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).

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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		860	1 257
	• Baltic Sea eutrophication		492 – 1 466	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.

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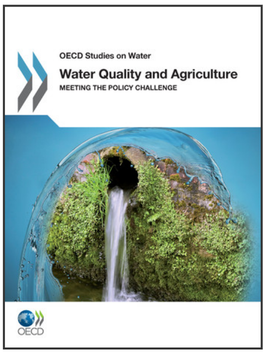

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