OECD Environment Working Papers No. 155

Managing the biodiversity impacts of fertiliser and pesticide use: Overview and insights from trends and policies across selected OECD countries

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https://dx.doi.org/10.1787/63942249-en

OECD

Organisation for Economic Co-operation and Development

ENV/WKP(2020)2

Unclassified **English - Or. English**

5 March 2020

ENVIRONMENT DIRECTORATE

Managing the Biodiversity Impacts of Fertiliser and Pesticide Use

Overview and insights from trends and policies across selected OECD countries – Environment Working Paper N°155

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Authorised for publication by Rodolfo Lacy, Director, Environment Directorate.

Keywords: biodiversity conservation, ecological economics, ecosystem services, government policy, environment & development, agricultural policy

JEL Classification: Q24, Q57, Q58, H23

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Abstract

This paper reviews the impacts and costs of pesticide and fertiliser pollution as well as the policy responses to counter these in selected OECD countries. More specifically, the paper begins with an overview of the main biodiversity and health impacts of excess pesticide and fertiliser. In economic terms, nitrogen pollution, for example, has been estimated to cost the European Union between EUR 70 billion and EUR 320 billion per year. The paper also provides an overview of the trends in both pesticide sales (per 1000 ha of agricultural land area), and pesticide use (in tonnes of active ingredients), as well as soil nutrient balances in OECD countries before reviewing policy instruments available to promote more sustainable fertiliser and pesticide use. Case studies of specific policy responses used to address adverse impacts of pesticides including in Denmark and France are presented along with case studies of policies to counter nutrient pollution in Denmark, Japan and the United States. Based on the literature review and case studies, the paper concludes with policy insights and recommendations.

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Résumé

Cet article examine les impacts et les coûts de la pollution par les pesticides et les engrais, ainsi que les mesures que les pouvoirs publics ont mises en œuvre dans une sélection de pays de l'OCDE. Plus précisément, le document commence par un aperçu des principaux effets sur la biodiversité et la santé de l'excès de pesticides et d'engrais. Sur le plan économique, la pollution par l'azote, par exemple, coûterait à l'Union européenne entre 70 et 320 milliards d'euros par an. Il décrit également les grandes tendances des ventes de pesticides (exprimées par millier d'hectares de terres agricoles) et de leur utilisation (exprimée en tonnes de substances actives), ainsi que les bilans nutritifs dans les pays de l'OCDE. Il passe en revue les actions possibles pour promouvoir une utilisation plus durable des engrais et des pesticides. Des études de cas présentent, d'une part, les actions menées pour limiter les impacts négatifs des pesticides au Danemark et en France, notamment, et, d'autre part, les instruments mis en œuvre pour lutter contre la pollution par les engrais au Danemark, aux États-Unis et au Japon. S'appuyant sur ces études de cas et une revue de la littérature, l'article apporte des éclairages sur l'action publique et formule des recommandations.

Codes JEL : Q24, Q57, Q58, H23

Mots-clés : préservation de la biodiversité, économie de l'écologie, services écosystémiques, politiques publiques, environnement et développement, politique agricole

Acknowledgements

This report has been prepared by Megha Sud, who was formerly with the OECD Environment Directorate. It was prepared under the supervision of Katia Karousakis (ENV/CBW). Comments and suggestions from Guillaume Gruére (TAD/ARP), Santiago Guerrero (TAD/ARP), Bob Diderich (ENV/EHS), Richard Sigman (ENV/EHS), Leon van der Wal (ENV/EHS), Magdalini Sachana (ENV/EHS), Gérard Bonnis (ENV/CBW) and Simon Buckle (ENV/CBW) are gratefully acknowledged. The paper has also benefitted from comments and input from Delegates to the OECD Working Party on Biodiversity, Water and Ecosystems (WPBWE), as well as the Joint Working Party on Agriculture and Environment and the Working Party on Pesticides.

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1. Biodiversity, ecosystems and agricultural intensification: an introduction

Agriculture is a major form of land use covering approximately 37.5% of global land area (World Bank 2017). In OECD member countries on average 35.6% of land area is under agricultural use, with wide variations amongst countries[1] (OECD 2013a). Agricultural land use provides a range of benefits including production of food, fodder, fibre, input for industry, and employment. Agricultural can also provide a variety of ecosystem services such as biodiversity habitat provisioning (especially in low intensity agro-systems), carbon sequestration, and resilience to natural disasters and shocks[2] (FAO 2019, OECD 2015b, OECD 2008). The agricultural sector (and some forms of agriculture in particular) however also exerts significant pressure on biodiversity, predominantly through conversion of land for agricultural expansion and through adverse impacts of input-intensive agriculture (OECD 2017e).

Expansion of agricultural land area has led to several negative impacts on biodiversity, yet this expansion contributed relatively little to global food supplies with most production gains having been achieved through agricultural intensification (Foley, et al. 2011). Intensive agriculture can also result in high environmental costs including loss of biodiversity and related ecosystem services (TEEB 2015, Foley, et al. 2011, Kleijn, et al. 2009, Green, et al. 2005). This is closely related to factors such as increased use of chemical inputs (per unit area) such as pesticides and fertilisers. Nitrogen (N) deposition, of which agricultural activities are the dominant source, has been projected to be one of the three major pressures on biodiversity between 2000 and 2100 (Sala, et al. 2000). The Global Biodiversity Outlook 3 found that nutrient pollution was one of the five main and growing pressures on biodiversity[3] (SCBD 2010). The most recent assessment of biodiversity for food and agriculture by the FAO found that "loss and degradation of forest and aquatic ecosystems and, in many production systems, transition to intensive production of a reduced number of species, breeds and varieties, remain major drivers of loss of biodiversity and ecosystem services" (FAO 2019). These negative environmental impacts on biodiversity can in turn jeopardise agricultural yields (OECD 2017).

Acknowledging the magnitude of the challenge involved, several calls have been made at the international level to address pesticide and fertiliser pollution. Under the Convention on Biological Diversity for example, Aichi Target 8 states: "By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity". Similarly, Target 14.1 of the Sustainable Development Goals is to prevent and significantly reduce marine pollution of all kinds, in particular from land-

[1] Countries such as Denmark (62%), France (52.5%) and USA (47.9%) have much of their land under agricultural use whereas in Japan and Sweden the percentage is much lower (12.4% and 7.4% respectively).

[2] Such as flooding, landslides, fire and snow damage.

[3] The others being: loss, degradation and fragmentation of natural habitats; overexploitation of biological resources; impacts of invasive alien species; and climate change and acidification of the oceans associated with the build-up of greenhouse gases in the atmosphere.

based activities, including marine debris and nutrient pollution by 2025[4]. In the context of pesticides, the International Code of Conduct on the Distribution and Use of Pesticides[5], adopted by the FAO council, serves as the globally accepted voluntary standard for pesticide management for all public and private entities engaged in, or associated with, pesticide distribution and use, particularly where there is inadequate or no national legislation to regulate pesticides[6].

[4] Also of relevance, SDG Target 2.4 is to "ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality" by 2030.

[5] http://www.fao.org/docrep/005/y4544e/y4544e00.htm.

[6] See Annex 1.1 for further information on international initiatives to manage pesticide use.

2. Biodiversity and human health impacts of excessive use of pesticides and fertilisers

Chemical inputs to agriculture, notably pesticides[7] and fertilisers, have played a major role in increasing global crop yields, contributing to food security and higher incomes for farmers (Sutton, Bleeker, et al. 2013, Popp, Pető and Nagy 2012). Pesticides have also provided a variety of other benefits along with enabling a more consistent yield, through protection of crops from pests and diseases. These include improved shelf life of produce and reduced management costs; reduced drudgery of weeding freeing labour for other tasks; reduced soil disturbance; reduced fuel use for weeding; control of invasive species; increased quality and yield of livestock and controlling human and livestock disease vectors (Cooper and Dobson 2007). Improper or excess-use of pesticides and fertilisers[8] however, can carry significant costs to the environment and to human health, depending on factors such as toxicity, mobility and persistence in the environment.

2.1. Impacts of pesticide pollution

Certain pesticides can lead to a decline in beneficial pest predators (Pimentel and Greiner 1997) and essential pollinators (Potts, et al. 2016) threatening crop yields. The impact of pesticides is not limited to farms as they are dispersed through the air, leach into the soil (Gil and Sinfort, 2005) and groundwater, run-off into surface water (Chopra, Sharma and Chamoli 2011), leave residues in food products and bio-accumulate in food chains9 (Reyes, et al. 2014, Gerber, et al. 2016), negatively impacting humans, livestock and wildlife (TFSP 2015). Moreover, risk of contamination can persist for decades as many pesticides remain in the environment over long periods of time (UNHRC 2017).

Various studies have shown that excessive use of pesticides has led to biodiversity loss and ecosystem degradation (Green, et al. 2005, Kleijn, et al. 2009). In particular, pesticide use has contributed to reducing populations of birds, insects, amphibians and aquatic and soil communities, either through direct exposure or reduction in food and habitat availability (Kennedy, et al. 2013, Hallmann, et al. 2014). A Europe-wide study found that insecticide and fungicide use had consistent negative effects on biodiversity and that insecticides also reduced the potential for biological pest control (Geiger, et al. 2010). Indirect effects of pesticides have been identified as one of the main causes of the decline in farmland birds

[7] The term 'pesticides' generally includes both chemical and biological pesticides; however, for the purposes of this document, the term only applies to chemical pesticides. These include insecticides, fungicides and herbicides and other chemical agents. It is to be noted that use and effects of substances vary between and within these categories.

[8] Excess nutrient use refers to inputs into an agricultural system that are in excess of what can be readily absorbed by intended target plant.

[9] Pesticides such as organotins accumulate and magnify through marine food web systems leading to significant health risks for those who consume greater amounts of seafood (Köhler and Triebskorn 2013).

in several European countries[10] (Geiger, et al. 2010, Donal, Gree and Heath 2001). This decline is reflected in the falling trends for farmland bird index[11] in several OECD countries (Figure 2.1). Trends show that farmland bird populations have continued to decline between 2002-14 in almost all OECD countries that monitor them. Moreover, the rate at which farmland bird populations declined has accelerated in the most recent decade (OECD forthcoming). Key factors explaining declining farmland birds trends include increased use of insecticides per hectare along with other factors such as the loss of landscape heterogeneity (particularly extent of crop fields without trees, bushes and other woody elements), as well as hotter temperatures (OECD forthcoming).

Neonicotinoids (a class of widely used insecticides) for instance, are linked to a range of impacts including soil degradation, water pollution and endangering biological pest control (TFSP 2015). A 2014 study showed that in the Netherlands local population trends of insectivorous birds were significantly more negative in areas with higher surface-water concentrations of a commonly used neonicotinoid insecticide, imidacloprid. At imidacloprid concentrations of more than 20 nanograms per litre, bird populations tended to decline by 3.5 per cent on average annually (Hallman et. al., 2014).Neonicotinoids also represent risks to pollinators (EFSA 2018), which is a cause for concern given that wild pollinator populations have declined in North West Europe and Northern America[12] (IPBES 2016). 75% of honey samples from across the world were found to contain neonicotinoids, confirming the global exposure of bees to this class of insecticides (Mitchell, et al. 2017). Given the growing evidence of risks, the EU restricted the use of three widely used neonicotinoids[13] in 2013 and decided to extend this to a full ban on the outdoor use of these neonicotinoids in 2018 (Belenkinsop, 2018).

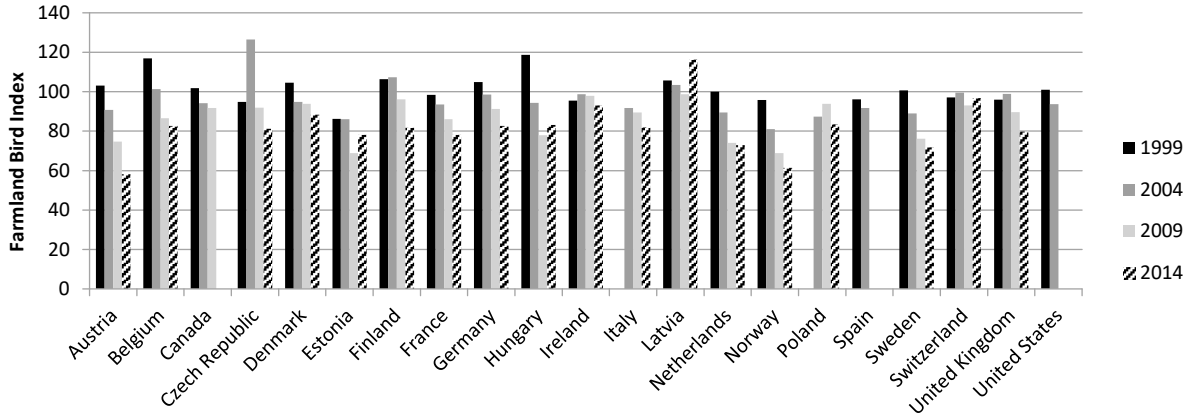
[10] Types of pesticides that have been found to lead biodiversity decline include neonicotinoids, organophosphates, pyrethroids and fipronil (a chemical substance that belongs to phenylpyrazole chemical family) among others (van der Sluijs, et al. 2015, Hallmann, et al. 2014, Kleijn, et al. 2009).

[11] The farmland bird index is the average trend in a group of species suited to track trends in conditions of farmland habitats. While bird populations are impacted by agricultural activities, other factors external to farming may also affect population dynamics, for example, changes in populations of 'natural' predators, the weather, and climate change.

[12] There is a lack of data for Latin America, Asia, Africa and Oceania to make global assessments.

[13] Namely, clothianidin, imidacloprid, and thiamethoxam.

Figure 2.1. Farmland Bird Index



Note: Due to absence of data for 2014, data for Germany is from 2013
Source: Data from OECD Agri-Environmental indicators database
http://www.oecd.org/agriculture/sustainable-agriculture/agri-environmentalindicators.htm.

A large scale study conducted in 2014 monitored 223 organic chemicals in 4,000 rivers and lakes in Europe and found that half of these water bodies had levels of pesticides that could harm key aquatic organisms such as fish, insects and algae (Malaj, et al. 2014). Another study found that 700 out of the 1566 surface water sites examined across EU, were polluted with insecticides above the regulatory acceptable concentrations (Stehle and Schulz 2015). A similar observation was also reported for fungicides (Knäbel, et al. 2014).

Direct or indirect exposure[14] to certain pesticides can also have negative effects on human health, including acute toxicity, carcinogenicity, reproductive and neurodevelopmental disorders and endocrine disruption (Alleva et.al., 2018; Kim et.al. 2017, WHO, 1990). Effects can range, depending on the toxicity of the substance and severity of exposure, from headaches, nausea and skin problems to severe illness and fatalities (Bourguet and Guillemaud 2016). In several cases possible health and environmental impacts have not been comprehensively evaluated. Moreover, the 'cocktail' effect of exposure to multiple pesticides and other chemicals is inadequately understood (Eyhorn, Roner and Specking 2015).

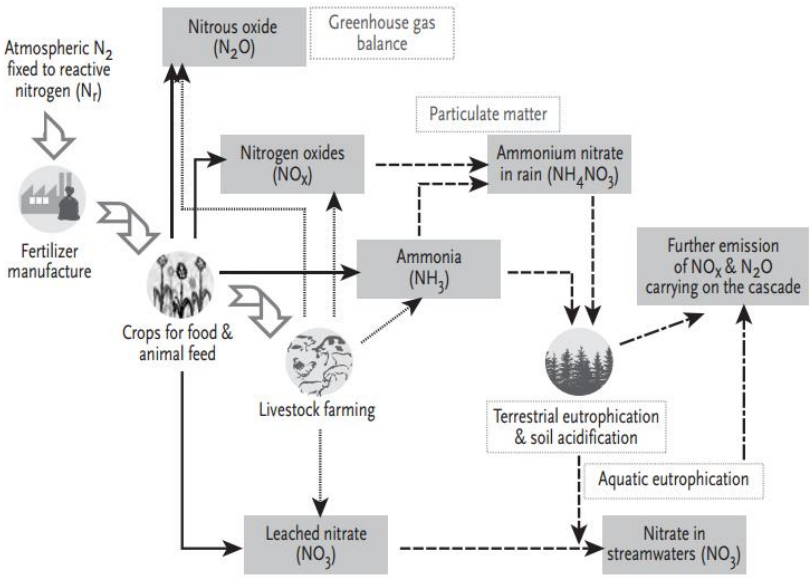
2.2. Impacts of nutrient pollution from fertilisers

Nutrient pollution from improper and excessive fertiliser use also has several negative consequences for ecosystems. These include both direct toxicity to organisms (high concentrations of N can be toxic to organisms that absorb elements directly from the environment such as algae, lichens or bryophytes) and indirect impacts through factors such as nutrient enrichment, oxygen depletion in aquatic ecosystems, soil or water acidification or intensifying the impact of other stressors such as pathogens, invasive species and climate change (Erisman, et al. 2013). The main consequence of phosphorus (P) pollution is

[14] Direct exposure includes occupational exposure or exposure of populations in areas around where pesticides are used. Indirect exposure includes exposure through consumption of contaminated food and water.

eutrophication of fresh waters. N pollution leads to a variety of impacts including coastal and marine eutrophication, groundwater pollution, changes in species composition[15], increased atmospheric concentrations of N2O (both an important greenhouse gas and stratospheric ozone depleting substance), increase in NOx resulting in atmospheric smog and ozone, and acidification of soil and freshwater (Tilman, Fargione, et al. 2001) (see Figure 2.1). Nutrient run-off from fertilisers has contributed to more than 500 hypoxic zones due to eutrophication around the world, covering 250,000 km sq. of ocean area (Rabotyagov, et al. 2014, UNDP 2012). Global trends point to continued deterioration of coastal waters owing to pollution and eutrophication. Of the 63 large marine ecosystems evaluated under the Transboundary Waters Assessment Programme, 16% of the ecosystems are in the "high" or "highest" risk categories for coastal eutrophication due to nutrient run-off[16] (UN ECOSOC 2017).

Figure 2.2. Simplified representation of successive losses of N from fertiliser use



Source: Sutton, Erisman and Oenema (2007) Strategies for controlling nitrogen emissions from agriculture: regulatory, voluntary and economic approaches

The potential impacts of nutrient pollution on human health include skin, respiratory and cardiovascular diseases and cancers, resulting from particulate matter and ground-level ozone (created when nitrogen oxides react with organic compounds), algal blooms of potentially toxic blue-green algae (cyanobacteria) and nitrate toxicity in drinking water (USEPA 2018; Manuel 2014; Erisman, et al., 2013; Brink, van Grinsven et. al., 2011; Mallin 2009).

[15] It is estimated that NH3 and NOx emissions have reduced forest biodiversity by more than 10% over two-thirds of Europe (Sutton, 2011).

[16] They are located mainly in Western Europe, Southern and Eastern Asia, and the Gulf of Mexico.

2.3. Economic costs of pesticide and fertiliser pollution

About half of the nitrogen in fertiliser and manure applied in Europe is lost to the surrounding environment (Sutton 2011). In economic terms, nitrogen pollution is estimated to cost the European Union between EUR 70 billion and EUR 320 billion per year[17](Sutton et. al., 2011). The highest societal costs are associated with loss of air quality and water quality, linked to adverse impacts on ecosystems and human health (Brink, van Grinsven et. al., 2011).

Similarly, in the case of pesticides, evidence shows that in several cases, reduction in pesticide use is possible without affecting productivity or profitability of farms. In France for instance, one study found that it is possible to reduce pesticide use by 42% without consequence on yields in 59% of the farms examined (Lechenet, et al. 2017), while another study concluded that it would be possible to reduce pesticide use by 30% nationally without reducing farmers' incomes (Jacquet, Butault and Guichard 2011).

Pesticide and fertiliser pollution also entail substantial negative externalities or hidden costs (see Table 2.1 for hidden costs related to pesticide use)[18]. In the United Kingdom, the total annual costs of environmental and health externalities of agriculture was conservatively estimated at GBP 2 343 million for 1996 alone (range for 1990-1996: GBP 1 149-3 907 million). These externalities comprised 89% of average net farm income (GBP 2.62 billion), and 13% of average gross farm returns (GBP 17.46 billion) for the 1990s (Pretty, et al. 2000). One assessment of pesticide costs in the United States estimated these to be around at USD 9.6 billion per year in environmental and societal damages[19]. The main losses were attributed to public health (USD 1.1 billion); pesticide resistance in pests (USD 1.5 billion); crop losses caused by pesticides (USD 1.4 billion); bird losses due to pesticides (USD 2.2 billion); and groundwater contamination, (USD 2.0 billion) (Pimentel and Burgess, 2014). Another assessment estimated the external costs of pesticide use in the United States to be higher at USD 12.5 billion annually (including USD 9.5 billion for human health, and USD 3 billion for environmental impacts), and amounting to a cost of USD 42 imposed from every hectare of agricultural land (Koleva and Schneider 2009).

Potential damages from agricultural N use in the United States have been estimated at USD 59 to USD 340 billion per year (a median of USD 157 billion per year) (Sobota et al 2015). Similarly, in Europe, the annual cost of pollution by agricultural N was estimated in the range of USD 35 to 230 billion per year (in contrast to the estimated economic benefit of

[17] In comparison, this study estimates that manufactured fertilizer produces a direct benefit to European farmers, in terms of crops grown, of €20 billion to €80 billion per year, when the long-term benefits are included.

[18] While several estimates for national annual external costs of fertilisers and pesticides have been reported in the literature (see OECD, 2017[108] for a review of recent literature on estimated annual costs of water pollution including form fertilisers and pesticides), these use different methodologies and account for different variables. The estimates are therefore not comparable across studies or across countries. Despite this, such estimates serve to illustrate the large magnitude of external costs and the need to reduce these.

[19] This assessment includes the following impacts: pesticide impacts on public health; livestock and livestock product losses; increased control expenses resulting from pesticide-related destruction of natural enemies and from the development of pesticide resistance in pests; crop pollination problems and honeybee losses; crop and crop product losses; bird, fish, and other wildlife losses; and governmental expenditures to reduce the environmental and social costs of the recommended application of pesticides.

N in primary agricultural production in the range of USD 20 to 80 billion per year) (van Grinsven et. al., 2015).

A portion of this cost is comprised of the cost to water companies in dealing with diffuse pollution from fertilisers and pesticides. In the UK water companies spent GBP 189 million removing nitrates and GBP 92 million on removing pesticides from water supply between 2004-2005 and 2008-2009 (National Audit Office 2010). In France, impacts of agricultural nitrate emissions and pesticides on water resulted in an estimated annual cost of EUR 610 and 1 070 million, respectively (Marcus and Simon 2015). Prevention of diffuse pollution is often more cost effective than treatment/restoration options (OECD 2017b). There is therefore an urgent need for policies that promote improved management and efficient use of pesticides and fertilisers in order to minimise external costs and reduce adverse impacts on ecosystems as well as human health.

Estimates suggest that there is a strong economic case to undertake actions that would stimulate improved nitrogen use efficiency (NUE) across a range of sectors including agriculture, transport, industry, waste and recycling and societal consumption patterns. An improvement of 20% in NUE by the year 2020 relative to 2008, would carry an indicative mitigation cost estimated at USD12 (5–35) billion and would lead to a global saving of 23 million tonnes of nitrogen, worth an estimated UDS 23 (18–28) billion. The value of annual benefits to the environment, climate and human health would be much greater, estimated at around USD 160 (40–400) billion. (Sutton, et al. 2014).

Table 2.1. Hidden and external costs of pesticide use

Category of cost	Pesticide impact	Hidden costs			External costs	
		Decrease in benefits (due to lower yields)	Increase in "usual internal costs" (due to increase in amount of pesticide applied)	Generation of other internal costs	Private external costs	External costs sensu stricto
Regulatory cost	Public research, communication, expertise on pesticides					X
	Regulations, decrees and laws					X
	Mandatory pesticide handling and disposal			X		
Human health costs	Preventive medicine, annual check-ups			X	X	
	Health issues for farmers	X		X	X	
	Health issues for the public					X
Environmental costs	Pesticide resistance	X	X			X
	Soil degradation	X				X
	Pollination decrease	X				X
	Decrease in natural enemies	X	X			X
	Lower plant production due to herbicide application	X				
	Bee renting			X		
	Degradation of the farm environment				X	
	Livestock health issues				X	
	Degradation of the environment					X
	Domestic animal health issues					X
Defensive expenditure	Purchase of protective clothing, glasses and masks			X		
	Purchase of organic food and bottled water					X

Notes:
Regulatory costs are those entailed as part of private or public mandatory measures to remove pesticides, to protect the environment or human health from the potential damage caused by pesticides and/or to repair damage already inflicted.
Human health costs are the expenses associated with acute or chronic pesticide poisoning.
Environmental costs are the costs of both pesticide damage to animals, plants, algae and micro-organisms and pest resistance to pesticides. These costs may be incurred by farmers or by society as a whole.
Defensive expenditures cover all expenses by farmers and society to prevent pesticide exposure, such as the purchase of organic food or bottled water consumption.
The above mentioned broad categories of costs include both internal and external costs. The internal costs of pesticide use are the costs to the farmer of pesticide use within the agricultural production process. These costs impact the price of the final product, i.e. they are internal to the market.
"Usual" internal costs of pesticide use include market prices of pesticides, taxes on these products, costs of the application, transport and storage of pesticides, accounting costs, etc. Whereas costs associated with the impact of pesticides on the environment and human health, regulatory measures and defensive behaviour are "hidden" in the sense that farmers are not necessarily aware of them.

Source: Bourguet and Guillemaud (2016) The Hidden and External Costs of Pesticide Use.

3. Trends in pesticide sale and use and nutrient balances

This section summarises the trends in both pesticide sales (per 1000 ha of agricultural land area), and pesticide use (in tonnes of active ingredients), as well as soil nutrient balances. It is important to note that national level trends in pesticide and fertiliser use are not sufficient to interpret environmental outcomes. Pesticides, for example, differ in doses required for effectiveness, toxicity and persistence and their need and impact depends on the context (such as timing of application, climate and crop type). A more useful measure in the case of pesticides would be indicators on pesticide risk[20]. Due to the lack of comparable cross-country data on risk however, commonly used proxy indicators include pesticide and fertiliser sales and use, nutrient balances[21], and nutrient use efficiency (the ratio between the amount of fertiliser N removed with the crop and the amount of fertiliser N applied).

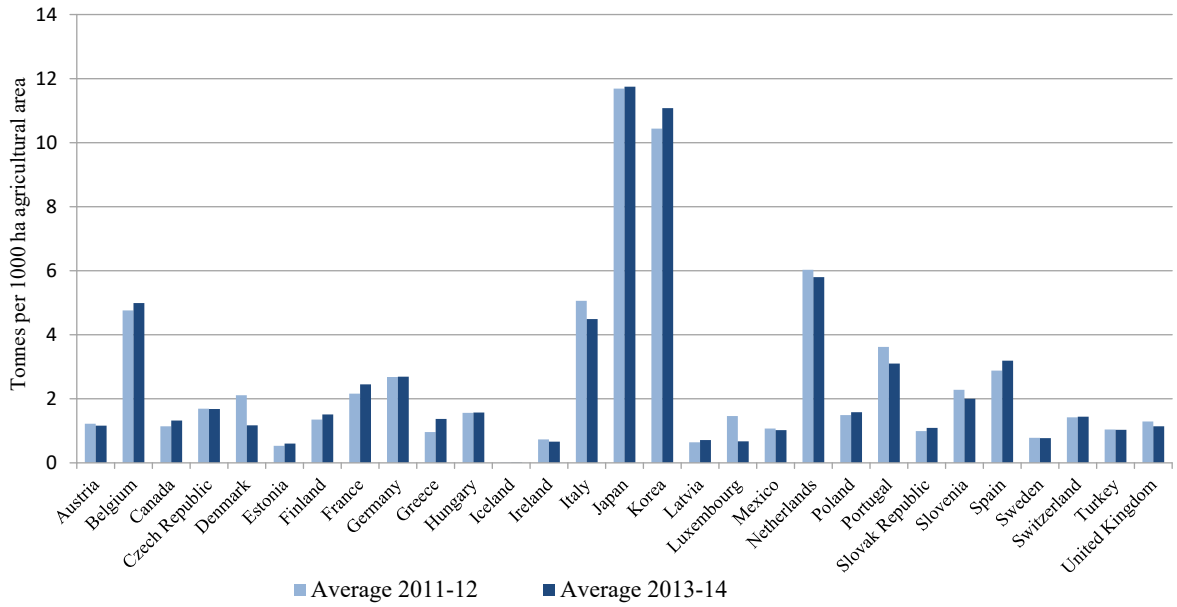
There is considerable variation in pesticide sales among OECD countries. Pesticide sales per 1000 ha agricultural land area in 2013-2014 were fairly high in some countries such as Japan (11.7 tonnes), Korea (11.7 tonnes), the Netherlands (5.8 tonnes) and Belgium (4.9 tonnes) (see Figure 3.1 and 3.2). It should be noted that the level of pesticide sales and use is fairly volatile and depends on a variety of factors such as crop composition, agriculture practices, crop and inputs prices and expectation of new policies that can result in pesticide hoarding. Moreover, pesticide sale and use does not equate level of risks and impacts as this data does not reflect the properties of the substance used.

Pesticide use is found to increase more than proportionately with agricultural intensification. It has been estimated that on average for every 1% increase in crop output per hectare, there is a 1.8% increase in pesticide use per hectare (Schreinemachers and Tipraqsa 2012). Although growth in pesticide use levels-off as countries reach a higher level of economic development, very few high-income countries have managed to significantly reduce pesticide use intensity. Meanwhile several middle income countries such as Mexico and Brazil continue to show rapid increase in pesticide use intensity (Schreinemachers and Tipraqsa 2012). A shift to less environmentally harmful substances is thus critical, along with a reduction in use to prevent mounting environmental costs.

[20] A common indicator on pesticide risk does not yet exist. The OECD Expert Group on Pesticide Risk Indicators (EGPRI) has developed a database which contains summaries of, and links to, available and active Pesticide Risk Indicators as well as developed and tested a list of aquatic and terrestrial pesticide risk indicators (http://www.oecd.org/env/ehs/pesticides-biocides/pesticides-risk-indicators.htm). The EU Harmonised Environmental Indicators for Predicting Pesticide Risk (HAIR) project also aims to deliver a set of indicators to assess pesticide impacts on agro-ecosystems and human health for use by EU member states (http://www.pesticidemodels.eu/home).

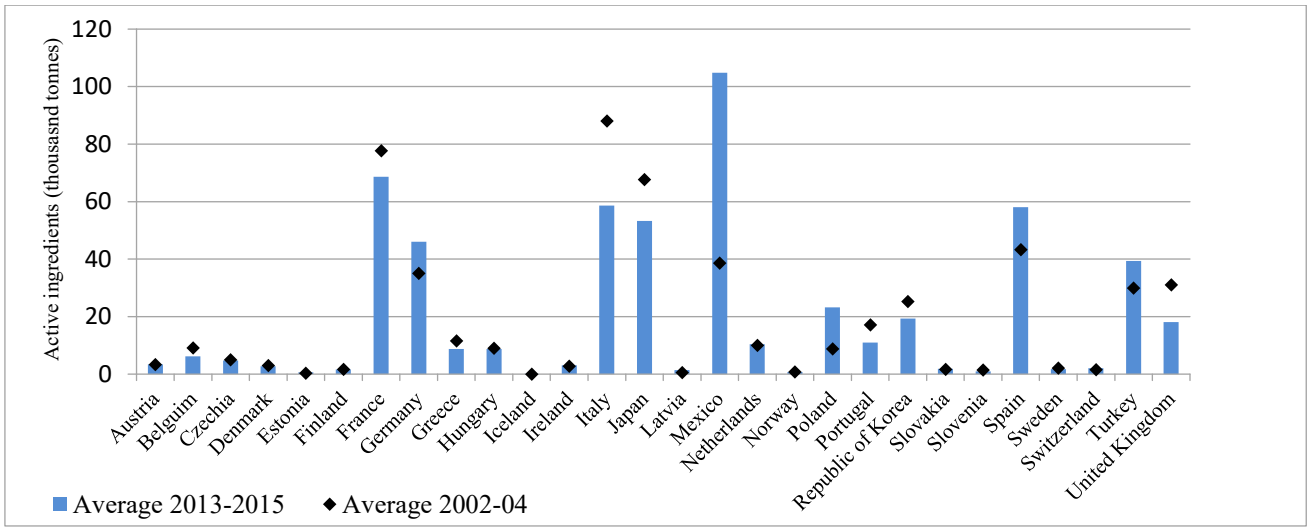
[21] The nutrient balance is defined as the difference between the nutrient inputs entering a farming system (mainly livestock manure and fertilisers) and the nutrient outputs leaving the system (the uptake of nutrients for crop and pasture production).

Figure 3.1. Sale of total agricultural pesticide per 1000 hectares agricultural land area in OECD countries



Notes:
1. Data for total agricultural land area is not available for many countries for 2015, hence 2014 data is used.
2. For EU countries, Norway and Switzerland, the total agriculture pesticides include Fungicides and bactericides, herbicides, haulm destructors and moss killers, insecticides and acaricides, molluscicides and plant growth regulators.
3. For non-EU countries, total agriculture pesticides include insecticides, fungicides, herbicides and other pesticides.
4. The following countries are not included in the figure: Australia (time series incomplete), Chile (time series incomplete), Israel (time series incomplete), New Zealand (data not available), United states (time series incomplete)
5. Data for Mexico expressed in tonnes of formulated product and not tonnes of active ingredient.
6. Data for Germany includes the sales of inert gases for storage protection.
Source: Data from OECD Agri-Environmental indicators database.
http://www.oecd.org/agriculture/sustainable-agriculture/agri-environmentalindicators.htm

Figure 3.2. Pesticide use in tonnes of active ingredient in OECD countries (2002-2004) and 2013-2015)



Notes:
1. The pesticides use database includes data on the use of major pesticide groups (insecticides, herbicides, fungicides, plant growth regulators and rodenticides) and of relevant chemical families. Data report the quantities (in tonnes of active ingredients) of pesticides used in or sold to the agricultural sector for crops and seeds.
2. The following countries are not included in the figure: Australia (time series incomplete), Canada (data refer to pesticide sales for use in the agricultural sector). Chile (data refer to the imports of formulated products for use in agriculture, forestry, veterinary and sanitary sectors), Israel (time series incomplete), Luxembourg (included in Belgium), New Zealand (data not available), and United states (time series incomplete).
3. For Denmark, Finland, France, Greece, Lithuania, Poland, Portugal, and United Kingdom, data refer to the sales for application to crops and seeds in agriculture.
4. For Belgium data refer to sales of pesticides including non-agricultural use. In 2007, the data collection methodology has been slightly modified; thus, data prior and after the year 2007 are not strictly comparable.
5. For France, starting in 2011, data include French Guiana, Guadeloupe, Martinique and Réunion
6. For Germany data refer to sales for use in agriculture, forestry and home gardening. Data includes "Inert Gases for storage protections"
7. For Hungary up to 2010, the content of the active substances was estimated as 50% of total Formulated Products. In 2011, the active substances were calculated by applying the % of concentration at product level.
8. For Iceland until 2008 data refer to the sales while as of 2009 data refer to the imports.
9. For Mexico data refer to Imports and production expressed an expressed in terms of formulated products.
10. For Slovenia data refer to wholesale of pesticides in the domestic market for agriculture and other purposes (roads, railway, golf courses, parks and etc.). Data do not refer to the actual use in the reference year; the use depends also on the stocks from previous years, individual purchase abroad, etc.
11. For Spain, in the period 1990-2010, data refer to pesticides use in agriculture. As of 2011, data refer to the sales for use in agriculture.
12. For Switzerland, as of 2007, the country improved the data collection methodology as to include data gathered from all pesticide suppliers. Data is therefore not strictly comparable.
Source: Data from Food and Agriculture Organisation (FAOSTAT 2017)

Approximately 50% of phosphorus fertilisers and 60% of globally applied nitrogen fertilisers are estimated to be in excess of the required amount and contribute to nutrient pollution (West, et al. 2014). Phosphorus (P) is a potentially dwindling resource as global phosphate rock reserves are finite and concentrated in a few countries. While there is continuing uncertainty and lack of consensus regarding the size and longevity of remaining

phosphate rock reserves[22], the current situation is unsustainable with respect to the environmental impacts associated with the use of phosphorus for food production, inequitable access and geopolitics surrounding the unequal distribution of phosphate resources and the finite nature of phosphate rock (Cordell and White 2011). Increasing the efficiency of the use of these reserves in crop production is vital to maintain current and future agricultural productivity (Cordell, Drangert and White 2009). Crop uptake of P is generally only 10–30% of P fertiliser applied in the first year, but a substantial part of applied P accumulates in the soil as residual P, released to crops over the subsequent months and years[23]. Build-up of soil P fertility as a result of substantial past inputs of organic and mineral P fertiliser in several world regions has reduced the P inputs required. In other words, when adequate soil-available P has built up, crop yields can increase despite decreasing P application (Sattari, et al. 2012) and increasing application levels is not only damaging to the environment but very likely uneconomical. For instance, between 1965 and 2007, cumulative inputs of P fertiliser and manure in Europe (1,115 kg·ha−1 of cropland) heavily exceeded the cumulative P uptake by crops (360 kg·ha−1). Since the 1980s in much of Europe, P application rates have been reduced, and uptake continues to increase due to the supply of plant-available P from residual soil P pool (Sattari, et al. 2012).

In contrast to P, N does not build up in the soil. Along with its inherently leaky nature, this makes N management more complex. Fertiliser requirements and impact depends on soil type, crop type, quantity used, method and timing of application and other factors. Thus, data on fertiliser consumption does not suffice to judge impacts. A better picture of potential environmental impacts is provided by nutrient balance data[24] (Figures 3.3, 3.4 and 3.5).

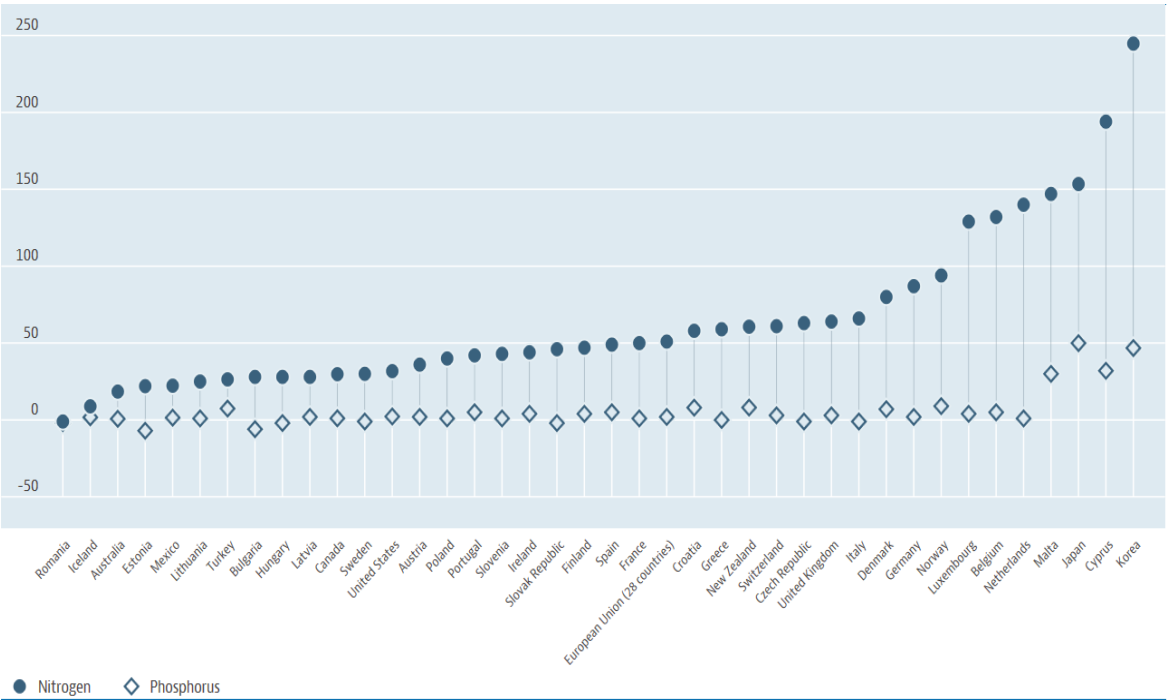
[22] Phosphorus reserve figures are intensely debated. Further research using uniform and transparent classification terminology is required as to the quantity of rock phosphate deposits and their viability for future extraction (Edixhoven, Gupta and Savenije 2014).

[23] The residual P is the difference between P inputs (mineral fertiliser, manure, weathering, and deposition) and P outputs (withdrawal of P in harvested products, and P loss by runoff or erosion) (Sattari, et al. 2012).

[24] The OECD indicators related to agricultural nutrient balances are gross balances, which are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilisers, livestock manure), and the quantity of nutrient outputs leaving the system (mainly uptake of nutrients by crops and grassland)). In the case of nitrogen, the gross nutrient balance includes all emissions of environmentally harmful nitrogen compounds from agriculture into the soil, water and the air; net balances exclude air emissions. In the case of phosphorus, since there are no air emissions, the gross balance is identical to the net balance (OECD/EUROSTAT 2012).

Figure 3.3. Nutrient balance

Nitrogen/Phosphorus, Kilograms/hectare, 2015 or latest available



Source: OECD, Nutrient balance (indicator). doi: 10.1787/82add6a9-en (Accessed on 06 September 2017)

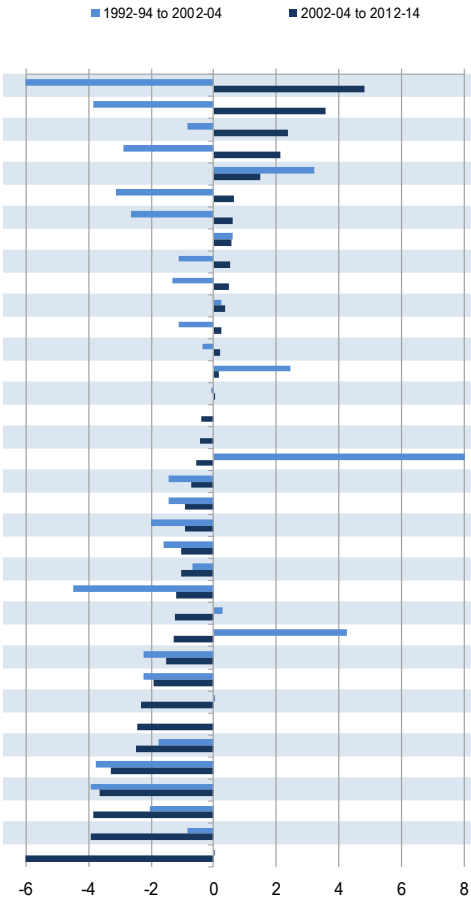
Between 1992 and 2014, nitrogen surplus decreased in OECD countries, on average, from 85kg/ha to 67kg/ha, while phosphorus surplus declined from 13kg/ha to 6kg/ha. Rates of decline have accelerated in the case of phosphorus surpluses during the last decade while they deaccelerated in the case of nitrogen. Countries, such as Austria, Iceland, Mexico and Turkey reversed the negative trends they experienced in P surpluses during the 1990s and have increased their surpluses per hectare since 2002. Similarly, countries such as Italy, Japan and Norway where nutrient surpluses are already high, experienced an increased in N surpluses. In contrast, countries which demonstrated progress in decreasing growth rates of N surpluses, also showed similar trends in declining growth rates of P surpluses. Examples include France, Greece, New Zealand and Spain (OECD, 2018a).

Declines in nutrient surpluses between 1992 and 2014 are mainly explained by improved fertiliser application rates, livestock and crop mix changes[25] as well as policy interventions (OECD, 2018a). While for P surpluses, reduction in P fertiliser application rates in most OECD countries was the main factor, in the case of N while application rates slightly declined across OECD countries, crop uptake increased due to changes in crop mix during this period. In most OECD countries, reductions in N surpluses between 2002-04 and 2012-14 were driven by reduction in N fertiliser and net inputs of manure. Exceptions include Canada, Estonia, Hungary, Israel and the USA where there was a decline in N surplus despite increase in fertiliser use due to corresponding increase in N output (notably crop uptake) during this time (OECD, 2018a).

[25] In particular, share of oil crops to total harvested crops and share of cattle to total livestock. impacted N balance.

Figure 3.4. Nitrogen balance per hectare of agricultural land, OECD countries: 1992-2014

Average annual % change

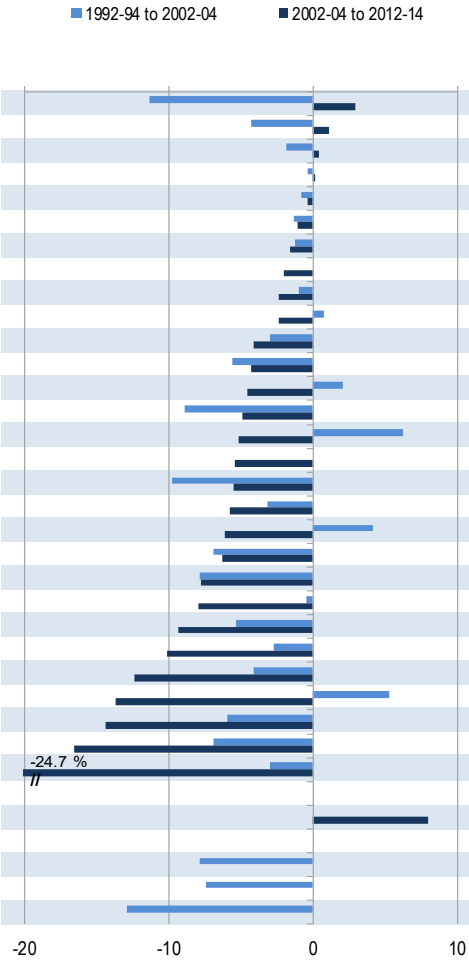


	Average (kg nitrogen/ha)			Average annual % change	
	1992-94[1]	2002-04[2]	2012-14[3]	1992-94 to 2002-04	2002-04 to 2012-14
Latvia	34	17	27	-6.9	4.8
Austria	40	27	38	-3.9	3.6
Iceland	7	7	9	-0.8	2.4
Slovak Republic	50	37	46	-2.9	2.1
New Zealand	33	46	53	3.2	1.5
Turkey	33	24	25	-3.1	0.6
Portugal	45	37	39	-2.7	0.6
Poland	42	45	48	0.6	0.6
Norway	102	91	96	-1.1	0.5
Australia	20	18	19	-1.3	0.5
Korea	234	240	249	0.3	0.4
Mexico	26	23	23	-1.1	0.2
Japan	179	173	176	-0.4	0.2
Czech Republic	58	74	76	2.5	0.2
Italy	72	72	72	-0.1	0.0
Israel	..	132	127	0.0	-0.4
Hungary	..	38	36	0.0	-0.4
Canada	14	30	28	8.2	-0.5
Switzerland (4)	74	64	60	-1.4	-0.7
OECD (5)	**85**	**73**	**67**	**-1.5**	**-0.9**
United Kingdom	84	71	65	-2.0	-0.9
Luxembourg	166	141	127	-1.6	-1.0
Germany	107	100	91	-0.7	-1.0
Belgium	246	156	138	-4.5	-1.2
United States	34	35	31	0.3	-1.2
Spain	31	47	41	4.2	-1.3
Finland	67	54	46	-2.2	-1.5
EU15	**107**	**85**	**70**	**-2.3**	**-1.9**
France	60	61	48	0.1	-2.3
Estonia	..	30	24	0.0	-2.4
Slovenia	88	73	57	-1.8	-2.5
Netherlands	304	207	148	-3.8	-3.3
Denmark	180	121	83	-3.9	-3.6
Sweden	57	46	32	-2.1	-3.8
Greece	89	82	55	-0.9	-3.9
Ireland	60	60	32	0.1	-6.8

Notes:
1. Average annual % change is calculated as geometric average growth rates between three-year period averages.
2. Balance (surplus or deficit) expressed as kg nitrogen per hectare of total agricultural land.
3. Countries are ranked in descending order according to average annual percentage change 2002-04 to 2012-14.
4. 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.
5. Data for 1992-94 average refers to: 1995 for the United Kingdom; and 1995-97 average for Portugal.
6. Data for 2002-04 average refers to: 2004-06 for Estonia.
7. Data for 2012-14 average refers to: 2011-13 average for Germany, Ireland, Sweden and Switzerland.
8. In the case of Switzerland, total agricultural area includes summer grazing.
9. The OECD total excludes Chile, Estonia, Hungary and Israel.
Source: OECD, Agri-Environmental Indicators: Nutrient Balances 2018a.

Figure 3.5. Phosphorus balance per hectare of agricultural land, OECD countries: 1992-2014

Average annual % change



	Average (kg phosphorus/ha)			Average annual % change	
	1992-94[1]	2002-04[2]	2012-14[3]	1992-94 to 2002-04	2002-04 to 2012-14
Austria	7	2	3	-11.3	2.9
Turkey	10	6	7	-4.3	1.1
Iceland	2	2	2	-1.9	0.4
Mexico	2	2	2	-0.4	0.2
Korea	52	49	47	-0.8	-0.4
Japan	76	66	60	-1.3	-1.0
Australia	1	1	1	-1.3	-1.6
Israel	..	44	36	..	-2.0
Norway	14	13	10	-1.0	-2.3
United States	3	4	3	0.8	-2.4
OECD (4)	**13**	**9**	**6**	**-3.0**	**-4.1**
United Kingdom	9	6	4	-5.6	-4.3
New Zealand	10	12	8	2.1	-4.6
Switzerland (5)	9	4	2	-8.9	-4.9
Spain	4	7	4	6.2	-5.1
Luxembourg	..	7	4	..	-5.4
Germany	9	3	2	-9.8	-5.5
Denmark	18	13	7	-3.1	-5.8
Poland	3	5	3	4.1	-6.1
Finland	16	8	4	-6.9	-6.3
Belgium	29	13	6	-7.8	-7.7
Portugal	11	11	5	-0.4	-7.9
EU15 (6)	**13**	**7**	**3**	**-5.4**	**-9.4**
Slovenia	14	11	4	-2.7	-10.1
Ireland	12	8	2	-4.1	-12.4
Canada	2	3	1	5.3	-13.7
France	12	6	1	-5.9	-14.4
Netherlands	33	16	3	-6.9	-16.6
Greece	8	6	0	-3.0	-24.7
Czech Republic	2	2	-1	0.0	n.c.
Estonia (7)	..	-5	-7	..	8.0
Hungary	..	1	-1	..	n.c.
Italy	8	4	-2	-7.9	n.c.
Slovak Republic	2	1	-1	-7.4	n.c.
Sweden	4	1	-1	-12.9	n.c.

Notes:
1. Average annual % change is calculated as geometric average growth rates between three-year period averages.
2. Balance (surplus or deficit) expressed as kg phosphorus per hectare of total agricultural land.
Countries are ranked in descending order according to average annual percentage change 2002-04 to 2012-14.
3. 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.
4. Data for 1992-94 average refers to: 1993-95 average for the Slovak Republic; 1995 for the United Kingdom; and 1995-97 average for Portugal.
5. Data for 2002-04 average refers to: 2004-06 average for Estonia.
6. Data for 2012-14 average refers to: 2011-13 average for Germany, Ireland, Sweden and Switzerland.
7 The OECD total excludes Chile, Estonia, Hungary, Israel and Luxembourg.
8. In the case of Switzerland, total agricultural area includes summer grazing.
9. The EU15 total excludes Luxembourg.
10. For Estonia, the average annual percentage change refers to change in phosphorus deficit.
Source: OECD, Agri-Environmental Indicators: Nutrient Balances 2018a.

4. Policy responses: Overview and selected country examples

4.1. An overview of policy instruments to address pesticide and fertiliser pollution

The main challenge for policy makers in addressing pesticide and fertiliser pollution is to reduce the risks to ecosystems and human health, while maintaining or increasing the level of crop productivity (OECD 2013a). Various policy instruments are available to manage excessive pesticide and fertiliser use. These include regulatory (command-and-control) instruments such as bans and standards; economic instruments such as taxes on pesticides and fertilisers, and subsidies to farmers for alternative protective measures; as well as other measures such as sustainability labels, incentives for the registration of biological pesticides to replace chemical pesticides, advisory and training services to support farmers' transition to more sustainable agricultural production systems and research and development of new technologies and practices to reduce chemical input use (Table 4.1).

International codes and directives[26] and national regulations related to pesticide and fertiliser sale and use exist in most OECD countries. In several countries, low-toxicity pesticides are given preferential treatment in terms of authorisation rather than facing the same complex authorisation process as conventional pesticides (OECD 2016b). Regulatory (command-and-control) approaches can provide a mechanism to clearly define and reach specified measurable environmental standards. However, regulatory approaches tend to provide less flexibility in compliance (compared with economic instruments) and are not necessarily able to achieve a given environmental target at least cost.

[26] These include the FAO International Code of Conduct on Pesticide Management, the Rotterdam Convention to promote shared responsibilities in relation to importation of hazardous chemicals including pesticides, the EU Sustainable use of Pesticides Directive (2009/128/EC) and the EU 'pesticide package' including regulations related to placing plant protection products in the market (EC regulation No.1107/2009) and maximum residue levels of pesticides in or on food and feed (EC regulation No. 396/2005), EU Nitrates Directive and the EU Water Framework Directive.

Table 4.1. Policy instruments to promote sustainable pesticide and fertiliser use

Regulatory (command-and-control) instruments	Economic instruments	Information and voluntary instruments	Other measures
Licences or certificates for sale and/or use and customs inspections/ monitoring for, and enforcement actions against, the illegal trade of pesticides	Pesticide and fertiliser taxes (undifferentiated or differentiated by impact on environment and human health).	Certification (for Integrated Pest Management or organic production)	Pesticide and fertiliser use guidelines
Mandatory registration and regulation of sale	Subsidies or direct payments including payments for ecosystem services for alternative pest and nutrient management and adoption of agricultural technologies and practices that mitigate environmental and health externalities.	Voluntary approaches such as negotiated agreements between businesses, farmers and governments to reduce pesticide and/or fertiliser use (through for instance, a code of good agricultural practices, cost-share programmes for investment in nutrient management	Awareness raising, information and advisory services and training in alternative pest and nutrient management
Pesticide/fertiliser quotas	Reform of environmentally harmful subsidies that promote pesticide or fertiliser overuse	Green Public procurement (e.g. for organically produced agricultural products)	Capacity building in agricultural extension services
Ecological and health standards such as maximum permissible levels of nutrient pollution/ chemical pesticide traces (for water, soil, food products etc.), maximum emission levels for pollutants	Cross-compliance or environmental conditionality (agricultural support conditional to improved input use)		Research and Development of alternative pest and nutrient management techniques and safer pesticides
Mandatory land and water management requirements*	Non-compliance fines		Crop risk insurance
Pesticide savings certificates (France)	Water quality trading programmes		
Ban on use of specific substances and restrictions on use (such as rate, area and timing of fertiliser application) and limitations on stocking rates, aerial spraying, etc.			

Notes: *Such as mandatory buffer zones around water bodies, establishment of nitrate vulnerable zones, mandatory catch crops, no spray zones.
Source: Authors.

Economic instruments include taxes, tradable permits and subsidies. Taxes can be used to internalise the external environmental (and health) costs of pesticides and fertilisers and have been adopted in a few countries (See Table 4.2 for an overview of pesticide taxes in OECD countries). In theory, optimal taxes should be set equal to the marginal external cost. Since the external damages are associated with the composition, quantity needed and efficacy of pesticides and fertilisers (which varies for example with crop, soil type and climate conditions), taxes can be differentiated to address the heterogeneity in environmental and health impacts of different substances where relevant information is

available[27] (Lefebvre, Langrell and Gomez-y-Paloma 2015). Differentiated tax schemes require fewer complementary policy measures to attain policy goals (Böcker and Finger 2016).

There are issues to be considered regarding the environmental effectiveness, transaction costs and political acceptability of using taxes to manage pesticide and fertiliser use (Aftab, Hanley and Baiocchi 2017, EC 2017b). Demand elasticity for pesticides and fertilisers is fairly low in the short term, necessitating high tax rates in order to achieve reductions[28].Böcker and Finger (2016) find that the effectiveness of pesticide taxes has been limited due to the low tax rates that are typically applied, a high enough tax on a specific pesticide can reduce application and associated risks. In the case of Norway for example, while there was only a slight decline in overall quantity of pesticide sold, there has been a shift towards using pesticides with lower environmental and health risks since the introduction of the pesticide tax (Bragadóttir et. al., 2014). Similarly, Söderholm and Christiernsson (2008) suggest that while environmental impact of fertiliser taxes are hard to judge in the short run (as taxes imposed are not proportional to environmental damage)[29], low price response can result in comparatively small reductions in quantity unless the tax rate is set fairly high.

A differentiated tax that takes into account the environmental damage caused by different types of pesticides would be more economically effective. However, given the high administration and monitoring costs involved, a simple uniform tax is often preferred in practice (Söderholm and Christiernsson 2008). Similarly, there are also trade-offs to be considered between a more cost-effective tax targeting environmental damage incurred and a tax levied upstream in the product chain targeting consumption and sale of pesticides and fertilisers that incurs lower overall costs. While governments may be inclined to design the tax to reduce administration and monitoring costs, the costs to society need also be taken into account. Moreover, strongly evident links between tax rates and reduction in environmental damages contribute to political acceptability of the tax (Söderholm and Christiernsson 2008).

[27] Unless objectives are well defined and chosen indicators are well developed, a highly-differentiated tax scheme which leads to a reduction of highly-hazardous pesticides could result in an increase in the application of less hazardous pesticides if suitable alternatives are available. Those pesticides often need a higher dose per hectare thus the overall risk to environment and health may not be reduced. Thus, indicators need to include both pesticide risk and pesticide use (Böcker and Finger 2016).

[28] For example, a review of the pesticide demand elasticity estimates of European countries and the USA shows that it ranges from –0.02 to –0.66 (Skevas, Oude Lansink and Stefanou 2013). Demand elasticity of fertilisers in Austria, Sweden and Finland were estimated to range between –0.1 and –0.5 (Rougoor, et al. 2001).This could be due to lack of knowledge regarding alternative practices amongst farmers, strong risk aversion tendencies, behavioural factors and lack of alternatives. In the long run, crop rotations and production technology adjustments can result in reduction in input use.

[29] The challenge for fertiliser taxes is to deal with the cascading problems from reactive nitrogen as well as the geographical heterogeneity of nitrate emissions. Constructing social and environmental damage function for N can be difficult due to technical and economic limitations. Specifically, nitrates have both natural and anthropological origins which are not easy to distinguish. Moreover, the amount of nitrates produced in soils varies locally even within the same region. Along with soil type weather conditions also have an impact. A great time lag between nitrate losses from the field and the consequent pollution of water bodies adds to the uncertainty about the true costs and benefits of any instrument of nitrate pollution control in the short run (Jayet and Petsakos 2013).

Table 4.2. Examples of pesticide taxes in OECD countries

Country (Year implemented)	Tax rate, base and target	Earmarking and Complementary measures	Outcomes and limitations
Sweden (1984)	The tax was increased from 30 SEK /kg active substance to 34 SEK/kg active substance in 2015 (Böcker and Finger 2016). Paid by manufacturers, wholesalers and importers. Total revenue generated in 2015 was SEK 70 million (around EUR 7.5 million)	There is a registration fee and an annual charge based on sales for companies seeking approval of placing plant protection products on the market (Plepys, Heiskanen and Mont 2015) The tax revenues are directly allocated to the state's budget	Absolute sales of active substance reduced more than 50% since the introduction of the tax. The Swedish pesticide risk indicator (indexed to the year 1998) shows a sharp decrease in risk to human health (now relatively constant at 20-40% as compared to 1988 levels) and to the environment (50-80% as compared to 1998 levels). Though the outcome coincides with the introduction of the tax, it is linked to a range of policy instruments (Böcker and Finger 2016)
Denmark (1996)	Since 1998, the tax rate was 54 % of retail price for insecticides and 34 % for herbicides, growth regulators and fungicides. The tax was revised in 2013 to take into account the load on environment and human health of each pesticide product. Paid by manufacturers, wholesalers and importers. Revenue generated in 2013 was DKK 659 million (EUR 88.4 million)	Around 75 % of tax revenues are returned to the farmers through reduced land taxes. The remainder is used to finance various actions such as farmers' education campaign, compensation to farmers for maintaining buffer zones, tighter pesticide approval procedures etc.	The treatment frequency index (TFI) has been at approximately the same level as before the tax was adopted (2.5), whereas the objective was to reach 1.7. However, the target to reduce environmental and health load measured by the Pesticide Load Indicator by 40% has been met.
Norway (1998)	The tax is area-based with a base rate of about EUR 3.4 per hectare. This is then multiplied with a factor (0.5 to 9) for one of the five tax classes, to provide the tax for each plant protection product. Standard area dose (g or ml per hectare) is used to convert tax per hectare to tax per kg or litres of product. Estimated revenue in 2015 was NOK 50 million (around EUR 5.8 million). Paid by Industry, importers/wholesalers.		There is only a slight decline in the quantity of pesticides sold since the introduction of the tax though there has been a shift to use of pesticides with lower health and environmental risks (Bragadóttir et. al., 2014).
France (1999 replaced by current tax in 2008)	Since 2008, a fee on diffuse agricultural pollution collected by public water agencies from pesticide distributors, according to the quantity of active substance and the toxicity level. The rate is EUR 5.1/kg on substances which are very toxic, toxic, carcinogenic, mutagenic or toxic to reproduction, EUR 2 /kg on substances harmful to the environment and EUR 0.90 /kg for mineral chemicals harmful to the environment. Total revenue in 2012 and 2013 was EUR 60 million.	The proceeds used to finance the Ecophyto plans I and II and the remainder is distributed amongst water and waste-treatment plant operators. The Ecophyto plan is mainly based on an awareness and education campaign, the development of a real-time warning system against pests and the banning of a number of substances used in pesticides. Reduced VAT rate on pesticide ended in 2011. VAT applied is now 20 %.	The tax rate is too low and the tax revenues cover less than the sole cost of treating pesticide contaminated water for drinking.

Country (Year implemented)	Tax rate, base and target	Earmarking and Complementary measures	Outcomes and limitations
Italy (2000)	2% of previous years sale of PPP (OECD 2017[53])	Under the Ministry of Finance a "Fund for the development of organic farming and quality products" was created in order to finance the following measures under the national and regional programmes: a) financing research and experimenting on low environmental impact agriculture; b) supporting promotion and information campaigns on organic agriculture, regional products and PDO (Protected Designation of Origin); c) producing, revising and publicising the code for good agricultural practise. However, not all the income raised by the pesticide tax has been used; 5million EURO was allocated to the national plan for organic farming but this plan is still to be implemented (PAN 2005)	
Mexico (2014)	Differentiated tax by toxicity level of the substance. For the most toxic substances, Category 1 and 2, the tax rate is 9%; Category 3 is 7%; Category 5 is 6%. Least toxic pesticides below category 6 are exempt. All segments in the supply chain are subjected to the tax.		The total amount of tax revenues collected by the federal government from the pesticide tax was USD 109 million (MXN 2 133.32 million) from February 2014 to September 2017 period

Sources: Authors based on OECD database on Policy Instruments for the Environment (PINE); OECD (2017f), Böcker and Finger (2016), (Lefebvre, Langrell and Gomez-y-Paloma 2015), Bragadóttir et al., (The 2010), Skevas, Oude Lansink and Stefanou, (2013).

While high tax rates for fertilisers and pesticides can be politically difficult to implement on their own (Lefebvre, Langrell and Gomez-y-Paloma 2015), tax revenues can be earmarked to be channelled back to the agricultural sector, including to undertake steps to promote sustainable agriculture. Such earmarking has been found to increase the political acceptability of pesticide and fertiliser taxes in European countries (Böcker and Finger 2016, OECD 2017). A reduction in other forms of taxation can also be used to prevent an overall increase in taxation to promote acceptability[30] (UNDP 2017). In any case, even at lower levels, taxes can raise revenue and stimulate innovation (Lefebvre, Langrell and Gomez-y-Paloma 2015).

Subsidies or direct payments to farmers for undertaking environmentally friendly agricultural practices can be used to encourage farmers to shift to more sustainable fertiliser and pesticide use. Subsidies can compensate farmers for the costs incurred in the learning phase of adoption and for bearing the risk associated with changed practices (Lefebvre, Langrell and Gomez-y-Paloma 2015). However, subsidy-based programmes can have limited success due to constraints in public budgets (Shortle and Horan 2013).

Payments for ecosystem services (PES) programmes can also be used to promote better environmental outcomes in this context. A successful programme is that in the Mangfall

[30] In Denmark for instance, reduced land tax ensures that around 75% of pesticide-related tax revenues are returned to farmers (Pedersen, Nielsen and Skou Andersen, et al. 2011).

Valley in Germany which supplies 80% of the drinking water in Munich. A voluntary payment scheme was offered by the municipal water provider to farmers in the area to compensate them for expected loss in income and investment needed to make the switch to organic farming. The scheme was more environmentally-effective and cost-effective than upgrading water treatment to remove nutrients and pesticides[31] (OECD 2017b). In such cases there is a need for collective compliance of farmers with baseline regulation in order to ensure 'additionality' and reduce concerns about equity where such payments are seen as rewarding polluters and neglecting those already demonstrating good practice (OECD 2013d).

In the meantime, there is a need to ensure that subsidies in place do not encourage overuse or misuse of pesticides and fertilisers. It is found that agri-environmental support policies that decouple support from production (such as those that provide payments for areas set aside or those that specifically target the conservation of high ecological value areas, wildlife or biodiversity), tend to improve farmland bird populations. An econometric analysis of 22 countries suggests that agri-environmental support policies that are coupled with input use or production are less effective at improving biodiversity (OECD *forthcoming*).

Countries need to review support that directly or indirectly incentivises excessive input use in order to provide the right signals to producers and free up finances that can then be redirected towards other uses. In Ireland for example, it is estimated that the removal of zero VAT for fertilisers would lead to an estimated 9.85% decline in N fertiliser use and an 8.97% decline in P fertiliser use and would generate EUR 35 million in tax revenue annually (Morgenroth, Murphy and Moore 2018). In Korea, the government set the target of reducing pesticide and fertiliser use by 30% between 2006 and 2010 as compared to average use levels in 1993-2003. In pursuit of this target, fertiliser subsidies were eliminated in 2005 in conjunction with policies to promote organic fertilisers. This contributed to decline in use of chemical fertilisers in the last decade (OECD 2018c).

Given that information related to environmental impact of pesticide and fertiliser use (such as monetary value of external costs in different contexts) can be difficult to obtain, Skevas et. al. (2013) suggest that the establishment of a set of standards and targets for environmental quality supported by economic instruments including taxes, would represent a cost-effective way of attaining the specified standards. In this case, charge rates or prices could be based on the standards in the absence of unknown value of marginal net damages.

Voluntary approaches can encourage development of creative solutions which are also more acceptable to stakeholders in the agricultural sector. On the other hand, lack of compliance and difficulty in quantifying overall benefits may reduce the appeal of such instruments (Sutton, Erisman and Oenema 2007). For these reasons, governments have in some cases turned voluntary codes of good agricultural practices into mandatory measures in certain areas (for e.g. in nitrate vulnerable zones, NVZs, designated under the EU Nitrates Directive). There is however, an increasing recognition of a need for a more collaborative approach to ensure uptake of measures to meet regulatory requirements including for water quality related issues such as nutrient pollution. In several cases

[31] The programme halved nitrate concentration (from 15 mg/L to 7 mg/L) and the price increase for final urban consumers due to the payment scheme (EUR 0.005/m3) was lower than avoided cost of water treatment facilities (EUR 0.23/m3).

governments are starting to work with stakeholders to identify issues, provide generic and customised advice and other services to farmer and other partners[32].

The impacts of change in pesticide and fertiliser use on crop yield and the environment are complex. Limited access to production and market information is a persistent barrier in adoption of alternative pest and nutrient management practices (Goodhue, Klonsky and Mohapatra 2010, OECD 2015a). Advisory services and training have therefore been found to be useful in encouraging a reduction in environmentally harmful input use by raising awareness and stimulating interest in alternatives and providing tools and technical assistance for farmers to make the shift to more environmentally sound practices (Schreinemachers and Tipraqsa 2012, Goodhue, Klonsky and Mohapatra 2010). Governments can also encourage or incentivise the development of alternative pesticides (e.g., biological pesticides) by reducing regulatory hurdles for manufacturers of such pesticides. Additionally, information-based voluntary instruments such as certification for organic farming or Integrated Pest Management (IPM) can be promoted through subsidies, tax breaks and education and training support (Lefebvre, Langrell and Gomez-y-Paloma 2015).

An overview of policies from selected OECD countries, namely Denmark, France and Mexico, for pesticides and Denmark, Japan and the United States for fertilisers, is provided below.

4.2. Policies to address adverse impacts of pesticides in selected countries

4.2.1. *Denmark*

Denmark has a long history of implementing policies aimed at reducing pesticide use which have been accompanied by quantitative targets. The first pesticide reduction plan was introduced in 1986 to protect groundwater that is consumed directly without any purification treatment. Since then, pesticides have been banned when it is proved that they have impacted lower reaches of groundwater used for drinking (MFVM and MIM 2013). Moreover, there was a major increase in the use of pesticides leading to a serious decline in farmland wildlife in the beginning of the 1980's. The wild plant diversity in farmland, for example, decreased by 60% between 1970 and 1990 (PAN 2005a). Consequently, only around 80 types of active substances are permitted in Denmark, compared to 3-400 in many other EU Member States (Coll and Wajnberg 2017).

The First Pesticide Action Plan (1986-1997) aimed at reducing pesticide consumption by 25% by 1992 and by 50% by 1997 (measured in amount of active ingredient). This was accompanied with a target to reduce the treatment frequency index (TFI) [33] by 50% by 1997 since there is weak correlation between amount of pesticide used and environmental

[32] In Scotland, for instance, under a targeted extension programme to reduce effluent pollution, catchments were prioritised followed by launch of data gathering exercises, awareness programmes for farmers, and one to one engagement with farmers to identify solutions which led to significant increase the uptake of best management practices (Aitken and Field 2015). See the following presentations from the OECD-European Commission Workshop on 'Pathways to policy change on water in agriculture' (20 – 21 February 2018) for further examples on Denmark (http://www.oecd.org/tad/events/1.%20Christensen.pdf) and Ireland (http://www.oecd.org/tad/events/3.%20Nolan.pdf).

[33] TFI is defined as the number of pesticide applications per hectare per calendar year assuming the use of a standard dose for each authorised use.

load (some pesticides can be biologically active in very small doses). The plan relied on advisory activities for farmers and on intensification of research on ways of reducing pesticide use such as new resistant crops, integrated pest management, crop rotation etc. Additional policy instruments were also introduced such as mandatory spraying certificates and journals, mandatory education programmes for professional users of pesticides and eventually a pesticide tax in 1996. This phase was successful in reducing consumption levels (by 40% between 1986 and 1996) but not the TFI (Coll and Wajnberg 2017). Under the second plan (2000-2004) an expert committee (the Bichel Committee) recommended a goal of a TFI of 1.7 implemented through a three-pronged strategy covering spraying-free zones, organic farming, and general use reduction through new technology and better farming practices. The Third Pesticide Action Plan (2004-2009) maintained the TFI target of less than 1.7%.

Under the fourth plan (2009-2013), to better target reduction in impact to human health and environment (rather than amount of pesticide used), the TFI was replaced by Pesticide Load Indicator (PLI) in 2009. The PLI includes: human health; environmental fate (degrading time and propensity to accumulate in soil and food systems); and environmental toxicity (to non-target organisms on farms and adjacent areas). The fifth plan (2013-2015) targeted a 40% reduction in PLI to reach the PLI of 1.4 in 2015 as compared to 2011.

A policy mix including regulatory and economic instruments along with provision of education and technical guidance has been used to promote pesticide management and to meet the targets under the various plans.

Regulatory approaches: Along with tightening of approval procedures, there are regulations for mandatory spraying certificates for professional users, mandatory spraying journals and mandatory buffer zones around water courses, lakes and public water supply (Pedersen and Nielsen 2017). Under the Pesticide Leaching Assessment Programme, authorised pesticides are applied to six representative test fields followed by intensive monitoring to determine if there is evidence of the pesticides, or their metabolites, leaching into groundwater. As a result of this programme, a small number of previously authorised pesticides have had their authorisations withdrawn in Denmark, and in some other cases the conditions of use have been modified (EC 2017b).

There are 26 000 trained operators covering distributors, advisors and professional users in the country. The authorities verify that professional users have the required certificates as part of their controls on these operators. Compliance levels are typically above 95%. A centralised database has been instituted for recording the results of all sprayer inspections, which can be used to prioritise future actions in this area (EC 2017b).

The target for pesticide-free buffer zones was moved several between 20 000 ha to 50 000 ha. A mandatory buffer-zone of 25m around public groundwater extraction sources was implemented in 2011 (Coll and Wajnberg 2017).

Pesticide tax: Denmark introduced an ad valorem pesticide tax on sales price in 1996. The tax was increased and differentiated by pesticide type in 1998 (for insecticides the tax was raised from 37 to 54% of the retail price and for fungicides, herbicides and growth regulators from 15 to 34%). Initially the tax was charged to manufacturers and importers and incorporated into the product price. Tax revenue was reimbursed to the agricultural sector through reduction in land tax and by channelling tax revenues to support sustainable

farming and administrative services[34] (Pedersen et al. 2011). Thus while the sector is reimbursed, individual farmers still have incentive to reduce pesticide use to reduce marginal costs.

After the introduction of the PLI, each pesticide product receives a specific tax rate which is based on PLI and the amount of active substance. Pesticides with higher loads in the three categories of human health, environmental fate and environmental toxicity, carry higher tax rates (Pedersen and Nielsen 2017). There is concern that the differentiated tax rate, which is far more heterogeneous than in other cases, may lead to use of less hazardous substances that require higher dosage, thus running the risk of development of pesticide resistance for these substances (Coll and Wajnberg 2017). Further the tax has been criticised for being too costly (due to high administration costs) and inflexible (Pedersen, Nielsen and Andersen 2015)[35].

Subsidies: On average 66% (up to a maximum of 80%) of the cost of IPM consultancy for farmers are covered. Between 2010 and 2015, such advice was supplied for about 15% of the arable land in the country (Underwood and Mole 2016). Subsidies are also provided to farmers for maintaining pesticide free buffer zones and for the use of alternative pesticides. A dedicated funding programme supports the costs of authorising non-chemical pesticides under which applicants can receive up to 100 % of the total costs associated with gaining authorisation for a new pesticide (EC 2017b)

Education and technical guidance: In Denmark, the independent advisory service provided a wide range of forecasting, warning, and decision-support systems and is credited with having contributed to reduced pesticide use compared with similar cropping systems in other countries (Kudsk and Jensen 2014). Pesticide reduction strategies have had strong components of information provision to farmers through agriculture consultancies and direct information from government to farmers. There is also a focus on intensification of research, including for instance on integrated pest management (IPM) and new resistant crops (Pedersen and Nielsen 2017).

Monitoring and evaluation: Annual statistics on sale and use of pesticides are used to calculate the PLI which is the overall indicator used to measure progress towards sustainable use of pesticides in Denmark (MFVM and MIM 2013). Other indicators to measure compliance with specific benchmarks include pesticides in groundwater (measured under the national ground water monitoring programme which also measures

[34] Of the estimated DKK 600 million tax revenue in 2015, DKK 250 million were earmarked for the agriculture fund which supports different measures related to the Danish agricultural sector, around DKK 175 million were designated for green growth measures (including measures related to the National Action Plan on Pesticides) and about DKK 75 million were designated for administrative purposes (Böcker and Finger 2016).

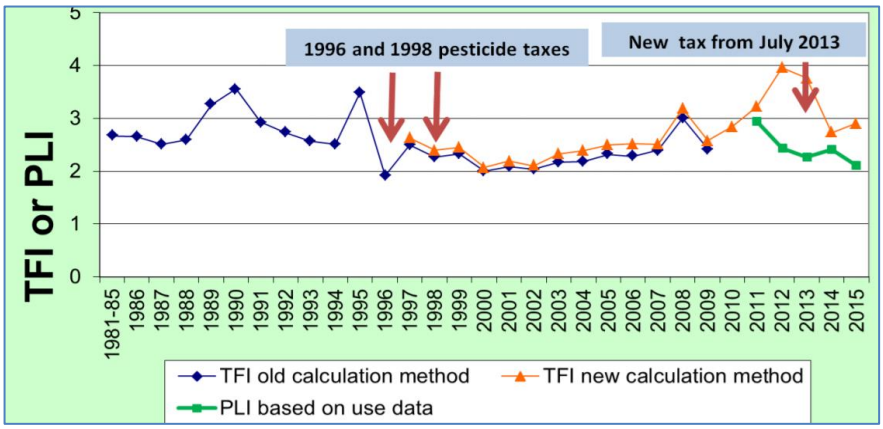
[35] In 2006 the Ministry of Taxation measured the burden induced by the tax and estimated it to be DKK 21 000 per year per manufacturer/producer.

nitrate concentration[36], and pesticide residue levels in food (residue analysis is carried out by the Danish Veterinary and Food Administration) (EC 2017a)[37].

In terms of results, early introduction of a pesticide policy has led to Danish agricultural products (especially fruit and vegetables) having residue levels of pesticides below the EU average (PAN 2013). The area under organic farms increased substantially, from 20 000 ha in 1995 to 150 000 ha in 2002 (Coll and Wajnberg 2017). It was estimated that between 1986 and 2015, despite the large reduction in use of approved pesticides, Denmark did not meet the target of a TFI of 1.7 (between 2000 and 2002, the TFI was just above 2.0 but increased again in subsequent years) (see Figure 4.1). However, given that pesticide use fluctuated with various factors (such as grain prices, crop composition etc.), it is difficult to estimate what the TFI would have been without these policies in place. Moreover, trends were distorted by the apparent hoarding of pesticides in anticipation of the changes in pesticide tax in 2013.

More recently available data, shows that the PLI declined by 40 % (from 3.27 to 1.95) based on sales by the end of 2015, thus achieving the target. The reasons for this have not yet been analysed, but it is thought that a change to using pesticides with lower loads is the most likely reason. This demonstrates that the TFI and PLI are not positively correlated as reduction in frequency of treatment is not correlated to the properties of the product used (EC 2017a).

Figure 4.1. Trends in Total Frequency Index and Pesticide Load Indicator in Denmark



Source: EC (2017), Final Report of a Fact-Finding Mission Carried Out in Denmark from 03 May 2017 to 10 May 2017 in Order to Evaluate the Implementation of Measures to Achieve the Sustainable Use of Pesticides.

[36] The Danish Groundwater Monitoring Programme comprises a network of 74 well catchment areas, dedicated to monitoring, spread across Denmark. Groundwater sampling is carried out by regional authorities and analyses, according to international standards, are conducted by laboratories appointed by the Ministry of the Environment. The Geological Survey of Denmark and Greenland (GEUS) is in charge of the monitoring programme and has produced associated technical specifications and guidance on monitoring network design, well construction, sampling, analysis, etc. Groundwater data from the monitoring are gathered in a national public available database at GEUS and results reported annually (Jørgensen and Stockmarr 2009).

[37] Other specific indicators include pesticide use on golf courses, in private gardens and in public areas.

The latest pesticide strategy (2017-2020) was released in October 2017 following a 6 month consultation with stakeholders. The PLI will remain the primary indicator and focus on priorities from the previous plan will continue. New targets are expected to be agreed upon in the course of 2018.

4.2.2. *France*

Despite policies in place to address pesticide pollution in France, the use of pesticides has increased, making the country one of the largest consumers in Europe in terms of total volume. This is linked to the level of production (18% of production in EU), type of cultivation (including vines and arboriculture), the increase in the surface of field crops at the expense of grasslands, and climate conditions (OECD 2016a). There was an increase of 5.8% in pesticide use between 2011-13 and 2012-14, including a 9.4% increase between 2013 and 2014 alone (MAAF 2016). The presence of pesticides in watercourses and aquifers is a cause for concern. In 2013, pesticides were detected in 92% of the measuring points for rivers and streams and 69% in groundwater bodies in France (with 21.6% of measuring points for groundwater and 5.1% for rivers and streams containing concentration of pesticides exceeding quality standards) (OECD 2017f). France has not achieved the "good status" objective set for 2015 by the EU Water Framework Directive (WFD), due mainly to diffuse pollution by nitrates and pesticides. These products also contaminate the air and soil, for which current control measures are insufficient (OECD 2016a).

France set a target to reduce pesticide use by 50% between 2008 and 2018 as mandated under the Ecophyto national action plan (2008). The plan did not yield the desired outcomes. For instance, the "number of unit doses", which calculates the average number of treatments per hectare of farmland, rose by 29% between 2008 and 2014. As a result, the achievement of this objective has been pushed back by separating it into two stages under the Ecophyto Plan II (2015): a 25% reduction in consumption of phytosanitary products by 2020, on the strength of measures already in place for optimising production systems; and a 50% reduction by 2025, to be made possible by more significant changes to production systems, scientific and technological progress, crop diversification and conversion to organic farming. The Ecophyto Plan II is a key component of the effort to promote agroecology in France. Research support was enlisted from scientific institutions (such as the French National Institute for Agricultural Research) in the development of the plan. An independent commission was established to ensure clear links between approved actions and actual reductions in pesticide use in the design of the recently introduced Pesticide Savings Certificate Scheme (see below). This evidence base played a key role in advancing policy changes, withstanding pressure from vested interests and engaging stakeholders (OECD 2017f).

A range of policy instruments have been put in place to reduce pesticide consumption in France. These include a tax on pesticides, a regulation on pesticide savings certificates and education programmes including demonstration farms:

Mandatory certification: Individuals must have mandatory certification (CertiPhyto) to ensure that all pesticide users have basic knowledge to apply pesticides safely and to reduce their use[38].

[38] Recently instituted measures to reduce pesticide pollution include prohibition of pesticides in public areas(such as public green spaces, forests, and public promenades) and withdrawal of over-the-counter sale of pesticides to amateur gardeners since January 2017 (AFB 2018).

Pesticide tax: The first pesticide tax was introduced in 1999 under the general tax on polluting activities (Taxe Générale sur les Activités Pollutantes) (TGAP). The tax rate varied according to the toxicity of the pesticide with several categories of substances identified (OECD 2017f). In 2008, the TGAP tax was replaced by a tax on diffuse agricultural pollution under the Law on Water and the Freshwater Environment. This charge is levied on the sale of pesticides, paid by farmers and collected by distributors rather than manufacturers and importers in order to make it more perceptible to farmers. The tax is differentiated according to the toxicity of the substance (the rate is EUR 5.1/kg on substances which are very toxic, toxic, carcinogenic, mutagenic or toxic to reproduction, EUR 2/kg on substances harmful to the environment and EUR 0.90/kg for mineral chemicals harmful to the environment) (OECD 2017f).

The rate of the diffuse pollution tax was raised several times between 2008 and 2011 (OECD 2017f). Despite the rise, the diffuse pollution charge represents on average only 5-6% of the sale price of pesticides, reducing its incentive effect (OECD 2016a). The relatively low tax rate and weak price elasticity of demand have rendered the current tax ineffective in reducing pesticide use in France[39] (Dutartre and et. al. 2014).

Subsidies: Subsidies in agriculture also being geared towards promoting agroecology in France (MAAF 2016). Moreover, following the publication of a comprehensive national study on public subsidies harmful to biodiversity (Sainteny et. al. 2011) in 2011, the reduced rate of the value added tax (VAT) for pesticides and fertilisers was eliminated via an amendment to the Law of Finance. The levy of a standard VAT rate on consumption of fertilisers and pesticides did not impact production costs, as most farmers are subject to the simplified VAT system and recover VAT that they pay on the purchase of their products (OECD 2017f).

Pesticide savings certificates: As an alternative to further raising the diffuse pollution tax or imposing more stringent regulations, an experimental instrument, the pesticide savings certificates, was included in the Law of the Future of Agriculture and Forestry (2014). Under the scheme, distributors must encourage farmers to adopt practices identified as leading to lower pesticide use, in order to receive savings certificates corresponding to the expected savings achieved. After a five-year trial phase, these certificates must prove a 20% reduction in use in relation to the initial benchmark. Distributors will be penalised if they do not fulfil their obligations, either by introducing recognised measures or by acquiring certificates from other members of the scheme (OECD 2017). The aim is to encourage distributors to advise farmers on alternatives to pesticides in a context where existing technical solutions may not be employed due to risk aversion or poor understanding of benefits of using alternatives (OECD 2017f).

Education and technical guidance: Guidelines for IPM in polyculture, viticulture, vegetables and fruits have been drawn up for farmers. Since 2009, the DEPHY network of demonstration farms (DEPHY Ferme) and test farms (DEPHY Expe) verifies, develops and rolls out agricultural techniques and systems for reducing the use of crop protection products. At the end of 2014, 1 900 farms were voluntary members of the DEPHY Ferme network, and 41 DEPHY Expe projects had been conducted on 200 test sites (OECD 2016a). All the sectors in the DEPHY network have managed to reduce their use of crop protection products while maintaining good productivity levels. Between 2012 and 2014, the average number of treatments fell by 10% for field crops and mixed crop-livestock

[39] Butault et al. (2011) estimate that to reduce pesticide use by 30%, the tax rate would need to be 100% of the sale price of the product, and for a reduction of use of 50%, the tax rate would need to be 180%.

farming, by 12% for orchards and vineyards, by 15% for vegetable crops, by 38% for horticulture and by 22% for sugar cane (OECD 2016a). The 2015 Ecophyto II Plan aims to increase the number of farms in the DEPHY network to 3 000 and to share their practices by supporting 30 000 farms in their transition to systems with little reliance on plant protection products (MAAF 2016).

Monitoring and evaluation: The indicators used to monitor progress under the Ecophyto plan include[40]: number of doses (NODU), treatment frequency index (IFT) and toxic equivalence. NODU calculations are based on annual sales data supplied by pesticide distributors to the French National Office for Water and Aquatic Spaces (ONEMA). IFT is the number of standardised applications per hectare calculated by correlating the dosage units and the usable agricultural area. However, these are not sufficient to assess progress in reducing environmental and human health load of pesticide use. It has also been pointed out that impact of pesticides on biodiversity is not adequately monitored and could be improved (Potier 2014). To address these gaps, the Ecophyto II plan mentions the development of further indicators to assess risks and impacts of pesticide use as an area of work to be pursued.

An example of a participatory programme launched by the Ministry of Agriculture and Food as part of the National Strategy for Biodiversity in response to the lack of indicators to monitor biodiversity in agricultural areas is the Agricultural Biodiversity Observatory (OAB). The aim of this effort is to spread awareness among farmers regarding biodiversity and involve them in its preservation. The OAB supports volunteer farmers by providing protocols for observing biodiversity in agricultural areas (these include protocols for earthworms, butterflies, solitary bees and terrestrial invertebrates). This information feeds a national database to trace trends in the observed populations, link these observations to the quality of soil, pest control and the presence of pollinators on farms. Information from 387 farms and 788 plots in 2016 and 278 farms and 540 plots in 2017 was gathered through the OAB[41].

4.2.3. *Mexico*

Excessive pesticide use is a matter of concern in Mexico. High levels of toxic contaminants including pesticides have been found in soil, water and plant and animal species in some locations. Pesticides have also led to degradation of ecosystems with noted cases of bio-accumulation in aquatic species (Reyes, et al. 2014). Adverse effects on human health, especially in children, have also been identified (OECD 2013b, Valdez Salas, Garcia Duran and Wiener 2000).

The tendency towards crop specialisation according to zones/states contributes to overuse of pesticides and encourages use of products found to be successful in controlling certain pests even on crops on which they are not authorised (Pérez-Olvera1, Navarro-Garza and Miranda-Cruz 2011). One of the major challenges in providing relevant practical information and available solutions for pesticide management in Mexico is the large number and diversity of agricultural producers (Blanco, et al. 2014)

[40] Monitoring of the Ecophyto plan is under the responsibility of a national level steering committee which is chaired by the Minister of Agriculture and Forestry (Comité National d'Orientation et de Suivi du plan Ecophyto).

[41] http://observatoire-agricole-biodiversite.fr/resultats.

While several toxic pesticides have been banned under international conventions, there are still some products in the Mexican market which carry a significant level of contaminants and toxicity. An excise tax was introduced in 2014 to signal consumers to move towards less harmful pesticides. The tax varies by the level of toxicity of the substance (as listed under WHO regulations) and increase with higher levels. For the most toxic substances, under category 1 and 2, the tax rate is 9%; for category 3 the rate is 7%; category 5 is 6%. The least toxic pesticides below category 6 are exempted from taxation. All segments in the supply chain are subjected to the tax. The total amount of tax revenues collected by the federal government from the pesticide tax was USD 109 million (MXN 2 133.32 million) from February 2014 to September 2017 period (OECD 2018b).

4.3. Policies to counter nutrient pollution in selected countries

4.3.1. *Denmark*

Denmark employs several regulatory policy instruments supplemented by education and information measures and national aquatic monitoring programmes to tackle nutrient pollution (Blicher-Matheisen, et al. 2015, Tan and Mudgal 2013). Agriculture covers over 60% of land area in Denmark and is thus a major form of land use in the country (World Bank 2017). Moreover, intensive livestock production in the country, generates substantial amounts of nutrient input from manure. Over the last three decades, fertiliser use has been absolutely decoupled from economic development in the agricultural sector (Tan and Mudgal 2013). During this time, N surplus declined by 47% and there has been a 40-50% reduction in nitrogen pollution from agriculture to coastal waters through policies targeting better use of fertilisers and lower N losses from agricultural systems (Blicher-Matheisen, et al. 2015). Despite these reductions in nutrient use and leaching, further improvements are required in water quality due to persistent problems such as oxygen depletion, particularly in lakes and coastal areas (fjords), and nitrate pollution in rivers and groundwater. This is due to the persistence of relatively high intensity of nutrient use per hectare in Denmark (around 85 kg N/hectare) compared to other OECD countries (Tan and Mudgal 2013, EEA 2012).

Two aspects of the measures to reduce N pollution in Denmark have been noted as contributing to the success of policy instruments in place: robust monitoring and reporting of the outcomes of measures undertaken; and a well-established advisory service that contributes to information and training (Blicher-Matheisen, et al. 2015) (discussed below).

Several policy instruments were employed to tackle excess N. Regulatory instruments including bans, limits and requirements are the primary instruments used in this context.

Fertiliser account system: In 1991, a mandatory fertiliser account was established whereby farmers are required to account for total N use. This was the basis for an efficient controlling system, which has been developed over time and includes almost all Danish farms including their export and import of manure and mineral fertiliser. In 2006, the integration with the Central Husbandry Register led to dependable accounting of livestock and use of manure in the fertiliser accounts (Blicher-Matheisen, et al. 2015). Applied P will also be registered through the fertiliser accounting system under the revised regulation addressing phosphorus introduced in 2017. P ceilings will be implemented with general ceiling for 76% of the land area and stricter ceilings for 26% area covering P vulnerable catchments.

N quota system: The quota system includes mandatory N standards per crop with focus on N housekeeping. The N quota is related to the specific crop rotation, soil type and region

of the individual farm. The fertiliser standard for each crop and soil is estimated at 10% below the economically optimal dosage. Farmers prepare plans for the use of N fertiliser prior to the growing season (including crop maps and soil types). After the growing season, the total fertiliser consumption for the farm is recorded in the fertiliser account. There is a non-compliance fine (up to DKK 20 (EUR 2.70) per kg N) levied on use of nitrogen beyond the amount allowed by the fertiliser account (Tan and Mudgal 2013).

There are large variations within and among catchments and measures to tackle nutrient pollution have become more expensive over time since 'low-hanging fruit' has already been availed. Therefore, a new geographically targeted regulation will be implemented starting in 2019. Rather than all farmers receiving quotas for the calculated 10% under economically optimal dosage, restrictions will be introduced where needed on individual farm's leaching of nitrogen based on sensitivity of coastal waters and the average retention from the root zone. A leaching permit to the aquatic environment (calculated in Kg N/ha) will be appointed for each farm in the targeted catchment area. Farmers will be given flexibility in choice of measures to meet this obligation (such as reduced fertiliser application, buffer strips or catch crops) and compensation will be provided to farmers for undertaking these.

Mandatory catch crops[42]: Farmers applying less than 80 kg N in manure per hectare must establish catch crops covering 6% of their farmland. Farmers applying more than 80 kg N per hectare must establish catch crops on 10% of land. A more targeted regulation on catch crops was introduced under the green growth agreement (2009-2015). An additional 140 000 hectares of catch crops was to be located in specific catchments discharging to estuaries where the ecological status was poor[43] (Blicher-Matheisen, et al. 2015).

Bans: There is a ban on applying manure in autumn and winter on bare fields. Additionally, a ban on broad spreading of liquid manure was introduced in 2002 for reduction of ammonia to meet Natura 2000 standards.

Fertiliser tax: In 1998, a tax of DKK 5 (EUR 0.7) per kg N for fertilisers was introduced targeting non-farm use. Farmers included in the fertiliser account registered with the authorities, are exempted from the tax (Blicher-Matheisen, et al. 2015). A tax is also levied in the amount of mineral phosphorus in animal feed (Tan and Mudgal 2013).

Subsidies: The definition of Sensitive Farming Areas restricted incentive agro-environmental payments to farmers who undertook certain nitrogen management measures[44]. Farmers voluntarily converting to organic farming or re-establishing former wetlands were provided compensation for production losses through a three-year regressive conversion payment. Subsidies are also provided for investments in proper manure storage (Tan and Mudgal 2013).

Information and training: Denmark has an efficient and well-established farmer advisory service which is owned and used by more than 80% of farmers enabling dissemination of the latest information. The role of the advisory service is to process and communicate latest

[42] A catch crop is a fast-growing crop that is grown between successive plantings of a main crop.

[43] For other catchments a no demand for additional catch crops was needed.

[44] Such as farmers who reduce nitrogen fertiliser application to 60 % of the needs defined by national standards; re-establish wetlands; establish 12 metre pesticide-free margins or (since 2005), 10-metre uncultivated buffer zones along watercourses and lakes; practice extensive permanent grassland management; cultivate catch crops; or set aside land over a 20 year period.

knowledge to advisors to disseminate in the country. Several nationally funded research programmes have been instrumental in providing new knowledge on effects of various measures (Blicher-Matheisen, et al. 2015).

Monitoring and evaluation of the environmental and cost effects of the agricultural load: The effects of policy measures are tracked in a nation-wide monitoring programme covering leaching from root-zone, load to groundwater and coastal and open marine waters. The Danish National Plans for Aquatic Environment (1987, 1998, and 2004) and the Green Growth Plan (2009) have been important means of targeting a reduction in, and reporting on level and trends of N load from agriculture on water resources. Each of the plans included clear targets and was monitored with regard to environmental outcomes and cost effectiveness through mid-term and ex-post evaluation of various policy instruments. Table 4.3 provides as an example, the estimated costs and cost-effectiveness of the Green Growth measures between 2009 and 2015 to reduce N in river basins and their re-estimation after implementation.

Table 4.3. Cost effectiveness of measures to reduce N in river basins in Denmark

			Green Growth (2009-15)		Re-estimation	
Measure	Area (ha)	Effect per year (tons N)	Cost (EUR mill./yr)	Cost-effect. (EUR./kg N)	Cost (EUR mill./yr)	Cost effect (EUR/kg N)
Adjustment of the N norm system (average for 5 years)		1 008	0.0	0	5.0	5
Ban on certain forms of soil cultivation in autumn	111 000	739	0.1	0.1	0.1	0.1
No ploughing of grass fields in autumn	15 000	230	0.1	0.9	0.9	4.0
Tightened regulation on existing APAE catch crops	50 000	690	2.8	4.0	3.2	4.7
New targeted catch crops	140 000	1 706	7.9	4.0	9.1	5.4
Buffer zones	50 000 (later reduced to 25 000)	2 561	14.8	5.8	12.8	5.0
Wetlands	10 000	1 131	8.3	7.6	8.3	7.6
In total		8 065	34.1	4.2	39.4	4.9
-cost to agriculture		4 373	11.0	2.5	18.3	4.2
-cost to State		3 692	23.1	6.3	21.1	5.7

Note: Price is per kg N loss in the sea (not in the root zone)
Source: Blicher-Matheisen et al., (2015), Danish policy measures to reduce diffuse nitrogen emissions from agriculture to the aquatic environment.

4.3.2. *Japan*

Japan faces a strong need to address nutrient balance to curtail negative impact on environment and has seen some success in this regard (see Figure 3.5). The environmental load from agriculture in Japan remain above world average for several indicators including N and P surpluses (OECD 2015b). Japan has some of the highest levels of fertiliser use in the OECD, despite the fact that levels have declined by 28% between 2002 and 2014 (World Bank 2017). Moreover, although farm rate of annual average increase in nitrogen and phosphorus surpluses have declined, absolute levels remain a matter of concern with

one of the highest N surpluses[45] and the highest P surplus in the OECD (see Figure 3.4). Small farm size, low productivity and part-time farmers contribute to the over-use of chemical inputs to compensate for the lack of land and labour availability (Jones and Kimura 2013).

Positive incentives, technical assistance and sustainability certification are the main instruments used to promote better environmental practices, including more sustainable fertiliser use in the Japanese agricultural sector (Uetake 2015).

Regulation on information labels: The Fertiliser Regulation Act (1950) was revised in 2001 to improve the system for including fertiliser composition information in labels to encourage the proper use. In this system, livestock composts, as well as other commercial organic fertilisers, must show their N and heavy metal contents, C:N ratios, alkalinity, and other characteristics to improve availability of information to farmers (Hayashi, et al. 2015).

Tax: There is no national tax on fertilisers though some of the general preferential tax treatment that aims to reduce water pollution is applicable in this case. For example, preferential tax treatments are to livestock farmers who introduce pollution control facilities (e.g., sewage treatment facilities). At the local level, Ibaraki Prefecture introduced the Forest Lake Environment Tax in 2008 with a 5-year term (the tax is currently in its second term), the goal of which is to conserve forests and lakes in the prefecture. Ibaraki Prefecture is the location of Lake Kasumigaura, where water pollution by N is a concern. Tax revenue collected from residents and businesses in the prefecture amounts to around JPY 1 600 million (USD 15 million) per year. Part of the revenue is used to implement measures against point and non-point sources of pollutants, including N, to improve the water quality of Lake Kasumigaura (Hayashi, et al. 2015).

Subsidies: Subsidies are provided for measures such as construction of compost production facilities which could help reduce fertiliser use. Producers certified as eco-farmers are eligible to receive direct payment for improving their agricultural practices as well as interest-free loans. The framework for direct payments was revised in 2011 to the Direct Payment for Environmentally Friendly Agriculture Programme to support individual farmers and groups of farmers (whereas the previous framework only applied to groups of farmers) who adopt farming practices that address global warming and increase biodiversity (OECD 2017c). Direct payments for environmentally friendly agriculture include, at the national level, payments for introducing cover crops and/or compost use to reduce fertiliser use and, at the regional level, payments for practices such as minimum tillage and use of slow release fertilisers (Asai, Yagi and Shirato 2017).

Eco-farmer System: Reflecting the variety of climate and natural features, Japan's eco-farmer system reflects regional diversity in faming styles. Ministry of Agriculture, Forestry and Fisheries (MAFF) recommends sustainable agricultural production practices including techniques to reduce the consumption of chemical fertilisers and agrochemicals and techniques to reduce environmental loads from excess N and P. Local governments establish guidelines for introducing these techniques, taking into account the local characteristics and the current status of environment. Farmers voluntarily implement the techniques based on the local guidelines and can then apply to the local governments to become certified "eco-farmers". 166,373 eco-farmer certificates had been issued (both to individual farmers and groups of farmers) by 2015.

[45] Only Korea and Cyprus have higher N surpluses.

Product certification: The Act on Promotion of Organic Agriculture (2006) aims at enabling expansion of organic agriculture through supporting organic farmers and distribution of organic products. Measures under the Act include promotion of R&D and extension services for organic farming, increasing awareness of organic farming among consumers and establishing organic farming promotion plans at prefectural and town/village levels. A certification system for Japanese Agricultural Standards, 'Organic JAS' requires sufficiently minimizing the use of chemical fertilisers and agrochemicals along with prohibiting the use of genetic modification technologies (Hayashi, et al. 2015, Uetake 2015). Several certification schemes exist at the level of local governments. Some of these precede the national level certification and others carry additional requirements as compared to the 'Organic JAS'. Most of these certifications target less than 50% of the application of chemical N fertilisers and agrochemicals as compared to average local levels. For instance, the 'clean products' certification in the Hokkaido Prefecture requires measurements of soil available N contents to determine permissible application rates of chemical N fertilisers. Moreover, application of organic fertilisers (manure, composted manure, green manure, plant residues, and other organic materials) is required, with specified lower limits for each material to maintain or improve soil fertility. 14% of the total number of farmers in the prefecture in 2013 and 4.1% of the total cropland area in 2012 were certified under this label. Okayama Organic and Chemical-Free Farm Products (Okayama Prefecture) label is more stringent and requires that no agrochemicals or chemical fertilisers be used at all. The Okayama prefecture supports expansion of production and development of sales to establish a stable supply for certified products[46] (Hayashi, et al. 2015).

Monitoring and evaluation: Long-term monitoring of soils has been in place since 1979 and includes direct sampling as well as information on soil management collected through questionnaires (Asai, Yagi and Shirato 2017). Water quality of rivers, lakes, coasts, and groundwater is monitored for compliance with national water quality standards (WQS) including substances such as nitrates, phosphorus and pesticides. Japan's water quality monitoring system has been expanded at the prefectural level and in the designated cities, with the emphasis being placed on installing automated water-quality monitoring equipment and regular reporting. However, the agricultural sector's share in water pollution cannot be identified precisely. Moreover, aggregated data cannot provide details regarding the diverse local situations. Improving agri-environmental data and monitoring in a cost-effective manner has been identified as an important challenge for Japan (OECD 2010).

4.3.3. *United States*

The United States has relied largely on voluntary approaches supported by financial and technical assistance to farmers to manage fertiliser use. Between 1992-2002 to 2002-2014, N inputs increased. However, the rate of change in N outputs (uptake by crops) was sufficiently large to compensate for the increase in inputs, leading to overall reductions in annual average per cent change in N balance from 0.3 kg N/ha between 1992-94 and 2002-004 to -1.2 between 2002-2004 and 2012-2014. Rate of annual average growth of the P

[46] Several other prefectures also offer local certification schemes for agricultural products that receive applications of agrochemicals and chemical N fertilisers at rates less than the local conventional rates, such as 'Yamagata Specially Cultivated Farm Products' (Yamagata Prefecture), 'Ibaraki Eco-Farm Products label' (Ibaraki Prefecture), 'Shinsyu Environmentally Friendly Farm Products' (Nagano Prefecture), 'Environmentally Friendly Farm Products' (Shiga Prefecture).

balance also declined in this period from 0.8 kg P/ha between1992-94 and 2002-004 to -2.4 kg P/ha between 2002-2004 and 2012-2014 (OECD 2018a). In the case of corn, which is the most widely planted crop in the United States and largest user of N[47], acreage treated with N fertilisers increased by 18% between 2001 and 2010 as more corn was planted in response to higher prices. At the same time there was also a more efficient use of fertilisers as acres receiving excess fertilisers (above agronomic rates) declined from 41% to 31%. This is thought to be in response to higher fertiliser prices in this period, as well as increased awareness and concerns regarding environmental quality (Ribaudo, Livingston and Williamson 2012).

The U.S. Department of Agriculture (USDA) carries the primary responsibility for programs and policies to address fertiliser pollution in agriculture, while the Environmental Protection Agency (EPA) works with states to set water quality standards under the Clean Water Act[48]. A majority of the programs aimed at reducing nitrogen and phosphorus impacts on the environment are therefore managed by the USDA in conjunction with the EPA and state governments (US EPA 2016). The USDA implements two broad programmes, namely the Working Lands Programmes, aimed at reducing excess nutrient runoff on cultivated lands; and Land Retirement Programs, which aim to reduce impacts by removing land from production. Both types of programs provide for technical and financial assistance.

Under the working lands programs, the Environmental Policy Incentives Program (EQIP) provides financial and technical assistance to implement a range of conservation practices set out in the National Conservation Practice Standards Handbook (such as planting cover crops, establishing riparian buffer zones, and implementing precision agriculture technologies). Similarly, the Conservation Stewardship Program (CSP) provides five-year contracts for agricultural producers to implement and maintain conservation practices.

Land retirement programs include the Conservation Reserve Program (CRP), which provides annual rental payments to producers in exchange for establishing conservation cover on environmentally sensitive lands (particularly those near waterways); and the Agricultural Conservation Easement Program (ACEP), which provides funding to place agricultural lands and wetlands into 30 year or permanent conservation easement (Carter and Rubenstein 2017). A summary of policy instruments applied in this context is provided in Table 4.4.

[47] In terms of application rated per acre, total acres treated and total applications.

[48] The National Nonpoint Source Programme under the Clean Water Act provides guidance and funding to states through the EPA to manage nonpoint source pollution.

Table 4.4. Examples of policy measures to reduce nitrogen loss from agriculture in the United States

Policy tool	Policy Participation	Selected U.S. programmes	Measures
Educational/Technical assistance	Voluntary	Conservation Technical Assistance, Co-operative Extension Programme	Provide farmers with information and training to plan and implement practices
Incentive Policies: Long term contracts	Voluntary	Conservation Reserve Programme (CRP)CRP" Continuous Signup; and, Conservation Reserve Enhancement Programme	Payments for retiring cropland Payments for partial-field practices (e.g. grass waterways, filter strips)
Incentive Policies: Financial Assistance	Voluntary	Environmental Quality Incentives Programme; Conservation Stewardship Programme; and, Point-nonpoint trading programme	Payments to offset the cost of adopting nutrient management practices (payments may originate from an environmental credit trading programme)
Incentive Policies: Easements	Voluntary	Agricultural Conservation Easement Programme	Long-term or permanent easements to restore and protect wetlands and farm and ranch open space
Environmental Taxes	Involuntary	None at the Federal level	Per-unit charges for failure to meet environmental goals
Nitrogen Input taxes	Involuntary	None at the Federal level.	Sales taxes at state level are small and are unlikely to affect behaviour
Regulatory Requirements	Involuntary	Clean Water Act (animal feeding operations) Various state laws	Producers may be subject to regulations if voluntary measures do not achieve environmental goals. Some animal operations may be subject to effluent discharge permits

Source: Ribaudo (2015), Policy measures to reduce nitrogen losses from agriculture in the United States.

Regulation: Addressing non-point source pollution to water is mainly the responsibility of the state governments[49]. Fertiliser activities on cropland can be regulated only at the state level, though most states have opted not to take this approach and instead rely on voluntary measures along with financial and technical assistance (Shortle, et al. 2012). Moreover, monitoring and enforcement of state level programmes is challenging, attributable to non-confrontational approaches to agriculture, funding shortages and difficulties in tracing source of water quality violations (Ribaudo 2015).

Examples of state level programmes include requirements for nutrient management plans in Maryland and Delaware. Under the Water Quality Improvement Act in Maryland, all farmers grossing USD 2 500 a year or more or livestock producers with 8 000 pounds or more of live animal weight, must follow nutrient management plans specifying how much fertiliser, manure or other nutrient sources may be safely applied to achieve yields while preventing excess nutrients from contaminating waterways. Revisions in 2012 added requirements to phase out winter applications of manure and limits fall applications to small grains. In 2013, 73 % of farms were found to be in compliance with these requirements (Maryland Department of Agriculture 2013).

A number of states have also developed (or are in the process of developing) water quality trading programmes for nitrates in order to meet improved water quality goals at least cost. Ex-post assessments of point source–non-point source (PS-NPS) water quality trading programmes have generally shown poor performance. Reasons include a lack of trading

[49] As stated in the Clean Water Act.

partners (due to limited regional scale or underlying economics), inadequate regulatory incentives (discharge cap was not binding enough for regulated firms to seek trades), uncertainty about trading rules and practice performance, excessively high point-nonpoint trading ratios (increase the cost of nonpoint credits), legal and regulatory obstacles (including liability concerns), high transaction costs, and unfamiliarity and inexperience of participants (Ribaudo 2015). An example of one of the more successful trading programme is provided in Box 4.1 below.

Box 4.1. Greater Miami Watershed pilot trading programme

The Greater Miami Watershed pilot trading programme is a promising programme established by the Miami Conservancy District in 2005. The programme pooled funding from federal USDA grants and voluntary donations from point sources to create a fund to pay for non-point source reductions. Participating municipal wastewater treatment plants can choose to purchase agricultural credits on favourable terms in advance of an expected tightening of discharge standards. The programme then uses the collected funds to implement agricultural best management practices (BMPs) through bi-annual reverse auctions. Farmers submit applications through participating Soil and Water Conservation Districts (SWCDs) while the SWCDs provide technical assistance to farmers.

By early 2013, 11 rounds of project submissions resulted in potential funding for 397 agricultural projects for adopting water quality-improving BMPs. These projects are expected to generate 1.14 million credits (572 tons of nutrients) over the life of the projects, and USD 1.6 million in credit sales to farmers.

Source: Ribaudo (2015) Policy measures to reduce nitrogen losses from agriculture in the United States.

Taxes: At least 46 states impose charges on the sale of fertilisers. Most of these are set at below USD 1 per ton. The USD 4 per ton fee in Nebraska is one of the highest. The charges are too low to significantly affect fertiliser use. The most common use of the tax revenues is for the inspection of fertilisers and fertiliser storage by state agencies (US EPA 2001).

Monitoring and evaluation of impacts: The USDA gathers information regarding the agricultural use of fertilisers through the Agricultural Resource Management Survey (ARMS). Producers of nine major field crops (barley, corn, cotton, oats, peanuts, rice, sorghum, soybeans, and wheat) are contacted in selected years to report on nutrient applications and application methods for synthetic fertilisers and manure. The quality of the country's coastal waters, lakes and reservoirs, rivers and streams, and wetlands are tracked using a statistical survey design under the National Aquatic Resource Surveys (NARS) which are collaborative programs between the Environmental Protection Agency (EPA) and states. However, due to differences in state-level assessment methods, the information collected cannot be used to compare water quality conditions between states or to determine water quality trends.

Under the Nutrient Framework Memorandum (2011), the EPA is to work collaboratively with states and other partners to accelerate nutrient load reductions and state adoption of numeric nutrient criteria. Currently 4 states have established a complete set of N and P criteria for all water types and 28 states have set partial criteria (US EPA 2018). The EPA has also developed a Nutrient Indicators Dataset which consists of a set of indicators to track associated state-level data and to serve as a regional compendium of information pertaining to potential or documented nitrogen and phosphorus pollution; impacts of that

pollution; and states' efforts to minimize loadings and adopt numeric criteria for nutrients into state water quality standards. Numerical water quality standards and national indicators will be useful in setting targets and tracking progress on a wider scale than is currently possible.

In the meanwhile, impacts at the local and regional level have been documented. A study in the Western Lake Erie Basin for instance, estimates that implementation of N management measures including under the Conservation Reserve Programme led to a decrease in nitrogen losses from cultivated croplands by 6%, and phosphorus losses decreased by 17%, between 2003-2006 and 2012; nitrogen and phosphorus loads to Lake Erie decreased by 1% and 3% during this same time, respectively (USDA 2017).

However, a review of N management practices supported by USDA conservation programme shows that rates of voluntary adoption of conservation practices in 2010-11 varied widely across regions and crops and remains limited in several cases. For example, farmer reported nitrogen rates are higher than benchmark application rates for 36% of corn acres, 19% of cotton acres and over 20% of wheat acres, only 6% of corn acres and 24% cotton acres reported use of multiple nutrient management practices[50] which provide greater potential to reduce N loses than using a single practice. Cover crops were in use on less than 2 percent of total cropland (Wade, Claassen and Wallander 2015).

[50] These are: (1) no application in the fall, (2) some application after planting, (3) nitrogen application at rates below a "benchmark," and (4) fertilisers incorporated or injected below the soil surface.

5. Policy insights and recommendations

While pest management and nutrient input are important for agricultural production, multiple and sometimes serious environmental and health externalities arise from current pesticide and fertiliser use patterns. Progress has been made in reducing nutrient surpluses and pesticide use in some OECD countries over the last two and a half decades, but pesticide and nutrient pollution remain a persistent issue requiring further attention and efforts.

Policy makers face several complexities and uncertainties in reducing environmental impacts of pesticide and fertiliser use. Complexities in the case of nutrient pollution include spatial heterogeneity of sources and sinks, difficulties in observing non-point source nutrient loads, time lags in nutrient transport and nonlinear nutrient dynamics in waterbodies (Shortle and Horan 2016). In the case of pesticides, current EU risk assessment models inadequately predict quantities of pesticides in surface waters and do not assess accumulated pesticides in sediments (Underwood and Mole 2016). The risks of ecological impacts of pesticides may therefore be significantly underestimated. Moreover, often the long-term effects and effects of interaction of multiple substances are not yet fully understood. At the level of individual pesticide substances, most countries carry out risk assessments prior to registration. However, it is difficult to assess the multi-dimensional risks of new pesticides. In addition, re-evaluations of existing pesticides need to be carried out periodically in light of new alternative substances, up-to-date scientific evidence and risk assessment methodologies. Co-operation in sharing information on risk assessments of pesticides regionally and internationally could be one way to optimise the use of limited resources and capacity (such information however, will need to be contextualised against local conditions and use practices). An example of such an initiative is the OECD Programme on Pesticides and Sustainable Pest Management, which has worked to streamline the process of pesticide approval and registration by helping governments work together to evaluate the risks of individual pesticides more quickly and thoroughly. To assist countries to co-operate in the review of pesticides, the OECD has created internationally agreed formats for registering and reviewing agricultural chemical and biological pesticides; is developing (jointly with the Test Guidelines Programme) guidelines for the methods used to fulfil the pesticide registration data requirements; and harmonising exposure, hazard and risk assessment methods to interpret the test results and to assess a pesticide's risk[51].

The literature and cases studies analysed here demonstrate that to reduce environmental externalities from pesticide and fertiliser use there is a need to:

Build a stronger knowledge base: Programmes for systematic collection and dissemination of data on pesticide and fertiliser use, risks and impacts can enable problem identification, selection of measures and monitoring of progress in reducing environmental and health externalities[52]. A clear understanding of socio-economic aspects is also essential

[51] https://www.oecd.org/fr/securitechimique/pesticides-biocides/pesticides-testing-assessment.htm.

[52] Examples of useful information in this regard include: pesticide and fertiliser use patterns for key crops; production, import and distribution of pesticide and fertilisers; use circumstances (storage, handling and application); environmental contamination (soil, ground water and surface water); impact on non-target species (including beneficial predators, fish, bees etc.); and documentation of economic and environmental impacts of measures in place.

to understand underlying economic drivers and for designing cost-effective policies (Shortle and Horan 2016). Stakeholder engagement can be a vital element of information collection, including on local contexts and impacts and in determining level of acceptable risk to society. For example, in Japan, information on soil management is collected through questionnaires along with direct sampling. In the United States, the EPA works collaboratively with the states and other partners to gather information on nutrient loads in water bodies and states' efforts to minimise these loads. Denmark and France also engage stakeholders extensively in the development and implementation of their pesticide management plans.

A robust evidence base, including on economic costs, and impacts on human health, can also help build support for policies and overcome resistance from vested interests (OECD 2017). In France for example, robust scientific evidence enabled the introduction of the pesticide savings certificate scheme despite pressure against such a measure from lobbying groups. In Denmark, evidence that groundwater used for drinking purposes had been polluted preceded the introduction of the first pesticide reduction plan in 1986. The Danish Pesticide Leaching Assessment programme was established to provide evidence for policy making and has led to bans on certain pesticides that were previously authorised for use.

Opportunities for using digital technology to address problems arising from information gaps, information asymmetry and transaction costs across the 'policy pipeline' could be further explored[53]. Governments could potentially support the development of data infrastructure in agriculture by supporting an enabling regulatory environment (addressing issues in relation to the collection, use and sharing of data and other relevant regulations); supporting improvements in connectivity and the development of a data collection infrastructure (sensors network, remote sensing etc.) and the development of innovative services.

Set clear quantitative targets and develop plans to achieve them: Time-bound plans can be used to set the objectives and level of ambition to reduce the negative externalities of pesticide/fertiliser use. Such plans should lay out clear targets, mandatory and voluntary measures, resource allocation and division of responsibilities along with time frames. High-level quantitative targets can provide a means of clearly communicating the desired outcome to all stakeholders and monitoring progress. Targets can be expressed in terms of use reduction (examples include France where the target is a 50% reduction in pesticide use and Denmark where N quotas are provided to farmers to reduce fertiliser use), risk reduction (such as the target to reduce Pesticide Load Indicator by 40% in Denmark) and/or in terms of actual environmental impacts (for example through water quality standards in Denmark, Japan and some areas of the United States).

Targets related to environmental outcomes are preferable to use reduction targets as they demonstrate environmental effectiveness of measures in place. As evident from the case of pesticide targets in Denmark, risk reduction can take place due to shift to less harmful substances. Thus risk reduction is not correlated with overall reduction in pesticide use. Similar results have also been noted in other countries with risk reduction targets[54]. There

[53] See preliminary report on *Digital Opportunities in Agriculture: Some Policy Implications* (COM/TAD/CA/ENV/EPOC(2018)3) for an overview of the opportunities offered by new technologies for improved decision-making, policy design and monitoring.

[54] Other countries with risk reduction targets include the Netherlands (Environmental Indicator for Pesticides), Sweden (National Risk Index for Health and Environment and Toxicity Index) and

is therefore a need to further develop risk indicators for pesticides. In France, indicators to track the risks and impacts of pesticides on environment are intended to be developed under the current pesticide reduction plan.

Impact reduction targets include level of pesticide or nutrient pollution in soil and water bodies, effects on non-target organisms or level of pesticide residue in agricultural produce. While some of these indicators are comparatively easier to measure (such as pesticide residue in agricultural products), others such as diffuse water pollution call for more sophisticated and costly monitoring and evaluation programmes.

Identify and implement an ambitious policy mix: An array of policy instruments will need to be employed to achieve defined objectives in the given context. These include:

Regulatory instruments: Regulatory instruments have been used to manage input use including through controlling available substances and setting ecological and health standards to control pesticide and nutrient pollution. Input management practices (such as restrictions on rate, area and timing of application) can be an effective means of reducing losses of diffuse contaminants such as pesticides and fertilisers. Moreover, input based regulations are often favoured, as calculating farm-scale losses of diffuse contaminants is comparatively challenging (OECD 2017a). Output-based regulations include standard setting such as water quality standards and maximum residue levels for pesticides. Transitional measures may be needed to counter the adjustment costs or distributional impacts of regulations. Advisory and informational services are also needed to facilitate necessary technical and economic adjustments and uptake of more sustainable alternatives. There is also increasing recognition of the need to work with stakeholders to enable necessary efforts to meet regulatory requirements.

Fertiliser and pesticide policies in Denmark have a significant component of regulatory measures as compared to other countries examined here. A robust scientific evidence base, regular monitoring for compliance, evaluation of impact of policies, and non-compliance fines (in the case of exceeding N quotas for example) and stakeholder involvement have been used to support regulatory measures in place.

Economic instruments*: Taxes***:** Pesticide and fertiliser taxes can form an important component of a coherent set of policies aimed at reducing use and risks. Relatively few countries have fertiliser taxes in place however. The low price elasticity of demand necessitates that the tax rate for pesticide and fertilisers be set relatively high to generate decline in their use. Pesticide tax rate in France and fertiliser tax rates in the United States have been too low to incentivise reduction in use.

Unlike uniform taxes (ad valorem or per unit), differentiated taxes rates that place a higher burden on substances with higher environmental (and health) risks, create incentives for a move towards lower-risk substances. Such differentiated tax systems have been employed for pesticide taxes in Sweden, Norway, Denmark, France and Mexico. Among these

Germany (Risk Index for Aquatic Non-target Organisms and Risk Index for Terrestrial Non-target Organisms). Each of these countries has seen a reduction in risks related to pesticide use since 1998-1999 due to a more favourable toxicological and environmental profile of active substances used. In both Sweden and Germany, there has been no significant reduction in pesticide use compared to the base period (EC 2017).

countries there has been a reduction in risk to the environment and to human health from pesticide use in Sweden, Norway and Denmark[55].

Re-imbursement of pesticide and fertiliser tax revenues to the agricultural sector is a common feature and has been employed in Denmark, France and Italy. This has been undertaken in part to help mitigate potential income effects and can promote the political acceptability of such taxes. This re-imbursement could be directed towards measures that further reduce pesticide and fertiliser related impacts such as investment in R&D or in extension and advisory services to support alternative pest and nutrient management as is done in Italy. In France, a part of the revenues from the pesticide tax are directed towards implementation of measures under the pesticide reduction plan, including research and information provision. A reduction in other forms of taxation to the sector is another option to minimise the cost to farmers. In Denmark part of the pesticide tax revenue is returned to the sector in the form of land tax abatement while another large part is invested an agriculture sector fund.

Subsidies: Positive incentives are the among the most commonly applied instruments, used to compensate farmers for the risks (real or perceived), time and skill required for shifting to more sustainable production patterns. Examples include subsidies and direct payments for promotion of organic agriculture (e.g. in Denmark, Japan and Italy) and agroecology (e.g. in France) or for adopting practices that reduce pesticide and fertiliser use or check pesticide and nutrient pollution. Examples of such measures include land easements (United States), employing specified N management practises (Denmark, United States), establishing buffer zones (Denmark), planting cover crops (Denmark and Japan), constructing compost production facilities and using slow release fertilisers (Japan). Moreover, support for advisory services, R&D and for development of markets for sustainably produced agricultural products downstream, could provide impetus for changes required beyond the farm level.

Subsidies have been used to promote uptake of voluntary measures in several cases. While voluntary instruments provide flexibility, it is not clear that such measures have achieved desired results where they have not been coupled with other policy instruments to set clear objectives or standards, as demonstrated by the case of the United States (Carter and Rubenstein 2017).

In the meantime, further efforts are needed to reform indirect or direct subsidies that encourage excessive pesticide and fertiliser use. Some countries have taken steps in this regard. In France, for instance, the removal of reduced VAT on pesticides did not affect production costs of most farmers as they benefited from a simplified VAT scheme. In Ireland, a recent study estimates that the removal of zero VAT for fertilisers would lead to an estimated 9.85% decline in N fertiliser use and an 8.97% decline in P fertiliser use and would generate EUR 35 million in tax revenue annually (Morgenroth, Murphy and Moore 2018). Another example is Korea where the fertiliser subsidies were eliminated in 2005, and policies introduced to promote organic agriculture contributing to a reduction in fertiliser use (OECD 2018a).

Information and advisory services: Regulatory and economic instruments will need to be complemented with technical assistance and advisory services to provide farmers with awareness and skills to shift to alternative pest and nutrient management practices.

[55] This reduction in risk coincides with the introduction of the pesticide taxes but is linked to a range of policies.

Independent publicly funded advisory services such as those available in Denmark have been instrumental in raising awareness of available alternatives and providing information and assistance to implement these. Danish farmers can also avail subsidised individual consultancy services for IPM adoption. There are increasing examples of state agencies moving towards collaborative approaches (including measures such as intensive extension programmes) to helping farmers move towards better practices and meet regulatory requirements.

There is a need for more empirical evidence regarding environmental benefits and economic sustainability of alternative production systems such as IPM and organic agriculture against *status quo,* especially in regional and crop specific contexts (OECD 2016b, Lefebvre, Langrell and Gomez-y-Paloma 2015). Demonstration and test farms such as the DEPHY *Expe* and DEPHY *Ferme* network in France, can be a good means for providing proof-of-concept and for exchange of knowledge between researchers, advisory services and farmers.

Consider targeting responses to 'hotspots': Focussing actions in particular areas within countries which are higher risk relative to other locations can help increase efficiency and effectiveness of policies. This is possible where risks are not uniform at the national level, high-risk regions are well-defined and hotspot assessments are based on robust data and information (OECD 2017g). This approach is particularly well suited to water risks arising from agriculture (including nutrient and pesticide pollution) since local specificities play a major role (OECD 2017g). In Denmark for instance, there is now a move towards geographically targeted regulations for fertilisers towards identified sensitive catchment areas to improve environmental and cost effectiveness.

Strengthen monitoring and evaluation processes: More robust monitoring and evaluation is required to assess progress and to enable adaptive management over time. Building a stronger knowledge base on pesticide and fertiliser use, risks and impacts (as mentioned above) will also enable the M&E efforts. Along with delineation of indicators, clear responsibilities and procedures for coordination need to be set out for data collection and dissemination. This information should ideally be made publicly available for use by various stakeholders. In Denmark mid-term and ex-post M&E of measures in place has been a key element in improving the effectiveness of policies. Better monitoring of impacts of pesticides and fertilisers on biodiversity is required. In several cases water quality standards need to be established (or strengthened) to enable tracking pesticide and nutrient pollution in water resources. Progress in this regard is being made in the United States where states have been directed to establish N & P criteria for all water body types. Further efforts are also required to improve data quality in a cost-effective manner and to promote comparability of data to determine larger trends.

Annex A.1. International initiatives for pesticide management

The FAO Code provides guidelines for managing pesticides in order to protect human health and the environment and promotes integrated pest management. All FAO Member Nations are encouraged to promote the Code of Conduct in the interest of safer and more efficient use of pesticides and it enjoys broad support from governments, the private sector, public interest groups such as the Pesticide Action Network (PAN) and international agencies such as the WHO. In addition, a voluntary policy framework and strategy entitled Strategic Approach to International Chemicals Management (SAICM) brings together various stakeholders facilitated by UNEP to catalyse achievement of the goal that by 2020 "chemicals are used and produced in ways that minimize adverse effects on human health and the environment". Stakeholders are drawn from several sectors including agriculture, environment, health, industry, labour, economics, science and academia.

The Rotterdam Convention covers international trade in hazardous chemicals (most of them being pesticides). If all parties agree that a specific pesticide constitutes severe health or environmental hazards it can be listed for prior informed consent procedures. They require exporting countries of these chemicals to notify importing authorities on data of known hazards. Currently the convention lists 33 pesticides.

The Stockholm Convention aims to eliminate or restrict the production and use of persistent organic pollutants (POPs), some of which are pesticides. Based on a specified review process pesticides that fulfil the criteria for POPs can be listed for elimination or restriction.

The Joint Meeting on Pesticide Residues (JMPR) is an expert ad hoc body administered jointly by FAO and WHO with the purpose of harmonizing the requirement and the risk assessment on the pesticide residues. It recommends maximum residue levels in food and feed commodities and provides guidance on pesticide product quality parameters for regulatory and trade purposes.

The OECD has developed an international platform on Integrated Pest Management entitled the *Integrated Pest management Hub* (https://www.oecd.org/chemicalsafety/integrated-pest-management/) to enable information sharing and cooperation between stakeholders. A 2nd OECD workshop on IPM was held in October 2011 to address four main aspects of IPM: technology and information; economics and market access; policies and strategies; measurement and impact (http://www.oecd.org/officialdocuments/displaydocument/?cote=ENV/JM/MONO(2012)32&doclanguage=en).

Annex A.2. Measures towards sustainable use of pesticides in the European Union

Directive 2009/128/EC on the sustainable use of pesticides, was adopted on 21 October 2009. The Directive provides for a range of actions to reduce the risks and impacts of pesticide use on human health and the environment and promote the use of Integrated Pest Management (IPM) and alternative approaches or techniques, such as non-chemical alternatives to pesticides.

A recent report provides an overview on the progress in implementation of the Directive (EC, Report from the Commission to the Europoean Parliament and the Council on Member State National Action Plans and on progress in the implementation of Directive 2009/128/EC on the sustainable use of pesticides 2017):

- All Member States have adopted National Action Plans (NAPs) as mandated by the Directive. However, there is a large diversity in their completeness and coverage. 21 countries have established pesticide risk reduction objectives, and nine countries have established use reduction objectives, with some countries having a combination of both. However, only five Member State NAPs set high-level measurable targets, of which four relate to risk reduction (Belgium, Denmark, Greece and Germany) and one to use reduction (France). The Netherlands also has measurable targets for risk reduction, although these are established outside their NAP.
- Although IPM is a key element of the Directive, compliance with the principles of IPM at individual grower level is not being systematically checked by Member States. Furthermore, clear criteria have not been set in order to ensure that the general principles of IPM are implemented by all professional users.
- Twenty six Member States have set up inspection systems for spraying equipment. However, based on available data, the level of compliance is less than 50 % in at least eleven Member States.
- All Member States have established a training and certification system and almost four million professional operators have been trained. However, not all Member States could provide data on the total number of operators who need to be trained and certified.
- Aerial spraying is prohibited in all Member States and derogations are only granted under strict conditions. The area sprayed is low, declining and effectively controlled.
- While Member States generally have systems to gather information on pesticide acute poisoning, the accuracy of this data is questionable. Systems for gathering information on chronic poisoning are not widely implemented.
- Member States have taken a range of measures to protect the aquatic environment from the impact of pesticides, to reduce the use or risks of pesticides in specific areas (such as public parks) and to promote the safe handling and storage of pesticides and remnants. However, progress in these areas is difficult to assess given the lack of measurable targets in most NAPs in this regard.

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