OECD Studies on Water

Water Quality and Agriculture

MEETING THE POLICY CHALLENGE



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Foreword

This report examines the linkages between agriculture and water quality. It discusses the overall trends and outlook for agriculture and water quality in OECD countries; describes recent actions by policy makers to address water quality issues in agriculture; and provides a set of recommendations for countries to meet the challenge of improving agricultural water quality. In an earlier publication, as part of OECD work on agriculture and water, the linkages between agriculture and water resources were examined in OECD (2010) *Sustainable Management of Water Resources in Agriculture*.

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 OECD Horizontal Programme on Water, including some of the results presented in *Water: Meeting the Reform Challenge* presented at the World Water Forum in Marseille, France, March 2012.

The analysis in this report was enriched by a set of background consultant reports on:

1. *Agriculture and Water Quality: Monetary Costs and Benefits across OECD countries*
2. *Water Quality Trading in Agriculture*
3. *New and Emerging Water Pollution arising from Agriculture*
4. *Agriculture's Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters* (this paper has also been published in OECD (2010) *Advancing the Aquaculture Agenda: Workshop Proceedings).*

These background consultant reports can be downloaded from the OECD website at: *www.oecd.org/agriculture/water*; *www.oecd.org/water*; and *www.oecd.org/fisheries*.

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Key Messages

The key challenges for policy makers in addressing water quality issues in agriculture are to reduce farm contaminant lost into water systems while encourage agriculture to generate or conserve a range of benefits associated with water systems (e.g. recreational use). Water pollutants from agriculture include runoff and leaching into water systems from nutrients, pesticides, soil sediments, and other contaminants (e.g. veterinary products).

The impact of agriculture on water quality is either stable or deteriorating, with few cases where significant improvements are reported across OECD from the mid-2000s to 2010. While the current situation varies within and across OECD countries, agriculture is often the main source of water pollution. Achieving further reductions is a challenge for policy makers, especially as a major part of agricultural water pollution is from diffuse sources.

The overall economic, environmental and social costs of water pollution caused by agriculture across OECD countries are likely to exceed billions of dollars annually. No satisfactory estimate of these costs exists, but the scale of damage to water as a result of agriculture needs to be placed in perspective. For most countries drinking water quality is high with limited health risks and agriculture is only one source of pollution.

The outlook over the next ten years for agriculture and water quality suggests that the growth and intensification of agricultural production could further heighten regional pressures on water systems in some countries. Moreover, the task of achieving water quality objectives in agriculture will become more difficult as a result of climate change.

Over many years policies to address agricultural water pollution across OECD countries have cost taxpayers billions of dollars annually. Policy responses have typically used a mix of economic incentives (taxes and subsidies), environmental regulations (prohibition and specific rules backed by penalties) and farm advice and education (information), but this has had mixed results in lowering agricultural pressure on water systems.

Policies have generally fallen short of requirements to meet water quality policy goals in agriculture based on the report's assessment of recent OECD country experiences. This report provides recommendations which countries could consider to move toward the sustainable management of water quality in agriculture, including:

- ***Use a mix of policy instruments to address water pollution.*** A mix of policy instruments to address water quality issues in agriculture is likely to outperform a single policy instrument, like a pollution tax. There is also increasing use of innovative policy tools, such as water quality trading and agreements between water supply utilities and farmers to reduce pollution and water treatment costs. An increasing emphasis of policies is in changing the behaviour of farmers, the agro-food chain and other stakeholders to improve water quality.

- ***Enforce compliance with existing water quality regulations and standards.*** Inefficiencies and failures in enforcing water pollution regulations is an issue in specific cases. Stricter enforcement of regulations can assist in meeting the Polluter-Pays-Principle, and also lower the burden on government budgetary resources compared to some other policy instruments to address water quality issues.

- ***Remove perverse support in agriculture to lower pressure on water systems.*** Policies that raise producer prices or subsidise input use, encourage farmers to increase production and use more inputs than would be the case in the absence of this support. Some 50% (2008-10) of total OECD agricultural producer support provides incentives to produce and/or use variable inputs, although compares to 85% in 1986-88.

- ***Take into account the Polluter-Pays-Principle to reduce agricultural water pollution.*** Encouraging farmers to internalise their environmental costs through implementation of the Polluter-Pays-Principle (PPP) can bring economic and environmental benefits. But application of the PPP in agriculture is not widespread mainly because diffuse source pollution cannot currently be measured at reasonable cost

- ***Set realistic water quality targets and standards for agriculture.*** Targets can help track progress towards water quality goals in agriculture, but need to be realistic, easily measurable and have a clear time frame.

- ***Improve the spatial targeting of policies to areas where water pollution is most acute.*** Spatial targeting within a water system can have a positive impact on water quality, such as differentiation by livestock density or by farms generating the most pollution in a catchment.

- ***Assess the cost effectiveness of different policy options to address water quality in agriculture.*** It is necessary to consider producer abatement costs and programme monitoring and enforcement costs, compared to the benefits generated by a given policy in terms of improving water quality.

- ***Take a holistic approach to agricultural pollution policies.*** Taking a more holistic view of agricultural pollution policy design can help to avoid adverse environmental effects and encourage co-benefits. For example, the development of riparian buffers which can limit pollutant farm runoff can also provide other benefits in terms of wildlife habitats and carbon sequestration by establishing green cover.

- ***Establish information systems to support farmers, water managers and policy makers.*** Policy makers need considerable technical and socio-economic information about the likely impact (science), costs (financial) and farmer reactions (social) to a given policy change to address water quality. Improving information systems is also critical in supporting farm advisory services to raise awareness of water quality management in agriculture, as typically in many OECD countries farmer awareness that they might be a cause of water pollution is low.

Executive Summary

Challenges for agriculture and policy makers in addressing water quality issues

A major challenge for agriculture is to produce more food, feed, fuel and fibre, to meet growing global demand. Agricultural production also generates effects external to markets, both positive, conserving a wetland, and negative, such as water pollution. As there are no markets for these externalities, although they can provide a great benefit or impose a high cost on society, there is little incentive for farmers to internalise the costs of these external production effects, other than the farmer's own motivation to do so.

The key challenges for policy makers in addressing water quality issues in agriculture are to reduce farm contaminant lost into water systems (negative externalities) while encourage agriculture to generate or conserve a range of benefits associated with water systems (positive externalities). Clean water is vital in securing economic benefits for agriculture and other sectors, meeting human health needs, maintaining viable ecosystems, and providing societal benefits, such as the recreational, visual amenity, and cultural values society attaches to water systems.

Improving water quality is consistently ranked as a top environmental concern in public opinion surveys across most OECD countries. Over decades, policy actions and major investment in OECD countries have helped to drastically reduce water pollution from urban centres, industry and sewage treatment works, with substantial gains for the economy, human health, environment and social values linked to water. In the light of this success focus has now switched in many countries to addressing agricultural water pollution. This is because agricultural water pollution principally originates from farms spread across the landscape (diffuse source pollution), as opposed to more spatially confined sources, such as urban centres and sewage treatment works (point source pollution). But agriculture is also a point source of water pollution, for example, from intensive livestock farms and the disposal of residual pesticides.

Designing policies to control diffuse source agricultural pollution is more complicated than addressing point sources of pollution, because they are: usually invisible due to low concentrations taking diffuse, indirect and often complex pathways into water systems; commonly extremely difficult and costly to measure; generally cumulative in their impact on water systems due to effects of runoff and leaching from large areas; highly variable in space and time because of influences outside of farmers' control, such as the weather and different soils; and, frequently require co-operation and agreement across sub-national jurisdictions (sub-catchments and catchments) and national borders.

Overall trends and outlook for agriculture and water quality in OECD countries

Water pollutants from agriculture include runoff and leaching into water systems from using and disposing of nutrients (inorganic fertilisers and livestock manure) and pesticides, soil sediments, and other contaminants (e.g. veterinary products). These

pollutants can lead to the: harm of aquatic ecosystems; damage to commercial freshwater and marine fisheries as well as farms and other industries; reduction of social values associated with water systems, such as swimming and waterscapes; and impair human health through contaminated drinking and bathing water, although this is less of a concern for most OECD countries.

The impact of agriculture on water quality is either stable or deteriorating, with few cases where significant improvements are reported, according to a review of OECD country studies from the mid-2000s to 2010. This marks a change from an earlier period, 1990 to the mid-2000s, when an OECD study concluded there was an overall slight reduction in agricultural pressure on water systems. While the current situation varies both within and across OECD countries, agriculture is often the main source of water pollution. As absolute pollutant levels remain high in many areas, achieving further reductions is a challenge for policy makers, especially as a major part of agricultural water pollution is from diffuse sources. But point source agriculture pollution is increasing in some locations, largely from intensive livestock farms.

There has been an overall increase in the uptake of farm management practices and systems beneficial to water quality, to a large extent encouraged by recent policy changes across many OECD countries. This is mainly because of the effort to decouple farm support from production and the strengthening of agri-environmental programmes with a positive effect on water quality, both in terms of the numbers of farmers and the agriculture land area covered under these programmes.

The disconnect between modest changes in the state of water quality linked to agriculture but higher adoption rates of farm practices and systems beneficial to water quality, can be explained, in part, by time lags and rising commodity prices. A time lag is the period elapsed between adoption of management changes by farmers and the detection of improvement in the quality of a specific water system. This can take from hours to decades depending on the site and type of pollutant. Also recent rises in agricultural commodity prices, projected by OECD/FAO to continue over the next ten years, may have slowed or even reversed the upward trend in adopting management practices beneficial to water quality, as farmers intensify production and/or extend production onto marginal land increasing risks of water pollution. At the same time, however, rising chemical input prices (fertilisers, pesticides) can have a counter-effect, by inducing farmers to use less of these inputs assuming no other changes in farm costs/output prices.

The overall economic, environmental and social costs of water pollution caused by agriculture across OECD countries are likely to exceed billions of dollars annually. No satisfactory estimate of these costs for all OECD countries currently exists. A comprehensive national study in the United Kingdom, however, has shown that in 2007 the annual cost of agricultural damage to water systems (pollution of freshwater, estuaries and drinking water treatment costs) was around EUR 330 million (USD 460 million).

The scale of damage to water systems as a result of agriculture needs to be placed in perspective. For most OECD countries drinking water quality is high with limited health risks, but removing pollutants from drinking water supplies is costly, and in some rural areas unconnected to water networks, health concerns can be important. Also agriculture is not the only source of water contamination, but is becoming a widespread cause of eutrophication of water systems, leading to rising economic, environmental and social costs. There is also concern with emerging contaminant pollution of water from

agriculture (e.g. veterinary medicines) and the effects of pollutant mixtures (e.g. pesticides and other chemicals) for human health and the environment.

The outlook over the next ten years for agriculture and water quality suggests that the growth and intensification of agricultural production in North America, Turkey, Korea, Australia and New Zealand, could further heighten regional pressures on water systems. For the EU27 the projected modest growth in agricultural production is likely to lower pressure on water systems, while for Japan this trend might be more pronounced as production could decrease, but localised water pollution "hotspots" could come under further pressure from intensive livestock farming. A number of future developments may help all countries to reduce the pressure of agriculture on water systems, including advances in technology (e.g. higher fertiliser use efficiency); improvements in farm management; and ongoing reforms of agriculture and water policies.

The future consequences of climate change for agriculture and water quality linkages are complex. The anticipated increased incidence and severity of flooding could mobilise sediment loads and associated contaminants and exacerbate impacts on water systems, while more severe droughts may reduce pollutant dilution, thereby increasing toxicity problems. But whatever the impacts on water systems, the task of achieving water quality objectives in agriculture will become more difficult in the coming years as a result of climate change, although this is a poorly understood and researched aspect of climate change science to date.

Recent actions by policy makers to address water quality issues in agriculture

Policy responses to address agricultural water pollution across OECD countries typically use a mix of economic incentives, environmental regulations and information instruments. A large range of measures are deployed at the local, catchment, through to national and transborder scales, across an array of different government agencies. Many measures to control water pollution from agriculture are voluntary. Water supply utilities and the agro-food chain are also engaged in co-operative arrangements with farmers to minimise pollution, such as providing farm advisory services.

This policy mix has had varying results in lowering agricultural pressure on water systems. Over many years these policies, according to OECD estimates, have cost taxpayers billions of dollars annually. For some countries policies to reduce agricultural water pollution have been successful, with a package of input taxes, payments and farm advice. In other cases despite substantial expenditure on efforts to lower agricultural pollution of a specific water ecosystem, little progress has been made. More recently, some private and public initiatives, for example, water quality trading in agriculture and establishing co-operative agreements to address water pollution are showing signs of success, albeit on a limited scale to date.

Policies have generally fallen short of requirements to meet water quality policy goals in agriculture based on the OECD assessment of recent country experiences. It would appear this is mainly due to: inefficiencies and failures in the development, implementation and enforcement of regulations to control agriculture pollution; increasing budgetary costs of policies that provide support to farmers to control water pollution in specific areas; frustration with the protracted time and institutional complexities to adopt new policy approaches; lack of comprehension of the scale and temporal dimensions of diffuse source agriculture water pollution; and, insufficient attention to establish a more inclusive consultation process and stakeholder involvement.

Policy recommendations in moving toward the sustainable management of water quality in agriculture

To meet the challenge of the sustainable management of water quality in agriculture requires a high level of political commitment and common vision among stakeholders. In this regard, the role of politicians is critical, as they are key players in promoting agriculture and water policy reforms, and can explain the impacts of reforms to society at large. There are often trade-offs between investing in short-term projects with an immediate effect and undertaking actions that can have a larger and longer-term impact, such as investing in research and data collection to improve decision making. Farmers and other stakeholders will also need to develop a common vision, agree shared values, and make collective decisions to manage water quality together, involving integration of all relevant stakeholders. Tradeoffs can then be initiated between different interests, openly and transparently, to move toward sustainable solutions. Based on the analysis of this report a number of recommendations are listed below, which countries could consider in their endeavour to move toward the sustainable management of water quality in agriculture.

Use a mix of policy instruments to address water pollution

A mix of policy instruments (economic incentives, regulations and information) to address water quality issues in agriculture is likely to out-perform a single policy instrument, like a pollution tax, especially where there are multiple impediments to adoption of pollution abatement practices. Each policy instrument has strengths and weaknesses that depend on the specific physical and economic context of the polluted area. The sequencing of policy instruments, starting with suasion and ending with enforcement, is likely to be as important as the policy mix and the targeting of the major polluters. Policies addressing water pollution in agriculture should also be part of an overarching national water policy framework, with all pollutants and polluters considered together, as agriculture is not the only source of water pollution.

There is increasing interest in using innovative policy tools and market approaches, because of growing difficulties in some regions to lower the pressure of agriculture on water systems by relying on the traditional mix of policies. These tools and approaches, albeit not widely used to date, mainly include: economic instruments, especially water quality trading; voluntary regulation supported by payments in some cases, such as between water supply utilities working with farmers to ensure improved water quality to reduce pollution and water treatment costs; information based instruments, like organic standards; and capacity building, such as setting environmental standards by agro-food chain companies, backed by farm advisory services, to encourage best management practices to protect water quality and meet other environmental goals.

A key focus in increasing the uptake of the policies, approaches and practices is in changing the behaviour of farmers, the agro-food chain and other stakeholders to improve water quality by: engaging different actors to address the problems of water quality from farm to water catchment level; enabling change by educating and raising the awareness of farmers and building the capacity of other stakeholders in a water catchment in the realisation of policy goals; encouraging desirable forms of behaviour and discouraging undesirable forms; and, ensuring that minimum standards of water quality are met.

Enforce compliance with existing water quality regulations and standards

Inefficiencies and failures in enforcing water pollution regulations is an issue in specific cases. While regulations are a widely used policy instrument to limit water pollution, there are cases where point sources of agricultural pollution, notably intensive livestock operations, are not covered under water pollution regulations that are applicable to all other causes of point source pollution, such as sewage works. Where non-compliance is widespread, the on-farm inspection of compliance could be improved and sanctions and penalties more effectively imposed, including the withdrawal of agri-environmental payments where applicable. Stricter enforcement of regulations can assist in meeting the Polluter-Pays-Principle, and also lower the burden on government budgetary resources compared to some other policy instruments to address water quality issues.

Remove perverse support in agriculture to lower pressure on water systems

Policies that raise producer prices or subsidise chemical input use, encourage farmers to increase production, use more inputs, and farm more fragile lands than would be the case in the absence of this support. Some 50% (2008-10) of total OECD agricultural producer support provides incentives to farmers to produce and/or use variable inputs, although this is a sharp reduction from the 85% share in 1986-88. Production and input support, fail to recognise the biophysical heterogeneity of farmed landscapes, leading to a mismatch between the capacity of the environment to absorb pollution and the intensity of agricultural production. The removal of perverse incentives in agriculture will lower pressure on water systems.

Take into account the Polluter-Pays-Principle to reduce agricultural water pollution

Encouraging farmers to internalise their environmental costs through implementation of the Polluter-Pays-Principle (PPP) can bring economic and environmental benefits. But application of the PPP in agriculture is not widespread across OECD countries mainly because: diffuse source pollution cannot be measured at reasonable cost with current monitoring technologies; there is poor enforcement of water pollution regulations in many situations; and also due to property rights, institutional and other barriers. Even so, where high levels of taxes have been applied to chemical inputs to comply with the PPP, often coupled with a mix of other policy measures, they have usually led to reductions in input use without loss of farm production or income.

Set realistic water quality targets and standards for agriculture

Targets can help track progress towards water quality goals in agriculture, but need to be realistic, easily measurable and have a clear time frame A target needs to take into account the balance between the marginal costs of adopting a farm practice or change to achieve the target and the marginal benefits of a given water quality improvement. Also water quality standards should be consistent with known biophysical responses, taking into account time lags between the introduction of a practice and measurable outcomes, as well as the difficulties of measuring and establishing the origin of agriculture diffuse source pollution.

Improve the spatial targeting of policies to areas where water pollution is most acute

Spatial targeting within a water system can have a positive impact on water quality, such as differentiation by livestock density or by farms generating the most pollution in a catchment. The spatial targeting of policies should be designed so that the specific policy instrument choice is sensitive to local conditions. Land retirement policies, for example, can be a blunt instrument to improve water quality, as they may primarily be focussed on other policy objectives, such as biodiversity conservation. They may help slow soil erosion rates, but do not require changes to management practices on other land under production that continues to contribute to water pollution. Some programmes target land under production which is not always the main source of pollution, while voluntary and farmer initiated participation may not reach the major polluters.

Assess the cost effectiveness of different policy options to address water quality in agriculture

It is necessary to consider producer abatement costs and programme monitoring and enforcement costs, compared to the benefits generated by a given policy in terms of improving water quality. Evidence from some countries shows that expenditure on reducing agricultural pollution has not been cost-effective and that incentive schemes to enhance compliance have been inadequately targeted. The cost of different policy options depends on the: specific farm practices chosen; the scale from farm to national or transborder level; and the selected policy tools. Determining the cost-effectiveness of different policy options to deliver water quality benefits, enables a more informed discussion about what can be achieved environmentally, and also about the agricultural production and environmental trade-offs in achieving those benefits.

Take a holistic approach to agricultural pollution policies

Taking a more holistic view of agricultural pollution policy design can help to avoid adverse environmental effects and encourage co-benefits. Illustrative is where a farmer to meet water quality regulations reduces the nutrient content of manure spread on fields by releasing more nitrogen from stored manure into the air as ammonia. Some policy approaches to abate water pollution can have co-benefits with other environmental goals, such as the development of riparian buffers which can limit pollutant farm runoff but provide other benefits in terms of wildlife habitats and carbon sequestration by establishing green cover.

Establish information systems to support farmers, water managers and policy makers

The linkages between agriculture and water quality are complex. Policy makers need considerable technical and socio-economic information about the likely impact (science), costs (financial) and farmer reactions (social) to a given policy change to address water quality. Estimating the economic costs and benefits from agriculture on water systems can also help in this regard, by defining the scale of different problems for farmers and policy makers and focusing policy responses. Improving knowledge and information systems is also critical in supporting farm advisory services to raise awareness of water quality management in agriculture, as typically in many OECD countries farmer awareness that they might be a cause of water pollution is low.

Chapter 1

Linking policies, farm management and water quality

A major challenge for agriculture is to produce more food, feed, fuel and fibre, to meet growing global demand. Agricultural production also generates effects external to markets, both positive, conserving a wetland, and negative, such as water pollution. As there are no markets for these externalities, although they can provide a great benefit or impose a high cost on society, there is little incentive for farmers to internalise the costs of these external production effects, other than the farmer's own motivation to do so. The key challenges for policy makers in addressing water quality issues in agriculture are to reduce farm contaminant lost into water systems while encourage agriculture to generate or conserve a range of benefits associated with water systems. Clean water is vital in securing economic benefits for agriculture and other sectors, meeting human health needs, maintaining viable ecosystems, and providing societal benefits, such as the recreational, visual amenity, and cultural values society attaches to water systems.

1.1 The challenge

High-quality water resources are vital not only in securing human health and maintaining ecosystems, but also in providing amenity, recreational, visual and other benefits. Over recent decades, major investment across OECD countries has helped to drastically reduce pollution from urban centres, industry and sewage treatment works, with substantial gains in improving the quality of rivers, lakes, reservoirs, estuaries and coastal waters.

With the achievement in reducing industrial, sewage and other "point" sources of pollution, focus has switched in many OECD countries to lowering diffuse source agricultural pollution. This is because water pollution from agriculture mainly originates from diffuse sources with many crop and livestock farms spread across agricultural landscapes. With structural changes in the livestock sector toward larger more intensive units and disposal of residual pesticides, however, agriculture is also contributing to point source pollution (Box 1.1).

In addressing water pollution in agriculture, governments over the past 20-30 years, but also water utilities and agro-chemical companies, have provided substantial support to the sector, introduced regulations and provided farmers with technical advice. While these efforts have resulted in some progress in lowering agricultural pressure on water systems, they have generally fallen short of what is required to meet policy goals. These goals include the need to improve the natural environment, lower drinking water treatment costs, protect public health and reduce costs to farmers through the inefficient use of pesticides and the lost of nutrients and soil into water bodies (Dexter *et al.*, 2010; Morton and Weng, 2009; Shortle *et al.,* 2012; Smith and Porter, 2009).

The public, as well as governments, water utilities and many actors along the agro-food chain attach high importance to the challenge of improving water quality in agriculture. In the **United States**, for example, an annual national public opinion survey from 1989 to 2009 has consistently ranked water pollution as one of the top environmental concerns from a list including climate change, loss of rain forest, air pollution, etc. (Gallup, 2008). A similar opinion poll in the **European Union** in 2009 showed comparable results to those of the United States (European Commission, 2009).

This report examines OECD countries' experiences with policies and other approaches to address issues related to water quality in agriculture. Drawing on these experiences the report provides a set of recommendations that could help countries move toward a more sustainable path of managing water quality in agriculture, to the benefit of farmers, human health, water treatment companies, and the wider public in terms of ecosystem, recreational, visual and other social benefits.

The narrative of the report, following this introductory chapter, continues in Chapter 2 by examining the main water quality trends and outlining the medium-term outlook, including the likely consequences of climate change for agricultural and water quality linkages. Chapter 3 defines the scale of water quality issues in agriculture by providing a review of monetary economic, social and environmental cost and benefit estimates.

Chapter 4 describes which policy instruments and mixes OECD countries use to address water quality issues associated with agriculture. Chapter 5 examines policy experiences in reducing diffuse source pollution from agriculture, including: addressing nitrate pollution from agriculture in the **European Union**; restoring the Chesapeake Bay

in the **United States**; reducing salinity in **Australian** agriculture; experimenting with water quality trading in **New Zealand**; improving research on diffuse source pollution in **France** and the **United Kingdom**; reforming governance to address social concerns with water quality in **New Zealand**; addressing transborder pollution control for countries surrounding the **Baltic Sea**; and establishing co-operative agreements in **France, New Zealand, United Kingdom**, and the **United States** to address diffuse source pollution. In Chapter 6 policy reforms and opportunities to move toward sustainable management of water quality in agriculture are identified.

The organising framework for this report is captured in Figure 1.1. The figure reveals the complex interactions and linkages between policies, markets and environmental conditions on farming systems, farm practices, farm input use and farm outputs, with implications for the state of the water system from streams, groundwater to deep seas, which in turn impacts on the quality of the water system in terms of human health, social benefits (e.g. recreational uses), commercial fishing and environmental attributes (e.g. ecosystems). Depending on the trends in the state of water quality this will feed back into possibly provoking a policy and/or market response.

Box 1.1. Diffuse and point source pollution from agriculture

Sources of water pollution are generally distinguished as point or diffuse (sometimes referred to as nonpoint) according to the pathways the pollutants or their precursors follow from the place of origin (e.g. a farm) to the receiving water system. Pollutants from point sources are discharged directly into receiving waters at discrete identifiable locations, such as large confined intensive livestock operations, sewage treatment works and industrial sites.

Pollutants from diffuse sources follow indirect, diffuse, and often complex pathways to water bodies. Diffuse sources can sometimes be converted to point sources by collecting and channelling diffuse emissions when technically and economically feasible. Agriculture contributes to both point and diffuse pollution. Runoff from fields and pollutants leaching into groundwater, for example, exemplify diffuse pollution. Discharges of animal wastes from pipes or ditches into streams, and disposal of residual pesticides into drains, for example, illustrate point source pollution.

The distinction between point and diffuse sources of pollution can also be a function of law. For example, confined animal operations in the United States are regulated as point or as diffuse sources depending on the size of the facilities. Large confined animal operations are treated as point sources and required to have and comply with point source discharge permits.

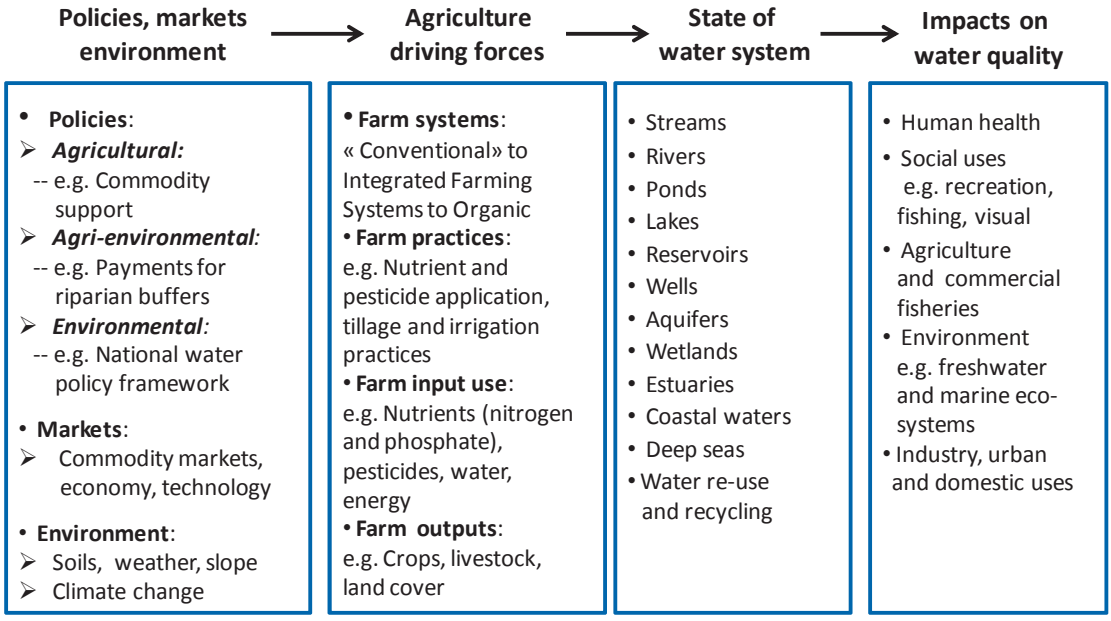
While point sources are usually cost effective to monitor and regulate, the control of diffuse sources of agricultural pollution are more complicated to measure and control mainly because: emissions are spatially and temporally highly variable; there are a large number of farmers, increasing transaction costs of policies to control pollution; and because pollution control may require co-operation and agreement across different sub-national jurisdictions or countries.

Sources: Adapted from Ribaudo, M. (2009), "Non-point Pollution Regulation Approaches in the U.S.", in J. Albiac and A. Dinar (eds.), *The Management of Water Quality and Irrigation Techniques,* Earthscan, London, pp. 83-102; Roberts, A.M, et al., (2010), Agricultural land management strategies to reduce phosphorus loads in the Gippsland Lakes, Australia, Working Paper 1011, 28 July, School of Agricultural and Resource Economics, The University of Western Australia, *www.are.uwas.edu.au;* and Shortle, J. (2012), *Water Quality Trading in Agriculture,* OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

It is beyond the scope of this report to examine all the linkages and feedbacks shown in Figure 1.1. Instead, the remainder of this chapter briefly examines those elements of Figure 1.1 that are important to the main focus of the report in terms of policy design, choice and mixes in addressing water quality issues in agriculture, including the following.

- Polluter-Pays-Principle.
- The policy mix and interactions affecting water quality in agriculture, including agricultural, water and environmental, and agri-environmental policies.
- Farm management practices and hydrological properties and processes.
- Challenges in the interaction between farm management and water quality.

Figure 1.1. Linkages between policies, agriculture driving forces and the state and impact on water quality



1.2 The Polluter-Pays-Principle

Agriculture produces marketed goods such as food, feed, fibre and fuel, but also generates a number of effects felt externally to any market. Some of these external effects, such as taking land out of production can generate positive externalities to the benefit of society, including the provision of wetlands, wildlife and water quality services. Others are costly to society producing negative externalities, such as water pollution.

As there are no markets for these externalities, a farmer's motivation to provide ecosystem services (either increasing positive services or reducing negative ones) are based on their own personal preferences rather than the value society places on them. It is important to note that farmer's motivations are more complex than simply profit maximisation and may sacrifice some potential income to either enjoy some ecosystem services on their farms, such as maintaining high quality water to fish or for livestock to

drink. Without markets, however, there is likely to be a sub-optimal provision of ecosystem services by farmers from society's perspective (Moxey, 2012; Ribaudo *et al.,* 2010a; Weersink and Livernois, 1996).

As a general principle of environmental policy to avoid this market failure and ensure polluters (e.g. agriculture) internalise the costs of their pollution, the OECD in 1972 adopted the Polluter-Pays-Principle (PPP) stating that (OECD, 1972):

> *The principle to be used for allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so-called "Polluter-Pays-Principle". The principle means that the polluter should bear the expenses of carrying out the above mentioned measures decided by public authorities to ensure that the environment is in an acceptable state. In other words, the costs of these measures should be reflected in the cost of goods or services which cause pollution in production and/or consumption. Such measures should not be accompanied by subsidies that would create significant distortions in international trade and investment*.

In its simplest form, the PPP can be expressed as *"Those who generate pollution should bear the costs that the pollution imposes on others."* While this is conceptually sound in terms of both equity and economic efficiency, it is politically and practically difficult to apply the PPP to every instance of pollution, because the regulatory burden would be immense for both governments and resource users. Hence, governments have to decide in what circumstances to apply the PPP, and what principles should apply to those decisions. Already in the early 1990s the OECD PPP evolved from a narrow "no subsidy" principle to a broader principle for internalising the environmental damage costs. Hence, the benchmark of the PPP is environmental damage rather than determination of an acceptable state.

In the case of agriculture this discussion also hinges around the reference level, which defines the point at which the environmental effects of agriculture change from "harm", necessitating remedial action by those responsible, to an environmental "benefit" for which the provider should be rewarded. Reference levels can be specified in many ways including input controls, specified farming or land management practices or maximum emission or pollution levels. The specific mechanism for setting reference levels, choosing from a broad range of policy instruments, is a country prerogative (OECD, 2007).

Defining reference levels does not have to mean entrenching the *status quo* and freezing impacts at their current level. This would only occur if reference levels were made synonymous with full and absolute property rights. These notions can be kept separate by making it clear that government reserves the right to change reference levels over time as technology, understanding of environmental effects, and public expectations evolve, taking due account of the need of farmers and other resource users for a degree of regulatory certainty (Farnese, 2010).

If set at the *status quo*, reference levels require no action by government other than monitoring, but do not reduce diffuse source pollution. Governments that set reference levels more stringent than the current discharge level impose a cost on the farming sector and will attract negative responses, i.e. political opposition and possibly non-compliance.

Establishing reference levels that impose restrictions raises equity issues as well as incurring potentially significant transaction costs (Smith and Tomasi, 1995). There is an optimal level of diffuse source pollution below which the transaction costs of addressing these externalities (and defining a property right) exceed the benefits of doing so. In sum, internalisation of environmental costs through implementation of the PPP can improve economic efficiency as long as transaction costs do not exceed the benefits of regulatory intervention.

1.3 The policy mix and interactions affecting water quality in agriculture

There are three broad policy types that influence farmers decision choice on management practices and systems and their use and management of farm inputs and waste, which in turn affect the state of and impacts on water quality, including (Figure 1.1): overall agricultural policies; water and environmental policies; and agri-environmental policies (this policy discussion is further elaborated in Chapters 4 and 5).

Agricultural policies

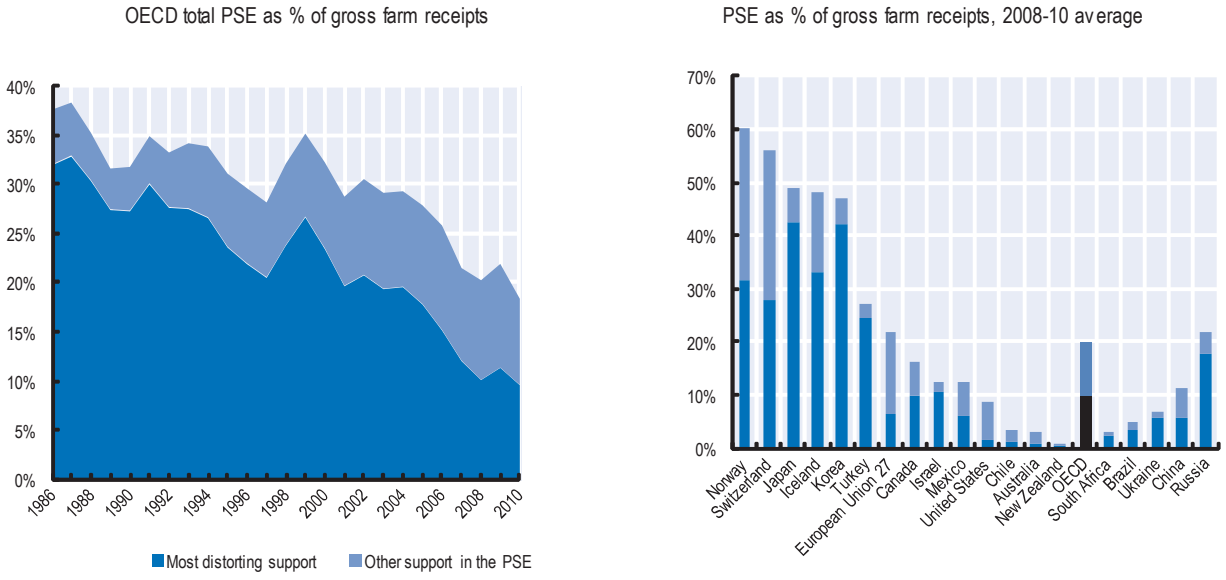
Reform in agricultural support policies across most OECD countries over the past 20 years have had a significant influence in lowering the overall pressure on water systems than would otherwise be the case in the absence of these policy reforms, including:

- ***Reduction in the overall level of support to farmers.*** In 2008-10 support to producers in OECD countries was estimated at almost USD 250 million (around EUR 180 billion), as measured by the Producer Support Estimate (PSE) (OECD, 2011a). The PSE fell from 37% of farmers' total receipts in 1986-88 on average to 20% in 2008-10, to a large extent due to lowering border protection and budgetary support to agriculture (Figure 1.2). Policies that increase producer prices or subsidise input use (e.g. pesticides, fertilisers) without restricting output encourage farmers to increase production, use more inputs, and farm more fragile lands (Shortle *et al.,* 2012).

  But the opportunity costs of improving the environment, including water pollution, are higher than they need be while support levels remain at current levels. Also production and input support policies by providing homogenous incentives across agriculture, fail to recognise the biophysical heterogeneity of agricultural landscapes, leading to a mismatch between the intrinsic capacity of the environment to absorb pollution and the intensity of agricultural production. This leads to pollution hotspots where inappropriate land use and management is practised in environmentally sensitive landscapes (Johnes, 2007). Agricultural commodity support can also act as a disincentive for farmers to participate in voluntary land and water conservation programmes (National Research Council, 2008). Rising commodity market prices may also provide a disincentive for farmers to participate in these programmes.

- ***Change in the way support is delivered toward support more decoupled from production.*** The ways in which support is provided to farmers have also changed (Figures 1.2 and 1.3). OECD governments are gradually shifting to support that is more decoupled from current production and which gives greater freedom to farmers in their production choices. Support is increasingly being tied to parameters other than commodity output, such as area or animal numbers, and with respect to historic levels of these parameters (OECD, 2011a).

Figure 1.2. Trends in total support and the composition of support



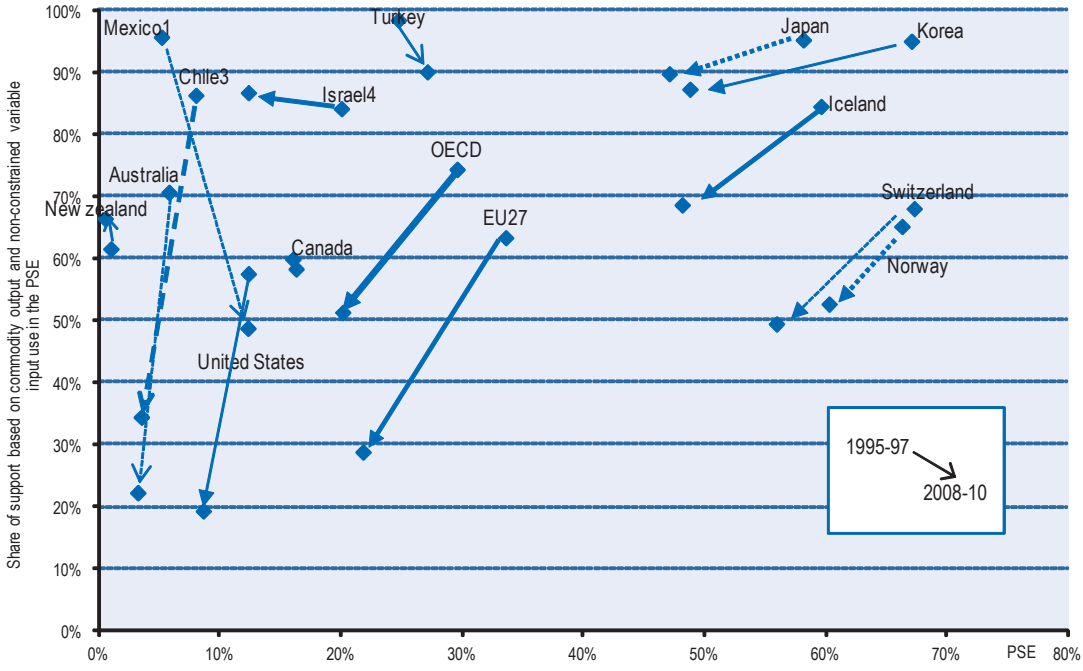
Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD, *PSE/CSE database*, 2011.

- ***Development of environmental conditionality*** (cross compliance). Support is also becoming more tied to certain conditions, as well as decoupled from production and input use. Producers, if they want to receive support, are now more often obliged to contribute to improvements, for example, in the environment, rural amenities, or better treatment of animals. In 2006-08, over 30% of support to OECD farmers had some such conditions attached to it, whereas in 1986-88 this share was only 4% (OECD, 2010a).

Increasing use of environmental conditionality (cross compliance) that links the provision (withdrawal) of support payments to the requirement they meet a number of specified conditions related to their environmental performance, is being used toward addressing water pollution problems in agriculture (Grundy and Barson, 2010; OECD, 2010b; 2011b; 2011c). The conditionality provision can also be linked to broader environmental policies and agri-environmental payments discussed below.

Figure 1.3. OECD: Changes in the level and composition of producer support



Note: The level of support is presented by the percentage PSE. The composition of support is presented by the share in gross farm receipts of Market Price Support, Payments based on output and Payments based on non-constrained variable input use.

1. For Mexico, the change is measured between 1996-98 and 2008-10.

2. EU15 for 1995-2003; EU25 for 2004-06 and EU27 from 2007.

3. For Chile, change is measured between 1997-99 and 2008-10.

4. For Israel, change is measured between 1997-99 and 2008-10.

5. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: OECD, *PSE/CSE database,* 2011.

Water and environmental policies

Water and environmental policies across OECD countries have historically largely resorted to regulations to control water pollution through emissions limits applied to industrial and municipal point sources of pollution. In most instances this regulatory approach achieved considerable success in reducing point sources of pollution, with the same type of approach extended to agricultural point sources of pollution, especially intensive livestock operations (Shortle, 2012). Environmental policies have also generally provided the regulatory framework for registration, handling and disposal of pesticides and some emerging contaminants in agriculture (e.g. pharmaceutical products for livestock), as part of broader and long standing environmental policies focusing on chemicals (Box 4.3).

In the **United States**, for example, large confined animal feeding operations (CAFOs) have been subject, under the overarching *Clean Water Act,* to the same types of federal regulations as industrial and municipal point sources of pollution for the past decade (Ribaudo, 2009). Moreover, to defray the costs of meeting federal regulations farmers can apply for financial assistance under the *Environmental Quality Incentives Program* (EQIP) to help develop and implement nutrient management plans, such as constructing suitable manure handling and storage facilities (Key, McBride and Ribaudo, 2009). Similarly in the **European Union,** under the *Integrated Pollution Prevention and Control Directive* large livestock facilities need a permit to comply with environmental emission standards (Oenema *et al* 2009). Even so, the number of farms regulated as point sources is generally a small proportion of the total number of farms, with CAFO's in the **United States**, for example, accounting for only 1% of US farms (Shortle, 2012).

With the reduction in point source pollution, policy focus is shifting to lowering the impact of diffuse sources on water quality (Graham, Schempp and Troell, 2011). As a consequence environmental agencies are increasing their attention to addressing diffuse source pollution in agriculture, with a number of recent developments across OECD countries which are important for agriculture and water quality:

- While many countries have an overarching national water policy, covering water quality and quantity, the burden for implementing it is usually devolved to the state/provincial level (e.g. **Australia, Canada, Japan, United States**) or countries (e.g. **European Union**'s *Water Framework Directive*) with oversight and some support often provided through Environment Ministries. Some countries have no national water policy or are in the process of developing a national policy strategy (e.g. **Chile, New Zealand**). Regulatory oversight for water pollution, including agriculture, usually involves a vast array of agencies operating at different spatial scales from the farm through to International Environmental Agreements.
- To date use and enforcement of regulations to control diffuse source agricultural water pollution is limited compared to the experience of the use of regulations for point source pollution (Dexter *et al.,* 2010; Shortle, 2012). Where regulations are used they are frequently tied to the provision of agri-environmental payments in terms of following best management practices (Chapter 4.2).
- There has been increasing focus in the role of agriculture in International Environmental Agreements concerned with water pollution, especially as it relates to the eutrophication of international waters, for example, the Great Lakes (**Canada-United States**) and the countries surrounding the Baltic Sea, including a number of **EU countries** (Chapter 5.7).

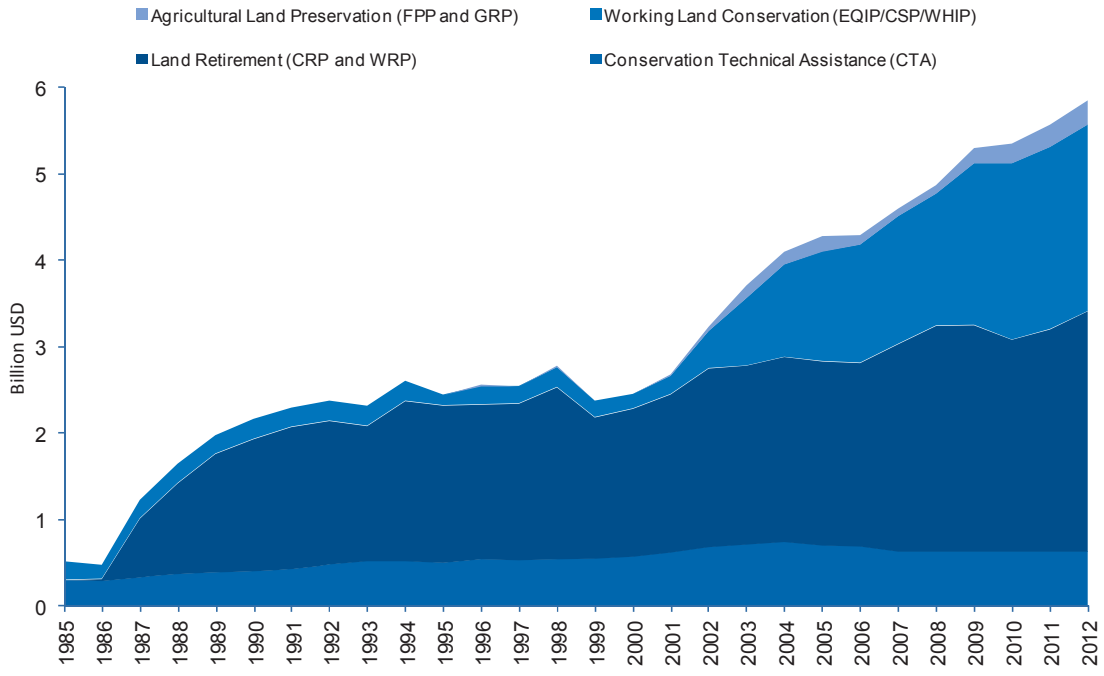
The water quality gains that have been achieved through national environmental policies have been overly expensive in many instances because the regulatory framework has not allowed point sources of pollution to use offsets from other point sources or from diffuse sources to help meet their regulatory limits, and because of constraints on technological choices in pollution permits (Shortle, 2012). A **United States** Environmental Protection Agency (USEPA) study estimated annual savings of nearly a billion dollars could be achieved from pursuing water quality goals using approaches, such as water quality trading, that encourage efficient emissions allocations among and between point and diffuse sources (US Environmental Protection Agency, 2001) (Chapters 4 to 6).

Agri-environmental policies

Agricultural policy reforms in OECD countries have seen a shift toward more decoupled support, as noted above, including the use of agri-environmental policies (AEPs). There has been a substantial increase across most OECD countries in the application of agri-environmental and natural resource management policies, commonly with the use of payments supported by regulatory instruments and technical advice to farmers (Chapter 4). This is illustrated with the expansion in agri-environmental payments in the **United States** (Figure 1.4); the development of environmental conditionality within the **European Union**'s *Common Agricultural Policy* (Table 1.1); and the increasing budgetary expenditure under **Australia's** *Natural Resource Management* measures (Figure 1.5) (Chapter 5.3).

AEPs, among other environmental objectives, are widely used to control water pollution, both directly, such as payments for riparian buffer strips and livestock manure storage facilities, and indirectly, including programmes aimed at soil conservation and extensification of farming. The use of AEPs has generally been in contrast to national environmental policies to address water pollution, with the emphasis on voluntary uptake of measures and with farmer adoption encouraged by payments. This relates, in particular, to the difficulties of developing policy approaches to address diffuse source pollution in agriculture (Chapter 5).

Figure 1.4. Trends in the United States Agri-environmental Conservation Payments: 1985-2012



Notes: Agricultural Land Preservation: FPP – Farmland Protection Program, GRP – Grassland Reserve Program; Working Land Conservation: EQIP – Environmental Quality Incentives Program, CSP – Conservation Stewardship Program, WHIP– Wildlife Habitat Incentives Program; Land Retirement: CRP – Conservation Reserve Program, WRP – Wetlands Reserve Program; Conservation Technical Assistance: CTA – Conservation Technical Assistance Program.

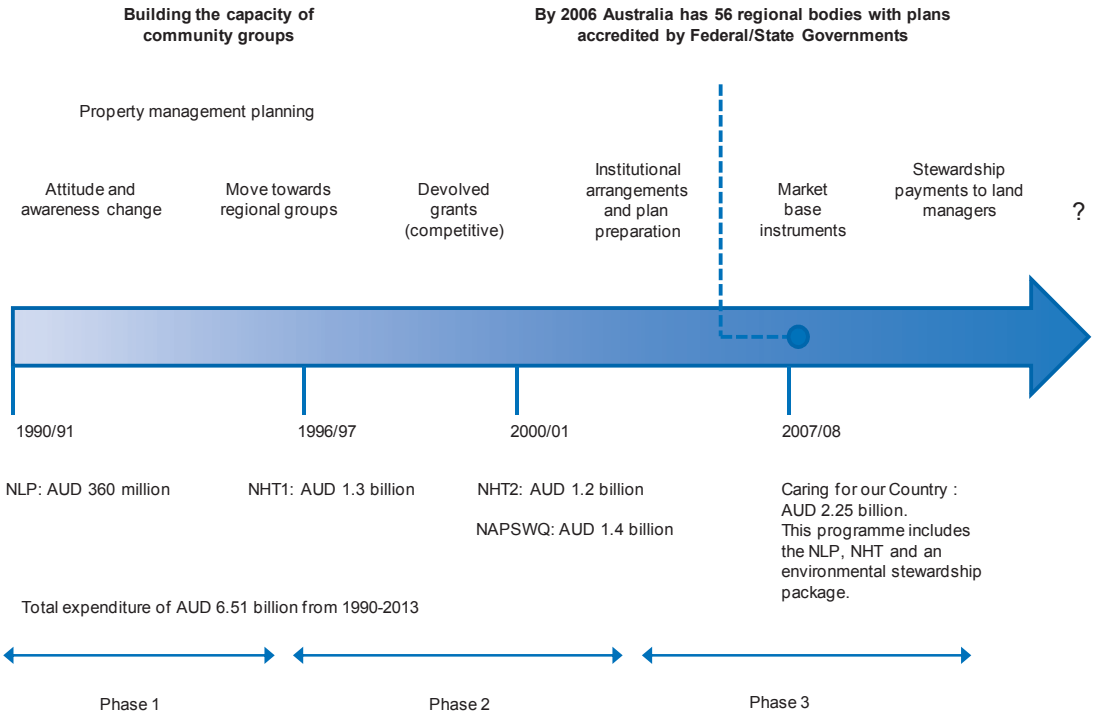
Source: OECD (2011), *Evaluation of Agricultural Policy Reforms in the United States*.

Table 1.1. The development of environmental conditionality in the EU's Common Agricultural Policy

Date	Type of support	Sectors	Conditionality
1992 MacSharry CAP Reform Implemented from 1994	Livestock headage payments; Set-aside.	Beef cattle and sheep	*"Appropriate Environmental Measures"* Member states given the option to attach "environmental measures" to receipt of payments. *Maximum Stocking Densities* Recipients of beef payments required to comply with maximum stocking densities.
		Arable crops	Member states to apply appropriate measures to ensure set-aside is managed with a view to protecting the environment .
1999 Agenda 2000 CAP Reform Implemented from 2000	Payments based mainly on crop area or livestock numbers	All those in receipt of direct payments.	*"Environmental Protection Requirements"* Member states to introduce appropriate environmental measures, which could include: — General mandatory environmental requirements. — Specific environmental requirements constituting a condition for direct payments. Member states were permitted to introduce penalties (reduction or withdrawal of payments) for not complying with environmental requirements.
		Farmers benefiting from the Less Favoured Area (LFA) Compensatory Allowance or an agri-environment payment.	*"Usual Good Farming Practice"* Farmers benefiting from either payment were obliged to "apply usual good farming practice compatible with the need to safeguard the environment and maintain the countryside, in particular by sustainable farming".
2003 2003 reform Implemented from 2005	Single Payments	All those in receipt of direct payments under the Single Payment Scheme and Single Area Payment Scheme	*"Cross Compliance"* Farmers receiving direct payments required to respect: — Statutory Management Requirements (SMRs). — Standards for Good Agricultural and Environmental Condition (GAEC). Direct payment is reduced or withdrawn if the farmer is found to be non-compliant with SMRs or GAEC.

Source: Drawn from OECD (2011), *Evaluation of Agricultural Policy Reforms in the European Union,* OECD, Paris.

Figure 1.5. Evolution of Australian national natural resource management policies



Notes: NLP – National Landcare Program; NHT1 and 2 – Natural Heritage Trust 1 and 2; NAPSWQ – National Action Plan for Salinity and Water Quality). Values are shown in Australian dollars for given year.

Source: Grundy, M. and M. Barson (2010), *Information, Indicators, Agricultural Productivity and Sustainable Practices – Australian Case Studies*, paper presented at the OECD Workshop on Agri-environmental Indicators, Leysin, Switzerland, March, available at: *www.oecd.org/tad/env/indicators*.

1.4 Farm management practices and hydrological properties and processes

In response to the mix of policies, market and environmental influences shown in Figure 1.1, a growing number of OECD farmers are adopting environmental farm management practices and farming systems that seek to minimise the impact of agriculture on water systems. To encourage more farmers to adopt such practices governments are: providing incentives through payments to offset the cost of adopting these practices (e.g. establishing riparian buffers); supporting farmers through advice; and enforcing compliance through regulatory measures which has a major influence on the uptake of farm practices to reduce water pollution.

An OECD (2008a) survey of trends in farming practices beneficial to water quality across OECD countries from 1990 to the mid-2000s revealed the following key trends.

- The adoption of improved *nutrient management practices* (NMPs) is widespread across OECD countries, with an increase in their uptake over the review period, for around half of the OECD countries monitoring NMP. The countries with a high and increasing uptake of NMPs mainly experienced a reduction in nutrient surpluses, but for countries where nutrient surpluses have risen or are well above the OECD average (in terms of kg nutrients per hectare of farmland) NMP adoption rates are generally lower but increasing in most cases.

- Despite the increase in adoption of environmental *integrated pest management* practices (IPM), the level of uptake across OECD countries was modest, although only about a third of OECD countries track IPM. But countries with a high IPM uptake or growth in organic farming have also experienced a decrease in pesticide use.
- The area of farmland under improved *soil management practices* (SMPs) remained stable, but only a third of OECD countries monitors changes in SMP. Where the rate of SMP adoption has risen, this has led to reduced soil erosion risks and eased the flow of sediments into water bodies, but where SMP uptake rates are low soil degradation problems remain.
- The OECD area under *certified organic farming* increased substantially over the survey period, even so it accounted for less than 2% of total farmland by 2002-04. The share is higher in most European OECD countries compared to most non-European OECD countries.

While a more recent OECD survey of farm management practices and systems is not available, extrapolating from policy changes made across OECD countries from the mid-2000s to 2010 would suggest the following trends:

- An overall increase in uptake of farm management practices and systems beneficial to water quality in view of the strengthening of agri-environmental programmes in most countries, both in terms of the numbers of farmers and the agriculture land area covered under these programmes.
- There is a growing share of agricultural support becoming conditional (cross compliance) on the adoption of best management practices beneficial to environmental improvements, including water quality.
- Some improvements in overall water pollution regulations with implications for agriculture, such as the disposal of residual pesticides, both products and containers.
- Farmers are also changing, albeit on a small scale at present, their farming practices in response to a range of voluntary private initiatives, often led by water treatment companies and interests in the agro-food chain (e.g. input suppliers and food retailers), but also non-profit environmental groups (Chapter 5.8).
- Recent rises in real agricultural commodity prices, projected to continue over the next ten years, has led to the further intensification of crop and livestock production in response to higher prices in some parts of the OECD (Chapter 2). This development may have slowed or even reversed the previous upward trend in adopting management practices beneficial to water quality for some regions within countries. At the same time, however, rising chemical input prices (fertilisers, pesticides) can have a counter-effect, by inducing farmers to use less of these inputs, assuming no other changes in farm costs/output prices. Deterioration in water quality of some water systems linked to agriculture over recent years provides further evidence to confirm this trend (Chapter 2).

Certain farming practices and management systems can result in improvements in water quality and contribute to sustainable water use (Cooper, Hart and Baldock, 2009; Ribaudo *et al*., 2010a). Creating riparian buffers, taking land out of production near watercourses, conservation tillage and organic farming are examples of such practices and farming systems. There may be some private interest by farmers in ensuring pollution of water courses is minimised. For example, to ensure healthy fish stocks in the rivers and lakes on the owner's property, providing uncontaminated drinking water in wells for the

use by farm households and livestock, and switching to an organic system to take advantage of market opportunities. In general, however, the supply of these ecosystem services is undersupplied by farmers.

Organic farming systems usually involve practices that maintain or improve the physical, chemical, and biological conditions of soil and minimise soil erosion compared to "conventional" farming systems. Organic farming practices can also bring benefits to water quality, such as not using synthetic pesticides, as well as providing other ecosystem services, for example, carbon sequestration and enhanced biodiversity (Greene *et al.,* 2009; OECD, 2003a; and Stolze *et al.,* 2000). Farm comparisons with conventional farming show that actual nitrogen leaching rates per hectare can be up to almost 60% lower on organic than on conventional fields, but leaching rates per kilogram of output were similar or slightly higher. Critical areas that can lead to higher nitrate leaching in organic farming are, for example: ploughing legumes at the wrong time; the selection of unfavourable crops planted in a rotation; and composting farmyard manure on unpaved surfaces (Stolze *et al.,* 2000). There are also situations where intensive management within organic farming can lead to livestock manure applied in excess of requirements (OECD, 2003a).

Under certain farming practices ***paddy rice production*** can also have beneficial impacts on water quality, depending on the quality of the incoming water, fertiliser and pesticide management practices, and irrigation water flow management (Bouman *et al.,* 2007; Yoshinaga *et al.*, 2007). The quality of water leaving rice paddy fields may be improved as a result of the wetland ecosystem to remove nitrogen and phosphorus. Nitrate leaching from flooded rice fields is normally negligible because of rapid denitrification under anaerobic conditions (Yoshinaga *et al*., 2007). High levels of nitrogen pollution, however, can be found in lowland rice growing regions where fertiliser application rates are excessively high and also where there is a high outflow of water from the paddy field (Bouman *et al.,* 2007; Yoshinaga *et al*., 2007). Percolating water from rice fields can lead to leaching of nutrients into groundwater, and also raise the groundwater table and salinise the root zone of non-rice crops where the groundwater is saline (Antonopoulos, 2010; Yoshinaga *et al.,* 2007).

Despite the progress toward higher adoption rates of on-farm environmental management practices that are leading to beneficial outcomes for water quality, impediments remain to a more rapid and universal uptake of best management practices (BMPs) for water quality improvement across OECD countries including (the relative importance of these impediments can vary both between catchments and between farmers within catchments) (Bryan and Kandulu, 2011; Christensen *et al.,* 2011; Jacquet *et al.,* 2011; Roberts *et al.,* 2010):

- *Economic (risk aversion):* adoption of water quality BMPs can have a high direct cost to the farmer and pose a risk to farm income, when not compensated by policy measures or markets. Equally the farmer's perceived transaction costs of complying with restrictions under a voluntary water quality programme may exceed perceived income losses.
- *Knowledge:* lack of farmer awareness of the impacts of different farm practices on water quality and knowledge of how to undertake water quality BMPs.
- *Labour:* limited availability of farm labour and time to undertake on-farm water quality BMPs, especially in the absence of programme incentives.
- *Advisors*: insufficient skilled BMP advisors to impart knowledge and train farmers.

- *Institutional*: lack of institutional arrangements to support adoption of water quality BMPs through farm industry groups or social networks.
- *Non-economic*: impediments to adoption of water quality BMPs may be driven by non-economic motives, such as pride in achieving high yields and remaining independent.

1.5 Challenges in the interaction between farm management practices and water quality

While the uptake of environmental farm management practices across OECD countries to address water quality issues has been increasing there remain on-going challenges common to most countries. Addressing these challenges would help develop policy approaches that encourage farmers to adopt management practices beneficial to improving the quality of water systems, including:

- Raising farmer awareness;
- Improving science and knowledge;
- Recognising the problem of pollutant time lags;
- Addressing information and monitoring data deficiencies; and,
- Considering a more holistic view of water quality issues.

Raising farmer awareness

There is considerable evidence from farm survey data across many countries that farmer awareness or recognition that agriculture makes a contribution to water pollution is low (Blackstock *et al.,* 2010; National Audit Office, 2010). Some 85% of farmers responding to a **United Kingdom** survey on diffuse source pollution, for example, felt pollution was not an issue, and that agriculture contributed little or not at all to the problem (National Audit Office, 2010). This might reflect a lack of understanding of the science of the transport and fate of pollutants on farms to water systems, especially groundwater. Also, in some cases, farmers may be in denial of scientific evidence, with the view that pollution from their properties is mainly caused by events beyond their control, such as heavy rainfall events and floods (Posthumus and Morris, 2010). Where farmers do recognise the problem of pollutant runoff from their properties, they can be unaware of the extent that this could be caused by poor soil management or other environmentally ineffective management practices.

In a four-state survey in the **United States**, more than 30% of respondents do did not know if the quality of their groundwater for drinking was good or not (Morton and Weng, 2009). The same survey also showed that farmers are more likely to believe that water quality was good in their catchment, compared to rural non-farm and urban residents whose assessment was more negative (Morton and Weng, 2009). A survey of compliance with the **EU** *Nitrates Directive* also found low awareness of nitrate problems, especially among small holders (European Commission, 2010). Moreover, a **UK** survey revealed that 50% of farmers did not recall any guidance on how to comply with the *Nitrates Directive* (National Audit Office, 2010), although this could be associated with the fact that only 55% of the agricultural land area is designated to comply with the Directive (Chapter 5.1).

Raising farmer awareness and acceptance of water quality problems is an important first step in getting uptake of mitigation measures (Blackstock *et al.,* 2010). Many policy interventions to control diffuse source pollution tend to proceed on the basis that the links

between farming activities and water pollution are understood by farmers (Blackstock *et al.,* 2010). But there is evidence that farmers are willing to accept further education and advice on nutrient and pesticide management on their farms in the interests of protecting the environment and that overall awareness is increasing and leading to improved management practices to control pollution (European Commission, 2010; Perez, 2010). Building social capital in a water catchment so that that farmers and other stakeholders are better informed of the processes impacting on water quality can be beneficial (Morton and Weng, 2009).

Improving science and knowledge

The pathways by which pollutants reach surface, groundwater and marine waters are often complex and not fully understood (Figures 2.1 and 2.2). The impacts of diffuse source pollution can depend: on the quantities of pollutants released; how easily the pollutants are transported into water systems; and how sensitive the water environment is to pollution (Environment Agency, 2007). Further improvements in scientific understanding and knowledge of these processes and linkages are critical to help highlight the most appropriate mitigation actions to alleviate water pollution pressures from agriculture, as for example being undertaken by the **French** National Water Office *(L'Office national de l'eau et des milieux aquatiques).*

Once a potential agricultural contaminant is released to or formed in the environment, it will experience a number of fate and transport processes that in general are common to all agricultural contaminants (Boxall, 2012). The contaminant may be degraded by biological, physical or chemical processes, it may stick to soil particles, can be taken up by plants, leach to groundwater or it might be transported to surface waters through runoff and drainage water. The extent to which any of these processes occur will depend on the underlying physical properties of the contaminant, including: how soluble it is in water; how attracted the contaminant is to organic matter and other soil components; the volatility of the substance; and the characteristics of the soil, topography and climatic conditions.

Changes in agricultural practices can minimise the risks of contaminants to the environment (Boxall, 2012). A range of approaches can be used including, for example: changes in pesticide treatment timings and intensities; altering manure/sludge application rates and timings; development of recommendations on when not to apply manure and biosolids (e.g. where slopes are unsuitable); and specification of buffer zone width and type to protect water.

It is also becoming clearer that a multi-disciplinary approach is required to better understand water pollution in agriculture that addresses the linkages between sources of contaminants; their management, mobilisation and transport through the environment; and their impact on receiving waters (Kronvang, Rubaek and Heckrath, 2009).

Recognising the problem of pollutant time lags

Over recent decades programmes aimed at reducing diffuse source pollution from agriculture have often reported little or no improvement in water systems. While there are many causes for this an important explanation are time lags. A time lag (sometimes referred to as the legacy problem) is the time elapsed between adoption of management changes by farmers and the detection of measurable improvement in water quality of the target water body (Kronvang, Rubaek and Heckrath, 2009; Meals, Dressing and Davenport, 2010).

The magnitude of the time lag is highly site and contaminant specific and can take: hours to months for some contaminants after heavy rainfall or from a point source in agriculture; years to decades for excessive phosphate levels in agricultural soils; and decades or more for sediment accumulated in river systems (Meals, Dressing and Davenport, 2010). Nutrient enriched lakes and acidified waters may also take years to recover (Environment Agency, 2007). Groundwater travel time is also an important contributor to time lags and may introduce a lag of decades between changes in agricultural practices and improvements in groundwater quality (Collins and McGonigle, 2008; Dubrovsky *et al.*, 2010; Environment Agency, 2007; Helmers *et al.*, 2007; Meals, Dressing and Davenport, 2010).

Modelling of an aquifer in the **United States** (Glassboro, New Jersey), for example, which had received a steady increase in nitrate inputs over decades, showed that under a gradual reduction programme it would take 50 years to return to the pre-use of commercial fertilisers era (around 1940). Even with an immediate decrease in nitrate input it would take 30 years to reduce concentrations to background levels (Dubrovsky *et al.,* 2010).

Before the effects of time lags are widely recognised and accepted, investment decisions are made, land is purchased and sold, and family livelihoods and commercial operations become dependent on management practices that may not be sustainable. In the process, practices become embedded in presumptive property rights, and governments are maybe reluctant to alter these. Moreover, as well as time lags in chemical and hydrological processes, delays can also occur in policy decision making and because of the complexity of institutional arrangements that often govern water policies. Thus, both chemical and hydrological and policy and institutional time lags point to the need for long-term commitments by policy makers in an effort to ameliorate the impacts of agriculture in water catchments, and a strategy that prevention of pollution is better than cure (Environment Agency, 2007; Helmers *et al.,* 2007; Sohier and Degre, 2010).

Addressing information and monitoring data deficiencies

Underlying the difficulties of insufficient farmer knowledge, inadequate scientific understanding, time lags, and stochastic processes that pervade policy related diffuse source pollution problems in agriculture, is the issue of information failure (Borisova *et al.*, 2003; Cabe and Herriges, 1992; Doole and Pannell, 2009). The lack of information that hinders efficient policy making relates to the: high number of polluters; asymmetric information between farmers and policy makers; temporal and spatial variation in pollution concentration; and the high cost of data collection for this kind of environmental issue. Imperfect information on the costs and benefits of different pollution abatement choices is further complicated by multifaceted production relationships, such as the response of farmers to weather, climate change, and market uncertainty (Doole and Pannell, 2009; National Audit Office, 2010).

Given growing interest in more comprehensive water catchment based approaches to address water pollution, this requires a broader set of information to support policy making than more traditional approaches. But because information is imperfect, decision making under uncertainty will be unavoidable. In the light of information and data deficiencies policy makers need to rely much more heavily on modelled information approaches, both economic models and bio-physical models, to inform policy design, choice, monitoring and evaluation (Cabe and Herriges, 1992; Doole and Pannell, 2009; Schreiber *et al.,* 2003) (Chapter 2.5).

Considering a more holistic view of water quality issues

While the focus of this report is on policy aspects of agriculture-water quality linkages (mainly to make such a report manageable), it is important to see these linkages as part of a broader more complex policy problem in terms of: natural water cycles; human and environmental land-water interactions, including protection of the marine environment; linkages to the mitigation of ammonia and greenhouse gas emissions; and interactions between water quality, water resources, agricultural and environmental policies (Chapter 1.3). This also applies at the farm level, where a farmer has to consider the management of the whole farm operation and not just those elements of the business important to water quality.

Viewing water quality in the context of the water cycle emphasises the dynamics of water systems, in that water pollution can be greatly exacerbated in situations of water resource stress and similarly in cases where there is heavy rainfall or storm events leading to heighten pollution (Falkenmark, 2011; Smith and Porter, 2009). Illustrative is the importance of stormwater management in helping to minimise nutrient and sediment loads from agriculture (Randhir and Tsvetkova, 2009). A further example is the reuse of irrigation water further down stream in a water catchment and the recycling of urban/industrial wastewater in agriculture, which raises both human health and environmental concerns, as recently illustrated by the growing use of recycled effluent water in **Israeli** agriculture (Box 1.2).

Given the large natural variation and differences between farms across water systems, water management is in most cases more efficient at the catchment or sub-catchment level (also referred to as water basins/sub-basins), with management initiatives best integrated across the different users and needs of the catchment (Land and Water Forum, 2010; Ministry of Infrastructure and Environment, 2010). Integrated catchment management refers to the process by which stakeholders can develop a common vision, agree shared values, make collective informed decisions and manage together the catchment. This process involves integration of water users, polluters, scientists, policy makers and other interested stakeholders where tradeoffs are made between these various interests, in an open and transparent way and where the focus is on synergy and win-win solutions (Collins and Anthony, 2008).

Addressing water pollution from agriculture at the catchment level, not only facilitates the involvement of all the relevant stakeholders, including the farming and non-farming community, but also offers scope for better targeting of mitigation efforts. Hence, as policies to reduce diffuse pollution from agriculture evolve, this can be integrated with efforts targeting other diffuse and point sources of pollution, such as from urban and industrial sources (Collins and McGonigle, 2008).

Box 1.2. Water quality and the use of recycled effluent in Israeli agriculture

Since the early 1960s Israel has embarked on an ambitious plan to recycle effluent water (REW, mainly from sewage but also industrial wastewater) for use largely by agriculture but also some other water users. The share of effluent recycled by Israel, about 70%, is now possibly the highest globally. Given that other countries are beginning to examine the greater use of recycling effluent in view of the growing pressure on freshwater resources, Israel's experience over many decades is one that can provide lessons on the costs and benefits of using REW in agriculture.

A key objective in Israel's *Plan for Sustainable Agricultural Development* is to increase agricultural use of REW, but also use REW to bring water to desert agriculture and as a solution to disposal of urban and industrial wastewater. In pursuit of these objectives the government has developed a policy framework to: provide financial support for treating, storing and supplying REW to agriculture; establish regulatory arrangements to address human health and environmental concerns associated with REW; develop research to improve the quality and farming practices in using REW; and organise farmer education and advisory services in the use of REW. The Jewish National Fund has also provided funding to establish a national network of reservoirs to hold REW.

REW now contributes about a third of the water supplies for irrigated agriculture, with this share expected to grow substantially over the coming decade. Support for use of REW by agriculture is mainly provided by: lowering the REW price relative to freshwater to encourage substitution on farm; offering grants that cover 40%-60% of the investment costs of treating, storing and supplying REW to agriculture; and support for the on-farm costs associated with adapting irrigation systems to using REW. This support has increased in absolute terms and as a share of both overall water support to agriculture and also in total agricultural budgetary support.

A benefit of developing the supply of REW for agriculture and other users has been to address the growing pressure on freshwater resources. It is also viewed by the government as a low cost and beneficial way of disposing of sewage that might otherwise be treated to a lower standard and lead to environmental pollution.

The expanding use of REW has made a significant contribution to water and sewage management in Israel, but it has raised a number of issues in terms of the economic, agronomic, environmental and human health costs of using REW in agriculture. The agronomic difficulties associated with using REW have mainly concerned the high concentration of pollutants in REW, even after treatment, damaging to soils and crop growth, in particular, high levels of salinity and excess boron. High salinity of REW has also led to environmental costs, especially REW leaching from irrigated agriculture leading to growing salinity of aquifers. Aquifers have also been affected by the leaching of nutrients from irrigated agriculture, in part, resulting from the high concentrations of nutrients in REW.

REW is mostly used to irrigate non-edible crops, but there are concerns with its use for food crop cultivation, although research on these links is still required. Pathogens and micro-organisms in REW can be passed through the soil into plant root systems and contaminate fruit, salmonella is an example. Also REW containing residual hormones from the dairy and meat industry, flushed birth control pills and similar chemicals might be causing endocrine disruption in males. Recent research, but as yet inconclusive, has made the possible link between the drop in male fertility in Israel over the past decade with the presence of endocrine disrupting chemicals found in REW and leached from agriculture into aquifers used for drinking water.

In efforts to address the environmental and health costs of using REW in agriculture, the government has implemented and revised health and environmental REW treatment standards. Research effort has been undertaken to address the problems associated with using REW, both for farmers, but also in terms of health and environmental costs. One such success story has been the use of soil aquifer treatment to ensure greater purification of REW. For Israel to move toward more sustainable use of REW, however, will further require: examining the stringency of treatment standards; investing in treatment infrastructure; and developing research, especially on the concerns related to the possible links between use of REW in agriculture and endocrine disruption in the male population.

Source: OECD (2010) *OECD Review of Agricultural Policies: Israel*, *www.oecd.org/agr*.

Bibliography

Antonopoulos, V.Z. (2010), "Modelling of water and nitrogen balances in the ponded water and soil profile of rice fields in Northern Greece", *Agricultural Water Management*, Vol. 98, pp. 321-330.

Blackstock, K.L., J. Ingram, R. Burton, K.M. Brown and B. Slee (2010), "Understanding and influencing behaviour change by farmers to improve water quality", *Science of the Total Environment*, Vol. 408, Issue 23, pp. 5631-5638.

Borisova, T., J.S. Shortle, R.D. Horan and D.G. Abler (2003), "The value of ecological and economic information in water quality management", paper presented at the American Agricultural Economics Association Annual Meeting, Montreal, Canada, 27-30 July.

Bouman, B.A.M., E. Humphreys, T.P. Tuong and R. Barker (2007), "Rice and water", *Advances in Agronomy*, Vol. 92, pp. 187-237.

Boxall, A. (2012), *New and Emerging Water Pollutants arising from Agriculture*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

Bryan, B.A. and J.M. Kandulu (2011), "Designing a policy mix and sequence for mitigating agricultural non-point source pollution in a water supply catchment", *Water Resources Management*, Vol. 25, pp. 875-892.

Cabe, R. and J.A. Herriges (1992), "The regulation of non-point source pollution under imperfect and asymmetric information", *Journal of Environmental Economics and Management*, Vol. 22, pp. 134-146.

Christensen, T., A.B. Pedersen, H.O. Nielsen, M.R. Morkbask, B. Hasler and S. Denver (2011), "Determinants of farmers' willingness to participate in subsidy schemes for pesticide-free buffer zones – A choice experiment study", *Ecological Economics*, Vol. 70, pp. 1558-1564.

Collins, A.L. and S.G. Anthony (2008), "Assessing the likelihood of catchments across England and Wales meeting 'good ecological status' due to sediment contributions from agricultural sources", *Environmental Science and Policy*, Vol. 11, pp. 163-170.

Collins, A.L. and D.F. McGonigle (2008), "Monitoring and modelling diffuse pollution from agriculture for policy support: UK and European experience", *Environmental Science and Policy*, Vol. 11, pp. 97-101.

Cooper, T., K. Hart and D. Baldock (2009), *Provision of public goods through agriculture in the European Union*, Report prepared for the European Commission (D-G Agriculture) and the Institute for European Environmental Policy, London, United Kingdom.

Dexter, J., *et al.* (2010), *Cultivating Clean Water: State based regulation of agricultural runoff pollution*, Environmental Law and Policy Center, Chicago, United States.

Doole, G. and D.J. Pannell (2009), *Nonpoint pollution policy evaluation under ambiguity*, paper contributed to the Australian Agricultural and Resource Economics Society's Annual Conference, Cairns, Australia, 11-13 February.

Dubrovsky, N.M., *et al.* (2010), *The quality of our Nation's waters – Nutrients in the Nation's streams and groundwater, 1992-2004*, U.S. Geological Survey Circular 1350, U.S. Geological Service, Reston, Virginia, United States.

Environment Agency (2007), *The unseen threat to water quality – Diffuse water pollution in England and Wales*, Bristol, United Kingdom, May.

European Commission (2009), "Flash Eurobarometer on water: Summary", *Flash Eurobarometer Series* No. 261, Brussels, Belgium.

European Commission (2010), *Report from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2004-2007,* COM(2010)47 final, Brussels, Belgium.

Falkenmark, M. (2011), "Water – A reflection of land use: Understanding of water pathways and quality genesis", *Water Resources Development,* Vol. 27, No. 1, pp. 13-32.

Farnese, P. (2010), *"Canadian Agri-Environmental Principles: A Report prepared for Agriculture and Agri-Food Canada,"* Ottawa, Canada, unpublished.

Gallup Poll (2008), accessed online, *www.gallup.com/poll/106660/Little-Increase-Americans-Global-Warming-Worries.aspx*.

Graham, S., A. Schempp and J. Troell (2011), "Regulating nonpoint source water pollution in a Federal government: Four case studies", *Water Resources Development,* Vol. 27, No. 1, pp. 53-69.

Greene, C., C. Dimitri, B.-H. Lin, W.D. McBride, L. Oberholtzer and T. Smith (2009), *Emerging issues in the U.S. organic industry,* Economic Information Bulletin Report Number 55, Economic Research Service, U.S. Department of Agriculture, March, Washington, D.C., United States.

Grundy, M. and M. Barson (2010), "Information, Indicators, Agricultural Productivity and Sustainable Practices – Australian Case Studies," paper presented at the OECD Workshop on Agri-environmental Indicators, Leysin, Switzerland, March, available at: *www.oecd.org/tad/env/indicators*.

Helmers, M.J., *et al.* (2007), "Theme overview: Agriculture and water quality in the Cornbelt: Overview of issues and approaches", *Choices*, Vol. 22, No. 2, pp. 79-86.

Jacquet, F., J.-P. Butault and L. Guichard (2011), "An economic analysis of the possibility of reducing pesticides in French field crops", *Ecological Economics*, Vol. 70, pp. 1638-1648.

Johnes, P. (2007), "Meeting ecological restoration targets in European waters: A challenge for animal agriculture", Chapter 11 in D. Swain, E. Charmley, J. Steel and S. Coffey (eds.), *Redesigning animal Agriculture*, CAB International, United Kingdom.

Key, N., W.D. McBride and M. Ribaudo (2009), *Changes in manure management in the hog sector: 1998-2004*, Economic Information Bulletin Report Number 50, Economic Research Service, U.S. Department of Agriculture, Washington D.C., United States, March.

Kronvang, B., G.H. Rubaek and G. Heckrath (2009), "International phosphorus workshop: Diffuse phosphorus loss to surface water bodies – risk assessment, mitigation options, and ecological effects in river basins", *Journal of Environmental Quality*, Vol.38, pp.1924-1929.

Land and Water Forum (2010), *Report of the Land and Water Forum: A Fresh Start for Freshwater,* Wellington, New Zealand, *www.landandwater.org.nz*.

Meals, D.W., S.A. Dressing and T.E. Davenport (2010), "Lag time in water quality response to best management practices: A review", *Journal of Environmental Quality*, Vol. 39, pp. 85-96.

Morton, L.W. and C.Y. Weng (2009), "Getting to better water quality outcomes: the promise and challenge of the citizen effect", *Agriculture and Human Values*, Vol. 26, pp. 83-94.

Moxey, A. (2012), *The Monetary Costs and Benefits of Agriculture on Water Quality: Estimates across OECD Countries*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

National Audit Office (2010), *Environment Agency: Tackling diffuse water pollution in England*, Report by the Comptroller and Auditor General, London, United Kingdom.

National Research Council (2008), *Mississippi river water quality and the Clean Water Act: Progress, challenges and opportunities*, The National Academies Press, Washington, D.C., United States, *www.nap.edu/catalog/12051.html*.

OECD (1972), *Recommendation of the Council on Guiding Principles concerning International Economic Aspects of Environmental Policies,* 26 May, OECD, Paris, *webnet.oecd.org/oecdacts/Instruments/ShowInstrumentView.aspx?InstrumentID=4&Lang=en&Book=False*.

OECD (2003a), *Organic Agriculture: Sustainability, Markets and Policies,* OECD, Paris, *www.oecd.org/tad/env*.

OECD (2007), *Instrument Mixes addressing Non-point Sources of Water Pollution,* OECD, Paris, *www.oecd.org/env*.

OECD (2008a), *Environmental Performance of Agriculture in OECD Countries since 1990,* OECD, Paris, *www.oecd.org/tad/env/indicators*.

OECD (2010a), *Agricultural Policies in OECD Countries: At a Glance*, OECD, Paris, *www.oecd.org/agr*.

OECD (2010b), *Environmental Cross-compliance in Agriculture*, OECD, Paris, *www.oecd.org/agr/env*.

OECD (2011a), *Agricultural Policies in OECD Countries and Emerging Economies, 2011,* OECD, Paris, *www.oecd.org/agr*.

OECD (2011b), *Evaluation of Agricultural Policy Reforms in the United States – A Preliminary Analysis*, OECD, Paris, *www.oecd.org/agr*.

OECD (2011c), *Evaluation of Agricultural Policy Reforms in the European Union: Draft Report*, OECD, Paris, *www.oecd.org/agr*.

Oenema, O., H.P. Witzke, Z. Klimont, J.P. Lesschen and G.L. Velthof (2009), "Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27", *Agriculture, Ecosystems and Environment*, Vol. 133, pp. 280-288.

Perez, M.R. (2010), *Does the policy-making process affect farmer compliance?: A three-state case study of nutrient management regulations*, PhD. thesis, School of Public Policy, University of Maryland, College Park, Maryland, United States.

Posthumus, H. and J. Morris (2010), "Implications of CAP reform for land management and runoff control in England and Wales", *Land Use Policy*, Vol. 27, pp. 42-50.

Randhir, T.O. and O. Tsvetkova (2009), "Watershed-scale tradeoffs in water quantity and quality attributes for conservation policy", *Water, Air and Soil Pollution*, Vol. 201, pp. 347-363.

Ribaudo, M. (2009), "Non-point Pollution Regulation Approaches in the U.S.", pp. 83-102 in J. Albiac and A. Dinar (eds), *The Management of Water Quality and Irrigation Techniques*, Earthscan, London, United Kingdom.

Ribaudo, M., C. Greene, L. Hansen and D. Hellerstein (2010a), "Ecosystem services from agriculture: Steps for expanding markets", *Ecological Economics*, Vol. 69, pp. 2 085-2 092.

Roberts, A.M., D.J. Pannell, G. Doole and O. Vigiak (2010), *Agricultural land management strategies to reduce phosphorus loads in the Gippsland Lakes, Australia,* Working Paper 1011, School of Agricultural and Resource Economics, The University of Western Australia, 28 July, *www.are.uwas.edu.au*.

Schreiber, H., *et al.* (2003), *Harmonised inventory of point and diffuse emissions of nitrogen and phosphorus for a transboundary river basin*, Federal Environmental Agency, Vienna, Austria.

Shortle, J. (2012), *Water Quality Trading in Agriculture*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

Shortle, J., M. Ribaudo, R.D. Horan and D. Blandford (2012), "Reforming Agricultural Nonpoint Pollution Policy in an Increasingly Budget Constrained Environment", *Environmental Science and Technology,* January.

Smith, L.E.D. and K. S. Porter (2009), "Management of catchments for the protection of water resources: Drawing on the New York City watershed experience", *Regional Environmental Change*, published online 22 October, *www.springerlink.com/content/l177727548811101/fulltext.pdf*.

Smith, R.B.W. and T.D. Tomasi (1995), "Transaction costs and agricultural nonpoint-source water pollution control policies", *Journal of Agricultural and Resource Economics*. Vol. 20, No. 2, pp. 277 -290.

Sohier, C. and A. Degre (2010), "Modelling the effects of the current policy measures in agriculture: An unique model from field to regional scale in Walloon region of Belgium", *Environmental Science and Policy*, Vol. 13, pp. 754-765.

Stolze, M, A. Piorr, A. Häring and S. Dabbert (2000), *The Environmental Impacts of Organic Farming in Europe*, University of Hohenheim, Stuggart, Germany, *www.uni-hohenheim.de/i410a/ofeurope/organicfarmingineurope-vol6.pdf*.

USEPA (U.S. Environmental Protection Agency) (2001), *The National Costs of the Total Maximum Daily Load Program (Draft Report),* Office of Water, USEPA 841-D-01-003, Washington, D.C., United States.

Weersink, A. and J. Livernois (1996), "The use of economic instruments to resolve water quality problems from agriculture", *Canadian Journal of Agricultural Economics*, Vol. 44, pp. 345-353.

Yoshinaga, I, A. Miura, T. Hitomi, K. Hamada and E. Shiratani (2007), "Runoff nitrogen from a large sized paddy field during a crop period", *Agricultural Water Management*, Vol. 87, pp. 217-222.

Chapter 2

Agriculture and water quality: Sources, trends, outlook and monitoring

The impact of agriculture on water quality is either stable or deteriorating, with few cases where significant improvements are reported across OECD from the mid-2000s to 2010. While the current situation varies within and across OECD countries, agriculture is often the main source of water pollution. Achieving further reductions is a challenge for policy makers, especially as a major part of agricultural water pollution is from diffuse sources. The outlook over the next ten years for agriculture and water quality suggests that the growth and intensification of agricultural production could further heighten regional pressures on water systems in some countries. But whatever the projections hold for the future, the task of achieving water quality objectives in agriculture will become more difficult in the coming years as a result of climate change, although this is a poorly understood and researched aspect of climate change science to date.

2.1 Sources of water pollution from agriculture

Agriculture has had considerable success in increasing production to meet the growing food, feed, fibre and fuel needs of the global population. The expansion of agricultural production has been, in part, made possible through greater use of nutrients, pesticides and intensification of crop and livestock production systems, including irrigation. Farming systems, however, have not been fully efficient in their use of farm inputs and intensification has led to degraded fragile soils, removal of vegetation from land, increased land drainage, and other changes altering the natural environment.

These changes, combined with a great range of landscapes from mountains to floodplains, climates, rainfall patterns, soil types, and vegetative cover, have led to varying exports of nutrients, pesticides, soils and other pollutants from agriculture into water systems (Table 2.1). The pollutants are transported into surface water and groundwater through various processes including in dissolved form (leaching), pollutants attached to eroding soil sediments (runoff) and gaseous release (volatilisation) which may get deposited into water, such as from manure and pesticides (Figures 2.1 and 2.2). Sub-surface field drainage and irrigated agriculture can also heighten pollutant releases into water.

This has mainly resulted in water eutrophication, soil siltation, and chemical deterioration of water (e.g. from nutrients, pesticides, salts, pharmaceuticals and chemical farm wastes). Under certain farm management practices and systems, however, agriculture can be beneficial to water quality, or cause little impact on water systems, as previously discussed. Elevated levels of pollutants from agriculture have damaging effects on the following (Table 2.1; Chapter 3).

- *Environment*, this includes not only aquatic ecosystems (e.g. from wetland to marine ecosystems) but also fauna dependent on the viability of these ecosystems.
- *Agriculture fisheries and other commercial users*, both fresh and marine water fisheries, and other commercial water uses.
- *Non-consumptive values of water systems*; mainly recreational uses (e.g. swimming), visual (waterscapes), and social values (e.g. spiritual).
- *Human health*, mainly through contaminants in drinking water and the quality of bathing water.

Table 2.1. Sources of water pollution from agricultural activities[1]

Pollutant	Key water quality issue related to pollutant	Main agricultural activities that are the source of the pollutant
– Nutrients mainly nitrates and phosphates)	– Eutrophication and impairment of drinking water mainly harmful to aquatic life, but also human health in some cases	– Agricultural production (runoff of excess nitrates and phosphates from fertilisers and animal manure into water)
– Toxic contaminants (largely heavy metals, pesticides)	– Harmful to aquatic life and impairs drinking water (contamination of water)	– Spreading sewage sludge on agricultural land (heavy metals) and plant protection (pesticides)
– Soil sediments	– Harmful to aquatic life and water transport ystems (turbidity of water)	– Inappropriate soil conservation practices (wind and water soil erosion)
– Organic matter	– Harmful to aquatic life (deoxygenation of water)	– Manure-spreading on livestock farms
– Acid substances	– Harmful to aquatic life (acidification of water)	– Livestock production (ammonia volatilisation)
– Biological contaminants	– Impairs drinking water (pathogenic bacteria and viruses) and bathing water	– Faecal discharge from livestock into water
– Mineral salts	– Impairs drinking water, the use of water for irrigation, and aquatic life (salinisation of water)	– Inappropriate land use (clearing of perennial vegetation and irrigation practices)

1. While agriculture is an important source of the pollutants described in this table, other sources can also contribute to these pollutants, e.g. pesticides and fertilisers from urban uses.

Figure 2.1. Nutrients in water: A schematic diagram of pathways from agricultural use

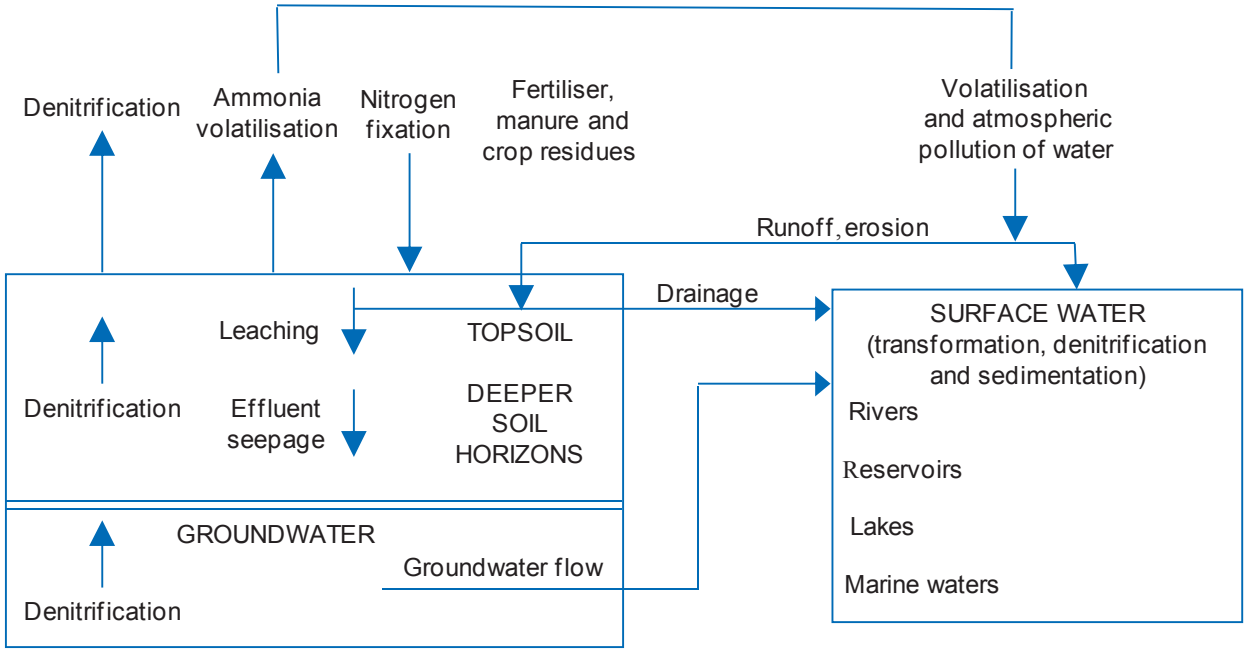
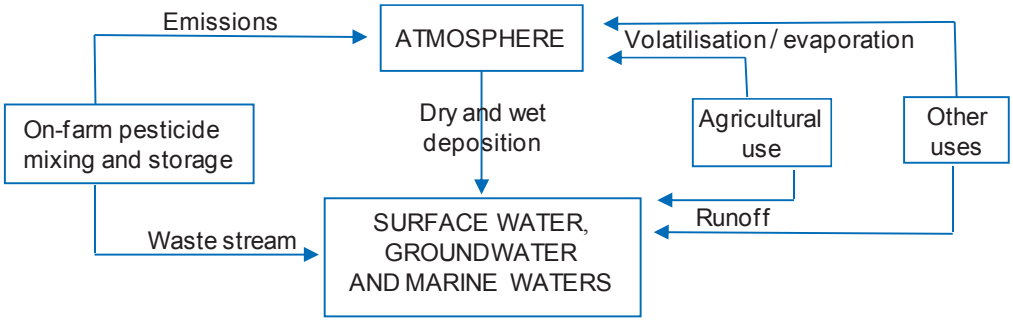


Figure 2.2. Pesticides in water: A schematic diagram of pathways from agricultural use



2.2 The contribution of agriculture as a source of water pollution

It is important to recognise that while agriculture contributes to pollution of water systems it is not the only source. Natural, urban and industrial sources of pollution of water systems continue, through runoff, including contaminants commonly associated with agriculture, such as urban use of pesticides, soil sediments from natural erosion and construction sites, and atmospheric pollution of water from industry (Farzin and Grogan, 2008; Wittmer *et al.*, 2011). Agricultural activities will usually involve some lost of contaminants, as it is technically impossible to achieve zero pollution in most situations. Even in pristine water environments natural sources (e.g. soil minerals) can cause changes in the physical, chemical and biological characteristics of water. Rather the challenge in agriculture is to seek ways to increase production while minimising farm contaminant lost and its subsequent damage to water quality (Galloway *et al.*, 2008).

Background (or natural) loss of nitrogen is usually small compared with human induced forms of nitrogen loss to water systems, and is typically estimated at around 1-2 kg/ha, derived from nitrogen fixing organisms, lightning and other sources (Dubrovsky *et al.*, 2010; European Environment Agency, 2005). This background loss of nitrogen does not reflect a reference condition, because many areas across OECD countries are subject to substantial atmospheric depositions of ammonia and nitrous oxide. For phosphorus the background loss is usually considered to be about 0.1 kg/ha, and occurrence will mainly depend on underlying geological conditions in sediment and rocks (Dubrovsky *et al.,* 2010; European Environment Agency, 2005).

Even so, agriculture is a significant source of nitrogen, phosphorus, pesticides in surface water, groundwater and marine waters for most OECD countries. Agriculture is also the main contributor to the siltation of surface water from eroded soils (European Environment Agency, 2005; OECD, 2008a).

For many countries the share of agriculture in the total pollution of surface water by ***nitrates*** is over 40% (OECD, 2008a). Evidence of the contribution of agriculture in groundwater pollution is limited, but some information suggests it may be lower than for rivers and lakes but increasing. Agriculture's contribution of nitrogen loadings into estuarine and coastal water is also above 40% for many countries, and often reported as the main cause of eutrophication (OECD, 2008a). But the share of agricultural nitrates in surface and coastal waters can reveal significant fluctuations depending on seasonal and annual river flows.

In most cases, agriculture's contribution of ***phosphorus*** to water bodies is lower than for nitrates, mainly because households and industry tend to be the most significant source (European Environment Agency, 2005; OECD, 2008a). Agriculture, however, is a major source of phosphorus in surface water and coastal waters accounting for a share of over 40% in some OECD countries (OECD, 2008a).

While agriculture is usually the main source of ***pesticide*** pollution in water systems, recent research points to the need to give more attention to other sources of pesticide pollution when formulating mitigation strategies, such as forestry, urban gardens, and golf courses (Wittmer *et al.*, 2011). In the **United States**, for example, agriculture accounts for 75% of pesticide use, and about 65-70% in **Belgium** (OECD, 2008a).

Soil erosion can originate from a number of economic activities (e.g. forestry, construction, off-road vehicle use) and natural events (e.g. fire, flooding and droughts). In many cases, however, the major share of soil erosion is accounted for by agricultural activities. In general, cultivated arable and permanent crops (e.g. orchards) are more susceptible to higher levels of soil erosion compared to pasture areas. This is because land under pasture is usually covered with vegetative growth all year. In some situations, however, where there is a lack of natural vegetative cover, agriculture crops and pasture can help reduce erosion.

Agriculture can also be subject to pollution itself from other sources. Irrigated agriculture is particularly prone to this problem, where it draws water either polluted by other agricultural producers upstream or where it has been polluted upstream by urban and industrial sources. In **Chile**, for example, the Fondo Quimavida irrigation district in central Chile, is downstream from the city of Rancagua which is depositing untreated sewage water into the river system used to supply the irrigation district and has led to microbiological (e.g. faecal coliforms) deterioration of the water used by the irrigators.[1] Equally, if properly treated wastewater can provide an asset for irrigated agriculture, as recent experience in **Israel** has shown (Box 1.2).

2.3 Overall trends of the impacts of agriculture on water quality

The scale of the impairment of water systems due to agriculture described in this section needs to be placed in some perspective. Across most regions in OECD countries drinking water quality is high and there is limited health risks linked to impaired drinking water, although water treatment costs can be high to remove pollutants (Chapter 4). In some rural areas of OECD countries, however, which are not connected to treated water infrastructure systems, health concerns can be more significant, especially where water is draw from wells.

Agriculture is also not the only source of contamination of water systems, as discussed previously. Eutrophication of water systems due to agriculture is becoming widespread and significant, leading to damage to ecosystems, commercial fisheries and detrimental to recreational and other social benefits attached to water systems. There is also growing unease with emerging contaminant pollution of water from agriculture, raising concerns for both human health and the environment. These issues are discussed in more detail at the end of this chapter.

The OECD (2008a) survey of the overall impacts of agriculture on water systems over the period from 1990 to the mid-2000s across OECD countries concluded that the:

- Pressure of agriculture on water quality in rivers, lakes, groundwater and coastal waters eased since the early 1990s due to the decline in nutrient surpluses and pesticide use, and improvements made in soil conservation leading to a reduction in soil erosion rates.
- Nearly a half of OECD countries recorded that nutrient and pesticide concentrations in surface water monitoring sites in agricultural areas exceed national drinking water limits for these contaminants. But the share of monitoring sites of rivers and lakes that exceeded recommended national limits or guidelines for environment and recreational uses was much higher, with agriculture a major cause of nutrient and pesticide pollution in many cases.
- With respect to groundwater (shallow wells and deep aquifers), agriculture over the review period was the major and growing source of pollution across many OECD countries, especially from nutrients and pesticides, although evidence of groundwater pollution is limited. This is a particular concern for countries where groundwater provides a major share of drinking water supplies for both human and livestock populations, and also as natural recovery rates from pollution can take many decades, in particular, for deep aquifers. There is also some evidence of increasing pollution of groundwater from pesticides despite declining pesticide use, largely explained by the long delays pesticides can take to leach through soils into aquifers.

Since the OECD (2008a) survey of water quality trends related to agriculture described above, ***a review of more recent national surveys from the mid-2000s to 2010***, suggests the situation of water pollution from agriculture is either stable or deteriorating in most cases. The absolute levels of agricultural pollutants also remain a challenge to achieve further reductions for most OECD countries, especially diffuse source pollution. There appear few situations where significant improvements are reported, according to the selected reports summarised below.[2]

- **European Union** (Chapter 5.1): The EU Commission's assessment has identified that 40% of surface water and 30% of groundwater is at risk across the European Union of failing to meet the objectives for good chemical and ecological status established under the European Union's *Water Framework Directive* (WFD) (Kanakoudis and Tsitsifli, 2010). Across most EU member states agriculture is an important source of nutrients and pesticides into surface and groundwater (European Environment Agency, 2010). While there are differences in trends and absolute pressures from agricultural nutrient surpluses on water systems across member states, the contribution of agriculture remains high. More specifically in most member states agriculture is responsible for over 50% of the total nitrogen discharge to surface water, although the overall trend in agricultural nitrogen discharges has been declining since the early 1990s (European Environment Agency, 2010; European Commission, 2010; OECD, 2008a). Even so, around a third of EU15 surface water and groundwater monitoring stations still show an upward trend in nitrate concentration levels in water and eutrophication of fresh and marine waters is significant (European Commission, 2010).
- **Baltic Sea** (Chapter 5.7): In the Baltic Sea catchment area, the major anthropogenic source of waterborne nitrogen is diffuse inputs, mainly agriculture (HELCOM 2009a; Malmaeus and Karlsson, 2010). They constitute 71% of the total load into surface waters within the catchment area. Agriculture alone contributed about 80% of the

reported total diffuse load. The largest loads of phosphorus originated from point sources (56%), with municipalities as the main source, constituting 90% of total point source discharges in 2000, with 44% from diffuse sources. For some Baltic countries, such as **Finland** and **Sweden**, agriculture is the major contributor of phosphorus into the Baltic.

- **Switzerland**: The quality of most ground and surface water is good but some local problems do occur, particularly with respect to nitrate and pesticides levels in intensive agriculture areas. Three-quarters of nitrate leaching into groundwater is estimated to be from farmland, leading to some eutrophication problems and breaches of drinking water standards.
- **Norway**: Agricultural influences on water quality are recognised with respect to sediment and phosphate loadings from soil erosion plus nitrates and phosphates from fertiliser and manure applications. These contribute to eutrophication issues in some inland lakes and coastal areas, particularly in the south. However, surface water quality is more commonly degraded by acidification unrelated to farming activities. Agricultural loadings to coastal waters are significant, 60% of nitrogen and 45% of phosphorus released to coastal areas of the North Sea classified as sensitive under the North Sea Declaration, although aquaculture is important, especially with respect to phosphates (OECD, 2011d).
- **Turkey**: Surface water quality in most agricultural catchments is degraded to some extent and groundwater contamination from nutrients and pesticides occurs locally, as do salinity problems in some cases. Coastal pollution, particularly of the Black Sea, is problematic, although sectors other than agriculture and neighbouring countries also contribute significantly to this situation.
- **Israel** (OECD, 2010c): Pollution of water from agricultural activities is a long standing problem in Israel. Salinity of water arising from irrigation practices, and pesticide and nutrient run-off from cropping and livestock activities are the main forms of water pollution. Other forms of agricultural pollution occur from soil sediments in water and air, as well as abattoir and plastic wastes. While agriculture is an important source of water pollution other sources also contribute to the problem, notably from industrial activities and urban sewage disposal. The issue of water quality is inextricably linked to water resources, as the pressure on water resources has led to deterioration in quality. In general the quality of surface water, groundwater and coastal waters have been impaired from agricultural activities. Almost all rivers are polluted with only limited sections open to use for recreational purposes, although for some rivers water quality has improved.
- **Canada** (Eilers *et al.,* 2010): Agriculture's environmental performance with respect to risks to water quality currently has a good status, but represents an overall decline from a desired state in 1981. Increased application of nutrients (N and P), as fertiliser and manure, was the main driver for the declining trend in the performance index for water quality throughout Canada. The shift of animal numbers from Eastern Canada to the Prairies has resulted in a declining agri-environmental performance for risk of contamination of water by coliforms, whereas in the rest of Canada, particularly Eastern Canada, overall declining animal numbers have resulted in a relatively stable situation for coliforms. Increased efforts are required throughout Canada to minimise the risk of nutrient, pesticide and coliform movement to surface water bodies and leaching beyond

the rooting depth of vegetation. This is particularly so in higher rainfall areas of the country.

- **United States** (Chapter 5.2): Although varying regionally in nature and severity, agricultural influences on water quality are important according to the US Geological Survey *National Water Quality Assessment Program* (USGS, 2010). In particular, sediment loadings, bacterial contamination, nutrients and pesticides all contribute to problems to varying levels across the country, with five major ecosystems especially vulnerable to agricultural pollutants, including the Great Lakes, Chesapeake Bay, the Everglades and South Florida, the California Bay Delta, and the Mississippi River basin and Gulf of Mexico (White House, 2011). Nationally, agriculture is estimated to account for around 60% of river pollution, 30% of lake pollution and 15% of estuarine and coastal pollution. For the latter, for example, agriculture is the major source of sediment, nitrogen and phosphorus loadings into Chesapeake Bay. The Gulf of Mexico's hypoxic (dead/eutrophic) zone, first detected in the 1970s, has increased in size substantially, with the U.S. National Oceanic and Atmospheric Administration estimating the area of the zone could be over 2 million ha in 2011, although the area of the zone varies annually according to climatic conditions (Devine, Dorfman and Rosselot, 2008; Rabotyagov *et al.,* 2010). Agriculture also contributes significantly to groundwater contamination (wells and aquifers) across the nation, especially from leaching of nutrients and pesticides (USGS, 2010). Of increasing concern to groundwater quality is the increasing and widespread detection of contaminant mixtures, including mixtures of pesticides and veterinary products from agriculture with other man-made and natural contaminants (USGS, 2010).
- **Mexico**: Irrigation is widespread and has caused salinisation and drainage problems in some areas. Many groundwater sources are over-exploited, leading to low river flows that concentrate pollution levels and degrade ecological conditions. Around 25% of surface water is considered contaminated or highly contaminated. Monitoring of water quality is improving, but nitrate and pesticide levels cause less concern than bacterial contamination which has promoted significant investment in water treatment and infrastructure to address industrial and municipal pollution sources. Mexico shares major watersheds with the Belize, Guatemala and the **United States**, meaning that some effects are transboundary.
- **Chile**: Farming has an acknowledged impact on water quality arising both from the intensity of chemical and nutrient applications but also changes in land use, for example, from forestry. Impacts include contaminating drinking water and eutrophication of lakes and coastal water that lowers recreational and fishing values. But biophysical measurement of impacts is relatively poor and pollution from other sources, such as aquaculture, heavy industry and municipal sewage, are generally regarded as more pressing issues. A need for research into the size and relative importance of agricultural impacts has been recognised if problems observed in other countries are to be avoided (Pizarro *et al.,* 2010).
- **Japan** (OECD, 2010d): Whilst over 90% of rivers meet health related water quality standards, many lakes, reservoirs and coastal waters do not. Nitrates, pesticides and sediments from agricultural activities are acknowledged to be among the causes of these problems, as well as discharges from other sources (e.g. sewage, industrial). Eutrophication continues to be a concern with nutrients, including from agriculture, especially intensive livestock operations but also fertiliser use leading to frequent algae blooms (red and blue tides) that damage aquatic life in coastal areas and increase costs

of water treatment from inland water intakes (Ileva *et al.,* 2009). The quality of groundwater is improving, with nitrogen (from all sources including agriculture) exceeded in 4% of monitored wells and less than 0.1% of wells for pesticides. The potential of paddy fields to mimic natural wetlands and filter excess nutrients, provide some benefits for water quality (Chapter 1.4).

- **Korea**: Despite some recent improvements, around a third of rivers fail to meet domestic quality standards and over a quarter of lakes are eutrophic. Groundwater quality is higher, but 6% still fails domestic standards. Coastal eutrophication is a localised problem for fisheries and aquaculture. Diffuse pollution, including from agriculture, is acknowledged as a source of pollution with increases in livestock numbers a growing pressure on water systems. Paddy fields mimicking natural wetlands hold the potential to improve water quality.
- **Australia** (Chapter 5.3): Problems arising from agricultural contaminants and salinity have been exacerbated by low flow conditions caused by abstraction and less rainfall in recent years. Most rivers exhibit a high degree of degradation, particularly within the Murray-Darling catchment, Australia's main agricultural producing region. Drinking water quality is impaired in many locations, and coastal regions downstream of large agricultural areas suffer from sediment and nutrient loadings. In terms of the environmental health of the Great Barrier Reef (GBR), recent research indicates that quantities of sediment, phosphorus and nitrogen entering the GBR have been increasing, with agriculture a key contributor to water quality issues in the GBR (Rolfe and Windle, 2011). But given the lack of a national monitoring system it is difficult to assess national trends in water quality related to agriculture (OECD, 2008a).
- **New Zealand** (Chapters 5.4 and 5.6): Overall water is of high quality, but the quality of a number of lowland rivers and streams is causing concern. There are expensive restoration clean-ups going on in some iconic lakes and there are questions over the state of groundwater. At a national level, diffuse discharges now greatly exceed point source pollution. Around 64% of monitored lakes in pastoral landscapes are classed eutrophic or worse (Ballantine and Davies-Colley, 2009; Land and Water Forum, 2010; Verburg *et al.,* 2010). Similarly groundwater quality has been deteriorating, with one third of sites monitored between 1995 and 2008 showed increasing trends in nitrate levels (Daughney and Randall, 2009).

Eutrophication of rivers, lakes and coastal waters

Eutrophication is the leading cause of water quality impairment around the world, and results in the over-enrichment of water with nutrients (nitrogen and phosphorus) as a result of human activity, including agriculture (Díaz, Rabalais and Breitburg, 2012). Eutrophication can be defined simply as the increase in the rate of production and accumulation of organic carbon in excess of what an ecosystem is normally capable of processing. Eutrophication can be harmful to both freshwater and marine ecosystems, and leads to a progression of symptoms that include:

- Excessive phytoplankton and macro algal growth that is the source of organic carbon. This can also reduce light penetration and lead to a loss of submerged aquatic vegetation.
- An imbalance of nutrient ratios that can lead to a shift in phytoplankton species composition and creating conditions that are favourable to toxic algal blooms. Harmful

algal blooms can cause kills of living marine resources and shellfish poisoning in humans.

- Changes in species composition and biomass of the benthic (bottom-dwelling) community, eventually leading to reduced species diversity and increased dominance of gelatinous organisms, such as jellyfish.
- Low dissolved oxygen and formation of hypoxic or dead zones (oxygen-depleted waters). These oxygen-starved areas stress aquatic ecosystems, often leading to kills of living marine resources, altered ecosystem energy flows, and in severe cases ecosystem collapse. Hypoxia is the most severe symptom of eutrophication and can make some rivers, lakes and coastal waters unfit for recreational uses.

Eutrophication is widespread across OECD countries and globally, affecting rivers, lakes, and reservoirs to varying degree of severity. But the most severe impacts of eutrophication are on estuarine, coastal and deep sea ecosystems, with damaging consequences for aquaculture and marine water fisheries.

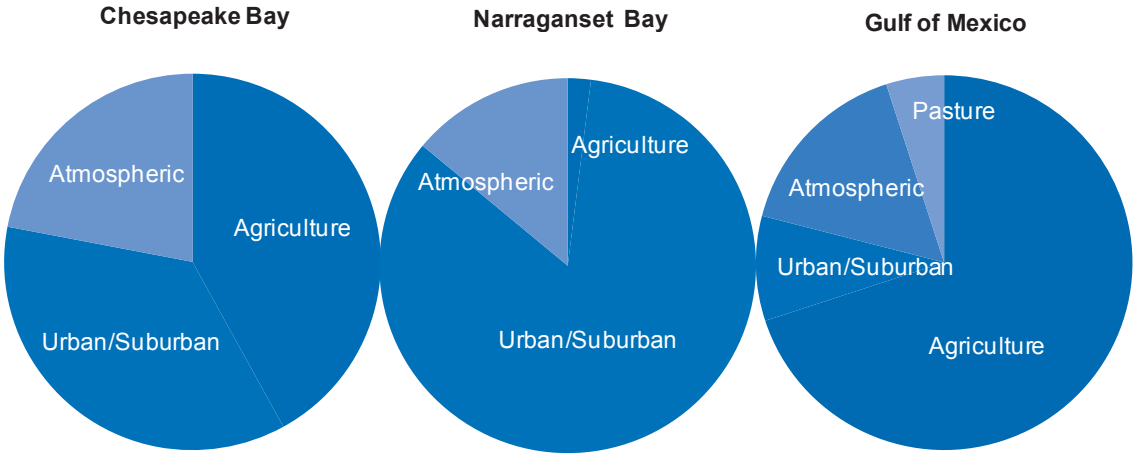
Current estimates are that hypoxia related to eutrophication annually affects at least 240 000 km^2 globally. About 70 000 km^2 are inshore (estuarine and brackish waters and embayments), and about 170 000 km^2 are coastal offshore waters. There is also another 1.1 million km^2 of bottom areas in the outer continental shelf affected by natural oxygen minimum zones. In total, about 4% of estuarine/brackish water and about 5% of shelf area are affected globally by hypoxia of some type. This translates to losses in ecosystem services estimated to be billions of US dollars (Díaz, Rabalais and Breitburg, 2012).

Sources of nutrients to coastal waters are diverse and vary from ecosystem to ecosystem (Díaz, Rabalais and Breitburg, 2012). Nutrients enter coastal ecosystems through atmospheric deposition, surface water runoff, and groundwater. Within the **United States**, for example, municipal wastewater is the primary driver of eutrophication in Narragansett Bay (an estuary in the North-East of the United States), in the northern Gulf of Mexico it is agriculture, and in Chesapeake Bay (an estuary of the US East Coast) atmospheric, urban/suburban, and agricultural sources are all co-equal (Figure 2.3). Broad scale regional differences also exist in the relative importance of nutrient sources, for example, in the United States and the European Union, agricultural sources are generally the primary contributors to eutrophication, while in some other OECD countries nutrient pollution is primarily attributed to municipal wastewater.

Human health risks with water pollution from agriculture

High concentrations of pollutants in water systems derived from agriculture can be dangerous to human health, especially where pollutants impair drinking and bathing water, such as from nitrates, heavy metals, pesticides and bacterial contaminants (Table 2.1). Overall for OECD countries harmful human health effects from agricultural contaminants is extremely low where water is drawn from treated water networks. There are concerns, however, for rural areas where water is consumed from untreated wells, as reported, for example, in the **United States** (USGS, 2010); and water quality close to large intensive confined livestock feeding operations (West *et al.*, 2011).

Figure 2.3. Comparison of the relative contribution of major sources of nitrogen pollution in three United States coastal ecosystems experiencing hypoxia



Note: Urban/suburban includes both point (industrial and sewage effluent) and diffuse sources (residential runoff).

Source: Díaz, Robert J., N.N. Rabalais and D.L. Breitburg (2012), *Agriculture's Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water,* based on Jewett, E.B., *et al.,* (2009), *Scientific assessment of hypoxia in U.S. coastal waters*, Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology, Washington, D.C., United States.

Human health impacts due to agricultural contaminants in drinking water is an issue under debate both in the scientific and policy arena, and the evidence for increased health risks is unclear or absent (Sutton *et al.*, 2011; US Department of Health and Human Services, 2010). This is in part because of the lack of scientific understanding of the effect of contaminant mixtures in the environment, which may derive from various sources, including agriculture, and link to the issue of emerging contaminants, as discussed below.

Illustrative are nitrates in drinking water which can cause cancers and (albeit rarely) infant methaemoglobinaemia (blue baby syndrome). In the **EU15**, for example, 3% of the population is potentially exposed to levels of nitrate exceeding the drinking water standard of 50 mg NO_3 per litre. This may cause a 3% increase in the incidence of colon cancer, but nitrate is also considered to be beneficial to cardiovascular health (Sutton *et al.,* 2011). It is estimated that this corresponds to an economic cost to the EU public that exceeds the costs of lowering nutrient input use in areas of intensive farming and/or the cost of improved water treatment abatement (van Grinsven, Rabl and de Kok, 2010). The authors of this study note that the epidemiological evidence for increased risk of colon cancer linked to nitrates is weak or absent, but that in view of the potential health gain from lowering nitrates in drinking water, improved epidemiological studies would be merited.

In recent years there has been increasing concern over the ***environmental and health risks of the so-called "emerging contaminants"*** (ECs) from agriculture and other sources into water systems. ECs originate from a variety of product types including human pharmaceuticals, veterinary medicines, transformation products of synthetic chemicals, nanomaterials, personal care products, paints and coatings. Some ECs, namely natural toxins, may be formed in the environment by animals, plants and microbes. A range of non-standard effects have been reported for different ECs. These effects are often seen at

concentration levels close to those measured in the environment. However, the implications of these effects in terms of ecosystem functioning have yet to be established (Box 2.1).

Box 2.1. Emerging water contaminants from agriculture

Until very recently, the main focus on the impacts that agriculture causes on water has been on nutrients, pesticides, and soils. However, in recent years, there has been increasing concern over the human health and environmental risks to water of so-called "emerging contaminants" (ECs). ECs originate from a variety of product types including human pharmaceuticals, veterinary medicines, nanomaterials, personal care products, paints and coatings. Some ECs, such as natural products and transformation products of synthetic chemicals, may be formed in the environment by biochemical processes in animals, plants and microbes.

The increasing concern over the risks of ECs is reflected by a rapid increase in the numbers of scientific publications exploring the impacts of ECs over the past decade and the appearance of numerous articles in the popular press across the world. ECs are not necessarily new chemicals, they may be substances that have been present in the environment for a long time but whose presence and significance are only now being recognised. Data for ECs are often scarce and methods for detection in the natural environment may be non-existent or at an early stage of development.

ECs are released to the agricultural environment via a number of routes. They may be released directly to the environment (e.g. veterinary medicines used to treat livestock grazing). They may also enter the environment indirectly during the application of manure, biosolids or other solid waste materials to soil. Once in soil the ECs may be transported to water bodies by leaching, runoff and drainage processes. The extent of the transport is dependent on the persistence of the EC and how it interacts with soil and sediment particles. Many ECs appear to behave differently in agricultural systems than other agricultural contaminants (such as pesticides). This means that modelling approaches that have been developed for predicting fate properties and exposure of other contaminants are not always appropriate for ECs.

While a large number of studies have investigated the occurrence of a wide range of ECs, only a few have specifically investigated occurrence of ECs in agricultural systems. The studies that have looked at agricultural systems have detected a range of ECs, such as veterinary drugs and pesticide transformation products. Generally, reported concentrations are very low. Detection of ECs in environmental media can be challenging. However, robust methods are now available for many ECs. But methods are currently poorly developed for the detection and characterisation of engineered nanoparticles in soils and natural waters.

The environment is exposed to a mixture of ECs and other contaminants. The impact of these mixtures is likely to be greater than the impact of the single substance on its own. It is therefore important that greater effort is made to consider the potential implications of these mixture interactions in terms of risk. This is a general problem that is also relevant to non emerging contaminants, such as pesticides and heavy metals.

New ECs are likely to emerge in the future due to changes in demographics, socio-economic factors, land-use and climate. It is important that a start is made to develop approaches to anticipate these changes, including identifying ECs of most concern so that resources can be focused on the bigger problems. A number of prioritisation approaches already exist for horizon scanning for different classes of ECs. However, these approaches need further development and applied more widely. In order to co-ordinate resources, it may be appropriate to establish international oversight on EC's and to promote greater international co-operation.

Source: OECD Secretariat adapted from Boxall, A. (2012), *New and Emerging Water Pollutants arising from Agriculture*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

2.4 Medium-term outlook and implications of climate change

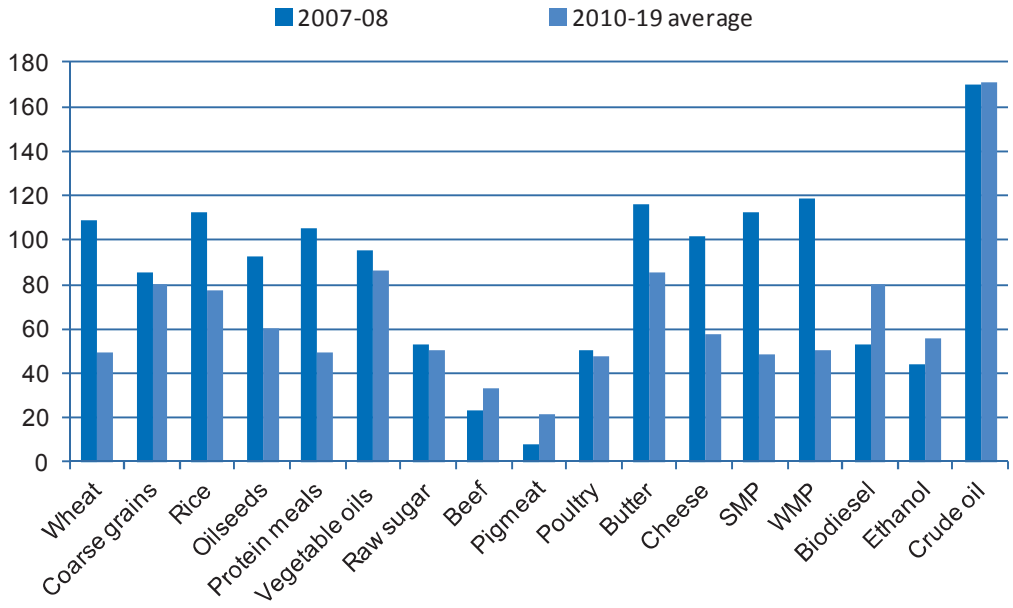
Medium-term outlook

The *OECD-FAO Agricultural Outlook* (OECD, 2011e) projects over the next decade to 2020 a trend of sustained rises in crop, sugar and vegetable oilseed product prices, in nominal and real terms (allowing for inflation). These commodity price projections are expected to remain well above the levels observed over the past decade, but fall from recent price peaks, i.e. during 2007-08 and 2010-11 (Figure 2.4).

Projections also indicate a similar trend to crops for bioenergy, with rising real prices for biodiesel and ethanol. More modest increases are expected for livestock prices, other than pig meat, over the coming decade, but average dairy prices are expected to be 30-70% higher in 2011-20 relative to 2001-10 (shown in terms of dairy products in Figure 2.4) (OECD, 2011e). -

The outlook for agricultural commodity prices translates into projected growth in agricultural production for nearly all OECD countries over the coming decade (Figure 2.5). From the trends in national agricultural production projections in Figure 2.5 it is possible to discern two broad groupings of OECD countries in terms of their potential pressure on water systems over the coming decade:

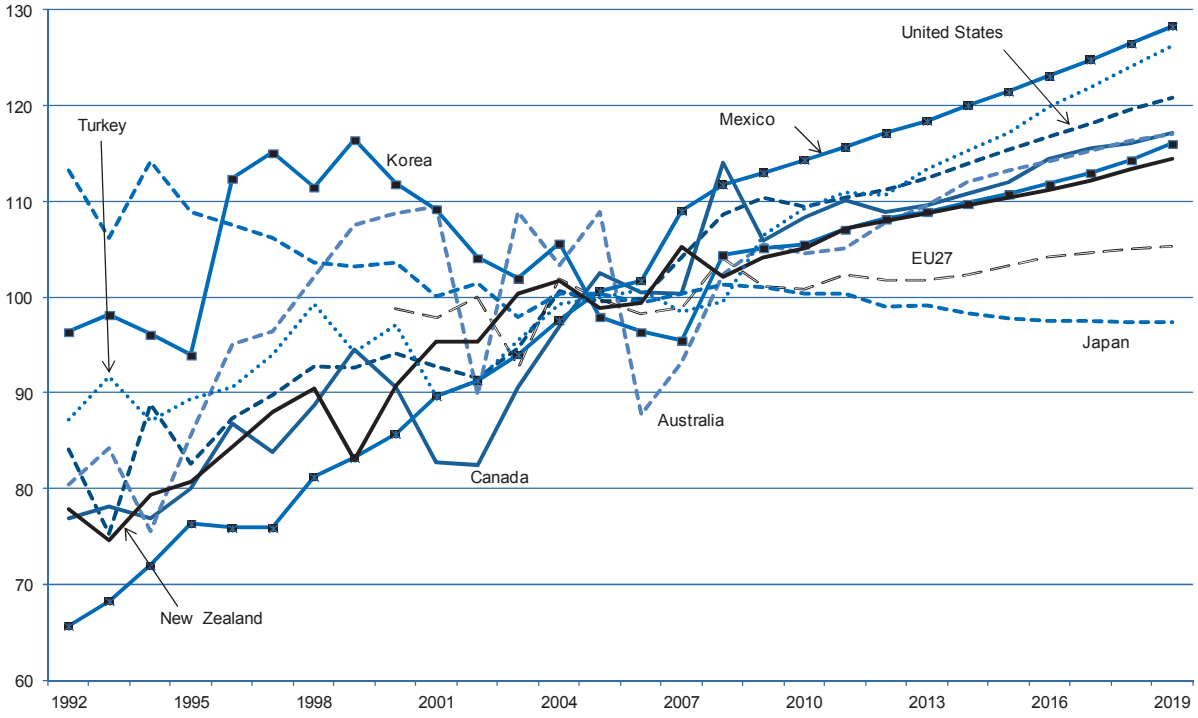
Figure 2.4. OECD projections for international commodity prices in real terms to 2019



Note: SMP – Skim Milk Powder; WMP – Whole Milk Powder. For biodiesel and ethanol the base period is 2001-06.

Source: OECD (2010), *OECD-FAO Agricultural Outlook 2010-2019*, www.agri-outlook.org.

Figure 2.5. Index of net agricultural production trends for selected OECD countries, 1992-2019 (Index 2004-06 = 100)



Note: Net agricultural production measures gross value of product produced, net of "internal" feed and seed inputs to avoid double counting (for example maize and livestock production), so that the production measure approximates a value added concept. There are no projections for Chile, Iceland, Israel, Norway and Switzerland.

Source: OECD (2010), *OECD-FAO Agricultural Outlook 2010-2019*, *www.agri-outlook.org.*

- **Group 1**: Countries which are projected to continue with strong growth in production over the coming decade, including: **Canada, United States, Mexico, Turkey, Australia and New Zealand.** Most OECD countries in this group have over the past decade largely expanded production by raising productivity and intensifying production on a reduced land area. However, in regions within some of these countries there is a risk of expanding production onto environmentally fragile land or marginal land not previously cultivated. **Korea** is the exception in this group, with production declining from the late 1990s to present but then projected to expand back to the levels of the late 1990s, largely explained by growth in beef production stimulated by a rise in Korean consumer demand and higher government support to producers. For this group of countries, the potential consequences for water quality of the projected growth in agricultural production might include (trends may vary within and across countries) the following.

  - Heightened pressure on water quality from the increased use of fertilisers and pesticides, and greater quantities of livestock manure, although absolute levels of pollution for many of these countries is below the OECD average (e.g. nutrient surplus/ha).
  - Elevated soil erosion leading to greater siltation of water systems as a result of farming more intensively environmentally fragile lands and/or expanding production onto marginal land not previously cultivated.

- Expanded production of bioenergy, especially using cereals, oilseeds and sugar crops as feedstocks for manufacturing biofuels, especially in the **United States**, which may lead to a rise in fertiliser and pesticide use (Box 2.2).
- Regionalised pressures on water systems could alter as a result of the continued structural changes in livestock production toward larger and more concentrated livestock operations, notably in the pig, poultry and dairy sectors, although in some cases larger, concentrated livestock operations do provide high levels of waste disposal management.
- Increased concerns with the growth in emerging contaminants, especially the release of medicines, veterinary products, etc., resulting from the growth in livestock production (Box 2.1).

➢ **Group 2**: Countries where projected production growth over the coming decade is expected to be modest for the **EU27** or decline in the case of **Japan**. Within the EU27, however, there could be some diverging trends, with the agricultural sector continuing to contract in many of the former EU15 countries, but expanding in some of the new EU member states (European Environment Agency, 2010). In addition, crop and livestock production could undergo further intensification and concentration of production on less land to maintain increases in productivity and profitability. For this group of countries, the potential consequences for water quality of the projected low growth or decrease in agricultural production might include (trends may vary within and across countries) the following.

- Reduced overall agricultural pollutant loadings into water, with this trend more pronounced in Japan given the projected decrease in agricultural production, although the absolute levels of pollution for many of these countries might remain above the OECD average (e.g. nutrient surplus/ha).
- Localised increases in water pollution, with structural changes in the livestock sector towards larger concentrated operations.

For all OECD countries over the medium term there are a number of developments that may generally help toward lowering the pressure of agriculture on water quality, including the following.

- Efficiencies in lowering farm chemical input use per unit of output, partly induced by higher prices for inorganic fertilisers and pesticides due to the projected increase in crude oil prices (Figure 2.4), which might also encourage greater use of livestock waste as a bioenergy feedstock.
- Improvements in farm management practices, and pollution related technologies, especially biotechnologies and use of global positioning systems (GPS).
- Increases in public pressure to reduce the health and environmental costs of water pollution from agriculture, likely to result in strengthening of environmental pollution policies, especially those policies addressing diffuse source pollution from agriculture.
- Reforms likely to continue with agricultural policies leading to further declines in overall OECD agricultural support and a continued shift towards decoupled support.
- Innovations in policy and market approaches to address water quality issues in agriculture, that seek to change the behaviour of farmers, the agro-food chain and other stakeholders to improve water quality (Chapter 4.3), and national water quality policies more generally (e.g. **Australia**'s *National Water Quality Management Strategy)*.

Box 2.2. Bioenergy production using agricultural feedstocks: Implications for water quality

Bioenergy production from agricultural feedstocks (e.g. grains, cereals, oilseeds, grasses, woody materials) can have significant impacts on water quality and availability, although impacts on water resources has already been considered by OECD (2010). The water quality impacts may be caused by the use of agro-chemicals in intensive bioenergy feedstock production systems, such as the use of fertilisers which pose a risk for eutrophication. In addition, the feedstock processing plants to convert raw materials to bioenergy can also have impacts on water quality, although this will vary depending on a range of factors, including for example, biorefinery technology, effluent controls and water recycling practices (FAO, 2008; Fingerman *et al.,* 2010; USEPA, 2011).

In the **United States**, for example, much of the increased production of biofuels is produced from maize, which usually entails large applications of inorganic fertilisers. As a result sediment and nutrient pollution from agricultural land is likely to increase, particularly where maize is cultivated on marginal agricultural land which contributes to the highest nutrient loads. This may have substantial consequences for water quality, especially in the Mississippi river and the northern Gulf of Mexico (De la Torre Ugarte *et al.,* 2010; Donner and Kucharik, 2008; National Research Council, 2008a, and 2008b; OECD 2008; USEPA, 2011).

For wood plantations used as bioenergy feedstocks, the clearance of streamside vegetation in wood management systems may also change physical properties of water systems, such as the turbidity, stream temperature and light infiltration of water bodies. If nutrient inputs are required for wood plantations, infiltration and runoff of nitrogen may also pose a risk to groundwater (Lattimore *et al.,* 2009).

A key conclusion from most studies on the links between bioenergy production from agricultural feedstocks on water quality is that in general feedstocks from annual crops such as maize and oilseeds can have a more damaging impact on water systems than feedstocks produced from grass and woody materials, such as reed canary grass and short rotation woodlands (FAO, 2008; OECD, 2008; USEPA, 2011). Another important conclusion is that the location of production and the type of tillage production, crop rotation system and other farm management practices used in producing feedstocks for bioenergy production will also greatly influence water quality (De la Torre Ugarte *et al.,* 2010; European Environment Agency, 2008; Lankoski and Ollikainen, 2011; Thomas, Engel and Chaubey, 2009). But a note of caution is important when considering the discussion here as the potential impacts on water quality from growing agricultural feedstocks for bioenergy production, have not been fully evaluated (National Research Council, 2008a; OECD, 2008).

With the expansion in the bioenergy industry it will be important to optimise benefits while minimising adverse outcomes on water quality, as well as other environmental impacts. Since many of the known adverse impacts on water quality from bioenergy production are due to the type of feedstock cultivated, there is potential to mitigate these impacts through the adoption of conservation practices and systems (USEPA, 2011).

Sources: De la Torre Ugarte, D.G., *et al.* (2010), "Expanded ethanol production: Implications for agriculture, water demand, and water quality", *Biomass and Bioenergy*, Vol. 34, pp. 1586-1596; Donner, S.D. and C.J. Kucharik (2008), "Corn based ethanol production compromises goal of reducing nitrogen run-off by the Mississippi River", *Proceedings of the National Academy of Sciences*, Vol. 105, pp. 4513-4518; European Environment Agency (2008), *A review of the possible impact of biomass production from agriculture on water*, Copenhagen, Denmark, available at: *www.eea.europea.eu*; Fingerman, K.R., *et al.* (2010), "Accounting for the water impacts of ethanol production", *Environmental Research Letters*, 5 014020, *iopscience.iop.org/1748-9326/5/1/014020;* Lattimore, B., *et al.* (2009), "Environmental Factors in Woodfuel Production: Opportunities, Risks, and Criteria and Indicators for Sustainable Practices", *Biomass and Bioenergy,* Vol. 33, pp. 1321-1342; Lankoski, J. and M. Ollikainen (2011), "Biofuel policies and the environment: Do climate benefits warrant increased production from biofuel feedstocks?", *Ecological Economics*, Vol. 70, pp. 676-687; National Research Council (2008a), *Mississippi River water quality and the Clean Water Act: Progress, challenges and opportunities*, The National Academies Press, Washington, D.C., United States, *www.nap.edu/catalog/12051.html;* and National Research Council (2008b), *Water implications of biofuels production in the United States*, The National Academies Press, Washington, D.C., United States, *books.nap.edu/catalog.php?record_id=12039*; OECD (2008), *Biofuel Support Policies: An Economic Assessment*, OECD, Paris, *www.oecd.org/agr*; OECD (2010), *Sustainable Management of Water Resources in Agriculture,* OECD, Paris, *www.oecd.org/agr/env*; OECD/IEA (2010), *Sustainable Production of Second-Generation Biofuels,* OECD/IEA, Paris, *www.iea.org/papers/2010/second_generation_biofuels.pdf;* Thomas, M.A., B.A. Engel and I. Chaubey (2009), "Water quality impacts of corn production to meet biofuels demands", *Journal of Environmental Engineering*, Vol. 1 235, No. 11, pp. 1123-1135; U.S. Environmental Protection Agency (USEPA) (2011), *Biofuels and the environment: First triennial report to Congress,* External Draft Review, EPA/600/R-10/183A, Washington, D.C., United States, *cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=217443*.

Climate change

The medium and long-term outlook for agriculture is expected to be increasingly impacted by climate change and climate variability. Changes in climate and climate variability that affect the profitability of agriculture will in turn lead to changes in locations of crop and livestock production, and technologies and management practices used to produce individual crops and livestock (Abler *et al.*, 2001). These economic responses to climate change could lead to indirect consequences in changing pollutant runoff and leaching rates as well as soil erosion rates, which may increase or diminish pollution from agriculture assuming no economic or policy response.

Recent research studies, although currently limited, that have explored the potential impacts of climate change and variability on the risks of water quality contamination related to agriculture have concluded that climate change could have the following impact.[3]

- Influence the amounts and types of contaminant run-off and leaching from agriculture, with the magnitude of the increases highly dependent on the contaminant type, although risks from pathogens might be highest.

- Fuel increased use of pesticides and biocides, as farming practices intensify and in some areas are subject to higher temperatures.

- Mobilise contaminants from soils and faecal matter as a result of extreme weather events; potentially increasing their bioavailability, as illustrated by the possible aggravation from climate change of chemical reactions in acid sulphate soils (Box 2.3).

- Affect the fate and transport of contaminants in agricultural systems, for example the increase in salinisation due to the intrusion of salt water when water discharge volumes are low, and the higher concentrations of nutrients with a greater chance of algal blooms (Box 2.4).

- Reduce, through increases in temperature and changes in moisture content, the persistence of contaminants, while changes in hydrological characteristics are likely to increase the potential for contaminants to be more easily transported to sources of water supplies.

- Lead to an impoverished ecological status of water systems, such as the decrease or disappearance of species, and shifting the range of distribution of species from elevated agricultural pollution.

- That climate change could be managed for the most part by farm management and policy adaptations, including through better regulation, monitoring and the development of long-term research programmes. Also various strategies for mitigating greenhouse gases in agriculture would for the most part be beneficial for water systems, such as through afforestation and other increases in green cover providing a buffer for soil sediment and contaminant flows across agricultural land (Wilcock *et al.,* 2008).

In summary, relationships between climate change and pollution from agriculture are likely to be complex, as increased flooding, for example, could mobilise sediment loads and associated contaminants and exacerbate impacts on water systems. On the other hand, more severe droughts could reduce pollutant dilution, thereby increasing toxicity

problems (Collins and McGonigle, 2008). But the expectations are that whatever the impacts on water quality, the task of achieving water quality objectives in agriculture will become more difficult in the coming years as a result of climate change.

These conclusions are tentative, not only because of the overall uncertainties of current climate change research, but more specifically that the linkages between climate change, agriculture and water quality are not yet extensively researched. Indeed there is a pressing need for more studies in this area, especially through the use of climate and water catchment modelling (Delpha *et al.,* 2009 and 2011; Ficklin *et al.*, 2010; Jennings *et al.*, 2009; Kronvang, Rubaek and Heckrath, 2009; Stuart *et al.,* 2011).

Box 2.3. Climate change, agriculture, acid sulphate soils and water quality: A case study of Finland

From an environmental point of view, acid sulphate soils (ASS) are regarded as the most problematic soils in the world. Finland has Europe's largest areas of ASS (c. 2 000-4 000 km^2). By reclamation, burning of peat cover and heavy liming they constitute some of the most productive farmland in Finland.

As a result of these farm practices groundwater level is strongly lowered during dry spells, enabling oxygen to penetrate the soil. When exposed to oxygen, sulphides oxidise and produce sulphuric acid and make the soil extremely acid (pH 2.5-4), which in turn mobilises enormous quantities of metals (e.g. cadmium, zinc) stored in the soil. Together with acidity, these metals are flushed from the soils into recipient estuaries during wet spells. Metal discharges from ASS are estimated to significantly exceed the corresponding total discharges from Finnish industry.

The extensive pool of toxic metals with high risk of mobilisation in these soils has not been fully understood until very recently. The chemical composition and quality of drainage water from ASS, resembles those of sulphur rich metal ores, which cause similar acidity problems in Europe and worldwide. In Finland, leaching of acidity and heavy metals from ASS is the most common cause for bad or poor ecological and chemical status of surface water bodies, affecting more than 30 coastal rivers and estuaries. Depleted or eradicated fish stocks in numerous rivers and estuaries are the most visible effect. Impacts of acid runoff vary according to the quantity, quality and proximity of ASS and the catchment characteristics of water bodies.

Climate change is likely to increase and widen the extent of environmental damage unless targeted mitigation measures are developed. High peak concentrations of toxic compounds occur especially after long dry periods and subsequent heavy rainfall. As a result of climate change, these hydrological extremes are expected to become much more common in river basins with small lakes and rapidly fluctuating discharges. For aquatic ecosystems and fish stocks this means increased probability of exposure to toxic metal compounds. In order to adapt ASS land use and water pollution control measures to climate change, the following actions are necessary:

- Increase knowledge on the location, quality and quantity of ASS;
- Develop cost-effective mapping tools and tools for identification of potential hotspot areas;
- Collate data on loading levels and degree of environmental degradation in water bodies affected by ASS;
- Construct climate change risk scenarios and identify future problem areas;
- Evaluate effectiveness and constraints of the current pollution control measures under changing climate;
- Develop and demonstrate pollution control techniques tailored for changing climate conditions; and,
- Assess the socio-economic impacts and feasibility of the adaptation tools.

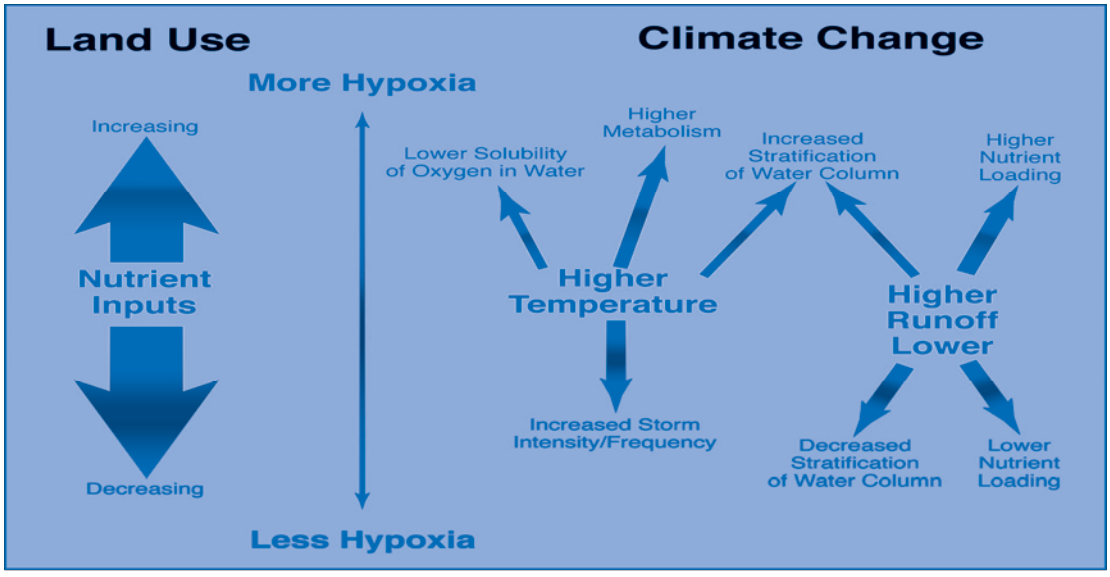
Source: Drawn from material provided to the OECD Secretariat by the Finnish Delegation to the OECD.

Box 2.4. Climate change, marine eutrophication and agriculture

Recent studies have shown that after years of eutrophication, it may not be as simple as reducing nutrients to reverse water quality problems, especially associated with hypoxia. If in the next 50 years humans continue to modify and degrade coastal systems as in previous years, human population pressure will likely continue to be the main driving factor in the persistence and spreading of coastal dead zones. Expanding agriculture for production of crops to be used for food and biofuels will result in increased nutrient loading and expand eutrophication effects.

Climate change, however, may make systems more susceptible to the development of hypoxia through direct effects on stratification, solubility of oxygen, metabolism, and mineralisation rates, as shown in the Box Figure below. This will likely occur primarily though warming, which will lead to increased water temperatures, decreased oxygen solubility, increased organism metabolism and remineralisation rates, and enhanced stratification.

Relative contribution of global climate change and land use to future hypoxia



Note: The thickness of the arrows indicates relative magnitude of effect.

Source: OECD Secretariat, adapted from Díaz, Robert J., N.N. Rabalais and D.L. Breitburg (2012), *Agriculture's Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

2.5 Issues related to monitoring water quality in agriculture important for policy makers

Monitoring efforts are crucial to provide information to policy makers and other stakeholders about the state, trends and outlook in water quality related to agriculture. There are a number of issues related to monitoring which are important in the policy making process to address water pollution from agriculture, including standards, targets and goals to measure progress, and developing water quality monitoring systems.

Standards, targets and goals to measure progress

All OECD countries have general drinking water quality chemical standards covering nutrients and pesticides, and nearly all have ecological standards (mostly lower) for

environmental water quality. For example, in most OECD countries the drinking water threshold value for nitrate is 50 mg nitrate per litre. Agriculture is not usually directly implicated in meeting drinking water quality standards, as this is usually the task of the public/private water suppliers. The source of water – rivers, lakes, reservoirs and groundwater – from which water suppliers draw, often requires treatment to remove nutrients, pesticides and other contaminants to meet drinking water standards, often at considerable cost (Chapter 3).

In situations where mains drinking water supplies are not available to the farm household, then the farm will draw water from wells on-farm, which do not necessarily meet the same chemical standards as mains water supplies. In the **United States**, for example, privately owned wells are not regulated under the Federal Safe Drinking Water or in most cases by State laws. About 15% of the US population rely on these wells, and where they are in or near agricultural settings have the highest probability of consuming nitrate concentrations, for example, at elevated levels (Dubrovsky *et al.,* 2010).

Few countries have comprehensive water quality standards, targets or goals specific to agriculture. **Sweden**, for example, has set agriculture specific water quality targets for surface, groundwater and marine water (OECD, 2008a). The **European Union** in the case of nitrates, through the *Nitrates Directive* (which forms part of the European Union *Water Framework Directive*), requires member states to designate as Nitrate Vulnerable Zones all areas of land where the corresponding surface water or groundwater contain more than 50 mg nitrates per litre or where the corresponding freshwater bodies, estuaries, coastal and marine waters are found to be, or risk being, eutrophic. Member states must establish and implement mandatory measures for farmers located in these zones (Chapter 5.1) (OECD, 2008a).

Broader national standards for water quality do have, however, implications for the policy abatement strategies that agriculture can pursue to meet the standards. Illustrative are the **United States** Total Maximum Daily Load (TMDL) regulation under the US *Clean Water Act*, and the **European Union's** water quality standards under the *Water Framework Directive*.

The TMDL is the **United States** Environmental Protection Agency's major initiative to remedy the nation's water quality problems. Under the Federal TMDL framework, states are responsible for compiling lists of water bodies not meeting their designated use which are then reported as impaired waters (Helmers *et al*., 2007). For each listed water body, the states need to identify the amount by which pollution loads from diffuse and point sources of pollution must be reduced to meet the standards, and to develop and implement plans to achieve the load reductions (Borisova *et al.,* 2003).

Until recently there has been no regulatory authority by the Federal or State governments to require that TMDL reductions occur. For the six States and the District of Colombia surrounding the Chesapeake Bay area the TMDL's will now be mandatory (Chapter 5.2) (Perez, Cox and Cook, 2009). In the TMDL process modelling and monitoring can play an important part in allocating pollutant loads to various sources, such as helping to determine the relative contributions of arable crops, intensive livestock operations and urban sources to loads of nutrients and pathogens observed in large water catchments (Helmers *et al.,* 2007).

Under the **European Union**'s *Water Framework Directive* (WFD) member states are required to regularly assess both the current ecological status of inland and coastal waters, defined as a function of deviation from an undamaged (reference) state; and also the

chemical status of water bodies. The resulting classification for each water body is reported to the European Commission (Johnes, 2007). The ecological status ranges which can range from "high" to "bad", is determined by a combination of biological quality elements (aquatic flora, benthic invertebrate fauna and fish fauna) and physico-chemical quality elements (such as oxygenation conditions, nutrient conditions, salinity, as well as specific pollutants). Good chemical status means compliance with the environmental quality standards defined in Directive 2008/105/EC. This Directive comprises a list of 33 priority substances and certain other pollutants (e.g. pesticides and heavy metals). In order for a surface water body to be classified as being of good status, the criteria for both good ecological and good chemical status have to be met. The overall good status objective represents surface water conditions that are appropriate for all types of water uses and functions, besides healthy aquatic ecosystems.

Under the **European Union**'s WFD timetable of requirements, member states must classify the chemical and ecological status of each water catchment, followed by specification of River Basin Management Plans by 2009, detailing measures for addressing diffuse pollution which must be operational by 2012 (Chapter 5.1). As with the TMDL in the United States, the WFD implementation requirements mean that modelling is increasingly being used by member states to characterise current environmental conditions and to predict for policy makers the potential impact of different abatement strategies (Collins and Anthony, 2008).

Developing water quality monitoring and modelling of water catchments

All OECD countries have monitoring networks to measure the actual state of water pollution of water bodies, while some countries use risk indicators which provide estimates, usually based on models of contamination levels, for example, as described previously for the **European Union** and the **United States**. However, monitoring of agricultural pollution of water bodies is more limited with just over a third of OECD member countries monitoring nutrient pollution and even fewer countries tracking pesticide pollution. Certain farm pollutants are recorded in more detail and with greater frequency (e.g. nutrients, pesticides), whereas an indication of the overall OECD situation for water pollution from pathogens, salts and other agricultural pollutants is unclear. Moreover, pollution levels can vary greatly between countries and regions depending mainly on soil and crop types, agro-ecological conditions, climate, farm management practices, and policy (OECD, 2008a).

The limitations to identifying trends in water pollution originating from agriculture are in attributing the share of agriculture in total contamination and identifying areas vulnerable to agricultural water pollution. In addition, differences in methods of data collection and national drinking and environmental water standards hinder comparative assessments, while nation-wide monitoring agricultural water pollution is poorly developed, especially for pesticides, in a number of countries, such as **Australia, Italy, Japan** and **New Zealand**, although in some of those countries, monitoring is carried out at the sub-national level The extent of agricultural groundwater pollution is generally less well documented than is the case for surface water, largely due to the costs involved in sampling groundwater, and because most pollutants take a longer time to leach through soils into aquifers (OECD, 2008a).

Most water quality monitoring is publicly financed, but there are increasing signs of private sector initiatives to improve the regularity and quality of water quality data, including data related to agriculture. In California, **United States**, privatised intensive

water quality monitoring efforts are being considered by farmers in the Central Coast district of the State as an interim approach while continuous monitoring technologies of diffuse source agricultural pollution are being developed (Dowd, Press and Los Huertos, 2008).

At a global scale the World Resources Institute (WRI), in partnership with General Electric and Goldman Sachs in the **United States**, has launched an initiative to measure water-related risks facing companies and their investors (see WRI website *www.wri.org/stories/2010/01/betting-water*). The initiative will develop a Water Index as a standardised approach to identify and mitigate water-related corporate risk, with the index aggregating nearly 20 weighted factors capturing water availability, regulations, and water quality (Stanton *et al.,* 2010). The index will allow companies and investors to capture the various components of water-related risks and enable business leaders to make more well-informed investment decisions. The index will draw on publicly available data regarding physical scarcity and water quality and overlay important factors including the regulatory regime and social and reputational issues that have not previously been incorporated into water risk measurement.

Similarly a **United Kingdom** based company, Maplecroft, is marketing a water security index to identify risks across supply chains, operations and investments of companies (see *www.maplecroft.com/*). The index measures four areas including: access to improved drinking water and sanitation; the availability of renewable water and the reliance on external supplies; the relationship between available water and supply demands; and the water dependency of each country's economy.

While physical monitoring of water quality provides a key tool to support policy makers, there are also a range of models that provide a policy support tool by linking policy and economic variables to bio-physical parameters and the ecological quality of water (Collins and McGonigle, 2008).[4] A major focus of this modelling effort is to reveal the relative economic effectiveness and environmental efficiency of different policy instruments or policy mix for diffuse source pollution (Collins and McGonigle, 2008; OECD, 2010g and 2010h). To date many modelling studies have simulated the impact of mitigation strategies on annual pollutant loss as opposed to pressures during seasonal ecological windows (Collins and McGonigle, 2008). Further development of these models to improve the targeting of policies, however, needs to pinpoint specific ecological windows of opportunity (e.g. salmon spawning season) as opposed to annual loadings and their abatement (Collins and McGonigle, 2008).

Notes

1. The Chilean Government is currently working with the irrigators and the water catchment authorities to address this problem, according to information provided by the Chilean authorities to the OECD Secretariat in 2010.
2. The country summaries mainly draw on national sources and Moxey, 2012.
3. These conclusions are based on a selected review of the literature including case studies of Denmark, Jeppesen *et al.,* 2009; Ireland, Jennings *et al.,* 2009; The Netherlands, The Netherlands Ministries of Transport, Public Works and Water Management; Housing, Spatial Planning and the Environment; and Agriculture, Nature and Food Quality, 2009; New Zealand, Wilcock *et al.,* 2008; United Kingdom, Boxall *et al.,* 2009; United States, Ficklin *et al.,* 2010; and globally see Meybeck, 2003.
4. For a review of modelling studies related to agriculture, water quality and policy choices and mixes, see for example, OECD 2010e and 2010f, and literature cited in Collins and McGonigle, 2008.

Bibliography

Abler, D., J. Shortle, J. Carmichael and R. Horan (2001), *Climate change, agriculture and water quality in the Chesapeake Bay region*, paper prepared for a presentation at the American Agricultural economics Association Annual Meeting, Chicago, August, 2001, *ageconsearch.umn.edu/handle/20504*.

Ballantine, D. and R.J. Davies-Colley (2009), *Water quality trends at national river water quality network sites for 1989-2007*, prepared for the New Zealand Ministry for the Environment, National Institute of Water and Atmospheric Research Ltd., Hamilton, New Zealand, *www.mfe.govt.nz/environmental-reporting/freshwater/*.

Borisova, T., J.S. Shortle, R.D. Horan and D.G. Abler (2003), "The value of ecological and economic information in water quality management", paper presented at the American Agricultural Economics Association Annual Meeting, Montreal, Canada, 27-30 July.

Boxall, A.B.A., *et al.* (2009), "Impacts of climate change on indirect human exposure to pathogens and chemicals from agriculture", *Environmental Health Perspectives*, Vol. 117, No. 4, pp. 508-514.

Daughney, C. and M. Randall (2009), *National groundwater quality indicators update: State and trends 1995-2008*, GNS Consultancy Report 2009/145, prepared for the New Zealand Ministry of the Environment, Wellington, New Zealand, *www.mfe.govt.nz/environmental-reporting/freshwater/*.

Collins, A.L. and S.G. Anthony (2008), "Assessing the likelihood of catchments across England and Wales meeting 'good ecological status' due to sediment contributions from agricultural sources", *Environmental Science and Policy*, Vol. 11, pp. 163-170.

Collins, A.L. and D.F. McGonigle (2008), "Monitoring and modelling diffuse pollution from agriculture for policy support: UK and European experience", *Environmental Science and Policy*, Vol. 11, pp. 97-101.

Delpha, I., E. Baures, A.-V. Jung and O. Thomas (2011), "Impacts of rainfall events on runoff water quality in an agricultural environment in temperate areas", *Science of the Total Environment*, Vol. 409, pp. 1683-1688.

Delpha, I., A.-V. Jung, E. Baures, M. Clement and O. Thomas (2009), "Impacts of climate change on surface water quality in relation to drinking water production", *Environment International*, Vol. 35, pp. 1225-1233.

Devine, J., M. Dorfman and K.S. Rosselot (2008), *Missing protection: Polluting the Mississippi river basin's small streams and wetlands*, Natural Resources Defense Council, Issue Paper, New York, United States, *www.nrdc.org/water/pollution/msriver/msriver.pdf*.

Díaz, Robert J., N.N. Rabalais and D.L. Breitburg (2012), *Agriculture's Impact on Aquaculture: Hypoxia and Eutrophication in Marine Waters*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

Dowd, B.M., D. Press and M. Los Huertos (2008), "Agricultural nonpoint source water pollution policy: The case of California's Central Coast", *Agriculture, Ecosystems and Environment*, Vol. 128, pp. 151-161.

Dubrovsky, N.M., *et al.* (2010), *The quality of our Nation's waters – Nutrients in the Nation's streams and groundwater, 1992-2004*, U.S. Geological Survey Circular 1350, U.S. Geological Service, Reston, Virginia, United States.

Eilers, W., R. MacKay, L. Graham and A. Lefebvre (eds.) (2010), *Environmental sustainability of Canadian agriculture*, Agri-environmental indicator report series, Report #3, Agriculture and Agri-Food Canada, Ottawa, Canada, *www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1288198675224&lang=eng*.

European Commission (2010), *Report from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2004-2007*, COM(2010)47 Final, Brussels, Belgium.

European Environment Agency (2005), *Source apportionment of nitrogen and phosphorus inputs into the aquatic environment,* Copenhagen, Denmark, *www.eea.europea.eu*.

European Environment Agency (2010), *The European environment state and outlook 2010: Freshwater quality*, Copenhagen, Denmark, *www.eea.europea.eu*.

Farzin, H. and K. Grogan (2008), "California water quality: The role of agriculture", *Agricultural and Resource Economics Update*, Vol. 11, No. 6, pp. 8-11.

Ficklin, D.L., Y. Luo, E. Luedeling, S.E. Gatzke and M. Zhang (2010), "Sensitivity of agricultural runoff loads to rising levels of CO_2 and climate change in the San Joaquin valley watershed of California", *Environmental Pollution*, Vol. 158, No. 1, pp. 223-234.

Galloway, J.N., *et al*. (2008), "Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions", *Science*, Vol. 320, pp. 889-892.

van Grinsven, H.J.M., A. Rabl and T.M. de Kok (2010), "Estimation of incidence and social cost of colon cancer due to nitrate in drinking water in the EU: A tentative cost-benefit assessment", *Environmental Health*, Vol. 9, Article number 58, *www.ehjournal.net/content/9/1/58*.

HELCOM (Helsinki Commission) (2009a), *Eutrophication in the Baltic Sea: An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea Region – Executive Summary*, Baltic Sea Environment Proceedings No. 115A, HELCOM, Helsinki, Finland.

Helmers, M.J., *et al.* (2007), "Theme overview: Agriculture and water quality in the Cornbelt: Overview of issues and approaches", *Choices*, Vol. 22, No. 2, pp. 79-86.

Ileva, N.Y., H. Shibata, F. Satoh, K. Sasa and H. Ueda (2009), "Relationship between the riverine nitrate-nitrogen concentration and the land use in the Teshio River watershed, North Japan", *Sustainability Science*, Vol. 4, pp. 189-198.

Jennings, E., N. Allott, D.C. Pierson. E.M. Schneiderman, D. Lenihan, P. Samuelsson and D. Taylor (2009), "Impacts of climate change on phosphorus loading from a grassland catchment: Implications for future management", *Water Research*, Vol. 43, pp. 4316-4326.

Jeppesen, E., *et al.* (2009), "Climate change effects on runoff, catchment phosphorus loading and lake ecological state and potential adaptations", *Journal of Environmental Quality*, Vol. 38, pp. 1930-1941.

Johnes, P. (2007), "Meeting ecological restoration targets in European waters: A challenge for animal agriculture", Chapter 11 in D. Swain, E. Charmley, J. Steel and S. Coffey (eds.), *Redesigning Animal Agriculture*, CAB International, United Kingdom.

Kanakoudis, V. and S. Tsitsifli (2010), "On-going evaluation of the WFD 2000/60/EC implementation process in the European Union, seven years after its launch: are we behind schedule?", *Water Policy*, Vol. 12, pp. 70-91.

Kronvang, B., G.H. Rubaek and G. Heckrath (2009), "International phosphorus workshop: Diffuse phosphorus loss to surface water bodies – risk assessment, mitigation options, and ecological effects in river basins", *Journal of Environmental Quality*, Vol.38, pp. 1924-1929.

Land and Water Forum (2010), *Report of the Land and Water Forum: A Fresh Start for Freshwater,* Wellington, New Zealand, *www.landandwater.org.nz*.

Malmaeus, J.M. and O.M. Karlsson (2010), "Estimating costs and potentials of different methods to reduce the Swedish phosphorus load from agriculture to surface water", *Science of the Total Environment*, Vol. 408, pp. 473-479.

Meybeck, M. (2003), "Global analysis of river systems: from earth system controls to anthropocene syndromes", *Philosophical Transactions of the Royal Society*, B Vol. 358, pp. 1935-1955.

Moxey, A. (2012), *The Monetary Costs and Benefits of Agriculture on Water Quality: Estimates across OECD Countries*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

OECD (2008a), *Environmental Performance of Agriculture in OECD Countries since 1990,* OECD, Paris, *www.oecd.org/tad/env/indicators*.

OECD (2010c), *OECD Review of Agricultural Policies: Israel*, OECD, Paris, www.oecd.org/agr.

OECD (2010d), *Environmental Performance Reviews: Japan*, OECD, Paris, www.oecd.org/env.

OECD (2010e), *Guidelines for Cost-effective Agri-environmental Policy Measures*, OECD, Paris, *www.oecd.org/agr/env*.

OECD (2010f), *Linkages between Agricultural Policies and Environmental Effects: Using the OECD Stylised Agri-environmental Policy Impact Model,* OECD, Paris, *www.oecd.org/agriculture/environment*.

OECD (2010g), *Sustainable Management of Water Resources in Agriculture*, OECD, Paris, *www.oecd.org/agr/env*.

OECD (2010h), *Taxation, Innovation and the Environment*, OECD, Paris.

OECD (2011d), *Environmental Performance Reviews: Norway*, OECD, Paris, *www.oecd.org/env*.

OECD (2011e), *OECD-FAO Agricultural Outlook 2011-2020*, OECD, Paris, *www.agri-outlook.org*.

Perez, M.R., C. Cox and K. Cook (2009), *Facing facts in the Chesapeake Bay*, Environmental Working Group, Washington, D.C., United States.

Pizarro, J., P. Vergara, A. Rodríguez, P. Sanhueza and S. Castro (2010), "Nutrients dynamics in the main river basins of the centre-southern region of Chile", *Journal of Hazard Materials,* Vol. 175, pp. 608-13.

Rabotyagov, S., T. Campbell, M. Jha, P.W. Gassman, J. Arnold, L. Kurkalova, S. Secchi, H. Feng and C.L. Kling (2010), "Least-cost control of agricultural nutrient contributions to the Gulf of Mexico hypoxic zone", *Ecological Applications*, Vol. 20, No. 6, pp. 1542-1555.

Rolfe, J. and J. Windle (2011), "Using auction mechanisms to reveal costs for water quality improvements in Great Barrier Reef catchments in Australia", *Agricultural Water Management*, Vol. 98, pp. 493-501.

Stanton, T., M. Echavarria, K. Hamilton and C. Ott (2010), *State of watershed payments: An emerging marketplace*, Forest Tends, Washington, D.C., United States.

Stuart, M.E., D.C. Gooddy, J.P. Bloomfield and A.T. Williams (2011), "A review of the impact of climate change on future nitrate concentrations in groundwater of the UK", *Science of the Total Environment*, Vol. 409, pp. 2859-2873.

Sutton, M.A., *et al.* (eds.) (2011), *The European nitrogen assessment: Sources, effects and policy perspectives*, Cambridge University Press, United Kingdom.

The Netherlands Ministries of: Transport, Public Works and Water Management; Housing, Spatial Planning and the Environment; and Agriculture, Nature and Food Quality (2009), *River basin management plans: 2009-2015 Ems, Meuse, Rhine Delta and Scheldt – A summary*, www.kaderrichtlijnwater.nl.

USGS (U.S. Geological Survey) (2010), *Quality of water from public-supply wells in the United States, 1993-2007: Overview of major findings*, US Geological Survey, Circular 1346, Washington, D.C., United States, *pubs.usgs.gov/sir/2010/5024/.*

Verburg, P., K. Hamill, M. Unwin and J. Abell (2010), *Lake water quality in New Zealand 2010: Status and trends*, prepared for the New Zealand Ministry for the Environment, National Institute of Water and Atmospheric Research Ltd., Hamilton, New Zealand, www.mfe.govt.nz/environmental-reporting/freshwater/.

West, B.M., P. Liggit, D.L. Clemans and S.N. Francoeur (2011), "Antibiotic resistance, gene transfer,, and water quality patterns observed in waterways near CAFP farms and wastewater treatment facilities", *Water, Air, and Soil Pollution*, Vol. 217, pp. 473-489.

White House (2011), *Clean Water: Foundation of healthy communities and a healthy environment*, Office of the U.S. President, White House, Washington, D.C., United States, www.whitehouse.gov/sites/default/files/microsites/ceq/clean_water_framework.pdf.

Wilcock, R., *et al.* (2008), "Climate change mitigation for agriculture: water quality benefits and costs", *Water, Science and Technology*, Vol. 58, pp. 2 093-2 099.

Wittmer, I.K., R. Scheidegger, H.-P. Bader, H. Singer and C. Stamm (2011), "Loss rates of urban biocides can exceed those of agricultural pesticides", *Science of the Total Environment*, Vol. 409, pp. 920-932.

Chapter 3

Monetary costs and benefits of agriculture's impact on water systems[1]

The overall economic, environmental and social costs of water pollution caused by agriculture across OECD countries are likely to exceed billions of dollars annually, although no satisfactory estimate of these costs exists. The economic cost of agricultural water pollution is significant in many countries. Treating water to remove nutrients and pesticides to ensure water supplies meet drinking standards can be substantial for water treatment companies, and ultimately paid for by consumers. Eutrophication of fresh and marine waters can also impose economic costs on ecosystems, recreational and amenity benefits, spiritual values, and recreational and commercial fisheries. Monetary values for the impacts of agriculture on water systems is lacking in the policy debate, with reliance largely on physical measures of water quality. When reliable estimates of economic costs and benefits from agriculture on the environment, including water systems, can be calculated, they can define the scale of different environmental problems for policy makers and direct focus to areas with the greatest potential societal costs.

Monetary values for the impacts of agriculture on water systems is lacking in the policy debate, with reliance largely on physical measures of water quality, as discussed in Chapter 2. When reliable estimates of economic costs and benefits from agriculture on the environment, including water systems, can be calculated, they can define the scale of different environmental problems for policy makers and direct focus to areas with the greatest potential societal costs (Dodds *et al.,* 2009).

Beyond the immediate agricultural policy interest, quantification of externalities is also relevant to improving the treatment of natural capital and environmental degradation in systems of national and agricultural economic accounting as a guide to the sustainability of resource usage. When viewed alongside conventional national and sector accounts, environmental accounts help provide information on agriculture's overall impact on welfare, including allowance for its impact on income in other sectors (EFTEC and IEEP, 2004; Jacobs Report, 2008).

The economic cost of agricultural water pollution is significant in many countries (Table 3.1). Treating water to remove nutrients and pesticides to ensure water supplies meet drinking standards can be substantial for water treatment companies, and ultimately paid for by consumers. Eutrophication of fresh and marine waters can also impose economic costs on ecosystems, recreational and amenity benefits, spiritual values, and recreational and commercial fisheries.

Although some of the effects of agriculture on water systems are tangible, many are not and their monetary quantification entails non-market valuation techniques. Valuation also requires some prior underpinning scientific monitoring and understanding of complex biophysical relationships –for example, to differentiate between agricultural and non-agricultural sources of pollution, or to trace the passage of diffuse pollution through complex hydrological systems (Chapter 2). The latter point is important since the separation of cause-and-effect by both physical distance and by time lags adds complexity to the measurement and comparison of monetary values.

Table 3.1. National costs of water pollution (not necessarily all due to agriculture)

Country (sources)	Type of water quality impact	Cost (millions)		
		National currency	EUR	USD
Australia (Atech Group, 2000)	Algal blooms associated with excessive nutrients in freshwater	AUD 180–240[1]	109 – 145	116 – 155
Belgium (Dogot *et al.*, 2010)	Drinking water treatment costs		120 –190	167 – 264
France (Bommelaer *et al.,* 2010)	Eutrophication of surface and coastal waters		70 – 1 000	97 – 1 389
Netherlands (Howarth *et al.*, 2001)	Nitrate and phosphate damage		403 – 754[2]	371 – 695
Spain (Hernandez-Sancho *et al.*, 2010)	Nitrate and phosphate damage		150	208

(continued)

Table 3.1. National costs of water pollution (not necessarily all due to agriculture *(cont.)*

Country (sources)	Type of water quality impact	Cost (millions)		
		National currency	EUR	USD
Sweden (Huhtala *et al.*, 2009)	• Costal eutrophication • Baltic Sea eutrophication		860 492 – 1 466	1 257 719 – 2 143
Switzerland (Pillet *et al.*, 2000)	Agricultural pollution[3]	CHF 1 000	608	690
United Kingdom (Jacobs Report, 2008)[4]	Agricultural pollution of surface water, estuaries and drinking water treatment costs	GBP 232	340	464
United States (Dodds *et al.*, 2009)	Freshwater eutrophication		1 500	2 200
(Pimentel *et al.*, 2005)	Pesticide contamination of groundwater		1 610	2 000
(Anderson *et al.*, 2000)	Marine algal blooms		32 – 46	34 – 49

1. Of this total around AUD 60 million were costs incurred by agriculture itself, and about AUD 100 million due to lost recreational value.
2. This estimate is a projection to 2010.
3. Agricultural pollution estimated for 1998.
4. This is the total of the costs shown in Table 5.2.

Sources: Atech Group (2000), *Cost of algal blooms,* report to Land and Water Resources Research and Development Corporation, Canberra, Australia, *npsi.gov.au/files/products/river-landscapes/pr990308/pr990308.pdf*; Dogot, T., Y. Xanthoulis, N. Fonder and D. Xanthoulis (2010), "Estimating the costs of collective treatment of wastewater: the case of Walloon Region (Belgium)", *Water Science & Technology,* Vol. 62, No. 3, pp. 640-648; Bommelaer, O., J. Devaux and C. Noël (2010), *Financing of water resources management in France – Case study for an OECD report,* Commissariat Général au Développement Durable, Paris, France, *www.developpement-durable.gouv.fr/IMG/pdf/ED33-eng.pdf;* Howarth, A., D.W. Pearce, E. Ozdemiroglu, T. Seccombe-Hett, K. Wieringa, C.M. Streefkerk and A.E.M. de Hollander (2001), *Valuing the benefits of environmental policy: the Netherlands*, National Institute of Public Health & Environment, The Netherlands, *rivm.nl/bibliotheek/rapporten/481505024.pdf*; Hernandez-Sancho, F., M. Molinos-Senante and R. Sala-Garrido (2010), "Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain," *Science of the Total Environment*, Vol. 408, No. 4, pp. 953-957; Huhtala, A., H. Ahtiainen, P. Ekholm, V. Fleming-Lehtinen, J. Heikkilä, A-S. Heiskanen, J. Helin, I. Helle, K. Hyytiäinen, H. Hällfors, A. Iho, K. Koikkalainen, S. Kuikka, M. Lehtiniemi, J. Mannio, J. Mehtonen, A. Miettinen, S. Mäntyniemi, H. Peltonen, E. Pouta, M. Pylkkö, M. Salmiovirta, M. Verta, J. Vesterinen, M. Viitasalo, S. Viitasalo-Frösen, and S. Väisänen (2009), *The economics of the state of the Baltic Sea : pre-study assessing the feasibility of a cost-benefit analysis of protecting the Baltic Sea ecosystem,* MTT Economic Research, Finland, *www.minedu.fi/export/sites/default/OPM/Tiede/setu/liitteet/Setu_2-2009.pdf;* Pillet, G., N. Zingg and D. Maradan (2000), *Appraising Externalities of Swiss Agriculture — A Comprehensive View,* Ecosys Sa Applied Economics and Environmental Economics, Geneva, on behalf of the Swiss Federal Office of Agriculture. *www.ecosys.com/spec/ecosys/download/Mandats/summary_swiss%20agriculture.pdf;* Jacobs Report (2008), *Environmental Accounts for Agriculture*, Final report prepared for the UK Department for Environment, Food and Rural affairs, *www.dardni.gov.uk/environmental-accounts.pdf;* Dodds, W.K., W.W. Bouska, J.L. Eitzmann, T.J. Pilger, K.L. Pitts. A.J. Riley, J.T. Schloesser and D.J. Thornbrugh (2009), "Eutrophication of U.S. Freshwaters: Analysis of potential economic damages", *Environmental Science and Technology*, Vol. 43, No. 1, pp. 12-19; Pimentel, D. (2005), "Environmental and Economic Costs of the Application of Pesticides Primarily in The United States", *Environment, Development and Sustainability,* Vol. 7, pp. 229-252; Anderson, D.M., Y. Kaoru and A. White (2000), *Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States,* Woods Hole Oceanographic Institution Technical Report, Woods Hole, United States, *www.whoi.edu/fileserver.do?id=24159&pt=10&p=19132*.

3.1 Key components in measuring the costs and benefits of agriculture on water quality

As a key component of human and ecosystem life, water is clearly central to economic activities linked directly to biological health and productivity. But freshwater and saltwater are also used directly or indirectly in a variety of other non-economic ways too. Although sensitivity to water quality varies across these different uses, some more important categories may be relatively easily identified and are described briefly below. As with most such categorisations, some categories may overlap to a certain extent and there is scope for further refinement.

Water treatment costs

Given the essential nature of drinking water to human survival, degraded water quality has implications for human health whether from pathogens or chemicals. Extreme contamination can render water physically undrinkable, posing an immediate health risk and/or recourse to expensive short-term alternative provision (e.g. bottled water). More typically, contamination poses a potential longer-term risk and is addressed through routine treatment of drinking water to remove pollutants (e.g. pathogens, nitrates, pesticides) that can cause immediate illness and/or longer term diseases. However, such treatment is not costless and represents an additional burden on water companies and thus consumers. The more degraded water is, the more costly it is to treat. Additional water treatment may incur not only significant capital costs, but also an increase in energy and chemical costs. There may also be secondary pollution issues regarding how extracted contaminants are then subsequently disposed.

Non-market costs: Agriculture

Agriculture can be both a source of water pollution and a victim. For example, water courses contaminated with pathogens, chemicals or salts can pose a health risk to both farmers and rural residents drawing water from private wells and also livestock and crops leading to lower productivity. In some cases, such effects may be felt on the farms causing them, but more often will spill-over onto other farms leading to lower yields and/or higher expenditure on counter measures elsewhere.

Non-market costs: Fishing

Commercial and recreational fishing activities can be directly affected by water quality issues. Toxic contaminants, for example, can directly or indirectly through bio-accumulation of contaminants, kill target species or they can simply render species unfit for human consumption – in both cases reducing catch volumes and values. Such problems have been encountered in relation to both free-swimming species and shellfish, with both being highly susceptible to eutrophication effects.

Non-market costs: Industrial

Other industries can also be affected by water quality issues. Over time, sedimentation of navigable waterways can disrupt water based transportation networks and incur additional (dredging) maintenance costs for the protection of lakes and reservoirs used to store drinking water. Equally, sediment, chemical and salt loadings can increase cleaning and corrosion maintenance requirements where water is used for industrial cooling (e.g. power generation). Similarly, as with drinking water, treatment

of water used in bottled mineral water, food processing or textile manufacturing may be necessary to avoid contamination of final consumer products.

Non-market costs: Ecosystems

The presence of pollutants in water can alter ecosystems, changing habitat characteristics and wildlife species and directly kill wildlife in-stream, whilst nutrient enrichment (eutrophication) can indirectly alter the relative prevalence of different species. Such impacts extend beyond wetlands, rivers and lakes into the marine environment, particularly around coasts or in enclosed seas with relatively shallower water and weaker currents where pollutants can accumulate and persist. In some cases, the species affected are of extractive commercial interest (i.e. for fishing), in others they are not – but may still have economic value through contributions to recreation or the background maintenance of ecosystem services which implicitly underpin many economic activities.

Non-market costs: Recreational, amenity and other social uses of water

Not all uses of water are consumptive in the sense of extracting water or something tangible from water, but can be used for recreational and amenity purposes, such as swimming in, canoeing on or enjoying the visual aspects of waterscapes. Yet such activities may be limited by the presence of pollutants, either because they pose an actual health risk or merely reduce potential enjoyment, but also in some situations pollution can lower riparian property and land values. In some cases, particular water systems may have specific cultural value and significance and degradation may reduce these values, as discussed below for the Maori in **New Zealand** (Chapter 5.6). Less easily detectable pollutants, such as some chemicals or pathogens, may degrade habitats and affect ecosystems without altering the appearance of water bodies, highlighting how water users may be affected in different ways. This is sometimes expressed as a "ladder" of water use, with progressively higher quality water permitting more uses.

3.2 Information needs to provide monetary cost and benefit estimates

It may be possible to identify the categories of agriculture's impact on water quality described previously, but translating these into quantitative estimates of their economic significance requires more detailed information on their physical scale and value. That is some effects may be relatively insignificant economically if they occur on only a minor scale and/or cause relatively little inconvenience to other water users. A comprehensive review of information needs is beyond the scope of this report but a number of key issues identified in the literature are described below.

Linkage complexity

The precise biophysical mechanisms linking agricultural activities to pollutant levels are complex and imperfectly understood. This largely reflects the predominantly diffuse source nature of agricultural pollution which makes it difficult both to observe polluting activities directly and to link them explicitly to pollution outcomes (Box 1.1). Originating activities may be separated from pollution outcomes by both physical distance and time as pollutants move from upstream fields to downstream sites through transboundary hydrological systems that can span several countries. Pollutants may also be reduced during their movement through natural assimilation processes or dilution, or conversely increased from other sources. In addition, observed impacts may not be

solely attributable to pollution, for example, lower fishing catches may also arise due to over-fishing. Improved monitoring data on management practices and water quality can help in this regard, as can modelling to identify linkages within hydrological systems, but both can be expensive.

Spatial and temporal variability

The polluting effect of any given agricultural activity is highly context-specific, depending not only on an activity's characteristics but also upon local site conditions, prevailing weather conditions, management of neighbouring land and past management practices. Again, improved monitoring data on site conditions and management actions can help. However, the time lag between pollution entering a hydrological system and becoming detectable can also be highly variable. This poses a challenge for monitoring but also for policy responses since observed water quality may reflect past rather than current agricultural practices and policy-induced changes may take considerable time to appear. Such time-lags also make comparing costs and benefits less straightforward and necessitate the use of discounting of future impacts, a topic in its own right.

Non-agricultural sources

Agriculture is not the only potential source of water pollution. For example, forestry operations can also involve soil disturbance and the application of fertilisers and chemicals, as can activities across private and municipal gardens, golf courses, airports and road and rail networks. Equally, municipal sewage from private residences and commercial premises also typically contain a mix of chemicals, nutrients and pathogens. Consequently it is often necessary to apportion any changes in water quality between different sources, something that can be difficult to do accurately.

Total economic value and non-market valuations

Even if the causal links between specific agricultural activities and resultant water quality can be clarified, the economic significance of such linkages may still be unclear. The total economic value of water quality encompasses several components lacking market prices, such as amenity and recreational activities which are usually unpriced. Hence, recourse to non-market valuation techniques is required, such as hedonic pricing, contingent valuation and analysis to identify citizens' or households' willingness to pay (WTP) for different levels of water quality per year. Although widely used, such approaches are not without difficulties, including assumptions about the ability of people to articulate their WTP for non-market effects and problems in transferring valuations between different locations and contexts. Separately, information on the market costs of some mitigation and adaptation activities may be obscured by commercial confidentiality. For example, private water companies are often reluctant to reveal treatment costs.

Other externalities

The jointness between producing agricultural commodities and water pollution also extends to other externalities. For example, sedimentation of watercourse arises from soil erosion which itself represents an environmental degradation cost in terms of lowering capacity for agricultural production and carbon sequestration. Equally, air quality can be reduced by nitrous emissions but subsequent deposition may also cause water pollution. This means that care needs to be taken to avoid misallocating values

between different externality effects and to avoid double-counting. It also means that attention needs to be paid to pollution-switching, such as whether reductions in water pollution cause an increase in other pollutants such as greenhouse gas emissions.

3.3 A survey of OECD countries' impact estimates

From a survey of OECD country estimates of annual agricultural water quality costs made in a background study for this report (Moxey, 2012), it is clear that agricultural activities have a substantial redistributive impact in society through external effects. Dealing with these external costs on water systems from agriculture poses an enormous policy challenge, especially because of the political resistance from the agricultural community in many countries to the distributional implications of allocating the external costs of their activities (Blandford, 2010).

A summary of studies which have provided a national estimate of the costs of water pollution across OECD countries is provided in Table 3.1, although for some studies not all these costs are necessarily due to agriculture. The table confirms, however, the existence of significant costs associated with agricultural impacts on water quality for many countries. This does not deny the potential for beneficial mitigation activities, merely that current production patterns and management practices are generally polluting in nature. An exception is paddy fields, which by mimicking natural wetlands can contribute to improvements in water quality, as well as certain organic farming systems, but this will depend on how paddy and organic farming systems are managed.

The need for caution in making comparisons and interpretations needs to be stressed for Table 3.1. In particular, although agricultural impacts are estimated for some countries, many studies are not specific about the origin of the pollution costs. But because few studies encompassed all of the categories of impact outlined above, the cited figures in Table 3 may understate overall impacts, including for agriculture.

As Table 3.1 reveals, estimates of treatment costs were less readily available and explicit valuation of health costs was rare. Treatment costs can provide a fairly reliable source of data compared to other cost estimates of pollution (e.g. estimates of non-market costs). However, calculation of treatment costs depends on the sources of pollution, and thus may over estimate specific costs related to agriculture, and also the stringency of health and environmental objectives and policies across countries. Comparisons over time are difficult to make, with treatment costs apparently rising in some countries as agricultural intensification progresses and/or regulatory standards are strengthened, but falling in others where technologies adjust and agricultural production contracts.

The variation in absolute figures between countries in Table 3.1 reflects not only differences in the size of countries, but also differences in national situations in terms of regulatory standards, monitoring and baseline water quality but also differences in the coverage and methodology of cited valuation studies. For example, studies varied in terms of the degree of degradation or improvement they considered and in how specific they were to agriculture. Equally, inclusion of more impacts tended to increase overall costs with, in particular, inclusion of marine eutrophication sometimes leading to significantly higher cost estimates. Consequently, comparisons between countries need to be treated with caution.

That the reported impacts related overwhelmingly to degradation rather than improvement of water quality through agricultural practices reflects the general relationship between commodity production and pollution. Higher water quality is not generally produced jointly with agricultural outputs, although paddy field and organic farming systems are exceptions depending on how they are managed. The relationship is not linear and it is perfectly possible to adjust management practices to reduce negative impacts on water quality, for example, through establishing farm wetlands, improving on-farm nutrient management or lowering the intensity of grazing. The degree to which such adjustments impose on-farm costs varies, with some actually improving farm profitability but many reducing it.

The OECD country survey by Moxey (2012) of studies estimating household WTP to improve water quality cover a range of situations over the period late 1990s to 2010, although they are rarely applicable to only agriculture. Household WTP for improvements in non-use values (e.g. recreational uses) of surface water, including lakes and marine waters damaged by eutrophication, are typically in the range of EUR 10-50. But for improvements to drinking water quality household WTP estimates can be much higher, up to EUR 250-270, while there are very few WTP estimates for improvements to groundwater quality.

3.4 Further research

The fragmented, incomplete and variable quality of valuation figures revealed in Table 3.1, suggests various themes for further research. These include: improvements to the underpinning science; continued refinement of non-market valuation techniques; more routine inclusion of water quality in environmental accounts; and further effort in collation and aggregation of data. To place the needs for further refinement to the data in some context, a final comment in this section relates to the diminishing marginal returns of increasing efforts to fill data gaps and improve data quality.

Underpinning science

Economic valuation cannot be attempted without some prior information on biophysical impacts. Yet, although the types of water quality externalities associated with agricultural activities may be identified relatively easily, scientific understanding and measurement of the underlying biophysical relationships is often imperfect. Simply distinguishing between agricultural and non-agricultural sources of nutrients is often difficult, for example, and the consequences of nutrient loadings depend upon volumes of water as well of the nutrients themselves. Such imperfect understanding reflects both a lack of monitoring data in some instances but also that biophysical relationships are highly complex (Chapter 1).

This points to a continuing need for scientific research into the underlying processes but also, at least in some countries, better monitoring of conditions. Both tasks are made more complicated by the typically transboundary nature of water pollution, with river catchments and marine areas often encompassing more than one country, and by the time lags between cause-and-effect in complex hydrological systems. Hence international efforts are needed in some cases to co-ordinate monitoring and modelling activities in order to better inform joint policy responses over time, such as being achieved through monitoring efforts of the Great Lakes (between **Canada** and the **United States**) and the countries surrounding the **Baltic Sea** (Chapter 5.7).

Non-market valuation

Consensus on how to conceptualise and value changes to water quality does not yet exist. Some commentators disagree with the premise of monetary valuation, whilst others accept the premise of non-market valuation but are critical of the design and interpretation of particular valuation techniques. This especially applies to the aggregation or transfer of results between locations and to differences between public and scientific perceptions of quality where the former's typical reliance on visual condition may conflict with indicators of chemical or ecological quality. The time lags involved in some diffuse pollution processes add a further complication by necessitating some form of discounting to compare costs and benefits accruing at different rates over a longer period of time.

Environmental accounts

Summarising impact estimates at a national level through environmental accounts provides a convenient means of reporting water quality externalities alongside more conventional economic statistics. By avoiding the need to collate individual results in an *ad hoc* manner and by systematically placing impact estimates in context, such an approach should facilitate clearer and more routine recognition of the scale of problems requiring policy attention. Several countries already have environmental accounts, but many do not express water quality impacts in monetary terms. Hence there is scope for further work to develop environmental accounts.

Collation and aggregation

Assembling national-level estimates is not necessarily straightforward since valuation studies often focus on a sub-national scale or on a sub-set of water quality impacts. Many studies are conducted at a catchment scale and aggregation from this to a national scale requires additional data and assumptions about how representative local results are. Equally, aggregation across different types of impact can be problematic if not all impacts have been valued and if different valuation techniques have been used in different studies. In addition, whilst on-line databases and previous meta-analysis of valuation studies are extremely helpful, collating results from individual studies remains impaired by the practicalities of searching across varied and scattered sources and by the variable degree of methodological detail reported in different studies.

Diminishing marginal returns of filling data gaps and improving data quality

While the areas for further data improvement outlined here may be desirable they are not costless. Improved monitoring data, scientific understanding and valuation accuracy all require resources to develop. Moreover, insights gained will typically be subject to diminishing marginal returns. Hence, there is a trade-off to be made between striving for a possibly unattainable level of information necessary to achieve an optimal resource allocation and accepting a level of information sufficient to achieve a desirable direction of travel towards an improved position.

Pragmatically, even partial and imperfect valuation estimates may still be sufficient to demonstrate the need for change when viewed alongside estimates of positive externality values and the mitigation potential of agricultural activities. Importantly, the need for accuracy may differ between national level strategic decisions and regional level implementation decisions. Relatively crude national figures, for example, may be

sufficient to shape overall policy directions but more accurate figures may be needed to guide practical/marginal design issues for individual catchments and negotiations between local stakeholder groups. From an economic perspective, information on total or average costs is of less policy relevance than information on how they vary with changes in water quality and management – the costs and benefits of marginal changes.

Note

1. This chapter is largely drawn from Moxey (2012), who also provides a detailed bibliography of valuation studies for nearly all OECD countries.

Bibliography

Blandford, D. (2010), "Presidential Address: The visible or invisible hand? The balance between markets and regulation in agricultural policy", *Journal of Agricultural Economics*, Vol. 61, No. 3, pp. 459-479.

Dodds, W.K., W.W. Bouska, J.L. Eitzmann, T.J. Pilger, K.L. Pitts. A.J. Riley, J.T. Schloesser and D.J. Thornbrugh (2009), "Eutrophication of U.S. Freshwaters: Analysis of potential economic damages", *Environmental Science and Technology*, Vol. 43, No. 1, pp. 12-19.

EFTEC (Economics for the Environment Consultancy) and IEEP (Institute for European Environmental Policy) (2004), *Framework for Environmental Accounts for Agriculture*, EFTEC in association with IEEP, report submitted to the Department for Environment, Food and Rural Affairs, London, United Kingdom, *statistics.defra.gov.uk/esg/reports/env.asp*.

Jacobs Report (2008), *Environmental Accounts for Agriculture*, Final report prepared for the UK Department for Environment, Food and Rural affairs, *www.dardni.gov.uk/environmental-accounts.pdf*.

Moxey, A. (2012), *The Monetary Costs and Benefits of Agriculture on Water Quality: Estimates across OECD Countries*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

Chapter 4

OECD policy instruments and mixes addressing water quality issues in agriculture

Policy responses to address agricultural water pollution across OECD countries have typically used a mix of economic incentives, environmental regulations and information instruments. A large range of measures have been deployed at the local, catchment, through to national and transborder scales, across an array of different government agencies. Many measures to control water pollution from agriculture are voluntary. Water supply utilities and the agro-food chain are also engaged in co-operative arrangements with farmers to minimise pollution, such as providing farm advisory services. This policy mix has had mixed results in lowering agricultural pressure on water systems. Over many years these policies, according to OECD estimates, have cost taxpayers billions of dollars annually. For some countries policies to reduce agricultural water pollution have been successful, with a package of input taxes, payments and farm advice. In other cases, despite substantial expenditure on efforts to lower agricultural pollution of a specific water ecosystem, little progress has been made. More recently, some private and public initiatives, for example, water quality trading in agriculture and establishing co-operative agreements to address water pollution are showing signs of success, albeit on a limited scale to date.

Typically OECD countries have addressed water quality issues in agriculture (e.g. pollution, wetland conservation) by using a mix of economic instruments (*stimulation*), environmental regulations (*regulation*), and information and other persuasive approaches (*persuasion*) (Oenema *et al.,* 2009; Vojtěch, 2010). A large array of measures has been deployed at the local, provincial/state through to national and transborder scales, with many initiatives that emphasise voluntary adoption of farm management practices to enhance water quality encouraged by payments (Shortle, 2012).[1]

Using a mix of policy instruments rather than a single instrument (e.g. pollution tax) has a number of advantages (OECD, 2007).

- Provide a multifaceted approach to water pollution so that not only the amount of pollution, but also where and when the pollution takes place, etc., are relevant.
- Encourage the mutual strengthening of policy instruments between each other.
- Enhance enforcement and reducing policy related transaction costs.
- Address pollution at a much finer scale, targeted to achieve a specific outcome, and achieve these outcomes at lower cost than a single untargeted measure.

There are reasons, however, for restricting the number of instruments in the mix. For example, when several instruments are applied in the mix there could be a danger that one instrument hampers flexibility to find low-cost solutions to a problem that another instrument could have offered if it had been implemented on its own. There are also cases where some of the instruments in the policy mix are redundant and only increase total policy related transaction costs (OECD, 2007, and 2010e)

A survey of OECD countries policy objectives and policy instruments addressing nutrient and pesticide diffuse source pollution, was completed by OECD (2007) in 2004 (Table 4.1). The main findings from the survey responses showed the following.

- Many policy instruments (346) are used to address diffuse source pollution of which 198 (57%) address nutrient pollution, 119 (34%) pesticide pollution, and 29 (8%) address both issues.
- Economic instruments are widely used to address both issues together, with the use of payments much more frequent than application of pollution taxes and charges, with infrequent application of the Polluter-Pays-Principle to diffuse source pollution;
- Regulatory instruments are the most common policy approach used for addressing nutrients and pesticides separately; and that,
- Information instruments and other persuasive approaches are also widely used by countries.

Table 4.1 Overview of policy instruments addressing diffuse sources of water pollution

	National level				State/provincial level				Total
	Nutrients	Pesticides	Both	Total	Nutrients	Pesticides	Both	Total	
Policy objectives	44	35	14	93	–	–	–	–	93
Policy instruments	137	78	25	240	61	41	4	106	346
Regulatory instruments	54	37	7	97	28	20	0	48	146
Economic instruments, of which:	37	8	9	54	17	7	1	25	79
Taxes	*2*	*4*	*0*	*6*	*2*	*1*	*0*	*3*	*9*
Subsidies	*32*	*1*	*7*	*40*	*13*	*7*	*1*	*21*	*61*
Information instruments	32	25	7	64	11	14	2	27	91
Other instruments	14	10	2	26	5	0	1	6	32

Source: OECD (2007), *Instrument Mixes Addressing Non-point Sources of Water Pollution,* OECD, Paris, www.oecd.org/env.

4.1 Economic instruments

Pollution taxes

Application of the *Polluter-Pays-Principle* (PPP) in agriculture, such as by using a ***pollution tax***, can produce efficient and effective economic and environmental outcomes (OECD, 2010e; Weersink and Livernois, 1996). Where taxes or charges have been applied in OECD countries they are usually applied to fertiliser and pesticide inputs (Box 4.1). Such taxes can have desirable effects on water quality by lowering chemical input use and encouraging farmers to switch to nitrogen saving crop varieties. Pollution taxes can also lower transaction costs, by incorporating the taxes into the existing tax system. In **Denmark**, for example, an objective of a 50% reduction in pesticide use was announced in 1986 and reached by the early 2000s, without any loss in national agricultural production of farmers' incomes. The two pillars of the Danish policy to achieve this reduction in pesticides included a high level of pesticide taxes (rising up to 54% of the sale price for insecticides and 34% for all other pesticides), combined with an active farm advisory service (Jacquet, Butault and Guichard, 2011).

But application of the PPP in agriculture is difficult and not widespread across OECD countries, mainly because diffuse source pollution from agriculture into water cannot be measured at reasonable cost with current monitoring technologies (this does not generally apply to point sources of pollution in agriculture), and also due to property right, institutional and other barriers (Blandford, 2010) (Chapter 1). Some studies have also shown that a nitrogen tax, for example, may induce a shift to cropping systems that use less nitrogen fertiliser but lead to higher groundwater nitrogen pollution (Randhir and Lee, 1997). Research in **Ireland** revealed that in view of the inelastic demand for inorganic fertiliser a tax of over 260% would be required to achieve compliance under the European Union *Nitrates Directive,* while other research has also pointed to the political problems of attempting to enforce very high taxes on farmers (Weersink and Livernois, 1996). Also regulatory limits on nitrogen fertilisers compared to a tax could achieve compliance more effectively and equitably for those farms already in compliance (Lally, Riordan and van Rensburg, 2007).

Box 4.1. Environmental taxation of pesticides and fertilisers in OECD countries

Only a few countries levy taxes on pesticides and nutrients (inorganic fertilisers and manure) as a means to reduce their use. The Box Table below shows the different approaches countries have taken in this area. The revenues derived from taxes also vary significantly, in line with the different tax rates that countries have imposed.

Sweden, for example, imposes the same per unit tax on the active ingredients for all pesticides, thereby levying the same rate on rather benign products as those which are more toxic. A percentage tax is used by other countries, which is dependent on the price of the pesticide, hence, a major user of pesticides will pay a smaller amount of tax on each unit of pesticide purchased than smaller users. **Norway** moved away from a system of percentage taxes on imports of pesticides in 1998, in favour of an approach that categorises each pesticide based on its negative human health and environmental effects. In doing so, it makes specific the value of the potential environmental and health damage, instead of relating the tax just to the price of the pesticide. Not only does this encourage more careful use of pesticides in general, it also provides incentives to substitute to less damaging products, as the price among pesticides are differentiated. The Norwegian system of pesticide taxes, however, can present a significant administrative burden, both for regulators and industry. While in Norway this is less of an issue as only 188 pesticides are approved for use, in the **United Kingdom** by contrast, for example, 3075 pesticides are registered for use.

Box Table. Environmental taxes related to water pollution from agriculture

	Description of tax rate as at January 2010	**Total annual tax revenue** (mill. USD)
Belgium	Flanders manure tax and water pollution tax	Not available
Canada[1] (British Columbia)	Pesticides: EUR 0.7568 per litre of pesticides	Not available
Denmark[2]	Pesticides: 35% of retail value for chemical products for disinfection of soil and insecticides; 25% of retail value for chemical deterrents of insects and mammals, chemical products for reduction of plant growth, fungicides, and herbicides; and 3% of retail value for deterrents against rats, mice, moles and rabbits, and fungicides for wood protection. Fertilisers: EUR 0.67 per kg of nitrogen	80 USD (2007)
France	Pesticides: Seven pesticide categories with rates ranging from EUR 0.38 per kg to EUR 1.68 per kg	Not available
Italy	Fertilisers: Tax on fertilisers and pesticides	Not available
Netherlands	Nutrients: Tax on surplus nitrogen and phosphate in excess of approved farm nutrient budget. Levy on water pollution; and tax on pollution of surface waters	Not available
Norway	Pesticides: Tax per kg or litre of agricultural pesticides = (base rate*factor)*1 000/standard area dose. Standard area dose is the maximum application rate in kg or litres per hectare for the main crop for which the particular pesticide is used. The base rate is set by the government and is the same for all products (was EUR 3.12 per kg or litre in 2005). The factor is a weighting based on the relative risk level of the	11.5 USD (2007)
Sweden[4]	Pesticides: EUR 3.11 per whole kg active constituent Fertilisers: Tax	Not available
United States[5]	Fertilisers: EUR 0.001-EUR 0.004 per kg tax in Louisiana	Not available

1. Earmarked for the residuals stewardship programme.
2. Exports are exempted. Earmarked for the environmental and agricultural sector. Only applies to nitrogen used outside the agricultural sector. Denmark also applies a DKK 4 kg-1 tax (EUR 0.54) on mineral phosphorus in animal feed (Box 5.1).
3. The weighting factors are as follows: 0.5: Products with low human health risk and low environmental risk; 3: Products with low human health risk and medium environmental risk, or products with medium human health risk and low environmental risk; 5: Products with low human health risk and high environmental risk, or products with medium human health risk and medium environmental risk, or products with high human health risk and low environmental risk; 7: Products with medium human health risk and high environmental risk, or products with high human health risk and medium environmental risk; 9: Products with high human health risk and high environmental risk; 50: Concentrated home garden products; 150: Ready-to-use home garden products.
4. Wood preservatives are exempted.
5. Earmarked for financing inspection activities.

Sources: OECD Secretariat drawing on: OECD (2010), *Taxation, Innovation and the Environment*, OECD, Paris; Vojtěch, V. (2010), "Policy Measures addressing Agri-environmental Issues", *OECD Food, Agriculture and Fisheries Working Papers,* No. 24, and the OECD *Environmental Tax database,* see www.oecd.org/env/policies/database.

Agri-environmental payments

Most OECD countries offer monetary payments (including implicit transfers such as tax and interest concessions) to farmers and other landholders to address environmental problems (e.g. to reduce pollution) and/or to promote the provision of environmental amenities associated with agriculture (Vojtěch, 2010). These payments are mainly provided on a voluntary basis, however, there are payments (mainly investment subsidies) provided to farmers to assist them to comply with environmental regulations. In practice, many agri-environmental payments tend to be linked to land or other factors of production, and often function by lowering the intensity of production. While payments directly tied to broad environmental outputs are rare, some countries are beginning to develop payments based on environmental outputs linked to farmer's practices, such as in **France** where a payment is tied to the objective of reducing pesticide use (OECD, 2010e; Vojtěch, 2010).

Overall the relative amounts of agri-environmental payments (AEPs) as a share of the total producer support estimate varies, while in the **European Union** and the **United States** total AEP expenditure has risen significantly since the early 1990s (Vojtěch, 2010). For the **EU27** total AEP expenditure in 2007-09 was about EUR 6 billion annually, around 7% of the total PSE. The respective figures (figure in brackets is the share of the PSE) for the **United States** are USD 5 billion (16%); **Norway** NOK 950 million (5%); **Switzerland** CHF 240 million (4%) and **Australian** payments under the Natural Heritage Trust (Figure 1.5) have been around AUD 460 million annually (18%).[2] For most other OECD countries AEPs have either only just been introduced on a limited scale to date or are not used as a policy instrument.

The AEP data provided here covers payments across all environmental domains in agriculture, such as payments for biodiversity conservation, air pollution control, and soil conservation. These data also include AEPs directly used for controlling water pollution, for example, for nitrate reduction, green cover and buffer strips, and conversion of land to wetlands and ponds (Table 4.2). Many AEP programmes, however, have indirect benefits for water pollution control, such as those aimed at soil erosion control which reduces soil siltation and the transport of nutrient and pesticide pollutants into water systems. Equally, payments for biodiversity conservation which by providing green cover, for example, can help absorb pollutants before they reach watercourses (Table 4.2). In other cases regulatory rules to control pollution may exempt farmers from receiving AEPs. For example, this is a requirement under the **European Union's** *Nitrate Directive*.

For these reasons it is difficult to provide accurate estimates of annual AEP expenditure across OECD countries used for water pollution abatement. But as water pollution control often figures prominently in programmes using AEPs, for example, to assist farmers with compliance with the **European Union's** *Nitrate Directive* and funding under the **US** *Environmental Quality Incentives Program* (EQIP), the total OECD annual expenditure on water pollution abatement in agriculture probably amounts to hundreds of billions USD (EUR) annually.

Table 4.2. Agri-environmental payments to address water quality in OECD member countries: 2008

Programme / country	Austria	Australia[1]	Belgium[2]	Canada	Czech Republic	Denmark	Finland[3]	France	Germany	Greece[3]	Hungary	Ireland	Italy	Japan	Korea	Mexico	Netherlands[3]	New Zealand[1]	Norway	Poland	Portugal	Spain	Slovak Republic	Sweden	Switzerland	Turkey	United States	United Kingdom[4]
1. Payments directly impacting water quality																												
Land improvement (liming, soil erosion prevention)	X	X	X	X			X	X	X				X		X	X		X	X	X	X	X	X	X		X	X	X
Payments for nitrate reduction	X	X	X			X	X	X	X	X			X		X				X	X	X	X	X	X	X	X		X
Nutrient management plan		X		X		X					X	X	X									X		X			X	X
Maintenance of wetlands and ponds[5]		X	X		X	X		X			X		X		X	X	X		X			X		X	X	X		X
Conversion of farmland into wetlands and ponds						X	X						X				X							X			X	X
Shelter belts/Buffer strips	X	X	X	X	X	X	X	X	X		X	X	X		X			X	X	X	X	X		X	X		X	X
2. Payments indirectly impacting water quality																												
Extensive crop production	X							X	X		X		X	X						X	X	X		X	X			X
Organic farming	X		X		X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X
Integrated production wine, fruits and vegetables	X		X		X			X			X		X			X						X	X					X
Integrated farming			X		X	X		X			X		X								X	X		X				X
Reduced tillage/Mechanical weed control	X	X	X	X			X		X		X	X	X						X		X	X			X	X	X	X
Green manure crops		X																										

(continued)

Table 4.2. Agri-environmental payments to address water quality in OECD member countries: 2008 (*cont.*)

Programme / country	Austria	Australia[1]	Belgium[2]	Canada	Czech Republic	Denmark	Finland[3]	France	Germany	Greece[3]	Hungary	Ireland	Italy	Japan	Korea	Mexico	Netherlands[3]	New Zealand[1]	Norway	Poland	Portugal	Spain	Slovak Republic	Sweden	Switzerland	Turkey	United States	United Kingdom[4]
2. Payments indirectly impacting water quality (cont.)																												
Green set-aside/Fallows	X	X		X		X		X			X		X		X		X					X			X		X	X
Catch crops, green/winter cover	X		X	X	X	X	X	X	X			X			X				X	X		X		X			X	
Extensive management of all land							X	X			X				X					X		X		X				
Extensive grassland management (pastures/meadows)			X	X	X	X		X	X		X	X	X		X		X		X	X	X	X	X	X	X	X	X	X
Conversion of arable land into grassland (pastures/meadows)				X	X	X		X	X		X		X									X	X		X		X	X
Grassland/biodiversity/habitat schemes	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X
Maintaining and improving groundcover		X																									X	
Long term set-aside	X	X				X			X	X		X	X									X				X	X	
Afforestation		X	X		X	X		X		X	X	X	X	X	X	X	X	X		X	X	X	X			X	X	X
Converting pasture to perennial vegetation		X																										

1. In Australia and New Zealand, there is very limited use of payments to farmers (and, where payments are made, this is in the form of one-off or transitional payments) and support to agri-environmental programmes is provided mostly through general services.
2. In Belgium, only programmes used in the Flanders region are reported.
3. In Finland, Greece and the Netherlands, the information for 2008 is not available and the programmes in the table correspond to programmes applied in 2000-06.
4. In United Kingdom, only programmes used in England are reported.
5. In Spain, the payments for water quality in wetlands are included in this line.

Source: Adapted from, Vojtěch, V. (2010), "Policy measures addressing Agri-environmental Issues," *OECD Food, Agriculture and Fisheries Working Papers,* No. 24.

Water quality trading[3]

Water quality trading (WQT) refers to the application of emissions trading to water pollution control. Traditional air and water pollution regulations entail imposing periodic (e.g. annual) maximum limits on emissions sources (e.g. smokestacks, outfalls), and requiring that those limits be met at the source. The requirement that limits are met at the source prevents emissions reductions from one source being used to meet the requirements of another.

Prohibiting the use of emissions reductions from one source to offset emissions from another serves no environmental purpose if the environmental conditions are unaffected by the offset. However, the inability to use offsets increases the costs of pollution control when the incremental cost of pollution abatement differs between sources. Emissions trading introduces flexibility into how emissions limits can be met, and a source may meet the limit on its allowable emissions in part or in whole (depending on trading rules) by acquiring offsetting emission reductions from other sources.

Applications of emissions trading to date have largely occurred in the domain of air pollution. There is now substantial interest in extending the method to water pollution, including to water pollution from agriculture. WQT initiatives have been implemented in **Australia**, **Canada**, **New Zealand**, and the **United States** (Figure 4.1). WQT is also being studied elsewhere, including by **Denmark**, **Finland**, **Sweden**, and other countries surrounding the Baltic Sea to address nutrient pollution in the Baltic Sea (Chapter 5.7).

WQT experiments began in the **United States** in the early 1980s, mostly in the form of pilot or demonstration projects. Early initiatives were disappointing, producing little or no trading activity. Despite this experience, but in the light of the success of air emission trading programmes, interest in WQT increased beginning in the mid-1990s with water quality policy developments requiring caps on pollution from point and diffuse sources in impaired waters. State water quality managers have been the innovators with support and encouragement from the US Environmental Protection Agency, including the creation of national policy guidelines for WQT in 2003, and technical assistance and funding for WQT projects.

The technical assistance addresses issues of legal compliance with national law but also presents guidelines for the creation of successful trading models based on lessons learned from *ex post* evaluations of early initiatives. These lessons include:

- Binding regulatory limits on pollution levels are essential for trading activity to occur. Such limits are essential to create the incentives for polluters to seek out options for pollution control cost savings.

- Trading activity requires sufficiently large differences in pollution control costs between polluters to make economic gains from trading possible, after deducting transactions costs incurred in conducting trade (Box 4.2).

- Trading rules must be clearly established to assure that water quality goals will be satisfied, but must also be designed to facilitate trading. Rules that are overly complex and costly create barriers to trading activity.

- Successful trading requires the development of institutions for organising trade that are trusted by, and effective for, intended programme participants.

The **United States** leads in the development of water quality trading initiatives, with 22 schemes located in 14 states. Agriculture is included as a potential participant in several US initiatives. Some of these are one-time sole-source offsets in which voluntary agricultural pollution reductions are used by a regulated point source to address facility-specific compliance problems. Agriculture is also a potential participant in several water catchment-based trading programmes that envision routine trading between multiple point and diffuse sources. The most notable of these are the Greater Miami River Watershed Trading pilot programme in Ohio and the Pennsylvania Water Quality Trading programme both initiated in 2005 (Figure 4.1). Both involve nutrient trading between point and agricultural diffuse sources.

The Grassland Farmers selenium trading project established in 1998 in the San Joaquin Valley in California, **United States**, is one water catchment based trading programme limited to agricultural sources. The Grassland Farmers traded and met pollution reduction goals for the two-year period before trading was suspended due to the development of a selenium recycling project that eliminated the need for trading. The Greater Miami programme is producing trade that promise reductions in nitrogen loads from agriculture, and has some innovative features that make it an important model for trading with agricultural diffuse sources. However, programme development and trading activity have been substantially supported by federal grants. The Pennsylvania nutrient trading programme has had only limited trade since its inception.

The **Canadian** programme, initiated in 2000, involves phosphorus trading between industrial and municipal point sources and agricultural diffuse pollution sources in the Ontario South Nation River water catchment (Figure 4.1). The programme has produced pollution reductions and pollution cost savings in the ten years that it has been in operation. The **New Zealand** programme, initiated in 2010, is limited to nitrogen trading between agricultural sources in the Lake Taupo water catchment on the North Island (Figure 4.1; and Chapter 5.4). **Australia** has a couple of successful trading programmes for industrial point sources but none at the present for agriculture. A nutrient trading programme that would include agricultural sources is being considered for Moreton Bay.

Emissions trading is typically described as a market-based pollution control instrument that sets a cap on the total emissions of a pollutant. Market transactions allocate emissions under the cap among individual pollution sources. The role of trading is to harness market forces to promote cost-efficiency in emissions reductions. WQT programmes that allow agricultural participants to conform to this description are only found under the **New Zealand** and Grassland Farmers selenium trading programme in the **United States**. Both of these are cap-and-trade programmes designed to achieve specific pollution reduction goals from agricultural sources. The **Canadian** and **US** nutrient WQT programmes that include agricultural sources are only partially capped. These programmes allow trading between point sources that are subject to explicit regulatory limits and agricultural sources that are not. They allow point sources to use pollution reductions produced voluntarily by agricultural diffuse sources to offset point source emissions as a means for complying with the point sources' emissions limits.

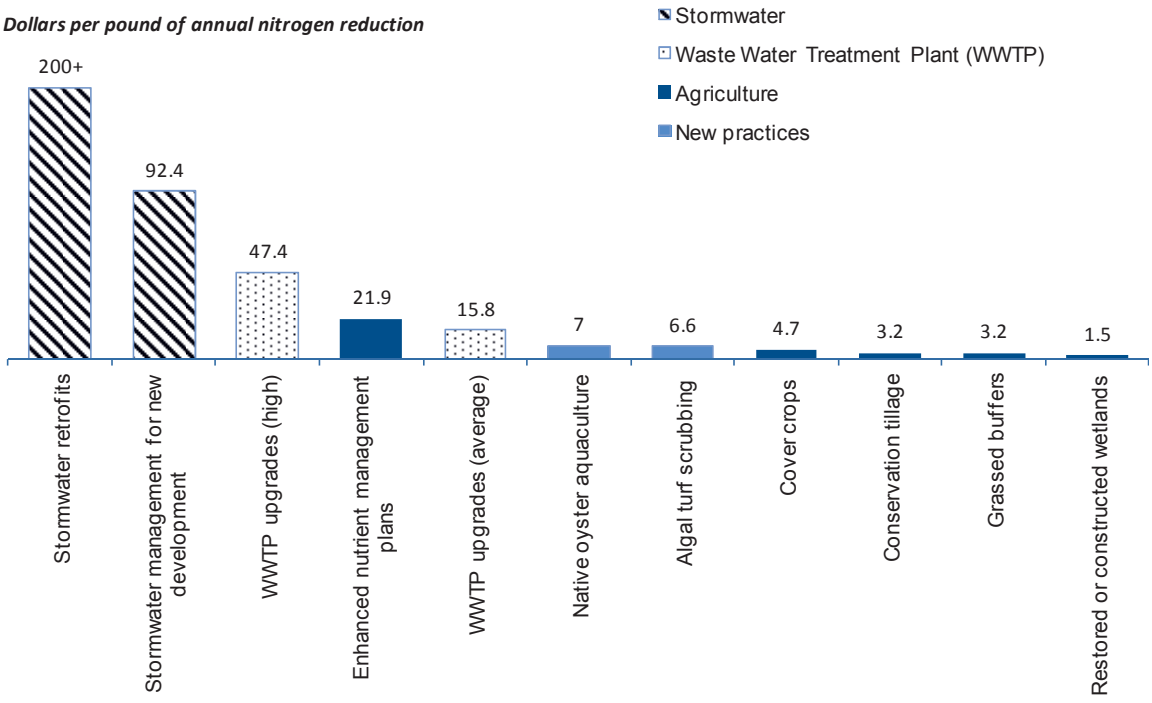
Figure 4.1. Water Quality Trading Programmes: Canada, New Zealand and the United States

	Canada	New Zealand	United States		
Programme	*Ontario South Nation River Total Phosphorus Management*	*Lake Taupo Nitrogen Trading Program*	*Grassland Area Tradable Loads Program*	*Greater Miami River Watershed Trading Pilot*	*Pennsylvania Water Quality Trading Program*
Administrator	South Nation Conservancy (SNC)	Environment Waikato	Grassland Area Farmers (GFA)	Miami Conservancy District (MCD)	Pennsylvania Department of Environmental Protection
Year initiated	2000	2010	1998	2005	2005
Pollutant	Phosphorus	Nitrogen	Selenium	Nitrogen, Phosphorus	Nitrogen, Phosphorus, Sediments
Eligible pollution sources	Industrial, municipal, agricultural	Agricultural	Agricultural	Industrial, municipal, agricultural	Industrial, municipal, agricultural
Commodity type	Emission reduction credits (ERCs)	Emission allowances	Emission allowances	Emission reduction credits	Emission reduction credits
Emissions quantification	Calculated	Calculated	Measured	Calculated	Calculated
Agricultural sources capped?	No	Yes	Yes	No	No
Market organisation	SNC sells ERCs to point sources. Proceeds are used to fund agricultural projects. Farmers do not participate directly.	The market is designed for voluntary exchange between landowners or third party agents. An online registry has been developed for posting offers.	Trades are negotiated between the 7 irrigation district members of the GFA association. Farmers do not participate directly.	MCD buys ERCs from Soil and Water Conservation Districts (SWCDs) using reverse auctions. The SWCDs use the proceeds to fund agricultural projects. Farmers do not participate directly. The programme is funded by ERCs sold to municipal waste water treatment plants and federal grants.	The market is designed for voluntary exchange credit suppliers and demanders, or third party agents. An online registry has been developed for posting offers. A clearing house intended to increase market activity was created in 2010.
Baseline participation requirements or initial allowances	None. Farmers do not participate directly. Eligible projects are funded by SNC.	Initial allowance allocation is based on the average nitrogen losses between 2000 and 2005	Total Maximum Daily Loads (TMDL)	Credits generated by agricultural projects funded by the programme cannot be funded by other programmes or otherwise required.	Farmers must meet minimum nutrient and sediment management requirements to be eligible to participate.
Trading activity	Yes. The programme has produced emissions reductions and cost savings.	Emerging	Yes. 39 trades during two years of operation. Pollution goals met. Trading has been suspended due to new control options.	Yes. 6 reverse auctions have been conducted providing funding for 99 agricultural projects.	Yes. Very low compared to the expected potential.

Source: Shortle, J. (2012), *Water Quality Trading in Agriculture*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

Box 4.2. Opportunities for water quality trading:
Nitrogen reduction cost differences within and between sectors – United States 2009

The opportunity for nutrient trading arises because large differences in the cost to reduce a kilogram (pound) of nitrogen exists within and between different sectors and practices, as shown in the Box Figure example of the Chesapeake Bay, United States. In a trading market, sources that can reduce nutrients at low cost have an economic incentive to make reductions below target levels and then sell the credits to those facing higher costs. Trading therefore creates new revenue opportunities for farmers, entrepreneurs, and others who can generate nutrient credits. At the same time, trading allows those wastewater treatment plants (WWTPs) and municipal stormwater programmes that face higher nutrient reduction costs to save money by purchasing credits to meet a portion of their nutrient reduction obligations. As a result, trading can help achieve overall nutrient reductions in a more cost-effective manner.



Note: It should be noted that the figure above does not show credit prices in a nutrient trading market, but current average costs to reduce a pound of nitrogen based on a number of studies. Prices are determined by the market dynamics of supply and demand. The costs in this figure do not take into account the baseline or minimum practices that agriculture would have to implement prior to selling credits.

Source: OECD Secretariat, adapted from World Resources Institute (2010), *How nutrient trading could help restore the Chesapeake Bay*, Working Paper, Washington, D.C., United States.

Trading rules are typically designed with the intent that agricultural offsets produce a net reduction in total pollution. For example, the Ontario South Nation River programme requires a reduction of 4 kg of phosphorus from an agricultural source for each kg of point source phosphorus emissions allowed. **Canadian** and **US** nutrient WQT programmes essentially create profit-making opportunities for agriculture that can reduce agricultural pollution, but do not cap agricultural pollution.

The partially-capped nutrient trading model used in **Canada** and the **United States** was developed by water quality managers seeking to improve the efficiency and effectiveness of water pollution control by adapting a first-generation (i.e. pre cap-and-trade) air emissions trading model to the trading of agricultural diffuse source pollution. This adaptation took place within water pollution policy frameworks that did not actively regulate agricultural diffuse source pollution, and which did not envision trading.

Agricultural and other diffuse source pollution can pose significant technical challenges to a fully capped trading design. One lesson is that some methods used in the design of point-diffuse source pollution trading programmes are scientifically flawed and may lead to designs that diminish the capacity of WQT to efficiently and effectively achieve water quality goals.

It is important to emphasise that water quality trading programmes differ substantially from theoretical models of emission trading and from well-known large scale cap-and-trade markets for sulphur dioxide air emissions in the **United States** and carbon emissions in the **European Union**. These differences include:

- Water quality trading programmes are not defined at national or international scales, instead, they address specific local or regional water quality problems within well-defined hydrological boundaries.
- With a few exceptions, existing water quality trading programmes make limited use of markets in the conventional sense. The most effective agricultural trading models to date make use of traditional agricultural soil and water conservation institutions to recruit farmers and fund agricultural pollution reduction projects, and do not engage farmers directly in trading.
- Theoretical models usually assume, and the major cap-and-trade programmes are defined for, point sources of pollution. Some water quality trading programmes are limited to point sources, but most include agricultural or other diffuse sources.
- By definition, theoretical models and the large cap-and-trade programmes place a cap on the total emissions of eligible participants. Markets serve to allocate emissions under the cap among the various sources. With one exception across OECD countries, active water quality trading programmes with agricultural diffuse sources are only partially capped. These programmes do not limit agricultural diffuse source pollution. Instead, they allow point sources to use pollution reductions produced voluntarily by agricultural diffuse sources as a technology for point source regulatory compliance. These water quality trading programmes essentially create profit-making opportunities for agriculture that can reduce agricultural pollution, but do not in fact cap agricultural pollution.

The differences outlined here emerge for several reasons, including:

- ***Spatial scales****:* the comparatively small spatial scales appropriate to water quality management.
- ***Regulatory context****:* The cap-and-trade air emission programmes result from legislation specifically intended to create them. Most water quality trading programmes have emerged as innovations within, and constrained by, existing water pollution control laws and policies that did not envision trading. Thus, for example, **US** and **Canadian** pollution control measures do not explicitly regulate emissions from most agricultural diffuse sources. Instead these programmes use agricultural diffuse source offsets as off-site technologies that can be used for point source compliance. Further, these programmes are

analogous to **US** first-generation (pre cap-and-trade) air emissions trading programmes that similarly emerged as cost-saving innovations within a pre-existing regulatory framework that did not specifically enable trading. Thus, these programmes trade emissions reduction credits rather than emission allowances.

- ***Point sources****:* The theoretical model of trading that has guided the development of cap-and-trade air emissions trading assumes participants are point sources. The point source model does not address challenging measurement and management issues associated with diffuse source pollution.

4.2 Environmental regulations

Since the 1980s there has been a general expansion in regulatory measures affecting agriculture to protect water systems, which usually make farmers liable for the water quality damage they cause. These measures are frequently compulsory or the producer faces penalties, such as fines and, where eligible, withdrawal of agri-environmental payments. Regulations are the most widespread and common policy measure used across OECD countries to limit the environmental impacts of agriculture on water systems (Table 4.3). Regulations range from very broad prohibitions (e.g. the blanket ban on DDT pesticide) or requirements (e.g. compliance with the **EU** *Nitrates Directive*) to intricate details about specific farm management practice (e.g. pesticide spraying distance from a river) (OECD, 2003b).

In brief the regulatory approaches across OECD countries that address water pollution from agriculture can be summarised in terms of (Table 4.3 provides an illustration of the range of these regulations related to pig and dairy cow manure management for selected OECD countries):

- Prohibitions on the direct discharge of farm wastes into rivers and lakes, such as livestock manure or disposal of unused pesticides;
- Limits on the marketing and sales of products prior to a human health and environmental risk assessment, which is mainly relevant to pesticides and other emerging contaminants (Box 4.3), to ensure their health and environmental safety prior to use on-farm;
- Rules concerning the distance and sitting of livestock waste and pesticide storage in the proximity to surface water and groundwater;
- Permits, for example, to operate large-scale livestock operations and control potential polluting emissions from these facilities, and also for aerial spraying of pesticides; and,
- Restrictions of on-farm management practices, which in general will affect the handling of potentially water-polluting materials (fertilisers, manure, pesticides), their storage and application onto fields (including the quantities that can be applied, the timing, and the distance from watercourses).

Regulations can lead to modifications in farmer behaviour, especially where the expectation is that a producer will have to pay a large fine, penalty or compensation for water quality damage. Such regulations can be effective for point source pollution in agriculture where the source of pollution and polluter is easily identified, and the transaction costs of regulatory enforcement can be minimal. But for diffuse source agriculture water pollution as these conditions do not prevail, then such regulations can only be a complimentary mechanism with other policy instruments, such as a compliance condition to receive a pollution abatement payment (Weersink and Livernois, 1996).

Table 4.3. Regulatory requirements for pig and dairy cow manure management in selected OECD countries

	Denmark	Netherlands	Switzerland	Canada (Ontario)	United States (Iowa)	Japan	Korea	Australia (New South Wales)	New Zealand (Waikato)
Maximum allowable manure application (kgN/ha)[1]	170 kgN	Arable land 170 kgN Grassland 230 kgN (total allowable nutrient surplus 100-180 kgN)	150-315 kgN (depending on region) or 3 large cows	244 kgN (Surplus ≈ 36 kgN)	Up to 1.5 times crop usage rates of N	Probably no regulation	340-640m^2 of land per pig	50-200 kgN/ha	No regulations but 150 kg from effluent. To this comes manure deposit in the field. (Surplus >140 kgN is assumed high leaching potential.)
Manure storage capacity and technology	Minimum 180 days (270 days in practice) Concrete	6 months. From 2012: 7 months Concrete with tent or hard cover	120-210 days Concrete	240 days Concrete or liners	Minimum 225 days' capacity; Tank or lagoon, with straw cover	n.a.; Concrete or liners with cover and side wall	180 days; for compost: 30-60 days; Tanks are common	Sufficiency requirement (180 days); Tank or lagoon	Not applicable - Sealed ponds
Allowed manure application technology	Trailing hose or injection	Injection and trailing hose injection	All	All	Any	All	Any	Any	All
Application-free period	From harvest to 1 Feb. On snow and frozen soils.	15 Sept.-1 Feb. On snow and frozen soils. From 1 Sept 2011 application on grass over sandy soils prohibited.	On snow and frozen soils	When snow cover >5cm and on frozen soils	Winter	-	Summer rainy season	Winter	Not applicable
Nutrient planning	Yes	Yes	Yes	Yes	Yes, except small farms	Yes	No	Yes	No
Nutrient book-keeping	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No

Table 4.3. Regulatory requirements for pig and dairy cow manure management in selected OECD countries (*cont.*)

	Denmark	Netherlands	Switzerland	Canada (Ontario)	United States (Iowa)	Japan	Korea	Australia (New South Wales)	New Zealand (Waikato)
Nutrient accounting	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Soil analysis	No	Yes	Yes, every year	Yes, every 3rd year	n.a.	No	n.a.	n.a.	No
Pollution permits required	No	Yes	No	No	Yes	No	Some	Yes	No
Environmental Impact Assessment	For farms larger than 250 animal units	Yes	No	Yes	Yes	No	No	Yes	No
Land ownership requirements	Yes	Yes	No	No	No	No	Yes	No	No
Buffer zones	Minimum 2 m along water-courses	2000 km fertiliser-free zones around ecologically sensitive streams	Minimum 3 m along watercourses and hedges	Different zones, minimum 3 m, and up to 30 m to water catchments. Minimum distance to several objects	Yes	n.a.	No	200 m from plant	20 m for effluents
Compliance incentives	Levies	Levies	Yes	Yes	Fines	Yes	Fines	Fines	No

n.a.: not available

Sources: OECD Secretariat, adapted from OECD (2003), *Agriculture, Trade and the Environment: The Pig Sector,* OECD, Paris, www.oecd.org/tad/env; and OECD (2004), *Agriculture, Trade and the Environment: The Dairy Sector,* OECD, Paris, France.

Box 4.3. Regulatory approaches to address agricultural water pollution from emerging contaminants

The environmental impacts of a number of classes of emerging contaminants (ECs) are largely controlled across OECD countries by conducting compulsory Environmental Risk Assessments (ERAs) of veterinary medicines, human pharmaceuticals, transformation products, engineered nanoparticles and other potential ECs before they are marketed.

Historically, individual authorities have had their own guidelines for assessing the risks of a ***veterinary product***. The Veterinary International Co-operation on Harmonisation (VICH) was officially launched in 1996 to harmonize technical requirements for veterinary product registration across the **United States, Canada, Australia, Japan** and **Europe**. Its members include representatives from government agencies and industry. VICH currently has working groups drafting recommendations in a number of areas including ecotoxicity, safety, efficacy, and pharmacovigilance.

In the **European Union** and the **United States**, guidelines are also available for the ERA of ***human pharmaceuticals***. The current guidance document, adopted by the European Medicines Evaluation Agency Committee for Human Medicinal Products, came into effect 2006. An ERA is required for all new marketing authorisation applications for medicinal products. Unlike veterinary medicines, a marketing authorisation for a human pharmaceutical will not be refused based on the ERA.

The environmental risks of ***transformation products*** have to be considered for many classes of chemicals. For example, the **EU**'s *Pesticides Directive* (2009/1107) requires assessment of major transformation products and relevant transformation products of plant protection products. Similar requirements also exist for transformation products of pesticides, biocides and human and veterinary medicines in other countries (e.g. **United States**).

As engineered ***nanomaterials*** are expected to be used in a wide range of product types, it is likely that a range of environmental regulatory frameworks will apply to them. For example, industrial uses are likely to be covered by the recent **EU** Regulation on the Registration, Evaluation, Authorization and Restriction of Chemicals (the "REACH Regulation") which, entered into force in 2007. Applications for pharmaceutical, biocides, veterinary medicines and plant protection products will be covered by other specific frameworks.

Many ECs that are not covered by the mechanisms described above are likely to be covered in the **European Union** by the REACH Regulations. REACH will require an environmental safety assessment of all chemicals used or imported into the European Union in quantities exceeding one tonne. The EU *Water Framework Directive* and the new European soils policy may also influence the management of ECs in the natural environment.

In the event that an EC is identified as posing an unacceptable risk to the environment, there are a number of options that exist for managing or mitigating the risks. For example, over recent years there has been a steadily increasing drive within the pharmaceutical industry towards the synthesis of "greener" pharmaceuticals and the adoption of green chemistry methods and technologies. Most improvements have been made to the manufacturing process, although increasing emphasis is being placed on the development of approaches for minimising impacts during use, including development of pharmaceuticals that are benign or designed to be biodegradable.

Classification and labelling approaches may also help to minimise risks. A good example of such a scheme is a system running in **Sweden**, which is voluntary and targets active pharmaceutical substances where information on their environmental impacts is made publicly available on websites and in information booklets. The extension of a model similar to the Swedish scheme could potentially be desirable at the OECD level. Key issues for developing and implementing classification and labelling schemes include: the standardisation of the information used; the criteria applied; who provides the information; and the mode of communication.

In **Europe**, drug take back schemes of unused/expired medication are an obligatory post-pharmacy stewardship approach that reduces the discharge of pharmaceuticals into environmental waters and minimises the amounts of pharmaceuticals entering landfill sites. Although the contribution of improper disposal of pharmaceuticals to the overall environmental burden is generally believed to be minor, drug take back schemes are still considered to be important. High levels of public awareness and education on the environmental consequences of the disposal of unused/expired drugs are key for the success of such schemes.

Source: Boxall, A. (2012), *New and Emerging Water Pollutants arising from Agriculture*, OECD Consultant Report, available at: *www.oecd.org/agriculture/water*.

4.3 Information instruments and other persuasive approaches to address water pollution

Information instruments are used widely across OECD countries in support of economic instruments and regulations to address water quality issues in agriculture. Some of these instruments are well developed, especially public and private research on water pollution abatement technologies and BMPs, and diffusing these technologies and practices to farmers through support mechanisms and capacity building (Table 4.4). Eco-labelling is one example of an information instrument that can provide incentives for farmers who wish to certify their products and adopt sustainable agricultural practices, and bring benefits for water quality and other environmental media (Box 4.4).

Other persuasive approaches are not so widespread and less developed, such as private and voluntary regulation and co-operative arrangements in the area of water pollution control, as summarised in Table 4.4 (Barnes *et al.*, 2009; Dowd *et al.*, 2008; Gouldson *et al.,* 2008; Kay *et al.*, 2009). There is growing interest and experimentation, however, with developing these approaches, especially co-operative arrangements, as discussed in the following section (Chapter 5.8).

Table 4.4. Information instruments and other persuasive approaches to address water pollution from agriculture

Communicative approaches	Specific policy instruments and approaches	Examples related to improving water quality in agriculture
Information-based instruments	• Targeted information provision	• Advice specific to a farm or sub-catchment
	• Publicising farmer performance	• Publicising farmers that have achieved improvements in water quality
	• Registration, labelling, certification	• Organic standards symbol
Private and voluntary regulation	• Self-regulation	• Farmers acting to regulate themselves
	• Voluntary regulation	• Developing agro-food industry codes of conduct, such as by the pesticide industry
	• Covenants and negotiated agreements	• Formalised voluntary agreement, that may include sanctions for non-compliance
	• Corporate regulation	• Water companies, for example, requiring farmers to comply with farming practices to ensure improved
	• Professional regulation	• Codes of practice developed by professional organisations
	• Civic regulation	• Community based regulation, such as between conservation groups and farmers
Support mechanisms and capacity building	• Research and knowledge generation	• Private and public research and knowledge to improve understanding of agriculture and water quality links
	• Demonstration projects and knowledge diffusion	• Farm advisory services and demonstration projects to encourage greater uptake of best management practice
	• Network building and joint problem solving	• Can involve developing network of farmers and other stakeholders in a water catchment to discuss problems collectively

Source: OECD, adapted from Gouldson, A., *et al*. (2008), "New alternative and complementary environmental policy instruments and the implementation of the Water Framework Directive", *European Environment*, Vol. 18, pp. 359-370.

Box 4.4. Eco-labelling and agricultural water pollution

Eco-labelling is a voluntary method of certifying products that are produced in a way that is environmentally preferable to other products in the same product category based on life cycle considerations. Eco-labelling is intended to stimulate consumer preference for "green" products and thus generate a financial return to the supplier of the certified product in the form of increased revenues. Eco-labelling of agricultural products can provide incentives for farmers who wish to certify their products and adopt sustainable agricultural practices, and bring benefits for water quality and other environmental media (Selman and Greenhalgh, 2009).

The organic label is the most well established eco-label across OECD countries, with organic farming seen as providing a host of environmental benefits, including improving water quality (Chapter 3). It has benefited from consumer demand, a clearly defined set of standards, a strong certification system, and a system of enforcement. However, the adoption of organic production systems across OECD countries still remains relatively low (OECD, 2008). Obstacles to adoption by farmers include: high managerial costs and risks of shifting to a new way of farming; limited awareness of organic farming systems; uncertainty over expected yields and returns; lack of marketing and infrastructure; and the inability to capture marketing economies. These factors are likely to be issues for other types of eco-labels (Ribaudo *et al.,* 2010a).

As well as organic labels, a number of other eco-labelling programmes have emerged with a specific connection to improving water quality related to agriculture. In 1998, the World Wildlife Fund collaborated with a **United States** environmental non-governmental organisation (NGO), *Protected Harvest*, to initiate a label for potato farmers in Wisconsin that would reduce the use of some toxic pesticides and encourage other environmentally beneficial production practices. Another US environmental NGO in the Pacific Northwest developed a *Salmon Safe* label that recognises the adoption of "ecologically sustainable agricultural practices that protect water quality and native salmon." This label encourages restoration of riparian habitat adjacent to fields, as well as improved cropping system practices.

About 100 growers in New York State, **United States**, with a variety of production systems, are using a *Pure Catskills* promotional label to indicate their participation in a water catchment protection programme. *Water Stewardship* is also working with agricultural producers in the Chesapeake Bay and other areas of the **United States** to develop and implement plans to reduce the impacts of nutrients on water. Producers that implement these plans will be able to market their products to beverage manufacturers, processors, and distributors as sustainably produced (Ribaudo *et al.,* 2010a; Selman and Greenhalgh, 2009).[1]

The proliferation of other local and national eco-labels for a variety of environmental services and labels for other causes may pose a challenge to consumers (Ribaudo *et al.,* 2010b). Many of these labels do not come with the standards and certification of the organic label, raising the uncertainty of the label claims. Even if consumers are willing to pay a premium to support the supply of environmental services on farms, too much information may make deciding between competing goods difficult. However, careful development of new production standards and labelling regulations, along with consumer education, production research, and other policy initiatives, can mitigate consumer confusion and address the obstacles to adoption (Ribaudo *et al.,* 2010b).

Even if price premiums for eco-labels can be maintained, however, the public-goods nature of environmental services, such as water quality, implies that they do not reflect the true social value of these services. Eco-labels alone cannot provide a socially optimal level of environmental services, such as high levels of water quality (Ribaudo *et al.,* 2010b).

1. For further details on these environmental NGOs with a focus on standards and certification of sustainable agriculture in relation to water quality, see the following websites: Protected Harvest: *www.protectedharvest.org/;* Salmon Safe *www.salmonsafe.org/;* Pure Catskills: *www.buypurecatskills.com/;* and Water Stewardship: *www.waterstewards.net/*.

Sources: OECD Secretariat, drawing on, in particular, Ribaudo, M., C. Greene, L. Hansen and D. Hellerstein (2010a), "Ecosystem services from agriculture: Steps for expanding markets", *Ecological Economics*, Vol. 69, pp. 2085-2092; Ribaudo, M., L. Hansen, D. Hellerstein and C. Greene (2010b), *The use of markets to increase private investment in environmental stewardship*, Economic Research Report No. 64, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., United States; Selman, M. and S. Greenhalgh (2009), *Eutrophication: Policies, actions and strategies to address nutrient pollution*, World Resources Institute, Washington, D.C., United States; OECD (2008), *Environmental Performance of Agriculture in OECD Countries since 1990,* OECD, Paris, *www.oecd.org/tad/env/indicators*.

Notes

1. There is a long tradition of analysis and quantitative modelling, both theoretical and empirical, describing how different policy instruments or mixes of policy instruments influence water quality related to agriculture, see for example: Ribaudo, Horan and Smith, 1999; and Shortle and Horan, 2001.
2. These data are from Vojtěch, 2010 and the OECD *PSE/CSE database*. For Australia the share of expenditure is the total support estimate, however, not all of the Natural Heritage Trust expenditure is directed at agriculture.
3. This section draws from Shortle, 2012.

Bibliography

Barnes, A.P., J. Willock, C. Hall and L. Toma (2009), "Farmer perspectives and practices regarding water pollution control programmes in Scotland", *Agricultural Water Management*, Vol. 96, pp. 1715-1722.

Blandford, D. (2010), "Presidential Address: The visible or invisible hand? The balance between markets and regulation in agricultural policy", *Journal of Agricultural Economics*, Vol. 61, No. 3, pp. 459-479.

Dowd, B.M., D. Press and M. Los Huertos (2008), "Agricultural nonpoint source water pollution policy: The case of California's Central Coast", *Agriculture, Ecosystems and Environment*, Vol. 128, pp. 151-161.

Gouldson, A., *et al*. (2008), "New alternative and complementary environmental policy instruments and the implementation of the Water Framework Directive", *European Environment*, Vol. 18, pp. 359-370.

Jacquet, F., J.-P. Butault and L. Guichard (2011), "An economic analysis of the possibility of reducing pesticides in French field crops", *Ecological Economics*, Vol. 70, pp. 1638-1648.

Kay, P., A.C. Edwards and M. Foulger (2009), "A review of the efficacy of contemporary agricultural stewardship measures for ameliorating water pollution problems of key concern to the UK water industry", *Agricultural Systems*, Vol. 99, pp. 67-75.

Lally, B., B. Riordan and T.M. van Rensburg (2007), *Controlling agricultural emissions of nitrates: Regulations versus taxes*, Working Paper 0122, National University of Ireland, Galway, Ireland.

OECD (2003b), *Agriculture, Trade and the Environment: The Pig Sector,* OECD, Paris, *www.oecd.org/tad/env*.

OECD (2007), *Instrument Mixes addressing Non-point Sources of Water Pollution,* OECD, Paris, *www.oecd.org/env*.

OECD (2010e), *Guidelines for Cost-effective Agri-environmental Policy Measures*, OECD, Paris, *www.oecd.org/agr/env.*

Oenema, O., H.P. Witzke, Z. Klimont, J.P. Lesschen and G.L. Velthof (2009), "Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27", *Agriculture, Ecosystems and Environment*, Vol. 133, pp. 280-288.

Randhir, T.O. and J.G. Lee (1997), "Economic and water quality impacts of reducing nitrogen and pesticide use in agriculture", *Agricultural Resources Economics Review*, Vol. 26, No. 1, pp. 39-51.

Ribaudo, M., R.D. Horan and M.E. Smith (1999), *Economics of water quality protection from nonpoint sources: Theory and practice*, Agricultural Economic Report No. 782, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., United States.

Shortle, J. (2012), *Water Quality Trading in Agriculture*, OECD Consultant Report, available at: www.oecd.org/agriculture/water.

Shortle, J. and R.D. Horan (2001), "The economics of nonpoint pollution control", *Journal of Economics Surveys*, Vol. 15, No. 3, pp. 255-289.

Vojtěch, V. (2010), "Policy Measures addressing Agri-environmental Issues", *OECD Food, Agriculture and Fisheries Working Papers,* No. 24, OECD Publishing, *www.oecd.org/dataoecd/57/44/44970440.pdf*.

Weersink, A. and J. Livernois (1996), "The use of economic instruments to resolve water quality problems from agriculture", *Canadian Journal of Agricultural Economics*, Vol. 44, pp. 345-353.

Chapter 5

OECD policy experiences in addressing water quality issues in agriculture

There are a vast number of policy instrument and policy mixes that OECD countries are using in their programmes to address water quality issues in agriculture. It is outside the reach of this report to provide a comprehensive assessment of these programmes, instead this chapter focuses on a number of illustrative policy case studies of how some OECD countries are addressing different aspects of water quality in agriculture, including: addressing nitrate pollution from agriculture in the European Union; restoring the Chesapeake Bay in the United States; reducing salinity in Australian agriculture; experimenting with water quality trading in New Zealand; improving research on diffuse source pollution in France and the United Kingdom; reforming governance to address social concerns with water quality in New Zealand; addressing transborder pollution control for countries surrounding the Baltic Sea; and establishing co-operative agreements in France, New Zealand, United Kingdom, and the United States to address diffuse source pollution.

There are a vast number of policy instruments and policy mixes that OECD countries are using in their programmes to address water quality issues in agriculture, as previously described in Chapter 4. It is outside the reach of this chapter to provide a comprehensive assessment of these programmes, instead the chapter focuses on a number of illustrative policy case studies of how some OECD countries are addressing different aspects of water quality in agriculture.

Point source pollution from agriculture is not the main focus of discussion here, as nearly all OECD member states are addressing this form of pollution from agriculture mostly through some form of regulatory measures, as previously discussed. The key challenge for policy makers with point source pollution in agriculture is largely one of enforcing greater compliance with the current set of regulations. This is proving a significant task in a growing number of countries, however, especially as some intensive livestock operations are finding loopholes in the regulatory framework.

In the **United States**, for example, the Environmental Protection Agency agreed in June 2010 to identify and investigate many thousands of concentrated animal feeding operations (CAFOs) that have been avoiding Federal regulations for point source pollution under the *Clean Water Act*. There is also recent research evidence that suggests some CAFOs in the United States will adjust size in order to avoid point source pollution regulations (Sneeringer and Kay, 2010). The regulations concerning CAFOs is creating tensions between owners who consider the regulations are too costly to be implemented and environmental groups who feel that the regulations are not properly enforced to prevent water pollution (Centner, 2011).

The greater policy challenge for nearly all OECD countries, however, is in addressing diffuse sources of pollution in agriculture, hence, the focus of discussion here. What distinguishes diffuse source pollution from point source pollution as a policy challenge, has been discussed in earlier sections, but to briefly summarise diffuse source pollution is:

- Usually invisible due to low concentrations and subsurface and/or diffuse pathways into water systems;
- Commonly difficult (or extremely costly) to measure or track with current monitoring technologies;
- Generally cumulative in its impacts, that is to say impacts usually arise due to cumulative effects of runoff from large areas concentrating in water systems; and,
- Highly variable in space and time, due to natural phenomena such as the weather, soils, and topography, and hence, difficult to manage.

The country case studies examined in this section are as follows:

- Addressing nitrate water pollution from agriculture in the European Union.
- Lowering pollution of the Chesapeake Bay, United States: The role of agriculture.
- Reducing salinity in agriculture to improve water quality: The case of Australia.
- Implementing water quality trading for nitrogen pollution in Lake Taupo, New Zealand.
- Improving research on diffuse source water pollution: France and the United Kingdom.
- Reforming governance to address social concerns with water quality in New Zealand.

- Addressing transborder pollution: The Baltic Sea, eutrophication and agriculture.
- Establishing co-operative agreements to address diffuse source pollution.

5.1 Addressing nitrate water pollution from agriculture in the European Union

Public opinion across the EU member states has ranked water pollution as one of their major environmental concerns (European Commission, 2009). This concern is borne out by the EU Commission's assessment which has identified that 40% of surface water and 30% of groundwater is at risk across the EU of failing to meet the objectives for good chemical and ecological status established under the EU's *Water Framework Directive* (WFD) (Kanakoudis and Tsitsifli, 2010). More detailed analysis at the EU member state level, for example in the **United Kingdom**, reinforces the EU Commission findings and also points to the importance of diffuse source pollution, mainly from agriculture, as a major cause of pressure on water systems (Table 5.1).

Table 5.1. United Kingdom water bodies at risk of failing to meet good ecological status in 2015 (%)

		Rivers	Lakes	Estuaries	Coastal waters	Groundwater
	Overall	**93**	**84**	**99**	**85**	**75**
Pressures	Diffuse pollution	82	53	25	24	75
	Physical changes	48	59	90	78	n.a.
	Point source pollution	23	20	49	18	4
	Alien species	21	9	37	46	n.a.
	Abstraction	11	2	14	n.a.	26

n.a.: not available
Source: Defra (Department for Environment, Food and Rural Affairs) (2008), *Future water: The Government's water strategy for England*, Defra, London, United Kingdom.

Over the past two decades the European Union has responded to the problem of nitrate water pollution from agriculture through three main policy approaches, including the:

- ***Nitrates Directive****:* The 1991 EU *Nitrates Directive* obliges member states to decrease the nitrate load from agricultural sources to groundwater and surface waters, and to avoid further pollution from these sources, with member states having to (OECD, 2007):
  - Assign areas that are vulnerable to nitrate leaching (*Nitrate Vulnerable Zones* – NVZ), with 40% of the area of the EU27 designated under NVZs by 2007, with the area under NVZs increasing over the period 2004-09 (European Commission, 2010);
  - Establish action plans to decrease nitrate leaching and to monitor their effectiveness, with all member states having now established over 300 action plans across the European Union; and,
  - Develop codes of good agricultural and environmental practice to guide farmers in reducing water pollution from fertiliser use and livestock waste.

Nitrate Vulnerable Zones (NVZs) are areas where: i) surface freshwaters contain – or could contain, if preventative action is not taken – nitrate concentrations greater than 50 mg per litre; ii) groundwaters which contain – or could contain, if preventative action is not taken – nitrate concentrations greater than 50 mg per litre; and iii) natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic, or may become so in the near future if protective action is not taken. The core of the Directive is that a balance should be reached between nitrogen supplied to the soil (e.g. animal manure and fertilisers) and nitrogen demand by the crops.

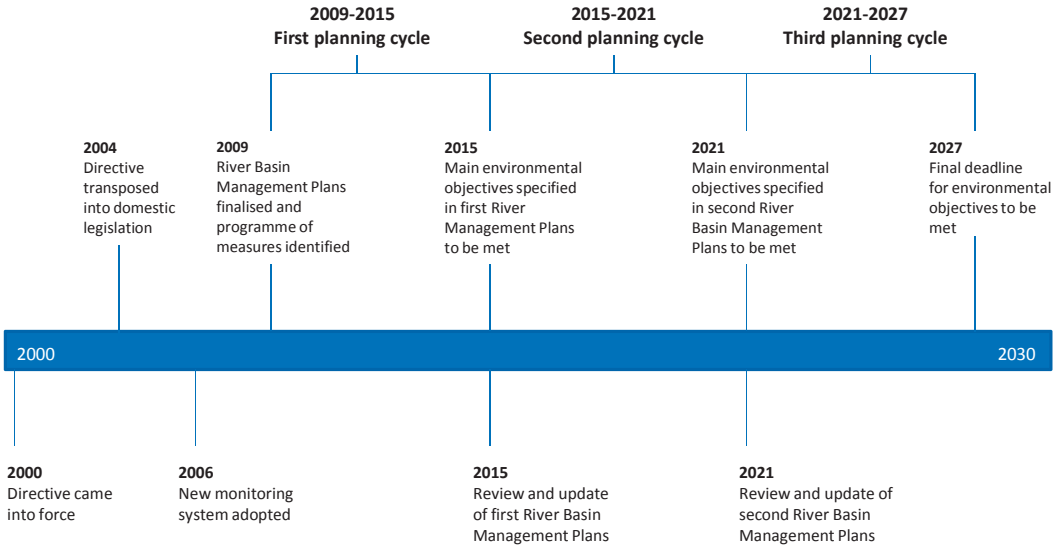
Outside NVZs, voluntary codes of good practice have to be promoted, and within the NVZs mandatory measures are required (e.g. regarding minimum manure storage capacities, restrictions in time and location on manure and slurry application). The maximum application of animal manure is 170 kg nitrogen per hectare annually, however, restrictions become more stringent if this limitation is insufficient to meet water quality objectives. A derogation allows member states to go beyond the 170 kg limit when justified on the basis of certain criteria laid down in the Directive, provided that the objectives of the Directive are achieved in time. Seven countries obtained derogations up to December 2009 (European Union, 2010).

- ***Water Framework Directive*** *(WFD):*[1] The WFD (introduced in 2000), provides the overarching policy framework to manage water (resources and quality) in the European Union, with a timetable set up to final WFD implementation by 2027 (Figure 5.1). The objective of the WFD is to protect all water systems and achieve good status (ecological and chemical) for these waters by 2015, which has implications for nutrient pollution from agriculture. Planning and action under the Directive aims to deliver a management plan for the whole river basin (catchment). The WFD is demanding as it: covers the total water system (quality and quantity); sets timelines; requires compliance with the Polluter-Pays-Principle; stipulates that economic criteria are necessary to ensure WFD goals are met at least cost; defines targets for the chemical and ecological status of water bodies; requires full monitoring and evaluation of programmes under the WFD; and comprises full stakeholder participation through the river basin management plans.

  It should be emphasised that while the WFD is a European wide common regulatory framework it makes allowance for the significant variations in water systems across the European Union. Therefore, differences exist in the types of mitigation measures adopted by member states reflecting variations in farming practices and systems and differences in the biophysical characteristics of each water catchment (Balana, Vinten and Slee, 2011).

- ***Common Agricultural Policy*** *(CAP):* Reform of the CAP over the past 20 years is increasingly decoupling farm support from production (Figures 1.2 and 1.3) and establishing environmental conditionality (Table 1.1). This has helped move the focus of farmers and landowners to address environmental issues in agriculture, including diffuse source pollution. These changes have largely been achieved through cross compliance mechanisms by providing voluntary agri-environmental payments conditional on ensuring "good agricultural and environmental conditions" (OECD, 2011c).

Figure 5.1. The European Union Water Framework Directive delivery timeline



Source: National Audit Office (2010), *Environment Agency: Tackling diffuse water pollution in England*, Report by the Comptroller and Auditor General, London, United Kingdom.

As the European Union progresses towards meeting the various deadlines under the WFD shown in Figure 5.1 and the requirements under the *Nitrate Directive* to further lower nitrate losses into water systems to good status under the WFD, it will be important to consider the following:

- ***Budgetary costs and policy cost effectiveness****:* The success in lowering nitrogen emissions into water from agriculture has come at a substantial cost to farmers and taxpayers. In **Denmark**, for example, the third Action Plan to lower nutrient emissions involved government expenditure over 2005-09 of DKK 863 (USD 144) million with a further DKK 68 (USD 11 million) provided by farmers (OECD, 2008a). If the European Union and its member states are to avoid rising budgetary expenditure with its nutrient abatement programmes which currently are many hundreds of millions of Euros annually, then other less costly policy alternatives may need to be considered, such as water quality trading or co-operative agreements.

- ***Policy coherence****:* Reform of the CAP through decoupling farm support from production and developing ***environmental*** conditionality is improving the coherence with water policies and striving to lower nutrient water pollution from agriculture (OECD, 2011c; Posthumus and Morris, 2010; Sinabell, 2005). Perverse incentives, however, remain with over 30% (2008-10) of EU agricultural producer support based on commodity output and non-constrained variable input use, although this is a marked reduction from the 90% share in 1986-88 (Figure 1.3).

  In an assessment of **Finnish** agri-environmental programmes (1995 to 2007) designed to reduce nutrient loads into water systems, Lankoski and Ollikainen (2011) found nitrogen loads increased while phosphorus loads only decreased slightly. They concluded this policy failure was due to the: CAP crop area payments and single farm

payment encouraging more land into cultivation; area payments tending to favour more fertiliser intensive land use forms; and also that the agri-environmental support acts to encourage more land into cultivation by keeping low productivity land in production.

- ***Spatial targeting**:* Many member states tend to use a uniform approach in applying policies to address nutrient ***management***. Research suggests that spatial targeting in parts of a water catchment, can have a positive impact on water quality, such as differentiation by farm type (e.g. farms with the largest potential to improve management and creating the major share of pollution in a catchment), biophysical situation or livestock densities (Bateman *et al.,* 2008; Mills and Dwyer, 2009)

- ***Regulatory complexity**:* The WFD has shifted water governance in the European Union from a previously top down regulatory approach to one that encompasses greater cross-scale collaboration through the *River Basin Management Plans* (Benson, Jordan and Huitema, 2011). At the same time farmers face a burdensome and complex set of regulations concerning nitrogen and water management, with multiple levels and objectives of regulations concerning, for example, nitrates emissions into water (*Nitrates Directive*); ***groundwater*** (*Groundwater Directive*), ammonia into the air (*Integrated Pollution and Prevention Directive and Emissions Ceilings Directive*); and good water quality standards (*Water Framework Directive*) (Mills and Dwyer, 2009; Ortolano, Baumont and Puz, 2009).

- ***Time lags**:* Measures to lower nitrogen discharges from agriculture may take a considerable time to show up in improved water quality (Collins and McGonigle, 2008). In the new member states of the European Union, for example, while there where drastic reductions in livestock numbers and the use of fertilisers over the 1990s this did not result in a rapid improvement in nitrate concentrations in water (OECD, 2008a; Oenema *et al.,* 2009).

- ***Pollutant swapping**:* There are potential conflicts between those nitrogen policies aimed at decreasing nitrate leaching into water and those aimed at abating ammonia air emissions. Reducing the timing of ***slurry*** application from winter to spring, for example, can reduce the risk of nitrate leaching but potentially increase ammonia emissions (Collins and McGonigle, 2008). More attention to a holistic approach to nitrogen mitigation on farms is necessary, supported by adequate research of the issue (European Commission, 2010; Godlinski *et al.*, 2010; Oenema *et al.,* 2009).

- ***Farm nutrient management**:* It appears that changes in farm nutrient management practices to comply with the *Nitrates Directive* is being driven by the threat of sanctions rather than a change in farmer behaviour and understanding of the nitrogen pollution problem (Barnes *et al.,* 2009; European Commission, 2010). This may in part be due to the perceived high costs by farmers of implementing nitrogen abatement management practices (Oenema *et al.,* 2009), but also the lack of awareness of many ***farmers*** to the links between their farming activities and water quality. This points to the need for greater farmer education, training and advice (Barnes *et al.,* 2009; National Audit Office, 2010; Ortolano, Baumont and Puz, 2009).

  Some countries have initiated research projects to improve the understanding and ways of managing diffuse source pollution at the river catchment level, such as **Ireland**'s Agricultural Catchment Programme and the **United Kingdom**'s Demonstration Test Catchments Programme (Chapter 5.5). Research also shows that there is an opportunity

for inefficient producers to reduce fertilisers and imported feeds without affecting output. Such efficiency gains have the potential to deliver a double divided by reducing risks of nutrient leaching from agricultural land while improving economic margins at the farm level (Buckley, 2010).

- ***Infringement and sanctions***: The implementation of the *Nitrates Directive* is still incomplete across the European Union, as the Commission has infringement cases with a number of member states. These include, for example, non-compliance with the 170kg/ha of nitrogen maximum livestock manure application standard, designation of NVZs, and insufficient provisions within the action plans, such as periods of fertiliser application (European Commission, 2007 and 2010; European Court of Auditors, 2008; Sinabell and Schmid, 2006).

  There is also evidence that: requirements under the *Nitrate Directive* are not being properly monitored on farm; standards vary across countries in the application of nutrient management practices (for example varying widths required for buffer strips, although this may in some cases reflect varying biophysical conditions and farming systems across the European Union); and that there is limited or non-existent sanctions for non-compliance with key requirements of both the *Nitrate Directive* and cross compliance provisions (European Court of Auditors, 2008; National Audit Office, 2010).

Overall, for the European Union further significant effort will be required to meet good water quality status under the WFD. Reporting under the *Nitrates Directive* shows that for surface water monitoring stations across the European Union which track the trophic status of water, a third defined the water as eutrophic or hypertrophic (European Commission, 2010). A report by the National Audit Office (2010) in the **United Kingdom** concluded that the considerable expenditure on reducing non-compliance with the WFD attributable to diffuse source pollution was not cost effective, and incentive schemes to encourage compliance have been poorly targeted (Balana, Vinten and Slee, 2011).

For some EU member states, however, a mix of policies to reduce diffuse source nitrate pollution from agriculture has led to a significant decrease in nitrogen discharges into water, especially the **Netherlands** and **Denmark** (Box 5.1). But even for **Denmark**, for example, while nitrate leaching has been reduced by almost 50% since 1985, a further 33% is needed to reach the WFD's good ecological status (Kronvang *et al.,* 2008; Vinther and Borgesen, 2010).

Even where full compliance with the *Nitrate Directive* has occurred, improvements to water quality will take some time because of the time lags in transport processes in soils and groundwater, estimated at 4-8 years in **Germany** and **Hungary** to several decades for deep groundwater in the **Netherlands** (European Environment Agency, 2010). Moreover, measures to address nitrate pollution may still be required in agricultural areas not classified as NVZs (European Environment Agency, 2010).

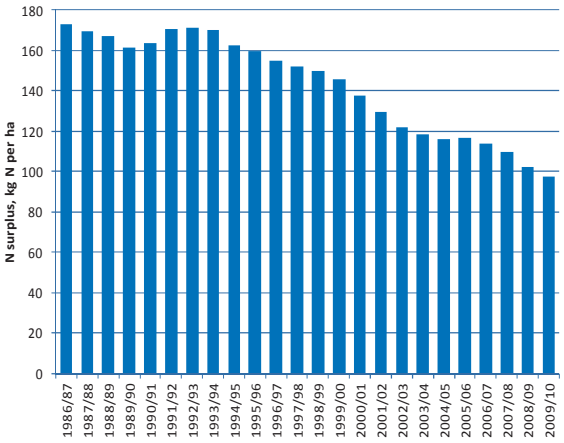
Box 5.1. Policy measures to reduce agricultural nutrient pollution of the environment in Denmark

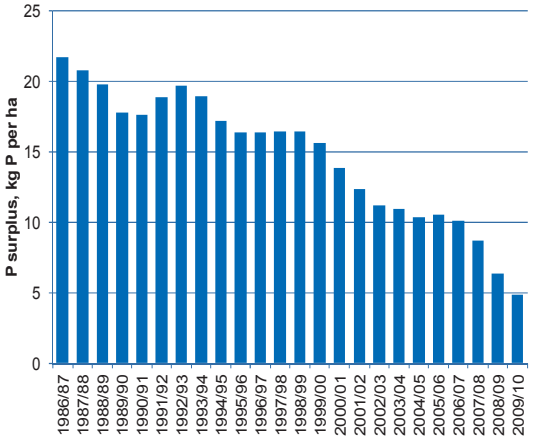
Since 1985 Denmark has implemented a set of national measures to reduce agricultural nutrient pollution of water systems, especially to avoid eutrophication of coastal water (Box table). These measures have been in conformity with the European Union's *Nitrate and Water Framework Directives,* and in part, funded through the *Common Agricultural Policy* (CAP).

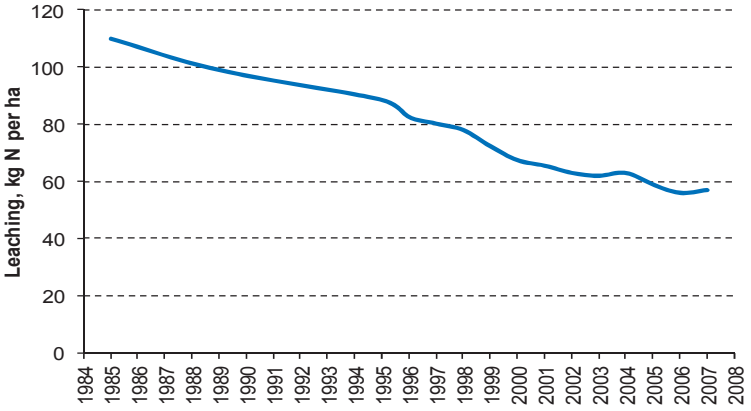
Danish policy actions	Policy measures imposed
1985: Nitrogen (N) and phosphorus (P) Action Plan to reduce N and P pollution.	• Minimum six months slurry storage capacity • Ban on slurry spreading between harvest and 15 October on soil destined for spring cropping • Maximum stock density equivalent to 2 livestock unit (LU) ha^{-1}. (1 LU corresponds to one large dairy cow) • Various measures to reduce runoff from silage clamps and manure heaps • A floating barrier (natural crust or artificial cover) mandatory on slurry tanks
1987: The First Action Plan for the Aquatic Environment (AP-I), aiming to halve N-losses and reduce P-losses by 80%	• Minimum nine months slurry storage capacity • Ban on slurry spreading from harvest to 1 November on soil destined for spring crops • Mandatory fertiliser and crop rotation plans • Minimum proportion of area to be planted with winter crops • Mandatory incorporation of manure within 12 hours of spreading
1991: Action Plan for a Sustainable Agriculture	• Ban on slurry spreading from harvest until 1 February, except on grass and winter rape • Obligatory fertiliser budgets • Maximum limits on the plant available N applied to different crops, equal to the economic optimum. • Statutory norms for the proportion of manure N assumed to be plant available (pig slurry: 60%, cattle slurry: 55%, deep litter: 25%, other types: 50%)
1998: The Second Action Plan for the Aquatic Environment (AP-II)	• Subsidies to establish wetlands • A reduction of the stock density maximum to 1.7 LU ha^{-1} • The statutory norms for the proportion of manure N assumed to be plant available were increased from 1999 (pig slurry: 65%, cattle slurry: 60%, deep litter: 35%, other types: 55%) • Maximum limits on the application of plant available N to crops reduced to 10% below the economic optimum • Mandatory 6% of the area with cereals, legumes and oil crops to be planted with catch crops
2000: AP-II Mid-term Evaluation and Enforcement	• Further tightening of the statutory norms for the proportion of assumed plant-available N in manure. From 2001; pig slurry: 70%, cattle slurry: 65%, deep litter: 40%, other types: 60%; from 2002 pig slurry: 75%, cattle slurry: 70%, deep litter: 45%, other types: 65%
2004: The Third Action Plan for the Aquatic Environment (AP-III). AP-III is closely related to the EU *Water Framework Directive* and the EU *Habitat Directive.* N-leaching must be reduced by further 13% by 2015.	• Further tightening of the request for catch crops • Establishment of buffer zones along streams and around lakes to reduce discharge of P • A tax of DKK 4 kg^{-1} (EUR 0.54 kg^{-1}) mineral P in feed • Evaluations of the effect of AP-III will be carried out in 2008 and 2011 • Based on the evaluations further initiatives will be implemented if necessary
2008: Evaluation of AP-III	
2009: Political agreement on initiating AP-IV; also called "Green growth" General reduction targets for the aquatic environment are estimated, and regional objectives are set for individual water bodies.	• Further tightening of the request for catch crops; in total 140 000 ha with catch crops is needed • Ban on soil tillage in the autumn before spring crops • Ban on re-establishment of fodder grass in the autumn • Work initiated to evaluate the possibilities of introducing tradable "leaching quotas".

Box 5.1 *(cont.)*

Implementation of the Danish Action Plans, together with the support and regulatory framework of the EU's *Nitrate and Water Framework Directives* and CAP, has substantially lowered nitrogen and phosphorus surpluses and leaching on nitrogen from the root zone shown in the Box Figures below.







Sources: Kronvang, B., *et al.* (2008), "Effects of policy measures implemented in Denmark on nitrogen pollution of the aquatic environment", *Environmental Science and Policy*, Vol. 11, pp. 144-152; Maguire, R.O., G.H. Rubaek, B.E. Haggard and B.H. Foy (2009), "Critical evaluation of the implementation of mitigation options for phosphorus from field to catchment scales", *Journal of Environmental Quality*, Vol. 38, pp. 1989-1997; and Vinther, F.P. and C.D. Borgesen (2010), *Nutrient Surplus as a Tool for Evaluating Environmental Action Plans in Denmark,* presented at the OECD Workshop on Agri-environmental Indicators, Leysin, Switzerland, March, OECD website at: *www.oecd.org/agriculture/env/indicators/workshop*.

5.2 Lowering pollution of the Chesapeake Bay, United States: The role of agriculture

Current pollution status

The Chesapeake Bay is North America's largest and most biologically diverse estuary, home to more than 3 700 species of plants and animals. It is about 320 kilometres (km) long, contains more than 17 500 km of tidal shoreline, and is fed by 100 000 creeks, streams and rivers. The water catchment spreads over 165 000 square km and includes parts of six states – Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia – and all of the District of Columbia. Approximately 17 million people live within the Bay water catchment. The Bay provides significant economic and recreational benefits to the water catchment's population, estimated to exceed USD 33 billion annually (U.S. Environmental Protection Agency, 2010a).

The current status of the Bay's health remains unacceptable, according to the United States Environmental Protection Agency (U.S. Environmental Protection Agency, 2010a). While total pollution levels have declined since 1985, most of the Bay's waters are degraded and are incapable of fully supporting fishing, crabbing, or recreational activities. Algal blooms fed by nutrient pollution block sunlight from reaching underwater Bay grasses and lead to low oxygen levels in the water. Suspended sediment from urban development, agricultural lands, and some natural sources is carried into the Bay and clouds its waters. Portions of the Bay and its tidal tributaries are contaminated with chemical pollutants that can be found in fish tissue. The Bay's habitats and lower food web (benthic and plankton communities) are functioning at 45% of desired levels. Many of the Bay's fish and shellfish populations are below historical levels.

The greatest pollution threats to the Bay originate from nutrients (nitrogen and phosphorus) and soil sediment. These pollutants come from many sources, including agricultural operations, wastewater treatment facilities, urban stormwater runoff, and air deposition from power plants, vehicles and agricultures. Agricultural sources contribute the largest nutrient and sediment pollution in the water catchment, accounting for approximately 38% of nitrogen loading, 45% of phosphorus loading, and 60% of the sediment loading (Figure 2.3). About 50% of the nitrogen from agriculture is from animal manure (U.S. Environmental Protection Agency, 2010a).

There has been a long history of initiatives dating back to the 1980s to restore and conserve the Bay, through a combination of local, State, Federal and private organisation efforts.[2] Over this period there has become a growing gap between the resources needed to implement restoration activities and the levels of expenditures on water catchment protection and restoration. In 2006 it was estimated that the total restoration needs from Federal sources to restore the Chesapeake Bay was between USD 15-30 billion annually, while actual expenditure was estimated in the range of USD 200-400 million (Stanton *et al.,* 2010).

Only a portion of the nutrient and sediment pollution in the Bay is regulated under the *Clean Water Act (CWA)* or the *Clean Air Act (CAA).* According to estimates by EPA's Chesapeake Bay Program Office, only approximately 49% of total nitrogen, 35% of total phosphorus, and 4% of total sediment is subject to Federal regulation. The best modelling indicates that nitrogen pollution to the Bay must be reduced by 30% and phosphorus pollution by 8% to meet water quality standards. Achieving that level of reduction will require significant and sustained reductions by all source categories, including agriculture.

Policies to address water pollution in Chesapeake

The continued deterioration in the Bay's water quality, billions of dollars of public expenditure over several decades to restore the Bay, and failure of the six states state and local governments surrounding the Bay to make sufficient progress in their conservation efforts, provoked three major policy changes in 2009 directed at restoring the Bay's health.

- President Obama issued an ***Executive Order*** in May 2009 that requires Federal Departments (Environment, Agriculture, Commerce, Defence, Homeland Security, Interior and Transportation) to launch a new restoration effort based on collaborative action between federal, state, local government agencies, private organisations and environmental groups. The *Executive Order* has four priorities: restoring clean water; recovering habitat; sustaining fish and wildlife, and conserving land and increasing public access. In effect the *Executive Order* shifts overall management of the Bay's restoration from the state and local government authorities to the Federal government.
- The ***Chesapeake Clean Water and Ecosystem Restoration Act*** introduced in October 2009, essentially provides the strategy to restore the Bay, and gives the EPA the regulatory power to compel states to submit and implement plans that will meet their obligations to reduce pollution and provide punitive powers if states fail to act. The Act will substantially increase the funding for restoration projects, with an estimated USD 200 million destined for agricultural projects.
- The Federal Environmental Protection Agency in May 2009 agreed to implement ***new pollution reduction standards,*** including the enforcement of the Total Maximum Daily Loads (TMDLs) or the maximum amount of pollution that the Bay can assimilate without violating water quality standards. The TMDLs essentially places a total cap on the pollution into the Bay and thus opens the possibility to water quality trading.

  The TMDLs are being established for each state and then further broken down into TMDLs by sub-state level jurisdictions, including for agricultural diffuse source pollution (Stanton *et al.,* 2010). Pollution targets have already been divided and fixed at the local level with the first milestone for pollution reduction to be met by December 2011, followed by two year milestone commitments which by 2017 should achieve 60% of the required TMDL reduction, with completion of the pollution reduction effort by 2025.[3]

  EPA has developed a *Chesapeake Bay Compliance and Enforcement Strategy* that provides the overall framework to bring together the three policy initiatives outlined above (US Environmental Protection Agency, 2010a). The *Strategy* guides the use of EPA's compliance and enforcement tools to target sources of pollution impairing the Bay. It is a multi-year and multi-state strategy combining water, air and waste enforcement authorities to address violations of federal environmental laws resulting in nutrient, sediment and other pollution in the Bay. The key actions under the EPA *Strategy*, specific to agriculture, include the following (U.S. Environmental Protection Agency, 2010a).

- Identifying agricultural sources releasing significant amounts of pollutants in excess of the amounts allowed by the CWA, the CAA and other applicable environmental measures.

- Expanding the definition of CAFOs to encompass smaller animal feeding operations (AFOs), as only about one-third of livestock manure produced in the Chesapeake Bay basin is regulated.
- Defining more stringent permit conditions related to the land application of livestock manure.
- Strengthening pesticide permit requirements under the *National Pollutant Discharge Elimination System* to reduce pesticide discharges into the Bay.
- Co-ordinating the funding of nutrient and sediment abatement programmes available to agriculture between the U.S. Department of Agriculture and Environmental Protection Agency.
- Developing appropriate opportunities for establishing environmental markets and nutrient trading in agriculture and with other polluters, to improve cost effective restoration of water catchments.

Strengthening policy reforms

The EPA views the new policy strategy for water catchment in the Chesapeake Bay as a model for similar water protection programmes in other parts of the United States, in particular, the Great Lakes, the Mississippi, and the Gulf of Mexico (U.S. Environmental Protection Agency, 2010b). It is clear that the policy strategy established for the Bay marks a major departure in US policy measures to address agricultural water pollution providing an ambitious overhaul of existing Federal policies aimed at Bay restoration and with broader implications for control of agricultural water pollution across the nation (Perez, Cox and Cook, 2009).

There are concerns, however, that the *Chesapeake Clean Water and Ecosystem Restoration Act* will raise costs for farmers, such as installing fencing to safeguard streams and rivers from cattle. The agricultural industry is also disturbed that the EPA's TMDL calculations are, in their view, based on flawed science and data. As noted, however, the EPA Strategy for the Bay envisages providing additional funding for agricultural restoration projects. However, an integral part of the EPA programme is also to develop the science, improve the monitoring data of the Bay's water quality, and also work in partnership with the relevant stakeholders. This will in particular concern working with farmers at the sub-catchment level in improving the understanding of the links between agriculture and water quality in the Bay (U.S. Environmental Protection Agency, 2010a).

The potential for expanding water quality trading in the Bay, opens a window of economic opportunity for farms to sell nutrient credits to those sources facing more expensive nutrient control options in the Bay such as wastewater treatment plants (Box 4.2). There is already some limited experience with water quality trading in the Bay related to agriculture through the *Pennsylvania Water Trading Program* (Figure 4.1). The combination of the government's cost sharing of adopting agricultural best management practices (BMPs) and a Bay wide nutrient trading market could benefit farms. This would be possible, for example, by covering many of the expenses of the practices that are required before trading can begin, and offering a source of revenue and profit for most, but not all, farms, with the benefits likely to vary according to the location and the pre-existing implementation of BMPs (Perez, Cox and Cook, 2009; Ribaudo *et al.,* 2010b).

There are also private voluntary co-operative agreements to develop nutrient trading in the Bay, as being attempted through the *Chesapeake Fund* programme.

Strengthening regulations to control simultaneously water and air emissions from livestock producers into the Bay can result in unintended and unanticipated economic and environmental costs (Aillery *et al.,* 2005). Widely adopted ammonia emission controls could encourage over application of manure nitrogen on land in non-CAFOs to the detriment of water quality. To address this problem may require additional measures such as increasing willingness of landowners to accept manure, developing industrial uses of manure, reducing livestock numbers, and supporting the long range transport of manure (Aillery *et al.,* 2005).

Over more than 25 years the U.S. Department of Agriculture has increased significantly funding of national agri-environmental conservation programmes (Figure 1.4). While these programmes were not intended to directly target agricultural pollution of the Bay, indirectly they have had a number of beneficial impacts on water quality in the Bay. Most significantly has been the decline in soil erosion on cropland and pasture attributed to conservation compliance under the *Conservation Reserve Program* (CRP) (OECD, 2011b). Also expenditure on the *Environmental Quality and Incentive Program* (EQIP) has been increased rapidly over recent years (Figure 1.4), with more than half the programme's funding directed at water quality conservation and managing livestock manure (Shortle *et al.,* 2012).

These policies, together with voluntary actions by farmers, appear to be having some success in reducing pollutant flows into the Bay. Based on recent U.S. Natural Resources Conservation Service (2011) assessment of practices on cultivated cropland in the Chesapeake Bay region, the research found most cropland has structural or management practices, or both, in place to control soil erosion. Nearly half of the cropland area is protected by one or more structural practices, such as buffers or terraces. Reduced tillage is used in some form on 88% of the cropland. Adoption of conservation practices has reduced field margin sediment loss by 55%, losses of nitrogen with surface runoff by 42%, losses of nitrogen in subsurface flows by 31%, and losses of phosphorus (sediment attached and soluble) by 41%.

Despite the benefits increased agri-environmental conservation programme expenditure have brought for water quality more generally across the United States and more specifically for the Bay, there remain a number of concerns with these programmes (OECD, 2011b; Shortle *et al.,* 2012):

- ***Poor targeting****,* as under the CRP, for example, which is a particularly blunt policy measure as it simply removes land from production without requiring any changes to management practices on land under production that continues to contribute to water pollution. Also conservation payments tend to be much larger for smaller rather than intermediate and commercial farms which account for around two-thirds of total US agricultural output. Hence, greater participation in conservation programmes by larger farms could be more effective in addressing problems such as water pollution.
- While the EQIP has the advantage that it targets practices on land under production, this land may not be the most important source of pollution as participation in the programme is voluntary and farmer initiated. A further problem with the reliance on incentive payments under voluntary conservation measures to help reduce agricultural water pollution is they can become uncompetitive as crop prices rise. With maize prices expected to remain high (Figure 2.4), conservation programmes will continue to be

uncompetitive compared to cultivating land for production, while higher maize prices may also encourage production on more erodible and marginal land to the detriment of water quality. More specifically, the Chesapeake Bay Programme has up to now placed much less emphasis on outlining the costs associated with farmer adoption of different abatement practices at the scale required to have an impact (Roberts *et al.*, 2010).

- ***Lack of coherence,*** as conflicts exist between farm programmes providing incentives to increase production and conservation programmes seeking to reduce the environmental damage that such programmes can provoke. Some 30% (2008-10) of US agricultural producer support is based on commodity output and non-constrained variable input use, although this is a marked reduction from a 50% share in 1986-88 (Figure 1.3). Recently the rise in US support for ethanol production, for example, has led to increasing production of maize with likely consequences for water quality from the greater demand for inorganic fertilisers (Box 2.2).
- ***Increasing cost and monitoring difficulties,*** especially as conservation programmes, such as EQIP, are expanded to cover a broader range of conservation practices on working land to a wider range of producers, making programme monitoring technically complex and enforcement more and more costly.
- ***Inadequate funding***, is acting to constrain the ability of agri-environmental conservation programmes to make significant improvements to problems such as water pollution. In the case of EQIP, for example, demand by farmers to participate in the programme has substantially exceeded funding levels.

5.3 Reducing salinity in agriculture to improve water quality: The case of Australia

One of the most significant causes of soil degradation in Australia is salinity, which poses a serious threat to native species, ecological communities and functioning ecosystems. Salinity occurs when the water table rises, bringing natural salts to the surface, and in sufficient quantity these salts become toxic to most plants.

Salinity has been caused by extensive land clearing in Australia, predominantly for agricultural purposes. The replacement of trees or other deep-rooted native vegetation with shallow-rooted crops and pastures that use less water, has resulted in rising water tables which can cause dryland salinity. Dryland salinity is more difficult to remedy than irrigation salinity which is in general better understood and managed. Land clearance can also lead to soil erosion and, when it results in a changing water balance, to dryland salinity.

In 2000, nearly 6 million ha of Australia were assessed as having a high potential to develop salinity. Predictions indicate that unless effective solutions are implemented, the area affected could increase to 17 million ha by 2050, most of which is agricultural land (more than 11 million ha). In 2002, about 20 000 farms and 2 million ha of agricultural land showed actual signs of salinity. For many farms, salinity has meant loss of productivity and income.

There are also many off-farm impacts of salinity, the most significant of which appears to be the salinisation of rivers which affects drinking and irrigation water, for example, in Western Australia some surface water is already too saline for domestic use. Other impacts include damage to biodiversity and infrastructure such as roads and pipelines.[4]

Since the 1980s Australia used a number of programmes to reduce the magnitude and threatened impacts of salinity. This culminated in 2000 with the largest programme in terms of expenditure, the *National Action Plan for Salinity and Water Quality (NAP)*. The programme was provided a budget of AUD 1.4 billion (USD 1.2 billion) over seven years and concluded in 2008, consisting half-Commonwealth and half-state funding. Programmes on salinity continue under the *Caring for our Country Programme* that began in 2008 and is the current national initiative for natural resource management relevant to agriculture (Grundy and Barson, 2010; Pannell and Roberts, 2010; and Figure 1.5). The NAP was delivered through 56 Catchment Management Organisations (CMOs), with 1 700 projects which were regionally based to reflect local problems and priorities and enhance links to local communities (Grundy and Barson, 2010).

While the NAP has now been concluded, the programme offers some useful experiences in the future design and implementation of environmental policies more generally, including those more specifically addressing water quality in agriculture. The lessons from these experiences are the basis of the discussion in the remainder of this chapter.

Overall the assessment of the NAP by four government reviews and academic researchers have all concluded that it did not result in the changes needed to contain salinity. The Australian National Audit Office 2008 review of NAP considered that there was little evidence as yet that the programmes under NAP were adequately achieving anticipated national outcomes. There was little information forthcoming that suggested targets, even if met, would be sufficiently robust to arrest or reverse the decline in catchment conditions in many areas (Auditor General, 2008).

Based on the experiences learned from the NAP it is possible to identify a number of key requirements for establishing effective policy programmes for natural resource management, such as those addressing agricultural diffuse source water pollution.[5]

- *Prioritising projects:* There is a tendency under environmental programmes to attempt to achieve too much and allocate to few resources to too many projects. Under the NAP the budget was considered limited for the level required to manage salinity comprehensively. Generalising from this to programmes that target diffuse source pollution in agriculture there should be an imperative to target funds to high priority projects.

  The highest priority investments for diffuse source water pollution should relate to particularly valuable environmental assets (e.g. a highly valued aquatic ecosystem), facing a high threat or rapid rate of degradation. The investment should have a high feasibility of reducing the threat or degradation at reasonable cost, with the required effort to improve water quality being reasonably attractive to farmers or water managers. This suggests that payments for ameliorating water systems should be outcome focused and subject to a cost-benefit analysis, encouraging water catchment managers to introduce well targeted measures.

- *Choosing appropriate policy mechanisms:* Even where sound decisions are made about which water quality problems should be targeted it is still possible for investment to fail to deliver outcomes because of the poor selection of policy mechanisms. The NAP used funds for extension not adapted on the required scale. This indicates that policy instrument choice (e.g. payments, regulation, water quality trading, co-operative arrangements) needs to be sensitive to local conditions and general characteristics of a problem.

- *Using the best available technical and socio-economic information:* Agriculture's linkages to *w*ater quality are complex and hence require considerable technical and socio-economic information about the likely impact (science), costs (economics) and farmer reactions (social) of management changes. Catchment Management Organisations (CMOs) working on NAP projects generally did not make good use of such information in their management of salinity projects and generally lacked the capacity to make sound judgements about the need for this information. This points to the need to: ensure water catchment stakeholders have the best science available to make decisions; provide farmers with the support and resources to use and incorporate technical and economic information into their farm planning; and provide catchment managers and farmers the training to use technical and economic information.

- *Setting realistic targets:* Targets can be useful to help reveal progress towards given goals, but they need to be realistic. While the NAP required CMOs to specify targets, the targets did not meet the criteria of being easily measurable or having a clear time frame. In addition, targets need to be consistent with known biophysical responses, in particular, in the case of water quality take into account time lags between the introduction of a practice and visible outcomes (Chapter 1.5).

- *Providing incentives and support to farmers:* As already noted the NAP provided inadequate incentives to farmers and landowners to remedy salinity, in terms of insufficient funding, weak underlying technical and socio-economic information to guide management decisions, and ineffective targets. For environmental outcomes to be achieved farmers or catchment managers need funding and other supporting mechanisms to be developed in a way to provide incentives to seek environmental outcomes cost effectively.

- *Investing in programmes that will deliver long-term outcomes:* Given the reality of a fixed budget in most environmental programmes, managers face a trade-off between investing in projects that will have an immediate effect and investing in actions that may have a bigger effect in the long term. Included in the latter category would be research to develop new technologies and research to provide information to allow improved decision making to address diffuse source pollution. The NAP made little investment either in new technologies or practices for improved salinity management.

- *Avoiding adverse side effects:* In some circumstances, programmes undertaken to improve one environmental problem can have negative consequences for another. For example, prior and during the NAP many trees were planted with the intention of reducing saline discharge into rivers, but they had a negative impact on the yield of fresh surface water into the same rivers.

  This also highlights the case relevant to water quality in agriculture, where a single pollution source (e.g. nitrogen) can simultaneously affect more than one environmental medium (water and air in this case). Hence, a single medium approach to pollution can result in unnecessary and unanticipated environmental and economic costs (Aillery *et al.,* 2005). For example, a logical response for a farmer to meet water quality regulatory standards may be might be to reduce the nutrient content of manure spread on fields by allowing more nitrogen to be released from manure storage facilities, thereby releasing ammonia into the air (Aillery *et al.,* 2005).

5.4 Implementing water quality trading for nitrogen pollution in Lake Taupo, New Zealand[6]

A recent assessment of the quality of New Zealand's water resources was that while overall they are still relatively clean, the quality of a number of lowland catchments are causing concern, there is expensive remedial action to improve iconic lakes and questions raised over the possible deterioration in groundwater quality (Land and Water Forum, 2010; OECD, 2011f). At a national level diffuse discharges into water systems, mainly from agriculture, now greatly exceed point source pollution (Chapter 2.3). This is causing disputes and governance problems about the intensification of farming, especially dairy farming, and agricultural diffuse source water pollution (Fisher and Russell, 2011; Land and Water Forum, 2010).

In recognition of the growing challenge of water management, including agricultural pollution and resource use, the New Zealand Government (2011) provided a national policy statement that sets out objectives and policies that direct local government (Regional Council) to manage water sustainably and in an integrated way. The policy statement is backed by NZD 15 million (USD 13 million) over 2011 and 2012 to provide financial assistance to Regional Councils for the remediation of historically contaminated freshwater bodies. In addition, the policy statement outlines the formation of an Irrigation Acceleration Fund, which will receive NZD 35 million (USD 31 million) within five years to help develop irrigation infrastructure proposals to be ready for the investment stage.

As part of the water management strategy, the Regional Council, the central government, the Taupo District Council, and Ngati Uuwharetoa (the local indigenous people) are implementing an innovative water quality trading project to address deteriorating water quality in Lake Taupo, a UNESCO World Heritage Site. Located in the centre of New Zealand's North Island, Lake Taupo is the largest freshwater lake in Australasia (616 km^2). The lake has high water clarity (average Secchi depth 14.6 m) and a highly valued recreational fishery for introduced trout. The lake, together with the town of Taupo on its shores, is the focal point for a significant local tourism industry drawing 1.2 million visitors annually. But water quality in Lake Taupo has decreased over the last 30 years. Nitrogen concentrations in streams draining pastoral sub-catchments have increased by between 50% and 300% since the 1970s depending on the catchment. Elevated nitrogen levels cause the proliferation of microscopic algae, reducing water clarity and increasing the growth of weeds in near shore areas.

While historic inflows included a larger proportion of urban wastewater and stormwater discharges, diffuse source pollution from pastoral farming now accounts for over 90% of "manageable" (i.e. human-induced) nitrogen inflows to Lake Taupo. Because of extended lag times for nitrogen runoff in groundwater to reach the lake, inflows are expected to increase based on existing land use.

To address this the Regional Council has introduced a water quality cap and trade system that with other measures seeks to reduce nitrogen inflows reaching the lake by 20% by 2020 (153 tonnes annually), arising from diffuse source pollution from farming and other land uses. This involves capping land use in the lake catchment at recent levels of nitrate leaching and providing NZD 81.3 million (USD 57 million) in public funding (45% government and 55% local government) to a non-profit trust to buy from farmers the target reduction of 20% of the "nitrogen discharge allowances" in the catchment (OECD, 2011f).

Landowners in the catchment now need a resource consent for a specific nitrogen discharge allowance to comply with the new rules. Consent holders may purchase additional nitrogen or sell surplus nitrogen with other consent holders in the lake catchment. The market is now operational, with some properties taking advantage of the scheme by refining their farming practices to reduce nitrogen discharges and thereby selling their surplus allowance (currently selling at around NZD 300-400/kg – USD 220-290/kg). Government and councils are also funding activities to reduce nitrogen inputs to the lake, buying nitrogen allowance to reduce nitrogen inputs (Land and Water Forum, 2010).

The scheme is not without contention among different stakeholders. Among the points of contention is the initial allocation of discharge allowances. The initial allocation of discharge rights was gifted to the current dischargers based on their historical discharges. This means forest owners need to purchase allowances if they wish to develop their land while, as many forest owners see it, farmers who have been a major cause of the pollution of Lake Taupo, will be rewarded with allowances and have no obligation to reduce their discharges to the environment.

The Regional Council has taken the view that many farmers might go out of business if allowances were allocated on the basis of land area or some other formula that would require farmers to purchase most of the allowances needed for their operations. The Regional Council's allocation rules mean that farmers will not be compelled to reduce discharges below recent levels and will be compensated if they do make reductions, a decision that was upheld by the Environment Court. It is not clear, however, if farmers will be compensated, when the plan is reviewed in 2020, if nitrogen reductions beyond 20% are required to protect the lake.

By granting allowances based on existing use, the Regional Council's policy may have created perverse incentives in other catchments that also have nitrogen concentrations that exceed policy targets. Farmers in those catchments might increase nitrogen use (and hence pollution) in anticipation of a future allocation of nitrogen allowances. In this sense, the policy promotes static efficiency but not dynamic efficiency.

An important element in the success of implementing the Regional Council scheme has been the institutional environment. The institutional environment in New Zealand agriculture is simpler than in most OECD countries in that there is little support for agriculture that distort production decisions. Also formal property rights were not a problem, as New Zealand's environmental legislation gives local councils the authority to control discharges to water, from diffuse sources pollution as well as point sources. Even so, EW chose to recognise existing use as an implied property right by agreeing to allocate historical discharge rights to farmers and compensate for any reductions. This was sufficient to get the programme approved and implemented by the Regional Council.

Overall, the Regional Council water quality trading programme is unique at present across OECD countries in that it is being designed as a cap and trade programme for agricultural diffuse source pollution, unlike the partially capped programmes that dominate North American water quality trading schemes (Chapter 4.2). Also the policy being implemented for Lake Taupo is a significant advance in terms of applying the Polluter-Pays-Principle to diffuse source agricultural water pollution. The New Zealand Land and Water Forum, however, has suggested that there is a need for further investigation of such schemes, including the nature of their use in different catchments (Land and Water Forum, 2010). Indeed, the Regional Council is now examining further

application of the Lake Taupo scheme across the region under Regional Council governance (OECD, 2011f).

5.5 Improving research on diffuse source water pollution: France and the United Kingdom[7]

In their respective efforts to better understand and reduce diffuse source water pollution from agriculture, France and the United Kingdom have established two major research projects. The **United Kingdom**'s Demonstration Test Catchments (DTC) project is a new initiative of the Department of Environment, Food and Rural Affairs (Defra) to provide a research platform from which a number of integrated ways of managing agricultural diffuse source pollution at the river catchment level can be developed. **France** also has launched a major research initiative by the Ministries of Agriculture and Environment, conducted through the *Institut National de la Recherche Agronomique (INRA),* to support the national *Ecophyto* plan that plans to achieve a 50% reduction in pesticide use by 2018.

The United Kingdom's Demonstration Test Catchments project

Diffuse pollution of aquatic systems is a significant barrier to continued improvements to UK rivers and lakes, while groundwater quality continues to deteriorate. Nearly three-quarters of the UK land surface is in agricultural production and the influence of farming on water and the ecosystems it supports is significant (Table 5.1). Valuation studies estimate that the cost of agricultural pollution of water systems in the United Kingdom is substantial. One of the more recent studies by the Jacobs Report (2008), which is broadly in-line with previous studies, reports that the total cost of agriculture on water systems in the United Kingdom in 2007 was over GBP 230 million annually (USD 460 million) (Table 5.2). Such calculations are acknowledged to probably be under estimates due to incomplete geographical coverage and on-going refinement of scientific understanding (Moxey, 2012).

Table 5.2. United Kingdom water quality costs as a result of agricultural water pollution: 2007

Category	Description	Value **GBP** (mill.)	Comments
Rivers	Rivers of less than "good" quality due to agricultural diffuse pollution	62 (EUR 91)	Likely to be under-estimate in light of more recent work
Lakes	Eutrophication in lakes due to agricultural diffuse pollution	27 EUR 40)	Under-estimate in light of more recent work and lack of spatial coverage.
Bathing waters	Bathing waters failing to meet faecal indicator organism (FIO) standards	11 (EUR 16)	Under-estimate in light of more recent work and lack of data on marine eutrophication.
Estuaries	Estuaries of less than "good" quality due to agricultural diffuse pollution	3 (EUR 4)	Likely to be under-estimate in light of more recent work
Drinking water	Removal of contaminants	129 (EUR 190)	Uncertainty due to data gaps and lack of spatial coverage.

Source: Jacobs Report (2008), *Environmental Accounts for Agriculture*, Final report prepared for the UK Department for Environment, Food and Rural Affairs, *www.dardni.gov.uk/environmental-accounts.pdf*.

As water catchments are highly complex systems, to improve the management of land, water and the rural economy and maximise ecosystem services, water catchments need to be better understood from both natural science and socio-economic viewpoints. But the many interactions between the sometimes competing environmental, social and economic factors in a water catchment are seldom considered holistically. Many knowledge gaps remain, for example, concerning how farmers respond to information, economic incentives and regulation, and also understanding the time lags in the recovery of ecosystems once water quality is improved (Chapter 1).

The DTC programme started in December 2009 and will run until November 2014, with a budget of GBP 8 million (USD 13 million). It aims to test the efficacy of both novel and existing measures which can be integrated into farming practice without disproportionately impacting food production across whole water catchments. The evidence base for existing measures will be drawn together from work already being undertaken within the Demonstration Catchments and elsewhere within the United Kingdom and Europe. Three catchments have been already been selected as case studies, with a fourth to be added in 2011. These have been chosen for their variable natural features, agricultural land use and the past research or level of monitoring and management.

The core purpose of the programme is to assess the effectiveness of potential mitigation measures for reducing diffuse pollution from farming, whilst maintaining the competiveness and productivity of farms. The project will develop an evidence-based approach so that the results are transferable to other catchments. Although the detailed way in which measures are applied will differ between catchments, the approach to designing the solutions will be similar to make the process more transparent to stakeholders. While the main focus is on diffuse source water pollution from agriculture, the programme will also consider biodiversity, air quality, soil quality and greenhouse gas emission tradeoffs. The measures to tackle diffuse pollution of water will particularly have to take account of the requirement to reduce greenhouse gas emissions whilst maintaining food security for the country. To help achieve this in rural England, existing schemes and initiatives, particularly cross compliance and agri-environment payment schemes, will be used.

An essential part of the DTC programme will be to undertake research in a much more collaborative and open way, using the concept of research platforms. The aim is to bring modellers and field practitioners together to accelerate the iterative learning process whereby new research should aim to test and improve the current conceptual models. Farmers, social scientists and economists are working alongside natural scientists to ensure that approaches are practicable and economically feasible. In the longer term, DTC aims to host research in a wider range of disciplines, such as climate change, flood risk, etc., to develop integrated approaches to land management that deliver across a range of ecosystem services. Hence, a more robust evidence base research should evolve through the wider involvement of the research community and not just as a result of single research projects.

An important component of the DTC programme is to consider new concepts and adopt more integrated and holistic management approaches to addressing diffuse source pollution. New environmental management approaches recognise the river catchment as the appropriate organising unit for understanding and managing the environment, in a context that includes social, economic and political considerations. The guiding principles of an integrated management approach can be distilled into three simple requirements.

- *Knowledge-based:* The biophysical system and the social system together form one, complex, close-knit "socio-ecological" system, and in order to improve management it is necessary to improve understanding of this complex relationship.
- *Adaptive:* As the social/ecological system is so complex, and non-linearities (surprises) are an inherent element of it, it is necessary to be adaptive in approach and "learning-by-doing."
- *Participatory:* The effectiveness of environmental management has been shown to increase by the involvement of all relevant stakeholders. It is through the interaction of these stakeholders in a suitable organisational structure that integrated catchment management develops.

The DTC project is investing in a high resolution monitoring infrastructure. This infrastructure will support a modelling approach to understand pollutant sources, mobilisation, transport and impact in different catchment systems and to predict the consequences of management interventions. To meet these requirements monitoring will be appropriately distributed across the catchment both at different geographical scales (i.e. from field to farm to catchment) as well as the temporal scales where a significant component of the pollutant flux is carried into groundwater. As understanding increases, data requirements will change and an iterative conceptual modelling approach will allow this to be clarified.

The outcomes of the DTC research platform are intended to benefit the whole community engaged in land and water management. Although the project is led nationally by policy makers (Department for Environment Food and Rural Affairs – Defra – and the Environment Agency), it will encompass the interests of all other relevant sectors in a collaborative approach, including the farming community, water companies, environmental non-governmental organisations, and the research community. The development of communities of practice, which develop approaches to fit their discrete geographical and local circumstances, but are also able to learn from each other and serve as examples to communities in other catchments, is an overarching goal of the DTC programme.

French research support for the Ecophyto pesticide reduction plan[8]

Recent assessment of pesticide pollution of water systems in France reveals they remain an important policy challenge. Pesticides are widely detected in surface and groundwater, and there is concern for their persistence in water, especially groundwater. Where major reductions in pesticides have occurred this has largely resulted from their removal and prohibition from the market (Ministry of Ecology, Energy, Sustainable Development and the Sea, 2010).

With growing public demand to address the pesticide pollution problem in France, together with the recent reinforcement of EU Directives and Regulations concerning pesticides (*Directive on the Sustainable use of Pesticides,* Directive 2009/128/EC; *Regulation on Plant Protection Product Authorisations,* EC Regulation No. 1107/2009), French policy makers have come under greater pressure to address the pesticide issue (Sanit-Ges and Belis-Bergouignan, 2009).

In their response the French Government launched in July 2007 the *"Grenelle de l'environnement"* a comprehensive multi-stakeholder consultation on environmental protection, including agriculture. Following the consultation the government brought the *Loi Grenelle* legislation into force in 2009, which concerning pesticides requires the following(Barzman, 2009).

- Total area certified as organic agriculture to increase from a 2% share of agricultural land in 2004 to 6% by 2012, and eventually to 20% by 2020.
- Number of farms under high nature value certification to reach 50% of all farms by 2012.
- Withdrawal from commercial use of 40 of the most harmful pesticides.
- Support for research aiming to reduce pesticide use.
- 50% reduction in the use of plant production by 2018 if feasible.

The most ambitious part of the *Loi Grenelle* is the plan under *Ecophyto* to achieve a 50% reduction in pesticide use by 2018, aimed at local and national concerns and implemented prior to the EU *Pesticides Directive*. The *Ecophyto* plan encompasses eight sets of actions to manage risks and monitor impacts, on the one hand, and to reduce cropping system dependence on pesticides, on the other hand, including the following.

- Assessing progress in pesticide use reduction.
- Identifying and mainstream practices and existing agricultural systems to enable pesticide use reduction by mobilising all research, extension and agricultural development partners.
- Encouraging innovation in the design and development of low pesticide input practices and cropping systems.
- Developing training in use reduction and safe use of pesticides.
- Strengthening pest surveillance networks and monitoring of non-intentional effects of pesticides.
- Adapting to the needs of pesticide requirements in exports to foreign markets.
- Reducing the use and improving the safety of pesticides used for non-agricultural purposes.
- Overseeing the plan at national and sub-national levels, including improving communication of the plan to stakeholders.

The research and development effort within the *Ecophyto* plan is seeking to develop new Integrated Pest Management solutions that can contribute to sustainable agriculture while preserving the competitiveness of French agriculture. Toward that end the Ministries of Agriculture and Environment have requested that the *Institut National de la Recherche Agronomique (INRA)* launch the research which is mobilising a hundred experts from over 30 organisations and is focusing on four main crop sub-sectors: arable crops, fruit arboriculture; viticulture; and vegetable crops. For each of these sub-sectors different strategies for limiting the use of pesticides are being analysed, with research effort on the following.

- Eco-physiology and population dynamics for the reduction of pest pressure.
- Cultivars with low pesticide dependence.
- Development of a suite of innovative low-input practices and application technologies.
- Establishing a robust set of pesticide health and environmental impact indicators.
- National scenarios on the reduced use of pesticides, to help identify alternative cropping systems that would result in a 50% use reduction, by making a cost-benefit assessment of these alternative systems, including consideration of the social processes associated with the scenarios.
- Potential of green insurance schemes to cover both the learning phase and compensation of the added risk associated with reducing or foregoing the use of pesticides, plus their compatibility with existing European and other insurance schemes.
- Policies needed to achieve the 50% reduction in pesticide use, taking into account social and economic incentives as well as the institutional changes that may be required to meet the goal.

The results of the research will link with the experimental and demonstration farm networks established under the *Ecophyto* plan. A process of stakeholder (farmers, the pesticide industry, environmental groups, etc.) consultation will also contribute to the reflections on the policy changes required to reduce the use of pesticides.

5.6 Reforming governance to address social concerns with water quality in New Zealand[9]

The Waikato River is the longest river in New Zealand, flowing over 425 km, its catchment covering 14 260 km^2 or 12% of the North Island. It is a nationally significant *taaonga* (treasure) vital for primary production (especially agriculture), power-generation, municipal drinking water and stormwater discharge. The Waikato River catchment has been occupied by various *iwi* (tribes) and *hapuu* (sub-tribes) of the indigenous people affiliated with the River (herein referred to as "Waikato Maaori") for over 500 years.

Traditionally, the River and its surrounding environs provided for their spiritual and material needs. It was a valued food source, utilised for cleansing and healing, and provided a network for trade, travel and communication. Such expansive connections mean that for many Waikato Maaori, the Waikato River and the people are indivisible. The river is considered a *tupuna* (ancestor) or *taaonga*, and represents the *mana* and *mauri* (life force) of the people who have, and continue to inhabit its lands and banks. Monitoring over the period 1998 to 2007, however, has revealed that the overall quality of the Waikato River has been in decline, especially nitrogen pollution which has largely originated from agriculture diffuse source pollution (Ballantine *et al.,* 2010).

The degradation of the Waikato Rivers, and other water systems in New Zealand, is in part due to a policy failure in not setting water quality limits, standards and goals. While it is possible to set water quality standards under the *Resource Management Act* (New Zealand's main environmental policy framework) this has not been the norm (Land and Water Forum, 2010). A contributing factor to this has been the general difficulty of engaging stakeholders, including *iwi* in water governance, which as a result has led to conflict, litigation costs and uncertainty. An effort is now being made to reform water

governance, including meeting the social aspirations of *iwi* (Land and Water Forum, 2010). But to understand the steps towards water governance reform concerning the *iwi* it is necessary to briefly recount the historical background.

In 1865, *iwi* such as Waikato-Tainui suffered *raupatu* (land confiscation) when the Crown assumed control of, and exercised jurisdiction over, the Waikato River. This breached the Treaty of Waitangi[10] and denied Waikato-Tainui and other *iwi* and *hapuu* decision-making rights and interests and *mana whakahaere* (authority, exercise of rights and responsibilities) in the Waikato River and its resources. This led to a historical claim under the Treaty of Waitangi in the 1960s, which was settled in December 2009 when the Crown and Waikato-Tainui signed the "Waikato-Tainui River Deed of Settlement". The settlement is given effect through the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010. The next steps will be to establish the Waikato River Authority (previously known as the "Guardians of the Waikato River") and the Waikato River Clean-Up Trust.

The overarching purpose of the settlement is to restore and protect the health and well-being of the Waikato River for future generations. Primarily, this will be achieved through the following.

- Development of *Te Ture Whaimana* – a Vision and Strategy.
- Establishment of a single co-governance entity over the River (the Waikato River Authority) with equal numbers of Crown and Waikato Maaori appointed members.
- Contribution from central government of NZD 210 million (USD 150 million) over 30 years towards the Waikato River Clean-Up Trust, a contestable fund.

The settlement outlines commitments of good faith engagement and consensus decision-making, while having regard to statutory frameworks, the *mana whakahaere* and *mana o te awa* (spiritual, physical and cultural relationship) of Waikato-Tainui with the Waikato River. This enables Waikato-Tainui to participate in central and local government decision-making concerning the River across their tribal area. An expression of this is using *iwi* stream health indicators, based on cultural values and knowledge, as a means by which *iwi* can communicate with water managers in a way that can be understood and integrated into resource management processes (Box 5.2). There will also be greater recognition given to the customary activities of Waikato-Tainui on the river.

The Waikato-Tainui settlement has also created opportunities for four other Waikato Maori *iwi* (*Tūwharetoa, Te Arawa* subtribes*, Ngaati Raukawa, and Ngaati Maniapoto*) and one *hapuu* (*Ngaati Korokii Kahukura*) to be represented on the Waikato River Authority and to develop their own co-management arrangements with relevant government agencies.

The diversity of interested parties in the catchment has meant that the settlement's development has required building trust and co-operation between the Waikato-Tainui, and the Crown. Management of expectations and balancing of interests have also required an adaptive course of action to achieve durable solutions. Overall, it hoped that the evolution of this new relationship has and will continue to provide for increased understanding of values, priorities and the decision-making frameworks of all interested parties.

Box 5.2. The Ngāi Tahu Cultural Health Index: Assessing the health of streams and waterways in New Zealand

Based on cultural values and knowledge, the Cultural Health Index (CHI) provides a means by which *iwi* can communicate with water managers in a way that can be understood and integrated into resource management processes. It is a method to develop Māori stream health indicators for important values such as *mauri* and *mahinga kai* (food gathering) developed by linking Western scientific methods and cultural knowledge about stream health. The *iwi/hapü* combine three assessments – status of the site, *mahinga kai* values and stream health – to give an overall CHI score for each river site. It should be noted that the use of such assessments will vary from *iwi* to *iwi* and will not be appropriate in all circumstances.

Tangata whenua will have the CHI score as well as all the data collected at the site, including an inventory of *mahinga kai* species. By analysing the individual scores for each of the factors that make up the index, they will be able to diagnose issues, decide on priorities, and devise remedial actions necessary for the restoration or enhancement of the cultural values of the site. The CHI will allow them to monitor changes and improvements over time. The CHI can be used as a tool to address questions such as:

- How healthy are the streams and rivers within the boundaries of each tribal group?
- How can *iwi* make the regional government aware of sites that are most significant to them?
- How can *iwi* work out what they can do together with water managers to restore and enhance the health of rivers?

Source: Land and Water Forum (2010), *Report of the Land and Water Forum: A Fresh Start for Freshwater,* Wellington, New Zealand, www.landandwater.org.nz.

5.7 Addressing transborder pollution: The Baltic Sea, eutrophication and agriculture[11]

Eutrophication is one of the most critical problems facing the Baltic Sea. Over the last 100 years, the Baltic Sea has been transformed from an oligotrophic, clear-water sea into a eutrophic marine environment. The key causes of eutrophication include excessive nitrogen and phosphorus loads, which enter the Baltic Sea from all countries bordering the Baltic catchment basin. Approximately 75% of the Baltic Sea's nitrogen load, and at least 95% of its phosphorus load, is discharged into it either through rivers or as loads disseminated directly by water. Roughly 25% of the Baltic Sea's nitrogen load originates from airborne sources (Chapter 2.3).

Developing policies that address eutrophication of the Baltic, especially linked to agriculture diffuse source pollution, is made difficult due to the complex linkages between emission sources and the condition of the Baltic, mainly because (Elofsson, 2010):

- Multiple countries, sectors and sources contribute to the pollution of the Baltic Sea;
- Only a fraction of the emissions from the sources finally reach coastal waters;
- The ecosystem reacts slowly and in complex ways to changes in nutrient loadings;
- Marine basins vary with regard to their sensitivity to nutrient loads;
- There is a considerable exchange of nutrients between different marine basins as well as between the open sea and the coastal zone;

- Algal blooms in the Baltic Sea vary from year to year depending on the weather conditions; and,
- In some parts of the Baltic Sea drainage basin, there has been a small reduction in nutrient loads due to, for example, reduced agricultural activity or efforts to reduce phosphorus emissions from point sources, but there is little evidence of a change in the environmental state of the sea.

Over the longer term climate change could create an additional challenge to managing eutrophication in the Baltic Sea. Climate change may present a further challenge because precipitation is projected to increase, especially in the northern part of the Baltic Sea catchment area, which may, in combination with increasing winter temperatures, lead to increased winter runoff and leaching of nutrients. Furthermore, an increase in water temperatures will make benthic communities more vulnerable to eutrophication and hypoxia (Box 2.4).

Ultimately, the effects of climate change could make the strategic goal to eliminate eutrophication of the Baltic Sea impossible to attain using currently agreed reduction targets (HELCOM, 2009a and 2009b). Policy responses to climate change, however, may limit the impacts of climate change. Thus, the net effect of climate change and climate policy for the Baltic Sea are not easily judged, especially as the relative abatement costs across different countries are also likely to change under these circumstances.

In November 2007, the Baltic Marine Environment Protection Commission (known as the Helsinki Commission, or HELCOM) approved the *Baltic Sea Action Plan* (BSAP).[12] The overall goal of HELCOM is to render the Baltic Sea unaffected by eutrophication. There are no internationally common policy instruments designed with the particular purpose to reduce eutrophication in the Baltic Sea (Elofsson, 2010). HELCOM has issued a large number of recommendations regarding measures that should be undertaken in order to reduce nutrient emissions. These recommendations, however, are not legally binding to the contracting countries.

All HELCOM countries, except Russia, are **EU** members and thus subject to a number of EU policies and directives that indirectly have implications for Baltic Sea inland and coastal water quality, in particular, for agriculture, the *Common Agricultural Policy* and the EU *Water Framework Directive*. With the different objectives of the EU policies compared to the BSAP, this has led to incoherence between policies, in turn affecting the relative costs of abatement outlays and options, although increasingly the European Union is trying to harmonise its policies with those of the BSAP.

Under the BSAP there are two sets of targets:

- *Basin targets,* that define required reductions of nutrient loads to each of the seven basins in the Baltic Sea, and
- *Catchment targets,* which define required reductions in nutrient loads *from each country* to each of the seven basins (Table 5.3).

The "basin targets" defines reductions of nitrogen and phosphorus to each basin of the Baltic Sea, necessary to meet ecological objectives. The "catchment targets" are intended to govern the implementation of the basin targets, and define the necessary nitrogen and phosphorus targets for each basin from each country. Thus, the latter implies further restrictions on the spatial distribution of abatement. It is estimated that it will cost EUR 3.8 billion annually (USD 5 billion) to meet the basin target, while the catchment

target will cost EUR 4.5 billion annually (USD 5.9 billion). The two different targets will be associated with different allocations of nutrient reductions between countries and basins.

Table 5.3. Country loads and targets under the Baltic Sea Action Plan 2007

	Loads in sub–basins with a reduction need (1997-2003)		Country reduction allocations		Percentage reductions	
	Nitrogen (%)	Phosphorus (%)	Nitrogen (%)	Phosphorus (%)	Nitrogen	Phosphorus
Germany	4	2	4	2	27	45
Denmark	11	0	13	0	30	31
Estonia	3	5	1	2	5	18
Finland	3	2	1	1	8	25
Lithuania	8	5	9	7	26	66
Latvia	2	6	2	2	25	19
Russia	16	25	5	19	8	37
Poland	39	52	48	66	29	64
Sweden	13	3	16	2	29	34
Total	100	100	100	100	24	50
TOTAL (tonnes)	**546 309**	**26 633**	**129 372**	**13 353**	**24**	**50**

Source: Elofsson, K. (2010), Baltic-wide and Swedish nutrient reduction targets: An evaluation of cost-effective strategies, Ministry of Finance, Stockholm, Sweden.

Total nitrogen reductions will exceed the reductions required by the BSAP targets by a substantial amount, because large abatement efforts are necessary to meet the phosphorus target and this will at the same time reduce nitrogen loads. The excess nitrogen reductions are likely to contribute to improving ecological status in both the Baltic Sea and in other basins beyond the improvements targeted by HELCOM. This suggests, however, that there is a possibility to save costs by adjusting basin targets such that ecological status targets are achieved, but not over-achieved. This could be attained through a reduction of some of the load targets.

The adoption of the BSAP in 2007 has set ambitious reduction targets for annual inputs of nutrients into the Baltic Sea. While progress is being made toward these targets there are a number of issues that need to be addressed to make further progress (Elofsson, 2010; HELCOM, 2009b; Larsson and Granstedt, 2010; Malmaeus and Karlsson, 2010; Ministry of Environment, 2010):

- The Baltic Sea is one of the best scientifically documented and monitored regions in the world. However, source apportionment of the nutrient loads is incomplete, in particular, the precision of estimating agricultural loads does not reflect the severity of the problem of agricultural nutrient inputs. In addition, pollution load compilations are produced far too infrequently.

- A drawback of the BSAP is that it does not cover all countries contributing to the eutrophication of the Baltic Sea. Belarus and the Ukraine contribute a significant amount of nutrients into the Baltic, but do not have any commitment under the BSAP.

By contrast, the Kyoto Protocol, concerning global greenhouse gas emissions, includes a flexible mechanism, the Clean Development Mechanism, which permits bilateral co-operation between countries with quantitative obligations and countries with no such commitments. The mechanism provides incentives for both types of countries to undertake low-cost abatement projects in countries with no commitment instead of more expensive ones in countries with a commitment. A similar system could be applied for Belarus and Ukraine in the case of the Baltic Sea.

- Within the **EU countries**, inland water quality management is governed by the *Water Framework Directive*, which assigns the responsibility for water management to regional Competent Authorities, while the **EU**'s *CAP* and *Nitrates Directive* have important implications for agricultural nutrient loadings into the Baltic (Chapter 5.1). In **Sweden**, for example, much of the decision making on water management lies with national and local authorities. The multiplicity of governmental levels and branches involved in decision making for water management, both at the EU and national level for Baltic states, opens up the potential for conflicting policy decisions based on local, sectoral or EU-level interests, which can hamper the implementation of the internationally agreed nutrient reductions under the BSAP, but there are growing initiatives to harmonise EU policies with the BSAP.

- With the expansion of **EU** membership, the adoption of the *Common Agricultural Policy* (CAP) by the new **EU** member states around the Baltic Sea (**Estonia**, Latvia, Lithuania) has raised concerns that this could lead to higher flows of nutrients into the Baltic as agriculture production expands under the stimulus of the CAP. This may depend, however, on the farm management systems adopted in these countries and also on further reforms to the CAP.

- Despite the long-term reductions in nutrient loadings that have been achieved by most Baltic States, this has not yet led to a significant reduction of eutrophication. Also, there are continued efforts to adopt measures and management practices to further reduce nutrient loadings. However, there is a time lag before these positive actions can be observed in the Baltic, which is also further complicated by hydrological processes that cannot be changed or controlled.

- Modelling results show that the marginal abatement costs for nitrogen and phosphorus reductions vary substantially between basins when basin targets are pursued (Elofsson, 2010). With catchment targets, marginal abatement costs vary substantially between different countries emitting to the same basin. This suggests that there could be gains from nutrient load trading between countries that emit to the same basin. Calculations show that if the initial permits are allocated according to the BSAP catchment targets all countries gain from the introduction of nutrient trading at the national level, although for **Poland** the gains would be minor (Balana, Vinten and Slee, 2011; Elofsson, 2010).

5.8 Establishing co-operative agreements to address diffuse source pollution

The historic reliance on a mix of payments and regulations supported by information instruments to address water pollution in agriculture outlined in Chapter 4 is encountering growing difficulties in many countries. This is because of the: inefficiencies and failures in the development, implementation, and enforcement of these policy approaches; rising budgetary cost of providing payments; problems with administering and enforcing regulations; and also the diminishing efficiency of these policy approaches to achieve continued and significant reductions in the impairment of water quality resulting from agricultural practices (Gouldson *et al.,* 2008).

In view of the mounting frustration with the traditional mix of policies to address diffuse pollution in agriculture, there is increasing interest in establishing co-operative agreements (CAs) to address the problem, as well as some other innovative policy instruments, such as water quality trading (Chapter 4.1). There are a number of reasons for the increased interest in the use of CAs, including (Blackstock *et al.,* 2010; Gouldson *et al.,* 2008; John, Smith and Stoker, 2009; Lennox, Proctor and Russell, 2011):

- Limitations with traditional rigid regulatory frameworks, when the public sector might draw on the more dynamic and less costly capacities of the private and civil sectors to achieve water quality goals in co-operative arrangements;
- Frustration with the protracted time and institutional complexities to adopt new policy approaches, when non-legislative approaches might be quicker and easier to apply;
- Realisation that environmental issues such as improving water quality are complicated because of the stochastic interaction of human activity with the natural environment;
- Comprehension that scale and context are important, so that common national policy frameworks need to be targeted and tailored to suit the water catchment and sub-catchment scale; and,
- Consideration that effective and legitimate public policy requires a more comprehensive and co-operative public consultation process and stakeholder involvement, whereas regulatory approaches may be perceived by individual farmers as not applying to them.

Examples of CAs examined in this section include: agreements between water supply utilities and farmers; CAs between farmers and non-governmental environmental groups; and self regulatory community based CAs. There are a number of factors that are likely to influence the increased uptake and implementation of the CAs examined here, including the (Blackstock *et al.,* 2010; Gouldson *et al.,* 2008):

- Extent of commitment from key groups in a catchment;
- Levels of stakeholder understanding of the water quality concern;
- Leadership from a lead implementing agency or farm community;
- Importance of timing, especially reducing the time from inception to effect of a project;
- Definition of a clear message as to the goals of the co-operative arrangement;

- Development of the maximum degree of social regulation among stakeholders; and the
- Enhancement of social capital in building networks, co-operation and trust among stakeholders.

Comparison between CA approaches to diffuse source pollution and other policy approaches – environmental regulations, taxes and agri-environmental payments – are provided in Table 5.4. A key difference with CAs is that they tend to be more self-regulatory and often privately organised, taking into account water catchment conditions (Brouwer, Heinz and Zabel, 2003). This in contrast to other policy approaches shown in Table 5.4 which are generally applied regionally or nationally. CAs also tend to go beyond the requirements of regulations providing a more preventative approach to pollution, while they are usually more targeted than pollution taxes and agri-environmental payments.

Although CAs can facilitate the achievement of water quality standards in agriculture they suffer, however, from a number of weaknesses (Brouwer, Heinz and Zabel, 2003). For example, in negotiating CAs with farmers water supply utilities might feel at a disadvantage, especially if they are under pressure to comply with water quality regulatory standards. Also participation is voluntary and usually the CA is limited in its duration. In areas of excessive water pollution from agriculture (e.g. areas with intensive livestock production), it might be difficult to reach a CA agreement if farmers have very high demands for compensation. There are also generally no penalties for not complying with a CA, other than withholding payments where these apply.

Co-operative agreements involving water utilities and farmers

One of the major areas for the development of CAs, to achieve water quality goals in agriculture, is between farmers and drinking (or bottled) water supply utilities (private and public), which sometimes involve other water catchment stakeholders, such as regulatory agencies and environmental NGOs. Water utilities can initiate or become part of a CA with farmers to (Brouwer, Heinz and Zabel, 2003):

- Meet health and environmental regulatory standards for water quality;
- Offset treatment costs of supplying either mains supplied drinking water or bottled water;
- Prevent future degradation to water sources used by water utilities, especially groundwater; and,
- Address public and utility concerns about contaminants in water.

There are multiple models in the use of CAs across OECD countries between water utilities and farmers to protect water quality (Brouwer, Heinz and Zabel, 2003). This in part reflects different legal and institutional settings, both within and across countries. In Europe, for example, water utilities tend to be much larger than their **US** counterparts, and hence, are able to have the resources to work with farmers and other stakeholders in a water catchment. A few, illustrative examples, of these initiatives are discussed below, from the **United Kingdom**, **United States** and **France**.

Table 5.4. Comparison of the key features between co-operative agreements and environmental regulations, pollution taxes and agri-environmental payments

Feature	Co-operative Agreements	Environmental regulations	Taxes on pesticides and nutrients	Agri-environmental payments
Legal basis	Voluntary but often embedded in regulatory framework promoting those arrangements	Obligatory for farmers and water suppliers		
Main actors involved	Water suppliers and farmers (or/and their representatives) and in many cases authorities	Public authorities (national, regional and local), farmers and water suppliers	Public authorities (national) and farmers	Public authorities (national and regional) and farmers
Feature of interaction between actors	Self-regulation	Mandatory approach	Mandatory approach	Governmental approach (related to special requirements for farmers)
Degree of state intervention	Generally moderate	High	High	High
Geographical scope	Water catchment area	National, regional and local	National (however, charges on nutrient surplus may focus on areas with severe environmental problems)	National or regional
Participation by farmers	Voluntary	Compulsory	Compulsory	Voluntary
Linkages to environmental policy	Partly replacing and partly beyond legal requirements	Restricted to legal requirements	Complementary to legal constraints	Beyond legal constraints
Link to agricultural policy	Not directly, but can be indirectly where incentives provided, for example, through agri-environmental payments	Yes, frequently agri-environmental payments linked to compliance with regulation		
Basis for compensation	Generally based on the loss of net income for meeting the requirements; free advisory services play a major role	Loss of net income especially in case of compulsory rules in water protection zones		
Source of budget	Paid by water suppliers and borne by consumers of water (sometimes paid by authorities funded from water abstraction charges)	Paid from state budget (revenues from taxes)	Farmers revenues	Taxpayers

Source: OECD Secretariat, adapted from Brouwer, F., I. Heinz and T. Zabel (2003), *Governance of water-related conflicts in agriculture*, Kluwer Academic Publishers, The Netherlands.

In the **United Kingdom**, an innovative way of addressing agriculture's impact on water is being deployed by the South West Water drinking water and waste water utility and the West Country Rivers Trust, an environmental NGO, and is based on the "beneficiary pays" approach rather than the Polluter-Pays-Principle.[13] The South West Water is paying farmers to implement land management changes that reduce pollutants and therefore improve environmental water quality and also reduce the costs of treatment for drinking water supply. Ofwat (the Water Services Regulation Authority which is the economic regulator of the water and sewerage sectors in England and Wales) allowed payment for these schemes because they demonstrated a high cost-benefit ratio and were deemed as cost effective for water consumers. A large number of UK water companies have been allocated funding to identify ways in which they – like South West Water – could work with and fund farmers to deliver land use change that would reduce nutrients, pesticides, and sediment pollution of drinking water.

Concerns about water quality in the 1980s led to the introduction of more stringent legislation in the **United States**.[14] Having the largest unfiltered water system in the United States, New York City (NYC) aimed to find a means of avoiding the need to implement costly filtration processes. To do so the city authority had to meet a range of criteria in order to receive "filtration avoidance" from the U.S. Environment Protection Authority (EPA) (i.e. to show the water was free from microbial contaminants). The approach taken to achieve this involved the establishment of a combination of regulation, advice, land use measures, incentives and voluntary action, and is a good example of a collaborative and adaptive approach to catchment management for the protection of rural land and water resources involving agriculture.

Delaware County accounts for about 50% of the NYC water catchment. The approach taken comprises of three distinct elements:

- ***Voluntary agreements*** with farmers through the *Watershed Agriculture Program*, promoting the adoption of best management practices by farmers based on advice and whole-farm planning financed from NYC and from other state and federal schemes. Approval is needed from the county Soil and Water Conservation Service and the Watershed Agricultural Council prior to any funding being received.
- ***Financing of wider community pollution reduction programmes,*** including funding for new infrastructure for sewage plants, septic systems, sand and salt storages, storm water, stream corridor protection, forestry management, public education, and a fund for environmentally friendly economic development.
- ***Land acquisition*** by NYC within the water catchment, with a schedule of priorities for land purchases based on their likely impacts on water quality. As alternatives to outright land purchase it is also possible for the City to purchase development rights in the form of conservation easements, or agricultural easements that place restrictions on agricultural practices while the owners continue occupation.

Since the start of the programme in 1994, nearly 85% of the farms within the water catchment have signed voluntary farm agreements (about 350 farms). The success of the scheme is largely attributed to the effective co-operation between the extension services and local planners, and also the full funding of on-farm implementation.

In the early 1980s it was recognised that the intensification of agriculture in the *Vittel* catchment, located in the Vosges mountain range in north-eastern **France**, posed a risk to the nitrate and pesticide levels in the mineral water of the catchment (Cooper, Hart and

Baldock, 2009; Perrot-Maitre, 2006). To address this issue Nestlé Waters, owner of the *Vittel* bottled water company, agreed to provide incentives to farmers to voluntarily change their management practices to reduce contamination (Cooper, Hart and Baldock, 2009).

Nestlé Waters initiated an incentive package which included payments of EUR 200/ha/year (USD 280/ha/year) over 18- or 30-year contracts, up to EUR 150 000 per farm (USD 210 per farm). This covers the cost of: all new equipment and building modernisation; labour to apply field manure; and technical assistance, including annual individual farm plans and introduction to new social and professional networks. All 26 farms in the area adopted the contract. Payments are not conditional on changes in the nitrate levels in the aquifer, but are based on new farm investment and the cost of adopting new farming practices. Both nitrate levels and farm management practices are regularly monitored, and recommendations for manure application are adjusted if necessary (Cooper, Hart and Baldock, 2009).

By 2004, after 12 years of operation, the programme had succeeded in enrolling 92% of the basin area and reduced the baseline nitrogen load of the spring's source waters (Stanton *et al.,* 2010). The value of direct payments to farmers was concentrated in the first seven years of operation, and payments decreased thereafter as the programme reached its goal of enrolling all farms in the target water catchment service area.

One of the main factors of the success of the scheme has been the trust built up between the farmers and the company as a result of, amongst other factors, a long-term participatory process (Perrot-Maitre, 2006). A key element of this was Agrivair, the intermediary organisation created by *Vittel* to negotiate with farmers, which implemented the key payment features and oversaw all aspects of the programme. Another key player providing critical scientific and research support was the French *Institut National de la Recherche Agronomique (INRA)*. From the beginning, these players made an effort to understand the motivations of farmers from the short to the long term and were able to design the programme to fit *Vittel's* objectives along with the life choices of those in the farming community. Threats to water quality in the catchment have moved from the rural to the urban areas, and Agrivair is shifting its focus accordingly to programmes targeting pollution loadings from stormwater and wastewater.

Co-operative agreements between farmers and non-governmental environmental groups

A consortium of non-governmental environmental organisations in the **United States** – Forest Trends, the Chesapeake Bay Foundation, and the World Resources Institute – **have established a voluntary nutrient market called the** *Chesapeake Fund*.[15] The Fund provides individuals and businesses the ability to calculate their nitrogen footprint and identify ways to reduce their impact. For those emissions that cannot be cost-effectively reduced, the Fund provides the ability to purchase offsets that will be used to pay for cost-effective projects in targeted water catchments. These projects are selected by the Fund because of their high nitrogen reduction return on investment, but often involve paying farmers in the water catchment to implement nutrient reducing best management practices.

As described in an earlier case study (Chapter 5.2), the Chesapeake Bay area on the eastern seaboard of the **United States** is threatened by pollution from a variety of sources, but especially nutrients from agriculture. The goal of the *Chesapeake Fund* is to initiate the reduction of nitrogen in "hotspots" around the water catchment. The Fund aims to

target investments from nitrogen offsets into conservation and restoration practices that are efficient, cost-effective, have the greatest ability to provide long-term reductions in nitrogen, and provide ancillary environmental benefits. Specifically, the Fund and co-operation between environmental groups and farmers is helping to:

- Provide opportunities for change through nitrogen accounting and nitrogen reduction services, that allows participants to reduce their impact on water quality, either by changing behaviour or by donating to nitrogen offsets, resulting in quantifiable pollution reductions across the Bay;

- Create a more efficient and effective process for restoring and protecting water quality and water resources across the region, with stakeholders getting the credit for taking steps to either reduce their nitrogen emissions or offset them by paying for reductions;

- Develop an innovative model that allows businesses to finance environmental compliance and advance restoration financing efforts; and,

- Achieve multiple environmental and community goals, as reducing nitrogen pollution not only helps improve water quality in the Bay, but also reduces greenhouse gas emissions, contributes toward developing sustainable agriculture, and supports new and innovative restoration economies.

Self-regulatory, community-based co-operative agreements[16]

There was conflict over water quality between dairying farmers and mussel farming in the northern area of the South Island, **New Zealand** – the Golden Bay's Aorere community – in 2005. Operating in an environment with high rainfall and rapid runoff, dairy farming was believed to be affecting mussel farming in the bay. Mussel farming had almost become unviable due to restrictions on the number of harvesting days resulting from poor water quality. With the help of the New Zealand Landcare Trust, local dairy farmers began to establish a self regulatory community based approach to address the issue.

A team of farmers applied for *Sustainable Farming Fund* (SFF) funding in 2006 to run a three-year project in the catchment. SFF funding of NZD 218 000 (USD 142 000) was granted, alongside funding from the Landcare Trust, Tasman District Council and a lot of voluntary work by farmers themselves. The project used local science, farm-scale nutrient management plans and farmer leadership as the tools to improve water quality. By 2009 the community had major on-farm investments in dairy effluent management and a significant increase in mussel harvesting days. This project finished in 2009, but SFF funding has recently been granted to take the Aorere approach to the neighbouring Rai Catchment.

Notes

1. For details concerning EU regulations, implementation and assessment of the *Water Framework Directive* see the EU website at: *ec.europa.eu/environment/water/water-framework/index_en.html.*

2. For a discussion of policy actions to restore the Bay prior to 2007, the reader is referred to Butt and Brown, 2000; and OECD, 2007.

3. For more information on the Chesapeake Bay TMDLs and overall Bay Programme see the EPA site at: *www.epa.gov/region03/chesapeake*/.

4. These introductory paragraphs on salinity in Australia are drawn from the Australian Bureau of Statistics website (accessed 2010): *www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1370.0~2010~Chapter~Salinity%20(6.2.4.4)*. For a more detailed assessment see the National Land and Water Resources Audit (2001).

5. The text that follows is drawn mainly from Pannell and Roberts, 2010, but also see Robertson *et al.*, 2009.

6. This section largely draws from Shortle (2012).

7 This section largely draws on material provided in 2010 by the French and United Kingdom Delegations to the OECD.

8. For further information on the *Ecophyto Plan* 2018 (in French only) the reader is referred to the INRA website at: *agriculture.gouv.fr/ecophyto_2018.*

9. This section largely draws from case study material provided to the OECD Secretariat by D. Flavell (1), T. Paki (1), C. van Schravendijk (1), N. Tomic (2) and M. Mossman (2): (1) Waikato Raupatu River Trust, Waikato-Tainui Te Kauhanganui Inc., and (2) New Zealand Ministry of Agriculture and Forestry. For further information see: Waikato-Tainui: *www.tainui.co.nz;* Waikato-Tainui River Deed of Settlement, at the Office of Treaty Settlements: *www.ots.govt.nz;* and Guardians of the Waikato River: *www.river.org.nz*.

10. The Treaty of Waitangi is an agreement, in Maaori and English, that was made between the British Crown and about 540 Maaori *rangatira* (chiefs) in 1840. The process of settling Treaty of Waitangi related grievances provides for historical claims against the government dating back to 1840. Treaty settlements are legal agreements between the Crown and Maaori to settle all historical claims against the Crown.

11. The discussion on eutrophication in the Baltic mainly draws on two case studies provided to the OECD Secretariat by Finland (Ministry of Environment, 2010) and Sweden (Elofsson, 2010), but see also Balana, Vinten and Slee (2011).

12. The countries included under the BSAP include Russia and eight EU countries: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, and Sweden. Belarus and Ukraine, with rivers draining into the Baltic, are not HELCOM member countries.

13. The UK example is taken from unpublished material provided to the OECD Secretariat by the UK Delegation to the OECD. Further information is provided on South West Water at: *www.southwestwater.co.uk/index.cfm?articleid=1*; and on the West Country Rivers Trust at: *www.wrt.org.uk/*.

14. The example from the United States draws mainly from Cooper, Hart and Baldock, 2009; and Smith and Porter, 2009.

15. The example of the Chesapeake Fund draws from the Fund's website at: *www.chesapeakefund.org/index.shtml*.

16. This example from New Zealand draws on Land and Water Forum, 2010.

Bibliography

Aillery, M., N. Gollehon, R. Johansson, J. Kaplan, N. Kay and M. Ribaudo (2005), *Managing manure to improve air and water quality*, Economic Research Service, U.S. Department of Agriculture, *www.ers.usda.gov/Publications/ERR9/*.

Auditor General (2008), *Regional Delivery Model for the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality*, Report No. 21, 2007–08, Performance Audit, Australian National Audit Office, Canberra, Australia.

Balana, B.B., A. Vinten and B. Slee (2011), "A review on cost effectiveness analysis of agri-environmental measures related to the EU WFD: Key issues, methods, and applications", *Ecological Economics*, Vol. 70, pp. 1 021-1 031.

Ballantine, D. and R.J. Davies-Colley (2009), *Water quality trends at national river water quality network sites for 1989-2007*, prepared for the New Zealand Ministry for the Environment, National Institute of Water and Atmospheric Research Ltd., Hamilton, New Zealand, *www.mfe.govt.nz/environmental-reporting/freshwater/*.

Barnes, A.P., J. Willock, C. Hall and L. Toma (2009), "Farmer perspectives and practices regarding water pollution control programmes in Scotland", *Agricultural Water Management*, Vol. 96, pp. 1715-1722.

Barzman, M. (2009), *Ecophyto 2018: Selected items from the French pesticide reduction plan*, ENDURE, *www.endure-network.eu/media/files/french_nap_ecophyto_2018*.

Bateman, I.J., *et al*. (2008), *WFD related agricultural nitrate and phosphate leaching reduction options*, CSERGE Working Paper ECM 07-03, Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia, Norwich, United Kingdom.

Benson, D., A. Jordan and D. Huitema (2011), "Involving the public in catchment management: an analysis of the scope for learning lessons from abroad", *Environmental Policy and Governance,* published online, 12 December.

Blackstock, K.L., J. Ingram, R. Burton, K.M. Brown and B. Slee (2010), "Understanding and influencing behaviour change by farmers to improve water quality", *Science of the Total Environment*, Vol. 408, Issue 23, pp. 5631-5638.

Brouwer, F., I. Heinz and T. Zabel (2003), *Governance of water-related conflicts in agriculture*, Kluwer Academic Publishers, The Netherlands.

Buckley, C. (2010), "*Efficient management – A win for the farmer and a win for the environment*," paper presented to the 84th Annual Conference of the Agricultural Economics Society, Edinburgh, United Kingdom.

Butt, A.J. and B.L. Brown (2000), "The cost of nutrient reduction: A case study of Chesapeake Bay", *Coastal Management*, Vol. 28, No. 2, pp. 175-185.

Centner, T.J. (2011), "Addressing water contamination from concentrated animal feeding operations", *Land Use Policy*, Vol. 28, pp. 706-711.

Collins, A.L. and D.F. McGonigle (2008), "Monitoring and modelling diffuse pollution from agriculture for policy support: UK and European experience", *Environmental Science and Policy*, Vol. 11, pp. 97-101.

Cooper, T., K. Hart and D. Baldock (2009), *Provision of public goods through agriculture in the European Union*, Report prepared for the European Commission (D-G Agriculture) and the Institute for European Environmental Policy, London, United Kingdom.

Elofsson, K. (2010), *Baltic-wide and Swedish nutrient reduction targets: An evaluation of cost-effective strategies*, Ministry of Finance, Stockholm, Sweden.

European Commission (2007), *Communication from the Commission to the European Parliament and the Council, Towards sustainable water management in the European Union,* First stage in the implementation of the Water Framework Directive, COM(2007)128 final [SEC(2007)363], Brussels, Belgium.

European Commission (2009), "Flash Eurobarometer on water: Summary", *Flash Eurobarometer Series* No. 261, Brussels, Belgium.

European Commission (2010), *Report from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2004-2007*, COM(2010)47 final, Brussels, Belgium.

European Court of Auditors (2008), *Is cross compliance an effective policy?,* Special Report No. 8, Brussels, Belgium.

European Environment Agency (2010), *The European environment state and outlook 2010: Freshwater quality*, Copenhagen, Denmark, www.eea.europea.eu.

European Union (2010), *The EU Nitrates Directive*, Brussels, Belgium.

Godlinski, F., *et al.* (2010), *Policy Targets related to Nitrogen Emissions from Agriculture- The Case of Germany,* paper presented at the OECD Workshop on Agri-environmental Indicators, Leysin, Switzerland, March, available at:www.oecd.org/tad/env/indicators.

Gouldson, A., *et al*. (2008), "New alternative and complementary environmental policy instruments and the implementation of the Water Framework Directive", *European Environment*, Vol. 18, pp. 359-370.

Grundy, M. and M. Barson (2010), "Information, Indicators, Agricultural Productivity and Sustainable Practices – Australian Case Studies," paper presented at the OECD Workshop on Agri-environmental Indicators, Leysin, Switzerland, March, available at: *www.oecd.org/tad/env/indicators.*

HELCOM (Helsinki Commission) (2009a), *Eutrophication in the Baltic Sea: An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea Region – Executive Summary*, Baltic Sea Environment Proceedings No. 115A, HELCOM, Helsinki, Finland.

HELCOM (2009b), *Eutrophication in the Baltic Sea: An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea Region*, Baltic Sea Environment Proceedings No.115B, HELCOM, Helsinki, Finland.

John, P., G. Smith and G. Stoker (2009), "Nudge, Nudge, Think, Think: Two Strategies for Changing Civic Behaviour", *Political Quarterly*, Vol. 80, No. 3,pp. *361-70.*

Kanakoudis, V. and S. Tsitsifli (2010), "On-going evaluation of the WFD 2000/60/EC implementation process in the European Union, seven years after its launch: are we behind schedule?", *Water Policy*, Vol. 12, pp. 70-91.

Kronvang, B., *et al.* (2008), "Effects of policy measures implemented in Denmark on nitrogen pollution of the aquatic environment", *Environmental Science and Policy,* Vol. 11, pp. 144-152.

Kronvang, B., G.H. Rubaek and G. Heckrath (2009), "International phosphorus workshop: Diffuse phosphorus loss to surface water bodies – risk assessment, mitigation options, and ecological effects in river basins", *Journal of Environmental Quality*, Vol. 38, pp. 1924-1929.

Land and Water Forum (2010), *Report of the Land and Water Forum: A Fresh Start for Freshwater,* Wellington, New Zealand, www.landandwater.org.nz.

Lankoski, J. and M. Ollikainen (2011), *Counterfactual approach for assessing agri-environmental policy: Theory with an application to Finnish water protection policy*, Discussion Paper No. 56, Department of Economics and Management, University of Helsinki, Finland, www.helsinki.fi/taloustiede/Abs/DP56.pdf.

Larsson, M. and A. Granstedt (2010), "Sustainable governance of the agriculture and the Baltic Sea – Agricultural reforms, food production and curbed eutrophication", *Ecological Economics*, Vol. 69, pp. 1943-1951.

Lennox, J., W. Proctor and S. Russell (2011), "Structuring stakeholder participation in New Zealand's water resource governance", *Ecological Economics*, Vol. 70, pp. 1381-1394.

Malmaeus, J.M. and O.M. Karlsson (2010), "Estimating costs and potentials of different methods to reduce the Swedish phosphorus load from agriculture to surface water", *Science of the Total Environment*, Vol. 408, pp. 473-479.

Mills, J. and J. Dwyer (2009), *EU environmental regulations in agriculture*, Countryside and Community Research Institute, Cheltenham, United Kingdom.

Ministry of Ecology, Energy, Sustainable Development and the Sea (2010), *"L'eau",* chapter in *L'environnement en France*, Paris, France, www.stats.environnement.developpement-durable.gouv.fr/acces-thematique/eau.html.

Ministry of the Environment (2010), *Implementation of HELCOM's Baltic Sea Action Plan (BSAP) in Finland*, Status Report 17 May, Helsinki, Finland.

Moxey, A. (2012), *The Monetary Costs and Benefits of Agriculture on Water Quality: Estimates across OECD Countries*, OECD Consultant Report, available at: www.oecd.org/agriculture/water.

National Audit Office (2010), *Environment Agency: Tackling diffuse water pollution in England*, Report by the Comptroller and Auditor General, London, United Kingdom.

National Land and Water Resources Audit (2001), *Australian Dryland Salinity Assessment 2000,* NLWRA on behalf of the Commonwealth of Australia, Canberra, Australia, *audit.ea.gov.au/anra/atlas_home.cfm*.

New Zealand Government (2011), *National Policy Statement: Freshwater Management 2011*, issued by notice in the Gazette on 12 May, Wellington, New Zealand, www.mfe.govt.nz/rma/central/nps/freshwater-management.html.

OECD (2007), *Instrument Mixes addressing Non-point Sources of Water Pollution,* OECD, Paris, *www.oecd.org/env*.

OECD (2008a), *Environmental Performance of Agriculture in OECD Countries since 1990,* OECD, Paris, *www.oecd.org/tad/env/indicators*.

OECD (2011b), *Evaluation of Agricultural Policy Reforms in the United States – A Preliminary Analysis*, OECD, Paris, *www.oecd.org/agr*.

OECD (2011c), *Evaluation of Agricultural Policy Reforms in the European Union: Draft Report*, OECD, Paris, *www.oecd.org/agr*.

OECD (2011f), "Green growth and climate change policies", Chapter 4 in *OECD Economic Surveys: New Zealand*, OECD, Paris, *www.oecd.org/eco*.

Oenema, O., H.P. Witzke, Z. Klimont, J.P. Lesschen and G.L. Velthof (2009), "Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27", *Agriculture, Ecosystems and Environment*, Vol. 133, pp. 280-288.

Ortolano, L., S. Baumont and G. Puz (2009), "Implementing programmes to reduce nitrate pollution from agriculture in Brittany, France", *Water Resources Development*, Vol. 25, No. 4, pp. 641-656.

Pannell, D. J. and A.M. Roberts (2010), "Australia's National Action Plan for Salinity and Water Quality: a retrospective assessment", *Agricultural and Resource Economics*, Vol. 54, pp. 437-456.

Perez, M.R., C. Cox and K. Cook (2009), *Facing facts in the Chesapeake Bay*, Environmental Working Group, Washington, D.C., United States.

Perrot-Maitre, D. (2006), *The Vittel payments for ecosystem services: a perfect PES case?*, International Institute for Environment and Development, London, United Kingdom.

Posthumus, H. and J. Morris (2010), "Implications of CAP reform for land management and runoff control in England and Wales", *Land Use Policy*, Vol. 27, pp. 42-50.

Ribaudo, M., L. Hansen, D. Hellerstein and C. Greene (2010b), *The use of markets to increase private investment in environmental stewardship*, Economic Research Report No. 64, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., United States.

Roberts, A.M., D.J. Pannell, G. Doole and O. Vigiak (2010), *Agricultural land management strategies to reduce phosphorus loads in the Gippsland Lakes, Australia,* Working Paper 1011, School of Agricultural and Resource Economics, The University of Western Australia, 28 July, *www.are.uwas.edu.au*.

Robertson, M.J., *et al.* (2009), "Effectiveness of a publicly-funded demonstration program to promote management of dryland salinity", *Journal of Environmental Management*, Vol. 90, pp. 3023-3030.

Shortle, J., M. Ribaudo, R.D. Horan and D. Blandford (2012), "Reforming Agricultural Nonpoint Pollution Policy in an Increasingly Budget Constrained Environment", *Environmental Science and Technology,* January.

Smith, L.E.D. and K. S. Porter (2009), "Management of catchments for the protection of water resources: Drawing on the New York City watershed experience", *Regional Environmental Change*, published online 22 October, *www.springerlink.com/content/l177727548811101/fulltext.pdf*.

Saint-Ges, V. and M.-C. Belis-Bergouignan (2009), "Ways of reducing pesticides use in Bordeaux vineyards*", Journal of Cleaner Production*, Vol. 17, pp. 1644-1653.

Sinabell, F. (2005), *An exploration of agricultural policy support and its impact on nitrate pollution in groundwater in Austria*, Austrian Institute of Economics Research, Vienna, Austria.

Sinabell, F. and E. Schmid (2006*), On the choice of cost and effectiveness indicators in the context of the European Water Policy*, paper presented to the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Sneeringer, S. and N. Kay (2010), "Effects of Clean Water Act regulations on firm level decisions in agriculture", paper presented to Agricultural and Applied Economics Association, Denver, Colorado, United States.

Stanton, T., M. Echavarria, K. Hamilton and C. Ott (2010), *State of watershed payments: An emerging marketplace*, Forest Tends, Washington, D.C., United States.

USEPA (U.S. Environmental Protection Agency) (2010a), *Chesapeake Bay Compliance and Enforcement Strategy*, Washington, D.C., United States, *www.epa.gov/compliance/civil/initiatives/chesapeake-strategy-enforcement.pdf*.

USEPA (2010b), *Coming together for clean water: EPA's strategy for achieving clean water,* Public Discussion Draft August, Washington D.C., United States, *blog.epa.gov/waterforum/wp-content/uploads/2010/08/Coming-Together-for-Clean-Water-Disc-Draft-Aug-2010-FINAL.pdf*.

U.S. Natural Resources Conservation Service (2011), *Assessment of the effects of conservation practices on cultivated cropland in the Chesapeake Bay region*, Natural Resource Conservation Service, U.S. Department of Agriculture, Washington, D.C., United States, *www.nrcs.usda.gov/technical/NRI/ceap/chesapeake_bay/ceap_chesapeake_bay_report.pdf*.

Vinther, F.P. and C.D. Borgesen (2010), *Nutrient surplus as a tool for evaluating environmental action plans in Denmark,* paper presented at the OECD Workshop on Agri-environmental Indicators, March, Leysin, Switzerland, March, *www.oecd.org/agriculture/env/indicators/workshop*.

Chapter 6

Moving towards sustainable water quality management in agriculture

Policy reforms to improve the economic efficiency and environmental effectiveness of the current policy mix to lower agricultural pressure on water systems are important steps toward the sustainable management of water quality in agriculture. Where there are policy and market failures to address water pollution in agriculture, it can also help to seek and introduce innovative policy tools and market approaches to overcome these failures. A strategy toward the sustainable management of water quality in agriculture, that seeks to lower budgetary expenditure of abatement programmes and reduces the external costs of agricultural pollution, while building on recent policy reforms in OECD countries should consider the following: enforce compliance with existing water quality regulations and standards; remove perverse support in agriculture to lower pressure on water systems; take into account the Polluter-Pays-Principle to reduce agricultural water pollution; set realistic water quality targets and standards for agriculture; improve the spatial targeting of policies to areas where water pollution is most acute; assess the cost effectiveness of different policy options to address water quality in agriculture; take a holistic approach to agricultural pollution policies; and establish information systems to support farmers, water managers and policy makers.

6.1 Policy challenges

Public opinion surveys across OECD countries have over recent years consistently ranked water pollution as one of the top public environmental concerns. There is also a growing global demand for agriculture to increase production of food, feed, fuel and fibre, some of which is supplied by OECD countries. Agricultural activity, however, will always involve some lost of nutrients, pesticides, soils and other contaminants into water systems (i.e. surface water, groundwater and marine environments).

The *overarching policy challenge* for agriculture is to seek ways to meet the growing demand to increase production while minimising contaminant loss into water systems. This needs to be achieved at the least overall cost to society, including farmers' compliance costs and policy related transaction costs, taking into account equity and social considerations.

Agriculture is a significant source of water pollution from nitrogen, phosphorus, pesticides, soil sediments and also a growing number of emerging contaminants (e.g. veterinary medicines). Agricultural pollution has a substantial redistributive impact in society, through the treatment costs to remove these pollutants from drinking water. Costs of agricultural pollution are also imposed on society by: impairing recreational (e.g. bathing) and amenity (e.g. waterscapes) benefits associated with water; damaging commercial fisheries; and harming ecosystems.

The overall economic, environmental and social costs of water pollution caused by agriculture across OECD countries are likely to exceed billions of dollars annually. No satisfactory estimate of these costs for all OECD countries currently exists, but a study in the **United Kingdom**, for example, has shown that in 2007 the annual cost of agriculture on water systems (pollution of freshwater, estuaries and drinking water treatment costs) was around EUR 340 million (USD 460 million) while total UK budgetary expenditure on agriculture in 2007 was EUR 1 430 million (excluding EU budget payments) (USD 1 960 million) (Tables 3.1 and 5.1).

A review of OECD country surveys from the mid-2000s to 2010 suggests the situation of water pollution from agriculture is either stable or deteriorating, with few cases where significant improvements are reported. While the situation varies both across OECD countries and regionally within countries, for most countries agriculture is often the major source of nutrient, soil and pesticide contamination of water. Given absolute levels of agricultural pollutants are still high in many countries, achieving further reductions in pollution remains a challenge for policy makers. This is, in particular, associated with the diffuse nature of much agricultural pollution from field runoff into surface water and leaching into groundwater. Point source agricultural pollution, largely from intensive livestock operations and residual pesticide disposal, while more easily controlled remains a major problem to control.

Certain farming practices and management systems, however, can result in improvements in water quality. Illustrative of these beneficial practices and systems include, creating riparian buffers, taking land out of production near watercourses, and undertaking conservation tillage, organic farming, and paddy rice production. But if poorly managed these practices and systems can also lead to pollution of water systems. There may be some private interest by farmers in minimising pollution of water courses, such as providing uncontaminated drinking water for livestock, but generally these ecosystem services in improving water quality are undersupplied by farmers.

Extrapolating from policy changes made across OECD countries from the mid-2000s to 2010 would suggest that there has been an overall increase in the uptake of farm management practices and systems beneficial to water quality in view of the strengthening of agri-environmental programmes in most countries, both in terms of the numbers of farmers and the agriculture land area covered under these programmes. Recent rises in real agricultural commodity prices, which are projected to continue over the next ten years (Figure 2.4), however, may have slowed or even reversed the previous upward trend in adopting management practices beneficial to water quality for some regions within countries. Deterioration in water quality of some water systems linked to agriculture over recent years provides further evidence to confirm this trend.

The *medium-term outlook* over the next ten years for OECD agriculture and water quality suggests that the projected growth in agricultural production in **North America**, **Turkey**, **Australia** and **New Zealand**, could further heighten pressure on water systems. This may result from the greater use of chemical inputs, farming more intensively fragile lands and/or expanding production onto marginal land not previously cultivated, and the increasing intensification of livestock production. For the **EU27** the projected modest growth in agricultural production is likely to lower pressure on water systems, while for **Japan** this trend could be more pronounced as production is projected to decrease. Localised water pollution "hotspots" could arise, however, in particular, from the continuing intensification of the livestock sector in both the **European Union** and **Japan**. At the same time, however, rising chemical input prices (fertilisers, pesticides) can have a counter-effect, by inducing farmers to use less of these inputs assuming no other changes in farm costs/output prices.

The medium and long-term outlook for agriculture is expected to be increasingly influenced by *climate change and climate variability*. The linkages between climate change, agriculture and water quality are likely to be complex, as increased flooding, for example, could mobilise sediment loads and associated contaminants and exacerbate impacts on water systems. On the other hand, more severe droughts could reduce pollutant dilution, thereby increasing toxicity problems.

Overall the expectations are that the task of achieving water quality objectives in agriculture will become more difficult in the coming years as a result of climate change. But these are tentative conclusions because of the uncertainties of current climate change research, and also as the linkages between climate change, agriculture and water quality are to date poorly researched.

6.2 Policy responses

In evolving policy responses to address the challenges outlined above, most OECD countries have typically relied on using a mix of economic instruments (*stimulation*), environmental regulations (*regulation*), and information instruments and other persuasive approaches (*persuasion*). A large range of measures have been deployed at the local, catchment, provincial through to national and transborder scales, across an array of different government agencies, with many initiatives that emphasise the voluntary adoption of pollution control practices in agriculture.

These policy measures have had varying success, within and between countries, in changing farming practices and systems leading to measurable improvements in water quality. But the mix of payments and regulations, supported by technical advice for producers to address water pollution in agriculture is encountering growing difficulties in

an increasing number of cases. This is in part because of the complexities of designing environmentally effective and economically efficient policies to address diffuse sources of water pollution in agriculture compared to point sources of pollution because they are:

- Usually invisible due to low concentrations or subsurface and/or diffuse pathways;
- Commonly difficult (or extremely costly) to measure or track with current monitoring technology;
- Generally cumulative in their impacts, that is to say impacts usually arise due to cumulative effects of runoff from large areas concentrating in water systems;
- Highly variable in space and time, due to natural phenomena such as the weather, soils, and topography, and hence, difficult to manage;
- Costly in terms of policy transaction costs to determine and monitor individual farmer emissions and implement policies for pollution abatement; and,
- Frequently require co-operation and agreement across sub-national jurisdictions (sub-catchments and catchments) or national borders.

Policies aimed at lowering agricultural pressure on water systems have also been encountering difficulties in many OECD countries, in particular, because of the:

- Rising government budgetary costs, and burden on taxpayers, of expenditure on programmes designed to mitigate water pollution from agriculture;
- Increasing monetary costs for water companies and consumers of drinking water, in treating drinking water to remove pollutants, as well as the growing costs as a result of agricultural pollution on commercial (fisheries), recreational, environmental and other social values that society attaches to water;
- Developing consensus that all agricultural producers should be included under programmes and regulations, given that voluntary participation can provide incentives for some farmers to avoid meeting regulatory provisions and/or provide payments to farmers who may not be the main source of pollution;
- Increasing frustration with traditional regulatory and institutional rigidities and complexities to adopt new policy and market approaches;
- Growing realisation that environmental issues, such as improving water quality, are complicated because of the stochastic interaction of human activity with the natural environment, and that there are frequently long time lags, from years to decades, between the implementation of a given policy measure, the change in farm management practices, and measurable improvement in water quality;
- Emerging comprehension of the low farmer awareness of their contribution to water pollution, and, even where awareness is higher among farmers this is rarely linked to the downstream impacts of farm practices in a water catchment;
- Continuing impediments to the more rapid and universal uptake by farmers of best management practices (BMPs) to lower water pollution from agriculture because of, for example, perceived high costs of adopting BMPs; lack of knowledge to undertake some BMPs; and limited labour and advice to undertake BMPs; and the,

- Mounting concern of how to address and prioritise the human health and environmental risks of contaminants from agriculture, especially emerging contaminants, so as to be better placed to optimise existing remediation technologies or develop new approaches to reduce risks.

6.3 Policy reforms

Policy reforms to improve the economic efficiency and environmental effectiveness of the current policy mix to lower agricultural pressure on water systems are important steps toward the sustainable management of water quality in agriculture. Where there are policy and market failures to address water pollution in agriculture, it can also help to seek and introduce innovative policy tools and market approaches to overcome these failures.

A key consideration in the increasing need to undertake reforms of existing policies and establish innovative measures is to focus on changing the behaviour of farmers, the agro-food chain and other stakeholders by (Blackstock *et al.,* 2010; Gouldson *et al.,* 2008):

- *Engaging* different actors to address the problems of water quality either on-farm or more broadly at the water catchment level;
- *Enabling* change by educating and raising awareness of farmers and building the capacity of other stakeholders in a water catchment in the realisation of policy goals;
- *Encouraging* desirable forms of behaviour and discouraging undesirable forms;
- *Ensuring* that minimum standards of water quality are met by, for example, enforcing compliance with regulations.

A strategy toward the sustainable management of water quality in agriculture, that seeks to lower budgetary expenditure of abatement programmes and reduces the external costs of agricultural pollution, while building on recent policy reforms in OECD countries should consider the following:

- *Integrate policy measures* so policies addressing pollution in agriculture are part of an overarching national water policy framework, so that all pollutants and polluters, not just agriculture, are considered together. This might also include a more balanced treatment across types and sources of pollution, especially pesticides in the case of agriculture. Establishing policy measures at the water catchment (or sub-catchment) level, so as to provide a more integrated and holistic management approach to the environment, in a context that includes social, economic and political considerations. It is also essential to recognise that agriculture-water quality linkages are part of broader systems including: natural water and nitrogen cycles; human and environmental land-water interactions; and interactions between water quality, water resources, agricultural and environmental policies.
- *Use a mix of policy instruments* (economic instruments, regulations and information instruments) to address water quality issues in agriculture. This approach is more likely to outperform a single policy instrument, such as a pollution tax, especially where there are multiple impediments to adoption of pollution abatement practices. This is because each policy instrument has strengthens and weaknesses depending on the specific physical and economic context of the polluted area. The sequencing of policy

instruments, starting with suasion and ending with enforcement, is likely to be as important as the policy mix and the targeting of the major polluters. This needs to be underpinned by scientific knowledge of the specific water pollution problem.

- *Enforce compliance of regulatory provisions,* by improving on-farm inspection of good farming practices, and where non-compliance occurs ensure that sanctions and penalties are effectively imposed. As water quality protection programmes in agriculture, however, are expanded to cover a broader range of best management practices and a wider range of producers, that can make programme monitoring technically complex and enforcement more costly.
- *Remove perverse incentives in agriculture.* As conflicts exist between agricultural support programmes that provide incentives to increase production and those policies seeking to reduce the environmental damage, including water pollution, that such programmes can provoke. Some 50% (2008-10) of total OECD agricultural producer support continues to be based on commodity output and non-constrained variable input use, although this is a marked reduction from the 85% share in 1986-88 (Figure 1.3).
- *Encourage appropriate farm management practices to internalise a farm's environmental costs through implementation of the Polluter-Pays-Principle (PPP).* This can improve economic efficiency, such as by using a pollution tax, as long as transaction costs do not exceed the benefits of other policy instruments. But application of the PPP in agriculture is not widespread across OECD countries, mainly because diffuse source water pollution cannot be measured at reasonable cost with current monitoring technologies (which does not apply to point sources of pollution), and also due to property right, institutional and other barriers. However, where high levels of taxes or charges have been applied to chemical inputs, usually coupled with a mix of other policy instruments, they have led to major reductions in input use without loss to agricultural production or farm income.
- *Set targets and standards,* which can help to reveal progress for a given programme. Targets need to be realistic, easily measurable and have a clear time frame. In addition, standards need to be consistent with known biophysical responses, in particular, in the case of water quality take into account time lags between the introduction of a practice and measurable outcomes. Moreover, targets and standards need to consider the difficulties of measuring and establishing the origin of agriculture diffuse pollution.
- *Improve the spatial and temporal targeting of policies,* so that the specific payment or policy instrument choice is sensitive to local conditions and the general characteristics of a problem. Land retirement policies, for example, can be a particularly blunt instrument to achieve water quality goals as while they may help slow rates of soil erosion they do not require any changes to management practices on land under production that continues to contribute to water pollution. Also in some cases the primary objective of land retirement policies may be biodiversity conservation rather than improving water quality. Moreover, while some programmes target practices on land under production, this land may not be the most important source of pollution as participation in the programme is often voluntary and farmer initiated.

  A further problem with the reliance on incentive payments under voluntary conservation measures to help reduce agricultural water pollution is they can become uncompetitive as crop prices rise. With cereal and oilseed crop prices, especially, maize, projected to rise over the next ten years (Figure 2.4), conservation programmes will become more

uncompetitive compared to cultivating land for production, while higher crop prices may also encourage production on more erodible and marginal land to the detriment of water quality.

- *Establish innovative policy tools and market approaches*. These tools and approaches, albeit not widely used to date, mainly include: economic instruments, especially water quality trading; private and voluntary regulation supported by payments in some cases, such as between water supply utilities working with farmers to ensure improved water quality to lower water treatment costs; information based instruments, for example, organic standards; and support mechanisms and capacity building, such as farm advisory services provided by agro-food chain companies to encourage best management practices to improve water quality.

  Compared to the traditional mix of policy instruments to address diffuse source water pollution in agriculture, these approaches tend to be more self regulatory and privately organised. They also usually take into account water catchment conditions, go beyond the requirements of regulations providing a more preventative approach to pollution, and are typically more targeted than pollution taxes and agri-environmental payments. Water quality trading, for example, allows wastewater treatment plants and municipal stormwater programmes that face higher nutrient reduction costs to save money by purchasing credits to meet a portion of their nutrient reduction obligations from farmers who generally face lower costs, such as from introducing riparian buffers and conservation tillage as pollution abatement practices. As a result, trading can help achieve overall nutrient reductions in a more cost-effective manner. Trading therefore creates new revenue opportunities for farmers, entrepreneurs, and others who can generate nutrient credits.

  But these policy tools and market approaches can suffer from a number of weaknesses. Co-operative agreements, for example, are often voluntary and usually the agreement is limited in its duration. In areas of significant water pollution from agriculture, it might be difficult to reach an agreement if farmers have excessive demands for compensation. There are also generally no penalties for not complying with co-operative agreements, other than withholding payments where these apply. For water quality trading, further research is required to determine the best application of this tool for diffuse source water pollution in agriculture to gain wider acceptance.

- *Examine the cost effectiveness of different policy options*, to address water quality issues in agriculture. In designing policy options to improve water quality in agriculture it is necessary to consider both the abatement costs incurred by the producer as well as the programme monitoring and enforcement costs, compared to the benefits generated by the policy in terms of improving water quality. Evidence from some OECD countries shows that expenditure on reducing diffuse source agricultural pollution has not been cost effective and that incentive schemes to enhance compliance have been inadequately targeted. The cost of different policy options policies depends on the: specific farm practices chosen (e.g. riparian buffers); the scale from farm to national; and the selected policy tools (e.g. taxes, payments, trading). Determining the cost effectiveness of different policies options to deliver water quality benefits in agriculture, enables a more informed discussion about what can be achieved environmentally with limited budgets, and also about the agricultural production and environmental trade-offs in achieving those benefits.

- *Invest in programmes that will deliver long-term outcomes.* Given the reality of a fixed budget in most water quality programmes, policy makers face a trade-off between investing in projects that will have an immediate effect and investing in actions that may have a larger impact over the long term. Such longer-term investment might include, for example, investing in research to develop new technologies and data collection to allow improved decision making to address diffuse source pollution.

- *Avoid adverse environmental side effects and encourage co-benefits.* Programmes undertaken to *improve* water quality can have negative consequences for another environmental problem. Illustrative is where a single pollution source such as nitrogen from livestock farming can simultaneously cause water and air pollution. Hence, a logical response for a farmer to meet water quality regulatory standards might be to reduce the nutrient content of manure spread on fields by allowing more nitrogen to be released from manure storage facilities, thereby releasing ammonia into the air. On the other hand some policy approaches to abate water pollution run-off can have co-benefits with other environmental goals. Illustrative is the development of on-farm riparian buffers which can help to limit pollutant runoff but can also provide other benefits in terms of wildlife habitats and carbon sequestration by establishing green cover.

- *Develop the best available technical and socio-economic information.* Agriculture's linkages to *w*ater quality are complex and require considerable technical and socio-economic *information* about the likely impact (science), costs (economics) and farmer reactions (social) to management changes, to better guide policy makers and form part of the overall policy reform programme to address water pollution. There is greater focus in the scientific community to see agricultural impacts on water quality in the broader and inter-linked context of hydrological (i.e. "cloud to coast") and ecological processes (i.e. land-water management interactions).

  But improving the science and information base to better manage agricultural impacts on water systems, will require increased collaboration among policy makers, scientists, economists and other social scientists. Research can also help farmers by improving the understanding of the links between different farm practices on the fate and transport of pollutants into water systems, for example, the width and type of riparian buffers most effective in reducing nutrient, pesticide, and soil runoff into waterways. Moreover, it is important to appreciate that a farmer has to consider the management of the whole farm operation, and not just those elements of the business important to water quality.

6.4 Policy governance and institutions

The success in executing the policy reforms and policy opportunities outlined in this chapter, will greatly depend on institutional structures and processes, as well as property rights, to implement and govern policy changes. At present most OECD countries have a myriad of regulations and institutions that either directly or tangentially govern the relationship between agricultural production and water quality outcomes. The complexity of agricultural and environmental policies, coupled with the unique characteristics of diffuse source water pollution, makes it difficult to create unambiguous incentives, governance structures, and property right arrangements to internalise pollution costs. Generally, each institution or water quality programme relevant to agriculture pursues its own goals without reference to the environmental incentives (or disincentives) it creates.

A further complication is the relative speed with which the structural change in agriculture can intensify and exacerbate diffuse source pollution problems, such as structural changes in the livestock sector and the disposal of manure. Political and regulatory change usually happens at a much slower pace, so that by the time the problem is recognised and solutions are proposed, more intensive farming practices are well established.

Illustrative of these governance challenges is the example of the ***Baltic Sea Action Plan*** (BSAP) to reduce eutrophication of the Baltic Sea (Chapter 5.7). For signatory countries under the BSAP, there is a multiplicity of governmental levels and branches involved in decision making for water management. This occurs from the sub-national, national, through to the **EU** level, which opens up the potential for conflicting policy decisions based on local, sectoral or EU-level interests. Hence, this has the potential to hamper the implementation of the internationally agreed nutrient reductions under the BSAP, although EU legislation is increasingly trying to harmonise with the BSAP. Similar issues arise within countries, for example, the co-operation of the six states surrounding the Chesapeake Bay estuary in the **United States** (Chapter 5.2).

There are a number of drivers that are likely to improve the effectiveness of governance structures addressing water pollution from agriculture, including the:

- Extent of commitment from key groups in a catchment, including political commitment;
- Levels of stakeholders' understanding of specific water quality concerns;
- Importance of timing by governance structures, especially reducing the time from inception to effect of a water quality project;
- Definition of a clear message by institutions as to the goals of a water quality project;
- Encouragement of the maximum degree of social regulation among stakeholders; and the,
- Development of social capital in building networks, co-operation and trust among stakeholders.

Many of the elements listed here are commonly included under integrated water catchment approaches to water management being undertaken by many countries. Addressing water pollution from agriculture at the catchment level, not only facilitates the involvement of all the relevant stakeholders, including the farming and non-farming community, but also offers scope for better targeting of mitigation efforts. Hence, as policies to reduce pollution from agriculture evolve, this can be integrated with efforts targeting other diffuse and point sources of pollution, such as from intensive livestock facilities, urban and industrial sources.

Essentially integrated water catchment management refers to the process by which stakeholders can develop a common vision, agree shared values, make collective informed decisions and manage together the catchment. This process involves integration of water users, polluters, scientists, government institutions and other interested stakeholders. Tradeoffs can then be initiated between these various interests in an open and transparent way, where the focus is on synergy and win-win solutions. The guiding principles of an integrated catchment management approach should be as follows.[1]

- *Knowledge-based,* as the biophysical system and the socio-economic system together form one, complex, close-knit "socio-ecological" system, and in order to improve management it is necessary to understand this complex relationship better;
- *Adaptive,* as the social-ecological-economic system is so complex, and non-linearities are an inherent element of it, approaches need to be adaptive to changes in the system, including the increasing risks of climate change and climate variability;
- *Participatory,* as the effectiveness of water quality management has been shown to increase by the involvement of all relevant stakeholders, and through the interaction of the stakeholders provides the organisational structure for integrated water catchment management to develop.

The move towards water catchment plans and levels of water governance, however, has brought with it some challenges. Monitoring and enforcement of national level government regulations and water quality standards and targets is sometimes weak at the local, water catchment and sub-national level. Experiences in the Chesapeake Bay in the **United States**, implementation of the **European Union**'s *Nitrate Directive,* and enforcement of water policy at the regional level in **New Zealand**, are all recent examples where central government has had to intervene because of poor governance and enforcement of water quality regulations at the regional water catchment level. Nevertheless, there are many examples across OECD countries that have been successful at implementing policies at sub-national levels to address water pollution from agriculture, as examples in this report have highlighted.

While policy making needs to focus at the water catchment level to address diffuse source agricultural water pollution, this needs to be balanced and accompanied by efforts and linkages at both the sub-catchment level, but also through to the national scale, and where relevant the trans-national boundary level.

Note

1. These guiding principles are based on case study material provided to the OECD Secretariat by the United Kingdom Delegation to the OECD.

Bibliography

Blackstock, K.L., J. Ingram, R. Burton, K.M. Brown and B. Slee (2010), "Understanding and influencing behaviour change by farmers to improve water quality", *Science of the Total Environment*, Vol. 408, Issue 23, pp. 5631-5638.

Gouldson, A., *et al*. (2008), "New alternative and complementary environmental policy instruments and the implementation of the Water Framework Directive", *European Environment*, Vol. 18, pp. 359-370.

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Chapter 2. Agriculture and water quality: Sources, trends, outlook and monitoring
Chapter 3. Monetary costs and benefits of agriculture's impact on water systems
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