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Environmental Performance of Agriculture in OECD Countries since 1990

Chapter 4

Using Agri-environmental Indicators for Policy Analysis

Agri-environmental Indicators (AEIs) can contribute to the needs of policy makers and other users in a number of ways examined in this chapter. A brief overview is provided in Section 4.1 of recent developments in domestic agricultural support; agri-environmental policy measures; and multilateral environmental agreements affecting agriculture, in particular, drawing a link to the material included in the country sections of Chapter 3. Section 4.2 discusses how selected OECD countries and international organisations, including OECD, are using AEIs as part of their toolkit to report on the environmental performance of agriculture. A selective literature review in Section 4.3 examines how AEIs are being used by OECD member governments, the OECD and other international governmental organisations, and other researchers, in analysing the linkages between the effects of agricultural and environmental policies on environment outcomes. Finally, Section 4.4 highlights where key gaps exist in terms of knowledge, methodologies, and data which are limiting the use of AEIs for reporting the state and trends of environmental conditions in agriculture and as a tool in policy analysis.

4.1. Policy context to OECD agri-environmental performance

Policies are identified in this report as a key driving force in determining the environmental performance of agriculture, as shown in the Driving Force-State-Response Framework (Figure II.1 in the *Background and Scope of the Report*, Section 2). Three broad categories of policies can act to intensify or reduce the pressure of agricultural activities on the environment:

1. ***Agricultural policies***, which have objectives other than environmental ones, such as market price support, output payments and input subsidies (*e.g.* for energy and water), which can provide incentives to intensify and increase production and thus, exacerbate pressure on the environment. These policies, however, are often accompanied by production constraints, such as production quotas, set-aside land and cross compliance which can act to reduce pressure on the environment.
2. ***Agri-environmental policies***, which are specifically designed to enhance some environmental benefits associated with agriculture or offset the effects of production-linked support.
3. ***Environmental policies***, aimed at specific environmental issues (*e.g.* water pollution) but that can have an effect on agriculture, and which can be either national or international in scope.

OECD agricultural policies resulted in 2004 in the value of support to producers as a whole at an estimated USD 279 billion or EUR 226 billion (OECD, 2005a). The level of support, as measured by the Producer Support Estimate (PSE), accounted for 30% of farm receipts in 2002-04 compared to 37% in 1986-88. Support continues to vary widely across countries and commodities. Governments are gradually changing the way in which support is provided, away from the most production and trade distorting measures like import tariffs and export subsidies, and towards payments based on areas farmed and historical entitlements.

In response to the growing attention focused on the effects of agriculture on the environment, ***agri-environmental measures*** have assumed a more prominent role in agricultural policy in OECD countries in the past two decades (Box 4.1 and discussed in greater detail in the country sections of Chapter 3). OECD countries currently address environmental issues in agriculture with a plethora of sometimes overlapping measures, combining elements of direct regulation, economic instruments, education, persuasion

Box 4.1. **Main agri-environmental measures in OECD countries**

European countries and the **United States**, in particular, have substantially increased the use of ***incentive payments*** in the past decade to improve environmental quality in agriculture. Some notable trends include the growing use of payments to support the adoption of less-intensive farming practices; land retirement payments tailored to specific environmental objectives; and transitional payments to assist farmers in implementing structural changes to benefit the environment. In budgetary terms these policies are becoming increasingly significant – for example, total **European Union** expenditure on agri-environmental payments is projected to increase by 68%, from an average of EUR 2.2 billion per annum in the 1994-99 period, to EUR 3.7 billion per annum over the 2000-06 period.

Some countries, including **Australia, Canada** and **New Zealand**, have made widespread use of ***community-based approaches*** to address environmental issues – *e.g.* through supporting collective action to solve environmental problems, variously known as landcare groups or conservation clubs. These approaches tend to take advantage of farmers' self interest in environmental conservation and make use of local expertise in solving environmental problems.

All OECD countries impose ***regulatory requirements*** to address the negative effects of agricultural activities on the environment, ranging from outright prohibitions, to standards and resource-use requirements. In many cases these requirements have been extended or developed over the past fifteen years. An increasing number of regulatory requirements derive from state, provincial, regional or local measures under the framework of national umbrella legislation, in order to accommodate the local nature of many environmental concerns.

There still appears to be only limited application of ***taxes*** and ***charges*** to directly integrate the environmental costs of agricultural activities into farmers' production decisions – particularly compared to the application of such measures in other sectors. This in part reflects the logistical difficulties of applying such measures in agriculture, but may also reflect differences in how property rights are regarded in agriculture compared to other sectors. Taxes and charges on farm inputs are, however, sometimes used. ***Tradable rights*** do not appear to play a significant role in agri-environmental policy, although they are applied in the **Netherlands**, and on a state/regional basis in the **United States** and **Australia**.

Many OECD countries have directed greater attention towards improving the knowledge-base relating to environmental issues in agriculture through increased spending on agri-environmental ***research***, often undertaken in co-operation with the private sector. Generally, greater emphasis has also been placed on communicating information to farmers on environmental issues via ***technical assistance*** and ***extension***, in order to induce voluntary changes in farming practices and on improving environmental outcomes, including through the adoption of low input and organic farming systems.

Source: OECD (2003), *Agricultural Policies in OECD Countries: Monitoring and Evaluation 2003*, Paris, France.

and community involvement (OECD, 2006, 2005b, 2004a, 2004b, 2003a). The key features of the measures currently in place include:

- ***targets or thresholds***, especially for pesticide use, water quality, and ammonia and greenhouse gas emissions;
- ***regulations***, often used to enforce particular farming practices (*e.g.* manure storage), supported by fines and charges for non-compliance;
- ***agri-environmental payments***, which vary considerably across countries as they are variously intended to contribute towards the cost of meeting regulations; compensate for income lost by adopting certain practices; and reward farmers for providing environmental services;
- ***taxes and charges***, the use of which is very limited; and
- ***market-based approaches***, such as tradable permits and voluntary community-based approaches are limited but of growing importance.

Environmental policies, operating at both the national and international scale and usually directed at a specific environmental issue, are also increasingly impacting on the agricultural sector. At the national level environmental policies that most commonly impact agriculture concern energy use, water pollution, use of water resources, air pollution from ammonia, ozone depletion, climate change and biodiversity. These policies are examined in greater detail in the country sections of Chapter 3. Multilateral environmental initiatives, and in many cases their respective reporting requirements, are also having an impact on agriculture (Box 4.2).

4.2. Tracking agri-environmental performance

4.2.1. Evolution of Agri-environmental Indicators to track sustainable development

Agri-environmental indicators (AEIs) have evolved as part of a long history of establishing socio-economic indicators and statistical databases to meet demands by the public and policy decision makers for better information on economic performance and social trends (Bonnen, 1997). The first efforts at developing environmental indicators for OECD countries came during the early monitoring of industrial pollution during the 1960s and 1970s. But it was not until the publication of the Brundtland Report (1987) *Our Common Future* in 1987 and the 1992 United Nations "Earth Summit" at Rio de Janeiro (United Nations, 1993) that development of sustainable development indicators began, leading to the completion of the UN's Commission on Sustainable Development Indicators set in 2001 (UNCSD, 2001).

By the time of the World Summit on Sustainable Development in Johannesburg in 2002 (United Nations, 2002), governments had introduced a range of new policy measures in an attempt to steer their economies along a sustainable path and in so doing began to use indicators to help assess the effectiveness and efficiency of these policies and in the reporting requirements of multilateral environmental protocols (Hardi and Zdan, 1997; Hass *et al.*, 2002; Lawn, 2004).

While AEIs have been developed as part of the wider effort to extend environmental reporting and broader sustainable development indicators, they have also been developed by national and international agencies in response to growing public interest in environmental issues and because of the introduction of agri-environmental policies in most OECD countries over the 1990s as described in Section 4.1 (Brouwer and Crabtree, 1999; OECD, 2001; 1999).

Box 4.2. **Selected international and regional environmental agreements relevant to agriculture**[1]

Issue	International agreements[2]	Regional agreements[2]
Nutrients, pesticides, water	• Convention on the Protection and Use of Transboundary Watercourses and International Lakes, *www.unece.org/env/water/*.	• Convention for the Prevention of Marine Environment of the North-East Atlantic (OSPAR Convention), *www.ospar.org/*. • Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM Convention), *www.helcom.fi/home*. • Agreement on International Commission for Protection of the Elbe, Danube and Odra, *www.internationalwaterlaw.org/europe.html*. • EU Directives: Water Framework, Nitrate, and Drinking Water, *http://ec.europa.eu/environment/water*. • Convention on the Cooperation for the Protection and Sustainable Use of Waters of Portugal and Spain River Basins. • North American Agreement on Environmental Cooperation (Canada, Mexico, United States), *www.cec.org/*. • Great Lakes Water Quality Agreement (Canada, United States), *www.ijc.org/*. • International Boundary and Water Commission (Mexico, United States), *www.ibwc.state.gov/*.
Soil	• UN Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, *www.unccd.int/*.	• EU Directive establishing a framework for protection of soil (proposal), *http://ec.europa.eu/environment/soil*.
Air	• UN Convention on Long-range Transboundary Air Pollution (Gothenburg Protocol), *www.unece.org/env/lrtap*. • *Montreal Protocol* on Substances that Deplete the Ozone Layer (related to the use of the methyl bromide pesticide), *www.unep.org/ozone/*. • UN Framework Convention on Climate Change (*Kyoto Protocol*), *www.unfccc.org/*.	
Biodiversity, landscape	• Convention on the Conservation of Migratory Species of Wild Animals, *www.cms.int/*. • Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), *www.cites.org/*. • Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention), *www.ramsar.org/*. • Convention on Biological Diversity, *www.biodiv.org/*. • Convention Concerning the Protection of the World Cultural and Natural Heritage, *www.unesco.org/whc/*.	• EU Habitat and Wild Birds Directive, *http://ec.europa.eu/environment/nature/*. • European Landscape Convention, *www.coe.int/t/e/cultural_co-operation/environment/landscape*. • Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), *www.coe.int/t/e/cultural_co-operation/environment/nature_and_biological_diversity/nature_protection/*. • Canada-United States Migratory Birds Convention, *www.fws.gov/migratorybirds/*. • Carpathian Convention, *www.carpathianconvention.org*.

1. For other international and regional agreements related to the environment, see the Environmental Treaties and Resource Indicators (ENTRI) website: *http://sedac.ciesin.columbia.edu/entri/*.
2. For each listed agreement, the respective website is indicated.

Source: OECD Secretariat.

Much of the initial effort in evolving AEIs has been to identify appropriate indicators, and establish data sets to track the state and trends of environmental conditions in agriculture. Progress has been made in this initial phase of AEI development across national government agencies (Section 4.2.2); international governmental organisations, including the OECD (Section 4.2.3); and non-governmental organisations and the private sector (Section 4.2.4). This body of work has provided the foundation to begin using AEIs as a tool in policy monitoring and evaluation to better understand the linkages between policies and agri-environmental outcomes (Section 4.3).

4.2.2. Tracking national agri-environmental performance

Many OECD countries have produced studies using AEIs to report on the state and trends of the environmental performance of agriculture, especially since the early 1990s (Baldock, 1999). This section provides a brief selective guide to these reports, highlighting where efforts have been made by countries to link agri-environmental reporting to policy developments. A more detailed survey of national efforts to track the environmental performance of agriculture is provided in each of the country sections in Chapter 3.

Australia

The National Land and Water Resources Audit (NLWRA) in Australia is periodically updating on the status of natural resources of the country and in 2002 presented a series of initial national assessments of resources used and affected by agriculture (NLWRA, 2002). The audit describes socio-economic and environmental issues of the farming community and examines in some detail soil and water resource degradation issues using regional economic assessments and case studies. The Audit quantified the natural resource base used by agriculture as well as agricultural outputs derived from these natural resources and in so doing established a baseline for agri-environmental policy-making in the country.

As an extension of the work of the NLWRA, in 2004 the Natural Resource Management Ministerial Council (2004) established and agreed a set of national resource (agri-environmental) condition indicators. The agreed indicators relate to: land affected by salinity (groundwater and surface land area); soil conditions, including acidification, wind erosion, water erosion and soil carbon content; water quality, including nutrients (nitrogen and phosphorus) and sediment in the aquatic ecosystem; and other related indicators not specific to agriculture on river, wetland and estuarine conditions; native vegetation cover; and invasive species.

Environmental monitoring data of relevance to agriculture is also collected and analysed by the Australian Bureau of Statistics (ABS). An ABS report in 2003 placed monetary values for the first time on some of the environmental conditions affecting agriculture, stating that in 2000, Australia had around 3 million hectares of saline soils, 109 million hectares of sodic soils and 21 million hectares of acidic soils (Trewin, 2003). These three types of degraded soils were estimated to cost Australian agriculture AUD 187 million, AUD 1 035 million and AUS 1 585 million respectively in annual production losses.

Canada

Agriculture and Agri-Food Canada published a national report on agri-environmental indicators in 2000 (McRae *et al*., 2000) and have updated this in 2005 (Lefebvre *et al*., 2005). The agri-environmental indicators were developed by an interdisciplinary team of specialists from the Department's Research Branch and Strategic Policy Branch. Where possible, data are presented spatially utilising a national soil landscape map base linked to variables derived from the Census of Agriculture, and often report on risk, based on the combination of known soil, climate and cropping information for a given landscape. Farm management and crop information come from the Canadian Census of Agriculture and Statistics Canada surveys. The utilisation of risk indicators in the absence of site-specific monitoring data characterise the Canadian agri-environmental reports.

Finland

AEIs have been developed by Agri-Food Research for the Finnish Ministry of Agriculture and Forestry (Yli-Viikari *et al*., 2002) that cover a wide range of issues including soil quality, nitrogen balances at national and regional watershed scales, greenhouse gas emissions from agriculture (utilizing IPCC methodology) and ammonia emissions. For the AEIs covering biodiversity, they include the genetic diversity in domestic plant and animal breeds, threatened species, bird populations and habitat use, butterflies and weeds. Structural landscape indicators have also been defined to include landscape openness, edge density of fields and agricultural land use trends. In addition to this effort, Statistics Finland (2004) publish annually a series of indicators on natural resource and environmental conditions. This includes coverage of agriculture, including impacts of nutrient run-off and regional information on tillage operations and pesticides.

France

In France, the Institut Français de l'Environnement (IFEN) has a mandate to identify the legislative and regulatory targets currently in force and to devise suitable indicators to measure performance against the targets (IFEN, 2000). France conducts environmental planning on administrative units based on the spatial hierarchy of Regions, Départements and Communes. This has resulted in various *ad hoc* studies related to AEIs but regularly published data series are lacking, except the frequently published series on pesticides in water (IFEN, 2006).

Italy

The National Institute of Agricultural Economics published a national report aimed at measuring the progress of Italian agriculture towards sustainability (INEA, 2004). The volume presents a set of *agro-sustainability* indicators allowing for simultaneous assessment of social, economic and environmental issues. Relationships with the other sectors of the economic system, and the complex articulation (and differentiation) at the territorial level with special attention to rural areas are taken into account.

The *economic dimension* mainly refers to the efficient use of resources, competitiveness, and viability of the agricultural sector. The *social dimension* refers to equity meant as "equal opportunity", both territorially (between rural and non-rural areas) and sector-wise (between agriculture and other economic sectors), and also between men and women in the sector. The *environmental dimension* concerns management and conservation of natural resources. The analysis is based on a list of environmental objectives of policy relevance: protection of water resources (qualitative and quantitative issues) and soil; combating climate change; protection of landscape; and biodiversity conservation.

The complexity of the relationships among the three dimensions has been analysed through the *dashboard of sustainability*. Using the metaphor of a vehicle's instrument panel in terms of sustainability, the "dashboard" method provides an efficient representation of the complexity of the issue of sustainability and of the impossibility of resulting in a universal assessment. To verify the sustainability of Italian agriculture over time, this report will be updated periodically.

Switzerland

Switzerland is developing a set of indicators allowing for an assessment of sustainability of agriculture under its three pillars, economy, social and ecology. For the environmental part, the Swiss Federal Office for Agriculture implemented in 2002 the first stage of designing and implementing a set of agri-environmental indicators with the full set planned to be operational (methodology and data) in a first step by 2008 (Swiss Federal Research Station for Agroecology and Agriculture, 2003). The set includes 3 types of indicators covering: farming practices; agricultural process (risk indicators); and environmental state, including various environmental themes such as nitrogen, phosphorus, water, soil, energy, climate and biodiversity. Indicators are established by a group of experts, with work in progress determining what are the most relevant methodology and data for the calculation of the indicators. The indicators already established are regularly reported by the government (Office fédéral de l'agriculture, 2005). In addition, the Swiss Federal Office for the Environment has a longer track record in overall environmental monitoring. It is constructing an Eco-Fauna Database, which is a matrix of the habitat and other requirements for nearly 3 000 species of fauna, *e.g.* mammals, butterflies, birds (Walter and Schneider, 2003) as well as networks for observation of water, air and soil quality. These environmental monitoring programmes are also being integrated into agri-environmental policy evaluation (Badertscher, 2005).

United Kingdom

Original work on sustainable development indicators relating to agriculture in the United Kingdom came from the Department of Environment's 1996 report (Indicators Working Group, 1996), that led in 2000 to publication of a full suite of AEIs (MAFF, 2000). These included certain economic indicators (agricultural support estimates, income and employment), input use (fertilisers, energy and pesticides) and resource use (water, soil organic matter, land use and heavy metals). Indicators were presented using time series data and trends for a 25-year period up until 1998. There is now an annual updating of this work providing key environmental indicators, which also include cover agriculture, such as the farmland bird index, agricultural land use changes, and water pollution (DEFRA, 2005).

United States

The Economic Research Service (ERS) of the United States Department of Agriculture (USDA) has prepared a series of reports starting in 1994 up to 2006 which have identified environmental trends in land, water, and biological resources as well as agricultural input use (nutrients, pesticides, seed and machinery) (USDA, 2006). These reports go beyond traditional "state of environment" reports in that monetary values are linked to physical units, (water and soil) in selected case studies. National scale maps illustrate resource conditions generally at one point in time such that trends are not easily established. Through the use of literature reviews and summaries of economic studies, the reports bring together a vast store of information to the topic of agriculture and the environment.

Two key data sources for the ERS AEI reports and other agri-environmental policy analysis in the United States are the USDA's *National Resources Inventory* (NRI) and the US Geological Survey (USGS) *National Water Quality Assessment* (NAWQA). The NRI programme, conducted by the Natural Resources Conservation Service formerly the Soil Conservation Service, has been collecting natural resources data since the 1930s. The current inventory (*www.nrcs.usda.gov/technical/NRI/*), which is updated regularly, is a longitudinal survey of

soil, water and related resources designed to assess condition and trends every five years on the non-federal lands of the United States (Goebel, 1998). The NRI has evolved over the decades as resource issues have changed in an effort to better assess soil conservation, natural resource health, and other environmental issues.

Under the NAWQA, scientists since 1991 have been collecting and analysing data and information in more than 50 major river basins and aquifers across the US. The goal is to develop long-term consistent and comparable information on streams, groundwater, and aquatic ecosystems, including in predominantly agricultural areas, to support sound management and policy decisions. The NAWQA programme is designed to answer the following questions (*http://water.usgs.gov/nawqa/index.html*):

1. What is the condition of our nation's streams and groundwater?
2. How are these conditions changing over time?
3. How do natural features and human activities affect these conditions?

The National Research Council (2000) formed a *Committee to Evaluate Indicators for Monitoring Aquatic and Terrestrial Environments* which reviewed indicator development and their relevance to policy makers. They observed that to develop and implement sound policies, data are needed that capture the essence of the dynamics of environmental systems and that these data then need to be incorporated into indicator calculations. The report identifies three families of indicators and their relation to agro-ecosystems:

1. Ecosystem extent and status (land cover, land use);
2. Ecological capital (species diversity, soil organic matter, nutrient run-off);
3. Ecosystem function (net primary production, carbon balance, nutrient balance).

4.2.3. International reporting on environmental conditions in agriculture

OECD Secretariat

The main OECD work on agri-environmental indicators has been published through the three volumes of the series *Environmental Indicators for Agriculture*, already discussed in the *Background and scope of the Report,* Section II (OECD, 2001a; 1999; 1997). This Volume in the series has also been supported by seven OECD Agri-environmental Indicator Expert Meetings on different indicator themes from which the Proceedings have been published (Box II.1, *Background and Scope of the Report*, Section 2). The AEI work has also draw from the OECD's Environment Directorate's regular publication of the series *Environmental Data Compendium* and related OECD *Environmental Indicators: Development, Measurement and Use* (OECD, 2003b). This work is supported by a regular environmental data questionnaire to OECD member countries, which also collects some data relevant to agriculture, such as on pesticide and water use. Both the AEI work and that of environmental indicators has also been part of a broader and ongoing effort by OECD to examine sustainable development. The analysis has included focus on frameworks to measure sustainable development (OECD, 2000a) and defining indicators to measure progress toward sustainable development (OECD, 2000b).

European Environment Agency and European Commission

A joint project co-sponsored by the European Commission (Directorate-General [D-G)] for Environment and D-G for Agriculture entitled *Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy* (IRENA) published a comprehensive report on

agri-environmental indicators for the EU15 (EEA and European Commission, 2006). The analyses utilised, wherever possible, a spatial framework of the EU Nomenclature of Territorial Units (NUTS) to report on many indicators in map form at national and sub-national levels. Data are also drawn from the various surveys of Eurostat (the EU Statistical Office), and both IRENA and Eurostat share data and some indicator development with OECD, most notably for nutrient balances (Chapter 1). The report builds on 40 agri-environmental indicators reporting on farm trends, water quality, land use, farm management, soil quality, climate change, air quality, biodiversity and landscape. Each indicator is evaluated for its usefulness and feasibility of on-going reporting, and IRENA covers the previous EU15 member states and the period 1990 and 2000. The IRENA operation integrates indicators with specific policy targets and environmental regulations or standards (EEA, 2006).

Building on an earlier FAO and UNCCD projects on defining environmental indicators related to desertification (FAO, 2003; Florke and Alcamo, 2004), the EU's DG-Research has funded work on desertification indicators for Mediterranean Europe (Brandt *et al.*, 2005). This extends the IRENA agri-environmental indicators on soil and water to address these specific issues in target regions of four EU15 countries (**Greece, Italy, Portugal** and **Spain**).

United Nations and UN agencies (FAO, UNEP)

The United Nations Commission on Sustainable Development (UNCSD) published in 2001 a report on sustainable development indicators that has acted as a guide and building block in the international effort to define and revise environmental indicators (UNCSD, 2001). The indicators under the land theme in the CSD framework focus on the key sub-themes of agriculture, forests, desertification, and urbanisation. Indicators specific to agriculture are limited to the national area of agricultural land use, the annual use of fertilisers, and the annual use of pesticides. Indicators are calculated largely from existing FAO databases of aggregated national data, and are expected to be revised in 2006.

UN reports on environmental indicators tend to be at highly aggregated levels and cover all UN member countries. Examples of this level of reporting include the United Nations Environment Programme (UNEP) ***Global Environmental Outlook*** series (UNEP, 2002) and more specific reviews, such as the integrated assessment handbook of agriculture and trade (UNEP, 2005). They tend not to provide the detail or focus of AEIs developed by OECD member countries. However, the recent ***Millennium Ecosystem Assessment*** project is a major research undertaking that documents scale and status of global agriculture and presents some challenging conclusions (Millennium Ecosystem Assessment, 2005).

The ***Land Quality Index*** programme was a joint initiative of FAO, UNDP, UNEP and the World Bank (FAO, 1997) that developed a set of land quality indicators aimed at assisting planners and policy-makers, particularly in developing countries, to make better use of their existing information on land quality and to promote more systematic data and information collection. This was followed by the production of a handbook (FAO, 2002) on the collection of data and compilation of indices. More recent FAO work has focused on desertification indicators (FAO, 2003). The Land Degradation Assessment in Drylands (LADA) project was designed to strengthen support to combat land degradation in response to the need identified by the UN Convention to Combat Desertification (UNCCD). Various indicators of potential use to LADA include indicators on soil moisture, soil depth and productivity, organic carbon, nutrient balance, erosion (including wind and water erosion), biodiversity, accumulation of salts, waterlogging, land use and cover change with application to some OECD Mediterranean countries.

World Bank

In the context of the World Bank's annual *World Development Report*, a subset of environmental indicators is also regularly published. These indicators have a global country coverage, with a sub-section of indicators related to agriculture. However, the agri-environmental indicators are highly aggregated covering only land area, irrigated land area, fertiliser consumption, agricultural water use, food production index and population density (World Bank, 2004).

North American Free Trade Agreement – Commission for Environmental Co-operation (CEC)

Agriculture is covered by the CEC in its *State of the Environment* report (CEC, 2001). Only broad summary statistics of land area, pesticide use, number and size of farms are presented, and no indicators as such were used. However, the CEC has published a much more thorough evaluation of policies and programmes within the NAFTA partnership (CEC, 2003). This report discussed present and future techniques for assessing environmental conditions. It concluded that trend analysis, such as is used in the OECD AEI programme, can be helpful to policy makers needing to understand what has happened in the past and what is happening now. They concluded that it is often less successful as a basis for predicting what will happen in the future. This is an important consideration if one objective of environmental policy is to take preventive action to limit environmental challenges before they become severe and widespread.

Other international governmental organisations

A number of other international governmental organisations are also active in the field of environmental monitoring, usually in the context as Secretariats to International Environmental Agreements (Box 4.2). This Volume has drawn on this work and co-operated closely with the UN Economic Commission for Europe (UNECE) for data on agricultural ammonia emissions (Section 1.7.1, Chapter 1); the UNEP for data related to agricultural methyl bromide use (Section 1.7.2); and the UNFCCC as regards agricultural greenhouse gas emissions (Section 1.7.3). In addition, the International Energy Agency maintains an energy consumption database, which has been drawn on for the energy Section 1.4, in Chapter 1.

4.2.4. Non-governmental organisations (NGOs)

The published inventories of ***BirdLife International*** covering bird population estimates, trends and conservation status (BirdLife International, 2004) and related Important Bird Area summaries (Heath and Evans, 2000) have become accepted as suitable data sources for farmland biodiversity indicators by an increasing number of OECD countries, such as the UK for example (DEFRA, 2005) and in this Volume (Section 1.8, Chapter 1). Birds are a well-studied species and thus have considerable utility in providing information on the overall health of the environment, including farmland habitats. The use of data collected world wide by a network of skilled volunteers is unique and efforts are underway to further enhance the efficiency of data capture and handling of bird observations that could lead to extending the use of bird census information in indicator reporting to other countries in the future (Roberts *et al.*, 2005).

The ***World Wide Fund for Nature*** (WWF) uses two main indicators in its *Living Planet Report* series to measure the world's progress on sustainable development and biodiversity conservation (WWF, 2004). The *Living Planet Index* measures overall trends in populations of wild vertebrate species around the world. The second is the *Ecological Footprint* that is a

measure of environmental consumption. The Ecological Footprint measures a community's use of natural resources and represents the bio-productive area necessary to both produce the resources (goods, services, energy, food) consumed by a population and absorb the waste it produces (Wackernagel and Rees, 1996). Since people use resources from all over the world, footprints add up the extent of these uses and express them on an area basis (Wackernagel *et al*., 2004), such as the recent report by the WWF on the *Ecological Footprint of Europe* (WWF, 2005).

The ***International Food Policy Research*** (IFPRI) and ***World Resources Institutes*** (WRI) published a pilot analysis of global agroecosystems (Wood *et al*., 2000). They reported a series of environmental (soil, water, air and land cover) impacts occurring from global agriculture and highlighted the double pressure on agricultural land of increasing food production while continuing to provide environmental goods and services. Data from this report has been used in the Millennium report of UNCSD (Section 4.2.3). The WRI also publish annually a series of global environmental data by country with some information on agriculture, but highly aggregated and largely drawn from other sources such as the FAO and the World Bank (WRI, 2005). On an *ad hoc* basis IFPRI publishes studies that analyse world agriculture and the status or outlook for supporting natural resources, such as soil and water (Rosegrant *et al*., 2001).

The US-based ***Heinz Center*** report *The State of the Nation's Ecosystems* was a collaborative effort between government, private sector and environmental organisations and academia (Heinz Center, 2002; 2006). A part of the report examined farmlands using a total of 18 indicators, however, only 9 of the 18 indicators specified had full data available and only 5 of these 9 had long enough data series to assess trends. Specified soil indicators include soil organic carbon content, wind and water erosion and salinity, comparable to the OECD soil quality indicators. The introduction to the report states, "we cannot know whether out current environmental policies and practices are sound, and we cannot make new policy with confidence, without a set of generally accepted measures of fundamental properties of the environment".

The ***European Centre for Nature Conservation*** (ECNC) made a pre-IRENA (Section 4.2.3) attempt at defining indicators for Europe, which was financed under the European Commission research programme (Wascher, 2000). The study focused on issues and methods but did not report performance, other than through illustrative example. Subsequent indicator reporting by the ECNC took the form of risk assessment (Delbaere and Serradilla, 2004).

4.3. Using Agri-environmental Indicators for policy analysis

This section provides a selective review of the literature in terms of providing illustrative examples of the use of AEIs for policy monitoring and evaluation. There are a number of ways in which to structure such a literature review, for example, in terms of policy categories and types (*e.g*. agricultural policies, agri-environmental measures, payments, taxes, etc., as in Section 4.1) or by environmental themes, such as those in Chapter 1 of this report (*e.g*. soil, water, air, etc.). The choice of structure to organise this section, however, is made in terms of the institutions that have prepared reports, including: OECD member country governments (Section 4.3.1); the OECD and other international governmental organisations (Section 4.3.2) and other research studies (Section 4.3.3), largely from academic research centres.

4.3.1. OECD member countries

Australia

In an examination of community based programmes in Australia, Lee and Wood (2005) examined the establishment of regionally developed indicators to monitor progress against environmental and natural resource targets. Indicators have been set at the national (Federal) policy level but need to be applied at the regional (State) level. Those with general applicability across a range of scales are indicators that relate to extent (*i.e.* the extent of native vegetation, extent of salinity, extent of soil erosion). More challenging is the application of indicators of resource conditions (*i.e.* the conditions of native vegetation, soil salinity, etc.), the setting of baseline conditions, and general data availability. Ultimately this leads to the preparation of a report card that will provide a mechanism for regular national reporting against targets for resource condition using an agreed set of indicators and consistent framework for reporting at regional, state and national levels. There are indicators for each programme area including land salinity, soil condition, native vegetation community integrity, inland aquatic ecosystems, coastal habitat, nutrients in aquatic environments, surface water salinity, and ecologically significant invasive species (Natural Resource Management Ministerial Council, 2004).

Canada

Canada uses an integrated modelling capacity linking its Canadian Regional Agricultural Model (CRAM), an economic model used for policy analysis, to science based agri-environmental indicators in order to understand how changes to agricultural policies and programs affect the sector's economic and environmental outcomes, and evaluate future plans. This multidisciplinary approach has recently been directed towards the assessment of possible greenhouse gas (GHG) mitigation strategies for agriculture (Junkins, 2005) and to support the selection of quantitative provincial environmental outcome targets under the *Agricultural Policy Framework* (APF). The APF analysis assessed the impacts of adopting a suite of beneficial management practices (BMPs) for agricultural production on a number of environmental indicators including GHG emissions, soil erosion from wind and water, residual nitrogen and the risk of water contamination from nitrogen, change in soil organic carbon, and wildlife habitat (Heigh *et al.*, 2005). MacGregor *et al.* (2001), outlined the data needs to support this integrated economic and environmental modelling system which is being used for policy assessment and development. An earlier application of integrated analysis involved a comprehensive environmental impact assessment of the *Canadian Federal-Provincial Crop Insurance Program* (AAFC, 1998). The study used CRAM to estimate changes in producer decisions attributable to crop insurance and linked the results to indicator algorithms to assess changes in soil erosion from wind and water. The crop insurance study assessed other environmental issues such as salinisation and wildlife habitat by linking CRAM results to GIS maps of environmental risks.

Denmark

A largely regulatory approach has been taken in Denmark to reduce water pollution by agriculture. To help evaluate the effectiveness of these regulations a set of national agri-environmental indicators were formulated, including nitrogen balances, nitrogen efficiency and nitrate leaching set within the Driving Force-Pressure-State-Impacts-Responses (DPSIR) framework. The indicators reveal reductions in aquatic system nitrogen concentrations, although biological response is still rather weak due to large annual variations and ecosystem complexity (Mikkelsen *et al.*, 2005).

Germany

Agri-environmental payment for the conversion to organic farming, have been examined in Germany, comparing farms with and without support (Osterburg, 2005). Payments were designed to help reduce nitrogen surpluses and maintain biodiversity on farmland. Data from farm accounts (changes in land use and input intensity) were used to evaluate the effectiveness of this policy approach, with changes in nitrogen balances used as one of the measures of the effectiveness of policy.

New Zealand

New Zealand uses indicators and other quantitative data extensively in reporting agri-environmental policy and climate change policies and in preparing New Zealand's Greenhouse Gas Inventory. Land and water data are used widely in forestry policy and management, analysis of soil quality and erosion, and in water policy, which needs indicators of improvement or deterioration in water quality. A *Linked Indicator Project* was recently instituted, which examines a range of economic, social, cultural and environmental measures significant to communities and their well-being. These indicators will provide information to support the monitoring and reporting requirements of local authorities, and will cover both urban and rural councils. The project aims to include measures of: energy use, water use, land use and cover, economic and industry activity, as well as a range of standard of living indicators.

Other work addresses environmental sustainability and natural resource accounting (environment accounts). Land and water information collected within the Agricultural Statistics programme includes areas in agricultural production, land use on farms and forestry blocks, areas of standing vegetation and crop residue burnt, quantities of nitrogen-based and other fertilisers applied, areas of land under an irrigation system and the areas actually irrigated, and the agricultural activity carried out on irrigated land.

Proposals for future activities include the collection of a wider range of additional agri-environmental information, including: water quality; irrigation methods; agricultural use of groundwater; frost protection; use of pesticides; herbicides and other agrichemicals; effluent and waste disposal; tillage practices; intensification of land; land use intentions; sustainable production and sustainable farming practices; agricultural impacts on the environment; effluent and toxic waste management; soil information and erosion; and fencing.

Norway

A pesticide tax was introduced in Norway in 1999 to reduce pesticide use with the aim of lowering risks of pesticides to human health and the environment. As a follow-up, indicators were developed to describe the trends of human health and environmental risks associated with pesticide use (Spikkerud 2005; and Section 1.3.2, Chapter 1). Calculations were based on sales data and not on actual use data.

Switzerland

Switzerland has established a set of AEIs specifically to aid policy evaluation, including indicators related to nutrient balances, energy efficiency, GHG emissions, risk of pesticide contamination of groundwater, risk of erosion, and biodiversity indicators (such as diversity of wild species and diversity of habitats on farmland). Indicators are also used to demonstrate whether or not environmental targets for reduced nitrogen and

phosphorous surpluses, ammonia emissions, lower pesticide use, nitrate content of water and habitat diversity have been reached.

Under the quadrennial revisions of the agricultural policy, agri-environmental indicators are variously used to analyse whether the agri-environmental objectives were achieved (objectives set most often on the basis of *ex ante* analysis of indicators) and, if that has not been the case, they are used to redirect or adapt agricultural policy measures. For example in 2006, the objectives for nitrogen and energy were not achieved, hence the Swiss Federal Office for Agriculture proposed that the Swiss government launch a new programme: sustainable use of natural resources. Furthermore, ecological payments for ecological compensation, animal welfare payments and cross-compliance were evaluated using agri-environmental indicators and a variety of other tools and methods (Badertscher, 2005) and are being revised following the results of these evaluations.

United States

In the United States an environmental benefits index (EBI) has been established to rank the impacts of the *Conservation Reserve Program* (CRP) on the provision of agri-environmental goods and services (Claassen *et al.*, 2001; Hellerstein, 2005). Farmers bid to retire land from production and the USDA has used the EBI to judge bids. The EBI balances expected environmental benefits against costs of retiring land, with points scored for wildlife habitat creation, water quality benefits from reduced erosion, run-off and leaching, reduced wind erosion and emissions of GHGs. An extension of the EBI was developed by Cattaneo *et al.* (2005) in terms of an Aggregate Environmental Index (AEI), which is similar to the EBI and used by the US Department of Agriculture (USDA) to assess CRP contracts. The AEI takes into consideration nine resource concerns: nitrogen into surface waters and subsurface waters, phosphorus in surface waters, pesticides into surface and ground waters, sediment into surface waters, wind erosion, carbon loss into the atmosphere and long-term soil productivity.

The effectiveness of the CRP in reducing soil erosion was also examined by Claassen (2005). During the time of the programme's existence, beginning in 1985 and up until 1997, soil erosion was reduced in the US by nearly 40%. However, in his analysis, he concludes that only a quarter of that can be attributed to conservation compliance, the rest coming from technological and market changes. This evaluation drew on the Natural Resource Inventory (NRI), as described in Section 4.2.2. From these data, together with those from the Agricultural Resource Management Survey (ARMS) and using the universal soil loss equation (USLE), changes in soil erosion by water over time were calculated.

A further USDA study (Aillery *et al.*, 2005) used a modelling mass balance approach to assess policy impacts of manure management on US farms. Modelling was focused at the farm and regional scales, and trade-offs between reduced ammonia emissions and increased nitrogen run-off into water bodies were examined as they relate to meeting regulations under the US *Clean Water Act* and *Clean Air Act*.

4.3.2. International governmental organisations

OECD Secretariat

The OECD Secretariat has used AEIs in three broad types of policy analysis:

1. statistical correlation;
2. outlook studies, involving the use of projection models; and,
3. in economic modelling of the linkages between policies and agri-environmental outcomes.

The use of AEIs in policy analysis by using statistical correlation of cause and effect has been most extensively used by the OECD in its country report series *Environmental Performance Reviews*, especially where agriculture has been highlighted as a special theme (*e.g.* **New Zealand**, see OECD, 2007a). Changes in nutrient balances and pesticide use, for example, have been correlated to relevant policy changes where these have occurred. A similar approach was taken in the case of the recent OECD series of country *Economic Surveys*, by drawing on the nitrogen balances in assessing policies to address water pollution (OECD, 2004c). A further example of using the nitrogen balance indicator was the OECD study that examined decoupling of environmental pressure from economic growth, including decoupling of resource use from agricultural production growth (OECD, 2002).

In a paper on the instrument mixes used to address non-point sources of water pollution from agriculture (OECD 2007b), a range of indicators are used to assess the effectiveness of various instruments, with case studies from **Denmark**, the **Netherlands** and **UK**. Indicators on fertiliser use, pesticide use, nutrient (N and P) balances are used. In both **Denmark** and the **Netherlands** case studies, detailed nutrient accounting system have been implemented to keep track of, and to control, the application of nutrients. Implementation of tracking systems provides additional information from which agri-environmental indicators can draw.

In terms of ***the use of AEIs in OECD outlook (projection) reports***, the AEIs have been used in the *Agricultural Outlook* (OECD, 2001b) to examine the long-term outlook for agriculture and the environment. In addition, AEIs were drawn on in the first *Environmental Outlook* (OECD, 2001c), and will do so again for the second report for 2008, providing projections to 2030.

The most extensive use of AEIs by OECD has been in economic modelling of the linkages between policies and agri-environmental outcomes. Particularly extensive use of AEIs in modelling various policy scenarios was included in the series of OECD commodity studies (pigs, dairy and arable sectors) Agriculture, Trade and the Environment (OECD, 2006; 2005b; 2004b; 2003a). A literature review into agricultural trade liberalisation impacts in several OECD countries as part of a review of the arable crops sector in agriculture revealed that AEIs were used to help evaluate environmental outcomes (OECD, 2005b). Based on projected changes in cropping mixes and patterns, soil wind and water erosion were reviewed in the **US**, nutrient balances and biodiversity in **Finland**, and nutrient balances in **Austria**. A modified Global Trade Analysis Project (GTAP) model was also used to simulate liberalisation impacts on the arable crops sector with respect to nutrient balances, pesticide use and greenhouse gas emissions indicators. In a parallel study on the dairy sector (OECD, 2004b), agricultural trade liberalisation was again modelled using a modified GTAP model. Production shifts to countries like **New Zealand** and **Australia** were associated with increased GHG emissions and nutrient surpluses that could have impacts on water quality, findings supported in an earlier study and related study which also used AEIs (Saunders and Cagatay, 2004) The OECD Secretariat is further developing its analysis of the linkages between agricultural policies and environmental effects.

Other international governmental organisations

The ***European Union*** has reinforced the monitoring and evaluation of the environmental impacts of the measures included in its rural development policy. The common monitoring and evaluation framework for the rural development programmes 2007-13 foreseen in the EU rural development regulation intends to more

effectively measure the progress in achieving the EU priorities. It will include a set of common indicators (baseline, output, result and impact) including agri-environmental indicators related to the measures concerning the improvement of the environment and the countryside (*e.g.* agri-environmental measures, support for protected *Natura* agriculture and forestry 2000 areas). The agri-environmental indicators will specifically refer to the three EU environmental priority objectives, which are: halting biodiversity decline and the preservation of high nature value farming; achieving the objectives of the *Water Framework Directive*; and mitigating and adapting to climate change (see the EU section in Chapter 3).

The ***European Environment Agency*** has begun to integrate the IRENA set of AEIs into various policy analysis activities (Section 4.2.3). The EEA (2006) report describes the integration of the *European Union's* environmental policy into the *Common Agricultural Policy* (CAP), drawing on the IRENA indicators. Also IRENA indicators were used in the EEA's (2005c) environmental outlook report, which assesses potential environmental consequences of key socio-economic developments in Europe, including agriculture; while another study on the environmental impacts within EU accession countries also utilised IRENA indicators (EEA, 2004).

The ***Secretariat to the Convention of Biological Diversity*** (SCBD, 2005) described the effects of trade liberalisation on agro-biodiversity within the context of the WTO Uruguay Round Agreement on Agriculture (URAA). In this qualitative study it was concluded that… "despite a number of methodological problems in designing agri-environmental programs for the conservation and sustainable use of agricultural biodiversity, mainly related to the lack of reliable and practical agri-biodiversity indicators and to the problem of choosing appropriate benchmarks, it seems that well-targeted, designed and implemented programmes that are based on scientifically sound environmental performance indicators are able to contribute to positive external effects of agricultural production on biodiversity".

The ***United Nations Environment Programme*** (UNEP, 2005) outlines agri-environmental indicators as one of a number of quantitative and semi-quantitative methods to assess environmental impacts of agriculture under a range of policy environments. The report presents a list of possible environmental indicators that could be used covering water quantity and quality, land, biodiversity, energy, air quality, and pesticides.

4.3.3. Research community

There is a growing literature from the research community that is using AEIs for policy analysis. The selective examples highlighted in this section are grouped under two broad headings, first studies that have used AEIs in policy analysis to examine a specific environmental outcome (*e.g.* effects on nutrient balances), and second, those studies that have sought to examine the effects of policy change across a range of environmental outcomes.

In a study of ***nutrient flows*** in agricultural production and international trade, nutrient balance calculations were used to illustrate trends and conditions in both developed and developing countries (Craswell *et al.*, 2004). The study revealed the situation of developed countries with nutrient surpluses and many developing countries with nutrient depletions. Bayliss *et al.*, 2004 also used the nutrient balances indicator as a way of comparing and characterising countries within the **EU** and the **US** and the type of agri-environmental programmes that exist. In comparing US and EU policies they used AEIs indicators to characterise the differences between the two jurisdictions.

While varying ***greenhouse gas emissions*** under different policy scenarios have been modelled for all OECD countries in a number of studies, only a few have done so within the context of examining the impact of agri-environmental policies on GHG emissions. Brito Soares and Ronco (2005) looked at **EU15** countries and equated emissions with the adoption of the Common Agricultural Policy (CAP), with results showing mixed correlations.

Oñate *et al.*, 2000 utilised farm level indicators to evaluate both policy performance and the outcomes of EU agri-environmental policies on ***agricultural landscapes*** in **Denmark** and **Spain**. Using their selected indicators (related to farm land use and farm management), they demonstrated positive and negative impacts on biodiversity values as the result of land use and farm management changes in these two countries.

In using AEIs to examine the effects of policy change across a range of environmental outcomes, a study of the effects of CAP reform in **Austria**, used a series of AEIs to model impacts on methane emissions, carbon storage in soil, nitrate leaching and nitrogen balances, and organic farming (Hofreither *et al.*, 2004). Similarly, the LEI *et al.*, 2003 describe the details of the incorporation of AEIs within the agricultural supply CAPRI model which runs at the regional level in Europe. The following indicator models are linked to CAPRI including nutrient balances, ammonia emissions, water balances and GHG emissions, across a number of policy scenarios including Agenda 2000 and the 2003 CAP Reform Proposal. Using a "Johansen-type" input/output model, the environmental impacts of the post 1992 CAP reforms was performed for a region of **Portugal** (Serrão 1998). The model linked AEIs of the use of fertiliser, pesticides, and energy to stocking density, land use change, crop production intensity and crop cover.

4.4. Knowledge gaps in using Agri-environmental Indicators

Policy decision-making in the environmental and agri-environmental domain is a challenging undertaking (Esty *et al.*, 2006). As highlighted in Chapters 1 to 3 in this report, all OECD countries are addressing a wide range of environmental issues in agriculture. But policy makers face a number of knowledge gaps in particular: incomplete scientific knowledge and data on the effects and timing of policies and agricultural practices on the environment; lack of a monetary numeraire to weigh up and assess the range of environmental impacts from agriculture; and partial knowledge of the impact of the environment on agriculture.

Given the evidence – including in this report – of the growing importance of agri-environmental policies across OECD countries, there is value in developing robust agri-environmental indicators and modelling efforts to improve policy decision making. For AEIs to better serve the needs of policy makers and policy analysis (at both the regional and national levels) as well as the wider public in communicating the state and trends of environmental conditions in agriculture, the knowledge gaps can be viewed in the light of the OECD indicator criteria of policy relevance, analytical soundness, measurability and ease of interpretation:

Policy relevance. There are a set of interrelated agri-environmental policy issues that all OECD countries, although in varying degrees of importance, are addressing:

1. controlling polluting emissions from farming activities (nutrients, pesticides, air emissions);
2. protecting natural resources (quality of soil, water, air, biodiversity);
3. providing ecosystem services (*e.g.* sink for greenhouse gases, flood control); and,

4. changing farm management practices to reduce pollution, protect natural resources and enhance ecosystem provision.

However, some agri-environmental issues that are common to most OECD countries are poorly tracked by the current set of AEIs, notably:

1. farm pesticide and pathogen pollution of water bodies, especially groundwater;
2. soil organic carbon changes in agricultural soils;
3. agricultural use of water resources, especially groundwater;
4. impacts of farming activities on wild species and ecosystems (biodiversity); and the,
5. extent of the adoption of environmental farm management practices and systems.

A key challenge for policy makers is to determine the highest priority investments in monitoring and reporting capacity given limited resources and the large array of "policy relevant" environmental issues faced by governments. This involves moving from physical measures of agricultural impacts on the environment to a set of economic or monetary measures of impacts.

Developing a system of national accounts to reflect the full economic costs and benefits to society of agricultural activities on the environment would enable comparison and evaluation of different environmental issues on a common basis, which is not satisfactorily achieved using physical measures. Hence, it would be possible to compare the relative importance of water pollution with soil erosion or the benefits from biodiversity conservation compared to carbon sequestration in farmed soils.

There are numerous difficulties in measuring the economic costs and benefits of agriculture on the environment; especially deriving estimates of the benefits for which markets frequently do not exist (*e.g.* biodiversity). A number of countries have begun to develop work in this area (Chapter 3). In the **United Kingdom**, for example, the government Department for Environment, Food and Rural Affairs (DEFRA) has research underway (see the reports at: *http://statistics.defra.gov.uk/esg/reports/env.asp*) that seeks to estimate the environmental cost and benefits of farming activities, including the publication of preliminary monetised environmental accounts for the UK agricultural sector (EFTEC and IEEP, 2004).

Analytically sound. A central problem in examining agri-environmental linkages is that it involves a scientific understanding of biophysical relations in the environment and their interaction with farming activities. Many of these relations and interactions are not fully understood at a scientific level, which can make it difficult to guide monitoring activities capable of generating data and indicators useful for policy analysis. There is now a growing effort to better link science with analytical policy tools, particularly through integrating biophysical with economic models, as for example with the ongoing research in **Canada** to develop in an agricultural context integrated economic and environmental models (Junkins, 2005).

As well as improving the underlying scientific understanding of agri-environmental linkages, there is a need at the international level to improve the definitions and methods by which indicators are derived and applied to ensure cross country consistency, which is also recognised more broadly for environmental indicators (Müller and Lenz, 2006). The OECD nutrient balance indicator methodology is an example of progress in this respect, as are the international efforts related to greenhouse gas and ammonia emissions indicators, and the common acceptance among researchers of using the Universal Soil Loss Equation (USLE) to

measure soil erosion (Chapter 1). For other indicators further improvement of the basic rules governing indicator definitions and calculation methodologies would be particularly useful to help policy analysis in the following areas related to primary agriculture:

1. pesticide use and environmental risk indicators;
2. water accounts (surface and groundwater agricultural abstractions and returns);
3. ecosystem indicators, particularly semi-natural habitats on agricultural land; and,
4. farm management, covering management of nutrients, pests, soil, water and biodiversity.

Measurable. Issues relating to data gaps are well recognised in this report and in previous OECD publications on AEIs, and are not further elaborated here (OECD, 2001a; 1999). Most OECD countries are seeking to improve the quality of the spatial and temporal resolution of their datasets used for the calculation of AEIs, not least because these are needed to apply and monitor policy. Other issues relating to improving the quantity and quality of data to calculate AEIs include:

1. ***Integration of databases:*** By seeking ways to integrate different agricultural and environmental databases that are commonly collected on a regular basis across most OECD countries (*i.e.* farm structure surveys, farm account surveys and agri-environmental datasets). For example, frequently farm structure surveys provide data on land cover changes, while farm account surveys may provide information on farm management practices. The integration of databases can provide the opportunity to achieve value added from existing datasets, which is especially important when additional resources for data collection are scarce.
2. ***Coupling indicators:*** By tracing through the cause and effect relationships that is explicit in the *Driving Force-State-Response* framework. For example, as an environmental *driving force* the pesticide use indicator is linked to pesticide risk indicators and the *state* or concentration of pesticides in water bodies. *Responses* to these changes in the state of the environment are revealed through indicators of pest management and environmental farm planning. Coupling indicators can also provide a means to verify the validity of the change in direction of a given indicator. For example, if the nitrogen surplus balance is showing a rising trend then it would be expected that this would be reflected in increasing trends for the ammonia and elements (methane, nitrous oxide) of greenhouse gas indicators.

Ease of interpretation: To clearly communicate to policy makers and the public, with least ambiguity, the state and trends of environmental conditions in agriculture. This involves the need to:

1. ***Limit*** the number and complexity of AEIs given the large differences between the extent of data needs required by researchers compared to those of policy makers and the public who seek a more condensed set of indicators. Efforts to develop "Headline" environmental indicators by some countries are a step in this direction, in an attempt to provide a set of indicators that can become as familiar as economic and social indicators such as inflation and employment rates.
2. ***Reconcile*** the need for indicators that address specific agri-environmental issues within a country or group of countries; provide comparative information across countries; and that are amenable for use in policy modelling.

In order to better serve the needs of policy makers and the public further to narrow the knowledge gaps identified in this section a relatively low-cost option would be to strengthen indicator networks at a number of levels including between:

1. International organisations (*e.g.* OECD, FAO, Eurostat, EEA).
2. Scientists, developers of indicators, policy analysts, farmers, and the agri-food chain.
3. OECD and non-OECD countries; and between.
4. Governments and non-governmental organisations (*e.g.* BirdLife International).

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