Executive summary

Water is a central issue of adaptation to climate change in agriculture. Agricultural production depends critically on how climatic variables such as precipitation and temperatures vary across regions and over time. The effects of climate change on agriculture occur through crop water requirements, availability and quality of water, and other factors, which are affected by both long-term gradual change and extreme events, and across a range of scales from local to regional to continental. Moreover, climate is not only changing but is becoming *non-stationary*, meaning that expectations can no longer be based only on past observations.

Interactions between climate change, water and agriculture are numerous, complex and region-specific. Climate change can affect water resources through several dimensions simultaneously: changes in the amount and time patterns of precipitation; impact on water quality through changes in runoff; river flows; retention and thus loading of nutrients; and through extreme events such as floods and droughts. Interactions between relevant weather variables that affect agricultural production, such as temperature and precipitation, are difficult to characterise. Moreover, scientific evidence underlying projected impacts on freshwater has significant limitations when it comes to informing practical, on-site adaptation decisions. These complex interactions multiply the uncertainties concerning the impact of climate change on agriculture.

The frequency and severity of extreme events such as floods and droughts may increase as a result of climate change and have substantial negative impacts on agricultural production. Much of the work undertaken on the potential impact of climate change has focused on projected changes in average temperature and rainfall, and links between these changes and measurable outcomes with clear economic implications. In contrast, there has been generally less confidence about how much night-time temperatures will rise relative to daytime temperatures, how much winter temperatures will rise relative to summer temperatures, whether or how much more variable temperatures will become, and how climate change may change the frequency and severity of extreme rainfall events, tornados and cyclones, etc. Despite the low level of certainty concerning the scientific evidence regarding shifts in extreme events, non-linear (convex) damage functions mean that changes in extremes are expected to be the most costly.

Because agricultural water management involves public goods, externalities and risk management issues, private adaptation to climate change is not equal to collective adaptation. A consistent strategy for agricultural water management needs to consider the following five levels of actions and their linkages.

- *On-farm*: Adaptation of water management practices and cropping and livestock systems.
- *Watershed*: Adaptation of water supply and demand policies in agriculture and with the other water users (urban and industrial) and uses (ecosystems).
- *Risk management*: Adaptation of risk management systems against droughts and floods.
- *Agricultural policies and markets*: Adaptation of existing agricultural policies and markets to the changing climate.
- *Interactions* between mitigation and adaptation of agricultural water management.

There is room for public policies that create an enabling environment for on-farm adaptation. Depending on the region, adaptation of agriculture may require only marginal adjustments, such as earlier sowing dates, or deep structural changes involving complete changes of production patterns, and update of cropping and livestock systems. These structural changes would be at the origin of substantial adjustment costs and may not be affordable by all farms, in particular those which already face severe financial constraints. Public policy interventions can facilitate on-farm adaptation by collecting and disseminating relevant and site-specific information about projected impacts of climate change and best adaptation practices and providing technical assistance. In cases of structural change, public policy could help smooth switching costs across time by adaptation planning and offering temporary financial assistance in clearly defined circumstances.

At the watershed level, well-designed, flexible and robust water sharing rules and economic instruments such as water pricing and water trading can foster adaptation of water systems. As climate is becoming non-stationary and climate risks are projected to increase, systems that allocate water across farms and across other uses should be flexible and robust enough to allow for efficient use of water, taking into account redistributive consequences and priority uses. The shadow price of water can vary a great deal within the growing season. Adaptation is a long-term, continuous process that involves learning, investment, and may be affected by path dependency. Two types of incentives for improving water allocation should be considered depending on the time horizon.

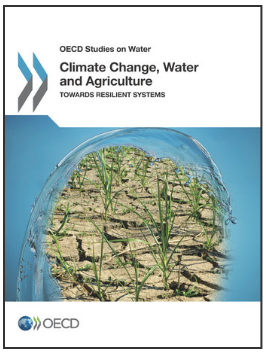
- ***Short-run incentives*** that allow farm systems to cope with intra-seasonal volatility of water supply and reallocate water to its most efficient uses within the growing season.
- ***Long-run incentives*** to adapt to continuously changing conditions of water supply, taking into account other factors (growing population, increase in urban demand, ecosystems, etc.).

The relative strength of economic instruments should be considered in light of these two time horizons. Past and current country experiences with these economic instruments constitute a strong basis for further development in the context of climate change. Water pricing and water trading systems could not only provide a stable economic incentive for investment in adaptation, but also valuable flexibility in the short run to adjust to seasonal variations of water supply and demand. Flexibility in the design of the system would send the proper signal of scarcity to water users and thereby allow the quantity or price of water to be adjusted accordingly. However, a major challenge is that it may be politically costly to reduce the size and number of quotas, or to increase the price of water in order to reflect projected decreases of average water availability. More generally, the issue of long-run incentives requires adopting adaptation planning based on the best scientific evidence available and to undertake careful consideration of the already existing set of water rights, whether these are explicit or implicit.

Risk management instruments such as prevention and insurance can play a major role for managing the increased risk of floods and droughts and contribute to the resilience of agriculture to climate change. Climate change is deeply reshaping the landscape of natural risk management. Even without non-stationary climate change, weather extremes such as floods and droughts were already not easy to insure for several reasons, including correlated risks and lack of statistical information for risk pricing. Innovative risk management tools, such as weather index insurance and catastrophic bonds, can potentially play a role by improving the efficiency of insurance systems but are still at an experimental stage. Moreover, it remains important to have a holistic approach of risk management in agriculture.

Commodity markets can play an important role in smoothing the impact of extreme weather events on price volatility over time. Open trade is an important vehicle to fully reflect shifting comparative advantage due to climate change while also pooling the risk so that yield losses in a given region can be offset through imports. Well-functioning competitive storage markets can reduce the cost of inter-temporal price volatility related to extreme weather events and reduce the probability of food price spikes on a temporary basis. The way storage markets can integrate non-stationary climate requires, however, further research. Government intervention could have a potential role in providing the enabling environment to promote private storage and competitive storage markets.

Climate change mitigation practices may have positive or negative implications on agricultural water management and on water quality. The potential synergies and trade-offs between mitigation and agricultural management practices are, however, site-specific and for many cases there are substantial knowledge gaps. Although this is a complex matter, it is important to recognise these linkages in the design of mitigation policies to reduce the risk of conflict between mitigation and water policy objectives and to maximise potential synergies.



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