Sustainable Management of Water Resources in Agriculture

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Foreword

This report explores the economic, environmental and policy dimensions and linkages related to the management of water resources, floods and droughts in agriculture. While the linkages between agriculture and water quality are touched on they are the focus of another study to be completed in 2011.

The report was carried out under the auspices of the OECD Joint Working Party on Agriculture and the Environment of the Committee for Agriculture and the Environment Policy Committee. The material in the report also contributed to the 2007-08 OECD Horizontal Programme on Water, the results of which were presented in *Managing Water for All: An OECD Perspective on Pricing and Financing* at the World Water Forum in Istanbul in March 2009.

Information on water resource management in agriculture across OECD countries was collected through a questionnaire and the analysis was also enriched by a set of background reports on:

- Agricultural water pricing in Australia, European Union, Japan, Korea, Mexico, Turkey and the United States.
- Financing water management and infrastructure related to agriculture.
- Policy issues concerning agriculture's role in flood adaptation and mitigation.
- Experiences and lessons from the Australian water reform programme.
- Economic analysis of the virtual water and water footprint concepts in relation to the agri-food sector.

Both the detailed material from the questionnaire and the background reports can be downloaded from the OECD website at www.oecd.org/agr/env and www.oecd.org/water.

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Overview

World-wide there is an enormous challenge to produce almost 50% more food up to 2030, and double production by 2050. This will probably have to be achieved with less water, mainly because of pressures from growing urbanisation, industrialisation and climate change. Consequently it will be important in future that farmers face the right signals to increase water use efficiency and improve water management, especially as agriculture is the major user of water, accounting for about 70% of the world's freshwater withdrawals and over 40% of OECD countries' total water withdrawals.

The scope of sustainable management of water resources in agriculture concerns the responsibility of water managers and users to ensure that water resources are allocated efficiently and equitably and used to achieve socially, environmentally and economically beneficial outcomes. It includes: irrigation to smooth water supply across the production seasons; water management in rain-fed agriculture; management of floods, droughts, and drainage; and conservation of ecosystems and associated cultural and recreational values.

Agricultural water resource management covers a wide range of agricultural systems and climatic conditions across OECD countries, drawing on varying water sources, including: surface water; groundwater; rainwater harvesting; recycled wastewater; and desalinated water. It also operates in a highly diverse set of political, cultural, legal and institutional contexts, encompassing a range of areas of public policy: agriculture, water, environment, energy, fiscal, economic, social and regional.

Future policies to address the sustainable management of water resources in agriculture will be greatly influenced by climate change and climate variability, including seasonality problems, such as changes in the timing of annual rainfall patterns or periods of snow pack melt. In some regions, projections suggest that crop yields could improve. For other localities, climate change will lead to increased stress on already scarce water resources, while some areas are expected to see the growing incidence and severity of flood and drought events, imposing greater economic costs on farming and the wider economy. Irrigated agriculture, which accounts for most water used by agriculture, will continue to play a key role in agricultural production growth.

Key policy messages

- ***Recognise* the *complexity and diversity of managing water resources in agriculture***

Recognition of the complexity and diversity of water resource management in agriculture, is important from a policy perspective, as it means there is no one-size-fits-all policy solution to improving water resource management. Policies addressing water resource management need to be tailored and targeted to situations specific to both countries and regions within countries. This reflects the great variety across different water basins from the local to international levels in terms of the: heterogeneity of water sources (*e.g.* surface, groundwater, recycled wastewater, desalinated water); linkages between water resource (quantity) and water pollution (quality) issues; allocation of water between consumptive uses (*e.g.* agriculture, domestic, industrial, power generation) and to meet environmental needs; and the management of the complex institutional and property right arrangements associated with water.

- ***Strengthen institutions and property rights for water management in agriculture***

A shift in water resource policies with a greater accent on demand rather than supply management, has brought reforms to the institutional and property right structures in many countries. But the progress and path of water policy reforms has been mixed across countries which indicates the need for further progress in reforming policies. There is frequently a plethora of institutions involved in managing, allocating and regulating water resources at different levels of government, and continuing rationalisation of institutional structures could improve transparency and accountability.

The institutional complexity is also reflected in most OECD by an intricate set of legal rules concerning water property rights, where water is often allocated in terms of quantities rather than prices. As pressures builds-up to reallocate water between different users and to meet environmental demands there is a need for water property rights to become more flexible, where these rights exist, and for supporting institutions to be more robust to ensure an economically efficiency and environmentally effective allocation of water. But it also emphasises the need to explore innovative water market solutions as allocative mechanisms.

- ***Ensure charges for water supplied to agriculture at least reflect full supply costs***

OECD analysis indicates that charges for water supplied to farms have been increasing in most OECD countries. However, in many countries farmers are only covering the operation and maintenance part of the full water supply costs, with little recovery of the capital costs for water supply infrastructure. Where countries have raised water charges, the available evidence indicates that it has improved water use efficiency rather than reduced output. But water charges rarely reflect scarcity and social values or environmental costs and benefits (*i.e.* full cost recovery). These are usually addressed by other policy measures, including agri-environmental payments, pollution taxes and water allocation mechanisms. These measures, however, do not address the scarcity value of water, but some countries are using the principle of full cost recovery to guide their water policy frameworks. Trading of water entitlements can provide a scarcity market price and lead to the highest value use of water resources.

Policies regarding on-farm water resources, mainly groundwater, usually involve licenses and other regulatory instruments, but because of high transaction costs to enforce compliance, the degradation and illegal pumping of groundwater remains a challenge. To achieve sustainable groundwater use more effort will be required to enforce regulatory measures and develop mechanisms for volumetric management and charging, especially where water stress is a serious issue.

- ***Improve policy integration between agriculture, water, energy and environment policies***

In many instances OECD countries policies across agriculture, water, energy and environment are formulated without sufficient consideration of their interrelationship in any comprehensive manner or their unintended consequences. Agricultural policies linked to production and inputs (water and energy), for example, can encourage less efficient use of water and energy, lead to off-farm pollution and soil degradation, which can exacerbate flood damage. In the case of links between the support for energy in agriculture and the production of biofuels from agricultural feedstocks, further progress is required to develop policy coherence in the context of improving water resource management in agriculture.

More integrated and coherent policy approaches, however, are beginning to take shape. The restoration of land in flood plains by planting trees, for example, has helped to reduce flood impacts, improved water quality, and led to co-benefits, such as restoring biodiversity and sequestering greenhouse gases. There has also been progress in lowering overall agricultural support levels and in decoupling support from production and inputs. This is beginning to encourage more efficient use of water, better adaptation to water scarcity, and lower off-farm pollution, while well-targeted agricultural support can maintain farming systems in those countries where there is an association between farming and the provision of ecosystem services. But identifying and quantifying the overall economic efficiency and environmental effectiveness of agricultural and agri-environmental support on water resources is difficult and further analysis on causation is needed.

- ***Enhance agriculture's resilience to climate change and climate variability impacts***

Many OECD countries are reporting the growing incidence, severity and costs of flood and drought events on agriculture. This has occurred from inappropriate land management practices and policies, and is being further exacerbated by climate change. In response countries are beginning to develop mitigation and adaptation strategies, including efforts to: improve food security and water use efficiency by farmers in areas of water scarcity; develop crops or change farm practices where climate change alters temperatures and precipitation; alter management practices that can contribute to slowing water transport across farmland and reducing flood damage in urban areas; and integrate sustainable water resource management in agriculture within the broader context of regional land use planning (*e.g.* the conversion of farmland to urban uses can increase flood costs as farmland has the potential to act as a flood sink).

These approaches are more likely to be effective if they are embedded in longer term strategies closely linked with overall agricultural policy reform, risk management policy and market approaches. Climate change will also require greater attention in agriculture to water saving practices both in terms of on-farm distribution systems and also the larger infrastructure systems delivering water to farms. Better understanding of the importance of extending risk management approaches in agriculture to existing climate variability, can also help build a more solid foundation for addressing climate change in the future.

- ***Address knowledge and information deficiencies to better guide water resource management***

As broader water reforms become more decentralised and complex (*e.g.* developing water trading, and changing water entitlements and institutional arrangements), policy implementation and evaluation needs to be underpinned by improving measurement of water resource availability and use, and developing knowledge, research, training and advice, monitoring and evaluation. There is a lack of transparency of information on water supply costs, while developing water markets and planning water allocation between different users and the environment requires detailed monitoring of water extractions and flows. The costs and benefits of agriculture's use of water (*e.g.* groundwater depletion, flood mitigation) need to be more precisely defined to better inform policy decision making. Farmers also need more technical advice and education on best practices to adopt, especially as climate change may render past farm practices obsolete.

Summary and Recommendations

Background

Until the 1980s, water resource management in agriculture in most OECD countries focused on the physical supply of water. Emphasis was on infrastructure "supply-side" *technical* solutions and harvesting the maximum amount from the resource. This technical-based path to water resource management is now being complemented with the accent on sustainable based water resource management and greater reliance on "demand-side" *economic* solutions. A turning point in this shift in the policy agenda was the *Dublin International Conference on Water* in 1992, where it was stressed that "managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources".

These developments have led to an emerging policy approach with emphasis on: meeting the diverse demands for water (economic, environmental and social); embracing participatory decision making and institutional structures; and encouraging a greater role for market-based allocation mechanisms. Nearly all OECD countries have policy strategies to address broad water management issues – water resources, quality and ecosystems – and in terms of the more specific objectives for managing water resources in agriculture they broadly share a strategic vision to:[1]

- Establish a long-term plan for the sustainable management of water resources in agriculture taking into account climate change and climate variability impacts, including the increased need for protection from flood and drought risks and alteration in the seasonality and timing of precipitation (rainfall and snow pack melt);
- Contribute to raising agricultural incomes and achieving broader social equity and rural development goals;
- Protect ecosystems on agricultural land or affected by farming activities;
- Balance consumptive water uses across the economy with environmental needs; and
- Improve water resource use efficiency, management and technologies on-farm and ensure the financing to maintain and upgrade the infrastructure supplying water to farms (and other users).

Evidence in this report indicates that agriculture's management of water resources has shown some signs of improvement but that more needs to be achieved, as revealed by the main trends in the use of water resources by agriculture across OECD countries since 1990 described below.

- ***Water use for agriculture*** and non-agricultural uses changed little between 1990-92 and 2002-04, although there has been considerable annual variability in water use in agriculture. The OECD trend in agriculture water use reflects significant growth in four countries (**Greece, Korea, New Zealand** and **Turkey**) mainly driven by an increase in the area irrigated (except **Korea**), but a substantial reduction in **Australia, Mexico** and most **European OECD countries**. For this latter group of countries the decrease in water use is due to a mix of factors varying between countries, but notably improvements in water use efficiency, drought, release of water to meet environmental needs, and, for OECD European countries contraction of the agricultural sector.

- Despite the near static demand for water by agriculture across OECD countries, there is growing ***pressure on water resources*** in some regions under water stress. This has arisen because of more intense competition between farmers and other water consumers, as well as diversion of more water for environmental purposes, such as in parts of California, **United States**, and in many **OECD European countries** surrounding the Mediterranean. Greater competition for water resources, however, can generate positive outcomes if it leads to more efficient resource allocation adjustments, generates environmental benefits, and fosters higher economic growth.
- ***Agriculture accounted for 44% of total water use overall*** in 2002-04, although for eight OECD countries where irrigated agriculture is important, the share is over 55%. Some of the water used by irrigated agriculture is reused by other downstream users or diverted to meet environmental needs, although there are also losses due to evapotranspiration; pollutant runoff from irrigated farming; and losses to groundwater sources which are no longer economic to pump.
- ***The area irrigated rose by 8%*** compared to a reduction of 3% in the total agricultural area between 1990-92 and 2002-04, although recently in a number of countries, the area irrigated has been decreasing, in part, reflecting an overall contraction of the agriculture sector.
- ***Irrigated agriculture*** provides a growing and major share of the value of farm production and exports for some OECD countries, and supports rural employment in a number of regions. As such irrigated agriculture accounts for most of agricultural water use, and will continue to play an important role in agricultural production growth in some countries.
- ***Improvements in physical water productivity*** by agriculture, through better management and uptake of more efficient technologies, such as drip irrigation and ***adoption*** of other water saving farm practices, has contributed to an increase in farm production. Overall the OECD average water application rate per hectare irrigated decreased by 7% between 1990-92 and 2002-04, while in most cases the volume of agricultural production increased.
- ***The adoption of drip irrigation, low-pressure sprinkler systems,*** and other water saving technologies and practices, are becoming more widespread. Water use efficiency in agriculture is also being improved through replacing earthen irrigation channels with concrete linings to reduce losses and upgrading flood irrigation systems (*e.g.* levelling of fields, neutron probes for soil moisture measurement, and scheduling of irrigation to plant needs).
- Agriculture ***abstracts*** an increasing share of its water from ***groundwater,*** and the sector's share in total groundwater utilisation, although data are limited, was above 30% in 12 OECD member countries in 2002. In some cases other sources of water are

becoming significant, especially the use of recycled wastewater, mainly sewage, and desalinated seawater.

- Over-exploitation of water resources by agriculture in certain areas is damaging ***ecosystems*** by reducing water flows below minimum flow (stock) levels in rivers, lakes and wetlands, which is also detrimental to recreational, fishing and cultural uses of these ecosystems. Groundwater use for irrigation above recharge rates in some regions is also undermining the economic viability of farming in affected areas.

- ***Pollutant discharges*** from agriculture into water bodies have been declining in recent years in many OECD regions, but for nutrients and pesticides agriculture still remains a major source of pollution in most cases. However, information on the trends in pollution from irrigated land is patchy.

- Agriculture is at risk from the growing incidence and severity of ***floods and droughts*** in many OECD countries. This has been associated with both human alterations of the hydrological characteristics of watersheds and land-use policies that have encouraged ***urbanisation*** in areas at risk to flooding events, and also increasingly the trend toward greater climatic variability leading to higher financial costs both through loss of production and damage to farm infrastructure, and also costs for the wider economy in terms of damage to property and in some cases loss of life.

- The 2007 projections of the Intergovernmental Panel on Climate Change in relation to ***climate change, water and agriculture,*** supported by the conclusions of reports from many OECD government agencies, indicate that changes in water quantity and quality will affect food availability, stability, access and utilisation. Climate change is also expected to affect the functioning and operation of existing water infrastructure, including hydropower, structural flood defences, drainage and irrigation systems. Current water management practices might also not be robust enough to cope with the impacts of climate change and climate variability on water supply reliability, flood risk, agriculture, energy and ecosystems.

The developments outlined above suggest that a future challenge will be to ensure water resources used by agriculture are allocated among competing demands so as to: sustain the agricultural industry; produce food, fibre and energy efficiently; minimise pollution and support ecosystems; and meet social and cultural aspirations. Hence, the broad directions for a strategy that could shift ***agriculture's management of water resources onto a more sustainable path across OECD countries suggest the need to:***

- Recognise the complexity and diversity of managing water resources in agriculture;

- Strengthen institutions and property rights for water management in agriculture;

- Ensure charges for water supplied to agriculture at least reflect full supply costs;

- Improve policy integration between agriculture, water, energy and environment policies;

- Enhance agriculture's resilience to climate change and climate variability impacts; and,

- Address knowledge and information deficiencies to better guide water resource management.

Recognising the complexity and diversity of managing water resources in agriculture

The scope of the complexity and diversity of water resource management in agriculture can be summarised in terms of hydrology, and water sources, uses, economics and institutional structures.

- ***Hydrology:*** the mobility of water – in that it flows, leaches, evaporates, and has the opportunity to be reused – makes it distinctive as a commodity compared to land, for example. Moreover, agriculture can contribute positively to the hydrological cycle, for example, through groundwater recharge and water purification functions. But agriculture can also contribute to surface water and groundwater pollution and through excessive extraction may lead to the diversion of water from supporting ecosystems.
- ***Sources:*** agricultural water sources are varied and not, in general, as reliable as piped supply networks, depending on precipitation (rainfall and snowpack melt) and "stored" sources, mainly surface water (rivers and lakes) and groundwater (shallow/deep aquifers). For those regions where competition for scarce water resources is most intense, there is growing use of recycled water, mainly from processed drainage or sewage wastewater, and also desalination of seawater and saline groundwater, but these options currently provide only a small and highly localised supply of water for agriculture in some regions of the OECD.
- ***Uses:*** heterogeneity of water use in terms of space, quality and variability over time (seasonal and annual) present challenges in matching supply and demand. A given quantity of water is not the same as another available at a different location, point in time, quality and probability of occurrence. The heterogeneity extends to structuring legal and institutional arrangements. Commonly, irrigation systems are a mix of publicly, collectively owned or private systems, where farmers have their own access to groundwater and/or invest in on-farm dams, reservoirs and irrigation infrastructure. Depending on how these different systems are managed they can have varying consequences for the environment. It should also be emphasised that in periods of severe drought, the agricultural sector will frequently be the first sector to have to release water to meet other user needs, especially for domestic water consumers.
- ***Economics:*** private (extraction) and public good (stewardship) characteristics of water imply different allocation mechanisms. When water is used on a farm it is a private good, but when left *in situ*, such as a lake or wetland, it is a public good for which private markets are generally absent. Moreover, water is largely used by the private sector (farms, households, industry) but its ownership and delivery is normally in the public domain.
- ***Institutions:*** water resources are frequently managed through complex and multi-layered *institutional* and governance arrangements, often through national institutions and governance and, in some cases, cross national border structures. Water institutions are also embedded in sub-national regional and local governments (water user associations), while the governance of surface water and groundwater are commonly separated.

Strengthening institutions and property rights for water management in agriculture

The shift in policies with a greater accent on demand rather than supply management policies has brought reforms to the institutional and governance structure managing water resources. But the progress and path of water policy reforms has been mixed across OECD countries. Some countries have already undertaken major changes in their management of water resources or are in the early stages of reform programmes. For a few countries, however, where reform of water and agricultural policies could be beneficial to sustainable water resource management, progress has been limited.

Water policy reforms need to be developed as an integrated part of a broader reform framework: encompassing institutional changes to the way water services are delivered; defining water property (access) rights and entitlements; recovering costs for the delivery of water to agriculture; and providing a solid base for the financing of water delivery infrastructure so that the capital stock is not degraded. Also water policy reform processes should be seen in a longer-term perspective as an integral part of the policy functions of government. This is becoming more important as climate change impacts on agriculture are taking the industry into uncharted territory in terms of water available to farmers and its seasonal variability.

Simplification of institutional structures, rules governing water charges and trading arrangements for agricultural water use would improve transparency and accountability. There is frequently a plethora of institutions involved in managing, allocating and regulating water resources at all levels of government from local to national. These complexities can result in differing practices and regulations at the river basin level that create inefficiencies in allocation or trading of water resources to the highest value uses.

Progress has been made, however, towards decentralisation of institutional arrangements concerning water governance, from national to a water basin level, favouring greater local engagement and involvement of water users in resource management. However, some caution is necessary with the process of decentralisation. Basin level management, for example, may require national or international governance to avoid inequities in water allocation within a water basin and also ensure that the public good aspects of environmental, recreational and cultural uses and values of water are given sufficient recognition.

Developing ***stakeholder involvement*** is crucial to improve water and watershed management, but this takes time. Targeting communities, rather than individuals, may be a preferred solution to water governance issues. Shared irrigation systems (managed by private entities or farmers' associations), for example, may bring greater economic and environmental benefits than farmer owned systems, through sharing costs and responsibilities among members of the local community or water basin.

But ***transaction costs*** for co-operative stakeholder involvement can be high, especially in the initial phase of pilot programmes, which points to the need to translate these pilots to a broader adoption level 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.

Water property (access) rights in most OECD countries involve a complex set of rules, where water is often allocated in terms of *quantities* rather than *prices,* between users and for environmental needs. As pressures build up to reallocate water between users, this underlines the need for water access rights to become more flexible, and supporting institutions more robust to ensure an economically efficient and environmentally effective allocation of water. But it also emphasises the need to explore innovative water market solutions as allocative mechanisms. Where farmers and other users own water distribution infrastructure they may be more likely to accept an increase in water charges and higher rates of cost recovery for water delivered to their properties than when they do not own the infrastructure and increases in charges are imposed externally.

Water planning and management of water in agriculture requires funding. The specification of entitlements and the development of water markets are often pre-conditions to a well functioning planning and management system. The operation of irrigation schemes, management of entitlements within them, and the delivery and pricing of the water under those entitlements occur within frameworks administered by water resource agencies, often in the public domain, and which need to be adequately resourced. But to the extent that farmers are beneficiaries of public water delivery systems, then the marginal costs for these services should be reflected in their water charges. There should also be processes in place that can ensure efficiency in the management of public sector water delivery services.

Ensuring charges for water supplied to agriculture at least reflect full supply costs [2]

OECD analysis indicates that ***rates of cost recovery,*** mainly operation and maintenance costs, for irrigation water delivered to farmers are increasing across most OECD countries, due to a combination of (which varies in importance regionally): changes in public preferences regarding water allocation among competing uses, including meeting environmental needs; greater budgetary scrutiny by national and sub-national governments; high energy prices raising the pumping costs of an irrigation system; and increased awareness and impact of climate change and climate variability on precipitation (rainfall and snowpack) and the availability of water resources.

These issues will likely, in most cases, continue to encourage policy makers to ***increase water charges*** and explore other market-based incentives to improve cost recovery rates for water supplies and motivate further improvements in water use efficiency in agriculture. Inevitably farm-level costs will increase (although the share of water in total farm costs is in many cases not very significant), but innovative management and wise use of technology will enable farmers to adjust and generate greater value from limited water resources.

The conventional wisdom regarding ***full cost recovery*** through water tariffs (or charges), including for the agricultural sector, is that water tariffs should be sufficient to cover the full supply costs of water (including the operation and maintenance costs and the capital costs for renewing and extending the water system), and ultimately opportunity costs (scarcity value) and externality costs (economic and environmental). The principle of full cost recovery is evoked in a number of OECD countries water policy frameworks, but in reality, very few countries practice full cost recovery through water charges, even if this definition is limited to full supply costs.

In recognition of the difficulties for countries in moving toward full cost recovery, OECD has endorsed the concept of ***sustainable cost recovery*** which highlights the need to establish the water sector on a financially sustainable basis, finding the right mix between the ultimate revenues for the water sector, the so-called “3Ts”: tariffs, taxes and transfers. Every country must find its own balance among these three basic sources of finance, but typically for OECD countries, with most of the agricultural sector (and domestic/industrial sectors) connected to a water infrastructure network, they largely rely on water tariffs to cover operation and maintenance costs for water supplies to agriculture.

The ***path to improved cost recovery*** may involve a phased approach, with tariffs increasing in stages to cover operation and maintenance costs, and thereafter depreciation of assets, new investment and, eventually – where relevant and possible – the externality and opportunity (resource) costs of water. Where tariffs are extremely low relative to full cost recovery or sustainable cost recovery, a gradual approach may not be sufficient and more drastic action may be called for. Increasing cost recovery rates through water tariffs also requires a comprehensive approach, which includes reforming tariff levels and structures and increasing bill collection rates, but also improving levels of service and establishing social protection measures where necessary.

There are still many farmers in some countries, and regions within countries, who benefit from policies that allow them to forego repaying capital expenditures for irrigation infrastructure, or to schedule repayment over many years with zero interest. But the number and proportion of such arrangements is beginning to decline with water policy reforms. Increasingly governments seem inclined to require marginal cost recovery for any future irrigation projects and to improve the rate of cost recovery, as much as possible, from existing projects. There is also an effort to shift from charging for irrigation water based on the *area* covered to the *volume* of water used in many countries, especially where water stress is a serious issue.

Water policies in many countries also need to address the imbalance between the current policy focus on surface water and pay greater attention to approaches that can address the ***overuse and pollution of groundwater*** and the full water cycle (*i.e.* connections between different water sources). Policies regarding on-farm water resources, mainly groundwater, usually involve licenses and other regulatory instruments, but because of high transaction costs to enforce compliance, the degradation and illegal pumping of groundwater remains a challenge. To achieve sustainable groundwater use more effort will be required to enforce regulatory measures and develop mechanisms for volumetric management and charging, which is also essential for the management of surface water, especially where water stress is a serious issue.

The ***costs of pumping groundwater*** can be expected to increase with the anticipated rise in energy prices and expected further decline in water table levels. OECD countries will likely increase their efforts to manage groundwater as scarcity increases and as the public becomes more concerned about the regional economic impacts of groundwater overdraft. But achieving marginal cost recovery for groundwater supplies is complex, as is the development of groundwater markets. The property rights issue is central in this respect.

Many irrigation areas in OECD countries face the ***problem of ageing infrastructures*** and a declining revenue base from which to fund maintenance and repair activities. The drive toward marginal cost recovery for storage and delivery services arising from water reform policies means that both water suppliers and irrigators are beginning to consider the strategic evaluation of infrastructure renewal to remain viable. This raises questions as to future sources of finance and asset management. Securing financial and investment assets may require water user groups to seek private-public partnerships to raise capital and develop skills in long term asset management for infrastructure renewal.

While higher water charges and water market formation can bring benefits in improving water use efficiency in agriculture, expectations that these approaches alone can adequately address economic, environmental and social issues related to water are often over-optimistic. This is because there remain many impediments to water market formation related to, for example, issues of equity, incomplete science, specific quantity-related property rights, high transaction costs in creating water markets, and the historical allocation of water.

The possibilities of ***using water markets and pricing*** as a policy tool to achieve environmental objectives in agriculture seem to be limited. In addressing these issues a different mix of policies may be appropriate, such as the use of well-targeted payments where farmers provide a clearly-defined and verifiable public good or service, such as wetland conservation areas. A few countries, however, are using water markets to meet consumptive (address the scarcity value of water) and environmental objectives. This includes, for example, purchasing water entitlements to rebalance water consumer and environmental needs, and public sector water purchases to supplement water supplies to wetlands. Trading of water entitlements can also provide a scarcity price in the market and lead to the highest value use of water resources.

Defining, securing and agreeing among stakeholders the quantity of water needed in a water basin to sustain environmental outcomes is a key issue for many OECD countries. This will necessitate enhancing the knowledge and monitoring of water flows and interconnections between surface and groundwater flows, and re-examining the concept of "minimum flows" as the sole measure to assess environmental needs in rivers and lakes. This is also linked to the need to improve methods for identifying natural water bodies and ecosystems that are considered to be under threat.

Improving policy integration between agriculture, water, energy and environment policies[3]

For many OECD countries policies across agriculture, water, energy and environment are formulated without sufficient consideration of their interrelationship in any comprehensive manner or their unintended consequences. Recognition (and practical implementation) of ***policy integration*** across different scales of decision-making – from the farm through to water catchment, national and international levels – is a gap in many countries. Policy coherence and integration also relates to broader national questions of which institutions make decisions to allocate water across sectors and for environmental needs.

More ***integrated and coherent policy approaches,*** however, are beginning to take shape. This is particularly evident with climate change as many countries have started to co-ordinate and integrate the previously separated policy domains of water policy, flood and drought control policies, and agri-environmental policies. For example, the restoration of land in flood plains by planting trees has helped to reduce impacts of floods, improved water quality, and led to co-benefits such as restoring biodiversity and sequestering greenhouse gases.

Agricultural and agri-environmental support policies across OECD countries provide an intricate mix of incentives and disincentives toward sustainable water resource management. The use of crop and livestock market price support provides incentives to intensify agricultural production. Additionally, support for farm inputs, especially water (lowering water charges and for on-farm irrigation infrastructure costs) and energy (for water pumping) misalign farmer incentives. This can aggravate water resource-use inefficiencies and lead to greater pollution and other environmental damage to water bodies, especially where water stress is a serious issue and the value of water is high.

Agricultural policy reforms across most OECD countries over the past 20 years, however, have led to an overall reduction in support levels (as measured by the OECD's Producer Support Estimate) and a decrease in the share of support most linked to commodity production and unconstrained use of inputs (such as water and energy). The shift to decoupled agricultural policy measures is likely to lead to a positive outcome for water resources and the environment, although the cause and effect relations here are complex.

Whether and to what extent the ***environment benefits*** from shifting to decoupled payments may depend, in part, on the use of the "saved" water. If it is used to expand irrigated land, or to shift to crops that are more water intensive, the environment will not necessarily benefit from efficiency improvements unless there is an incentive to do so (*e.g.* a regulation or market incentive). Again, the complicated set of water allocation institutions and property rights will drive this relationship. Moreover, some environmental policies have affected the supply of water for agriculture, by increasing quantities available for the environment. In sum the conclusions from current research suggests that in some countries the shift to decoupled payments has led to changes in the cropping mix on irrigated land toward less water demanding crops and/or a reduction of irrigation in areas where water stress is an issue.

Continued use of ***support for energy in agriculture,*** both directly through support for diesel and electricity use, and indirectly for feedstocks to produce biofuels and bioenergy, can increase pressure on water resources. This is most evident where support for energy, by reducing pumping costs, in some countries is leading to excessive extraction of groundwater. Removal of this form of support may contribute to more sustainable water use in agriculture.

The impact on water balances of supporting agricultural feedstocks to produce ***biofuels and bioenergy,*** however, is complex and remains unclear. It is a largely empirical question and needs to be assessed in a way that compares the effects of alternative uses of resources. However, research suggests that the quantity of water needed to produce each unit of energy from second generation biofuel feedstocks (*e.g.* lignocellulosic harvest residues and forestry) is much lower than the water required to produce ethanol from first generation feedstocks (such as from maize, sugar cane, and rapeseed), although this can vary according to the location and practices adopted to produce these different feedstocks.

Overall, ***isolating and quantifying the economic efficiency and environmental effectiveness of agricultural and agri-environmental support on water resources, is difficult,*** and further analysis on causation is needed. This is because farmers are usually responding to a very complex set of signals in making water management decisions, including institutional constraints (*e.g.* regulations on water allocations), or because the change in relative prices associated with reduced output-linked payments may cause farmers to switch to previously non-supported crops that are more water intensive than those that benefited from coupled support payments.

Enhancing agriculture's resilience to climate change and climate variability impacts

Farming systems and water resources are becoming increasingly vulnerable to climate change and climate variability, although there is significant regional variation within and across OECD countries. The most recent Intergovernmental Panel on Climate Change assessment (IPCC, 2008) and OECD government reports confirm that this trend is expected to continue.

Climate change projections make clear that changes in water availability, the timing and seasonality of precipitation, and warming, as well as the growing incidence and severity of floods and droughts, will require high levels of adaptive responses to address these issues so as to enhance the resilience of agricultural systems to produce enough food, fibre and fuel. However, it should be stressed that in some countries (that are constrained at present in terms of expanding agriculture) climate change may lead to benefits and positive opportunities for agriculture. Better understanding of climate variability and extension of risk management approaches in agriculture to existing climate variability, can help build a more solid foundation for addressing climate change in the future.

The ***increasing frequency and severity of drought and flood events*** is leading to higher budgetary costs for governments in supporting affected farmers and rural communities, and an increase in farmer insurance costs. The rising cost of flood and drought relief, for agriculture and society as a whole, is exacerbated in some cases by the fragmentation of responsibility and the lack of policy coherence in agricultural, environmental, land and water policies to address these problems.

Where farmers are guaranteed government support in times of flood and drought disasters this does not give farmers the right incentives to improve self-reliance and risk management for adverse events (moral hazard). Hence, greater policy attention and investment will be required in water control (for floods) and water retention (droughts) management. There is also a need for farm practices that can reduce economic losses and lead to better management of water flows and stocks on farmland, taking into account the impact on any water entitlements that are established.

Given the prospect for increasing ***flood events*** associated with climate change, farmland is likely to play an important role in mitigation and adaptation strategies for flood risk management. Policies that are able to combine flood risk management with other objectives, such as for nature conservation, the protection of natural resources and agricultural production, are likely to offer the best long term solutions. Even without the changes associated with climate change, the frequency of flood events has increased along with the damages. Human alterations of the hydrological characteristics of watersheds has increased runoff and narrowed channels. Land-use policies have also encouraged urbanisation in areas at risk to flooding events, and thus increased the economic cost associated with a given flood event.

Where land management practices are known to result in serious flood risk, there is a call for regulation and compliance with "good practice". In cases where farmers purposefully manage land to retain and store potential floodwater to reduce flood risk for the benefit of others, there can be scope for policies to reward them accordingly, although this may be highly localised. Integrating sustainable water resource management in agriculture within the broader context of regional land use planning is also important as a broader economy-wide mitigation strategy to address flood risks (*e.g.* the conversion of farmland to urban uses can raise flood costs as farmland has the potential to act as a flood sink).

The expectation is that ***drought events*** will occur more frequently in the future as a result of greater climate variability. So improving the resilience of agriculture to droughts will also be important, including by developing water storage capacity. It is essential in drought prone areas for agriculture to improve its water use efficiency (or even consider abandoning agriculture completely in more extreme cases), in part, to free water for other users and environmental purposes. This might be achieved through:

- Reducing leakages in delivery systems;
- Developing on-farm rain harvesting practices and systems, *e.g.* conservation tillage;
- Making greater use of recycled sewage and drainage water and desalinated water;
- Improving soil moisture measurement;
- Increasing adoption of efficient water application technologies, such as nanotechnologies;
- Encouraging greater adoption of drought-resistant cultivars; and,
- Recharging groundwater during times of low seasonal water demand.

In many cases these practices and technologies to make water savings are already known. However, it is the barriers to their adoption, such as a lack of farmer training, that are an important challenge for policy makers.

Addressing knowledge and information deficiencies to better guide water resource management

Improving the effectiveness and efficiency of policies to achieve societal goals related to water requires better information at many levels. This is especially important because water reforms are tending to become more decentralised and complex, while management of water in agriculture is highly diverse. Achieving cost recovery targets, developing water pricing and trading mechanisms, clarifying water entitlements and changing institutional arrangements, need to be underpinned by more and reliable information.

A substantial effort is underway in many OECD countries to address information deficiencies to better guide policy making, taking into account specific natural conditions and historical backgrounds. Encouraging examples are the monitoring of minimum water flow rates in rivers as part of environmental planning, and comprehensive river basin assessments being undertaken in a number of countries. However, considerable information and knowledge gaps still remain. In five areas improvements in knowledge, science and monitoring of water resources in agriculture could help to better inform policy makers, stakeholders and the wider public:

- ***Improving the knowledge of the interrelationships between agriculture and water availability,*** and between surface water and groundwater flows.
- ***Establishing robust databases on trends in water resource availability and use,*** including use by agriculture. This encompasses data on the sources of water used; improved calculations of the physical and economic efficiency of water use in agriculture; and a better understanding of the links between on-farm water use and off-farm environmental impacts.
- ***Increasing the quantity and quality of information on cost recovery rates*** for water supplied to agriculture, as considerable caution is required in using and comparing data on cost recovery rates and agricultural water charges, both within and between countries.
- ***Developing information systems and tools to better inform water management allocation decisions.*** This applies at the: strategic planning level, in order to optimise the planning of irrigation infrastructures, such as information systems to assist planning decisions in the face of increasing climatic variability; tactical level, to identify the optimal allocation of water for a given period (season, year); and at the operational decision making level, to optimise water distribution at the farm level. The latter also requires improvements in the tools to manage water systems, such as providing technical information and advice, and offering farmers educational programmes on best practices to adopt, especially as climate change impacts may require changes to current farm practices.
- ***Undertaking evaluation of the impacts of policies on environmental and economic outcomes in the context of agricultural water resource management.*** This would provide a contribution to broader based agri-environmental policy evaluation, such as the need to better understand the link between agricultural policies and water use efficiency. Aside from academic research of these linkages, there is little evaluation by governments of the environmental effectiveness and economic efficiency of agricultural water resource management policies. Quantifying the net costs and benefits of water resource use by agriculture in a sustainable development framework is a necessary component, and requires attention to the “soft” infrastructure – meters, stream gauging networks, hydrologic and scientific support, water reporting systems, farm surveys, and benchmarking of irrigation businesses.

None of the information requirements described above are obtained cheaply or easily. But without better information policy reforms will be at a disadvantage and effective water policy decision making, planning and management could be impeded.

Notes

1. Agriculture and water quality linkages are not covered in this report, but will be the focus of a forthcoming (2011) OECD study.
2. Full water supply costs include operation and maintenance costs and capital costs, covering both renewal of existing water supply infrastructure and new capital investment costs for water supply infrastructure, see Figure 1.4.
3. It is beyond the scope of this report to provide a comprehensive analysis of the integration and linkages between agriculture, water, energy and environmental policies: for example, in the energy context the focus here is mainly on the water demand from growing energy crops and not the links between irrigation and hydro-electric power (dams).

Introduction

Water serves a range of productive, environmental and social purposes in the agricultural sector and wider economy. Governments, water managers and consumers/users have a role to ensure that mechanisms and actions are in place to make certain that water is allocated and used to achieve socially and economically beneficial and efficient outcomes in a manner that is environmentally effective and sustainable. But management of water resources in agriculture is being severely tested with rising food and energy prices, growing competition for water resources between different users, an expanding global population, and concerns related to climate change.

Agriculture is a primary target for policies that move the sector towards sustainable management of water as it uses about 70% of the world's freshwater withdrawals and over 40% of total OECD countries water withdrawals. The anticipated growth in world population from 7 billion currently to 9 billion by 2050, will involve a major expansion in demand for food and water, not only for use in agriculture but for drinking, sanitation, industry, the energy sector, as well as to meet demands for environmental improvements of ecosystems and associated recreational and cultural uses.

These global developments have implications for OECD countries, given they are major players in world food markets as exporters and importers. But the focus of water resource management in agriculture differs greatly within and across countries, ranging from concerns with water scarcity and stress in some regions, to a focus on water drainage and flood control in others, reflecting varying climatic and agricultural systems. Consideration of climate change further complicates this picture.

This report explores the economic, environmental and policy dimensions and linkages related to the management of water resources, floods, droughts, and drainage in agriculture. While the linkages between agriculture and water quality are touched upon in the report, they are the focus of a forthcoming OECD project to be completed by 2011.* The report examines sustainable management of water resources in agriculture by:

- Setting the scene: Hydrology and economics of water resource management in agriculture (Chapter 1).
- Reviewing recent trends and outlook for water resources in agriculture (Chapter 2).
- Examining OECD countries' policy experiences in managing water resources in agriculture (Chapter 3).

*Broader considerations of the multi-dimensional aspects of water, in both the OECD member country and non-OECD country context, are provided in OECD (2009), *Managing Water for All: An OECD Perspective on Pricing and Financing* (www.oecd.org/water).

Chapter 1

Setting the Scene: Hydrology and Economics of Water Resource Management in Agriculture

1.1. Hydrology

There is a high level of diversity in hydrological conditions and farming systems operating in a greatly varying set of political, cultural legal and institutional contexts, both across and within OECD countries. Management of water resources in agriculture includes a spectrum of options (Figure 1.1). These include totally rain-fed dependent farming systems, where on-farm conservation practices focus on storing water in the soil. As climatic conditions become drier and dry season shortages more frequent (moving from left to right along the spectrum in Figure 1.1), increasing use is made of supplemental surface water and groundwater sources to enhance crop production, and in some cases other water sources (*e.g.* recycled wastewater and desalinated water).

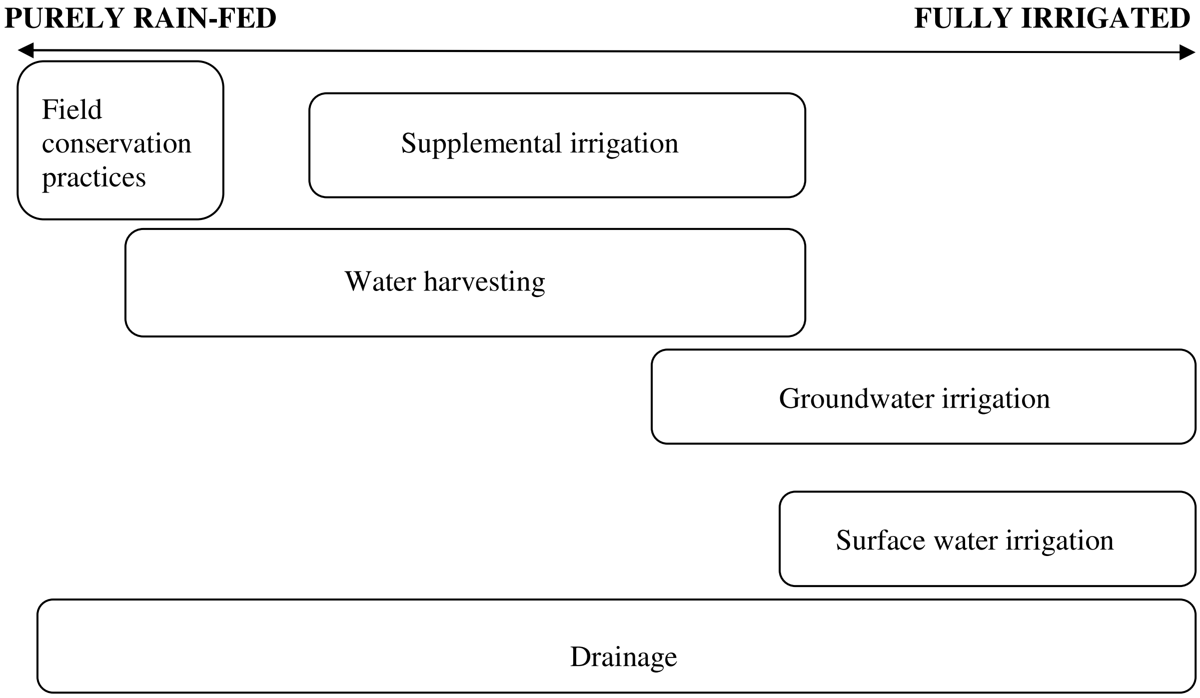
For semi-arid and arid regions agriculture maybe totally dependent (but not always) on irrigation from groundwater and stored surface water supplies (Box 1.1). Under monsoonal conditions agriculture can also be dominated by irrigated farming, but these systems are more concerned with controlling the large volumes of rainfall received during the wet season and ensuring sufficient supplies during the dry season.

Irrigated agriculture in OECD countries and globally, has been associated with bringing significant gains, not only to the private benefit of farmers, but providing a public benefit in terms of expanding food production, and positive externalities, such as contributing to rural development. Irrigation adds flexibility and competiveness to agriculture, especially in those regions where seasonal rainfall patterns would make farming extremely difficult (in some cases impossible) without irrigation. The benefits associated with irrigated agriculture need to be taken into account when considering the negative externalities and inefficiencies with inappropriate irrigation practices and system management.

Agricultural water resource management systems in OECD countries can be broadly categorised into two groups (Figure 1.2), comprising first, those countries where irrigation plays a major role in the farm sector, both in terms of the share in the total value of agricultural production and agricultural exports, and, second, countries where farming operates under predominantly rain-fed conditions. Figure 1.2 further sub-divides countries within these two broad categories, according to how rapidly the area irrigated is expanding, and with commentary on the trends over the past 20 years (or projected trends) on the incidence and severity of flood and drought events as they impact agriculture.

There are agricultural regions within some countries that may fit all the categories shown in Figure 1.2. This is notably the case for countries with a highly varied range of climatic conditions, such as **Australia, Canada, France, Italy, Mexico, Spain** and the **United States**. The irrigated farming in the Murray Darling Basin in **Australia**, for example, accounts for around 40% Australia's total value of agricultural production, and two-thirds of Australia's total irrigated land and over 50% of national water withdrawals (Australian Bureau of Statistics, 2008).

Figure 1.1. Diverse options for agricultural water management



Source: IWMI (2007).

The ***physical water availability*** for agriculture is determined by precipitation (rainfall and snowpack melt) and the effective mean runoff that flows into surface water and groundwater stores (Productivity Commission, 2006), as well as other sources of water (Box 1.1). Globally average rainfall increased by about 2% over the period 1900 to 1998 (Huntington, 2006). But regional variations in rainfall are highly significant rising over this period, by 7-12% between 30^0N-85^0N, compared with a 2% increase for 0^0S-55^0S, but with substantial reductions in some regions.

A key issue in hydrology is that with climate warming in the future there could be an intensification of the water cycle leading to changes in precipitation and an increase in the intensity and frequency of floods and drought (Chapter 2.2). Based on a survey of OECD countries the incidence and severity of flood and droughts has been increasing for the majority of countries (Figure 1.2). Many of these countries also project that with climate change the incidence and severity of flood and drought events may continue to increase, while other research also supports an ongoing intensification of the hydrologic cycle (Huntington, 2006; IPCC 2008). This highlights the need to: improve capabilities to monitor and predict the consequences of changing hydrologic regimes; reduce current levels of scientific uncertainty; and establish longer periods of data collection, combined with enhanced understanding of the complex feedbacks involving water systems (Huntington, 2006; and Chapter 3.6).

While agriculture is affected by changes in hydrologic conditions, ***the expansion and intensification of agriculture has also altered the natural hydrology*** of surface water, groundwater and the environment (Gordon *et al.,* 2007). This applies to rain fed farming systems, but is especially relevant to irrigated areas where upstream extractions and storage reduce the quantity available for environmental services, floodplains, and other uses downstream, including irrigation (Productivity Commission, 2006). There remains a considerable policy challenge to identify ways to build resilience to the hydrologic changes caused by agriculture.

Water is used for a variety of purposes, from which society derives a range of values (FAO, 2004). Some of these use categories are defined in Figure 1.3 (Moran and Dann, 2008). Many of the uses of water are well understood and easily monitored (*e.g.* surface water), but for others the science is poorly developed (*e.g.* groundwater recharge and flows). In addition, while the economic valuation of some water uses are established (*e.g.* crop production), many of the externalities and public goods associated with water systems are inherently difficult to value (*e.g.* support for wildlife, amenity and cultural values) (Chapter 3.6).

Box 1.1. Water sources and characteristics with regard to agriculture

The ***principal sources of water supplies for agriculture*** are rainfall and “stored” sources, mainly surface water (rivers and lakes) and ***groundwater*** (shallow and deep aquifers). In some countries agriculture may draw for part of its supplies on the main water supply distribution network (mainly used by urban and industrial users), but this can be an expensive option. For some countries sharing surface and groundwater across national boundaries is important (*e.g.* Mexico-US, Portugal-Spain).

For those regions where competition for scarce water resources is more intensive, there is growing interest in using ***recycled water,*** mainly from processed drainage water or sewage water, and also ***desalinated water*** largely from seawater but also saline aquifers. But both options, recycled and desalinated water, provides only a very small and highly localised supply of water for agriculture in most situations. Moreover, use of recycled water has raised health concerns when applied to agricultural land, especially where horticultural crops are grown. Desalinated water, although once a costly option, is now a much lower-cost option, with technological improvements which have greatly reduced costs and the energy needed to produce desalinated water.

The ***physical characteristics*** of fresh water resources are well documented. In brief, for surface water these mainly include site-specificity, mobility, variability and uncertainty, bulkiness and solvent properties. Groundwater shares similar characteristics but has other attributes setting it apart, including relative immobility, security and divisibility. Surface water and groundwater are components of a water catchment, an area of land supplying water to a common watercourse which is host to a variety of socio-ecological systems. The interdependent components of a catchment – land, vegetation, fauna, human – are linked together by the water component (*e.g.* rivers, lakes, dams, reservoirs, irrigation networks or systems, groundwater, stormwater and wastewater). The concept of water catchment is also referred to as a watershed, water or drainage basin.

Source: Adapted from Molle and Berkoff (2007a); Syme *et al.* (2008).

Figure 1.2. Typology of agricultural water resource management systems across OECD countries

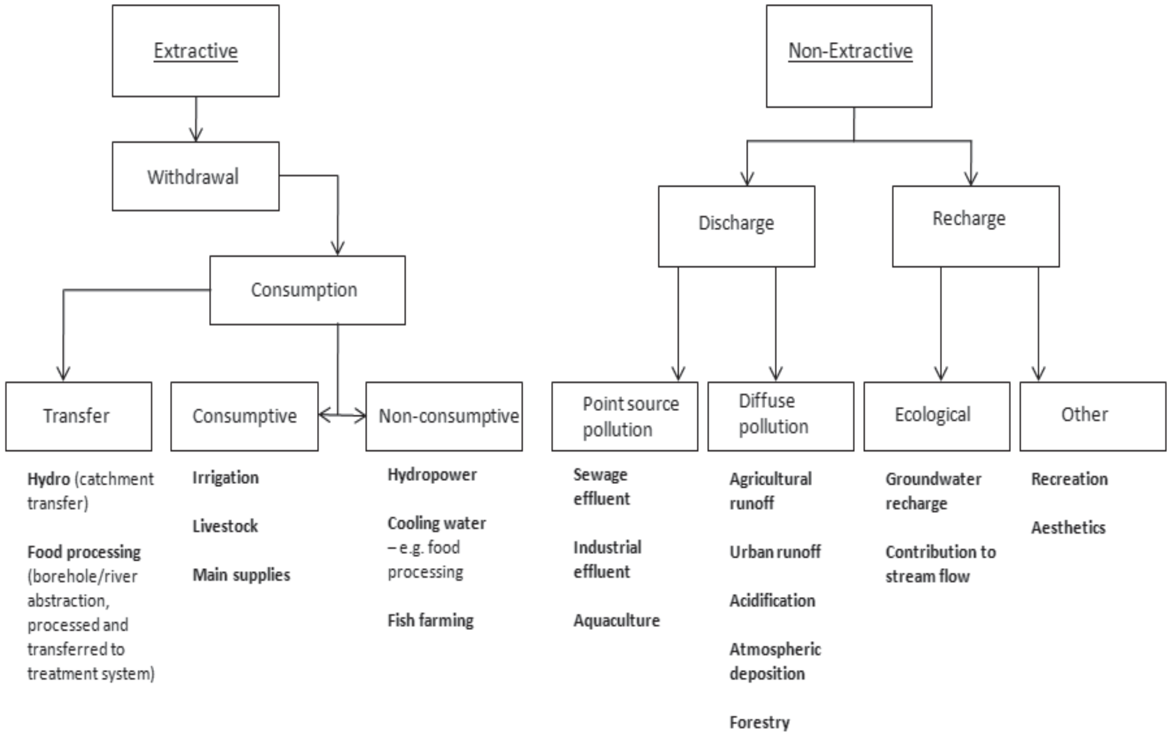
OECD COUNTRIES WHERE IRRIGATION PLAYS A MAJOR ROLE IN THE AGRICULTURAL SECTOR					
A major share of agricultural production operating under climatic conditions requiring irrigation during seasonal dry periods				Irrigation operating in largely monsoon conditions, dominated by paddy farming	
Area under irrigation has grown rapidly since 1990		Area under irrigation has grown slowly or declined since 1990			
	Comments		*Comments*		*Comments*
Australia	Drought events increasing	**Italy**	Drought events increasing	**Japan**	Flood events increasing
Greece	Flood/drought events increasing	**Mexico**	More prolonged drought events		
Spain	Drought events increasing	**Portugal**	Drought events increasing	**Korea**	Flood events increasing
Turkey	Flood/drought events increasing	**United States**	Drought events increasing		

OECD COUNTRIES WHICH HAVE PREDOMINANTLY RAIN-FED AGRICULTURAL SYSTEMS					
Agricultural systems predominantly rain-fed, but requiring irrigation in some regions during the summer dry period				Agricultural systems almost entirely rain-fed, with little or no irrigation	
Irrigated agriculture is rapidly expanding		*Irrigated agriculture is expanding slowly or declining*			
	Comments		*Comments*		*Comments*
Canada	Drought events increasing	**Denmark**	Flood events increasing	**Austria**	Drought events increasing
New Zealand	Flood/ drought events increasing	**France**	Drought events increasing	**Belgium**	Flood/drought events increasing
		Germany	Projected increase in area irrigated	**Czech Republic**	Flood events increasing
		Hungary	Flood/drought events increasing	**Finland**	Flood events increasing
		Netherlands	Flood/drought events increasing	**Iceland**	No information
		Slovak Rep.	Drought events increasing	**Ireland**	Flood events increasing
		Switzerland	Projected increase demand for irrigation	**Luxembourg**	No information
				Norway	No clear evidence
				Poland	Flood/drought events increasing
				Sweden	Flood events increasing
				United Kingdom	Flood/drought events increasing

Trends in drought/flood events for most countries reflect regional trends, rather than a nationwide pattern.

Source: OECD Secretariat, based on Figure 2.2, and responses from member countries to an OECD questionnaire at www.oecd.org/water.

Figure 1.3. Defining uses of water



Source: This figure does not provide exhaustive coverage of the uses of water use and mainly focuses on uses related to agriculture, and is adapted from Moran and Dann (2008).

The characteristics of ***water use in agriculture*** set it apart in many ways from its use in domestic household and industrial sectors. Diversions for consumptive use are invariably larger than the fraction actually consumed with the balance returning to the water system (Molle and Berkoff, 2007a). Agriculture usually accounts for the major share of water withdrawals for consumptive use in most OECD countries (over 40%), with evapotranspiration accounting for 40-60% of agricultural withdrawals rising to 70% with repeated reuse in modern irrigation systems. Agriculture can also contribute positively to the hydrological cycle in some irrigation systems, for example, through groundwater recharge and water purification functions, but also have negative impacts through pollution or excessive pumping.

Water losses from agriculture are an important water policy concern, especially in situations of water stress. Depending on site-specific factors, some water is irretrievably lost to the hydrologic system. What returns to the water system (as surface return flow and groundwater percolation) is often altered in time, location, and quality. In particular, the characteristics of irrigation losses have important implications for the effectiveness of water-efficiency improvement in achieving net water savings. While improvements in the physical efficiency of water use may indeed result in a decline in water consumption, actual water saved is less clear, due to changes in area irrigated and water use per hectare.

1.2. Economics

In the past to address some of the hydrologic challenges focus was typically placed on influencing the performance of farmers by the manipulation of the hydrologic cycle through engineering solutions, such as building new dams and canal networks. Increasingly, however, emphasis is being placed by many countries to improve the economic and environmental performance of the water system through providing economic incentives by taking into account the cost, value, price and demand for water in agriculture (Molle and Berkoff, 2007a).

With growing intersectoral competition for water and increasing emphasis on environmental externalities associated with agriculture, from around the late 1980s the policy agenda shifted to considering the economic and environmental dimensions of water. A key turning point was the ***Dublin International Conference on Water in 1992***, which stressed that “managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources” (Molle and Berkoff, 2007b).

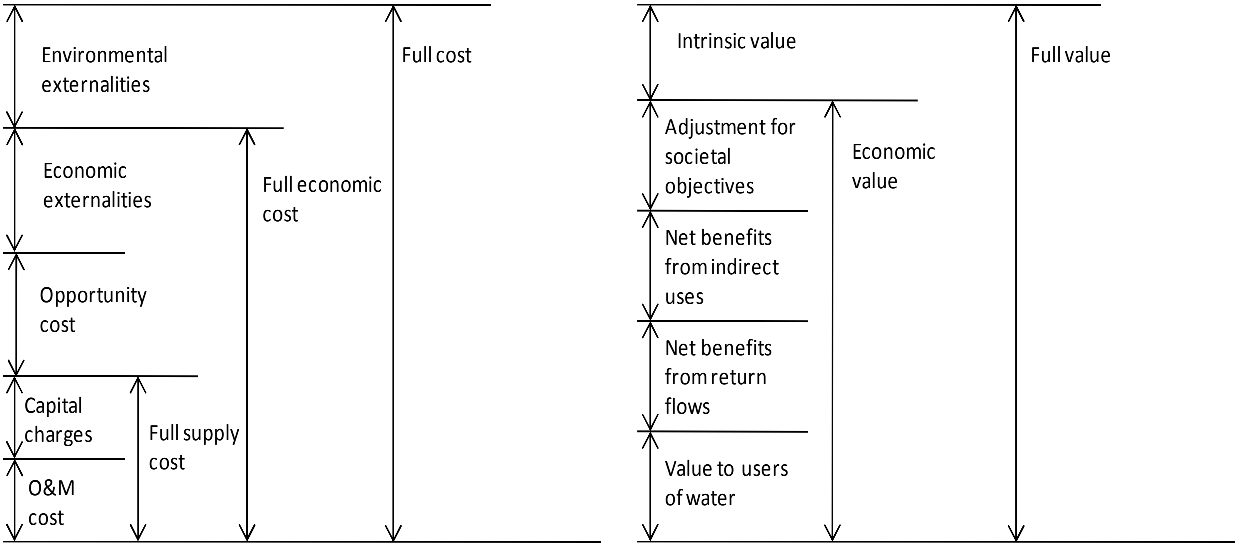
There are some distinctive economic features that make the supply and demand for water more complex than other economic goods and services, including (Hanemann, 2006; Thompson, 2006):

- Private (extraction) and public good (stewardship) characteristics of water imply different allocation mechanisms. When water is used on a farm it is a private good, but when left in situ, such as a lake or wetland, it is a public good for which private markets are generally absent. Moreover, water is largely used by the private sector (farms, households, industry) but its ownership and delivery is normally in the public domain;
- Mobility of water, in that it flows, leaches, evaporates, and has the opportunity to be reused, which makes it distinctive as a commodity compared to land, for example. Moreover, agriculture can contribute positively to the hydrological cycle, for example, through groundwater recharge and water purification functions; it can, however, also contribute to surface water and groundwater pollution and through excessive extraction may lead to diversion of water from supporting ecosystems;
- Heterogeneity of water in terms of space, quality and variability over time (seasonal and annual), which presents challenges in terms of matching supply and demand and structuring legal and institutional arrangements, as a given quantity of water is not the same as another available at a different location, point in time, quality and probability of occurrence;
- Critical nature of water is evident in terms of sustaining human life and agricultural production, but beyond minimum thresholds to maintain life and farming this notion conveys no information on the productivity or value of water, for example, the marginal value of applying 80 or 90 cm of water to irrigate cotton; and, the

- Complex and multi-layered institutional and governance arrangements for water resources, reflected in the national institutions and governance of water resources (and in some cases cross national border structures) and sub-national regional and local governments (water user associations) management of water, while the governance of surface water and groundwater are often separated.

Understanding the economics of water can help inform decision makers of the full social costs of water use in agriculture and the full social value or benefits that agriculture's use of water can provide (Hanemann, 2006). The usefulness of understanding these concepts for policy analysis is the transparency they bring in terms of how the value of water to society is more that just as an agricultural input, and to clarify what the costs are of agriculture's use of water resources (Malik, 2008; Rogers *et al.,* 1998; Rogers *et al.,* 2002). The value and cost of water can be summarised as follows (Figure 1.4):

Figure 1.4. General principles for cost and value of water



Source: Rogers et al. (2002).

- ***Value of water,*** is the sum of the economic and intrinsic value.
  - The ***economic value*** includes the:
    - *Value to users* of water for productive activities, such as irrigated farming;
    - *Net benefits of return flows* of water diverted for agriculture and other users, which may also include groundwater recharge, although these benefits will depend on the lost to evapotranspiration;
    - *Net benefits from indirect use,* such as drinking water for domestic purposes and providing habitat for flora and fauna, although these benefits can be offset by various negative environmental externalities, such as salinisation of soils and pollution of water from farm chemicals used in irrigation; and,

    - *Adjustment for social objectives and values,* such as the additional increase in commodity production gained from irrigation, higher employment and benefits for rural development.
  - The ***intrinsic value*** of water is linked to the attributes of water that are the most difficult to assign values, for example, the aesthetics of waterscapes and recreational attributes.
- ***Cost of water,*** consists of three elements, full supply cost, full economic cost, and the full cost:
  - The ***full supply costs*** are the costs associated with supplying water to consumers without considering either the externalities of water consumption (positive or negative) or alternate uses of water (opportunity costs). These costs consist of two elements, which are also important in terms of measuring agricultural support for irrigation (Chapter 3.2), including:
    - *Operation and maintenance costs,* associated with daily running of the water supply system, such as electricity for pumping, labour and repair costs;
    - *Capital costs,* covering both capital for renewal investment of existing infrastructure and new capital investment costs, such as building a new dam and canal network.
  - The ***full economic costs*** are the sum of the supply costs, plus the:
    - *Opportunity (or resource) costs,* which address the cost of one consumer depriving another of the use of the water if that other use has a higher value for the water, although opportunity costs are zero when there is no alternate use, that is no shortage of water, while opportunity costs also apply to issues of environmental quality already discussed; and, the
    - *Economic cost of externalities,* consisting of positive externalities, for example the groundwater recharge benefits from irrigation; and negative externalities, typically upstream diversion of water or the release of pollutants downstream within an irrigation system.
  - The ***full costs*** are the sum of full supply and economic costs, plus environmental externalities. While economic externalities cover costs to producers and consumers upstream and downstream, environmental externalities are associated with costs to public health and ecosystems.

Usually the value of delivering water is easily determined from the charges made by water companies in supplying water to farms, but valuing the opportunity cost of water can be extremely difficult. The economic value of water, however, covers goods and services that are not usually marketed, such as the net benefits from return water flows (*e.g.* groundwater recharge) and indirect use (*e.g.* wetlands or pollution); social values (*e.g.* rural employment); and intrinsic values (*e.g.* recreational, scenic, and cultural attributes). While economists have tools to provide proxy values for these non-marketed goods and services (*e.g.* contingent valuation) there application to guide policy decisions can be difficult.

The cost of supplying water has several distinctive features compared to other commodities:

- Water is bulky and expensive to transport relative to its value per unit of weight, unlike electricity, where there is usually a national grid;
- There are significant economies of scale in water supply, such as the use of a dam to store surface water, while the physical capital in the water industry is typically long-lived, for example, irrigation canals; and,
- Water supply projects are usually designed to meet multiple needs (*e.g.* agriculture, hydroelectric power, urban use), which makes defining the marginal benefit very difficult, as in many uses an additional unit of water may have little value at certain times, but considerable value at others.

The capital intensity, longevity and economies of scale of irrigation infrastructure mean that fixed costs dominate. As a consequence the short-run marginal cost of water supply for irrigation systems can be very low except for the costs of pumping water through the delivery system. These characteristics of water supply make it likely that there will be a monopoly supplier in any given area, requiring a high degree of managerial and social control. Also because of the capital lumpiness in water supply this provides an incentive to expand the capacity in surface water storage at a single point in time rather than spread out over time, which can mean that it may be a considerable duration before demand materialises to use this capacity.

A distinction needs to be made between the marginal and average or total value of water, in policy related applications of the economic valuation of water. Policy interventions in agriculture regarding water commonly involve changing the quantity and/or quality of access, as usually farmers have some access to water. Hence, to measure the benefit from an increment in water supply for farming in the receiving areas it is necessary to estimate the marginal value of water (marginal net profit) in the agricultural uses that would go out of production without the new increment of water.

This is because the profit from farming is not exclusively a return on water as an input, but also a return on labour, land, other fixed assets and variable inputs. Moreover, the return to water is not constant and declines as more water is supplied, because farmers are likely to alter their cropping patterns with varying supplies of water. In a number of irrigated areas there is usually some substitutability between surface and groundwater supplies, although in the **United States**, for example, less than 20% of the farms, accounting for less than 25% of the total US irrigated area, have access to multiple water sources.

Water charges can, in principle, be used to recover the full costs or value of water (Figure 1.4). This embodies the "user pays principle" in that the opportunity costs, economic and environmental externality costs and benefits should be fully reflected in the charges paid by water users, and not just the supply costs (*i.e.* operation, maintenance and capital costs). The principle of full cost recovery is evoked in a number of OECD countries water policies, but in reality few countries practice full cost recovery through water charges or even achieve full supply cost recovery. In recognition of the difficulties for countries in moving toward full cost recovery, OECD has endorsed the concept of *sustainable cost recovery* which recognises the need to establish the water sector on a financially sustainable basis, finding the right mix between the main revenues for the water sector, the so-called "3Ts": tariffs, taxes and transfers (Box 1.2).

In nearly all cases the water charges paid by agricultural users reflect only a part of the full costs for water (Chapter 3.4.3). This is partly due to the difficulty of evaluating opportunity costs and environmental costs and benefits. Moreover, there is usually a sharp difference in the water charges paid by agriculture compared to urban water users, which can be explained for a number of reasons as listed below.

- Where water is supplied through the same network to agriculture and other users, it may be under charged to all users because most water agencies set charges to cover the historic cost of a water delivery system rather than the future replacement costs. Frequently there is a large gap between historic and future costs because of the lumpiness and longevity of surface water supply systems.
- There is a strong incentive to cover only the short-run marginal cost of a new water supply project, since initially the supply capacity of such projects often exceeds current demand. As demand grows and the capacity is more fully utilised it is optimal to switch to a charging system based on long-run (*i.e.* replacement) marginal cost, but often public water agencies get locked 'politically' into only recovering historic costs.
- Historically, water supplied to irrigate agriculture in most OECD countries has been provided through public irrigation schemes, and, as such, has been frequently supplied covering only operation and maintenance costs of water deliveries (Chapter 3.4.3).
- Agriculture water, unlike urban water, is usually not treated and generally not available on demand via a pressurised system, making price comparisons difficult.
- In many circumstances irrigators do not have the opportunity to trade their water entitlements with other users: as no markets exist to do so; there are often legal and administrative restrictions to developing such markets; the transactions costs of water markets can be high; there is uncertainty about the supply and demand for water at a given point in the future; and also the water delivery systems supplying agriculture, urban and industrial users are rarely physically interconnected.
- Agriculture can be a secondary objective of water supplied from a project where water has been provided to meet other primary objectives, such as supplying a hydroelectric scheme.

The use of financial instruments to cover costs of supplying water to irrigators is necessary to maintain or develop the physical infrastructure and avoid degradation of the water delivery system. There are also equity considerations in recovering financial costs in that farmers might be expected by society to repay the benefits they receive where public investment has been involved. But governments may justify financing the capital costs of irrigation projects for a variety of reasons other than economic optimisation, such as rural development and for water and food security objectives (Molle and Berkoff, 2007a).

Box 1.2. Full cost recovery and sustainable cost recovery for water supplied to agriculture

The conventional wisdom regarding ***full cost recovery*** through water tariffs (or charges), including for the agricultural sector, is that water tariffs should be sufficient to cover the full supply costs of water (including the operation and maintenance costs and the capital costs for renewing and extending the water system), and ultimately opportunity costs (scarcity value) and externality costs (economic and environmental), as shown in Figure 1.4.

The principle of full cost recovery is evoked in a number of OECD countries water policy frameworks, for example the **EU** *Water Framework Directive* requires member states to take account of the principle and ensure adequate contributions by all users after accounting for the social impacts of cost recovery (see the example of **Greece** in Box 3.11), while the same is true in **Australia** (Box 3.8). In reality, very few countries practice full cost recovery through water charges, even if this definition is limited to full supply costs, as shown in Figure 3.1.

In recognition of the difficulties for countries in moving toward full cost recovery, and even recovery of full water supply costs, the concept of ***sustainable cost recovery*** was formulated by the Camdessus Panel* and later endorsed by OECD (see sources below). The panel's report identified three main characteristics of sustainable cost recovery:

1. An appropriate mix of tariffs, taxes and transfers (the 3Ts) to finance recurrent and capital costs, and to leverage other forms of financing;
2. Predictability of public subsidies to facilitate investment (planning); and,
3. Tariff policies that are affordable to all, including the poorest, while ensuring the financial sustainability of service providers.

Sustainable cost recovery recognises the need to establish the water sector on a financially sustainable basis, finding the right mix between the ultimate revenues for the water sector, the so-called "3Ts": tariffs, taxes and transfers Revenues from these sources need to increase to cover the costs of achieving agreed policy objectives for the provision of water supply, including to agriculture. This approach, which on the basis of country experience, is now considered a more realistic and practical policy principle than "full cost recovery" based on water charges alone. Covering costs solely on the basis of water charges may not take sufficient account of the burden this would place on the poorest consumers, or of the merit or public goods character of some ecosystem services provided by agriculture.

Every country must find its own balance among the three basic sources of finance (the 3 Ts), but typically for OECD countries, with most of the agricultural sector (and domestic/industrial sectors) connected to a water infrastructure network, they largely rely on water tariffs to cover operation and maintenance costs for water supplies to agriculture, as described in Chapter 3.4 of this report. However, public budgets based on taxes often continue to play a role in covering capital costs of water infrastructure. Indeed public budgets have historically played the major role in financing initial investments in water infrastructure in virtually all countries.

The path to improved cost recovery may involve a phased approach, with tariffs increasing in stages to cover operation and maintenance costs, and thereafter depreciation of assets, new investment and, eventually – where relevant – the externality and opportunity (resource) costs of water. Where tariffs are extremely low relative to full cost recovery or sustainable cost recovery, a gradual approach may not be sufficient and more drastic action may be called for. Increasing cost recovery rates through water tariffs, also requires a comprehensive approach, which includes reforming tariff levels and structures and increasing bill collection rates, but also improving levels of service and establishing social protection measures where necessary.

Where a phased approach is adopted, the water tariff-setting process becomes a vital consideration. Many countries have decentralised responsibilities for services, including those for tariff setting (Chapter 3.4). This can delay tariff reform and the regular adjustments necessary to account for inflation. In some countries the central government determines the tariff structure and level, for local governments to implement. A realistic central-local balance of obligations and responsibilities is the key to tariff reform.

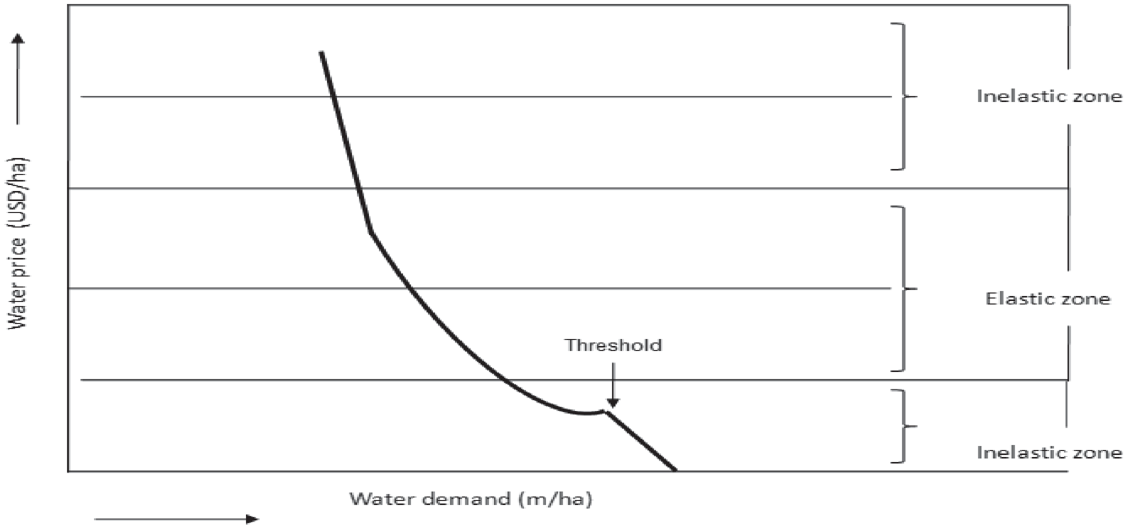
* The Camdessus Panel Report is available at Winpenny, J. (2003), *Financing Water for All, Report of the World Panel on Financing Water Infrastructure,* chaired by Michel Camdessus at www.financingwaterforall.org.
Source: Adapted from OECD (2009a; 2009b).

Raising water charges can reduce pressure on water resources by inducing greater efficiencies in the use of water, bringing both economic and environmental benefits through water conservation, especially where water stress is an issue. The possibilities for water conservation in agriculture can potentially release supplies for other users and to meet environmental demands, especially as agriculture tends to account for the major share of national water withdrawals (Figure 2.1). But raising water charges will not improve water use efficiency where water supply constraints are binding, a situation common in many OECD countries and as discussed above.

But the ***responsiveness of farmers to changes in the price of water*** (the elasticity of demand) is complex (Figure 1.5). At low price ranges demand is unresponsive to price, inelastic, and hence, is not a determining factor affecting application efficiency or water application technology choice (de Fraiture and Perry, 2007; OECD, 1999; Rieu, 2006). At a certain threshold demand for water becomes elastic in the short run, more responsive as prices rise, but becomes inelastic again at higher price ranges as water quantities approach the minimum needed for plant growth. In general farmers responsiveness to price requires that water charges comprise a volumetric component, they have control over the water they take from the irrigation system, and that the price is sufficiently high to correspond to the elastic range of their demand curve.

Over the long run irrigators may respond to rising water charges by adopting water saving technologies, altering the mix of irrigated activities or shifting to non-irrigation activities (Appels *et al.,* 2004). A major problem for water providers is estimating the price responsiveness of demand for irrigation water, as there is little published information on the relationship, although with increasing water trading more data could become available (Appels *et al.,* 2004; de Fraiture and Perry, 2007). Moreover, while water demand in generally inelastic, as shown in Figure 1.5, this does not imply that water demand is necessarily stable. Hence, water demand by irrigators may be highly responsive to agricultural and agri-environmental policies and also technological changes.

Figure 1.5. Agricultural water demand curve



Source: de Fraiture and Perry (2007).

Trading in water entitlements can encourage investment by farmers in water saving technologies and promote agricultural production diversification, especially toward higher value commodities. But as water is just one of the inputs for agricultural production, adoption of water saving technologies or production diversification is seldom driven by water prices or water scarcity alone (Cai *et al.,*, 2008; Molle and Berkoff, 2007a). Instead changes in farm technology choice and production patterns are likely to be driven by substitution between water and other inputs (*e.g.* farm chemicals, labour) and market opportunities (i.e. changes in commodity prices). Also farm input and output markets are also influenced in most OECD countries by the level and form by which governments provide support to agriculture.

Trading can provide a scarcity price in the market and help allocate water among competing users (urban and industrial) ***and uses*** (environmental). By this reasoning higher water prices would release water from use in low value agricultural activities to high value uses, such as for higher value agricultural commodities, and urban and industrial users, and raise social welfare (Molle and Berkoff, 2007a). While fully functioning water markets might be able to achieve such an outcome there are a number of obstacles in reaching such a result, as already discussed in this chapter.

Transfers of water entitlements between different users can also depend on government policies (*e.g.* water expropriation, investment in desalinisation), and the strength of market regulations. ***Surface water allocations can be traded***, within season, between seasons or permanently, or where the market is regulated the regulator can set the price, price limits, and serve as a broker, for example, to facilitate market operations. For tradable water markets to operate effectively between agriculture and other users requires having a robust knowledge and monitoring of hydrologic conditions; a modern and comprehensive hydraulic infrastructure; well defined water property rights; and established legal, institutional and regulatory arrangements (Chapter 3.5).

In terms of using ***water charges and trading for groundwater management***, there are some important differences compared to the discussion above which has largely focused on water charges and trading for surface water irrigation. Farmers commonly have the right to exploit any aquifer lying below the surface of their properties, but usually subject to a system of permits and regulations to control groundwater abstractions (Chapter 3.4.3 and the OECD questionnaire at www.oecd.org/water).

But the lack of enforcing groundwater regulations and illegal groundwater pumping, has led to the fall in groundwater tables and consequently a rise in the costs of pumping water, while over the longer term the resource can become unsustainable. This implies that the farmer has no incentive to limit extractions since others may continue to pump the resource. In saline groundwater areas the farmer also has no incentive to install drainage facilities since all farmers would have to install facilities to be effective. The over exploitation of saline groundwater can lead to a complexity of threats to aquifers, including waterlogging and secondary salinity, involving salinity intrusion in coastal areas (Hellegers *et al.,* 2007).

The use of groundwater rather than surface is attractive for farmers because it can allow farmer control over the resource, and offsets the risks and uncertainties where entitlement and allocation systems are poorly defined. Moreover, use of groundwater allows water on demand and can support crop diversification and high value farming. In contrast to surface water, however, the transaction costs to regulate the sustainable use of the resource can be high, hence, the long term degradation of groundwater resources represents a major policy challenge (Molle and Berkoff, 2007a).

In principle raising water charges to farmers (or trading water entitlements) can ensure demand is consistent with the supply needed to meet environmental demands, if externalities (positive and negative) are included in the traded price (Molle and Berkoff, 2007a). The user-pays and polluter pays principles embody the idea that water quantity and quality externalities should be reflected in the charges paid by water users as an incentive to reduce adverse environmental impacts (Box 1.2) (OECD, 1999).

A major obstacle in using water charges and trading to address environmental issues in agriculture is the difficulty in valuing the environmental externalities associated with agricultural use of water resources. While there has been a burgeoning literature on valuing the environment assets associated with ecosystems (see the review in FAO, 2004), there is less research on how these values can be incorporated into the costs of production and resource use, and few examples where this has been implemented in practice. This reflects, as in the case of opportunity cost pricing, problems of estimation, implementation and enforcement, plus the social and political challenge of farmers who commonly consider these externalities are the responsibility of society more widely (Molle and Berkoff, 2007a).

Chapter 2

Recent Trends and Outlook for Water Resources in Agriculture

2.1. Trends in water resource use and management since 1990[1]

The key trends in OECD agriculture's use of water resources since 1990, include:

- Use of freshwater resources by agriculture and non-agricultural users has changed little;
- Agriculture accounts for the major share of total water use;
- The area irrigated has been increasing, while the total agricultural land area has decreased; and,
- Abstractions from groundwater resources by agriculture have been increasing.

Overall OECD agricultural and non-agricultural uses changed little between 1990-92 and 2002-04, although there has been considerable annual variability in water use in agriculture (Figure 2.1). The OECD trend in agriculture water use reflects significant growth in four countries (**Greece, Korea, New Zealand** and **Turkey**) mainly driven by an increase in the area irrigated (except **Korea**), but a substantial reduction in **Australia, Mexico** and most **European OECD countries**. For this latter group of countries the decrease in water use is due to a mix of factors varying between countries, but notably improvements in water use efficiency, drought, release of water to meet environmental needs, and contraction of the agricultural sector in **Europe**.

OECD agriculture accounted for 44% of OECD total water use overall in 2002-04, although for eight OECD countries where irrigated agriculture is important, the share is over 55% (Figure 2.1). Some of the water used by irrigated agriculture is reused by other downstream users or diverted to meet environmental needs, although there are also losses due to evapotranspiration; pollutant runoff from irrigated farming; and losses to groundwater sources which are no longer economic to pump. Even so, there are no cases of an overall national physical shortage of water, as the share of total water use in total availability of annual freshwater resources is low.

The supply and demand for water resources, however, varies greatly within most countries. As a result competition for water between agriculture, other users (*e.g.* industrial, urban) and the environment, especially in drier regions, is becoming a growing concern in many countries. In the **United States**, for example, the 17 western contiguous States are generally characterised as arid/semi-arid with seasonal periods of moisture deficits during the growing season. This region in 2002 accounted for 51% of US cropland, 76% of the US irrigated area. The rest of the US is generally characterised as more humid, where most irrigated agriculture is generally considered to be supplemental.[2]

In aggregate the OECD area irrigated rose by 8% compared to a reduction of 3% in the total agricultural area between 1990-92 and 2002-04, although while the area that is irrigable is normally greater than the actual area irrigated in any given year (Figure 2.1). For some countries where irrigation plays a key role in the agricultural sector and farming is also a major water user in the economy (**Greece** and **Turkey**), the growth in agricultural water use over the past decade has been substantially above that compared to other water users (Figure 2.1).

For a number of other countries where irrigation is important (**Australia, Korea, Mexico, Portugal** and **Spain**) the growth in agricultural water use has been below that compared to other water users (Figure 2.1). The value of production from irrigated agriculture has a high and growing share in total agricultural production value (in excess of 50%) and value of exports (more than 60%) in a number of OECD countries, *e.g.* **Italy, Mexico, Spain** and the **United States** (crop sales only).

Box 2.1. Water use terminology and water balance calculations

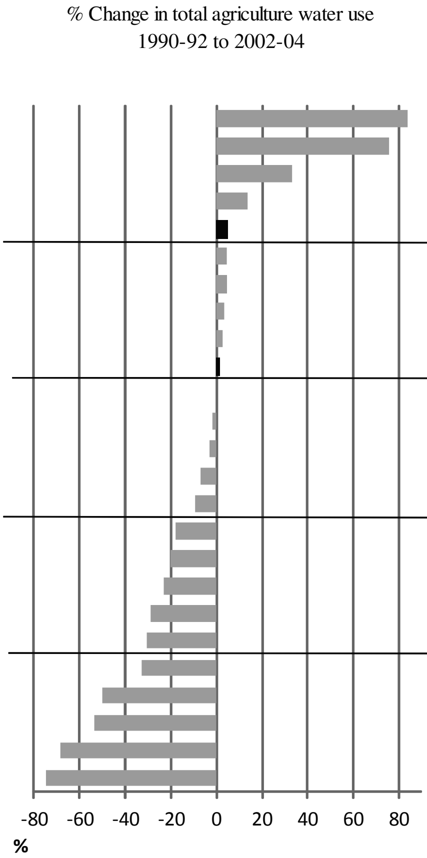
The term "agricultural water use" used in the text and figures in this chapter refers to "water abstractions" for irrigation and other agricultural uses (such as for livestock) from rivers, lakes, and groundwater, and "return flows" from irrigation but excludes precipitation directly onto agricultural land. "Water use" or in the technical literature "water withdrawals", is different from "water consumption" which relates to water depleted and not available for reuse. Canadian agriculture's use of water resources provides an illustrative numerical example of the use of these terms. Agriculture in Canada uses (withdraws from total available water sources) 7-9% of Canada's overall water use. Agriculture consumes (does not return to the water system) 70-80% of the water it withdraws to make it the leading user of water in Canada (about 70% of total consumption).

Calculations of water balances are complex (from which the data in Figures 2.1 to 2.4 are drawn), and not all OECD countries use the same data collection methods, which is a limitation in using the indicators, shown in the figures. A further limitation is that water use balances are usually not calculated annually, but derived from 5 or even 10-year surveys, and cover all uses of water across the economy, including agriculture. Moreover, the extent of groundwater reserves and their rate of depletion are also not easily measured, and cross country time series data are lacking. An additional complication is that under some systems, agriculture has the potential to recharge groundwater.

Cross border sources of water also need to be taken into account in establishing water balance calculations, for a considerable number of countries. While internal renewable water resources, represented by annual flow of rivers and recharge of aquifers generated from endogenous precipitation make-up the major part of a water balance, water generated outside the border of a country can also be important, such as natural inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers. Similarly, not all the water resources generated by endogenous precipitation in a particular country are available for that country. This is because, for example, a certain quantity of water must remain to maintain the natural flow of the river which ultimately leaves the nation's (nations') border. Thus, the water balance equation of a country also needs to include the external renewable water resources that naturally flow into that country and the amount of water generated by endogenous precipitation that naturally flows out of the country.

Source: OECD Secretariat, and the Canadian response to an OECD questionnaire at www.oecd.org/water.

Figure 2.1. Agricultural water use[1]



	Total agriculture water use[1]		Change in total agriculture water use	Change in total water use[2]	Share of agriculture in total water use[2]
	1990-92	2002-04	1990-92 to 2002-04	1990-92 to 2002-04	2002-04
	million m^3	million m^3	%	%	%
Turkey (3)	18 812	34 552	84	48	75
New Zealand (4)	1 281	2 254	76	56	57
Greece (5)	5 694	7 600	33	24	87
Korea (6)	14 100	16 032	14	42	55
EU15 (7)	43 625	45 557	4	-6	29
Spain (8)	23 700	24 701	4	4	60
United Kingdom (9)	1 347	1 402	4	14	10
France	4 901	5 067	3	-12	15
Canada (10)	3 991	4 104	3	-6	10
OECD (11)	414 385	419 883	1	1	44
Iceland (12)	70	70	0	-1	42
United States (13)	195 200	191 555	-2	2	40
Japan (14)	58 642	56 840	-3	-3	66
Portugal (15)	5 547	5 162	-7	2	59
Mexico	62 500	56 811	-9	1	77
Austria (16)	100	82	-18	-50	5
Sweden (17)	169	135	-20	-10	5
Australia (18)	13 384	10 310	-23	-6	55
Germany (19)	1 600	1 140	-29	-21	3
Poland	1 527	1 065	-30	-18	9
Hungary	968	651	-33	-8	11
Netherlands (20)	184	91	-50	27	1
Denmark (21)	383	177	-54	-39	27
Slovak Republic (22)	192	59	-69	-42	6
Czech Republic (23)	93	24	-75	-43	1
Italy (24)	..	20 865	..	0	50

1. Agricultural water use is defined as water for irrigation and other agricultural uses such as for livestock operations. It includes water abstracted from surface and groundwater, and return flows from irrigation, but excludes precipitation directly onto agricultural land.
2. Total water use is the total water abstractions for public water supply + irrigation + manufacturing industry except cooling + electrical cooling.
3. Data for irrigation are used because data for agricultural water use are not available. For Turkey, change in total agricultural water use is +84%.
4 Data for the periods 1990-92 and 2002-04 refer to the years 1999 and 2006.
5. Data for the period 1990-92 and 2002-04 refer to the year 1990 and 1997. Share of agriculture in total water use is for 1997.
6. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and average 2002-03.
7. EU15 excludes: Belgium, Finland, Ireland, Italy and Luxembourg.
8. *Sources:* OECD and national data.
9. England and Wales only.
10. Data for the periods 1990-92 and 2002-04 refer to the years 1991 and 1996.
11. OECD excludes: Belgium, Finland, Ireland, Italy, Luxembourg, Norway, and Switzerland.
12. Data for the period 1990-92 refer to the year 1992. Data include water use for fish farming.
13. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and 2000.
14. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and 2001.
15. Data for the periods 1990-92 and 2002-04 refer to the years 1989 and 1999.
16. Data for the period 2002-04 refer to the year 2003. *Sources: Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management, Facts and Figures 2006* and *Austrian Water, Facts and Figures.*
17. Data include water use for fish farming.

(Notes continue on following page.)

(Notes to Figure 2.1 continued.)

18. Average 1990-92 = average 1993-95, Average 2002-04: data for irrigation are used because data for agricultural water use are not available. *Sources: irrigation in water use on Australian farms 2002-2003, 2003-2004, 2004-2005.*
19. Data for the period 2002-04 refer to the year 2001. Data for irrigation are used because data for agricultural water use are not available.
20. Data for the period 1990-92 refer to the year 1991.
21. Until 1999 abstraction for irrigation included abstraction for freshwater fish farms, accounting for approximately 40 million m^3/year.
22. For the Slovak Republic, the change in total agricultural water use is –69%.
23. For the Czech Republic, the change in total agricultural water use is –75%.
24. For 1990-92, data for agricultural water use are not available. Data for the period 2002-04 refer to the year 1998.

Source: Updated from OECD (2008a).

Irrigated agriculture provides a growing and major share of the value of farm production and exports for some OECD countries, and supports rural employment in a number of regions. As such irrigated agriculture accounts for most of agricultural water use, and will continue to play an important role in agricultural production growth in some countries.

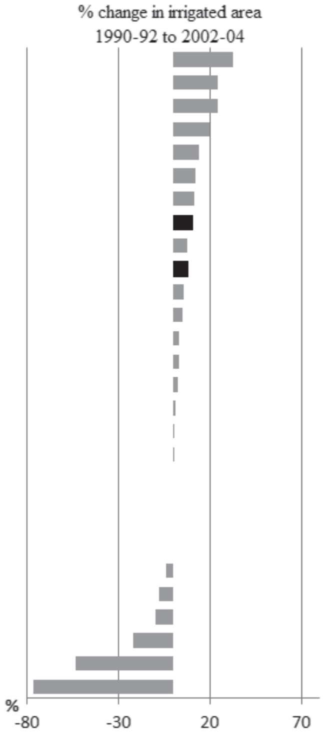
Increases in physical water productivity by agriculture, through better management and uptake of more efficient technologies, such as drip irrigation and adoption of other water saving farm practices, has contributed to higher farm production. Overall the OECD average water application rate per hectare irrigated decreased by 7% between 1990-92 and 2002-04, while in most cases the volume of agricultural production increased (Figure 2.2).

In the **United States,** for example, efficiency gains have been made in irrigation water use over the 1990s, with a decline in per hectare application rates by 7% (Figure 2.2, Hutson *et al.*, 2004). Reduction in water application rates per hectare irrigated have also been achieved in other countries where irrigated agriculture is important, notably in **Australia**, but also to a lesser extent in **France**, **Mexico**, **Spain** and the **United States** (Figure 2.2), but irrigation water use efficiency has deteriorated for others (**Greece** and **Turkey**) (Figure 2.2).

The adoption of drip irrigation, low-pressure sprinkler systems, and other water-saving technologies and practices, are becoming more widespread (Figure 2.3). The uptake of more efficient water management technologies (*i.e.* low-pressure sprinklers and drip emitters) in countries where irrigation is important covers over 25% of the total irrigated area for **Australia, France, Czech Republic**, **Greece, Italy, Spain** and the **United States** (Figure 2.3). In addition, water use efficiency in agriculture is being improved through replacing earthen irrigation channels with concrete linings to reduce losses, and upgrading flood irrigation systems (*e.g.* levelling of fields, neutron probes for soil moisture measurement, and scheduling of irrigation to plant needs).

The low uptake of water-conserving irrigation technologies, such as drip emitters, and the poor maintenance of irrigation infrastructure (*e.g.* canals) has for some countries, however, led to inefficiencies in water use and water losses through leakages leading to an increase in water withdrawal and application rates per hectare irrigated. Estimates for **Mexico**, for example, show that only 45% of water extracted reaches irrigated fields. Even so, overall the OECD average water application rate per hectare irrigated decreased by 12% between 1990-92 and 2002-04 (Figure 2.2).

Figure 2.2. Irrigated area, irrigation water use and irrigation water application rates



	Irrigated area (1)		Change in irrigated area		Change in total agricultural area	Share of irrigated area in total agricultural area	Share of irrigation water use in total agricultural water use	Irrigation water application rates		
	'000 hectares		'000 hectares	%	%	%	%	Megalitres per hectare of irrigated land		
	1990-92	2002-04	1990-92 to 2002-04	1990-92 to 2002-04	1990-92 to 2002-04	2002-04	2002-04	1990-92	2002-04	% change
Turkey	3 933	5 215	1 282	33	3	13	..	4.8	6.6	39
Greece	1 195	1 482	287	24	-3	16	..	4.8	5.1	8
France	2 107	2 611	505	24	-3	9	..	2.3	1.9	-17
Canada (2, 3)	900	1 076	176	20	-1	2	94	3.5	3.6	1
New Zealand (2)	250	285	35	14	-1	2	..	..	..	..
Spain	3 388	3 787	399	12	-3	9	98	7.0	6.4	-9
Sweden (2, 4)	48	54	6	12	-6	2	70	2.1	1.7	-19
EU-15 (5)	11 791	12 994	1 203	10	-3	10	..	3.6	3.4	-6
United States (2, 6)	20 900	22 543	1 643	8	-3	5	99	9.0	8.4	-7
OECD (7)	50 827	54 808	3 981	8	-3	4	..	8.0	7.5	-7
Belgium	24	25	1	6	2	2	..	0.5	1.5	189
Australia (2)	2 380	2 497	117	5	-4	1	99	7.5	4.1	-45
Denmark	433	448	15	3	-4	17	95	0.6	0.4	-35
United Kingdom	165	170	5	3	-6	1	7	1.0	0.6	-46
Mexico	6 170	6 313	143	2	1	6	97	9.9	8.7	-12
Netherlands	557	565	8	1	-8	29	..	0.3	0.2	-51
Germany	482	485	3	1	-2	3	..	3.3	2.4	-29
Poland	100	100	0	0	-12	1	8	3.7	0.9	-77
Austria	4	4	0	0	-4	0	..	12.5	20.5	64
Finland (2)	64	64	0	0	0	3	80	0.3	0.6	100
Switzerland	25	25	0	0	-3	2	..	..	..	..
Italy (8)	2 698	2 698	0	0	1	17	..	..	7.7	..
Portugal (2, 9)	626	601	-25	-4	-3	16	..	8.9	8.6	-3
Japan	2 846	2 624	-222	-8	-8	50	99	20.6	21.4	4
Korea	977	879	-98	-10	-11	46	95	14.3	17.4	22
Hungary	213	166	-47	-22	-8	3	26	2.3	1.0	-55
Czech Republic (2)	43	20	-23	-54	0	0	..	0.7	1.2	64
Slovak Republic (2)	299	70	-229	-76	0	3	80	0.5	0.7	31

. . : not available

1. Covers area irrigated and not irrigable area (*i.e.* area with irrigation infrastructure but not necessarily irrigated.) To be consistent, the years used for the average calculations are the same for irrigation water use and total agricultural water use, irrigated area and total agricultural area.

2. For some countries, data in brackets below are used to replace the average due to missing data: Australia: 1990-92 (1997), Canada: 1990-92 (1988), 2002-04 (2003). Czech Republic: 1990-92 (1994), 2002-04 (2003). Finland: 2002-04 (2001). New Zealand: 1990-92 (1985), 2002-04 (2003). Portugal: 1990-92 (1989), 2002-04 (1999). Slovak Republic: 1990-92 (1993), Sweden: 1990-92 (1985), 2002-04 (2003). United States: 1990-92 (1990), 2002-04 (2000).

3. For Canada, the source is the OECD questionnaire at www.oecd.org/water.

4. For Sweden, the source is the OECD questionnaire at www.oecd.org/water.

5. EU15 excludes Ireland and Luxembourg.

6. For the United States, the source is the *Census of Agriculture*.

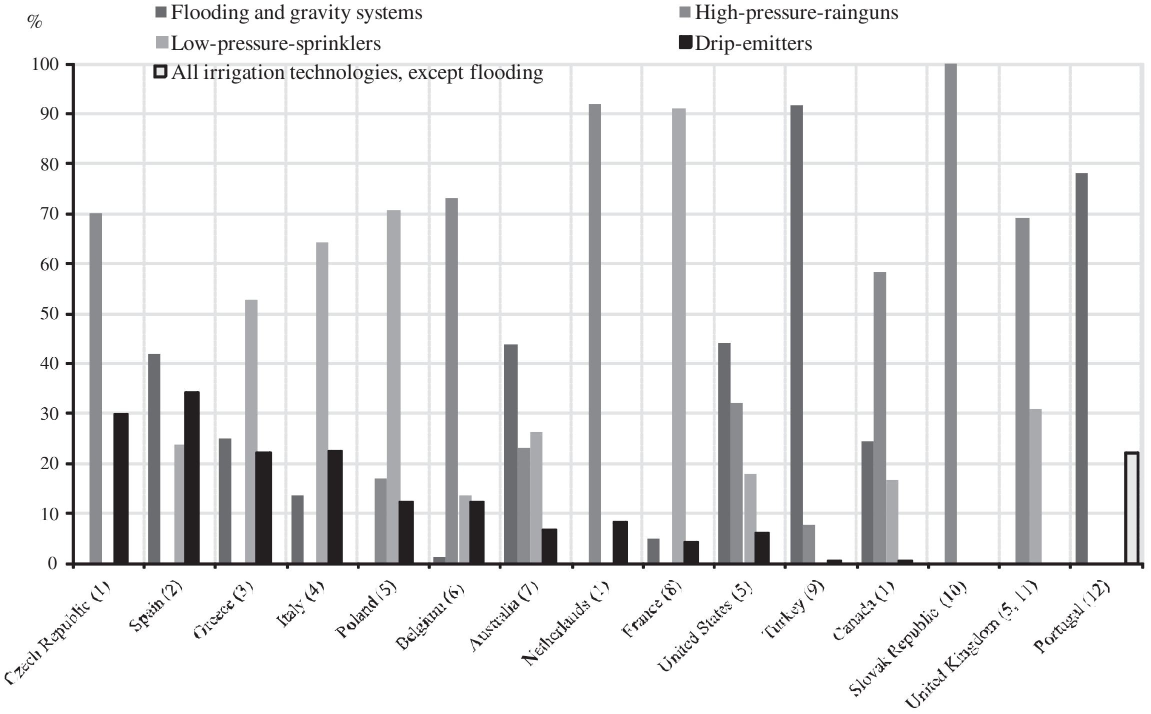
7. OECD excludes: Iceland, Ireland, Luxembourg, Norway, Switzerland.

8. For Italy, share of irrigation water in total agriculture water use, for 1998.

9. For Portugal, the area irrigated is that equipped for irrigation and not the actual area irrigated which was 453 540 ha for 2002-04.

Source: Updated from OECD (2008a).

Figure 2.3. Share of irrigated land area using different irrigation technology systems: 2000-03



1. Data for 2003.

2. The data are for 2002-03 and represent the area for flooding, sprinklers and drip emitters that are irrigable but not necessarily irrigated.

3. Data for 1999, which show different irrigation technologies' share of total irrigation water use.

4. Data for 2000.

5. National data.

6. Data for Flanders refer to 2002. Flooding data include Wallonia and Flanders data, but for Flanders only ornamental plant cultivation in greenhouses is included; high-pressure raingun data refer only to Flanders; data for low-pressure sprinklers and drip emitters are the sum of Flanders and Wallonia data.

7. Data are taken from the Australian Bureau of Statistics (2005), *Irrigation Methods 2002-03;* flooding refers to surface; low-pressure sprinklers refers to microspray; drip-emitters refers to drip or trickle; and high-pressure rainguns refers to portable irrigators, hose irrigators, large mobile machines and solid set.

8. Values are an average of data for 2000 and 2003.

9. Data for 2000, values for high-pressure rainguns include area irrigated by low-pressure sprinklers.

10. Data for 2000-03.

11. Data for England.

12. 78% for flooding and 22% covers all others.

Source: Updated from OECD (2008a).

In **Turkey**, despite the increasing adoption of low-pressure sprinkler and drip irrigation systems, irrigation through flooding remains dominant, used on over 90% of irrigated land (Figure 2.3). Moreover, the water application rate per hectare irrigated in **Turkey** increased by 39% between 1990-92 and 2002-04 (Figure 2.2), partly explained by losses from the irrigation infrastructure and inefficiencies in managing irrigation systems due to lack of irrigator management skills and poor advisory services (OECD, 2008a). But water policy reforms in both **Mexico** and **Turkey** are beginning to address these deficiencies in managing the irrigation systems (Box 3.8).

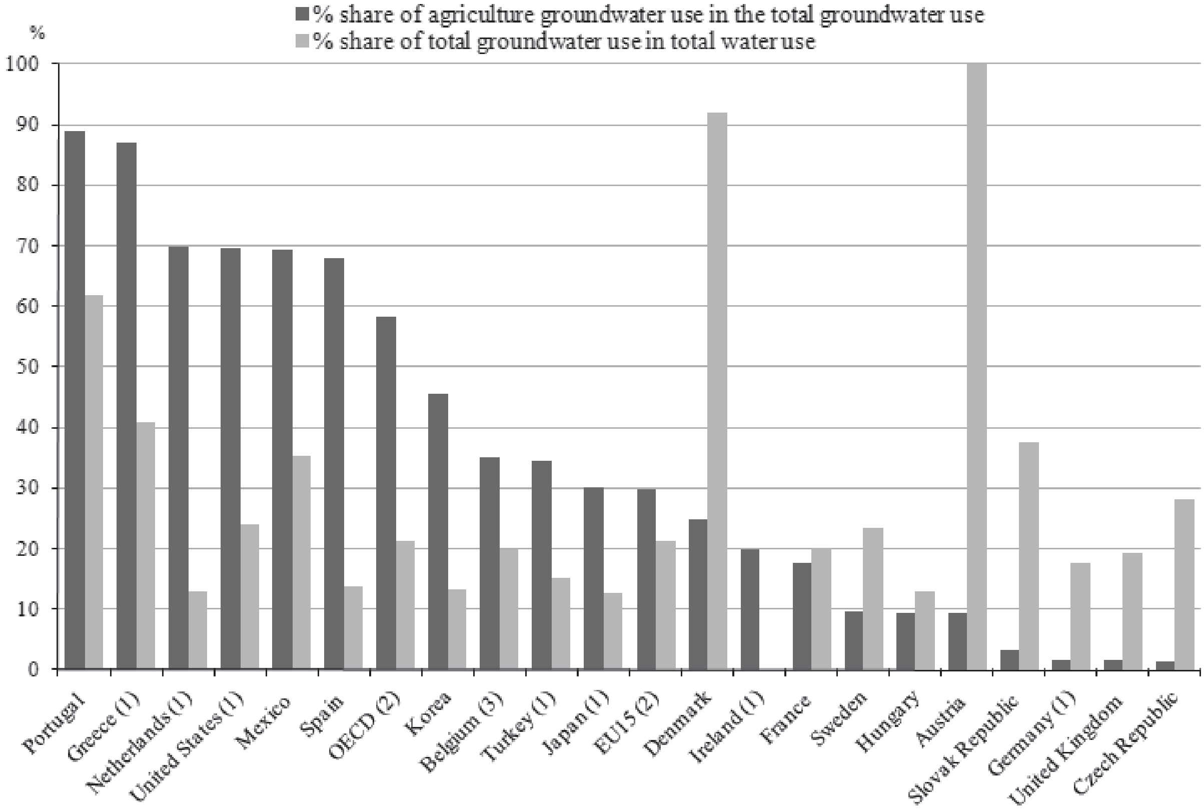
Agriculture abstracts an increasing share of its water supplies from groundwater. The sector's share in total groundwater utilisation, although data are limited, was above 30% in 12 OECD member countries in 2002, notably for **Greece, Japan, Korea, Mexico, Portugal, Spain, Turkey** and the **United States** (Figure 2.4). Although data are limited, farming is drawing an increasing share of its supplies from groundwater, and agriculture's share in total ***groundwater utilisation*** was above 30% in a third of OECD member countries in 2002 (Figure 2.4).

Over-exploitation of water resources by agriculture in certain areas is damaging ecosystems by reducing water flows below minimum flow (stock) levels in rivers, lakes and wetlands, which is also detrimental to recreational, fishing and cultural uses of these ecosystems. Groundwater use for irrigation above recharge rates in some regions (**Australia, Greece, Italy, Mexico** and the **United States)** is also undermining the economic viability of farming in affected areas. Also farming is now the major and growing source of groundwater pollution across many countries. This is of particular concern where groundwater provides a major share of drinking water supplies for both human and the farming sector (*e.g.* **Greece, Mexico, Portugal,** the **United States**) (Figure 2.4).

In those regions were growing water scarcity is an issue, greater use is being made of recycled wastewater and desalinated water from seawater and saline aquifers. These sources of water still remain marginal in most OECD countries, although they are important for agriculture in some localities within countries, especially near large population centres (recycled sewage wastewater) and coastal areas (desalinisation), such as beginning to emerge in some OECD Mediterranean countries, for example, Spain.

Changing cropping patterns is also being explored as means to alter virtual water trade flows. ***Virtual water trade*** is considered by some researchers as a way to make water savings in countries where water resources are under pressure from competing users. In brief, virtual water trade is importation by water scarce nations of their least water efficient crops from countries that have a lower opportunity cost of water and higher productivity (World Bank, 2006). But the policy recommendations that follow from virtual water trade analysis can be incorrect and misleading, as discussed in Box 2.2.

Figure 2.4. Share of agricultural groundwater use in total groundwater use, and total groundwater use in total water use: 2002



1. Data for 1994 are used to replace missing data of 2002 for: Ireland.
Data for 1995 are used to replace missing data of 2002 for: Netherlands.
Data for 1997 are used to replace missing data of 2002 for: Greece, Turkey.
Data for 1998 are used to replace missing data of 2002 for: Germany.
Data for 2000 are used to replace missing data of 2002 for: United States.
Data for 2001 are used to replace missing data of 2002 for: Japan.

2. The EU15 and OECD data must be interpreted with caution, as they consist of totals using different years across countries, and do not include all member countries. EU15 excludes: Finland, Italy and Luxembourg. OECD excludes: Australia, Canada, Finland, Italy, Luxembourg, New Zealand, Norway, Poland and Switzerland.

3. Data for Belgium only cover the Flanders region.

Source: Updated from OECD (2008a).

Box 2.2. Economic analysis of the virtual water and water footprint concept related to agriculture

The term "virtual water" began appearing in the water resources literature in the mid-1990s. Professor Tony Allan of London University chose the term to describe the water used to produce crops traded in international markets. During the 15 years since its inception, the virtual water concept (or metaphor, symbol) has been very helpful in gaining the attention of public officials and policy makers responsible for encouraging wise use of limited water resources.

Several authors have conducted empirical analyses of "virtual water flows" between countries, by comparing the water requirements of crops and livestock products involved in international trade, concluding that some countries are "net importers of virtual water," while others are "net exporters." They also suggest that, based on the virtual water concept, water-short countries should import water intensive goods and services, while water-abundant countries should export water intensive products. This line of reasoning, while simple, is not based on a legitimate conceptual framework. Hence, the policy recommendations that follow from this form of virtual water analysis can be incorrect and misleading.

The fundamental shortcoming of the virtual water concept that prevents it from serving as a valid policy prescriptive tool is the lack of an underlying conceptual framework. Some researchers have incorrectly described virtual water as analogous to, or consistent with the economic theory of comparative advantage. The virtual water concept is applied most often when discussing or comparing water-short and water-abundant countries. By focusing on the water resource endowment, alone, virtual water represents an application of absolute advantage, rather than comparative advantage. For this reason, policy prescriptions that arise from virtual water discussions are not those that will maximise the net benefits of engaging in international trade. Comparative advantage is the pertinent economic concept, and virtual water considers only absolute advantage.

Recent empirical analyses of international trade data generally confirm the lack of consistency between virtual water prescriptions and actual trade patterns. A number of authors have begun describing the important role of non-water factors in determining optimal production and trading strategies, such as the importance of considering population densities, historical production trends, national food security goals, poverty reduction targets, and the availability of complementary inputs when determining whether to transfer water from one region to another, or to achieve desired outcomes alternatively by transporting or trading agricultural commodities.

The notion of water footprints describes the volume of water required to support production and consumption in selected regions or countries, and to assess whether a region or country is consuming resources in a sustainable or unsustainable fashion, from a global perspective. Water is one of many inputs in those activities. Hence, estimated water footprints are somewhat one-dimensional, as they depict the use of only one resource. In addition, water footprints do not describe the implications of water use. Rather, they consider only the amounts of water used in production and consumption activities. Hence, ecological water footprint analysis is not sufficient for determining optimal policy alternatives, as it does not account of the net benefits generated as resources are consumed.

The costs and benefits of water use depend largely on the opportunity (scarcity) costs of water resources and the ways in which water is combined with other inputs in production and consumption. Water footprints enable one to compare estimated water use, per person or in aggregate across countries, but they are inadequate for evaluating the incremental costs, benefits, or environmental impacts of water use. For this reason, empirical estimates of water footprints do not provide sufficient information for assessing environmental implications or determining policy goals and strategies pertaining to water resources. Like the virtual water concept, water footprints bring helpful attention to important policy issues, but they lack the conceptual foundation and breadth required to support policy analysis.

Some researchers have described ***the "green" and "blue" components of virtual water and water footprints***. "Green water" is used to denote effective rainfall or soil moisture that is used directly by plants, while "blue water" denotes water in rivers, lakes, aquifers, or reservoirs. "Blue water" generally refers to water that can be delivered for irrigation or made available for alternative uses, while "green water" must be used directly from the soil profile.

Like virtual water, the blue-green concept has helped increase public awareness of an important dimension of water resource management. The terms "green water" and "blue water" generate easily recallable images of soil moisture and stored surface water in a manner that is likely to be helpful to many public officials and agency staff members.

Yet the notions of green and blue water do not establish a new conceptual framework that can be used alone to guide policy decisions. Some authors have suggested that the opportunity cost of "green water" is generally smaller than that of "blue water". They propose trading "green water" for "blue water", when possible, to generate meaningful water savings. The perspective regarding opportunity costs is not accurate and the recommendation is not based on a legitimate conceptual framework.

In summary, the virtual water, water footprint, and blue-green concepts have brought much-needed attention to important issues regarding water resources, within countries and around the world. These concepts serve well in gaining the attention of public officials and policy makers. Current patterns of water allocation and use often reflect underlying market failures that can be corrected with appropriate policy interventions. In this context the concepts are helpful in bringing attention to these market failures, particularly among members of the media, public officials, and the general public.

Yet none of these concepts is based on an established, underlying conceptual framework, and none is a sufficient criterion for determining optimal policy decisions. Farmers, traders, and public officials must consider many economic and social issues when determining optimal strategies. Virtual water, water footprints, and the blue-green concepts will be helpful in starting policy discussions in many settings. But they will not be sufficient for determining the optimal outcomes of those discussions and establishing economically efficient and environmentally effective policy alternatives.

Source: Adapted from Wichelns (2010a).

2.2. Outlook for water resources in agriculture

2.2.1. OECD Environmental Outlook baseline scenario projections

Projections of agriculture's use of water resources up to 2050 from the OECD (2008b) *Environmental Outlook*, highlight a number of new developments of concern to water users and consumers, as well as policy makers.[3] The OECD baseline scenario results provided in the *Environmental Outlook* and shown in Figures 2.6 to 2.9 in this chapter are policy-neutral, as they project current policies into the future to show what the world could be like in 2050 if current policies are maintained. Also the baseline scenario does not include any climate change impacts. The main baseline projections relevant to water and agricultural linkages included in the *Environmental Outlook* are summarised below.

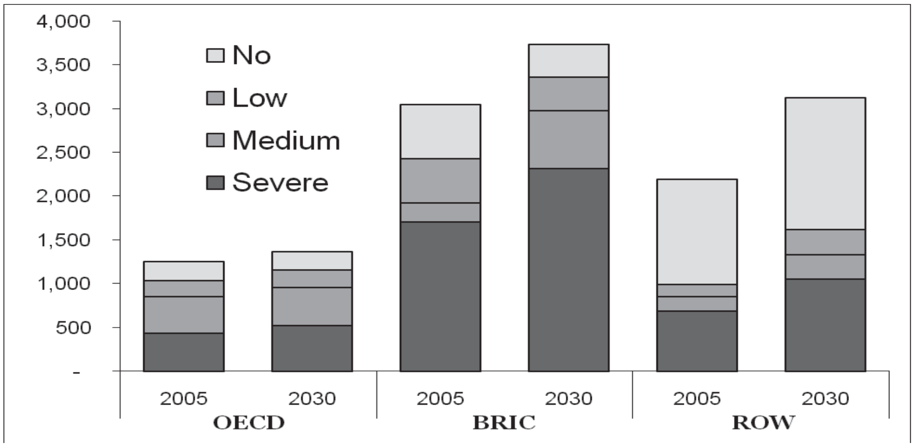
- Overall water scarcity is an increasing threat in many regions within countries, as water pollution and overuse are damaging to water sources, while populations grow and competition between different uses increases (Box 2.3). Currently, 1.4 billion people live in water basins where the water usage rates exceed recharge rates. In 2005, 35% of the population of the OECD was living in areas characterised by severe water stress, compared with 44% worldwide. By 2030, the number of people living under severe water stress is expected to increase by 1 billion from the 2005 baseline to an estimated 3.9 billion people (47% of the world population), mostly in non-OECD countries.

- Water withdrawals are projected to increase at a much higher pace in developing relative to OECD countries, and for non-agricultural compared to agricultural uses (Figures 2.6, 2.7). As a result global and regional quantities and shares of water withdrawals by agriculture decline (Figures 2.8, 2.9). Around a half of the projected increase in total water withdrawals would be used by the power generation industry, although a major share of water used for power generation is returned into the water system (OECD, 2008b). Even though, the baseline scenario suggests that developing countries will need to expand their supply of water resources to meet the expected growth in consumer demand and to secure environmental needs.
- At the same time as water use by agriculture declines, global food and non-food demand will continue to increase mainly as a result of the growth in incomes, population, urbanisation and industrialisation. This will chiefly be driven by developing countries, but agricultural production in many of these countries will be much more constrained by pressures on the natural resource base, including land and water, notably in China and India.
- The global decrease in agricultural water withdrawals is dominated by developments in irrigation, as this is assumed to account for 99% of agricultural water withdrawals (the remainder is accounted for by livestock), and, in particular, by China and India as the volumes involved in these countries are so large. The OECD *Environment Outlook* under the baseline scenario projects that for both these countries there will be a steady decline in the physical volume (and share) of water withdrawals by agriculture up to 2050 (Figures 2.6 and 2.9).

Box 2.3. Water stress

Figure 2.5. People living in areas of water stress

Projections, by stress level (millions)

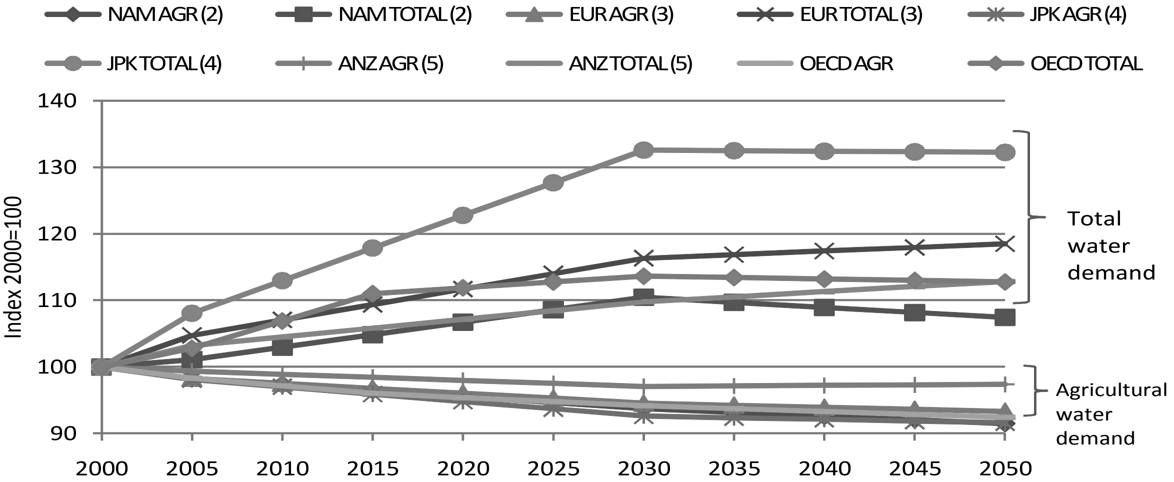


BRIC: Brazil, Russia, India, China. ROW: Rest of World. Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

OECD's indicator for water stress, is based on the ratio of water withdrawal to annual water availability, which uses the following thresholds: below 10% water stress **low**; the 10-20% range indicates **moderate** stress, *i.e.* "water availability is becoming a constraint on development and that significant investments are needed to provide adequate supplies"; above 20% stress is **medium** and "both supply and demand will need to be managed and conflicts among competing uses will need to be resolved"; while above 40% stress is **severe.**

Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.6. Projected total and agricultural water withdrawals in OECD countries: 2000-50

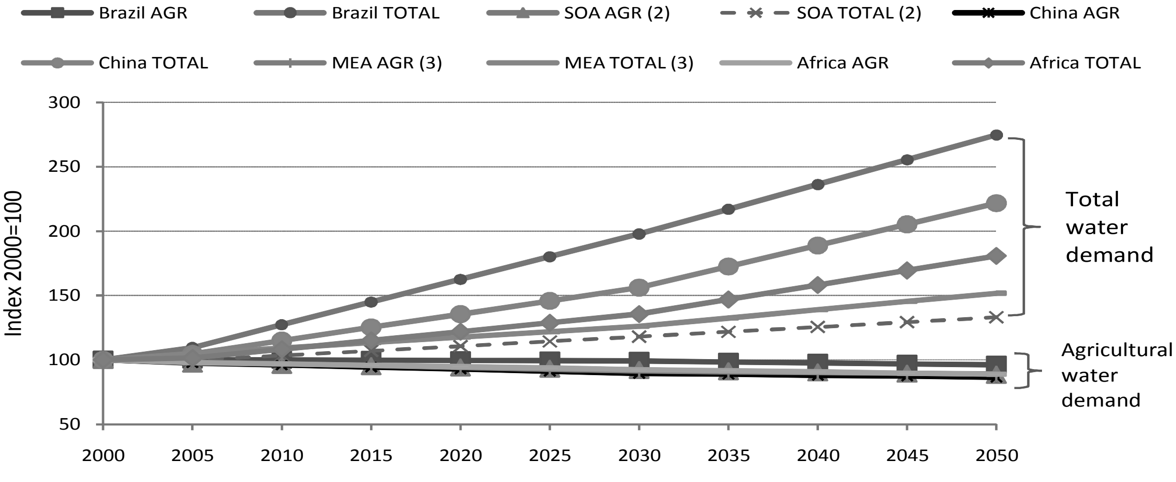


Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

1. Water quantity demand in agriculture includes water for irrigation and water for livestock.
2. NAM includes: Canada, United States and Mexico.
3. EUR includes: all OECD European countries, including Iceland and Turkey.
4. JPK includes: Japan, Korea and North Korea.
5. ANZ includes Australia and New Zealand.

Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.7. Projected total and agricultural water withdrawals in selected non-OECD countries/regions: 2000-50

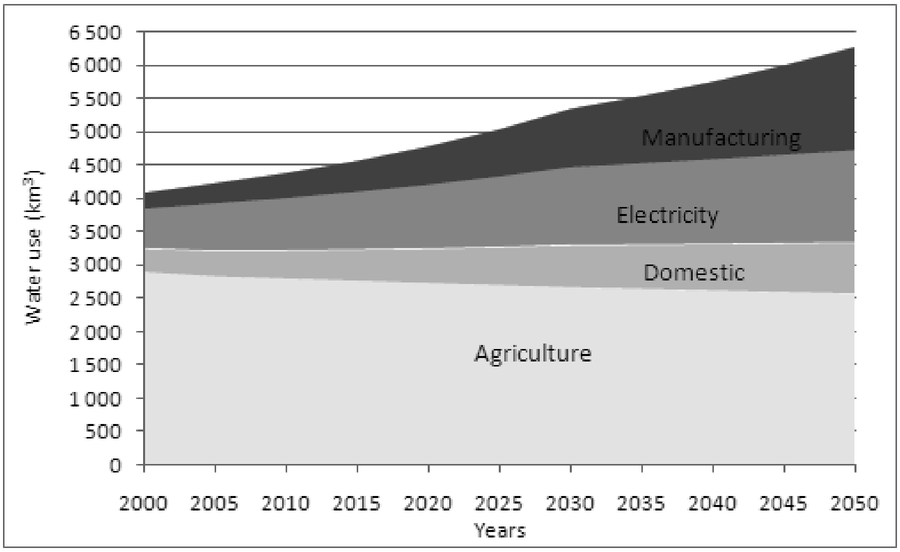


Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

1. Water quantity demand in agriculture includes water for irrigation and water for livestock.
2. SOA includes India and South Asia.
3. MEA includes the Middle East.

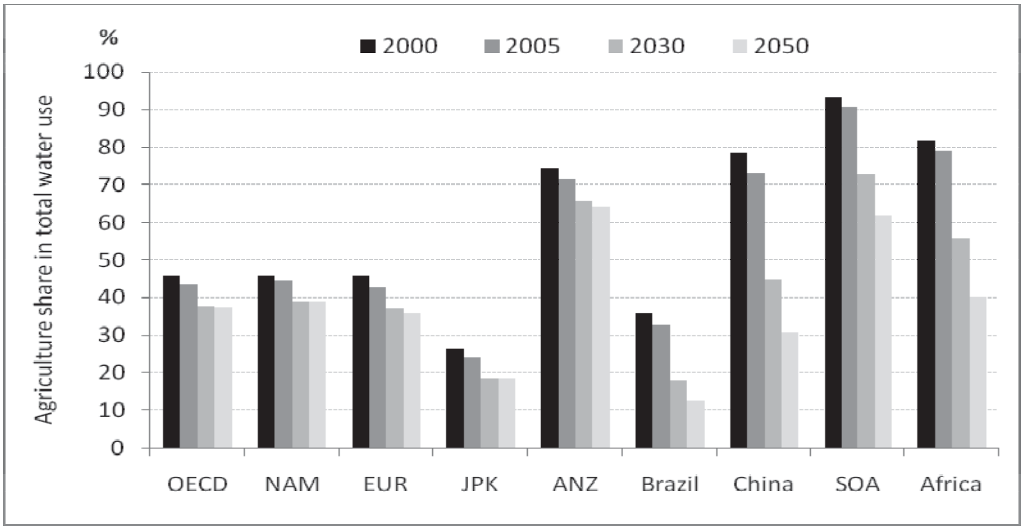
Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.8. Projected world water withdrawals by sector: 2000-50



Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.9. Projected share of agriculture in total water withdrawals: 2000-50



Projections are the OECD *Environmental Outlook* baseline scenario, which assumes no new policies and does not include climate change impacts.
For definitions of country groupings, see Figures 2.6 and 2.7.
Source: OECD (2008b), *Environmental Outlook* baseline.

- Consistent with the expectation in the International Water Management Institute Report (IWMI, 2007), it is assumed that the global irrigated area changes little under the baseline scenario. Hence, there is much need for improvement in the physical efficiency of water use in agriculture in all irrigated regions of the world, to help toward meeting the projected global increase in agricultural commodity production, and also to release water for other uses. Some of this improvement is included in the *Environment Outlook* baseline scenario projections.
- OECD agricultural exporting countries are expected to be a continuing and expanding source of food and non-food agricultural commodity exports, mainly to Asian, African, and Middle Eastern countries (some developing countries will also continue as major agricultural exporters, especially in Latin America). Such an expansion in OECD agricultural production and exports will necessitate improving water use efficiency in agriculture, both in largely rain-fed and also irrigated farming systems, if the overall use and pressures on water resources in agriculture are to be reduced.
- It is important to emphasise that these highly aggregated projections for the demand for water, both by agriculture and other water users, mask significant variations within countries in the overall directions and causes of changes in the water situation over the coming decades.

It is pertinent to review the OECD *Environmental Outlook* projections against other studies of future global irrigation water withdrawals (Table 2.1). While the OECD *Environmental Outlook* projections expect a reduction in global irrigation water withdrawals, this compares to a projected increase by most other studies. The OECD results, however, concur with the more recent projections of Alcamo *et al.* (2007), and the descriptive conclusions of the IPCC (Bates *et al.,* 2008; and Tables 2.2 to 2.4).

Table 2.1. A selection of global projections for irrigation water withdrawals

Source	**2000** Cubic kilometres	**2025** Cubic kilometres	**Change 2000-25** %
OECD (2008b)	2 874	2 631[1]	–8
Shen *et al.* (2008)	2 658	3 388 – 3 665[2]	+27 to +38
IWMI (2007)	2 630	2 800 – 3 400[2]	+6 to +29
Alcamo *et al.* (2007)	2 498	2 341 – 2 366[4]	–5 to –6
Shiklomanov (2000)	2 488[3]	3 097	+24
Seckler *et al.* (2000)	2 469[3]	2 915	+18
Alcamo *et al.* (2000)	2 465[3, 4]	2 292 – 2 559[2]	–7 to +4

1. Projection year is 2030 instead of 2025. Projections are the OECD *Environmental Outlook* baseline scenario, which assumes no new policies and does not include climate change impacts.
2. Projections show data for a range of different scenarios.
3. Base year is 1995 instead of 2000.
4. Projections include total agricultural water withdrawals (*i.e.* including water for livestock).

Sources: OECD, adapted from IWMI (2007) and other sources.

Projections of global irrigation water withdrawals differ for a number of reasons including, for example, varying use of data (note the differences in the base year – 2000 – estimates of global irrigation withdrawals in Table 2.1); and differences in the underlying model structures and expert assumptions. For example, researchers have used different definitions of irrigation water use (*e.g.* some define this as total withdrawals others as crop depletion); and make assumptions and judgments regarding irrigation water use efficiency, as well as irrigated versus irrigable area (IWMI, 2007). This highlights the need to improve the underlying water resource related data in projection models and refine model specifications (Chapter 3.6).

2.2.2. Climate change, climate variability, agriculture and water resources

The Intergovernmental Panel on Climate Change (IPCC) report on climate change and water (Bates *et al.,* 2008), concludes that "observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies." Climate change's main water-related impacts with regard to agriculture are expected by the IPCC to be felt in terms of shifting and more variable hydrological regimes, as summarised in Box 2.4.

IPCC also projects a decline in the melt water from major Asian mountain ranges where more than one-sixth of the world's population currently live (Table 2.2). Climate change is expected to affect the function and operation of existing water infrastructure (*e.g.* irrigation systems) as well as water management. Moreover, current water management practices may not be robust enough to cope with the impacts of climate change on, for example, water supply reliability, flood risk, agriculture and ecosystems. Specifically concerning agriculture, the IPCC projects that changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation (Table 2.3).

Climate change can also have a dual effect on irrigated agriculture. This may occur through both higher water demand by agriculture and an expansion of the area irrigated. These developments are due to both general climate change (higher temperatures and lower precipitation) and climate variability leading to an increase in extreme events, especially the frequency of droughts.

Climate variability is also a concern in terms of changes in the seasonality of precipitation, which is of particular importance for agriculture as it affects the timing of annual rainfall patterns or periods of snow pack melt, necessitating the restructuring of irrigation storage systems. Better understanding of climate variability and extension of risk management approaches in agriculture to existing climate variability, can help build a more solid foundation for addressing climate change in the future.

Many other reports from OECD government agencies have reinforced the IPCC view on climate change (*e.g.* **Australia**, Commonwealth Scientific and Industrial Research Organisation [CSIRO], 2008; **Canada**, Lemmen *et al.,* 2007; **EU**, European Parliament, 2008 and Portuguese Ministry of Environment, 2007; **United States**, United States Environmental Protection Agency [USEPA], 2008). Overall these reports have indicated that in terms of the linkages between climate change, water resources and agriculture, farming systems are increasingly vulnerable to changes in water availability and temperature, requiring high levels of adaptive responses. Projections also expect there to be significant regional variation within and across countries as a result of climate change (Table 2.4).

In some situations climate change will also lead to beneficial opportunities for agriculture, as research is already suggesting in some countries (*e.g.* **Finland** – see the OECD questionnaire at www.oecd.org/water), and as projections reveal in terms of the increase in wheat yield potential in Northern Europe and overall crop yields in North America (Table 2.4).

This report reveals that the incidence and severity of flood and droughts has been increasing for the majority of OECD countries, which has put increasing pressure on irrigated farming in drier and semi-arid areas. In many cases this trend is associated with greater risks associated with climate change (Figure 1.2; Chapter 3.5; and the OECD questionnaire at www.oecd.org/water). Many of these countries also project that with climate change the incidence and severity of flood and drought events may continue to increase, while other researchers also support the view of an ongoing intensification of the hydrologic cycle (Huntington, 2006; Bates *et al.,* 2008).

2.2.3. Agriculture, water, energy and renewable energy

The outset of the new millennium has seen significant increases in ***energy prices and growing concern about climate change***. Energy price increases can affect rain-fed agriculture by raising the cost of transporting agricultural commodities to market and by increasing the cost of agricultural inputs, like fertilisers and pesticides. Because water conveyance and irrigation systems require energy, irrigated agriculture faces the additional burden of increasing water costs as energy costs increase.

Recent increases in energy prices have also led to a growing interest in expanding bioenergy production in many OECD countries. This development has included using agricultural feedstocks for the production of biofuel and bioenergy which can have implications for agricultural water use (Box 2.5). The overall impacts on water balances of supporting agricultural feedstocks to produce biofuels and bioenergy, however, is complex and remains unclear. It is a largely empirical question and needs to be assessed in a way that compares the effects of alternative uses of resources.

Research suggests, however, that the quantity of water needed to produce each unit of energy from second generation biofuel feedstocks (*e.g.* lignocellulosic harvest residues and forestry) is much lower than the water required to produce ethanol from first generation feedstocks (such as from maize, sugar cane, and rapeseed) (Box 2.5). But this can vary according to the location and practices adopted.

Box 2.4. Intergovernmental Panel on Climate Change: Climate change and water

This Box provides the key conclusions from the IPCC's recent report (2008) on climate change and water. The main conclusions, of particular relevance to water resources and agriculture, are listed below.

- Observed warming over several decades has been linked to changes in the large-scale hydrological cycle.
- Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (*likely/very likely*).
- By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics (*high confidence*).
- Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas *(likely/very likely*).
- Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution (*high confidence*).
- Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (*high confidence*).
- Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation.
- Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems – as well as water management practices (*high/very high confidence*).
- Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems *(very high confidence*).
- Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions (*very likely*).
- Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies.
- Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.
- Water resources management clearly impacts on many other policy areas, *e.g.*, energy, health, food security and nature conservation.
- Several gaps in knowledge exist in terms of observations and research needs related to climate change and water.

Source: IPCC (2008).

Table 2.2. Key conclusions from the 2007 IPCC 4th Assessment Report on Climate Change and Water

	Quantitative Assessment		**Expert Judgment**	
	Chance of finding correct:		*Probability of occurrence:*	
	Very high confidence: 9 out of 10	High confidence: 8 out of 10	Very likely >90%	Likely >66%
Global	Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation	Shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed. Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress.	Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions	The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas Globally the area of land classified as very dry has more than doubled since the 1970s.
Regional		Many semi-arid and arid areas (*e.g.* the Mediterranean Basin, western US, southern Africa and north-eastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change. Water supplies stored in glaciers and snow cover are projected to decline in the course of the century in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world's population currently lives	Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes.	Climate model simulations for the 21st century are consistent in projecting precipitation increases in parts of the tropics, and decreases in some sub-tropical and lower mid-latitude regions.
Floods and droughts			The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will increase over most areas during the 21st century, with consequences for the risk of rain-generated floods.	The proportion of land surface in extreme drought at any one time is projected to increase.

(Table 2.2 continued)

	Quantitative Assessment		**Expert Judgment**	
	Chance of finding correct:		*Probability of occurrence*	
	Very high confidence: 9 out of 10	High confidence: 8 out of 10	Very likely >90%	Likely >66%
Agriculture		Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected. Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems.		

These conclusions are based on the quantitative projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used by the IPCC see the source below.

Source: Adapted from Bates *et al.* (2008).

Table 2.3. Summary of key 2007 IPCC 4th Assessment conclusions by warming increments for agriculture

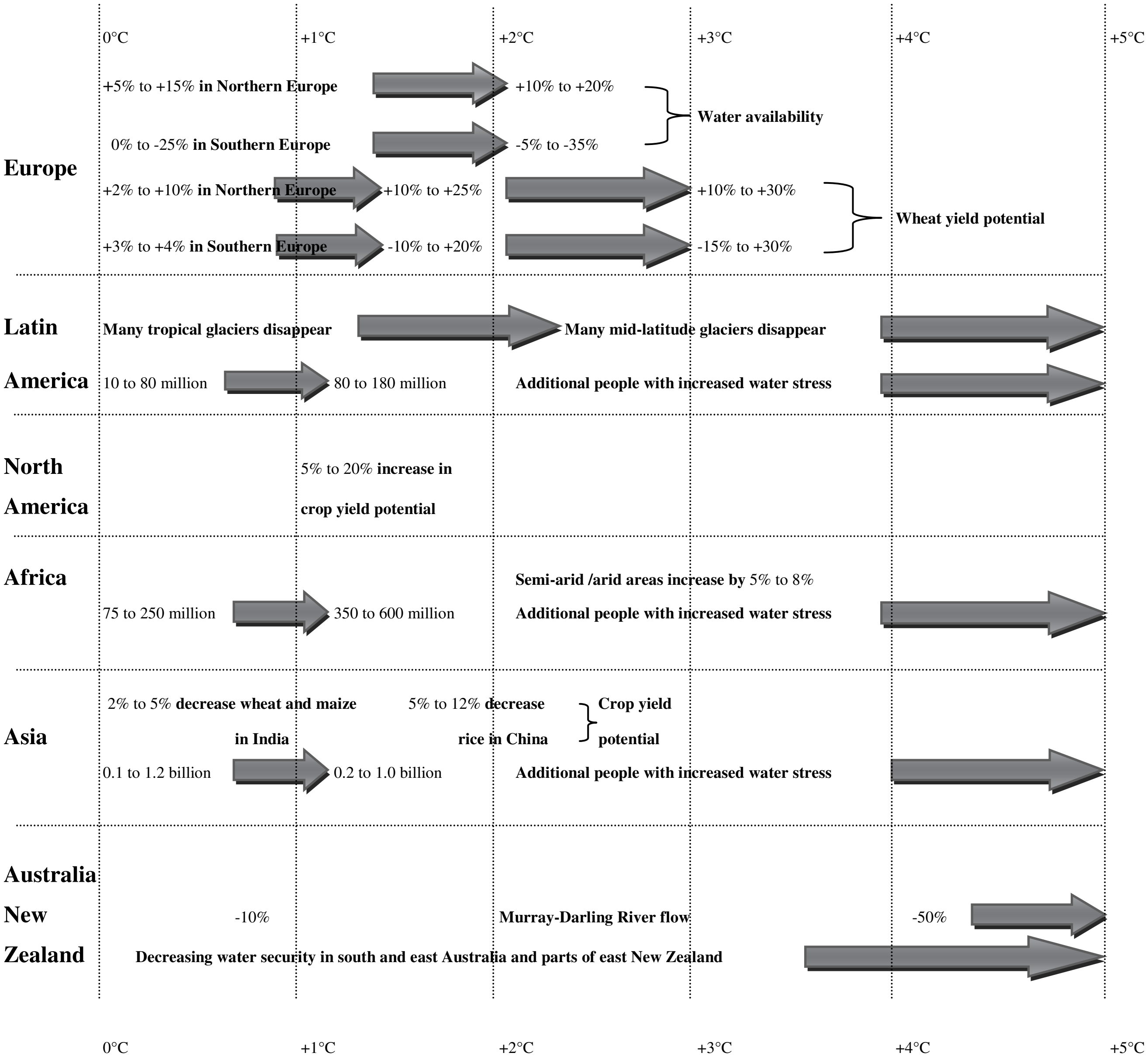
Global mean annual temperature change relative to the 1980-99 (°C) baseline

Sub-sector	**Region**	**+1°C to +2°C**	**+2°C to +3°C**	**+3°C to +5°C**
Food crops	Global		550 ppm CO_2 (approx. equal to +2°C) increases crop yield by 17%; this increase is offset by temperature increase of 2° C assuming no adaptation and 3° C with adaptation	
	Mid- to high latitudes	Cold limitation alleviated for all crops Adaptation of maize and wheat increases yield 10% to 15%; rice yield no change; regional variation is high	Adaptation increases all crops above baseline yield	
	Low latitudes	Wheat and maize yields reduced below baseline levels; rice is unchanged Adaptation of maize, wheat, rice, maintains yields at current levels	Adaptation maintains yields of all crops above baseline; yields drop below baseline for all crops without adaptation	Adaptation maintains yields of all crops above baseline; yield drops below baseline for all crops without adaptation Maize and wheat yields reduced below baseline regardless of adaptation, but adaptation maintains rice yield at baseline levels
Pastures and Livestock	Temperate	Cold limitation alleviated for pastures; seasonal increased frequency of heat stress for livestock	Moderate production loss in swine and confined cattle	
	Semi-arid	No increase in net primary productivity; seasonal increased frequency of heat stress for livestock	Reduction in animal weight and pasture production, and increased heat stress for livestock	
	Tropical			Strong production loss for pigs and confined cattle
Fibre	Temperate		Yields decrease by 9%	
Real Agricultural Prices and Trade	Global	Real agricultural prices: –10% to –30%	Real agricultural prices: –10 to +30%	Real agricultural prices: +10 to +40% Cereal imports of developing countries to increase by 10-40%

These conclusions are based on the quantitative projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used by the IPCC, see the source below.

Source: Adapted from Easterling *et al.* (2007).

Table 2.4. Regional impacts of global annual temperature change as they relate to water and agriculture relative to 1980-99 (^{o}C)



Edges of boxes and placing of text indicate the range of temperature change to which the impact relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. These conclusions are based on the projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used in this figure by the IPCC, see the source below.

Source: Adapted from IPCC (2008).

Box 2.5. Agriculture, biofuels and water resources

The rapid growth of biofuel production from agricultural feedstocks over the past decade has implications for the demand on water resources. This has raised concerns that further expansion of biofuel production from agricultural feedstocks could increase pressure on water resources in regions where competition for water resources is an issue.

The extent to which biofuel production draws on the need for irrigation varies by region (Table 2.5). Rain-fed rapeseed in Europe requires virtually no irrigation. Maize in the United States is largely rain-fed, and only 3% of national irrigation water withdrawals are devoted to biofuel crops. Globally only 2% of water withdrawn for irrigation is estimated to be applied to biofuel crops, and on average an estimated 2 500 litres of evapotranspiration (ET) and 820 litres (L) of irrigation water are needed to produce one litre of biofuel, although regional variation is large.

Table 2.5. Biofuels, land and water use, 2005

	Ethanol	Main feed-stock	Feed-stock used	Area planted to biofuel crops	% Total crop area grown for fuel	Crop water ET	% Total ET used for biofuel	Irrigation with-drawals for biofuel	% Total irrigation with-drawals for biofuel
	(mill. L)		(mill. t)	(mill. ha)		(km^3)		(km^3)	
Brazil	15 098	Sugarcane	167.8	2.4	5.0	46.02	10.7	131	3.5
US	12 907	Corn	33.1	3.8	3.5	22.39	4.0	5.44	2.7
Canada	231	Wheat	0.6	0.3	1.1	1.07	1.1	0.08	1.4
France	829	Sugarbeet	11.1	0.2	1.2	0.90	1.8	--	0.0
Italy	151	Wheat	0.4	0.1	1.7	0.60	1.7	--	0.0
UK	401	Sugarbeet	5.3	0.1	2.4	0.44	2.5	--	0.0
China	3 649	Corn	9.4	1.9	1.1	14.35	1.5	9.43	2.2
India	1 749	Sugarcane	19.4	0.3	0.2	5.33	0.5	6.48	1.2
Indonesia	167	Sugarcane	1.9	0.0	0.1	0.64	0.3	0.91	1.2
S. Africa	416	Sugarcane	4.6	0.1	1.1	0.94	2.8	1.08	9.8
World	36 800			10.0	0.8	98.0	1.4	30.6	2.0
Biodiesel	1 980			1.2		4.7			0.0

Source: Adapted from de Fraiture *et al.* (2008).

The amount of water needed to produce each unit of energy from second generation biofuel feedstocks (*e.g.* lignocellulosic harvest residues and forestry) is three to seven times lower than the water required to produce ethanol from first generation feedstocks (*e.g.* from maize, sugar cane, rapeseed) (Table 2.6). Hence, production of first generation feedstocks could increase demand for water and raise prices. Second generation biofuels, however, can be expected to reduce demand for water for energy crop production as less water-intensive crops replace maize and sugar as the principal feedstocks for ethanol.

Feedstocks such as tree plantations, for example, can capture a greater share of annual rainfall in areas where much of the rainfall occurs outside the normal crop growing season, and also help to reduce soil erosion and bring flood control benefits. While second generation feedstocks offer the potential for reducing water demand, it is not necessarily a clear outcome, as this may depend on the types of feedstocks grown, the location of production and the reference first generation feedstocks. Moreover, new pressures on water systems may arise in some areas where second generation feedstocks are established, while some of these feedstocks (*e.g.* forestry) may require irrigation during establishment and to achieve high yields, hence, the final impact on water balances are uncertain.

Table 2.6. Water intensity of biofuel feedstocks

Biofuel / Feedstock	Water use efficiency[1,2] (kg. DM ha^{-1} mm^{-1} ET)	Energy crop evapotranspiration	
		Mg GJ^{-1} feedstock	Mg GJ^{-1} gross bioenergy
Rapeseed (biodiesel)	9-12	48-81	100-175
Sugarcane ethanol	17-33	23-124	37-155
Sugar beet ethanol	9-24	57-151	71-188
Maize ethanol	7-21	37-190	73-346
Cellulosic ethanol	10-95	7-68	11-171

1. The water-use efficiency is given as kg above-ground DMmm_1 evapotranspiration (ET). The depth of water supply is often given in mm, where 1mm corresponds to 10 Mg water ha_1. 50kgDMmm_1 is equivalent to a water loss as ET of 200 g per g DM produced.

2. Lower range numbers refer to systems where: (i) harvest residues from non-lignocellulosic crops (50% of total) are used for power production (at 45% efficiency); or (ii) higher efficiencies in processing lignocellulosic crops are achieved. When ethanol is produced from sugarcane or lignocellulosic feedstocks, process by-products (bagasse and lignin, respectively) are used for internal heat and electricity. Here, lower range numbers refer to system designs allowing for export of electricity in excess of internal requirements.

Source: Adapted from Berndes and Borjesson (2001).

Projections estimate that an additional 30 million hectares (ha) of cropland may be needed to meet world food and biofuel demand in 2030 using first-generation feedstocks, such as maize, sugar, and rapeseed. This would require 170 km^3 of additional evapotranspiration and 180 km^3 of additional irrigation. Given that increasing global demand for food crops will require 1 400 million ha of land and 2 980 km^3 of irrigation withdrawals, the biofuel-induced demand seems modest. At the regional level within countries, however, the increased demand for water resources may be difficult to achieve.

Sources: OECD Secretariat, drawing on Berndes (2008); Berndes and Borjesson (2001); European Environment Agency (2008); de Fraiture *et al.* (2008); Hellegers *et al.* (2008); Liao *et al.* (2007); National Research Council (2008); Varis (2007).

Notes

1. This chapter is largely drawn from OECD, 2008a. Also, for the terminology relevant to this chapter see Box 2.1.
2. The information on the US was taken from the US response to an OECD questionnaire at www.oecd.org/water.
3. The OECD projections described here are outlined in OECD (2008b), but for full documentation of the OECD *Environmental Outlook* model and underlying assumptions, see the OECD website at www.oecd.org/environment/outlookto2030.

Chapter 3

OECD Countries' Policy Experiences[1]

3.1. Policy overview and objectives

All OECD countries have policy strategies to address broad water management issues – water resources, quality and ecosystems – and in terms of the more specific objectives for managing water resources in agriculture they broadly share a common strategic vision to:

- Establish a long-term plan for the sustainable management of water resources in agriculture taking into account climate change impacts, including protection from flood and drought risks;
- Contribute to raising agricultural incomes and achieving broader rural development goals;
- Protect ecosystems on agricultural land or affected by farming activities;
- Balance consumptive water uses across the economy with environmental needs; and,
- Improve water resource use efficiency, management and technologies on-farm and ensure the financing to maintain and upgrade the infrastructure supplying water to farms (and other users).

Most OECD countries have established policy targets to meet the strategic vision for agricultural water management listed above, although the emphasis varies between countries reflecting differing national priorities (see the OECD questionnaire at www.oecd.org/water). The policy targets for agricultural water resource management across OECD countries reveal that:

- Quantified policy targets are established by a third of OECD countries, usually in terms of a specific planned increase in the area to be irrigated or a financial target mainly aiming to improve water use efficiency in agriculture (*e.g.* **Canada, Greece, Italy, Korea, Mexico, Portugal, Spain, Turkey**);
- Sustainable limits on the use of surface water and groundwater are a key focus of many countries policy targets, especially to ensure sufficient quantities of water to meet environmental needs (*e.g.* **Australia**);
- Frequently while there are no overarching national policy targets there are more often targets for water resource management established at the water basin or local level of management (*e.g.* **Australia, Belgium, Canada, France,** the **United States**);

- Where irrigated agriculture is important policy targets usually seek to improve water use efficiency and upgrade the existing water delivery infrastructure (*e.g.* **Greece, Italy, Mexico, Portugal, Spain, Turkey,** the **United States**); and, that
- An increasing number of countries are linking policy targets and plans across the domains of agriculture, water and climate change (*e.g.* the **United States**) (see the OECD questionnaire at www.oecd.org/water).

Policy responses by OECD countries in moving towards the sustainable management of water resources in agriculture are in most cases part of a package that encompasses a mix of: policy instruments (*e.g.* market-based, economic, regulatory and planning approaches); institutional reforms; and community engagement. The key policy domains affecting water resource management in agriculture examined in this report cover:

- Agricultural and agri-environmental policies (Chapter 3.2);
- Farm management and technology measures (Chapter 3.3);
- Water policies and agriculture (Chapter 3.4);
- Climate change and flood and drought risk management (Chapter 3.5); and,
- Knowledge and assessment of water resource management in agriculture (Chapter 3.6).

For most OECD countries their policy strategies for water resources often seek to link these different elements together in a coherent policy framework. The Integrated Water Resource Management approach is one way in which some countries have tried to better integrate the various policy dimensions of water resource management, but its adoption in practice has been difficult and more limited (Box 3.1).

3.2. Agricultural and agri-environmental policies

3.2.1. Overview

Agricultural and agri-environmental support policies across OECD countries act to provide an intricate mix of incentives and disincentives toward the sustainable management of water resources. The widespread use of crop and livestock market price support provides incentives to intensify agricultural production, while support for farm inputs, especially water, drainage and energy (for water pumping) misalign farmer incentives and can aggravate overuse and create pollution and other environmental damage to water resources. The disincentives caused by these farm support measures for improving water resource management is further compounded by support for water irrigation infrastructure costs and support to lower water supply charges for agriculture.

The shift to agricultural policy measures not linked to production (decoupled) or the unconstrained use of inputs is likely to lead to a positive outcome for water resources and the environment, although the cause and effect relations here are complex. Hence, the increasing adoption of agri-environmental measures by OECD countries has both a direct (*e.g.* wetland conservation) and indirect (*e.g.* conservation tillage helping to retain soil moisture) effect on improving water resource management and environmental outcomes.

Box 3.1. Integrated water resource management: Potential and limitation

To improve the integration of different institutions and policy measures covering water management, Integrated Water Resource Management (IWRM) came to prominence over the 1990s, as a possible solution to enhance integration and policy coherence. Advocates see IWRM as a process which promotes the co-ordination of water, land, and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of ecosystems. The World Summit on Sustainable Development in 2002 called for all countries to adopt IWRM strategies.

Although IWRM has been widely embraced by international organisations and researchers, its adoption in practice by countries and regions appears more limited. While IWRM may work for some micro-scale water management projects, there appears to be no evidence that it has been effective for large projects. Some key drawbacks to the IWRM approach appear to be that:

- It is defined in too general terms to be easily interpreted for practical implementation;
- The concept is too complex to be managed;
- There has been little consideration given to how to monitor if a system is becoming integrated;
- The concept overlooks the integration with other sectors in the economy, such as the energy sector;
- Climate change, and more recently concerns over energy security has exposed water systems to situations never envisaged by those who originally developed the IWRM concept, and requires more innovative water management regimes and institutional arrangements.

Source: Adapted from Biswas (2008); Global Water Partnership (2000); Mukhtarov (2008); Pahl-Wostl (2008).

As long as market support for commodity production remains and water and energy support to farmers persists, however, this will work against the gains from decoupled support measures. But decoupling support from production and inputs appear to provide a basis for improving water efficiency and enhancing environmental benefits in agriculture, especially where there is a cross compliance condition attached to a decoupled payment (*e.g.* authorisation of water abstractions rights as a precondition for implementing "good" agri-environmental practices).

Overall, isolating and quantifying the overall economic efficiency and environmental effectiveness of agricultural and agri-environmental support on water resources, however, is difficult, and further analysis on causation is needed. This is because farmers are usually responding to a very complex set of signals in making water management decisions, including institutional constraints (*e.g.* regulations on water allocations), or because the change in relative prices associated with reduced output-linked payments may cause farmers to switch to previously non-supported crops that are more water intensive than those that benefited from coupled support payments.

3.2.2. Trends in agricultural support[2]

OECD agricultural support indicators show a gradual lowering of the Total Support Estimate (TSE) over the period 1990-92 to 2006-08. The downward trend was evident in the Producer Support Estimate (PSE, *i.e.* support for agricultural producers) as a share of farm receipts, and the General Service Support Estimate (GSSE, *i.e.* support for the agricultural industry but not producers individually) as a share of GDP. From 1990-92 to 2006-08.

Overall support specifically related to management of water resources in agriculture (*i.e.* support for irrigation, drainage, and conservation of aquatic ecosystems related to farming activities) ***is a very small share of the OECD TSE*** to agriculture, accounting for just under 2% of the TSE (2006-08), its share of the TSE rising by 18% since 1990-92 (Table 3.1). For some countries this share is much higher such as in **Australia** (7%) and **Japan** (8%), but these two countries are marked by very different absolute levels of producer support in total farm receipts (%PSE), respectively in 2006-08, 6% and 49%.

In broad terms, the reduction in overall agricultural support has helped to reduce pressure on the use of water resources by agriculture. This pressure has been further eased due to the decrease in the share of OECD support most linked to commodity production and unconstrained use of inputs (such as water and energy), which fell from 81% in 1990-92 to 55% in 2006-08.

This is reflected in the ***trends in support for irrigation,*** which although the TSE increased from 1990-92 to 2006-08 (+26%), it has seen a reduction in water producer support (PSE -7%) but rise in support provided for off-farm water supply infrastructure for agriculture (GSSE +36%). There has also been greater emphasis on support for water efficient technologies, management systems, farmer education and advisory services, and research and decision planning systems related to water resource management.

Despite the increase in total OECD support (TSE) to cover the investment and maintenance costs for ***farmland water drainage*** facilities, such as surface ditches and drainage, and sub-surface drainage pipes, this has been confined to only a very few countries (**Korea, Poland, United Kingdom**). The majority of OECD countries have either ceased making these payments or they have been gradually reduced and strictly regulated in conjunction with wetland conservation measures (Chapter 3.2.5).

Support for energy inputs in agriculture has been stable/declining in many cases, and while this support is usually provided to lower costs of electricity or diesel fuel for farm machinery and buildings, it also reduces costs for pumping irrigation water. In **Mexico** and **Turkey**, for example, support for electricity to pump irrigation is undermining efforts to achieve sustainable agriculture water resource use, especially groundwater (OECD, 2008a).

Support provided for feedstocks to produce biofuels and bioenergy has been increasing in recent years (OECD, 2008d). As the support to agricultural feedstocks to produce biofuels and bioenergy is relatively new and also covers a diversity of raw materials (*e.g.* from maize to short rotation coppice), however the overall impacts on water resources are difficult to determine at this stage, as discussed in Box 2.5.

Growing budgetary payments for agri-environmental measures linked with greater regulation of farming practices to protect the environment, has also had a positive impact on water resource management, either directly (*e.g.* payments for aquatic ecosystem services such as wetland conservation, Table 3.1) or indirectly (*e.g.* support for riparian buffer strips mainly for pollution control, but which also serve to provide flood control benefits by slowing water flows across farmland).

There has been little direct support provided for flood and drought adaptation and mitigation measures in agriculture, although indirect support is more important (*e.g.* construction of on-farm water storage facilities to combat droughts) (Chapter 3.6 and the OECD questionnaire at www.oecd.org/water). This contrasts with much higher levels of farm support in the form of flood and drought disaster relief payments to compensate for the damage to farm production and infrastructure by these events.

Overall levels, trends and emphasis of direct support for water resource management in agriculture show considerable variation across OECD countries (Table 3.1). Some countries, for example, provide have little or no support for water resource management (*e.g.* **Canada, Iceland, Norway, Switzerland** and many **EU** countries), while others have show an increasing trend in total support since 1990-92 (*e.g.* **Australia, EU27, Japan, Korea, Poland, Portugal, Spain, United Kingdom**). For other countries the level of water resource support has declined (*e.g.* **France, Mexico, New Zealand** and **Turkey**). But these varying trends in support also need to be viewed in the context of the absolute share of producer support in total farm receipts (%PSE), which varies greatly between countries (Table 3.1).

3.2.3. The effects of agricultural and agri-environmental policies on water resources

Isolating and quantifying the overall economic efficiency and environmental effectiveness of agricultural and agri-environmental support on water resources is difficult, but some research has provided insights into these relationships. Preliminary studies of the **EU** Common Agricultural Policy reforms, for example, suggest that the shift to decoupled payments has led to a reduction of irrigation (especially maize) in areas where water stress is an issue (Box 3.2).

3.2.4. Impact of agricultural support on aquatic ecosystems

All OECD countries use a combination of support payments to farmers and regulatory instruments for the conservation and restoration of on-farm aquatic ecosystems (*e.g.* wetlands, ponds) (see the OECD questionnaire at www.oecd.org/water). This support is also provided in a few countries through property/land tax exemptions for landowners protecting aquatic ecosystems (*e.g.* **Canada, France**). In some cases support is provided to farmers to protect waterscapes, and associated cultural and recreational values (*e.g.* bathing, fishing), for example, in ***Austria, Canada, France, Ireland, Japan, Korea, Portugal, Spain, Switzerland*** *and the* ***United States***.

Support payments for aquatic ecosystem conservation are usually made subject to certain regulations, such as placing limits on drainage where it affects wetland conservation (see the OECD questionnaire at www.oecd.org/water). For most countries conservation of aquatic ecosystems are linked to obligations under International Environmental Agreements, for example, the Ramsar Convention on Wetlands. Only a few countries use a ***farm pollution tax*** to protect aquatic ecosystems (*e.g.* **Czech Republic, Netherlands, Poland**).

Table 3.1. Summary of OECD countries budgetary expenditure on irrigation, drainage and aquatic ecosystem services

million USD

	Irrigation			Drainage			Aquatic ecosystems		
	1990-92 average	2006-08 average	% change	1990-92 average	2006-08 average	% change	1990-92 average	2006-08 average	% change
OECD[1,4]									
PSE	1 157	1 077	-7	175	272	56	16	315	1 849
GSSE	3 765	5 121	36	64	229	259	1	25	3 361
TSE	4 923	6 197	26	238	501	110	17	340	1 913
% of water TSE in total TSI	1.4	1.7	18	0.1	0.1	97	0.0	0.1	1 791
Total % PSE	33	23	-30						
Australia									
PSE	0	83	n.c.	0	0	n.c.	0	0	n.c.
GSSE	0	116	n.c.	0	3	n.c.	0	23	n.c.
TSE	0	199	n.c.	0	3	n.c.	0	23	n.c.
% of water TSE in total TSI	0	6.8	n.c.	0	0.1	n.c.	0	0.8	n.c.
Total % PSE	7	6	-12						
Canada									
PSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
GSSE	0	14	n.c.	0	0	n.c.	0	0	n.c.
TSE	0	14	n.c.	0	0	n.c.	0	0	n.c.
% of water TSE in total TSI	0	0.2	n.c.	0	0	n.c.	0	0	n.c.
Total % PSE	32	18	-44						
Japan[2]									
PSE	151	170	12	0	0	n.c.	0	0	n.c.
GSSE	2 970	3 663	23	0	0	n.c.	0	0	n.c.
TSE	3 121	3 833	23	0	0	n.c.	0	0	n.c.
% of water TSE in total TSI	5.3	7.9	48	0	0	n.c.	0	0	n.c.
Total % PSE	53	49	-8						
Korea									
PSE	52	76	45	0	0	n.c.	0	0	n.c.
GSSE	312	874	180	62	215	248	0	0	n.c.
TSE	365	950	161	62	215	248	0	0	n.c.
% of water TSE in total TSI	1.6	3.5	116	0.3	0.8	188	0	0	n.c.
Total % PSE	74	61	-17						
Mexico[5]									
PSE	361	177	-51	0	0	n.c.	0	0	n.c.
GSSE	242	160	-34	0	0	n.c.	0	0	n.c.
TSE	602	338	-44	0	0	n.c.	0	0	n.c.
% of water TSE in total TSI	7.0	4.5	-35	0	0	n.c.	0	0	n.c.
Total % PSE	24	13	-43						
New Zealand									
PSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
GSSE	6	0	-100	0	0	n.c.	0	0	n.c.
TSE	6	0	-100	0	0	n.c.	0	0	n.c.
% of water TSE in total TSI	3.8	0	-100	0	0	n.c.	0	0	n.c.
Total % PSE	1.6	0.9	-41						
Switzerland[5]									
PSE	1	2	160	2	1	-47	1	1	80
GSSE	1	2	160	2	1	-47	1	1	80
TSE	1	4	160	4	2	-47	1	3	80
% of water TSE in total TSI	0.0	0.1	227	0.1	0.0	-33	0.0	0.0	126
Total % PSE	71	60	-15						
Turkey									
PSE	32	22	-31	43	0	-100	0	0	n.c.
GSSE	18	3	-84	0	0	n.c.	0	0	n.c.
TSE	50	25	-50	43	0	-100	0	0	n.c.
% of water TSE in total TSI	0.6	0.2	-69	0.5	0.0	-100	0	0	n.c.
Total % PSE	26	21	-17						
United States[4]									
PSE	538	331	-38	0	0	n.c.	15	307	1 952
GSSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
TSE	538	331	-38	0	0	n.c.	15	307	1 952
% of water TSE in total TSI	0.8	0.3	-56	0	0	n.c.	0.0	0.3	1 379
Total % PSE	17	10	-43						

Table 3.1 (continued)

million USD

	Irrigation			Drainage			Aquatic ecosystems		
	1990-92 average	2006-08 average	% change	1990-92 average	2006-08 average	% change	1990-92 average	2006-08 average	% change
European Union 27[3,4,6]									
PSE	22	215	856	129	272	111	1	8	1 325
GSSE	217	288	32	0	10	n.c.	0	0	n.c.
TSE	240	503	110	129	282	119	1	8	1 325
% of water TSE in total TSI	0.2	0.4	95	0.1	0.2	104	0.0	0.0	1 229
Total % PSE	35	27	-23						
France									
PSE	0	0	n.c.	0	0	n.c.	0.5	6.1	1 051
GSSE	216	31	-86	0	0	n.c.	0.0	0.0	n.c.
TSE	216	31	-86	0	0	n.c.	0.5	6.1	1 051
Italy									
PSE	14	164	1 102	0	0	n.c.	0	0	n.c.
GSSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
TSE	14	164	1 102	0	0	n.c.	0	0	n.c.
Poland									
PSE	0	0	n.c.	37	123	228	0	0	n.c.
GSSE	1	1	-27	0	0	n.c.	0	0	n.c.
TSE	1	1	-27	37	123	228	0	0	n.c.
Portugal[5]									
PSE	5	39	722	1	0	-100	0	0	n.c.
GSSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
TSE	5	39	729	1	0	-100	0	0	n.c.
Spain									
PSE	4	10	132	0	0	n.c.	0	0	n.c.
GSSE	0	252	n.c.	0	0	n.c.	0	0	n.c.
TSE	4	262	6 263	0	0	n.c.	0	0	n.c.
United Kingdom									
PSE	0	0	n.c.	91	142	56	0	0	n.c.
GSSE	0	0	n.c.	0	0	n.c.	0	0	n.c.
TSE	0	0	n.c.	91	142	56	0	0	n.c.

n.c.: not calculated

PSE : Producer Support Estimate; GSSE : General Services Support Estimate; TSE : Total Support Estimate.

1. Iceland and Norway are not included in the table because there are no entries in the OECD PSE database for irrigation, drainage or aquatic ecosystem services. Data on these items are aggregated under other headings in the database.
2. For Japan, drainage expenditure is included in irrigation, and sub-national data are included in 2007 and 2008.
3. Belgium, (Bulgaria), (Cyprus), Denmark, (Estonia), Greece, Ireland, (Lithuania), Luxembourg, (Malta), Netherlands, (Romania) are not included in the EU27 total because there are no entries in the OECD PSE database for irrigation, drainage or aquatic ecosystem services. Data on these items are aggregated under other headings in the database.
4. % share of water TSE in total TSE is as follows:
   OECD, aquatic ecosystems, 1990-92 average=0.005%
   Switzerland, irrigation, 1990-92 av.=0.02%; drainage, 2006-08 av.=0.04%,
   Switzerland, aquatic ecosystems, 1990-92 av.=0.02%; 2006-08 av.=0.05%
   United States, aquatic ecosystems, 1990-92 average=0.02%
   EU27, aquatic ecosystems, 1990-92 av.=0.0005%; 2006-08 av.=0.007%.
5. 2006-08 average refers to 2005-07.
6. National expenditure, excluding EU co-financing.

Source: OECD PSE and CSE database: see www.oecd.org/tad/support/psecse.

Box 3.2. The EU’s Common Agricultural Policy reforms and water resources

EU agricultural policy “Agenda 2000” aimed at supporting a multifunctional, sustainable and competitive agriculture. It was based on the establishment of production-related direct aid payments and gave a prominent role to agri-environmental instruments to support farmers’ income. In June 2003, the EU decided to replace from 2006 onward most of the direct aid with a single farm payment scheme that is not linked to production. Beneficiaries will be obliged to accomplish certain environmental and food safety requirements, and which are almost identical for irrigation and rain-fed agriculture. This means that farmers, in most EU member states are entitled to support based on the direct payments received during a reference period (years 2000, 2001 and 2002), irrespective of their cropping patterns and farm-size.

Other EU farm policy reforms affected the sugar, cotton, olive and wine sectors, making the support mechanisms less, but not entirely decoupled from production. In the case of Spain, for example, these farm policy reforms have had marked impacts on irrigated agriculture, especially in the regions where fruit and vegetables were less important in terms of value and acreage. While in the Mediterranean provinces of Spain, fruit and vegetables consume most water available for irrigation, in the mainland provinces cereals, protein and forage crops, sugar beet, potatoes and a few fruit crops have been the primary irrigated crops.

Examples of crops, across the European Union, with high water requirements that were supported by the Common Agricultural Policy (CAP) programmes were numerous. Maize is considered a water demanding crop in temperate countries, and EU growers were until 2003 entitled to a direct subsidy of EUR 54/tonne. Since the CAP direct subsidies were defined to deliver equivalent levels of income support to all cereal, oilseeds and protein crops, they favoured crops such as maize, rice, cotton or tobacco, that demand much more water than oilseed crops such as sunflower or colza (rapeseed). With decoupling, this inconsistency was eliminated, and farmers’ use of water will not be driven by subsidy differences across crops. Garrido and Varela-Ortega (2008), for example, have reported the gradual but steady changes of irrigated land allocation that have occurred in Spain since the 2003 CAP reform. The major and most significant changes were that more irrigated land resources have been allocated to vineyards, olive trees and citrus (especially in Andalusia), and less irrigated lands allocated to water-consuming crops such as maize and other reformed sectors, including sugar beet, cotton and tobacco.

Many authors have established a connection between farm support and irrigation water demand in Spain (Arriaza *et al.,* 2003; Gomez-Limón *et al.,* 2002; Iglesias *et al.,* 2004; Sumpsi *et al.,* 1998). Their results indicate that the lowering of farm support has a larger impact on farmers’ welfare than the rise of water prices. When EU farm subsidies become completely decoupled from production in 2012, the economics of irrigation will be more guided by the relative productivity of crops and water accessibility than by relative agricultural support granted to the crops. Moreover, Mejias *et al.* (2004) show that the EU policy based on full decoupling will likely reduce the income losses resulting from increased water tariffs under the EU’s Water Framework Directive, at least in Andalusia (Spain).

Source: Adapted from Garrido and Calatrava (2010).

In the case of wetlands, the impact of support and regulatory policies across OECD countries in halting the loss of wetlands to agricultural use was mixed over the period 1990 to 2004 (OECD, 2008a). There was a net loss (restoration minus conversion) of wetlands converted to agricultural use, although at a declining rate of loss over this period in ***France, Italy, Japan, Korea*** and ***Norway,*** but reported net gains of wetlands in the ***Czech and Slovak Republics, United Kingdom*** and the ***United States*** (Box 3.3).

The extension of the area irrigated and some irrigation practices have also led to harmful impacts on aquatic ecosystems in a number of OECD countries. In Australia, nearly 10% of wetlands are affected by salinity, to some extent caused by irrigated farming, but also by the natural presence of salt in the landscape. By 2002 two-thirds of irrigated farms in Australia had changed practices to address salinity issues (OECD, 2008a). For some other countries the extension of the area irrigation and irrigation practices have also had harmful impacts on aquatic ecosystems, such as in **Greece, Portugal, Spain** and **Turkey** (OECD, 2008a).

Research on **Japan,** for example, has shown that modernisation of some paddy systems, including lining waterways and ponds with concrete, field consolidation and removing field interconnections, has reduced the abundance of aquatic species and birds that feed on them (OECD, 2008a). Equally the decline in the area of paddy fields, and lost of its benefits in terms of flood land landslide control, is considered by some researchers to have increased flood and landslide risks in **Japan**.

3.2.5. On-farm water drainage policies and the environment

There has been a significant positive shift in drainage policy across OECD countries since the 1980s. Prior to 1990s on-farm drainage (*i.e.* removal of excess water through surface – *e.g.* ditches or channels – or sub-surface field drainage – *e.g.* networks of pipes, tiles) was viewed in most OECD countries as a farm management area apart, with the aim of land improvement, especially to avoid soil water logging (see the OECD questionnaire at www.oecd.org/water). There was a policy shift, however, from around the early 1990s as increasingly countries begun to combine drainage into an integrated agricultural water resources management approach. For a considerable number of countries support payments for on-farm drainage have ceased since the 1990s (*e.g.* **Austria, Czech Republic, France, Germany, Ireland**).

This policy change was, in particular, driven by environmental demands for the conservation and restoration of wetlands, although for some countries drainage management was also seen as means to achieve other environmental objectives, such as contributing to flood control, avoiding nutrient leakage and soil waterlogging; and preventing soil erosion (see the OECD questionnaire at www.oecd.org/water). The **United States** provides an illustrative example of the evolution of Federal US farmland drainage policies being adapted over recent decades to address environmental concerns, especially wetlands conservation (Box 3.3).

Most OECD countries now place limits to on-farm drainage where it can damage aquatic ecosystems (see the OECD questionnaire at www.oecd.org/water), although drainage of farmland continues to have adverse impacts on aquatic ecosystems in a number of OECD countries. For example, in **Finland**, the loss of open ditches due to the expansion of sub-surface drainage has been harmful to biodiversity, while in **Ireland** drainage, among other factors, has placed pressure on some marginal wetland habitats (OECD, 2008a).

Box 3.3. Drainage of farmland and wetland conservation in the United States

Historically, cropland development and improvement, flood control, water quality improvement, and watershed enhancements for wildlife habitat and recreation were all objectives of US Federal drainage policy. Early U.S. Department of Agriculture (USDA) drainage policy was, as part of a broader federal policy, essentially a "wetlands conversion policy," supporting the installation of surface and sub-surface tile drainage systems to convert wetlands to productive pasture or cropland. The USDA began to support cost-sharing for wetland drainage in 1936, and in 1953 Congress explicitly linked flood control and agricultural drainage under the Federal Watershed Protection and Flood Prevention Act. This Act authorised the USDA to plan and construct watershed improvements, with the USDA providing both technical assistance and cost-sharing of ditches, subsurface drains, and conduits to convey water from fields.

By the late 1970s, after ***significant private and public acknowledgement of the many public-good aspects of wetlands*** (including those for waterfowl and wildlife habitat, ecological, and water quality values) Federal drainage policy began to shift from a "wetlands conversion" policy to a "wetlands conservation" policy. Eventually, with the passage of the Clean Water Act (CWA) and each Farm Bill (starting from 1985) drainage policy evolved into what exists today. This consists of a "wetlands conservation/restoration" policy, supported largely through the USDA's 1990 Wetlands Reserve Program (WRP) and working-lands conservation policies that can support on-farm drainage improvements, but only if they are consistent with the CWA requirements, administrative "no net loss" policy, and the USDA farm programme "conservation compliance" requirements, including the 1985 Farm Act "swampbuster" provisions.[1]

WRP goals are the restoration of high-risk agricultural land located in, or adjacent to, flood-prone areas. Through the fiscal year 2007, the WRP enrolled 1.947 million acres of land, mostly in permanent easements. Expenditures in 2004 and 2005 were about USD 275 million and USD 240 million (at an average cost of USD 1 400 and USD 1 688 per acre) respectively. Average contract size is 194 acres, with much of WRP land in Missouri, Arkansas, Louisiana, Mississippi, Florida, and California. In addition, under the "swampbuster provisions", farm program eligibility can (since 1990) be denied to producers who produce an agricultural commodity on a wetland or convert a wetland in a way that makes the production of an agricultural commodity possible.

Recognising that agricultural activities contribute to hypoxia in the Gulf of Mexico, and that the Midwest includes more than 50 million acres of surface and subsurface drained cropland, USDA in 2003, through its Partnership Management Team, established the Agricultural Drainage Management Systems (ADMS) Task Force to devise an approach to ***improve drainage practices to reduce adverse offsite impacts of drainage waters***. The ADMS Task Force is a joint effort by USDA's Agricultural Research Service (ARS), Natural Resources Conservation Service (NRCS), and the Cooperative State Research, Education, and Extension Service (CSREES), and includes university researchers, extension professionals, as well as scientists from local, state, and federal agencies. The focus of the ADMS Task Force is to work with farmers, contractors, and agricultural advisors to:[2]

- Implement improved agricultural surface and subsurface drainage in both new and retrofitted systems.
- Reduce nitrate loads in drain outflow, a major source of poor stream water quality and hypoxia in the Gulf of Mexico.
- Improve efficiency of production and economic returns through managed surface and subsurface farm drainage.

1. There are numerous studies on the Wetlands Reserve Program: for a selection, see the USDA website at www.ers.usda.gov/Browse/NaturalResourcesEnvironment/

2. For more information on the ADMS Task Force, its charter, vision/goals, objectives and action plans, see www.ag.ohio-state.edu/~usdasdru/ADMS/ADMSindex.htm. For more information about the ADMC, see www.admcoalition.com/.

Source: OECD Secretariat, adapted from the United States government's response to the OECD questionnaire at www.oecd.org/water.

3.2.6. Agricultural support and agricultural water resource management benefits

In some OECD countries agricultural support has been provided on the basis that it can help provide a range of agricultural water resource management benefits (positive externalities). In the case, for example, of **Japanese** and **Korean** paddy rice cultivation under monsoonal conditions these benefits cover the (Box 3.4): environment, such as flood control, water purification and filtration, habitat values such as paddy fields acting as a wetland habitat; rural development, acting as a multiplier on rural incomes and providing ecotourism income through upland paddies providing waterscapes; social outcomes, such as developing community solidarity; and cultural and religious benefits, for example, the cultural identity from the cycle of paddy cultivation (World Bank, 2006).

These environmental benefits need to be weighed against the environmental costs of paddy cultivation systems (*e.g.* methane emissions, chemical runoff). Moreover, the estimated benefits that do flow from support to rice cultivation in **Japan** and **Korea**, involves agricultural support that is significantly above the OECD average.

3.3. Farm management and technology measures

A variety of farm management, advisory and technology approaches are being used by OECD countries to improve agricultural water resource management. For countries concerned with improving on-farm water use efficiency, especially irrigated farming systems, support is widely provided for upgrading irrigation equipment, together with providing farm advisory services and developing research to support irrigators (*e.g.* **Australia, Italy, Mexico, Turkey,** the **United States**) (see the OECD questionnaire at www.oecd.org/water). **Canada** and **France** provide good examples of how countries are seeking an integrated approach to improve water use efficiency in agriculture (Box 3.5).

Promotion of technologies and practices to use on-farm water more efficiently tend to centre on encouraging use of drip emitters and lining irrigation canals. Some practices are geared to enhancing the provision of ecosystem services related to water from agriculture, for example, the use of a network of water corridors in **Japan** and **Korea** linking rivers, paddy rice fields, and irrigation ponds to sustain aquatic biodiversity in these water bodies. Other approaches to encouraging improvements in on-farm water use efficiency include (see the OECD questionnaire at www.oecd.org/water):

- Benchmarking among water suppliers to limit distributional channel losses (**Austria**);
- Establishing an industry code of practice for irrigation system design and use (**New Zealand**);
- Capturing and using rainwater (**Belgium**);
- Developing high water use efficiency cultivars in a wide range of crops to meet increasing drought risks (**Canada, Finland, Italy, Switzerland, United Kingdom, United States**);

- Making greater use of recycled water, including treated sewage and drainage wastewater, and recycling water in greenhouse horticultural systems (**Belgium**); and,
- Exploring the potential of using nanotechnology to improve agricultural water resource management (**United States**) (see Box 3.6).

Box 3.4. Costs and benefits of paddy cultivation systems in Japan and Korea

There have been a number of studies of the positive externalities (multifunctionality) of paddy farming, and Kim *et al. (2006)* list the positive functions as:

- Flood alleviation, due to small irrigation ponds as well as the retaining capacity of bounded rice fields;
- Groundwater recharge, estimated in Korea to be as high as 80% of the rate of surface runoff;
- Water purification of paddy soils acting as nutrient sinks;
- Soil erosion and landslide control on sloped lands;
- Air purification and cooling; and,
- Biodiversity and amenity.

Estimates vary widely as to the value these positive functions, but are generally high, possibly higher than the value of rice produced. In Japan there have been a number of efforts to evaluate the environmental benefits of multifunctionality of paddy fields in Japan (*e.g.* Science Council of Japan, 2001; Yamaoka, 2004).and compensatory payments are made for a limited number of these, such as the use of farm drains by non-farm users and for ecologically beneficial farming. The Japanese Ministry of Agriculture hosts the Secretariat of the International Network for Water and Ecosystem in Paddy Fields (INWEPF), established in 2004, as a forum for those involved in rice growing to network in areas such as giving consideration to multiple uses of agricultural water resources, including environmental aspects (Yamaoka, 2004).

Focus in both Japan and Korea, however, appears to be heavily on estimating multifunctional benefits but these need to be balanced by cost estimates, but valuation of these costs is far less advanced. Kim *et al.* (2006) have described a number of negative externalities associated with paddy farming, such as methane emissions, or disturbance of the ecosystem by land improvement measures such as canal linings and independent drainage canals.

Source: Adapted from Nickum and Ogura (2010), drawing on Kim *et al.* (2006); OECD (2008a); Science Council of Japan (2001); Yamaoka (2004).

There is increasing emphasis being placed in many countries in establishing policy decision support tools to guide agricultural water management strategies (see the OECD questionnaire at www.oecd.org/water). A key element to supporting policy decision making is data collection and monitoring of water resource use in agriculture, including the use of seasonal and inter-annual water balances (accounts/audits) sometimes to provide a national overview of water flows and stocks (*e.g.* **Australia, Greece, Netherlands,** the **United States**) and in other cases as an on-farm tool to help farmers monitor water use on farm and guide their irrigation practices to reduce water use (*e.g.* **Denmark, France, New Zealand, United Kingdom**).

Different ***government*** research agencies provide *research and analysis of water resources in agriculture* to assist policy makers, with increasing focus on the impacts of climate change on agriculture and water resources and projections of future water demand by agriculture (*e.g.* **EU, Korea, Portugal, Switzerland, United Kingdom**) (see the

OECD questionnaire at www.oecd.org/water). *Water planning* is also an important part of the policy tool kit for decision makers, in particular, to assist in the allocation of water resources between agriculture, other water users and environmental needs (Chapter 3.4.2). In this context, **Canada** is one of the few OECD countries to involve public consultation at all levels of government to examine water planning, programmes and targets.

Box 3.5. Improving agricultural water use efficiency in Canada and France

Canada

- Water resource conservation approaches among Canadian jurisdictions are quite variable.
- More emphasis has been placed on efforts to reduce water use in households relative to agriculture and industry.
- Federal government has generally focused its attention on water research, outreach/education, and advancement of technologies and practices.
- Agricultural Policy Framework's National Farm Stewardship Program has provided financial and technical assistance to implement on-farm beneficial management practices.
- Provinces have been more active in this area and have enacted legislation, implemented overarching water strategies/policies, set water use targets, completed awareness campaigns, and a variety of other conservation/efficiency initiatives.
- Improving the efficiency of water use for irrigation is researched and demonstrated at The Canada-Saskatchewan Irrigation Diversification Centre, a partnership between the federal, provincial governments and local organisations.

France

- Introduction of a water abstraction charge.
- Review of licensed volumes, based on actual need and environmental capacity, and enforcement of licensing arrangements.
- Support for adopting water-saving irrigation technologies, such as low-interest credit for purchase of equipment. Support for purchasing equipment (government subsidy not exceeding 40%) under the *Plan Végétal Environnement* (Environmental Crop Production Scheme). Support to purchase metering and management equipment to enhance practices, or specific water-saving equipment (including input control, electronic flow control systems, and rainwater collection/storage).
- Agri-environmental measure to limit irrigation: support to reduce the amount of irrigated farmland.
- Investment support from Water Agencies to create substitute storage and modernise water supply systems (to limit water loss) under the National Rural Development Programme (PDRH).
- Use of farm advisory services, and also support training courses in irrigation, particularly through Chamber of Agriculture networks, although there is no feedback on the scale or impact of these services.

Sources: OECD Secretariat, adapted from the Canadian and French governments' responses to the OECD questionnaire at www.oecd.org/water.

Box 3.6. Potential of nanotechnology for improved water management in agriculture

Nanotechnology: "... the understanding and control of matter at dimensions of roughly 1 to 100 nanometres, where unique phenomena enable novel applications…" (US National Nanotechnology Initiative). "… Utilising the properties of nanoscale materials … to create improved materials, devices, and systems …" (ISO TCC 229). One nanometre is one millionth of a millimetre.

The nanotechnologies being used in agriculture involve carbon nanotubes, nano-cantilevers, nanoparticles, nanosurfaces and nanosensors. They can be applied in diagnostics; in detecting parasites and bacteria; encapsulation and controlled release of herbicides, pesticides and drugs; for grass growth regulation; and, of course, for water management and sensing.

Precision farming is increasingly using satellite-positioning systems (GPS), geographic information systems, automated machine guidance and remote sensing devices. Researchers are working to improve these systems – their accuracy and response rates as well as their size and robustness – through the use of nanotechnology. Water management in agriculture can be significantly improved in the future through the effective application of such emerging technologies.

Currently, wireless nanosensors are facilitating intensive sensing of environmental conditions to control the automated application of water, as well as fertilisers and pesticides. Sensing drought through nanosensors, levels of irrigation are automatically adjusted in the field in real time, making for more effective and efficient water use for better crops and lower costs. Likewise, sensors using nanotechnology can be fitted to combine harvesters to measure the amount and moisture levels of grains being harvested on different parts of a field, generating computer models which guide decisions about the application or timing of water inputs.

Industry is already applying wireless sensor networks in agriculture, combining electronic chips with nano-scale features into wireless networks of "motes" (i.e. miniature, self-contained, battery-powered computers with radio links: motes can self-organise into networks, communicate with each other and exchange data). Motes can be used on the farm for irrigation management, frost detection and warning, pesticide application, harvest timing, bio-remediation and containment, and water quality measurement and control.

Installed in vineyards in Oregon and California, United States, sensors measure the soil temperature once every minute but can equally be applied to measuring moisture levels and determining the need for irrigation. Networked sensors scattered on fields can also provide detailed data on crop and soil water content and relay that information to the farmer. As nanotechnology developments lead to better and cheaper sensors, this technology may be more widely applied.

Source: OECD Secretariat, drawing on a project on *Global Challenges: Nanotechnology and Water,* OECD, forthcoming, 2010.

3.4. Water policies and agriculture

3.4.1. Overview

For most countries up to the early 1990s water management related to agriculture largely focused on the supply of water, with emphasis on infrastructure, technical solutions and harvesting the maximum amount from the resource, within a command and control institutional structure (Hamstead *et al.,* 2008; Pahl-Wostl, 2008). This "hard" technology based and centralised path to capture and deliver water to agriculture is now being complemented by a path with a shift to the sustainable use of water. The emphasis here is on: meeting diverse demands for water (*i.e.* economic, environmental and social) to match user's needs; embracing participatory and collaborative decision making and institutional structures; and encouraging a greater role for market mechanisms (Pahl-Wostl *et al.,* 2008).

The shift from the "hard" to the "soft" path of water management and governance has reflected a number of developments over the past two decades, including:

- Greater focus on attaining environmental objectives, such as water conservation and pollution control to limit adverse impacts on ecosystems;
- Recognition that economic instruments, such as water pricing, can help cover the financial costs of irrigation systems and improve water use efficiency in situations of water scarcity;
- Pressure on governments to control budgetary expenditure on costly technical solutions to providing water to agriculture;
- Concern to develop management and governance systems that can address the uncertainties induced by climate change impacts on water resources;
- Decline in long-run "real" agricultural commodity prices over many decades has made it difficult to justify major expenditure in "new" irrigation facilities; and,
- Increased attention on moving from national and state control of water policy to a more decentralised, participatory and integrated forms of management and policy decision-making, to encourage the involvement of all stakeholders in a water basin and better address local economic, environmental and social needs (Box 3.7).

Box 3.7. Institutional organisation for agricultural water resource governance across OECD countries

The ***institutional frameworks governing water management across most OECD countries,*** within which water in agriculture is managed and allocated across competing demands, can be broadly characterised as follows, although there are some marked differences from this description (see the OECD questionnaire at www.oecd.org/water):

- *National/Federal level of government:* Ministries of Agriculture, Environment, Infrastructures, etc., have overall but split responsibilities for determining policy objectives and targets for water resources (where appropriate), involving co-ordination across Ministries and sub-national layers of government (see below). In most countries these responsibilities extend to monitoring and research activities, control of regulatory arrangements, especially governing groundwater, and also transboundary water resource issues.
- *Provincial/Regional/State level of government:* Water resource planning and management functions are usually conducted at this level, although this is generally organised in terms of jurisdictional (State/Provincial) boundaries (*e.g.* **Australia, Canada, Japan,** the **United States**) some countries also organised water resource management through Regional Water Management Boards which may be in control of one or several water basins (*e.g.* **Greece, Italy, Mexico, Poland, Spain**).
- *Water basin (or water catchment) authorities:* These authorities are typically involved with managing water rights, licences for water abstract and financial control (*e.g.* collecting and determining water charges) and inspection of irrigation infrastructure.
- *Water user associations/co-operatives:* Water user groups operate usually at the sub-basin level, involved with the day to day management responsibilities of the irrigation system.

Source: OECD Secretariat, based on responses from member countries to the OECD questionnaire at www.oecd.org/water.

3.4.2. Water policy reforms and the agricultural sector

The shift in policy focus with a greater accent on demand rather than supply management policies has brought reforms to the institutional and governance structure managing water resources. The evolution and key elements in water policy reforms across OECD countries and important to agricultural water resource management are summarised in this section, drawing on the OECD questionnaire at www.oecd.org/water.

The progress and path of water policy reforms has been mixed. Over the past decade some major changes in water resource policies have taken place, for example in **Australia, Mexico** and **Turkey** (Box 3.8). The **European Union** has also embarked on an ambitious programme of water reform through the *Water Framework Directive* (WFD) which came into force in 2000. EU member states have now transposed the WFD into national law as the overarching framework guiding each member state's water policy, with the key dates for the national implementation of the WFD including finalising river basin plans (2009); introducing pricing policies (2010); meeting environmental objectives (2015); and finalising implementation of the WFD (2027).

The United States does not have a comprehensive national water policy, and water resource policy is essentially pragmatically managed at the State level, with a general trend towards increased use of water markets, water banks and per-unit water pricing. Some countries are only just beginning to embark on a process of water policy reforms (*e.g.* **Canada** and **New Zealand**), and it is too early to make assessment of these policies. In other cases progress in reforming policies has been more limited (*e.g.* **Japan, Korea**), with some change in focus on environmental issues and some reorganisation of the institutional structure governing water. There are plans, however, in many of these countries to consider developing water markets, water pricing or using other more market-based policy instruments to manage water resources (see the OECD questionnaire at www.oecd.org/water).

The institutional arrangements governing water management in OECD countries remains multifaceted and multilayered. This structure results in practices and regulations that are complex and differ regionally, even at the level of water basins, reflecting varying political systems, histories and cultures not only across OECD countries but within them. **Mexico** provides an illustration of this complex structure with overall national planning under the National Water Commission (NWD), with involvement of other Federal Ministries (Agriculture, Environment and Irrigation Agency), and power of the NWD devolved to 85 Irrigation Water Basin Districts located in 30 States (which also have some interest and involvement in water management), which in turn co-ordinate with nearly 500 Water User Associations which deliver water to farmers individually and farmer co-operative.

Even in situations where reforms to water institutions and policies have been very rapid over recent years, for example **Australia,** there are significant regional variations even within States such that there can be dozens of water supply schemes, some with different owners, and varying water pricing structures and tariffs (Parker and Speed, 2010). But some countries, for example **Spain,** have created a single Water Authority and streamlined the institutional arrangements to manage water resources.

Box 3.8. Water policy reforms and agriculture: Experiences of Australia, Mexico and Turkey

Australia

Australia has embraced the idea of competition and markets as a paradigm for water management. The establishment of a nationally consistent water entitlement and trading system is providing security to both water users and the environment in Australia. Water trading allows scarce water resources to be transferred to their most efficient and productive uses, and is being delivered through a range of State and National initiatives. The result has been the generation of significant opportunities to achieve sustainable and efficient water use. The development of water markets is seen as a key mechanism, along with planning and appropriate regulation, to address over allocation of water resources whilst optimising the economic, social and environmental outcomes in Australia. This integrated approach will also assist to adapt to changing water availability in the face of a climate change.

Underpinning the Australian experience is a suite of institutional and property right reforms that have made it easier to set up viable water markets. The general model is one that has involved development of a water entitlement regime that allows people to own the right to use water. State governments' legislation makes it clear that water is controlled by the State on behalf of the general public. Water users may only acquire or hold an entitlement to use water that is available according to a statutory water plan. Moreover, it is the role of governments rather than the courts to determine how much water is available for use. The result is a property right regime that is conducive to the development of efficient markets. In general the rights to use water is 'unbundled' into a three part structure:

- The ***entitlement*** is a proportionate share of water as specified in a water plan. This entitlement is separate from any land title and may be traded among any willing purchasers. These are referred to as permanent trades.
- Decisions on ***volumetric allocations*** are made on an ongoing basis throughout a water year. The allocation is made to an entitlement and recorded in the water account associated with the entitlement. Allocation trades, or temporary trades as they are called in Australia, can then be made by debiting one account and crediting another. Allocations are not linked to land titles. These annual allocations may be traded among willing purchasers.
- ***Use approvals*** then set out the rules for applying water to a nominated area of land and deducting the amount used from a water account associated with the use approval. Site use approvals are not generally tradable as the conditions relate specifically to a piece of land.

In the face of worsening climatic conditions in eastern and southern Australia and difficulties in rebalancing the amount of water in the environment pool versus the consumptive pool and addressing institutional weaknesses, the Federal Government announced Water for the Future in 2008. Water for the Future is a AUD 12.9 billion investment over 10 years with overarching objectives to take action on climate change, use water wisely, secure water supplies and support healthy rivers and waterways. Investment is being mainly used to purchase water entitlements for the environment and infrastructure upgrades and reconfiguration, with water savings being returned to the environment on a shared basis.

Water information is critical to the effective operation of water markets, and is vital to underpin and build confidence in all aspects of sustainable water planning and management. ***Under Australia's*** national Water Act 2007, the Federal Bureau of Meteorology is authorised to collect and publish high-quality water information. The publications will include an annual National Water Account and periodic reports on water resource use and availability. The Bureau is also empowered to set and implement national standards for water information.

Complimenting Water for the Future, the Council of Australian Governments agreed in November 2008 to a number of initiatives to improve the operation of water markets and trading through faster processing of temporary water trades, and to co-ordinate water information and research through the development of a national research plan and water modelling strategy. Australian experience with water reform suggests that investment returns well in excess of 15% per annum are achievable. In May 2009, Water Ministers approved trading standards for permanent water trades.

Mexico

Since the passing of the Water Law in 1992 and the creation of the National Water Commission, Mexico has embarked on a major policy reform to devolve water management of its large water districts to Water Users Associations (WUAs). This has involved setting new institutions such as basin agencies, giving WUAs managing capacity to administer both capital assets and water resources, and transferring the financial responsibility of running districts and collecting charges to the WUAs. Research has shown that between 1990 and 1996 government water subsidies and tariff deficit had gone down to 15% and 13% respectively, from 35% and 26%. By 1996, 372 WUAs had been formed to control water delivery to nearly 3 million ha. During this time water prices increased by 45–180% and government operation and maintenance (O&M) subsidies had been removed, but some researchers claim that O&M charges are too low (equivalent to 2-7% of the gross product), and that maintenance may be suboptimal in many cases.

Overall water policy reforms have helped toward improving water use efficiency and reducing losses and there has been some improvement in irrigation water application rates per hectare irrigated. But subsidies for water charges and electricity for pumping are undermining the efforts to achieve sustainable agricultural water use and, in the case of energy, reduce greenhouse gas emissions. There is also concern that the subsidy to electricity is also exacerbating the pumping of groundwater and the growing overexploitation of this resource above recharge rates. Moreover, the irrigation and electricity subsidy appears to be in contradiction to the new programme to purchase water rights from farmers, raising the costs to the government of achieving their environmental objectives.

Turkey

The costs of irrigation systems are being transferred from the government to local water user associations. With the progressive transfer of the operation and maintenance (O&M) of irrigation networks from the government General Directorate of State Hydraulic Works (DSI) and General Directorate of Rural Services (GDRS) to self financing local water user associations, farmers are supporting a higher share of the costs of maintaining irrigation systems. The DSI is mainly responsible for the development and maintenance of large irrigation infrastructure (*e.g.* dams, drilling wells), while the GDRS largely develops small scale on-farm irrigation works.

Farmers partially cover O&M costs of irrigation water through annual crop and area based charges. While collection rates of water charges in publicly operated schemes are low and never exceed 54%, those in farmer operated schemes are almost 90%. The DSI expenditure on irrigation O&M costs (net of farmer’s fees) averaged TKY 103 (USD 75) million over 2004 and 2005. In recent years water charges have risen, as a result of the transfer of irrigated areas operated by the DSI to water user associations. A study of cotton and grape production in the Gediz Basin, for example, showed that where these transfers have occurred and water charges increased, irrigation water productivity showed significant gains.

Some regional development projects have significant implications for agriculture and the environment. Many of these projects are financed by international development agencies and donors (*e.g.* the World Bank), as national funding is limited. The South-Eastern Anatolian Project (GAP) (1983-2001), which was financed mostly by national resources, is the largest regional development project in Turkey covering 10% of the total land at an estimated cost of TKY 50 (USD 32) billion. GAP involves, among other objectives, to expand agricultural production in the region through building 22 dams and providing irrigation infrastructure for 1.7 million ha of land by 2015. For the World Bank- funded Anatolian Watershed Rehabilitation Project (DOKAP), with funding of TKY 65 (USD 45) million over 2004 to 2012, the aim is to restore degraded soils to increase farm and forestry production. But some major irrigation projects, such as the GAP, have also been undertaken with little consideration of environmental management or impacts, with the loss of valuable ecosystems (*e.g.* steppe, wetlands) and increasing problems of salinity and agro-chemical runoff becoming widespread. Even so, the GAP project is increasing the supply of domestically produced hydroelectricity and has brought socio-economic welfare gains to villagers.

Overall the continued subsidies for water charges and electricity for pumping are undermining the efforts to achieve sustainable agricultural water use, especially groundwater. The operation and management responsibilities for local irrigation networks (previously run by a national monopoly), however, have been transferred to self-financing water user associations. This has led to an increase in water charges in order to cover operating costs and is helping toward more effective use of scarce water resources. This pricing scheme may be appropriate as an agricultural policy targeted to increase the income of the farmers and boost the contribution of agriculture to the overall development. However, the water pricing approach used in Turkey disregards several factors that may improve the performance of the agricultural sector and possible externalities that may arise because of irrigation development. Volume independent price may cause overuse of water with a negative impact on the yields of irrigated crops even if water is abundant. Water allocation problems will arise within agriculture and pressure for intersectoral transfers of water will augment when water is scarce. Irrigation related environmental externalities will further create social and economic costs.

Sources: Adapted from Young (2010) (Australia); Garrido and Calatrava (2010) (Mexico); Cakmak (2010) and OECD (2008a) (Turkey).

There has been a shift towards decentralisation of institutional arrangements concerning water governance, from national/regional governments levels to one encouraging greater local engagement and involvement of water users in resource management in agriculture. Over many decades the **United States**, for example, shifted water policy from mainly major Federal water development projects to a highly decentralised pragmatic form of management at State and sub-State level (Deason *et al.,* 2001; Gerlak, 2008). A key element under the **EU's** *Water Framework Directive* is to move member states towards a river basin management planning (RBMP) system, with all member states having to finalise their RBMPs, including a programme of measures, and then updated every six years (2015).

Some countries have begun to embrace the idea of competition and water trading as a paradigm for water management. So far development of water markets and water trading arrangements are limited across OECD countries (*e.g.* **Australia, United States**). Even in countries where the progress in developing water markets is more advanced, such as **Australia**, trade in water and water access entitlements has been small, such that during 2004-05 only 7% of total water consumption and 4% of water entitlements were traded (Parker and Speed, 2010; Young, 2010). A number of countries are beginning to evaluate the possibilities of developing water markets (*e.g.* **Canada, New Zealand**), but in other countries (*e.g.* **Austria, Belgium, Japan, Portugal**) the possibility of developing water markets are hindered by a combination of publicly owned water rights, water entitlement law and government regulations (see the OECD questionnaire at www.oecd.org/water).

While in principle there are no reasons in most OECD countries why water markets (*i.e.* trading of water entitlements) cannot be established, ***impediments to water market formation*** remain mainly because of the:

- Incomplete understanding of the science of water resource and ecosystem linkages;
- Lack of physical interconnecting networks between water delivery systems supplying agriculture, urban, industrial and other users;

- Uncertainty about the supply and demand for water at a given point in the future;
- Poorly defined property rights, including problems over separating land from water entitlements;
- Defining, securing and agreeing among stakeholders the quantity of water needed in a water basin to sustain environmental values;
- High transaction costs in creating water markets;
- Issues of equity in that water markets are perceived to ignore the poor, and that they are also largely considered to focus on economic efficiency overlooking environmental and social considerations; and, that in
- Many circumstances irrigators do not have the opportunity to trade their water entitlements with other users as no markets exist to do so.

The transfer of water from potential agricultural use to meet environmental needs is, however, becoming more widespread (*e.g.* **Australia,** Box 3.8). This is being achieved mainly through the use of regulatory policy instruments (*e.g.* abstraction licences – see the OECD questionnaire at www.oecd.org/water), as part of the water allocation process. The use of minimum river flow standards, is employed by some countries to ensure environmental water used for maintaining ecosystems (*e.g.* **Australia, Japan, Korea, Norway, Spain, Switzerland,** the **United States**), with more rivers expected to be subject to minimum instream river flows in **EU** member states under the *Water Framework Directive* (see the OECD questionnaire at www.oecd.org/water).

Intersectoral transfers of water between agriculture and other users is infrequent, and mainly occurs in extreme cases of drought for urban users, in which case government's usually has the right to revoke private water rights in the public interest. Some States in the **United States,** for example, have assisted farmers and other water users in obtaining water during sustained droughts by creating centralised water banks in which buyers and sellers can exchange information and conduct transactions (Wichelns, 2010b).

Regimes for groundwater rights are generally less developed compared to surface water (see the OECD questionnaire at www.oecd.org/water). User right systems are also frequently unco-ordinated between groundwater and surface water. Typically the landowner (farmer) is given the exclusive right to extract from groundwater beneath their property, although most countries have introduced regulations to limit private extraction from commonly shared groundwater resources and landowners will normally require consent from a government agency prior to making extractions. The conditions attached to a water permit/licence to extract groundwater (or surface water) can be extremely detailed, such as highlighted by the example of **New Zealand's** system of water permits (Box 3.9). Some states in **Australia** have more advanced water rights regimes for groundwater, involving water entitlement licences (which might only be issued for 5 to 10-year periods), annual allocations and trading in groundwater (see the OECD questionnaire at www.oecd.org/water).

Box 3.9. Conditions attached to water permits in New Zealand

Water permits are limited use rights, constrained by conditions set by the consent authority (for a water permit this is the regional council or unitary authority). Under section 14 of the national Resource Management Act (which was established in 1991 and is the key national legislation governing management of freshwater resources in New Zealand) extracting water from rivers, lakes and aquifers must either be authorised by consent or qualify as a permitted activity in a water plan. This excludes the extraction of drinking water for livestock and domestic purposes, which are specifically permitted by section 14.

Conditions attached to a water permit consent may include:

- The location(s) of the point of extraction or diversion.
- The ultimate use of the water.
- Volumetric controls on the rate of take (instantaneous, daily, weekly, monthly, seasonal, annual).
- Land titles (or designated areas) over which the consent may be utilised.
- Controls on the technical or physical efficiency of water use.
- Specification of environmental compliance monitoring requirements.
- Implementation of controls or restrictions on the exercise of the consent.
- Provisions to enable review of the consent.

Source: New Zealand government’s response to the OECD questionnaire at www.oecd.org/water.

3.4.3. Agricultural water charges and cost recovery: Surface water and groundwater

Surface water

Water charges across most OECD countries usually involve a mixed system of a fixed charge and a volumetric charge above a certain threshold for surface water (Box 3.10 and the OECD questionnaire at www.oecd.org/water). Per-hectare water charges (flat rate) are widely used for gravity fed irrigation systems across OECD countries. Flat rate charges per hectare are perhaps the most adverse incentive affecting irrigators' use of surface water, especially where water stress is an issue. Hence, the extent of using volumetric water charges in agriculture is highly variable across OECD countries. For example, in **France** by 2005 over 70% of farms and 85% of the area irrigated were equipped with volumetric devices, while from 2006 it became obligatory for farmers to install volumetric meters. In Japan, however, less than 1% of the 6 000 irrigation districts (Land Improvement Districts) use volumetric charges (see the OECD questionnaire at www.oecd.org/water).

Numerous obstacles hinder progress in replacing flat rates with volumetric rates (Garrido and Calatrava, 2010), including the high transaction costs of installing, implementing and monitoring volumetric charges in large scale irrigation projects. Research by Tsur and Dinar (1997) illustrates how the efficiency gains may not justify the costs of restructuring tariffs, while Chakravorty and Roumasset (1991) and Hafi *et al.* (2001) show that volumetric charges could have wealth re-distributional effects in large districts with network losses.

There are significant variations in surface water charges for farmers not only across OECD countries, but between regions and different water basins within regions. This reflects to some extent the variety of water rights, allocations, and contractual arrangements that characterise water use across OECD countries (see the OECD questionnaire at www.oecd.org/water). In **Spain** (Table 3.2) and the **United States,** for example, there is a wide range in the charges paid for irrigation water.

Some farmers in the **United States,** with riparian water rights or exchange agreements with the federal government, receive water at very low cost (USD 5 to USD 10 per 1 000 m^3), while other farmers with less favourable contracts or those who purchase water from some state-level irrigation agencies pay much higher prices (ranging from USD 20 to more than USD 100 per 1 000 m^3). Farmers purchasing water in market transactions to finish an irrigation season or to ensure water supply for perennial crops might pay prices that exceed USD 100 per m^3 for a portion of their irrigation supply (Wichelns, 2010b).

Box 3.10. Water charges, tariffs, prices and markets: A note on terminology

- ***A water charge*** can be defined as an actual financial payment by users to access water. It is equivalent to a ***water tariff*** a term commonly used in the domestic/urban water sector when differential charges are set. Sometimes the term water charge is replaced by the term irrigation service fee, as the term charge is disliked by some policy makers as it suggests water is taxed.
- ***The main types of water charge mechanisms*** include (FAO, 2004; Molle and Berkoff, 2007a):
    a. ***A flat rate or fixed charge,*** based on the nature of the supply contract. The most common form of charging is based on land area, as this is easy to administer and suited to continuous flow irrigation, such as gravity fed systems and canal irrigation.
    b. ***Volumetric supply charge*** is based on actual water diversions to a user or group of users (bulk water pricing), and requires some form of water metering, which can include:
        1. "Block prices", fixed for different levels of consumption; and,
        2. "Mixed tariffs", which combine a flat rate (usually area based) with a volumetric price, providing stable minimum revenue to the water provider and a variable charge according to use.
- ***The price of a unit of water*** is defined as the price set by the market, in a given political and social context, to ensure cost recovery, equity and sustainability and which may or may not include subsidies. By understanding the full long run and short run opportunity cost of water this should provide the context for establishing water markets, pollution charges and incentives for pollution control or increasing positive externalities.
- ***Water markets*** involve transactions in water between users and water providers affected by supply and demand. Water entitlements (allocations) can be traded, within season, seasonally or permanently, or where the market is regulated the regulator can set the price, price limits, and serve as a broker, for example, to facilitate market operation. The market price of the entitlements to receive water, is a price for allocating water and a price to determine the share of the water available.

Sources: Adapted from Molle and Berkoff (2007a); FAO (2004).

Table 3.2. Operation and Maintenance Costs and Recovery Rates for irrigation water services in Spain

Euros (only in the inter-regional basins)

Basin	Groundwater		Surface			Total		% Operation and maintenance cost recovery rates
			EUR per ha					
	EUR per ha	EUR per m^3	Distribution	ID and Basin tariff	EUR per m^3	EUR per ha	EUR per m^3	
Duero	500	0.095	19.88	46	0.012	231	0.044	89
Ebro	829	0.15	49	12	0.011	113	0.020	86
Guadalquivir	744	0.15	101	70	0.035	400	0.081	98
Guadiana	232	0.048	19	102	0.025	188	0.039	54
Júcar	383	0.074	81	16	0.02	283	0.055	85
Segura	789	0.163	34	151	0.038	464	0.096	n.a.
Tagus	541	0.1	36	67	0.02	199	0.038	n.a.
TOTAL	**500**	**0.09**	**50**	**56**	**0.021**	**263.5**	**0.051**	**87%**

n.a. : not available

Source: MMA (2007).

Korea also has a wide range of irrigation charges (Table 3.3), and operates a dual system of full support for major irrigation schemes (excluding mandatory labour levies) and no support for smaller schemes. This is asymmetric in terms of water management and may be deleterious to the small irrigators, who must cover the full supply costs for water supplies. At the same time, farms within the major irrigation schemes (“superior” farms) are legally restricted to cereal production, while farmers operating under smaller irrigation schemes are not so constrained in their production options (Nickum and Ogura, 2008).

Depending on the regulatory and institutional setting, ***full supply costs of surface water delivered to the agricultural sector on-farm*** (operation and maintenance, plus capital renewal and new capital costs) are usually those costs covered at the level of the: private irrigator (*e.g.* water charges for water delivered on-farm); irrigation district or water user association (*e.g.* operating and maintaining the irrigation capital infrastructure); and state or water authority (*e.g.* renewal and investment costs associated with the construction of irrigation infrastructure).

Full recovery of operation and maintenance (O&M) costs for water supplied to agriculture but low capital cost recovery is common for most countries (Figure 3.1 and the OECD questionnaire at www.oecd.org/water). For those countries where there is full supply cost recovery (O&M and capital costs) for surface water delivered to farms, none have large scale irrigation projects, with most irrigation networks privately owned.

Table 3.3. Average irrigated association charge on farmers by region in Korea, 2005

Unit: USD/ha	Average	Highest	Irrigated paddy field ('000 ha)*
National average	**31**	**387**	..
Incheon- gwangyeoksi	45	75	8
Gwanju-gwangyeoksi	36	247	8
Gyeonggi-do	30	185	80
Gangwon-do	19	103	38
Chungcheongbuk-do	24	78	50
Chungcheongnam-do	54	387	139
Jeollabuk-do	85	156	128
Jeollanam-do	32	59	151
Gyeongsangbuk-do	24	68	135
Gyeongsangnam-do	26	222	98

.. : not available

Data show the range of Irrigation Associations (IA) charges on Korean farmers for irrigation by region. The average varies substantially, from USD 19/ha in mountainous, little-irrigated, north-eastern Gangwon-do, to USD 85 ha in south-western Jeollabuk-do, with a substantial area of irrigated paddy.

* Data for 2006.

Source: Adapted from Nickum and Ogura (2010).

Where irrigation plays a more significant role in the agricultural sector and there has usually been a history of major publicly funded irrigation projects, more rapid progress is being made to recover capital costs from farmers (*e.g.* **Australia, France** and the **United States**). But the recovery of capital costs for irrigation costs, even for these countries, can be highly variable (*e.g.* in **France** 15-95% of capital costs recovered depending on the water basin). However, in the case of major projects of irrigation infrastructure rehabilitation, modernisation or refurbishment, urban/industrial water consumers (through cross-subsidisation) and taxpayers in most OECD countries continue to bear the main share of the capital costs, with public agencies managing the water delivery systems. Even so, water service infrastructure for urban and industrial water users is also frequently publicly financed (OECD 2009a).

Rates of cost recovery for water supplied to agricultural are increasing for most OECD countries. Evidence from studies of EU member states (Garrido and Calatrava, 2010), the **United States** (Wichelns, 2010b), **Australia** (Parker and Speed, 2010), **Mexico** (Figure 3.2; Garrido and Calatrava, 2010) and **Turkey** (Figure 3.3; Cakmak, 2010) all confirm this trend. Concerning the EU, under the *Water Framework Directive* (WFD) member states from 2010 will be required to ensure that the water prices charged to all consumers reflect the full costs (O&M + capital costs + environmental and resource [opportunity] costs, Figure 1.4), although derogations will be possible for less-favoured areas or on grounds of social welfare to ensure all consumers have a basic service (see the OECD questionnaire at www.oecd.org/water). **Australia** also expects that some States will reach full cost recovery for irrigation water by 2010 (*e.g.* New South Wales).

Figure 3.1. Full supply cost recovery[1] for surface water delivered on-farm across OECD countries,[2] 2008[3]

- **100% cost recovery of Operation and Maintenance and Capital Costs:**
  Austria; Denmark; Finland; New Zealand; Sweden; United Kingdom
- **100% cost recovery of Operation and Maintenance Costs, but less than 100% recovery of Capital Costs:**
  Australia; Canada; France; Japan; United States
- **Less than 100% cost recovery of Operation and Maintenance and Capital Costs:**
  Greece; Hungary; Ireland; Italy; Mexico; Netherlands; Poland; Portugal; Spain; Switzerland; Turkey
- **Less than 100% cost recovery of Operation and Maintenance Costs, with Capital Costs supported**:
  Korea
- **Recovery of other costs through water charges or water pricing: Opportunity costs, economic and environmental externality costs:[4]**
  - Australia, some environmental costs already recovered, but planned to recover opportunity costs; economic and environmental costs by 2010;
  - France, is recovering a share of the environmental costs through water charges;
  - United Kingdom, currently recovering share of environmental costs.

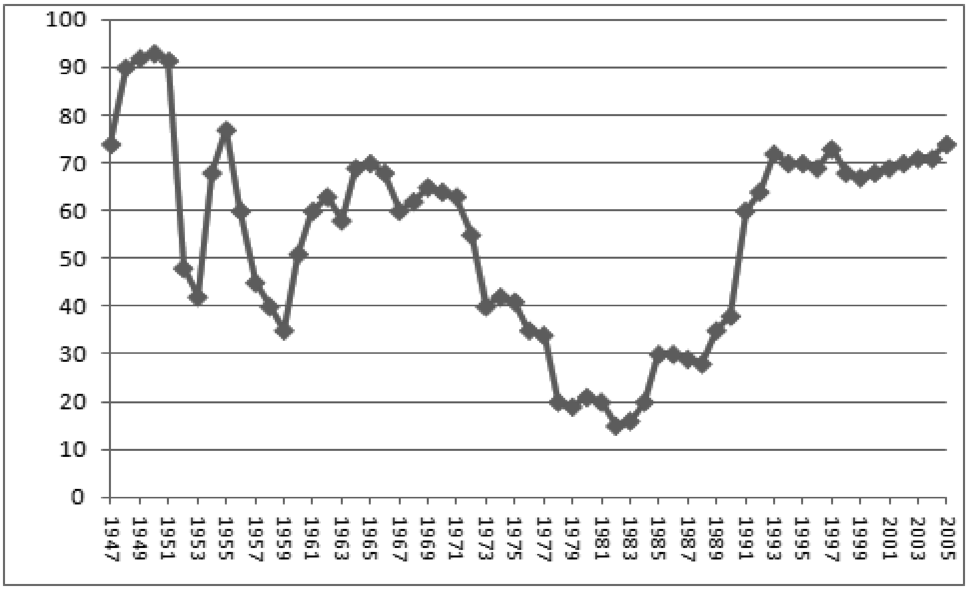
1. This is equivalent to the full supply costs shown in Figure 1.4, *i.e.* operation and maintenance costs and capital costs (renewal and new costs).
2. No information is available on the following OECD countries: Belgium; Czech Republic; Germany; Iceland, Luxembourg, Norway, Slovak Republic.
3. This figure summarises the information from the OECD questionnaire at www.oecd.org/water.
4. Other costs including opportunity costs, economic and environmental externality costs are shown in Figure 1.4.

Source: OECD Secretariat, based on responses from member countries to an OECD questionnaire at www.oecd.org/water.

For **Japan**, however, there has been little change in the rate of cost recovery for irrigation water supplies, while for **Korea** cost recovery rates have been declining for more than a decade (Nickum and Ogura, 2010). **China** (although not an OECD member country) has embraced, but not always implemented, market principles for water cost recovery in agriculture (Nickum and Ogura, 2010).

There have been major increases in water charges for irrigation water supplies in **Australia** since 1994, and increasing acceptance amongst irrigation customers of the logic of, and need for, charges to recover "lower bound" costs (*i.e.* water charges cover the operation, maintenance and renewal capital costs of supplying irrigation water) (Table 3.4, and Parker and Speed, 2010). However, "lower bound" pricing can mean improvements in service standards are small. Capital for significant scheme efficiencies and improvements require either increases in water charges toward "upper bound" (*i.e.* full supply costs, including financial, externality and opportunity costs), or capital support to realise efficiencies. The Federal government has recently provided capital support to some of the larger irrigation schemes to increase efficiency, with the intent that volumes of water saved are returned to the environment (Box 3.8).

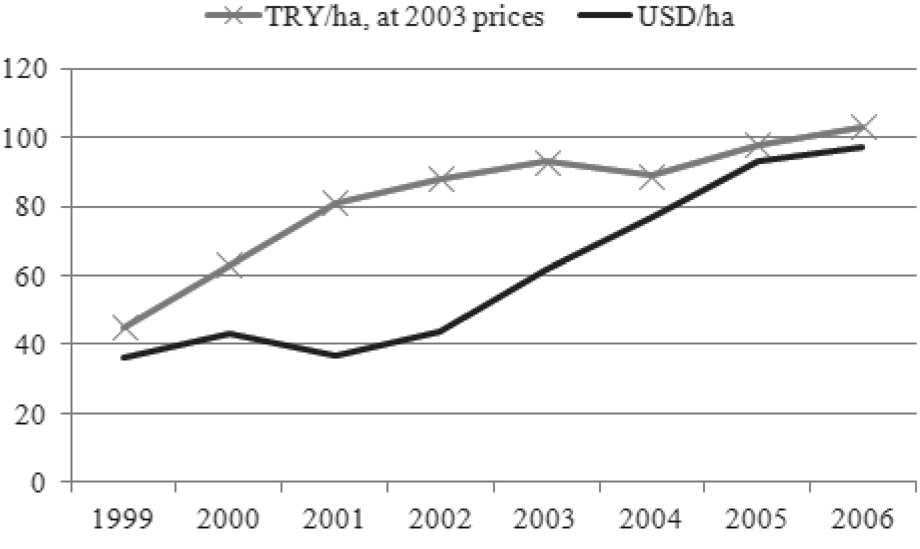
Figure 3.2. Recovery rates for Operation and Maintenance costs in irrigated areas in Mexico



Source: Garrido and Calatrava (2010), adapted from Silva Ochoa and Garcés-Restrepo (2002).

Figure 3.3. Average Turkish irrigation Operation and Maintenance charges, 1999-2006

(TRY/ha, at 2003 prices and USD/ha)



Source: Cakmak (2010).

Table 3.4. Cost recovery rates for irrigation water in Australia

	Volume of irrigation water supplied (megalitres)	**Share of cost recovery** (%)
New South Wales	4 777 604	88
Queensland	1 206 725	97
Victoria	1 192 983	100
Total of above States	**7 177 312**	**91**

Cost recovery is defined as including: the operation, maintenance and renewal capital costs of supplying irrigation.

Source: Adapted from Parker and Speed (2010).

Water authorities are beginning to recover the opportunity (resource) costs and environmental and economic externality costs associated with water use in agriculture, but this applies to only a very few countries (Figure 3.1 and the OECD questionnaire at www.oecd.org/water). These costs, however, are sometimes recovered through other policy instruments, such as the use of water pollution taxes in **France** (Table 3.5), **Belgium** (pollution tax); Portugal (from 2008 tax on water users to cover economic and environmental costs); or where agriculture provides positive environmental externalities, such as conservation of wetlands, then payments are paid to farmers for maintaining this public good (see discussion above, Chapter 3.2.3 and 3.2.4).

Greece has made a comprehensive calculation of water demand and the full cost and cost recovery of water services for agriculture and other water users (Box 3.11). This calculation has been made as part of Greece's submission under the **EU** Water Framework Directive.

For most OECD countries quotas, allocations, licences, or annual entitlements are the usual allocative mechanisms between different water users or for environmental needs. The use of water markets and trading water entitlements to allocate water is only practised in a very limited number of OECD countries (*e.g.* **Australia**). In effect the opportunity (resource) cost of water used by agriculture is implicit in the use of quotas, licences, permits and other rationing mechanisms used by policy makers.

Table 3.5. Water taxes for irrigation charged by the *Agences de l'Eau* in France

Water basin authorities	**Average tax** (2002, EUR/m^3)	**Minimum-maximum** (2003-06, EUR/m^3)	**Abstracted volume** (million m^3, 2002)
Adour Garonne	0.0047	0.0026 – 0.0057	758
Artois Picardie	0.0134	0.0012 – 0-0609	15
Loire Bretagne	0.0066	0.0044 – 0.0175	499
Rhine 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: Garrido and Calatrava (2010), drawing on Rieu (2006), using data from the *Agences de l'Eau.*

Considerable caution is required in using and comparing data on cost recovery rates and agricultural water charges, both within and between countries. In particular, difficulties relate to (Garrido and Calatrava, 2010; Nickum and Ogura, 2010):

- Lack of transparency in data concerning financial costs for supplying water, especially concerning capital costs. A simplification of the water pricing and cost-sharing systems on a system-wide basis would improve transparency and make it possible to establish more precise estimates of how much of total irrigation capital costs are covered by central and local governments as well as farmers;
- Many water distribution networks and storage facilities are often shared with multiple users, including agriculture, so allocating financial costs to different water users is complex;
- Major publicly funded irrigation projects can be implemented over many decades in a piecemeal fashion, making accountancy of the projects difficult; and,
- Evaluating replacement costs over the life cycle of a dam or reservoir can be complex.

Groundwater

As discussed in the previous chapter, the landowner (farmer) is usually given the exclusive right to extract from groundwater beneath their property. The use of regulatory instruments, however, is widespread across OECD countries in an effort to achieve sustainable use of commonly shared groundwater resources. Typically most countries apply a fixed fee and volumetric charge extraction groundwater were the resource is shared with other users, although **Turkey** uses a per hectare (flat rate) charge, while **Japan** and **Korea** have no charges for extracting groundwater (see the OECD questionnaire at www.oecd.org/water).

Irrigation costs have been increasing in many regions of OECD where farmers rely on limited supplies of groundwater. Moreover, increases in the price of energy for pumping groundwater coupled with declining groundwater levels has motivated farmers to improve their irrigation practices and increase the values they generate per unit of water extracted from groundwater resources.

This situation is well illustrated by the High Plains of Texas and other regions of the **United States** served by the fossil Ogallala Aquifer (Box 3.12). Several states have established groundwater management districts and limited the development of new wells, in an effort to slow the rate of depletion in a largely agricultural region that depends on irrigation. Some states also require farmers to measure and report the volume of water they withdraw from the aquifer each year, thus generating helpful data for state agencies, while also increasing farm-level awareness of the rate of aquifer depletion in the region.

Box 3.11. Measurement of full cost recovery in Greece

As part of the Greek Final Report for Article 5 of the EU's Water Framework Directive, the government has established official data for water consumption, cost of water services and level of cost recovery for the 14 Greek water regions (see Tables 3.6 and 3.7 below: for the regional data, see Source below). The different categories of costs shown in the tables below have been determined as follows:

- The ***financial (supply) cost*** was taken from the annual financial reports of the companies providing water for both domestic (DEYA) and irrigation (TOEB) purposes.
- The ***resource (opportunity) cost*** was only calculated for four water regions where the demand-supply water balance is negative, *i.e.* in Aegean Islands, East Sterea Ellada, East Peloponnesos and Thessaly. The resource cost was approximated considering the best water source alternative in each area (the cost of water desalination, the cost of recycled water, etc.)
- The ***environmental cost*** was obtained using a "Benefits Transfer" of values obtained in a large number of valuation studies which applied stated preferences methods. This technique allows for adjusting the values obtained in these studies using relevant socio-economic data for the areas where the studies were performed and the areas where the values are to be "transferred".

The level of cost recovery has been calculated as the percentage of the total cost of water services that are recovered by the collected revenues from water services. The revenue figures used by the Greek Government include both tariffs set by water companies to water users and water polluters. Furthermore, Common Agricultural Policy subsides attributable to irrigated agriculture are included as a cost in the calculation of cost recovery for agricultural water users. The average cost recovery level in Greece is nearly 65% for domestic and industrial uses and 54% for agricultural users. Total cost recovery level is also 64% for all uses. With a couple of notable exceptions, water companies do not cover their costs. Furthermore, not even financial costs are covered with the collected revenues. Average water tariffs have been calculated by dividing the total amount of revenues paid by farmers and the amount of water used in each water region. These range from an average EUR 0.011/m^3 in Central Macedonia to EUR 0.1/m^3 in Crete.

Table 3.6. Water demand and cost of water services in Greece, 2007

	Water demand (Hm^3/year)		**Financial cost** ('000 EUR/year)		**Resource (opportunity) cost** ('000 EUR/ year)	**Environmental cost** ('000 EUR/year)		**Total costs** ('000 EUR/year)	
Water district	Irrigation	All uses	Irrigation	All uses	Irrigation	Irrigation	All uses	Irrigation	All uses
TOTAL	6 827	7 907	118 950	3 408 488	140 166	47 502	62 165	306 618	3 610 819

Table 3.7. Full cost recovery for water services in Greece, 2007

	Revenue collected from water tariffs ('000 EUR/year)		**Average water tariff** (EUR/m^3)		**Total cost recovery** (%)	
Water district	Irrigation	All uses	Irrigation	All uses	Irrigation	All uses
TOTAL	165 608	2 301 955	0.0243	0.2911	54	64

Source: Adapted from Garrido and Calatrava (2010).

3.4.4. Financing water infrastructure related to agriculture

Many irrigation areas in OECD countries face the problems of ageing infrastructure and a limited revenue base from which to fund maintenance and repair activities. The drive toward cost recovery for storage and delivery services arising from water reform policies described above, means that both water suppliers and irrigators are beginning to consider the strategic evaluation of infrastructure renewal to remain viable. Losses typically arise from poorly maintained water delivery systems and on-farm pipelines, as well as losses from inefficient water application technologies (some of these losses leach back into the environment, although may involve transporting pollutants, such as salts, into water bodies).

In **Japan** and **Korea**, for example, there is a pressing need to upgrade and repair the massive stock of ageing irrigation facilities accumulated in earlier decades (Nickum and Ogara, 2010). **Japan's** Stock Management Programme is aimed at this problem, while in **Korea,** such upgrading may involve renovation for multipurpose uses. For **Hungary,** most of the public water facilities, (serving drainage and irrigation purposes) amounting to about 37 000 km and 312 public-purpose pump stations, are in poor condition and require reconstruction (Hungarian government's response to the OECD questionnaire at www.oecd.org/water). The **United States** has also been concerned with addressing the maintenance of its public irrigation infrastructure, in common with many other OECD countries, as discussed in Box 3.13.

Answers to many irrigation infrastructure maintenance questions turn on which parts of the water control system can be maintained and on the consequences of a loss of function due to poor maintenance of any part. Canals and structures in irrigation canals should have sufficient capacities, and should be able to assure required water levels. Drainage systems should also have sufficient capacities to secure a desired level for water distribution. Proper maintenance requires information on the characteristics of the system and its elements and an understanding of which functions each contributes. Such an information database is necessary for an adequate monitoring, planning, execution and control of maintenance, for cost effectiveness of the work and for its cost recovery.

In general, however, information on the current levels and future needs for financing water management and infrastructure related to agriculture is poor across OECD countries. The total costs for maintaining and modernising the existing water delivery systems to farms is likely to be substantial. This is because of the need to address leakages and losses from water delivery systems on and off-farm, and also that in most cases no contingency has been made for capital investment for system renewal given that typically publicly owned irrigation systems have only charged farmers for O&M costs and not capital renewal costs. In addition, there are the financial costs for controlling non-point pollution from agriculture, and flood control costs, such as on-farm drainage.

With the increasing transfer of water infrastructure operation and maintenance from government agencies to farmer or water user associations this raises questions as to future sources of finance and asset management. The transfer of financial control and investment management requires water user groups to seek private-public partnerships to raise capital and develop skills in long term asset management for renewal of irrigation infrastructure. In addition, given the environmental considerations in large scale irrigation schemes there has been reluctance of financial institutions to engage in these projects irrespective of their overall benefits.

Box 3.12. Irrigating with groundwater from the Ogallala Aquifer in the United States

The Ogallala Aquifer lies beneath portions of eight states in the American west, including Texas, New Mexico, Kansas, Oklahoma, Colorado, Nebraska, Wyoming and South Dakota. The Ogallala has been the source of substantial, large-scale irrigation development, beginning in the 1950s, when affordable technology became available for extracting groundwater and applying it to large fields of cotton, corn, winter wheat, and sorghum. The number of wells on the Texas High Plains rose from 48 000 in 1958 to 101 000 in 2000, as farmers increased their production of irrigated crops. The Ogallala is largely a fossil aquifer with a very slow rate of natural recharge. By 1977, groundwater levels were declining by at least 15 cm per year in 82% of the area irrigated with groundwater in Texas. Severe overdraft was observed also in Kansas, Oklahoma, and New Mexico. The cumulative decline in groundwater levels has exceeded 30 metres in some areas of Texas and Oklahoma.

The economy of the region depends largely on crop and livestock production and processing, yet the rate of withdrawal from the Ogallala greatly exceeds the rate of recharge. The unsustainable use of water from the Ogallala has attracted substantial attention from state and federal agencies in recent years. Most states have passed laws that enable the formation of groundwater management districts, controlled by local irrigators, to implement programs for optimising the long-term use of water from the aquifer. In Kansas, New Mexico, and Colorado, farmers must apply for permits from groundwater management districts to drill new wells. Permits are not issued if new wells will impact water availability for nearby farmers. Farmers in Kansas are required also to measure the volume of groundwater they use each year and to provide that information to the local management district.

Farmers on the High Plains region of Texas can withdraw and utilise groundwater without regulation, as the Texas Supreme Court has ruled that a landowner is the absolute owner of the soil and percolating water. Irrigation expanded rapidly in the region during the 1960s and the early 1970s, before entering a period of decline, driven largely by the increases in energy costs and the diminishing productivity of irrigation wells. Irrigated area reached a low point of 1.59 million ha in 1989, before recovering to 1.87 million ha in 2000, about the same area that was irrigated in 1958. As the irrigated area has changed over time, so too have farm-level choices regarding irrigation technology. Gravity-flow surface irrigation methods have largely been replaced by centre-pivot and low-pressure sprinkler systems and subsurface drip irrigation.

Lacking administrative authority to limit pumping in Texas, several agencies have worked with irrigators to encourage improvements in water management that will reduce the aggregate rate of groundwater withdrawals. Declining groundwater levels and rising prices of natural gas also have motivated farmers to improve irrigation management. The estimated cost of pumping water from the Ogallala increased from USD 0.08 per mm to more than USD 0.20 mm in some areas. The current estimated investment cost for an irrigation system in the region is USD 741 per hectare and the estimated variable cost of pumping water (from a depth of 61 metres) and operating the system is USD 772 per hectare. In a sense, the increasing costs of two scarce resources (water and natural gas) are motivating necessary adjustments in water use, with research indicating that in any given year, higher natural gas prices can cause up to an 18% reduction in the volume of water pumped for irrigation in the region.

The costs of pumping groundwater will continue to increase with rising energy costs and with declining water levels. State governments will likely increase their efforts to manage groundwater as scarcity increases in many areas, and as the public becomes more concerned about the regional economic implications of groundwater overdraft. Recent increases in public awareness of the potential implications of climate change and public concerns regarding sustainability are likely to encourage public officials to intensify their management of groundwater resources, while also enhancing the likelihood that farmers will accept new regulatory measures that might include charges that reflect scarcity values.

Source: OECD Secretariat, adapted from Wichelns (2010b).

Box 3.13. Financing irrigation infrastructure in the United States

The experience of the United States Bureau of Reclamation (Reclamation) provides an illustrative example among OECD countries of the issues and challenges for policy makers in addressing irrigation infrastructure maintenance. The Reclamation Act of 1902, which created the Reclamation, set in motion a major programme to provide federal financing, construction, and operation of water storage and distribution projects to reclaim arid lands in the western states. Most large dams and water diversion structures in the west were built by, or with the assistance of, the Reclamation (the U.S. Army Corps of Engineers [Corps] also operates and maintains a considerable inventory of dams and other water control infrastructure throughout the US, with the Corps indicating in financial year 2006 it had USD1.8 billion in deferred maintenance for its civil works activities)

The Reclamation's mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner. In most cases this has meant developing water supplies primarily for irrigation to reclaim arid lands in the West. As of 2008, the Reclamation operates and maintains 2 122 water and power structures in the 17 western states. Among these facilities are 471 dams, 348 reservoirs, 58 power plants, and numerous water delivery facilities. This infrastructure provides water to 31 million people and provides irrigation water for 10 million acres of farmland that produce 60% of the nation's vegetables and 25% of its fruits and nuts. With US population and accompanying development continuing to move into the west, the need for secure infrastructure to deliver greater quantities of water in future will be important.

Almost from the beginning, the U.S. federal government has wrestled with the problem of repairing the Reclamation's infrastructure. Early in the reclamation programme, the US Congress decided to require water users to pay for a part of the repair and maintenance of the facilities. The Reclamation reported recently that its current infrastructure systems are in generally good condition, but acknowledged that the long term trend will show some decrease in reliability of the facilities under its control in 2009. The Reclamation recognises that it faces approximately USD 3 billion worth of rehabilitation needs for its ageing infrastructure over the next 20 years.

Based on the agency's internal facility reliability rating system, which measures the percentage of water facilities in good or fair condition, it determined that in the financial year (FY) 2007 that 99% of all facilities met those criteria. The agency stated that the reliability index may fall below 90% in FY 2009 and following years. Much of the Reclamation's current infrastructure is now 50 years old or older, and its proper operation and maintenance are a top priority. The administration has proposed USD 396 million in budget authority for FY 2009 to ensure that its facilities are operated and maintained safely and reliably, a slight increase over the USD 388 million enacted for operation and maintenance expenditure in FY 2008.

At the inception of the Reclamation Program the philosophy was that all reclamation project costs should be repaid in full except interest on construction costs. However early reclamation cost sharing policy resulted in repayments to the government falling short of planned levels. This led to a series of changes in the repayment provisions culminating with the Reclamation Act of 1939, which completely revised reclamation policy from total repayment of cost to repayment on an ability to pay basis as determined by Reclamation. Charges for Reclamation supplied irrigation water were no longer required to reflect the cost of water supply. The Reclamation Reform Act of 1982 required that new contracts charge full supply costs of operation and maintenance (including repayment of previously underpaid operation and maintenance). Even so, concerns have persisted about the degree to which reclamation irrigation projects are subsidised and the potentially inefficient economic use of public resources. However, since the 1982 Reclamation Act, the 1986 statutory requirement, and the 1992 Central Valley Project Improvement Act have generated notable increases in irrigation prices in California's Central Valley (Wichelns, 2010b).

Source: Adapted from Ward (2010) and Wichelns (2010b).

The key factors that might be able to promote increased levels of investment in irrigated agriculture include:

- Defining clearer titles to water rights that promote market transfers of water;
- Increasing competition for water, and a reallocation of agricultural water supplies to meet emerging uses;
- Developing regulatory measures that require the upkeep and maintenance on infrastructure, as well as minimum flows for environmental needs; and,
- Increasing the cost recovery rates of water supplied to farmers so there is a flow of financial resources to support water delivery infrastructure maintenance and renewal.

3.5. Climate change and flood and drought risk management[3]

3.5.1. Overview

Nearly all OECD countries are actively engaged in government led research concerning the future impacts of climate change on agricultural water management. The emphasis of research varies across countries, however, reflecting the varying anticipated impacts of climate change on agriculture and water resources across OECD countries (see the OECD questionnaire at www.oecd.org/water).

The main focus of climate change research for almost all countries involves analysing the implications for agricultural production, assessing regional impacts of expected changes in precipitation and water availability, and examining the efficiency (mitigation and adaptation) of different farm practices and systems under a range of climate change scenarios. Where issues of water scarcity are already exerting pressure on agricultural production (*e.g.* regions of **Australia, Spain** and the **United States**) climate change research is directed, in particular, at evaluating soil conditions and land use suitability, improving water use efficiency, and developing drought resistant new crop varieties (see the OECD questionnaire at www.oecd.org/water).

The climate change research undertaken by most countries is already being factored into water resource management policy considerations related to agriculture in a growing number of countries (see the OECD questionnaire at www.oecd.org/water). The emphasis in most countries continues to be on researching climate change impacts on agriculture and water resources and raising policy decision makers and the public's awareness to the issues and challenges. Nearly a quarter of the OECD membership, however, report that climate change has a medium to a very extensive ranking in terms of the extent to which climate change is currently being taken into account in policy decision making in relation to agricultural water resource management (see the OECD questionnaire at www.oecd.org/water).

Illustrative of the growing priority of climate change in policy decision making in agricultural water resource management includes (see the OECD questionnaire at www.oecd.org/water): the 2008 **Australian** national plan *Water for the Future*, one of four key priorities for the Federal government (Box 3.8); recognition in the **French** Water Act (2006) of the need to adapt water management policies to the impact of climate change; inclusion of climate change in the **Spanish** Hydrological National and Basin Plans (Box 3.17); the **United Kingdom's** Environment Agency new climate change policy strategy is taking account of the expected increase in irrigation demand; the

United States is developing long term strategies to update institutions and agricultural policies to adapt to climate change; and in **New Zealand** water policy and climate change policy are becoming more inextricably linked (Box 3.14).

As the frequency and severity of drought and flood events is increasing this is leading to rising budgetary costs for governments to support farmers and the rural community, and higher costs for private insurers (OECD, 2006). Efforts to address flood and drought events in agriculture and society as a whole, is being frustrated by the fragmentation of responsibility and the lack of policy coherence in agricultural, environmental, land and water policies to address these problems.

Where farmers are guaranteed government support in times of flood and drought disasters, this is not providing the necessary incentives to improve farmer self-reliance and risk management for adverse events. Hence, greater policy attention and investment will be required in drainage and water control (for floods), water retention (droughts) and farming systems and practices that can reduce economic losses to farmers and water flows across farmland (Rosenzweig *et al.,* 2004).

3.5.2. Flood policies and agriculture

Flooding remains the most significant natural hazard worldwide. In the period 1985-2008 extreme rainfall events may have been responsible for over USD 320 billion of damages and over 10 000 deaths in OECD countries (Morris *et al.,* 2010). Although the largest share of economic flooding costs is borne by urban communities, agriculture occupies a large proportion of the landscape and has an important role to play in both flood mitigation and adaptation.

There is clear evidence from many OECD countries that the incidence and severity of flooding events have been increasing over recent decades, with the resulting damaging impacts on agricultural production and infrastructure (*e.g.* buildings, fencing, etc.). Human alterations of the hydrological characteristics of watersheds has increased runoff and narrowed channels. Land-use policies have also encouraged urbanisation in areas at risk to flooding events, and thus increased the economic cost associated with a given flood event. The expectation is that such events will occur more frequently in the future due to climate change and changes in catchment land use (see the OECD questionnaire at www.oecd.org/water).

Flooding can be viewed as an environmental risk. Hence, a flood event has a *source,* such as an extreme rainfall event, with potential to cause flooding conveyed through a *pathway,* the land surface and hydrological system, to a *receptor* where flooding occurs (Figure 3.4). The risk of flooding to people and communities depends on the likelihood of a flood occurring (probability) and the consequences of the event when it does occur. The risk may be reduced by a combination of mitigation and adaptation. *Mitigation* refers to actions that impact the source or pathway to reduce the probability of a flood occurring. *Adaptation* refers to actions taken to reduce the impact of flooding in receptor areas.

Box 3.14. Developing policy linkages between agriculture, water and climate change in New Zealand

The linkages between water policy and climate change policy are becoming inextricably linked. It is becoming more prominent in the work on climate change adaptation. Within the Sustainable Land Management and Climate Change Programme, significant work under one pillar of the programme, is looking at the issue of adaptation to climate change.

Adapting to climate change

Climate change is likely to have a mixed impact on New Zealand land management. Over the next 100 years, the country is expected to experience warmer temperatures and changes in the amount and distribution of rainfall. This will result in improved growing conditions and longer seasons in some regions. It is also likely to lead to an increase in the frequency and severity of both extreme storm events (in some areas) and drought in others (especially in the east). Increased biosecurity risks from pests and diseases will also need to be managed. Agricultural productivity is expected to be affected, for better and worse, by these projected changes.

The Government will work with the agriculture and forestry sectors, local government and Māori to identify activities to be included in a proposed new five-year Adaptation Programme for the sectors. This programme will help the sectors build up the necessary skills and infrastructure needed to respond to the risks posed by the changing climate, as well as take advantage of the new opportunities. The Government has agreed to fund this work to a total of more than NZD 7 million over the five years 2008-12 and a further NZD 910 000 per annum thereafter. This will be supported by further investment in research and innovation and technology transfer. The Adaptation Programme will be linked to work already being carried out by the sectors, to local authority regional, district and community plans, and to broader central government sustainability initiatives, among which of particular relevance to agriculture, include the Community Irrigation Fund and Flood Risk Management Review, described below.

Community Irrigation Fund

The Community Irrigation Fund (CIF) was established in 2007 and is a contestable fund of NZD 6.4 million spread over an 8-year period. It is part of the government’s wider sustainability and climate change initiatives and funds up to half of the cash costs of appropriate activities. The CIF aims to build resilience in agricultural producers and rural communities, and ensure their long-term economic growth within sustainable environmental limits by reducing the risks they face from water shortages caused by climate change.

The CIF helps agricultural producers and rural communities adapt to climate change by assisting promoters of community water storage and/or irrigation schemes overcome the high transaction costs of generating investor and/or community support. A community scheme is one that is initiated, developed and used by multiple members of a rural community, primarily for irrigation.

Flood risk management review

The Ministry for the Environment led a two-year review of how New Zealand manages its flood risk and river control. This was completed in June 2007. The Ministry worked closely with local government and other government agencies on the review, including the Ministry of Civil Defence and Emergency Management, Ministry of Agriculture and Forestry, Department of Internal Affairs and the Department of the Prime Minister and Cabinet.

The review found that central government needs to strengthen the current policy framework and provide better guidance on flood risk assessment and good practice. The challenge New Zealand now faces is how best to reduce the damages and losses from flooding as part of our everyday living and working lives. Over 100 New Zealand cities and towns, along with some of our most productive farmland, are located on floodplains. The review looked at what was being done to manage flood risk and where there were any problems.

New Zealand suffered major flooding in 2004, affecting the lower North Island and the Bay of Plenty. The floods led to major regional social, economic and environmental disruption, requiring substantial relief from central government. Following these events the flood risk management review and work programme was agreed, and a steering group was established. Over the years ways to manage this flood risk have been developed. After the large floods in 2004 the Government decided to review flood risk management to ensure the current framework is robust. The Ministry for the Environment led the review, and a Steering Group provided direction and guidance throughout the review. The review covered three key topics:

- The role(s) of central government, local government and communities in ensuring good risk management practices are adopted in managing rivers and floods.
- Funding and affordability, essentially asking who benefits, who pays, and who can afford flood risk mitigation.
- Current flood risk management practices and whether these practices are appropriate, now and into the future, to meet the needs of New Zealanders.

Briefly, the review found that the current flood risk framework is not fundamentally flawed but that important issues need to be addressed. The current practices of central and local government need to improve to manage current flood risk and adapt to future climate change. Funding and affordability are very real concerns for smaller, less wealthy communities. The roles of communities, central and local government are broadly right, although central government could be more active in reducing flood risk.

Flood risk will increase with climate change. Central government currently spends most of its investment in flood risk management on the response and recovery phases. Investment in the reduction phase – to provide information, guidance and assistance, as well as resources – would help local government to more effectively manage flood risk and prepare for climate change. One of the main outcomes of the review is the development of a National Policy Statement on Flood Risk Management, which will be developed under the Resource Management Act 1991.

Source : New Zealand government's response to the OECD questionnaire at www.oecd.org/water.

Figure 3.4. Sources – Pathways – Receptors model applied to flood risk

Sources →	**Pathways** →	**Receptors**
Weather-related phenomena which generate water that could cause flooding — heavy rain, snowmelt, extreme tide, defence breach.	Mechanisms by which water travels from its source to places where it may affect receptors — overland flow, streams, rivers, flood plains.	Physical entities that are potentially vulnerable to flooding — people, property, infrastructure, habitats.

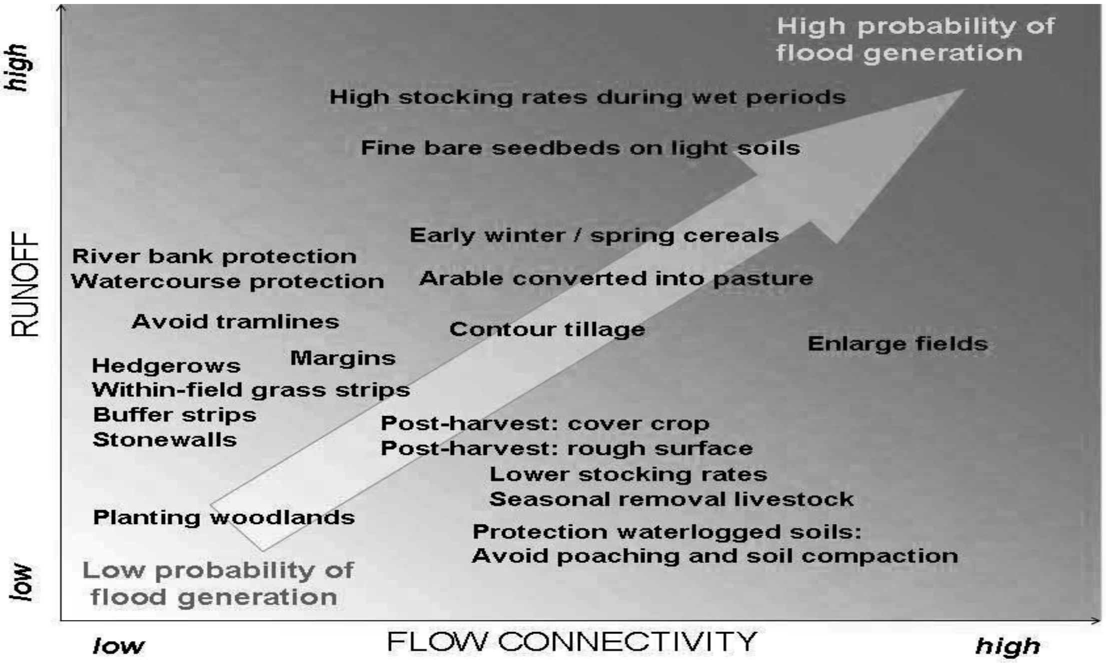
Source: Morris *et al.* (2010).

Agricultural land can act as a "pathway" for the generation of floods which can result in damage. There is a general perception that the intensification of agriculture over the past 50 years in many OECD countries has resulted in greater and more rapid floods following extreme rainfall (Morris *et al.,* 2010). Some changes in land management practices, for example, have reduced the infiltration capacity of the soil, for example, drainage systems have been "improved" to evacuate water from agricultural land more quickly. But practices that encourage retention of water in the landscape can contribute to flood risk mitigation, especially for smaller, more frequent events. Practices such as (*inter alia*), low stocking rates, grazing management, low ground pressure tyres, and soil improvement measures encourage infiltration and reduce surface runoff, whereas measures such as contour ploughing and retention ponds slow down the rate of runoff from the land (Figure 3.5).

The linkages between flooding and land management practices in agriculture also need to be viewed within the context of regional land use planning and broader, economy-wide mitigation strategies to address flood risks. Increased impervious surfaces with urban expansion results in reduced groundwater retention that supply base flows during drought and increased intensity of flows during flood events. Conversion of farmland to non-agricultural uses in floodplain areas increases the potential cost of flood damages while reducing the potential use of these lands as a flood sink. This highlights the point that planning for sustainable water resource management in agriculture should not be independent of regional land use planning.

Agricultural land is often the receptor of flooding. The impact of flooding on agriculture varies considerably according to tolerance of the particular crop or land use activity to excess water, and the frequency, duration, depth and seasonality of the event. Where flooding is frequent, the use of the land may be limited to low productivity, flood resilient enterprises. Less frequent flooding may cause damage and losses to higher value land uses. If the likelihood of flooding is going to increase in the future, farmers will need to adapt by moving to more flood resistant or resilient enterprises and adopting measures to facilitate recovery after a flood event. These adaptations may also provide opportunities for parallel enhancements, such as biodiversity improvement through wetland re-creation and enhanced public access.

Figure 3.5. Impacts of selected land management practices on flood generation



Source: Morris *et al.* (2010).

National policies for agricultural flood risk management in OECD countries have included a combination of mitigation and adaptation (Figure 3.6 and the OECD questionnaire at www.oecd.org/water). Mitigation has mainly taken the form of public investments in flood defence and land drainage to support agricultural production. There have been few policies that directly mitigate flood generation from farm land, despite concerns that rural land use can contribute to flooding. Some features of agri-environmental schemes now include components which are likely to reduce runoff, which contributes towards lower rates of soil erosion and diffuse water pollution. However, many policies that seek to influence agricultural land management in order to control diffuse pollution and soil erosion are also thought to have a beneficial impact on flood risk management. These policies typically adopt a non-regulatory approach, with emphasis on a mix of voluntary measures (such as agri-environmental schemes), supported by economic incentives to farmers, with advice on improved environmental practices.

Adaptation interventions that reduce vulnerability to flooding, mainly involve in OECD countries providing flood warning systems, guidance on building flood resilience, and emergency relief and compensation (Figure 3.6 and the OECD questionnaire at www.oecd.org/water). Policies also include adaptation measures which seek to exploit potential synergy in the landscape. Examples include flood management and agri-environment initiatives that combine flood risk management, biodiversity and agricultural livelihoods in floodplains. The creation of washlands and wetlands are examples of this.

National initiatives, such as "Making Space for Water" (**England** and **Wales**), "Space for Rivers" (the **Netherlands**), or **Hungary's** *Improvement of the Vásárhelyi Plan* (Box 3.15), have encouraged a re-appraisal of land management options for floodplain areas. Agricultural land in washlands, polders and flood retention basins may be used for floodwater storage (reservoirs) to mitigate flood risk elsewhere in the catchment. They provide opportunities to deliver multiple benefits, such as floodwater storage and enhancement of biodiversity, and potentially provide alternative sources of income to land managers.

New Zealand has also undertaken a review of its flood risk management policy framework, with emphasis on the need for local and national governments to adapt current practices to prepare for climate change (Box 3.14). The approach of New Zealand to flood management risk, related to agriculture, involves a mixture of regulations, voluntary and other measures, but not economic incentives.

3.5.3. Drought policies and agriculture

As in the case of floods, the evidence is clear that in many OECD countries the incidence and severity of drought events have been increasing over recent decades, with the resulting damaging impacts on agricultural production, as has been the case for floods. The expectation is that such events will occur more frequently in the future due to climate change (Figure 1.2 and the OECD questionnaire at www.oecd.org/water).

National policies that directly address agricultural drought risk management in OECD countries are not widespread, but where they have been adopted include a combination of mitigation and adaptation measures (Figure 3.7 and the OECD questionnaire at www.oecd.org/water). Typically, most countries mitigation measures have taken the form of increasing water retention and storage both on-farm and off-farm (i.e. in terms of improving irrigation infrastructure).

Figure 3.6. Policies regarding flood risk management and agriculture in OECD countries

Policies	Instruments	Countries
MITIGATION		
Regulatory instruments		
Planning	Restrictions in high risk zones	Austria, Finland, France, Ireland, Poland, Portugal, Spain
	Consideration of changes in land use management on runoff	Belgium, the Netherlands, Portugal
Economic incentive measures		
Water retention and storage	Upland runoff retention	Belgium, Finland, France, Poland, Spain
	Lowland water storage: polders, washlands	Austria, Belgium, Czech Republic, France, Hungary, the Netherlands, United Kingdom, United States
	Best management practices (*e.g.* agri-environment schemes)	Czech Republic, France, Greece, Hungary, the Netherlands, Portugal, United Kingdom
	Wetlands	Belgium, Finland, France, Hungary, Poland, Sweden, United States
	Erosion control	Belgium, Czech Republic, France, United States
	Afforestation	Poland, Portugal
Other policy instruments		
Flood defence agricultural areas	Increase flood defence	Belgium, Czech Republic, Greece, Hungary, Poland, Spain
	Withdrawal of flood defence	Austria, Finland, Ireland, United Kingdom
	Land drainage	Poland, Portugal, Sweden
	River restoration	Austria, Canada, France, the Netherlands, Switzerland, United Kingdom
Land use	Lowland water storage: paddy fields	Japan, Korea
ADAPTATION		
Economic instruments		
Compensation mechanisms flood damage	Disaster relief agriculture	Australia, Austria, Belgium, Czech Republic, Finland, France, Greece, Hungary, Italy, Japan, Korea, the Netherlands, Poland, Portugal, United States
	Subsidised crop insurance	Canada, France, Japan, Korea, Poland, Portugal, Spain, United States
	Interest subsidies for loans	Belgium, Poland, Portugal
	Compensation for water retention	Austria, Belgium, Hungary, the Netherlands
Other policy instruments		
Information	Flood risk maps	Austria, Belgium, Japan, Spain
	Warning system	Belgium, Spain, United Kingdom

Source: Adapted from Morris *et al.* (2010), and drawing on the OECD questionnaire at www.oecd.org/water.

Box 3.15. Flood risk management and agriculture in Hungary

Between 1994 and 2004, floods occurred annually except in 1997, 2003, and 2004. The two major rivers, the Danube and the Tisza, overflow their banks every 2-3 and every 1.5-2 years, respectively. Nearly one-half (44%) of the length of principal levees (4 180 km) does not meet regulatory standards for levee height. Former flood plains accommodate one third of all arable land, as well as 32% of railroads, 15% of roads, and over 700 settlements with 2.5 million inhabitants. Four extraordinary flood events have happened in the Tisza River Basin area between 1998-2001, causing considerable damage.

The evaluation of the serial floods made it clear that the approach to flood prevention by heightening and strengthening dykes should be reconsidered. As a result the Hungarian Government launched a programme in 2003, the so called Improvement of the Vásárhelyi Plan (IVP), which aims to increase the discharge capacity of the flood bed together with ecological revitalisation of the floodplain area through reservoirs that can receive flood water. The IVP in addition to its main objective to increase flood safety along the Tisza River, also aims to develop landscape management in the area of the reservoirs, as well as encourage regional, rural and infrastructure development, which may result in social and environmental benefits in the Tisza River Basin.

The reservoirs have been established on low-value, privately owned farmland. In the frame of the IVP the government provides support for establishment of wetland ecofarming, and extensive pasturage in the area of the flood bed and reservoirs, as well as providing other agri-environmental support. Most of the territory of the Tisza-Valley is canalised for conveying water and supplying other rivers (Körös and Szamos). On these rivers there are also reservoirs for flood management and supplying water for irrigation. Payments are also available to the owners whose territories are located on the reservoirs used for flood protection purposes, with farmers eligible for agri-environmental support.

Source: Hungarian government's response to the OECD questionnaire at www.oecd.org/water.

Mitigation measures have also encouraged the adoption of agri-environmental practices that increase soil moisture retention, such as changing cropping systems toward drought resistant crops and the uptake of conservation tillage, as well as providing farm advice and technical guidance to mitigate drought risks. The development of processes for monitoring and evaluating drought situations, supported by research and experimental development, together with technological changes in using water and adapting crops, will play a role in the context of climate change. There have been few policies that directly seek to adapt agriculture to drought risks, leaving aside the widespread use of disaster relief payments and loans.

With growing concerns for the expected increase in drought events under climate change, a number of countries have initiated recent reviews of their existing drought policies. **Canada, Hungary, Turkey** and the **United Kingdom**, for example, are all in the process of examining their national drought policies as they affect agriculture. **Australia** is also undertaking a review of national drought policies, against a backdrop of the worst period of drought impacting agriculture on record (Box 3.16). While in **Spain** several measures have been adopted in response to climate change, as precipitation and runoff patterns have been on a declining trend during the last 20 years compared to the long-term average, especially in dry regions (Box 3.17).

Figure 3.7. Policies regarding drought risk management and agriculture in OECD countries

Policies	Instruments	Countries
MITIGATION		
Regulatory instruments		
Planning, including economy wide level flood protection programmes	National Drought Strategy or Water Efficiency Programme	Australia (under review), Canada (under review), Portugal, United Kingdom
	Water user association and Farm water plan	Netherlands, Turkey
Minimum environmental flows (rivers) and stocks (lakes)	Benchmarking in water channels	Australia, Austria, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, New Zealand (proposed), Poland, Portugal, Spain, Switzerland, UK, US
Irrigation restrictions	Bans on irrigation in times of drought	UK
Economic incentive measures		
Water retention and storage	Off-farm irrigation infrastructure	Australia, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Slovak Republic, Spain, Turkey, United States
	Upgrades of on-farm irrigation/ water storage	Australia, Canada, Greece, Italy, Poland, Portugal, Switzerland, Turkey
	Rainwater storage/capture	Belgium, Ireland, Poland, United Kingdom
	Water recycling in fields or paddy rice fields	Japan, Korea
	Desalinisation	Spain
	Recycled treated sewage	Spain
Soil Moisture retention	Agri-environmental practices (*e.g.* conservation tillage, restoration of terraces, change cropping system)	Canada, Czech Republic, France, Greece, Hungary, Poland, United States
	Wetlands restoration and conservation	All OECD countries, except Turkey,
Other policy instruments		
Farm advisory, farmer technical guidance and education	Farmer advice, technical guidance and educational programmes	Australia, Austria, Canada, Hungary, New Zealand, Portugal, United States
Information	Research	Australia, Austria, Belgium
	Water scarcity indicators	Spain
ADAPTATION		
Economic instruments		
Compensation for drought losses	Disaster relief payments and loans	All OECD countries
Other policy instruments		
Information	Risk management advice	Australia
	Research	Australia, Belgium

Source: OECD Secretariat, drawing on the OECD questionnaire at www.oecd.org/water.

Box 3.16. Australia's comprehensive review of national drought policy

The Australian Government is conducting a comprehensive national review of drought policy. The review includes three separate assessments: the first examines the implications of future climate change for the current Exceptional Circumstances (EC) standard of a one in 20-25 years event, while the other two cover reviews of economic and social aspects.

The Australian Bureau of Meteorology and CSIRO (2008) analysis of the extent and frequency of exceptionally hot years have been increasing rapidly over recent decades and that trend is expected to continue. Further, over the past 40 years (1968-2007), exceptionally hot years are typically occurring over 10-12% of the area in each region, i.e about twice the expected long-term average of 5%. By 2010-40, the mean area is likely to increase to 60-80%, with a low scenario of 40-60% and a high scenario of 80-95%. On average, exceptionally high temperatures are likely to occur every one to two years.

The current Exceptional Circumstance trigger, based on historical records, has already resulted in many areas of Australia being drought declared in more than 5% of years, and the frequency and severity are likely to increase. The principal implication of the CSIRO study is that the existing trigger is not appropriate under a changing climate.

Farmers and their suppliers need user-friendly, reliable and up-to-date location-specific information on historical climatic conditions and future climate variability. Key here is the risk of drought on timescales from seasons to decades. The CSIRO report identifies a number of activities and areas of research for improving information, including:

- Further improvement of drought monitoring capability and maintenance of networks for rainfall and other key climate observations.
- An online climate information system which readily integrates climate change projections with the historical database.
- Participatory studies to more accurately identify the climate change information needs of the different rural sectors.
- Research to improve climate change projections and seasonal-to-interannual forecasts, particularly with respect to specific rural sectors and a localised scale.
- More detailed analyses of projected changes in exceptional climatic events in smaller regions and beyond the next 20-30 years.

In a parallel review of Government Drought Support by the Productivity Commission (2008) some of the key conclusions to emerge to date from this review are that:

- Many Australian farmers and rural communities are experiencing hardship as a result of a severe and prolonged drought. While this is not new to dryland farming, the ‘irrigation drought’ is uncharted territory.
- Australia has always had a variable climate, with drought being a recurring feature. Looking to the future, most agricultural regions need to prepare for higher temperatures and for some, more frequent periods of exceptionally low rainfall.
- Most farmers are sufficiently self-reliant to manage climate variability. In 2007-08, 20% of Australia’s 150 000 farms received drought assistance, totalling over AUD 1 billion, with some on income support continuously since 2002. Even in drought declared areas, most farmers manage without assistance. For instance, from 2002-03 to 2006-07, on average, more than 70% of dairy and broadacre farms in drought areas received no drought assistance.

- All governments agree that the current approaches to drought and *Exceptional Circumstance* declarations are no longer the most appropriate in the context of a changing climate. In marked contrast to the policy objectives, current drought assistance programs are not focussed on helping farmers improve self-reliance, preparedness and climate change management.
- The National Drought Policy should be replaced with expanded objectives for *Australia's Farming Future*. These would recognise that the primary responsibility for managing risks, including from climate variability and change, rests with farmers — underpinned by more appropriate forms of government support.
- Research, development, extension, professional advice and training to improve business management skills can help build farmers' self-reliance and preparedness. These areas warrant significant government funding provided they are well targeted, area appropriate and deliver a demonstrable community benefit.
- Policies relating to water, natural resource management and climate change all impact on farm businesses and local communities and need to be better integrated.

Sources: OECD Secretariat, adapted from the Australian Bureau of Meteorology and CSIRO (2008); Productivity Commission (2008).

Box 3.17. Spanish measures to prepare irrigated agriculture for climate change impacts

In Spain, the precipitation and runoff patterns show a clear decrease during the last 20 years compared to the long-term average, especially in dry regions. Several measures have been adopted as a response to potential climate change.

The river basin Plans currently under preparation, which are the basis for the assignment of water rights to different users, use the short hydrological series which goes from 1980/81 to 2005/6. In addition, the basin Plans include a specific analysis of the potential effect of climate change, taking into consideration a potential decrease in runoff of up to 11%, depending on the basin.

During the period 2006-08 an investment of EUR 2 billion has been made to improve irrigation systems and enhance water savings, covering an area of 876 000 ha. The modernisation schemes include:

- Transforming gravity irrigation systems into pressure systems, allowing an increase of global irrigation efficiency;
- Enabling irrigation system operators to measure volumes and apply volume-based tariffs; and,
- Improving the irrigation system infrastructure (although at present, around 60% of the total irrigated area is equipped with pressure systems).

Drought Management Plans have been prepared for different river basins, including defining an indicator system, and determining objective thresholds and specific measures to be gradually implemented. The indicator and threshold system establishes the starting and ending for a drought, and the severity levels, as well as thresholds of pre-alert and alert to re-assign water resources in situations of shortage and prevent the deterioration of water status. Once the drought event has finished, all practicable measures are taken to restore the water bodies to their previous status. An evaluation of the effectiveness and efficiency of the threshold system and the measures taken is to be undertaken, in order to subsequently revise and update the existing Drought Management Plans.

Source: Personal communication with the Spanish authorities.

3.6. Knowledge and assessment of water resource management in agriculture

The knowledge and monitoring of hydrological, agricultural and environmental linkages is less well developed than have been the advances in water policies. The continuation of this disconnect runs the risk that decision makers are poorly informed and that policies are inadequately implemented and evaluated. These gaps in knowledge, science and monitoring are compounded as agriculture and water resources enter an era of uncertainty, greater variability and higher risks as a result of climate change.

A substantial effort is now underway across most OECD countries to address information deficiencies to better guide policy-making (see the OECD questionnaire at www.oecd.org/water). Encouraging examples are the monitoring of minimum water flow rates in rivers as part of environmental planning in many countries. Moreover, comprehensive river basin assessments are being undertaken, for example, in the EU under the Water Framework Directive and in Australia under the National Water Initiative.

There are five key areas where improvements in knowledge, science and monitoring of water resources in agriculture could help to better inform policy makers and the wider public.

- ***Improving the knowledge of the interrelationships between agriculture and water availability*** and the connection between surface water and groundwater flows.
- ***Increasing effort to establish robust databases on trends in water resource use*** by agriculture, as well data on the sources of water used, improved calculations of the physical and economic efficiency of water use in agriculture, and other information related to on-farm water use and the off-farm environmental consequences where water is recycled into the water system, including better quantifying the net costs and benefits of water resource use by agriculture (Chapter 2.1).
- ***Enhancing the quantity and quality of information on the cost recovery rates for water*** supplied to agriculture (Chapter 3.4.3). At present considerable caution is required in using and comparing data on cost recovery rates and agricultural water charges.
- ***Appreciating that climate change may render historical data on past trends of precipitation and temperature obsolete,*** hence, scientists and decision makers will need to be receptive to this problem in managing agriculture's use of water resources; moreover, policy makers will increasingly need to factor into their decision making the results from the extensive research underway in many OECD countries on climate change, agriculture and water resources (Chapter 3.5 and the OECD questionnaire at www.oecd.org/water).
- ***Encouraging greater evaluation of the cause and effect linkages between policies and environmental and economic outcomes in the context of agricultural water resource management,*** and as a contribution to broader based agri-environmental policy evaluation. Aside from academic research on these linkages, responses from member countries to an OECD questionnaire have revealed that there is little government evaluation of the environmental effectiveness and economic efficiency of agricultural water resource management policies (see the OECD questionnaire at www.oecd.org/water).

While there is a need to focus on the higher level policy settings around cost recovery targets and tariff structures, policy implementation and evaluation requires ***attention to the "soft" infrastructure*** – meters, stream gauging networks, hydrologic and scientific support, water reporting systems, farm surveys, and benchmarking of irrigation water businesses. As the policy settings become more sophisticated, the analysis and evaluation needs to be underpinned by good information (Parker and Speed, 2010).

Water entitlements and trading, moreover, requires real-time management of flows in rivers and detailed monitoring of extractions. In the longer term, a sustainable water entitlement system requires good science on river health and hydrologic performance, as well as assessments of the efficiencies of monopoly water businesses and the consequences of the reforms for agricultural production (perhaps the most important indicator of all). None of this information is obtained cheaply or easily, but without it reforms will falter (Parker and Speed, 2010).

There are also considerable needs for improved information in order that economic principles be put to best use in ensuring orderly maintenance of irrigation infrastructure. ***Information is needed on cost sharing arrangements*** between irrigators and public suppliers of irrigation, impacts on water savings at the project level as well as at the basin scale from infrastructure improvement. Robust data combined with judicious use of economic principles have considerable potential to productively inform decisions on how to best sustain irrigation infrastructure (Ward, 2010).

Notes

1. This chapter draws on responses from member countries to an OECD questionnaire covering water resource management in agriculture, and a number of OECD consultant reports, including: Cakmak (2010); Garrido and Calatrava (2010); Morris (2010); Nickum and Ogura (2010); Parker and Speed (2010); Ward (2010); Wichelns (2010b); and Young (2010), all available at www.oecd.org/water.
2. Discussion of agricultural support draws on Table 3.1; OECD (2008c); and the OECD questionnaire at www.oecd.org/water.
3. The focus of this section is on agriculture and flood risk management, as discussion of climate change projections and agriculture water consumption were examined in Chapter 2.2, while policy experience and responses to situations of agriculture, water scarcity and irrigation were the main focus of Chapter 3.2.

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Sustainable Management of Water Resources in Agriculture

Agriculture is the major user of water in most countries. It also faces the enormous challenge of producing almost 50% more food by 2030 and doubling production by 2050. This will likely need to be achieved with less water, mainly because of growing pressures from urbanisation, industrialisation and climate change. In this context, it will be important in future for farmers to receive the right signals to increase water use efficiency and improve agricultural water management, while preserving aquatic ecosystems.

This report calls on policy makers to recognise the complexity and diversity of water resource management in agriculture and the wide range of issues at stake. And it gives them the tools to do so, offering a wealth of information on recent trends and the outlook for water resource use in agriculture, including the impacts of climate change. It examines the policy experiences of OECD countries in managing their water resources for agriculture, with focus on: the extent to which countries subsidise the supply of water to farmers; flood and drought risk policies; and institutional organisation and governance as it relates to water and the agricultural sector. The report offers concrete recommendations on what countries should be doing and why.

The analysis is supported by data from an OECD questionnaire about agricultural water resource management and by background reports on:

- Agricultural water pricing in Australia, the European Union, Japan, Korea, Mexico, Turkey and the United States
- Financing water management and infrastructure related to agriculture
- Policy issues concerning agriculture's role in flood adaptation and mitigation
- Experiences and lessons from the Australian water reform programme
- Economic analysis of the virtual water and water footprint concepts in relation to the agri-food sector

The questionnaire and reports can be accessed at ***www.sourceoecd.org***, as well as at ***www.oecd.org/agr/env*** and ***www.oecd.org/water***.

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