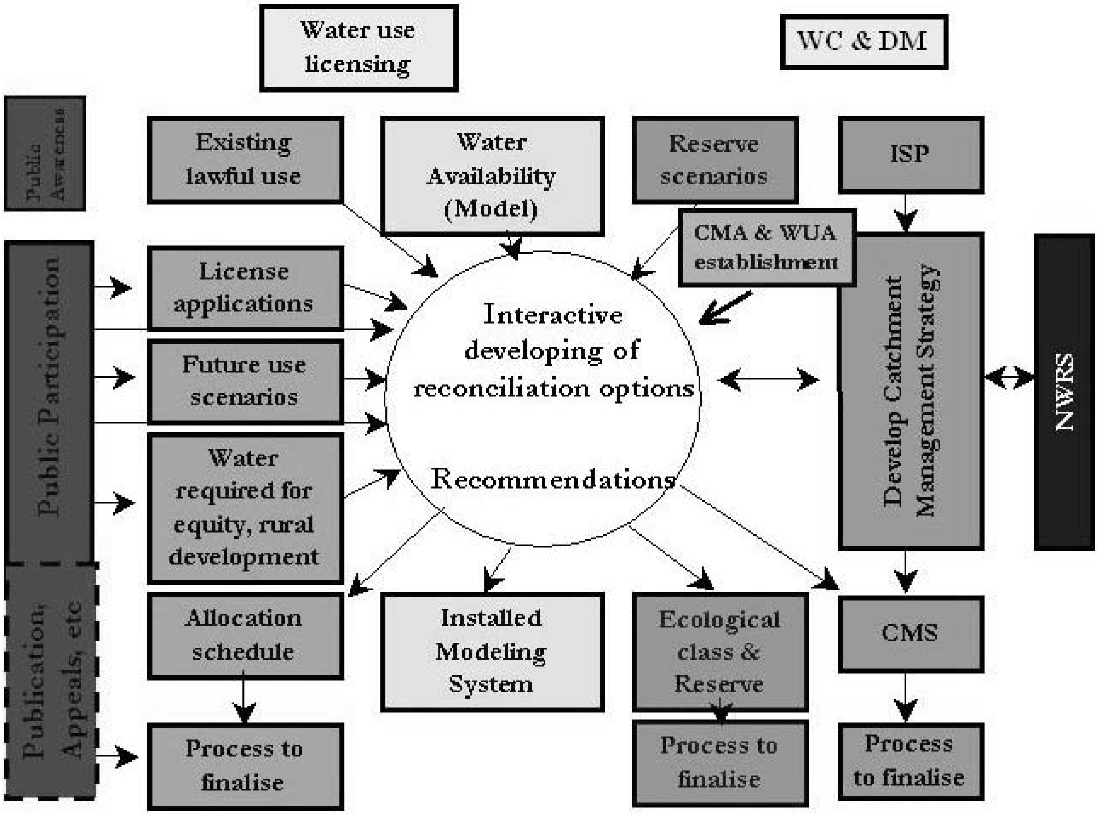
The risk management and mitigation measures mainly relate to issues of process (consistency, fairness and reasonableness) regarding legal matters, creative innovation regarding capacity and resources constraints and shrewd negotiation tactics in dealing with issues of bad faith and power blocs. A potential fatal risk factor is the lack of high-level departmental support for the programme, which only a political intervention could neutralise.

9. Conclusions and way forward

South Africa has embarked on one of the most ambitious redistributive water rights reform processes in the world. These reforms must be seen as a process, not something that is accomplished all at once (Ashwin R Seetal & Gavin Quibell, 2003a). Figure 2 depicts some of the complexities and considerations that are factored into the WAR programme. Although this is a simplistic illustration, that does not give an exhaustive account of the multitude of considerations, it does indicate the land use and water use planning linkages and the interfaces between public engagement, planning and the other water management disciplines. Each box within the diagram can be further exploded out into greater detail.

The WAR roll-out has commenced, even though the cost and capacity requirements for the entire programme have not been fine-tuned. Experience to date has demonstrated the value of practical and common sense approaches to implementation of all aspects of the programme. These must be mixed with a healthy dose of innovative, out-of-the-box thinking and, finally, an appreciation that no matter how sophisticated the technical tool or model is, it has no value and cannot substitute for good-faith people participation in complex processes of this nature where adaptive management is the preferred and demonstrated successful approach.

Figure 2. An illustration of the structural and institutional linkages for the various considerations taken into account in the WAR programme, specifically its implementation



NWRS = National Water Resources Strategy;
ISP = Internal Strategic Perspective (a catchment situation assessment);
CMA = Catchment Management Agency;
WUA = Water User Association;
WC & DM = Water Conservation and Demand Management.

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Chapter 25.

The Challenge of Reconciling Water and Agricultural Policies — The Role of Public Hearings

Denis Boutin[1]

In recent years, the Québec government has introduced new measures that significantly reinforce frameworks for both water protection and agricultural activities. In late 2002, it adopted the Québec Water Policy, which undertakes to introduce a watershed-based management strategy for cleaning up watercourses and intensifying agricultural clean-up efforts. Agricultural policies have also been undergoing important transformations in Québec over the past few years. The Regulation Respecting Agricultural Operations has reinforced controls over agricultural pollution, while the policy directions for the sustainable development of hog farming, adopted in 2004, have led to the implementation of new measures and requirements favouring the integration of sustainable development principles in pig farming. These changes were legitimised by extensive public consultations conducted by a specialised office for public hearings on the environment, the Bureau d'audiences publiques sur l'environnement (BAPE). Through these consultations, BAPE provided advice and recommendations to guide government decision-making with a view to sustainable development. It held comprehensive public hearings on water management in 1999–2000 and on sustainable development for hog farming in 2002–2003. These two consultation processes were the key events on which current reforms are based, and they have contributed to meeting the challenge of reconciling water and agricultural policies.

Introduction

Although water is often the resource most affected by farming activities, agricultural pollution frequently appears as the most difficult form to prevent and clean up. This is mainly due to the fact that it is non-point source pollution that involves many different farm operations, using very diverse practices and spread over a large territory with varying biophysical characteristics. To counteract the environmental impacts of agriculture, governments are seeking to exercise greater control over agricultural activities. However, reducing agricultural water pollution remains a challenge to policymakers, with no clear pathway to success.

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In Canada, jurisdiction over agriculture and water is shared between the federal and the provincial governments, but agricultural production and freshwater management and protection are primarily provincial responsibilities. The Québec government is therefore a very active player in both these fields. In recent years, it has made some significant advances in protecting water from agricultural pollution, notably as a result of extensive consultations on related issues. These processes are presented in the following sections as well as their outcomes.

The water management hearings

A consultation process on freshwater …

Québec's renewable freshwater resources account for 3% of the world's total reserves. To preserve the abundance and quality of this resource, the Québec government launched an initiative in the late nineties to develop a water management policy based on principles of sustainable development. One of the key steps in this process was an extensive series of public hearings conducted in 1999–2000 by the *Commission sur la gestion de l'eau au Québec* (Québec water management commission), which was set up by the *Bureau d'audiences publiques sur l'environnement* (BAPE, or office for public hearings on the environment). A brief description of BAPE is presented in Box 1. All of Québec's administrative regions were visited twice by the Commission, first to provide the public with information on various water-related issues and, second, to receive proposals from individuals and groups interested in water management and the protection of both public health and aquatic ecosystems. During the hearings, the Commission held a total of 143 public sessions, received 379 briefs and heard over a thousand citizens and stakeholders.

This process led to a comprehensive report by the Commission entitled *L'eau, ressource à protéger, à partager et à mettre en valeur* (Water, a resource to protect, share and develop) (BAPE, 2000). The report addressed strategic issues related to freshwater management (massive exports of freshwater, commercial use of groundwater and the privatising of water services); presented a description of regional concerns and priorities regarding freshwater; and emphasised the importance of involving native people in developing Québec water policy. It also identified the various issues and objectives related to water and aquatic ecosystem management, as well as possible actions and measures that could be included in a water policy. As a general recommendation, the commission stressed the importance of adopting an integrated water management approach at the watershed level, notably for the St Lawrence River and its tributaries.

… which identifies the need for better control of agricultural pollution

One of the major concerns identified at the hearings was the control of agricultural pollution. The Commission concluded that most of Québec's efforts in this area to date have focused on manure storage facilities, a form of point source pollution, while not enough has been done to target non-point source pollution. The report indicates that "non-point source pollution may even pose a threat to what has been achieved through municipal and industrial clean-up efforts" (BAPE, 2000; p. 61, translation). Therefore, the Commission has advised the provincial government to completely review its strategy for agricultural clean-up, acknowledging that previous educational and regulatory measures alone were not sufficient.

Box 1. BAPE : A tool for participative democracy

The *Bureau d'audiences publiques sur l'environnement* (BAPE) was established in 1978 under the *Québec Environment Quality Act*. It is a quasi-judicial government organisation dedicated to informing and consulting the public on questions related to the quality of the environment. BAPE reports to the Minister of Sustainable Development, Environment and Parks, who assign the organisation's terms of reference. BAPE members are appointed by the government. As a tool for participative democracy, social convergence and decision-making assistance, BAPE helps citizens influence the decision making process for projects that may have major repercussions on the environment.

BAPE may be asked to:

- conduct environmental impact assessments and reviews involving public participation
- conduct a public review of a specific environmental problem, and
- hold public consultations on protected area projects within the context of the Natural Heritage Conservation Act.

A mandate to hold inquiries and public hearings

The BAPE president sets up a commission and designates the BAPE member who will serve as commission chairperson. Commissioners have the status of investigators and, as a result, benefit from quasi-judicial powers allowing them, among other things, to subpoena documents for release to the public. Commissioners are empowered to take such action under the *Act respecting public inquiry commissions*. They must take an oath and must also abide by a code of ethics and professional conduct. In addition to holding inquiries, the commissioners help citizens understand the technical aspects associated with a project. Hearings take place in two parts. The aim of the first part is to inform the public and the commission about the project, whereas the aim of the second is to solicit public opinion. Any person may submit a brief or orally present their opinions and/or suggestions concerning a project, impact study or any other document related to the mandate of inquiries or hearing.

BAPE reports

Each BAPE commission drafts a report containing an analysis of the viewpoints expressed during the hearings and reports on the commission's findings and opinions. At the end of the commission's mandate, the BAPE report is submitted to the Minister of Sustainable Development, Environment and Parks, who then has 60 days to make it public. In light of the BAPE report and the environmental analysis prepared by his department, the minister makes his recommendation to the Cabinet, which is responsible for the final decision concerning the project.

Source: BAPE, 2005 and www.bape.gouv.qc.ca/

According to the Commission, a new strategy for farm pollution control should include the following key elements:

- eliminate inconsistencies between government agricultural and environmental policies
- establish environmental cross-compliance measures in farm support programmes
- reinforce control and monitoring measures for farming operations
- offer payment for environmental services provided by farmers
- apply the polluter-payer principle through the use of economic tools
- adopt proper management measures for watercourse buffer strips, and
- encourage the adoption of best management practices.

As we will see in the following sections, the BAPE Commission's report on Québec water management has set forth guiding principles for the development of provincial water policy and, in the specific case of agricultural activities, has played an important role in identifying the conditions and incentives necessary to bring stakeholders a step closer to adopting more appropriate measures for dealing with non-point source pollution.

The adoption of the *Regulation Respecting Agricultural Operations* (RRAO)

In June 2002, the Québec government adopted the *Regulation Respecting Agricultural Operations* (*Éditeur officiel du Québec*, 2002). The new regulation updated and simplified the existing regulation and reinforced pollution control measures for farming operations, notably by increasing the number of farm inspections. Besides requiring the farmer to have watertight manure storage facilities, it sought to address the non-point source pollution problem by striking a balance between soil-carrying capacity for phosphorus and the quantity of fertilising substances being spread. This provision took immediate effect for new facilities or herd increases, whereas existing farms were given until 2010 to fully comply. The regulation aims to ensure sound management of fertilising substances by requiring each farm to prepare an agro-environmental fertilisation plan, submit regular phosphorus balance reports, and comply with newly prescribed restrictions on the spreading of livestock waste (protective distances, use of low ramp equipment for liquid manure management, periods permitted, etc.).

Along with these measures, the new regulation introduced administrative requirements that imposed temporary limitations on the development of new hog farming operations. The measure was a response to growing controversy over hog farm expansion in rural Québec, where there are widespread concerns about odours and watercourse degradation resulting from over-fertilisation. The Québec government also felt that a provisional halt was justified by the new mandate it had given to BAPE, this time to conduct hearings on the sustainable development of hog farming. The moratorium was seen as a way to create a more constructive working atmosphere for the new BAPE Commission and to foster stakeholder participation in the consultation process.

The Québec Water Policy

A policy framework …

Adopted in November 2002, the Québec Water Policy was the outcome of several years of research, consultation, recommendations and positions taken on the issues, directions and actions required to manage Québec's water resource. It was developed to provide a better framework for water management and guarantee the sustainability of the resource. The policy proposes a new approach to water governance based on grassroots participation and the democratisation of information, as well as a consistent strategy of integrated water management involving close coordination among government departments, public agencies, and water-management stakeholders at the different levels of intervention (MENV, 2002).

Recognising water as part of Québec's collective heritage, the policy sets forth measures and government commitments in five key areas:

- implementation of watershed-based management to reform water governance
- integrated management of the St. Lawrence River system, notably by granting this important watercourse a special status
- protection of water quality and aquatic ecosystems

- continued clean-up and improved management of water services, and
- promotion of water-related recreational activities.

Two of these areas have a more specific impact on the farming sector: implementation of watershed-based management and the intensification of agricultural clean-up efforts.

… affecting the farming sector

Implementation of watershed-based management — a territorial approach which defines the watershed as the territorial unit of intervention for water management — requires a concerted effort on the part of all water management stakeholders (municipalities, citizens, developers, interest groups, and government departments and organisations). The goal is to facilitate integration of the multiple interests, uses, concerns, and action mechanisms of the community. This approach strives to take a comprehensive view of natural phenomena and the impact of human activities on the watershed, in order to better understand and explain problems related to water quantity and quality and develop more effective policies, programmes, and projects. To support implementation of this approach, the government of Québec has committed to: *i*) gradually introduce integrated watershed-based management; *ii*) provide financial and technical support for the establishment of 33 watershed-based organisations. And since agricultural activities may have important impacts on the water resource, the farming sector is therefore expected to play a significant role in achieving water quality standards in the watersheds.

The water policy also sets forth commitments to intensifying agricultural clean-up efforts complementary to the *Regulation Respecting Agricultural Operations* (RRAO). This regulation, as seen earlier, seeks to achieve balanced phosphorus levels in the soil by 2010 through the management and control of the spreading of animal waste. It also imposed a temporary moratorium on new pig farming operations. However, these measures alone were considered insufficient, which is why the Québec government has made further commitments to stepping up agricultural clean-up efforts. Under the Water Policy, for example, a sustainable agricultural development strategy has been developed to re-establish and maintain a balance between an economically viable and socially acceptable agricultural sector and quality rural environment preserved for the enjoyment of current and future generations.

This strategy is based on the coordination of actions addressing agro-environmental issues, and comprises the following measures:

- a government investment plan —“*Un environnement à valoriser*”— which focuses mainly on the implementation of sound farm practices
- support for the establishment of wooded riparian corridors in agricultural areas
- introduction of environmental cross-compliance measures within a range of financial assistance programmes in the agricultural sector
- reduction of the environmental impact of pesticides in agricultural areas by 2010, and
- provision of technical and financial support to existing freshwater fish farming operations to reduce waste discharges into the environment.

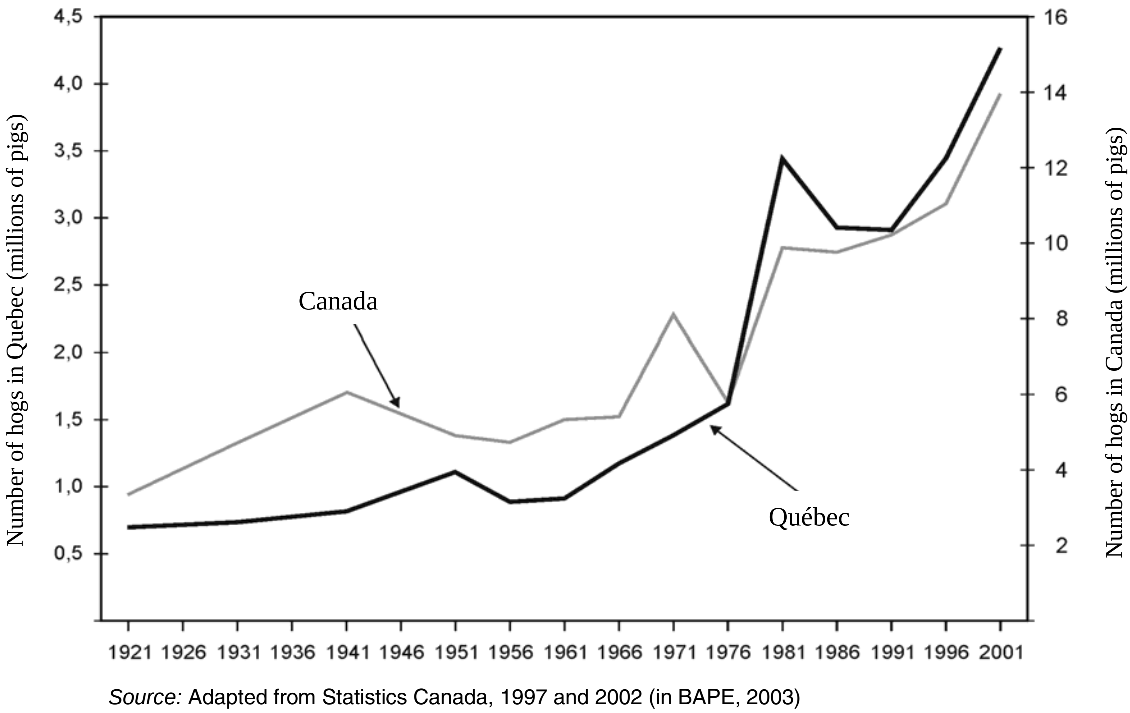
This agricultural strategy, together with the other measures comprising the RRAO, is expected to provide better control of point and non-point sources of agricultural pollution, improve the quality of water and aquatic ecosystems, increase the overall effectiveness of environmental measures for the agricultural sector, and enhance consistency in government policy through the introduction of cross-compliance.

The hearings on the sustainable development of hog farming

Hog sector expansion: a cause for growing public concern

Over the last four decades, the hog industry has undergone tremendous growth in Québec, with the number of animals more than quadrupling since the early sixties (Figure 1). Even though Québec only accounts for 5% of total farmland in Canada, Québec farmers raised about 30% of all hogs produced in the country in 2002. Moreover, hog raising in the province is very much concentrated in a few geographic areas (three-quarters of all animals are raised in only three regions), a phenomenon similar to that observed in other parts of the world in recent decades (OECD, 2003a).

Figure 1. Evolution of hog raising in Québec and Canada



Source: Adapted from Statistics Canada, 1997 and 2002 (in BAPE, 2003)

The international market has been a major factor driving expansion, with half of the province's hog production now exported. However, this growth has also contributed to a significant increase in pressure on natural resources from farming activities and raised serious public concerns about the environmental impacts of hog farming, especially regarding water pollution and odour issues (MENV, 2003).

Bringing sustainability to hog farming: a new consultation becomes necessary

This is the context in which the Québec government imposed a temporary moratorium on further hog farm development and asked *BAPE* to conduct a new public consultation—this time on the sustainable development of hog farming. A new commission was set up with the following mandate:

- Evaluate the strengths and weaknesses of hog production models in Quebec;
- Draft a framework for sustainable hog farming; and
- Propose one or more industry models capable of ensuring harmonious relationships and protecting the environment.

The work of the new commission began in the fall of 2002 with a number of theme conferences. Then, as with the water management hearings, two series of regional meetings were held, the first one to provide information and the second to obtain public input. In total, the commission held 132 sessions, received 382 briefs, and heard over 9,100 citizens and nearly 260 experts. The commissioners also gathered information by traveling to other regions of Canada, the United States, and Europe with concentrated or expanding hog industries.

In the fall of 2003 the Commission presented its report on bringing sustainability to the hog farming entitled *L'inscription de la production porcine dans le développement durable* (BAPE, 2003). The document highlights the important role the three dimensions of sustainability play in ensuring the long-term viability of the pork industry. It contains numerous recommendations and concrete suggestions for policymakers on how to enhance the sustainability of hog farming and agriculture in general, including measures to help make hog farming socially acceptable, economically viable and compatible with the ecological equilibrium. Some of the key recommendations of this report are presented in Box 2.

In general, the Commission concludes that sustainable hog farming is possible in Québec. However, as an examination of the recommendations illustrates, integrating sustainable development principles into agricultural policy will require more than just a series of measures to foster the adoption of best management practices at the farm level. Therefore, the commission concluded that it would be socially risky to lift the moratorium on new hog farming operations until the government has taken genuine and concrete actions toward this goal.

The Québec Government's responses to the BAPE report on the sustainable development of hog farming

Extending the restrictions on hog farm expansion

On the advice of the BAPE commission on the sustainable development of hog farming, the government decided to extend the temporary limitations on new hog operations. It considered that before any further development could occur, an action plan had to be implemented to ensure environmentally sustainable hog farming acceptable to rural communities. Through the *Regulation Respecting Agricultural Operations* (RRAO), the restrictions on new facilities were first extended until the end of 2004. This was followed by a partial lifting of limitations in watersheds where water quality met provincial standards for phosphorus concentration. Restrictions were maintained for an extra year in those watersheds said to be "degraded," i.e., where phosphorus concentrations exceeded norms. Now, in a recent proposal introduced to amend the RROA, the government plans to remove the last remaining limitations on new hog farm development in December 2005. The prolonged moratorium was necessary to allow the various government departments involved to develop, adjust or reinforce certain policies to bring them in line with the new government policy directions for the sustainable development of hog farming.

Policy directions for the sustainable development of hog farming

In the spring of 2004, the government identified seven key components for an action plan to end the moratorium on hog production (MENV *et al.*, 2004):

- Protect the environment with a commitment not to exceed watershed carrying capacity and to intensify farm controls as per the RROA;
- Progressively introduce environmental cross-compliance, starting with certain RROA provisions for the pig sector in 2004;
- Modify the legal framework governing land use planning to allow counties to impose a regional quota for hog operations and request odour mitigation measures for new operations;
- Implement a local consultation process for all hog farm projects applying for a certificate of authorisation;
- Provide financial aid to farmers to assist with the implementation of buffer strips and the adoption of good management practices that reduce non-point source pollution and odours;
- Support research and development, especially in liquid manure treatment technology and agri-environmental indicator; and
- Improve monitoring of health risks associated with hog farming and examine options for banning the use of meat and bone meal in feed as well as systematic use of antibiotics as growth factors.

All of these commitments are directly linked to the BAPE commission's recommendations on the sustainable development of hog farming. Some of the key measures to implement the above actions were reconfirmed or more precisely defined by the Québec government in March 2005 and are briefly presented below (Gouvernement du Québec, 2005).

Box 2. Summary of the key recommendations of the BAPE Report on the Sustainable Development of Hog Farming

Toward socially acceptable hog farming

Through land use planning	• Adjust the legal framework governing land use planning and increase involvement by local authorities in planning farm and non-farm land uses • Review odour-related parameters for distance restrictions imposed on hog operations • Request odour mitigation measures for expanding hog farms unable to comply with distance restrictions • Allow production zoning and regional quotas for hog operations • Provide better access to information on hog operations and manure spreading within the region
Through participation and involvement of rural stakeholders	• Establish an environmental and social review process for all hog farm projects applying for certificates of authorisation • Limit farmer immunity against liability (dust, noise, odour) to "normal" farm practices • Improve public access to information as well as the quality of information
Through health safety	• Increase public health research on risks associated with hog farming • Provide transparent information on health risks • Outlaw meat and bone meal in feed and the use of antibiotics as growth factors

Toward economically viable hog farming

- Provide financial support to farmers for the implementation of new environmental standards
- Review the current farm income stabilisation insurance (FISI) programme for the hog sector
- Maintain the current collective marketing system
- Allow provincial pig sector growth at same pace as the world market

Toward hog farming compatible with ecological equilibrium

Through manure management	• Improve enforcement of environmental regulations on farms • Reinforce requirements and controls for manure spreading • Require land ownership for new hog farm development or expansion in all regions with a phosphorus surplus • Among farms with a phosphorus surplus, provide financial support only to those that went into a surplus situation as a result of changing regulatory requirements
Through ecosystem protection	• Reinforce protection control measures and provide information on spreading near wells • Intensify surface water quality monitoring in agricultural zones • Increase extension efforts for farmers on the importance of aquatic ecosystem protection • Provide adequate protection to riparian strips along watercourses and increase erosion control measures • Provide proper financial support to farmers to encourage adoption of good management practices not comprised in regulation standards • Allow municipal jurisdictions to control forest clearing • Rapidly implement environmental cross-compliance measures • Develop environmental, social and regulation compliance indicators for farming
Through watershed management	• Watershed management of farming activities is essential to ensure respect of watershed carrying capacity, establish land use priorities, achieve water quality standards and appropriately manage manure surplus problems

Source: BAPE, 2003.

Respect for watershed carrying capacity

In addition to remaining restrictions on pig farm development, two amendments to the RRAO were adopted in December 2004 to take into account watershed carrying capacity (Éditeur officiel du Québec, 2004). First, in degraded river basins (i.e., phosphorus concentration above 0.03 mg/l at the river mouth), the regulation now prohibits any further increase of cropland acreage until water quality standards can be met. This measure takes into consideration the importance of limiting forest clearing and maintaining sufficient forest cover to preserve water quality and uses, especially in watersheds where there is intensive farming. The second amendment is specific to new hog operations. It stipulates any farmer wishing to set up a new hog farm in a degraded watershed must own 100% of the cropland required for spreading all new manure as set out in their nutrient management plan. In non-degraded watersheds, the land ownership requirement for new hog farms is set at 50% of the cropland needed for manure spreading.

Implementation of environmental cross-compliance

In 2004, the Québec government passed the first Canadian legislation on environmental cross-compliance in agriculture. The following year, *Financière agricole*, Québec's agricultural financing agency, introduced its first cross-compliance measure (FADQ, 2004). It makes the phosphorus balance report required under the RROA since 2003 a condition of eligibility for agency programmes. Moreover, if a farm cannot satisfy RROA acreage spreading requirements, it must draw up, with the assistance of its agricultural adviser, an agri-environmental support plan (*Plan d'accompagnement en agroenvironnement*), the provincial equivalent of the federal environmental farm plan. This plan commits the farmer to implementing practices that will help meet the phosphorus regulation requirements. Failure to respect these conditions may reduce or eliminate the financial support that the farm is entitled to from the financing agency. In May 2005, the requirements for the phosphorus balance report also became eligibility criteria for the Québec Department of Agriculture property tax refund programme (MAPAQ, 2005). These measures were the first to be introduced as part of plans to progressively make provincial financial support programmes conditional to compliance with environmental regulations.

Modification of the legal framework for land use planning and development

The adoption of Bill 54 in late 2004 brought some significant changes to land use planning legislation. This modification concerns three key measures. First, a local public information and consultation process is now compulsory before any new hog farm applying for a certificate of authorisation can be approved. A guide explains the public consultation process for new hog farm projects (MAMR, 2005a). Subsequent to local consultations, the second measure allows municipal authorities to impose certain mitigation requirements to help foster social acceptance of hog farm projects (roofing on manure storage tanks, use of windbreaks to limit odours, location of hog barns, etc.) before issuing a construction permit. Third, regional counties and municipalities may also impose a quota on the total number of hog farms allowed in its designated agricultural zones. On top of these measures, municipalities can also impose specific restrictions for protecting wooded areas, buffer strips and sensitive ecosystems, and they may identify up to 12 days when any manure spreading is forbidden (MAMR, 2005b).

Agri-environmental support for farmers

The *Prime-Vert* programme offers agri-environmental payments to farmers, notably to help meet the regulatory requirements. The programme provides financial assistance for the construction of liquid manure storage structures, the purchase of odour-reduction equipment (low ramp manure spreaders, roofing for manure storage structures, etc.), agri-environmental advisory services as well as the development of liquid manure treatment technology. In more recent years the programme has begun to target non-point source pollution by providing financial aid to encourage specific management practices such as soil conservation, windbreaks, winter cover crops and the withdrawal of animals from watercourses (MAPAQ, 2004). A portion of the programme funding is provided by the federal government through its strategic agricultural framework. This framework has also led to the implementation of an agri-environmental support plan at the farm level in partnership with the provincial department of agriculture (*Plan d'accompagnement en agroenvironnement*). This plan, which aims to help Québec farmers meet RROA regulatory requirements and improve their agri-environmental practices, is based upon a three-step on-farm initiative comprising a diagnosis, an action plan and implementation of best practices, all under the advice of an agrologist.

Further developments to watch for in the future

Review of the current Farm Income Stabilisation Insurance (FISI) programme

One of the key issues identified by the BAPE commission on the sustainable development of hog farming relates to the Farm Income Stabilisation Insurance (FISI) programme. Indeed, the commission report calls for a complete overhaul of the programme based on the following recommendations:

- *Replace the current FISI program for hog producers with a general farming income protection plan that puts a ceiling on the maximum net income protected and applies to all farmers, regardless of output, type of commodity, or cost of production*

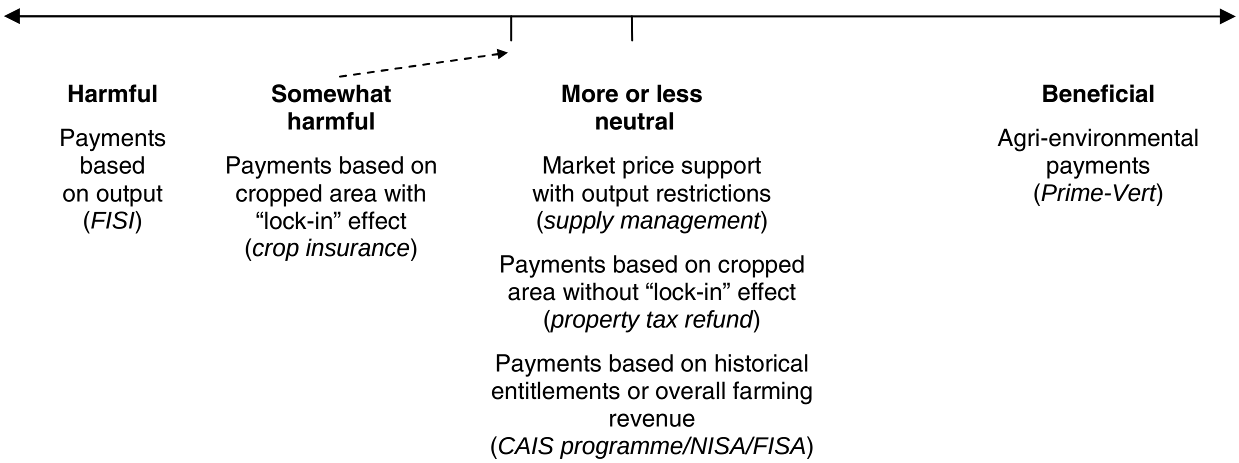
- *Target all agricultural income support programs to family or small farms, i.e., farms worked by no more than four people*

- *Make agricultural income support programs available to individuals only, even for people who exercise farming activities through the intermediary of a corporate entity.*

(BAPE, 2003; p. 154, Recommendations 25, 26 & 27)

To fully appreciate the significance and scope of these recommendations, let us take a closer look at the FISI programme from a sustainable development perspective, especially its impact on the environment and social equity. Our assessment of Québec farm support measures (Boutin, 2005) draws on recent OECD works and findings on environmentally harmful subsidies (OECD, 2003b; Unisféra, 2003; Portugal, 2002), to evaluate their potential role in fostering environmentally harmful practices. The classification scale developed to rate these support programmes according to environmental impact is shown in Figure 2.

Figure 2. Classification of farm support measures available in Québec according to their environmental impact



Source: Boutin, 2005.

As Figure 2 illustrates, the FISI programme is the Québec support measure considered most harmful for the environment. It encourages overproduction by linking support payments to production levels and also provokes a lock-in effect that leads to specialisation and inadequate crop rotation. In the past, Québec's auditor general (1996) has also criticised the fact that the FISI programme is entirely based on models that maximise production and does not include any environmental criteria.

The pervasiveness of this type of support programme makes it harder and more expensive to achieve environmental objectives and is in contradiction with agri-environmental measures. Conversely, environmental pressures would be eased if support were accompanied by restrictions on production or, as recommended by the BAPE Commission, were decoupled from production (Portugal, 2002).

From a social viewpoint, an examination of the distribution of the financial aid provided to hog feedlots through the FISI programme also illustrates the inequities inherent to the distribution of this form of farm support. Indeed, the FISI programmes, which provide support based on output, tend to benefit larger operations and to introduce inequities into the distribution of farm assistance (Boutin, 2005). According to other OECD (2002) studies on farm household income, generic support measures, like payments based on output levels, lead to inequalities in the distribution of farm support. In this area, too, the decoupling of aid measures and the targeting of payments specifically on the basis of farm revenue is viewed as one way to alleviate the problem and to guarantee greater equity between agricultural beneficiaries. Again, these conclusions fit with the recommendations of the BAPE Commission regarding the FISI programme.

These observations raise several points worth considering if we are to introduce a sustainable development approach to agricultural policy. Indeed, although the Canadian Agricultural Income Stabilization (CAIS) programme — a whole-farm income support — became the front-line programme in Québec in 2003, the FISI programme is still the predominant means of providing direct financial support to Québec farmers. However, the transition to sustainability cannot be readily achieved without undertaking a genuine review of existing farm support measures developed under previous "productivist" policies. Therefore a reform of the FISI programme, as suggested by the BAPE Commission, would contribute greatly to enhancing the productivity of agri-environmental investments and make farm support measures more effective vehicles for meeting the goal of sustainability. Such reform could be expected as part of a second set of measures to be elaborated in the future.

The introduction of new environmental cross-compliance measures

In its policy directions for the sustainable development of hog production, the Québec government has defined environmental cross-compliance as: i) an economic instrument to make government financial support conditional on the respect of environmental criteria in order to influence farmers' practices; and *ii*) a public administration tool to ensure consistency in government policies, sound management of government spending, and compliance with environmental regulations. Moreover, the government envisages the progressive introduction of environmental cross-compliance and the implementation, by 2010, of a comprehensive cross-compliance policy that makes all government farm support conditional on full compliance with all environmental legislation pertaining to the agricultural sector (Provençal, 2005). As we have seen, the first cross-compliance measures implemented had to do with the phosphorus balance report, an RROA requirement. But other cross-compliance mechanisms can be expected for farm support programmes in the years ahead. These measures are a necessary step toward restoring public confidence in the capacity of the farming sector to produce without damaging the environment.

Gradually introduction of integrated watershed-based management

Several watershed-based organisations have been established to implement this territorial approach, which requires extensive cooperation on the part of all water management stakeholders. Under this approach, objectives identified in the watershed management plan (*Plan directeur de l'eau*) must be taken into account before decisions affecting land use or water resources are taken. For example, regional agricultural planning would have to factor in targets for reducing phosphorus inputs from diffuse sources to ensure that the carrying capacity of the territory is not exceeded or threatened by new development projects. Implementation of sustainable watershed-based management will provide systematic protection of water bodies, wetlands and ecosystems; improve the health of watercourses, lakes and associated ecosystems; and progressively restore, or preserve, uses like swimming, fishing and other recreational activities.

Conclusion: A consultation process to help build solutions

As this review of current Québec water and agricultural policies has shown, provincial government interventions have evolved significantly in recent years. Several measures have considerably reinforced frameworks for water resource protection, accelerated clean-up efforts and fostered integration of the three dimensions of sustainability into agricultural development planning. The two public consultations led by BAPE —the first on water management, the second on sustainable hog farming—laid the groundwork for these ongoing policy transformations. Indeed, the two processes have been fundamental to fostering a comprehensive shared vision among stakeholders and to building consensus around solutions.

While the hearings on water management have clearly illustrated the need to better control agricultural pollution, the hearings on hog farming have fostered public reflection and debate and helped identify ways to steer hog farming – and agriculture in general – on a course toward sustainability. The two reports drafted by the respective commissions contained numerous concrete suggestions for improving water management practices and integrating sustainable development principles into farming activities. Many of the recommendations have led to the implementation of new government measures and initiatives that are helping to eliminate inconsistencies between water protection measures and government agricultural support programmes. An approach for participative democracy as the one used by BAPE has been a very efficient way in making further progress to meet the challenge of reconciling water and agricultural policies.

The adoption of the Québec Water Policy in 2002, as well as the important changes that are under way in agricultural policies, were legitimised by the extensive public consultations conducted by BAPE. More than a quarter century after its foundation – and numerous studies and inquiries later – this agency has become a widely respected and highly trusted provincial institution with a clear vision for:

> *… a Québec where the citizens of all regions are better informed about environmental questions and major projects submitted for public consultation. Citizens know that they have the possibility of being consulted by an independent and impartial organization to ensure that their concerns and opinions are taken into consideration when the government makes its decision*

(BAPE, 2005).

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Chapter 26.

Sustainable Nitrogen Management in Agriculture: An Action Programme towards Protecting Water Resources in Walloon Region (Belgium)

Charles Hendrickx, Richard Lambert, Xavier Sauvenier and Alain Peeters[1]

In order to reduce the pollution caused by nitrates from agricultural sources, the Walloon region has established a Programme of Sustainable Nitrogen Management in Agriculture. This legislation encompasses all compulsory measures mentioned in the European Directive known as 'Nitrate Directive' (Directive 91/676/EEC), but its scope is larger, as it defines obligations regarding storage and management of livestock manure outside vulnerable zones.

The Walloon legislation is the result of a long negotiation process and represents a common understanding between the Public powers, the farmer's unions and the water producers, purifiers and distributors. It was launched in October, 2002.

Three complementary levels are concerned: the field, the whole farm and the region.

At field level, the objective is to reduce nitrate losses through leaching during winter. The farmer must put in place some "good agriculture practices", particularly regarding authorised doses and periods of application of nitrogen fertilisers.

At the whole farm level the farmer must maintain a balance between the organic nitrogen compound to be applied and his "land application capacity" (i.e.: the applicable quantity legally authorised). Every year, the "soil link rate" (LS) of each farm is calculated by the government administration, taking into account several factors: the number of animals on the farm, average values of nitrogen production per animal category, agricultural land surface available and authorised doses of nitrogen organic compound applicable. In vulnerable zones, organic nitrogen application is limited to 80 kg N/ha on arable land and 210 kg N/ha on grassland. Outside these vulnerable zones, the amount of livestock manure applied is limited to 120 kg N/ha on arable land and 210 kg N/ha on grassland. The organic nitrogen in excess of the "land application capacity" must be transferred to other farms that are able to value it.

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At regional level, these transfers are facilitated by the setup of a database linking "givers" and "receivers" of such livestock manure.

An originality of the programme is the possibility of benefiting from an exemption raising the quantities applied yearly to 130 kg N/ha on arable land and 250 kg N/ha on grassland. To this end the farmer must enrol in a specific programme called "Quality Approach" involving additional measures limiting the risk of pollution by nitrates (cultivation of catch crops, "reasoned" fertilisation, limiting the number of cattle on grassland in autumn). His/her good nitrogen management is controlled yearly by the dosage of residual nitrogen in the soil profile before winter on a representative sample of the fields. This residual quantity is compared to reference values established every year. A nitrogen assessment for the whole farm and the rotation is also carried out yearly.

A "coaching" structure called "Nitrawal" has been created by the government to help farmers reaching the norms regarding livestock manure storage facilities, manure transfer agreements and demands regarding the "quality step". It is also a communication tool to farmers and the larger public, as well as a means of validating the programme results and possibly propose modifications.

Water pollution and agriculture in Walloon region

The Walloon region constitutes the southern part of Belgium and spreads across 17,000 square kilometres in the heart of Western Europe. A very small region in Europe, it receives an adequate supply of rains throughout the year with an annual average ranging from 750 mm in the lower parts of the region to 1400 mm in the highlands, and an average temperature ranging from 2°C in January to 19,5 °C in August.

Wallonia uses its water quite intensively, since 2/3 of the yearly renewable underground resources are exploited every year, mainly to feed the local distribution network, but also other regions of the country (Brussels and Flanders).

Agriculture is also intensive in this region where the soil is generally fertile and deep. Many types of crops are grown but cereals, sugar beet and maize are the most common. Half of the acreage is devoted to grassland and cattle rearing (both dairy and beef) is widespread.

Therefore it is not surprising that a conflict occurs between the intensity of agriculture and the quality of water resources, as it is the case in other European regions.

With respect to the environment, the most important challenges facing Walloon agriculture are the reduction in the use of pesticides, curbing the current biodiversity erosion and the protection of water resources against nitric pollution.

This paper will focus on the latter problem. It describes in details the action plan developed by the Walloon region in order to reach a more sustainable nitrogen management in agriculture. This programme is original in some of its aspects, more developed in these pages.

The European Nitrate Directive

Already in 1991, the problem of nitrate pollution from agricultural sources was addressed at European level through the adoption of the Nitrate Directive (91/676). This directive obliges member states to:

- define zones vulnerable to nitrate pollution on their territory;
- establish a Code of Good Agricultural Practices;
- fight the causes of nitrate pollution, by an adequate action programme compulsory in the defined vulnerable zones. Surprisingly the compulsory programme defined by the Directive nearly exclusively focuses on nitrogen losses from animal production. In this regard the maximum dose of manure applied must never exceed 170 kg $N.ha^{-1}.yr^{-1}$ anywhere in the EU.
- establish a water quality monitoring network;
- submit a report on water quality and action programme efficiency every four years.

The Walloon Programme of Sustainable Nitrogen Management in Agriculture

In the Walloon region, the general situation is not alarming concerning nitrate pollution but some regions are clearly more at risk than others, depending mainly on geological factors.

In conformity with the above-mentioned European directive, the regional government has identified five vulnerable zones in the Walloon territory so far. Each of these has its own specificities, but their underlying geological rocks make it easy for nitrates to percolate up to the water table. However, although the water tables are easily polluted, the nitrates transfer time is very long and a decrease in nitrate concentration in these underground waters is not expected before several years.

Soil link rate

The main pillar of the Walloon Action Programme is the ‘soil link rate (LS) indicator, i.e., the ratio between the organic nitrogen produced annually on the farm (and possibly imported from neighbours) and the amount of organic nitrogen allowed to be spread annually on the same farm.

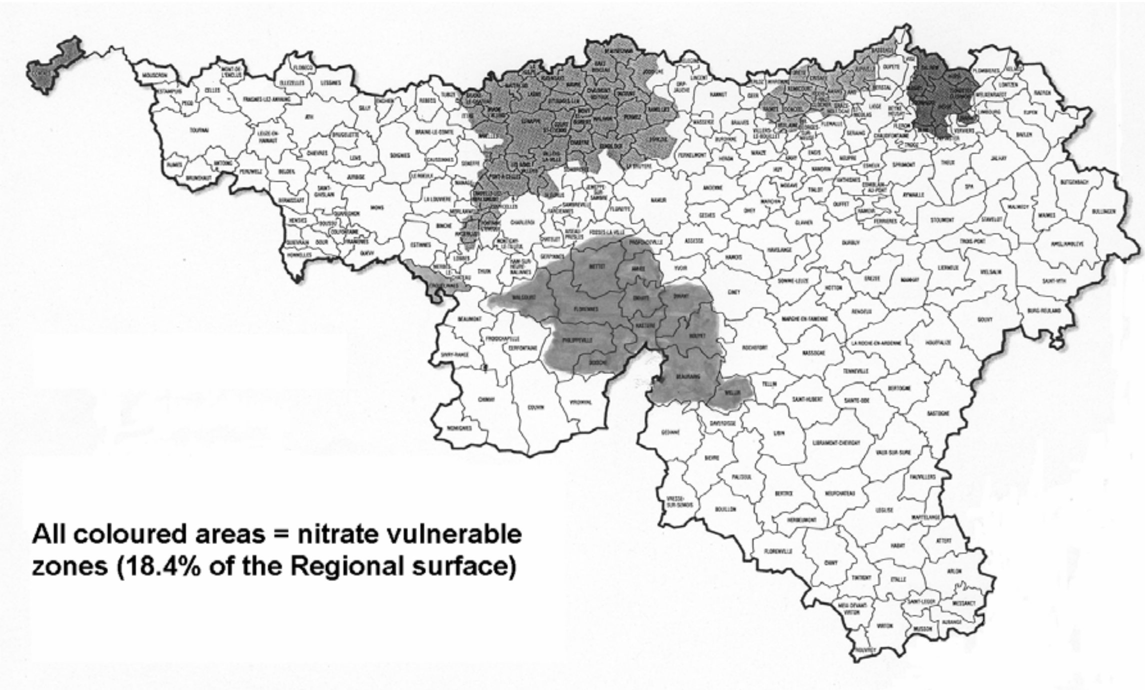
The annual quantities of manure allowed to be spread on a farm parcels depend both on the location of the farm (in or outside vulnerable zones) and its land use (grasslands and crops area). These values are displayed in Table 1.

Table 1. Authorised quantities of nitrogen from animal manure in Walloon region

	In Vulnerable Zones	Outside Vulnerable Zones	Quality Approach
Arable land	80 kg $N.ha^{-1}.yr^{-1}$	120 kg $N.ha^{-1}.yr^{-1}$	130 kg $N.ha^{-1}.yr^{-1}$
Grassland	210 kg $N.ha^{-1}.yr^{-1}$	210 kg $N.ha^{-1}.yr^{-1}$	250 kg $N.ha^{-1}.yr^{-1}$

Source: Walloon Code of Water.

Figure 1. Vulnerable zones in Walloon region



This soil link rate is calculated every year for each of the 18,000 farms of the Walloon region by the Administration in charge of the environment. Its calculation needs an impressive amount of accurate data, i.e. yearly, the number of animals in each category for each farm, the accurate acreage of each field and the type of speculation allocated to each field. The several databases needed are built up and maintained by the Administration of Agriculture on the basis of the compulsory declarations of farmers for the veterinary inspection and for the Common Agricultural Policy. The nitrogen production per animal is calculated on basis of standards for each animal category. However, in case of disagreement, the farmer has always the right to ask for a more accurate value estimated with a nitrogen excretion balance and standard losses for manure and slurry or with weighing and analysing effluents produced.

For a particular farm, the soil link rate must never exceed 1. If so, it indicates that animal production on the farm is too intensive as compared to the acreage of land that supports it. In other words, there is a danger of water table pollution (if all of the manure produced by animals is spread on the farm). In this case, several options are offered to the farmer:

- reducing his/her herd;
- increasing the surface (or the balance between fields and grasslands);
- transferring the exceeding manure to a farm where the 'soil link rate' is inferior to 1, via a special 'manure transfer agreement' authorised by the Administration. To this end, a database linking potential manure 'givers' and 'receivers' is maintained by the administration.

- take part in a special fertiliser management programme called ‘Quality Approach’ raising the authorised yearly applicable (see Table 1). The way this programme is monitored (and the corresponding derogations granted) constitutes the main originality of the Walloon programme and is detailed in point 3 below.

Given the fact that the surface of the Walloon region devoted to agriculture is nearly equally divided between arable land and grassland, the corresponding authorised doses on average at regional level is 145 kg $N.ha^{-1}.yr^{-1}$ in vulnerable zone and 165 kg $N.ha^{-1}.yr^{-1}$ outside, which is inferior to the maximum quantity set by the nitrate directive (170 kg $N.ha^{-1}.yr^{-1}$).

Some other aspects of the Walloon Action Programme pertain to the period during which manure application is forbidden (hence the corresponding storage facilities that have to be installed), the restriction in the total quantity of nitrogen fertilisers applicable and the use of a provisional nitrogen balance calculation to predict the right quantity of manure that should be applied on a particular field.

Manure application period

Regarding the manure application period (see Figure 2), the Walloon legislation differentiates between fast-acting and slow-acting manures:

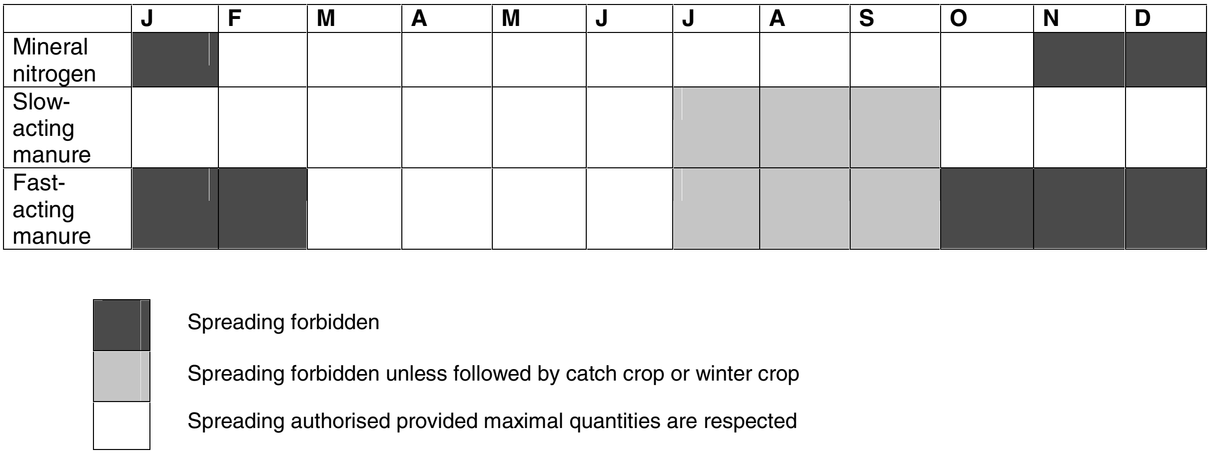
- Fast acting manures are slurries and poultry manure and their spreading is forbidden during the winter months, as no vegetation can really take advantage of the high nitrogen content readily available for the plant during this period; hence, the danger of leaching up to the water table is very high. The same restriction applies for mineral nitrogen fertilisers.

- Slow-acting manure is solid manure (apart from poultry manure), composted or not. In this case, the forbidden period for application on crops is the summer, because the nitrogen contained in it is mineralised at a slower pace. However, if a crop staying in place throughout the winter is sown directly after manure application (or a nitrogen catch crop), this application is tolerated.

Manure storage facility

These restrictions in manure application suppose the availability of a storage facility. Here again, the danger of polluting the water table is substantial if precautions are not observed. For liquid manure, the storage tanks of a particular farm must hold a minimum of six months’ manure production and must be fully waterproof. The investment needed is quite high in regard to the financial capabilities of our farmers and is partly supported by the Regional authorities. For solid manure, a concrete platform with collecting drains is required or storage in the field is tolerated provided that manure is dry enough. However, if this latter solution is chosen the place must change every year.

Figure 2. Application period of nitrogen fertilisers in the Walloon region



Source: Walloon water code.

Mineral nitrogen

If one is only concerned about farm manure, the objective of reducing nitrate pollution of both underground and surface waters is likely not to be met. One must also focus on the total nitrogen applied by agricultural activities, and even also on the total nitrogen released by domestic as well as industrial activities. The last two factors are being taken care of by a very dense sewage and sewerage plants network. According to other European regulations (Directive 2000/60: Water Framework Directive), medium and high-capacity plants are currently being upgraded in order to substantially reduce the nitrate loads at the outlet of the plant.

Regarding nitrogen directly linked to agricultural activities, the total quantity (organic + mineral) applied in a field is also restricted by law. The upper limit depends on the type of crop and ranges from 30 kg $N.ha^{-1}.yr^{-1}$ for the common pea to 330 kg $N.ha^{1}.yr^{-1}$ for sugar beet with a restriction of 250 $kg.ha^{-1}.yr^{-1}$ on the total arable land surface of the farm. On grassland, the total nitrogen applied must not exceed 350 $kg.ha^{-1}.yr^{-1}$.

These amounts stand of course for legal upper limits. The aim is to sensitise farmers to use only the appropriate quantity, strictly necessary to feed the plant. Today, the farmer is advised to calculate this quantity for each of his field using a balance between the nitrogen supplied by the soil (fertilisers, mineralisation of humus, nitrogen remaining from last crop …) and the expected needs of the plant.

Water monitoring network

Of course, all those measures would not make sense without a performing water monitoring network. In this regard, the Walloon region benefits from one of the most dense networks with more than 950 measuring points for underground water and 300 points for surface water on such a small territory. Very detailed reports, measures and maps can be obtained on line by visiting the site: http://environnement.wallonie.be.

Supporting structure

To practically implement this legislation, a non-profit organisation has been set up and is funded by the Regional government: ‘Nitrawal’. This structure, composed of some 15 doctors, engineers and technicians, is exclusively conceived as an advisory body at the service of farmers. The information gathered by Nitrawal may therefore never be used by the administration to control or sanction the farmers. In this way, an atmosphere of confidence and transparency towards the farmer can be created to guarantee an efficient action of the organisation. The day-to-day work of Nitrawal is controlled by the same stakeholders having negotiated the Walloon Programme of Sustainable Nitrogen Management in Agriculture, i.e. the government, the main farmers’ union, the companies distributing public water and the two main universities involved in agriculture (Catholic University of Louvain and Agronomic Faculty of Gembloux).

Several other aspects less important are not detailed here, such as the authorised spreading material, the regular inspections, the fractioning of the fertiliser doses, the spreading rules on slopes or near rivers … but one of the most original sides of the programme is the Quality Approach developed with farmers.

The Quality Approach, or how to reconcile water quality and derogations

When a farm produces too much manure than the quantity authorised to be applied, the Walloon government, under strict conditions, offers the possibility to participate in a programme helping the farmer to manage in a more sustainable way a bigger amount of the nitrogen produced on the farm.

Derogation

In this case, the farmer benefits from a derogation raising the yearly applicable quantity to 130 kg N.ha^{-1}.yr^{-1} on arable land and 250 kg N.ha^{-1}.yr^{-1} on grassland, the maximum dose without derogation being 80 kg N.ha^{-1}.yr^{-1} or 120 kg N.ha^{-1}.yr^{-1} (in or outside vulnerable zones) on arable land and 210 kg N.ha^{-1}.yr^{-1} on grassland (Table 1).

This derogation is granted on a case by case basis and for a period of four years during which the performance of the farm in regard to nitrogen management is periodically assessed. This particular programme started its operations in 2004. So far, out of the 2450 farms having a soil link rate above 1, close to 400 farmers have been registered in the Quality Approach programme.

Follow-up

In return to the derogations mentioned above, farmers participating in the Quality Approach will have to submit to a close and personalised follow-up by the non-profit organisation Nitrawal. This follow-up consists in a global reflection combined with an action plan to reduce and possibly avoid nitrate leaching in the soil profile. Hence, the farmer will have to comply with strict obligations:

1. Provide all data relevant to nitrogen flows, at farm and at field level;

2. Apply a series of good agricultural practices in order to limit the nitrate leaching below the root zone. Amongst other measures, let us mention:

- The systematic use of nitrate catch crops after harvest of the cereals, peas, early maturing potatoes and other crops (when these are not harvested too late making the use of catch crop meaningless) if no winter crop follows. These catch crops are plants growing fast, with a strong rooting system and valuing well nitrates. The main catch crops used in Belgium are mustard, phacelia (*phacelia tanacetifolia),* ryegrass (English or Italian) and rye. These catch crops must be established before 15th September and destroyed after 30 November.

- The application of a quantity of nitrogen fertiliser resulting of a balance between the needs of the plants and the nitrogen mineralised, left in the soil by the previous crop … This type of balance, recommended to all farmers, is compulsory in the framework of the Quality Approach for all crops likely to leave substantial nitrate residues leached during winter, (such as maize, potatoes… see Table 2).

- The cattle stocking rate on grassland must be limited before winter, as urine patches leave a substantial amount of nitrate and the vegetation cannot value too much nitrogen during this period. More precisely, the stocking rate must not exceed 150 Livestock Unit.day.ha^{-1} from 15 September to 31 December.

These latter measures are compulsory for each farmer registered in the Quality Approach. On top of them, the farmer and the advisors of Nitrawal may choose between various other ways of limiting nitrate pollution, on a case by case basis. Let us mention:

- Optimisation of the feeding of ruminants by calculating regularly the rations and analysing the fodder.

- Optimising the feeding of pigs and poultry by precisely adapting the diet to the age of the animal and using feeds enriched in essential amino-acids but poorer in other proteins.

- Composting solid manure.

- Using a more performing equipment for spreading slurries (advanced band spreader, trailing shoe spreader, shallow injector).

- Inserting a temporary grassland in the rotation.

- Protecting water streams with a fence.

- Using early maturing maize, or potato varieties so as to harvest before 15th September and enable a catch crop or winter crop to be grown efficiently, and

- If the previous measure is not practicable, establishing a rye crop not destroyed before 15th February.

Performances control

The most important aspect of the Quality Approach is to be found in the fact that the performance of the farmers are assessed in regard with nitrate pollution and in the way this assessment is performed. Indeed, one of the best ways agricultural practices in a particular farm can be evaluated in this regard is to quantify the amount of nitrates present in the root profile before winter ('Potentially Leachable Nitrogen — PLN'), as this quantity is likely to percolate sooner or later up to the water table.

However, many factors influence this residue before winter and these are not necessarily related to the quality of agricultural practices implemented in a farm: type of crop, amount and distribution of rains, temperature, actual yield, sampling date and depth… So a 'simple' measure of the pre-winter residue is not informative enough. Therefore, a standardised method of evaluation has been adopted.

First of all, the crops and pastures of each farm are divided into four categories, according to the amount of nitrogen residues likely to be found in the profile after harvest, as it is shown in Table 2 below.

Table 2. Crop categories with respect to nitrogen residues before winter

Class C1 Low nitrogen resudie	Class 2 Average nitrogen residue	Class C3 High nitrogen residue	Class P
Sugar and fodder beet cereal with catch crop fallow cut grassland vegetable with catch crop flax with catch crop	Chicory maize interplanted with catch crop, cereal w/o catch crop	Flax w/o catch crop maize potato rape vegetable	Grazed grassland

Source: Walloon region Ministerial Decree 6/04/2004.

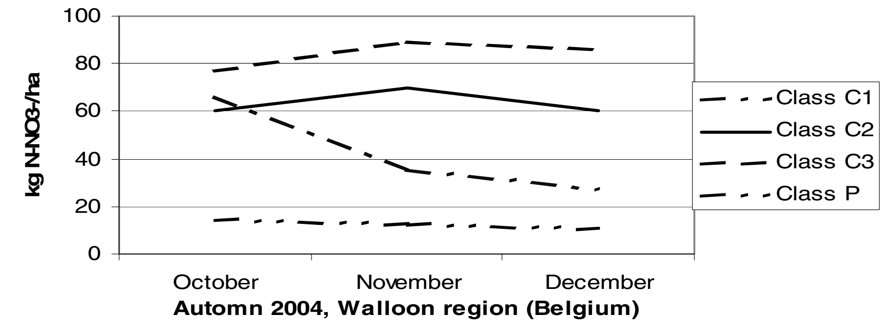
Each year, five soil samples are collected, four of them in each of the classes above, the last one in the class representing the biggest surface. The precise fields in each category are selected at random. If one class is missing for a particular farm, only four samples are collected. For each sample collected, a sampling procedure is strictly followed: each one is in fact the mixture of not less than ten, and sometimes not less than thirty individual samples, depending on the expected statistical variability. The soil is extracted up to a depth of 90 cm and subdivided in three different layers: 0–30 cm, 30–60 cm, 60–90 cm. The nitrate residues of each layer are analysed separately in a laboratory approved by the government, following a standardised method.

The result obtained for each of the classes mentioned above is then compared with the values obtained from a network of 250 reference fields scattered throughout the region. These fields are exactly similar to those whose performances have to be evaluated, apart from the fact that nitrate residues were measured out in the spring and on the basis of these results appropriate techniques to limit nitrate leaching were implemented. Typical results for the reference farms are shown in Figure 3 for the year 2004 and the four classes of crops/pastures.

According to the sampling date, it is thus possible to evaluate the performances of a particular farm to the above standard, considered to be a good result achievable for a given year in a comparable environment.

If, for a particular class, a farm registered in the Quality Approach exceeds more than 30 kg $N–NO_3.ha^{-1}$, the reference value, the farm is penalised by receiving a negative point (or two negative points if the excess is over 60 kg $N–NO_3.ha^{-1}$). The farmer will have then to improve its agricultural practices in regard to nitrogen management. The duration of the programme is four years. If a farmer still receives a negative appreciation in the fourth year (or on the average of the three other years), he/she is excluded from the programme and the derogation is no longer granted. As the programme was only launched in 2004, this situation has not yet occurred, but exclusions have already been decided on the basis of the poor quality of the collaboration between the excluded farm and the coaching structure Nitrawal.

Figure 3. Reference values for nitrogen residues in soil profiles



Source: Nitraw al, 2005

This programme has the advantage of assessing the performance of a farm towards water pollution directly on the result of its practices and thus on objective criteria. It is a very good pedagogic tool as the farmer can directly ‘see’ the effect of his/her practices on water pollution. On the other hand, it requires a substantial amount of work and dedication from Nitrawal to prepare the reference curves for each year, analyse the results and explain them to the farmer. The price of the dosages themselves is paid by the farmer enrolled in the programme. The sampling is done by the laboratory performing the dosage.

N balance

In addition to this nitrate residues control in soil profile, a complete nitrogen balance of each farm is carried out every year, both at farm gate and soil surface level. The *farm gate* balance tries to show if and where *improvements* can be made to the system, without taking into account the type of speculation present on the farm. The *soil surface* balance on the other hand focuses more on the pollution *risk*: it tries to determine whether the speculations chosen by the farmer and his management present a risk of nitrate pollution.

As every balance, the calculation aims to determine the difference between nitrogen entering in the system and nitrogen leaving it. The result is either nitrogen stored or nitrogen lost in the environment.

Having regard to the many different speculations existing in the region, the interpretation of the result is difficult without reference values:

- The reference value used in the *farm gate* balance is calculated on the basis of the nitrogen production of each speculation multiplied by an efficiency factor specific to the speculation. The nitrogen efficiency of manure is also taken into account. The comparison between the surplus of the farm and the reference value is an indicator of the potential progress in nitrogen management to be made, taking into account the N efficiency specific to each speculation in optimal management conditions.

- The reference value for the *soil surface* balance is calculated on the basis of the different nitrogen fertilisers applied and their respective gaseous or de-nitrification losses, of the nitrogen storage in humus in relation to the relative importance of meadows in the total surface, the presence of catch crops, the efficiency of manure and a quantity unavoidably lost in the soil profile. If the surplus determined for each farm is superior to the reference value, it is an indicator that the nitrate pollution risk is high for the considered farm.

By combining the two indicators (from the farm gate and soil surface balances), it is possible to classify the farms in four categories:

- Those that use nitrogen efficiently and present little risks of nitrate leaching
- Those that use nitrogen efficiently but present a risk (due to the type of speculation they undertake)
- Those that could use better their nitrogen resources but present little risk, and
- Those that could use better their nitrogen resources and present a risk of nitrate pollution.

This typology allows prioritising the action on categories 2 and 4 presenting important risks for the environment, with special focus on category 4 where it is possible to lower this risk by decreasing the nitrogen inputs to the farm. For category 2, it is not possible to reduce the nitrate leaching risk without modifying the speculation or lowering the expected production volume. However, the implementation of a catch crop, the lower use of organic fertilisers or the relative increase of the acreage devoted to grassland could decrease this risk.

With these two balances, combined with the nitrate residue measures, the Walloon region has not only an objective tool to assess the performance of the farmers in regard to nitrate pollution, but also a clear indication of where the possible problem lies and how it could be solved.

Water and agriculture: other potential challenges in Walloon region

Since the region uses its renewable water resources quite intensively, it is all the more important that their quality be irreproachable.

That is why, on top of the nitrate pollution, the Walloon government investigates also other issues linking agriculture and water, and particularly the problem of pesticides and phosphates in our water tables.

On the side of pesticides, the main problem in underground waters concerns the active substance *atrazine* and its metabolite *desethylatrazine*. Their concentrations vary between 25 ng/l and 100 ng/l in a quarter of the sampling sites, and special activated carbon filters have been installed in a few harnessing sites to make sure the concentration decreases below detection level. Fortunately, this active substance was forbidden in 2002; it was in fact far more widely used by the municipalities and the national railways company than by farmers.

Similar problems have been observed for surface waters, where the two main problematic substances are *simazine* and *diuron*, again mainly used in the non-agricultural sector. While these two substances were banned in 2001 with a substantial decrease in water concentration, efforts have still to be made in raising awareness to the users and proposing more biodegradable substances.

Regarding phosphates directly coming from agricultural activities, their concentration in both underground and surface waters is not a problem in the Walloon region, as the soils are naturally poor in phosphorus. Of course, solid or liquid manure contains also a proportion of phosphorus that is not always exported with the harvest, but the soil concentration is far from reaching a preoccupying level. Nevertheless, a map will be drawn to isolate the few spots where the saturation (and hence the possibility of leaching) could be reached in the future, in order to propose adequate measures.

Conclusion: Water protection needs a mentality change

The Quality Approach is original by its objective measure of the nitrate pollution risk. This clear picture of the situation in a given farm is not only important to decide whether derogation deserves to be granted or not, but is also a very precious tool in extension. Indeed, by these measurements, the intensive farmer is for the first time placed in a position where he/she can see the direct effect of his/her own agricultural practices on the pollution of the water table. Therefore, the farmer tends to modify his/her practices, or even the farm structure, far more easily and he/she can become a convinced pilot farmer ready to persuade others.

Indeed, in spite of all existing and future regulations, the main step in reconciling agriculture and water in the Walloon region is a mentality change amongst intensive farmers. If this change becomes a reality, the constraints imposed by law — seen so far by many farmers as an unnecessary burden — will become part of their natural habits far faster. This in turn will save a precious time in the protection of our endangered natural resources.

Of course, this step needs also a strong supporting structure such as Nitrawal to face the work load involved in field samplings and calculation of nitrogen balances. But results are worth the concerted efforts.

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Water and Agriculture

SUSTAINABILITY, MARKETS AND POLICIES

Agriculture is a major user of water and is responsible for much of its pollution. But the agricultural sector faces increasing competition for scarce water supplies from urban and industrial users and, increasingly, to sustain ecosystems. The 21st century could see ever more extreme weather events, from floods to droughts, which could have significant impacts on where farms are located and what they produce.

There is growing interest by both governments and the private sector in expanding the role of markets to allocate water used by all sectors, including agriculture, and to get producers to account for the pollution that their sector generates. But how can these objectives be achieved so that farmers can both efficiently produce enough food and fibre while ensuring that sufficient water is available for environmental needs? What is the role for different types of policies, management practices and property rights? What are governments actually doing and how effective are their actions?

The OECD Workshop on Water and Agriculture addressed these questions. It concluded that countries must make greater efforts to develop policy mechanisms to take into account the economic, environmental and social costs and benefits of water used in agriculture, and to ensure that it is sustainable in the long run.

The Workshop recognised that countries are at very different stages in developing water pricing and trading systems, and that a wide range of ownership, regulation and management practices prevail across countries. Policies need to reflect these differences across countries, but the involvement of stakeholders in developing, designing and implementing policies and approaches is crucial everywhere.

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