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Water and agriculture: towards sustainable solutions

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Contents

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Key messages

- In 2016, around 50 % of surface water bodies and 25 % of groundwater bodies in the 28 EU Member States and Norway were not achieving good status according to the Water Framework Directive (WFD), in part due to pressures from agriculture. Reducing pressures from agricultural activities is key to achieving good status of all surface water and groundwater bodies. Agricultural activities affect the ecological, chemical and quantitative status of surface water and groundwater across Europe and are a main pressure on Europe's seas.

- The main pressures from agriculture are linked to diffuse pollution from nutrients and chemicals, water abstraction and hydromorphological changes. Often several pressures act at the same time, potentially increasing the range of ecological impacts. According to information reported under the WFD, around one third of surface water bodies fail to achieve good status because of one or several of these pressures.

- Climate change exacerbates regional water stress due to increasing temperatures and altered and less predictable precipitation patterns, especially in southern Europe. This may both increase existing pressures on water and have an impact on agricultural production itself, shifting the geographical suitability of crops towards northern Europe, where conditions are predicted to become more favourable for their growth.

- Provision for a wide variety of management measures to tackle agricultural pressures on the water environment already exists within the EU policy framework. They are mainly focused on efficiency gains in the use of nutrients, pesticides and water which has led to some improvements. To date, nitrate concentration in rivers has reduced by 20 % since 1990 and agricultural abstraction by 25 %.

- Despite improvements, pressures remain at unsustainable levels with high nitrogen surpluses and over-abstraction in large parts of Europe and few signs of further improvement over the past 10 years. More in-depth analysis is needed to quantify the magnitude of changes needed in agricultural practices on a European scale to reach water objectives. However, it is unlikely that incremental efficiency gains in the use of nutrients, pesticides or water will be sufficient.

- Wider uptake of sustainable management practices based on agroecological principles, organic farming and nature-based solutions is essential for achieving the objectives of the WFD. Such practices have multiple sustainability benefits, contributing to reducing the magnitudes of the four groups of pressures on water, while they also reduce greenhouse gas emissions, enhance the long-term resilience of agriculture to climate pressures and benefit biodiversity.

- Tackling agricultural water pressures will require going beyond the strict remit of water policy. In particular, to achieve WFD objectives, more ambitious measures to promote sustainable agricultural practices are needed in the upcoming EU common agricultural policy 2021-2027. It also requires facilitating systemic changes across agricultural, food and energy policies to tackle drivers leading to unsustainable agricultural production

- The European Green Deal, including the proposed European Climate Law, adaptation strategy, biodiversity strategy, farm-to-fork strategy, chemical strategy for sustainability and zero pollution action plan for air, water and soil, does support this transition. Together they pave the way to a non-toxic environment, set a number of targets for input reduction and promote more sustainable agricultural production overall.

Executive summary

Recently the EU adopted the European Green Deal, which aims to put Europe on a path to sustainable development through its EU biodiversity strategy for 2030, farm-to-fork strategy, chemical strategy for sustainability, the proposed European Climate Law and upcoming zero pollution action plan, climate adaptation strategy and forest strategy. Among the many areas of action required to achieve this objective, Europe will need to reduce the environmental impact of the agricultural sector, in particular on freshwater ecosystems. According to the results of the second river basin management plans, reported to the European Commission by the EU-28 and Norway in 2016, only 44 % of Europe's surface water bodies have achieved good ecological status, as required by the Water Framework Directive.

Agriculture occupies more than 40 % of the European land area and it is an important sector for the European economy, providing food security for European citizens and livelihoods for a large share of its population. With 10.5 million farms across the EU, the agricultural sector plays an important role in the rural economy. Around 44 million jobs in farming and food processing are dependent on agricultural production. Europe is also an important contributor to the global food market. Around 25 % of the value of its agricultural production is exported, and a similar amount is imported. In the period 2014-2020 around 38 % of the overall EU budget was used for the EU common agricultural policy (CAP) (EUR 408 billion).

Agricultural yields have increased gradually over the decades following the Second World War, thanks to changes in crop varieties and breeding techniques, new technologies and machinery, new farming practices and increased use of inputs such as fertilisers, pesticides and irrigation water. In 2011, average crop yields in Europe were 60 % more than the global average, and livestock units in Europe more than doubled between 1960 and 2014. However, growth in agricultural productivity has been accompanied by increased pressures and impacts on water and aquatic ecosystems in the form of pollution from nutrients and pesticides, together with over-abstraction of water for irrigation, and hydromorphological alterations, in particular from drainage, irrigation (water storage) infrastructure and livestock trampling. Nitrogen emissions, for example, increased three-fold between the 1960s and the 1980s, while irrigation more than doubled during that period, mostly in southern European countries. Many northern European countries such as Denmark have drained large areas to increase agricultural production.

The last 30 years have seen some reduction in pressures, achieved thanks to efficiency gains in resource use. Agricultural water use at the EU level has decreased by 28 % since 1990, while nitrogen surplus has decreased by 10 % and nitrate concentration in rivers by 20 % since 2000. However, further gains were modest in the 2010s and pressures continue to remain at highly unsustainable levels. Nitrogen surpluses due to fertilising grassland and crops remain very high in northern and central Europe, and nitrate concentration in groundwater has not changed for 30 years. Total pesticide consumption at EU level has not changed since 2011, while agricultural water abstraction is a key driver of water stress in most southern European countries. These pressures continue to affect water quality, quantity and ecology and the biodiversity in Europe's groundwater, rivers, lakes, transitional and coastal water bodies as well as the marine environment.

Today, Europe's surface waters and groundwaters are also affected by climate change, and that will continue as the dual influence of changing precipitation patterns and temperatures affect water resources and water demand in agriculture. Precipitation has increased in some parts of Europe and decreased in others. The growing season is also getting longer, increasing the number of crops produced and demand for water, while seasonal variability is increasing. In southern Europe, precipitation is expected to decrease, increasing the risk of water scarcity in a situation in which a very large share of the water resource is already under stress. In other parts of Europe, extreme precipitation will increase the transport of nutrients and chemicals into streams, potentially increasing pollution and its impacts. More water will also increase the risk of flooding and general water logging of soil, potentially increasing hydromorphological alterations. In other words, in coming decades, the impact of global warming on water resources and aquatic ecosystems is likely to become greater. It will result in an increased level of unpredictability and uncertainty for farmers and public authorities alike.

This places more urgency on the need to develop resilient agricultural systems to buffer the impacts of climate change, both on agricultural production and farmers' livelihoods, and on aquatic ecosystems. Many measures based on agroecological principles, organic farming and nature-based solutions exist and can enhance the overall resilience of Europe's agricultural systems. While we have chosen to focus on the water perspective, many of the solutions discussed are multifunctional and also relevant to air quality, biodiversity, soils, and climate change mitigation and adaptation challenges.

The uptake of more sustainable farming systems depends critically on their being attractive to individual farmers and the stakeholders in value chains benefiting from agricultural production. Thus, developing a more sustainable agricultural production system cannot be seen in isolation from farmers' incomes, societal and life-style considerations, consumer demands and overall market forces. The European and global consumer preferences of citizens and industries are extremely important drivers of food production and prices. Hence, achieving the reductions needed to reach water and other environmental targets requires a combined approach, changing both agricultural practices and consumer demands, which is supported by a transition in food and energy systems. Managing sustainably in this context requires that changes are perceived as fair by balancing the need for affordable and healthy food, the socio-economic well-being of farmers and the protection of the natural environment and water resources.

EU policies are key to achieving a transition to a sustainable economy that also sustains aquatic ecosystems' health. The Water Framework Directive, together with other environmental legislation, climate policy, circular economy policies and the CAP instruments need to work together to maximise their effectiveness. Today, a broad portfolio of solutions is brought together under the European Green Deal and its farm-to-fork and biodiversity strategies, zero pollution ambition and European Climate Law, which have established ambitious new targets. As additional legislation is adopted, further targets and initiatives will come, aiming to:

- reduce fertiliser use by at least 20 % and nutrient losses by 50 % while ensuring that there is no deterioration in soil fertility, among others building on an integrated nutrient management action plan;

- reduce by 50 % the overall use of and risk from chemical pesticides and the use of the more hazardous pesticides by 50 % by 2030;

- reduce by 50 % the sales of antimicrobials used in farmed animals and aquaculture;

- have 25 % of agricultural land organically farmed by 2030;

- have 10 % of the agricultural area designated as high-diversity landscape features by 2030;

- achieve EU commitments on land degradation neutrality.

In addition, the newly adopted farm-to-fork strategy provides leverage towards a sustainable food system, and it calls for a change in systemic drivers, such as consumer preferences and diets. Meanwhile, other drivers linked to energy and the demand for natural fibres also need further attention.

To achieve those targets, greater coherence is also needed between EU environmental policies and the CAP. Recent decades have seen improved integration of water targets into the CAP. However, future agricultural policies need to be more ambitious with regard to production systems, in particular to support the uptake of organic farming and agroecological principles to minimise the use of inputs. More systemic attention also needs to be given to how CAP regulatory and incentive instruments support a transition in farming production systems that is coherent with environmental goals and in value chains that provide market opportunities for sustainable agricultural products. The main tools in EU policy for managing this challenge for water are a combination of the river basin management plans and the new CAP strategic plans. Other sources of public and private finance and more systemic policies linking water, agriculture, and the food and energy systems should be part of an integrated response.

Overall, this report highlights the need to manage environmental pressures on water in a broad societal context and calls for three areas to be improved: (1) more resilient management actions at basin and farm level; (2) improved implementation and integration of EU policies; and (3) more holistic and global approaches through systems thinking. Developing sustainable and long-term multifunctional solutions for water, air quality, biodiversity and soils, and to climate change mitigation and adaptation challenges, is complex. Nevertheless, the ambitions of the European Green Deal provide a unique opportunity to achieve such large-scale and systemic transformation across Europe.

Photo: © Jeanette Völker

1 Introduction

This report was initiated following the EEA's 2018 assessment of the status of and pressures on European waters, to highlight the role of agriculture in achieving an improved status of surface water and groundwater in future river basin management plans (EEA, 2018b; EC, 2019c). The EEA's 5-yearly state of the environment assessment further highlights the need for an increasingly systemic approach to overcome environmental challenges and to achieve sustainability.

In this report we analyse how agricultural production affects water quality and quantity, and aquatic ecosystems, as well as the relevant policy interventions. With the aim of addressing how the water-agriculture-food system could be better managed, the assessment is organised around two guiding questions:

- How does the current system of managing agricultural pressures on water work?
- What is needed to improve environmental outcomes?

Agriculture has an important role in providing food security and a large share of Europe's citizens live in agricultural areas. Since the Second World War, Europe has experienced unprecedented economic growth and prosperity and, together with this, a very large growth in agricultural output, delivering a great diversity of food at affordable prices across Europe. Unfortunately, this has resulted in a deterioration of the aquatic environment and ecosystems. In the same period, intensification of agricultural production has been driven by an increased use of nutrients, chemical pesticides and irrigation water inputs, while very large areas have been drained to increase productivity and the land area available for agricultural production.

The main pressures from agriculture on water are diffuse nutrient and chemical pollution, water abstraction and hydromorphological pressures. These pressures affect water quality, quantity and ecosystems and the biodiversity in Europe's groundwaters, rivers, lakes, transitional and coastal water bodies as well as the marine environment (EEA, 2018b). In addition, around 90 % of EU ammonia emissions to the atmosphere stems from agricultural sources (EEA, 2020a). Agriculture also affects biodiversity and soils and contributes around 10 % of greenhouse gas emissions (EEA, 2019g). According to the latest EEA *State of nature in the EU* report, more than 83 % of agricultural habitats are in poor or bad conservation status (EEA, 2020d). These impacts are not discussed further in this report, although they are certainly of equal importance.

1.1 Towards achieving good status in Europe's waters

The reporting of the second river basin management plans under the Water Framework Directive in 2016 showed that 44 % of EU-28 and Norwegian surface water bodies were in good ecological status or potential and 30 % were in good chemical status and that 74 % and 90 % of groundwater bodies) were in good chemical and quantitative status, respectively (Table 1.1). The second river basin management plans also showed that about one third of EU-28 and Norwegian water bodies were subject to significant pressures from diffuse sources and hydromorphology, whereas 6 % of surface water bodies and 17 % of groundwater bodies were subject to significant pressures from water abstraction (Table 1.2). Reducing these pressures will contribute to improving the status of water, a process that in many cases is complex, as each water body can be subject to multiple pressures.

Agriculture is a major contributor to pressures on Europe's waters. Pressures from agriculture on the aquatic environment are linked to specific farming practices. Fertilisers (nutrients), pesticides and water are used on crops to promote plant growth and to prevent pests or diseases damaging crops. Intensive livestock farming produces excess nutrients and ammonia emissions. Furthermore, river habitat quality is affected by a wide range of hydromorphological river modifications, made as a

Table 1.1 Overview of status assessment reported in second river basin management plans

Status assessment	Good or better (%)	Less than good (%)	Unknown (%)
SWB ecological status	44	51	5
SWB chemical Status	30	36	34
GWB chemical status	74	25	1
GWB quantitative status	90	9	1

Note: The EEA website holding this information is subject to continual updates as Member States report data. The information in this table was downloaded on 11 March 2020.

Source: EEA (2018d).

Table 1.2 Overview of significant pressures reported in second river basin management plans

Significant pressures	Surface water bodies (%)	Groundwater bodies (%)
Diffuse sources	33	34
Water abstraction	6	17
Hydromorphology	34	-
Diffuse sources (atmosphere)	32	-

Note: The EEA website holding this information is subject to continual updates as Member States report data. The information in this table was downloaded on 11 March 2020.

Source: EEA (2018d).

consequence of drainage, water storage structures, flood protection, or overgrazing and trampling by livestock. With climate change, many of these pressures are expected to increase, in response to temperature rise and water scarcity. Additional impacts on agricultural production may become considerable, although large differences are expected between southern and northern Europe (Feyen et al. 2020).

Today global planetary boundaries associated with genetic diversity and interference with nitrogen and phosphorous mineral cycles have also been surpassed, and land system change is in an increasingly risky zone, partially or fully as a consequence of agricultural production (EEA, 2019h). At the same time the global challenge is to feed a population growing from 7.8 billion in 2020 to 9.1 billion in 2050, but without undermining the environment and resources on which food production depends, or jeopardising food security which encompasses available, affordable and safe food. To achieve this, sustainable and more resilient farming systems are needed, i.e. systems that are more diverse and require fewer resource inputs, together with declining shares of meat consumption and food waste (Gerten et al., 2020).

1.2 Policy context

The EU has a comprehensive environmental policy framework, developed over decades, that has contributed to tackling agricultural pressures on the water environment. The Water Framework, Floods, Nitrates and Marine Strategy Framework Directives require management plans, action programmes or programmes of measures to be adopted to reduce pressures on the freshwater and marine environments.

In this regard, particularly important policies are the Nitrates Directive with its standards for nitrogen use in agricultural areas and the Water Framework Directive which requires that good ecological and chemical status of surface waters and good chemical and quantitative status of groundwaters be achieved by 2027 at the latest. The Marine Strategy Framework Directive builds on the objectives of the Water Framework Directive, in particular by requiring that nutrient and chemical pollution does not extend to the sea. These directives are supported and reinforced by others such as the Environmental Quality Standards Directive, the Groundwater Directive and the Drinking Water Directive. Table 1.3 provides an overview of EU policy objectives for surface water and groundwater bodies.

Table 1.3 Overview of EU policies and objectives relevant for surface waters and groundwater bodies

Policy	Policy objectives linked to agricultural pressures on water	Target year
	Environmental policies	
Water Framework Directive (WFD; 2000/60/EC)	To achieve good ecological and chemical status of surface water bodies and good chemical and quantitative status of groundwater bodies (EU, 2000)	2015/2027
Groundwater Directive (2006/118/EC and 2014/80/EU)	To improve groundwater quality in line with the goals of the WFD (EU, 2006b)	2015
Environmental Quality Standards Directive (2008/105/EC)	Defines water quality standards for pollutants of EU-wide concern, i.e. priority substances (EU, 2008b)	2015
Nitrates Directive (91/676/EEC)	To reduce and further prevent water pollution by nitrates from agricultural sources (EU, 1991b)	NA
Drinking Water Directive (98/83/EC)	Sets standards for drinking water (EU, 1998)	NA
Marine Strategy Framework Directive (2008/56/EC)	To achieve good environmental status of marine waters in the EU (EC, 2008)	2020
Floods Directive (2007/60/EC)	Assessment and management of floods (EU, 2007)	NA
Urban Waste Water Treatment Directive (91/271/EEC)	To protect the environment from adverse effects of urban wastewater through collection and treatment of wastewater (EU, 1991a). Implementation period varies depending on year of accession	EU-15: 1998-2005 EU-13: 2006-2023
Bathing Water Directive (2006/7/EC)	To measure and monitor the quality of bathing water (EU, 2006a)	2015
Water scarcity and drought communication and policy review	To address the challenge of water scarcity and droughts in the EU (EC, 2007, 2012)	NA
Soil thematic strategy	A strategy towards legislation to protect soils from key threats (EC, 2006a)	NA
EU strategy for adaptation to climate change	Aims to contribute to a more climate-resilient Europe by enhancing the preparedness and capacity to respond to the impacts of climate change at local, regional, national and EU levels (EC, 2020a)	NA
	Circular economy	
Second circular economy action plan	Launches initiatives throughout the entire life cycle of products, aiming to ensure that the resources used are kept in the EU economy for as long as possible (EC, 2020d)	2030
Sewage Sludge Directive (86/278/EEC) (The evaluation of the directive has been extended)	Encourages the use of sewage sludge in agriculture and regulates its use to prevent harmful effects on soil, vegetation, animals and humans (EEC, 1986)	NA
Regulation on minimum requirements for water reuse ((EU) 2020/741)	Sets minimum requirements for water quality and monitoring and provisions on risk management for the safe use of reclaimed water (EU, 2020a)	NA
Regulation laying down rules on the making available on the market of EU fertilising products ((EU) 2019/1009)	Sets standards for fertilising products (EU, 2019b)	NA

Policy	Policy objectives linked to agricultural pressures on water	Target year
Roadmap to a Resource Efficient Europe	To achieve transformation within a generation — in energy, industry, agriculture, fisheries and transport systems and in producer and consumer behaviour (EC, 2011)	NA
Agricultural policies		
Common agricultural policy, pillars 1 and 2	To address climate change and sustainable management of natural resources	2013-2020 and 2021-2027
Plant Protection Products Regulation (1107/2009/EC)	Rules for the approval of active substances to ensure protection of both human and animal health and the environment (EU, 2009c)	NA
Directive on the Sustainable Use of Pesticides (2009/128/EC)	To achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and to promote the use of integrated pest management (EU, 2009a)	NA
Regulation on organic production and labelling of organic products ((EU) 2018/848)	Sets out the principles of organic production (EU, 2018)	NA
European Green Deal		
Farm-to-fork strategy	Aims to make food systems fair, healthy and environmentally friendly (EC, 2020e)	2030
Biodiversity strategy for 2030	Aims to put Europe's biodiversity on a path to recovery with benefits for people, the climate and the planet (EC, 2020f)	2030
A zero pollution action plan for air, water and soil	Aims to better prevent, remedy, monitor and report on pollution (EC, 2021)	2030
New European Climate Law (forthcoming, 2021)	To achieve net-zero greenhouse gas emissions in the EU as a whole	2030
Global policies		
Sustainable Development Goal 2	To end hunger, achieve food security and improved nutrition and promote sustainable agriculture	2030
Sustainable Development Goal 6	To ensure the availability and sustainable management of water and sanitation for all	2030
Sustainable Development Goal 15	To achieve land degradation neutrality and halt desertification	2030

Note: EU-13, Member States joining the EU since 2004; EU-15, EU Member States before 2004; NA, not applicable.

Across these policies, a wide variety of measures and funding instruments are proposed and implemented to tackle agricultural pressures on the water environment, and new ones are being developed through research and innovation. Many of the measures relate to sustainable agriculture, such as organic farming, and agroecology and the use of green infrastructure and nature-based solutions. They promote efficient use of resources (fertilisers, pesticides, water), and enhance biological processes in agroecosystems.

The common agricultural policy (CAP) is the main policy that influences the development of the agricultural sector in the EU and influences how individual farmers choose to manage their land, crops and livestock. In particular, funding under the CAP can directly or indirectly promote farming practices leading to greater or less use of nutrients, pesticides and water and the development of drainage, water storage and irrigation schemes — all of which are key factors determining the intensity of agricultural pressures on the water environment. The CAP is a key EU financing instrument for promoting sustainable agriculture and reducing agricultural pressures.

The CAP has multiple objectives, from ensuring a stable supply of affordable food to enabling farmers to make a reasonable living and addressing climate change and the sustainable management of natural resources. It consists in several regulations that are organised around two 'pillars':

- The 'first pillar', financed via the European Agricultural Guarantee Fund, supports agricultural income by delivering yearly direct payments worth 72 % of the CAP's 2014-2020 total budget (i.e. EUR 312 billion) to 6.7 million farmers (out of 10.5 million) and by intervening on agricultural commodity markets, accounting for 5 % of the total budget (i.e. EUR 22 billion) (EC, 2013a).

- The 'second pillar', financed under the European Agricultural Fund for Rural Development, aims to support more broadly the competitiveness, social cohesion and environmental performance of agriculture and the rural economy. It covers the remaining 23 % of the CAP's 2014-2020 budget (i.e. EUR 96 billion), complemented by national or regional funds.

In the period 2014-2020, Member States budgeted around EUR 9.6 billion for organic farming (i.e. measure 11) and EUR 25 billion towards environmental initiatives for restoring, preserving and enhancing ecosystems related to forestry and agriculture, increasing the efficiency of water use and reducing greenhouse gas emissions and carbon sequestration from agriculture (i.e. measure 10), in their rural development plans.

A recent study by the European Commission on the impact of the CAP on water (Devot et al., 2020) drew a number of important conclusions with regard to the most recent CAP programming period, 2014-2020:

- The CAP is an important funding source to support agricultural measures to achieve the Water Framework Directive's objectives, but problems arise because of its low ambition and insufficient implementation of more sustainable measures.

- Cross-compliance instruments link CAP payments to the Nitrates and Water Framework Directives and standards for good agricultural and environmental condition of the land. They target establishing buffer strips, authorising and issuing permits for water abstraction and preventing the discharge of dangerous substances into groundwater. Member States, however, often opt for the minimum standards.

- Greening practices (crop diversification, ecological focus areas, permanent grassland) only indirectly support the achievement of water objectives, but the measures were not ambitious enough to achieve significant changes in farming practices.

- It was extremely difficult with the data and information available to actually pinpoint the effectiveness of the CAP instruments.

The study and its conclusions are important in terms of understanding the strengths and shortcomings of the CAP in the period 2014-2020. The forthcoming CAP strategic plans 2021-2027 have a central role in facilitating the transition towards sustainable agriculture. They will need to be more ambitious than those of previous programming periods on the environmental obligations associated with CAP payments and on the financing of measures that benefit the water environment.

It is expected that the broad portfolio of solutions that are brought together under the European Green Deal and its farm-to-fork and biodiversity strategies, zero pollution ambition and the European Climate Law, in combination with the new CAP, will strengthen sustainability objectives. Already, ambitious new targets have been established, and further targets and initiatives will follow as additional legislation is adopted, to:

- reduce fertiliser use by at least 20 % and nutrient losses by 50 % while ensuring that there is no deterioration in soil fertility, among others building on an integrated nutrient management action plan;

- reduce by 50 % the overall use of and risk from chemical pesticides and the use of the more hazardous pesticides by 50 % by 2030;

- reduce by 50 % the sales of antimicrobials used in farmed animals and aquaculture;

- have 25 % of agricultural land organically farmed by 2030;

- have 10 % of the agricultural area designated as high-diversity landscape features by 2030;

- achieve EU commitments on land degradation neutrality.

In addition, the newly adopted Farm to Fork Strategy provides leverage towards a sustainable food system, and it calls for changing systemic drivers such as consumer preferences and diets.

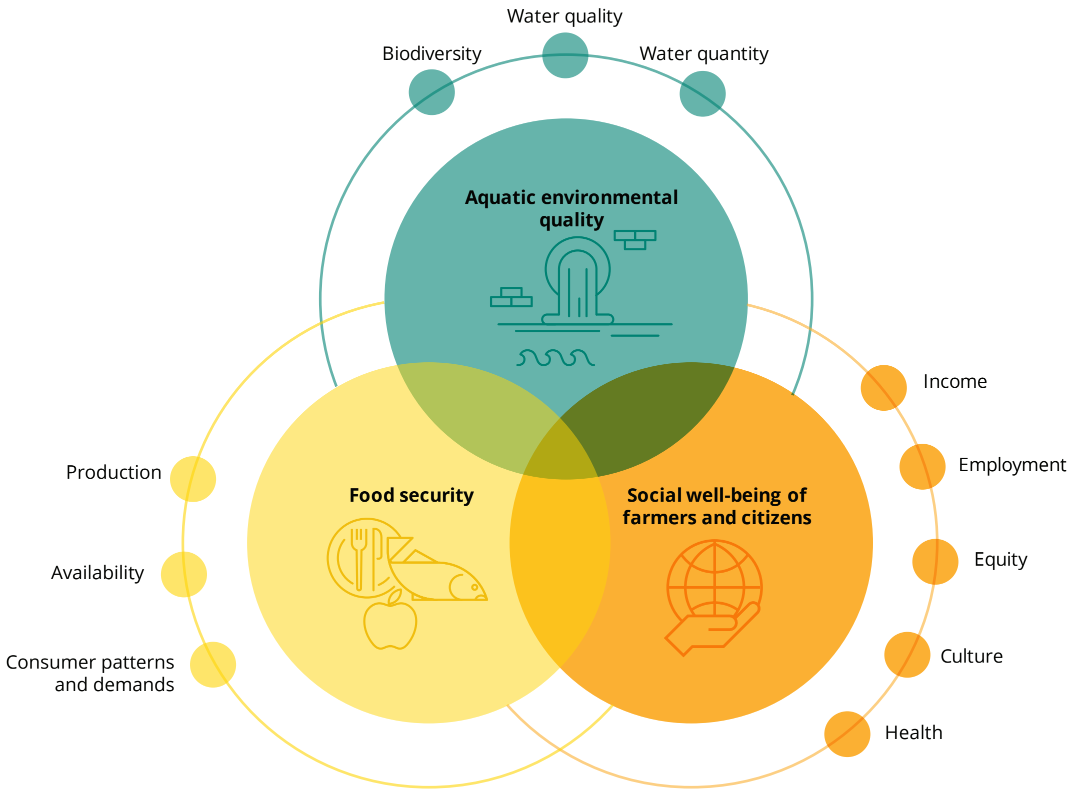
1.3 The importance of a systemic approach

In its 5-yearly flagship report, *The European environment — state and outlook 2020*, the EEA highlighted the need to take a systems approach to respond to sustainability challenges. Meeting Europe's sustainability goals in nutrient flows and freshwater use from agriculture is possible by taking a systemic approach involving the widespread adoption of agroecology and organic production, combined with changing diets and cutting food waste across Europe. While improvements towards achieving good water status are possible through the uptake of more sustainable farming practices, a systemic sustainability transition will require the mobilisation of stakeholders throughout the production and consumption value chains, from agricultural producers to retailers and consumers. Public policies at EU and Member State levels also have an important role in facilitating such collective action.

Agricultural production is a central component of the food system (Figure 1.1) and also the energy system, for instance in the production of bioenergy and other bio-products, thus contributing to the pressures on water. A sustainable food system is based on three interdependent pillars: the environment, food security, and the social well-being of farmers and consumers alike. Long-term sustainable development requires the three pillars to be balanced.

The importance of food and other consumption systems in achieving sustainability is increasingly recognised in Europe. The European Green Deal, and its instruments such as the farm-to-fork strategy, are examples of such systemic policy thinking. Studies have shown that environmental pressures could be reduced and human health improved considerably if consumer preferences for meat and dairy products were reduced by 50 % (Westhoek et al., 2014). The farm-to-fork strategy, for instance, attempts to achieve just this, notably by influencing consumer preferences towards choices that are more environmentally and climate friendly.

Figure 1.1 **Food system outcomes**



Source: EEA (2017b).

1.4 Outline of report

In this report we provide a European overview of the agricultural sector and its main pressures on the aquatic environment. We put this into a context of solutions needed to develop more sustainable food production and discuss how this development trajectory is supported by European policies. The report has been organised around a drivers-pressures-state-impact-response (DPSIR) framework to demonstrate the many interconnections between agricultural production, pressures and impacts on the water environment and the management and policy responses (Figure 1.2):

- Chapter 2 provides an overview of the characteristics of the agricultural sector and of sustainable farming approaches.
- Chapter 3 goes into depth on the process of intensification of the pressures on water stemming from agricultural production and climate change.
- Chapter 4 provides an overview of the approaches available to achieve more resilient and sustainable agriculture and highlights the role of European policies in achieving them.
- Chapter 5 discusses the wider context of a more sustainable food production system.

This analytical framework demonstrates that, although specific agricultural activities lead to pressures on the aquatic environment, long-term and sustainable solutions require a much more fundamental approach that also encompasses the key drivers of the overall food system and that policies and coherence among policies is important for achieving this.

Figure 1.2 DPSIR for water and agriculture

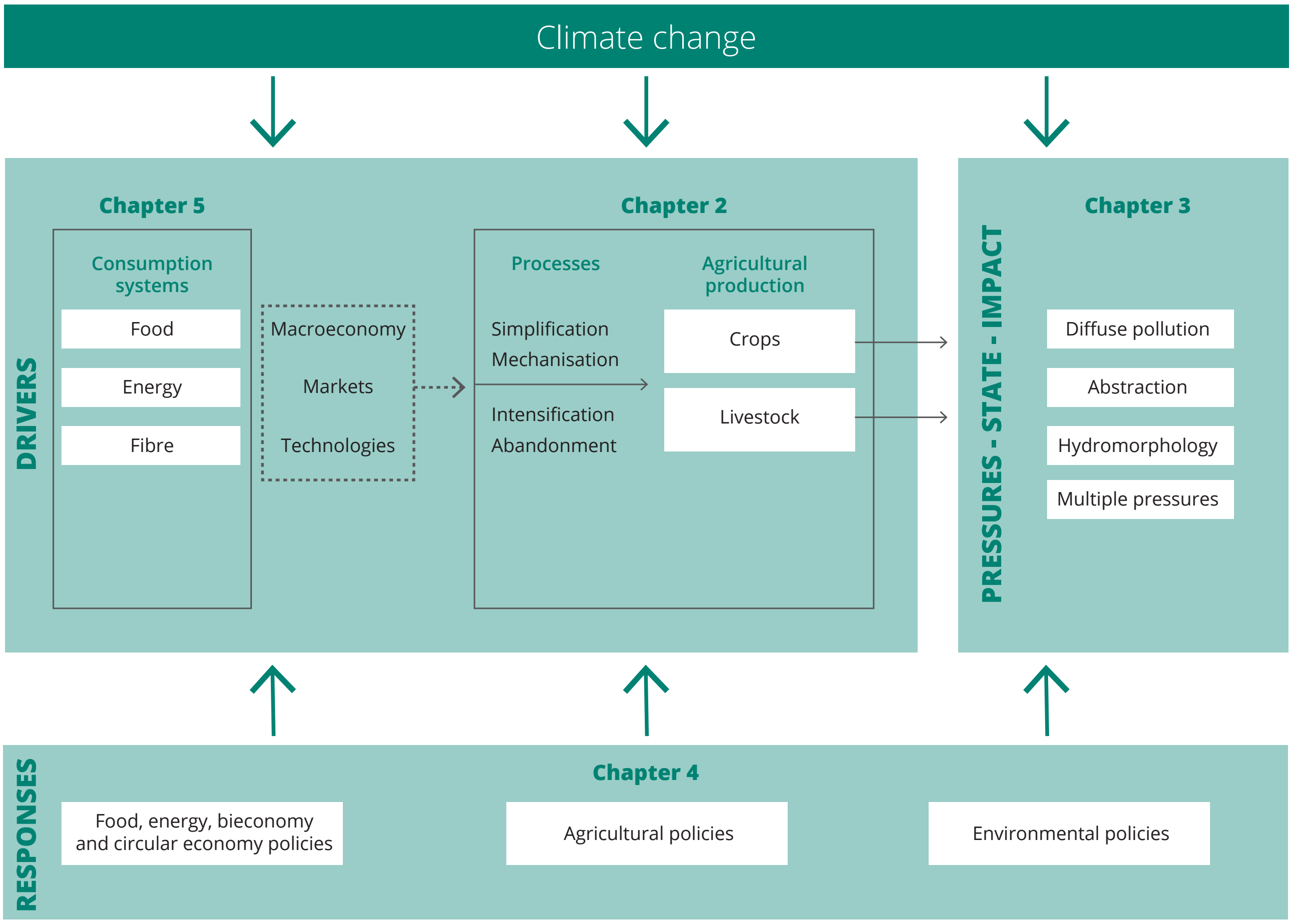


Photo: © Ma-Ti Ubtu, Unsplash

2 The agricultural sector in Europe

Key messages

- European agriculture plays an important role in providing food and livelihoods for European citizens. Agriculture and the agri-food sector provide 44 million jobs in Europe. The EU is also the world's largest agri-food exporter, contributing 20 % of world food and drink exports in 2017.
- Agriculture occupies more than 40 % of the European land area, and 61 % of the utilised agricultural area is managed by farms of high to medium intensity in terms of their expenditure on inputs such as fertilisers, pesticides and feedstuffs. High livestock densities can be found in several European countries, such as the Netherlands, Malta, and Belgium. Eastern Europe generally presents the lowest farm intensities and livestock densities, although recent trends indicate intensification there too.
- Agricultural intensification in the second half of the 20th century has led to considerable growth in crop and livestock production. However, it also causes environmental impacts and, when coupled to the large area occupied, those impacts on water, but also on biodiversity, soils and climate, are considerable.
- More intensive forms of agriculture co-exist with more sustainable forms, which have a lower impact on the water environment. Sustainable farming systems encompass a wide variety of types of agriculture, such as organic farming, which covers 7.5 % of the EU's Utilised Agricultural Area, and agroecology. They share a desire to optimise the use of natural resources, enhance biological processes and nature-based solutions, and improve biomass, nutrient, carbon and water cycles.

2.1 European agriculture

2.1.1 Agriculture in the European economy

About 10 million farms existed in the EU-28 in 2017, contributing to 1.1 % of the European gross domestic product (GDP) and 4.5 % of total employment, equivalent to 8.8 million full-time workers (ESTAT, 2020i). If jobs created in the agri-food sector are included, 44 million jobs are dependent on agricultural production. The total value of the agricultural sector was around EUR 405 billion in 2018, with EUR 214 billion (53 %) coming from crop production and EUR 156 billion (39 %) from animal products, in particular milk and pigs (ESTAT, 2020i).

Agriculture generated economic activity for 280 000 companies in the food and beverage manufacturing industry and 920 000 wholesalers and retailers (ESTAT, 2020i). The food and beverage industry is itself an important manufacturing sector in Europe, contributing to a network of small and medium-sized enterprises, including in rural areas. The processing of food nearly doubles the value of primary agricultural goods, with an estimated value of EUR 860 billion in 2018 (ESTAT, 2020i).

The European bioeconomy is the part of the economy that uses renewable biological resources from crops, forests, fish, animals and microorganisms to produce food, materials and energy. In 2017, the bioeconomy represented about 9 % of the EU-27 (excluding UK) labour force and 5 % of its GDP (Ronzon et al., 2020). Agriculture and the food and beverage industry represent 78 % of the employment and 66 % of the added value of the European bioeconomy. Agriculture also contributes to the manufacture of biomaterials such as bio-based textiles, plastics, chemicals, pharmaceuticals and liquid biofuels, worth an added value of EUR 34 billion (Ronzon et al., 2020).

Agriculture accounts for the majority of biomass supply in Europe. In the EU-28 in 2014, it represented 63 % of the total biomass supply. This is mostly in the form of food and feed for animals, while bioenergy production and biomaterials accounted for a small share of 2 %

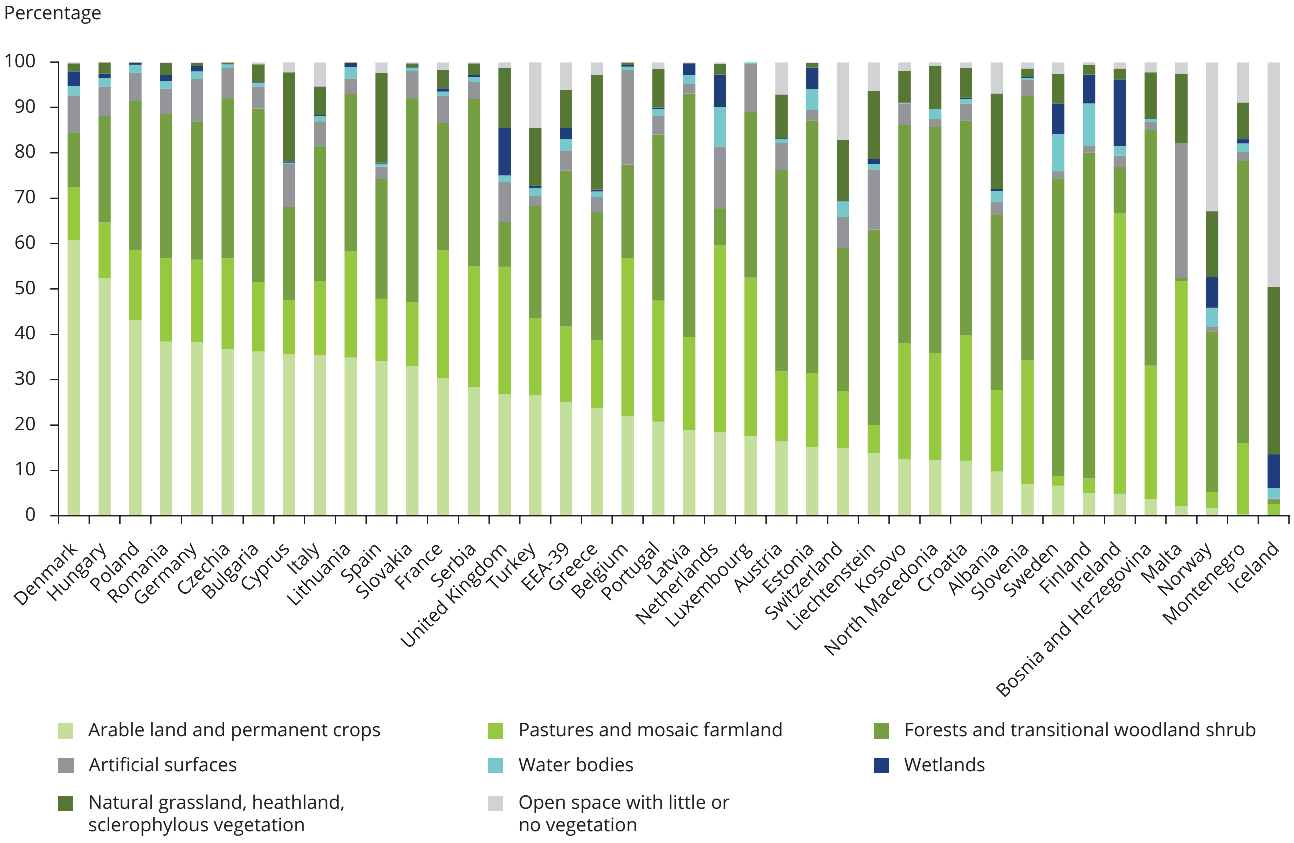
and 0.1 % of agricultural biomass, respectively (Gurria et al., 2017). The market for biomaterial and bioenergy is, however, expected to grow in response to the shift away from fossil fuel-based products. This may lead to increased competition for agricultural goods between the food and non-food sectors, although the use of biomass unfit for consumption as food or feed, such as food waste, could mitigate this impact (EEA, 2018c).

Agricultural goods represent 8 % of the EU's international trade in goods (ESTAT, 2020h). The EU is the world's largest agri-food exporter, contributing 20 % of world food and beverage exports in 2017. EU international trade in agricultural products has continued to grow, doubling in value since 2002. In terms of value, the EU is a net exporter of processed food and animal products, but it runs trade deficits in vegetable products. Major exports include beverages and spirits, cereals and cereal products, and dairy produce and meat. In addition to tropical products, the EU mainly imports animal feed and ingredients used in processing, such as palm oil.

2.1.2 Agricultural land cover

Agricultural land covers 42 % of the 39 EEA member countries (EEA-39) land area or a total of 245 million hectares (EEA, 2019d). In the EU-28 the proportion is slightly higher, with a coverage of 199 million hectares or 45 % of the area. Most of the agricultural land is used for arable crops, in particular cereals, and for permanent crops, such as olives, grapes or fruits (25 % of EEA-39), and the rest is pastures and mosaics of mixed land uses (17 %). The distribution and importance of different land cover classes vary considerably between Member States (Figure 2.1). The land cover in countries such as Denmark and Hungary is strongly influenced by arable land, covering more than half of their area. Ireland and Malta, in contrast, are characterised by a high proportion of pastures and mosaics. In Sweden, Finland and Montenegro, more than 60 % of the area of each is covered by forests and transitional woodland shrub, and a much smaller proportion of their area is used for agriculture, although large parts of their forest areas are managed.

Figure 2.1 Agricultural land use



Notes: Based on Corine 2018. Country coverage: EEA-39.

Source: Corine land cover, 2018 (EEA, 2019e).

Photo: © Andreas Dress, Unsplash

A loss of agricultural land has been observed across Europe in recent decades, due to the dual factors of the expansion in the artificial (urban) area, known as land take, and agricultural land abandonment on more marginal areas (EEA, 2017c). Agricultural land abandonment means that land that was previously used for agricultural production but no longer has a farming function and has not been converted into forest or artificial areas is abandoned. Abandonment of agricultural land has been observed across Europe for decades, driven by biophysical, agroeconomic, demographic, geographical and macro-economic factors (Perpiña Castillo et al., 2018; ESTAT, 2020c). Agricultural land abandonment has particularly affected remote and mountainous regions.

Between 2000 and 2012, there was a net loss of agricultural land of nearly 100 000 ha per year across the EEA-39 (EEA, 2019e). Between 2012 and 2018, the rate fell to around 50 000 ha per year. Urban land take of agricultural land in the EEA-39 alone represented about 85 000 ha per year between 2000 and 2012 and slowed to 57 000 ha per year between 2012 and 2018.

Land take does not necessarily reduce the overall pressure on the water environment, as other types of pollution, abstraction pressures or hydromorphological modifications may be associated with the development of artificial areas. The transfer of agricultural land into forest and semi-natural cover can, however, result in a reduction of pressure on the water environment (Perpiña Castillo et al., 2018).

2.1.3 Agricultural production

Total utilised agricultural area (UAA), the total area taken up by arable land, permanent grassland and permanent crops, as reported by Member States through the Farm Accountancy Data Network, was around 173 million hectares in the EU-28 in 2016. Nearly 60 % was used for arable crops, 34.2 % for permanent grassland and meadows, and 6 % for permanent crops.

In 2016, cereals covered around 50 % of arable land in the EU-28, followed by crops harvested green from arable land (20 %) and industrial crops (12 %). All other crops take less than 5 % of arable land each (ESTAT, 2019a). Crop yields are generally highest in western Europe in all categories, except for vegetables and 'special crops' such as citrus fruits, grapes or olives. Vegetable yields are particularly high in eastern Europe and the Mediterranean, with the latter also producing the majority of the 'special crops'.

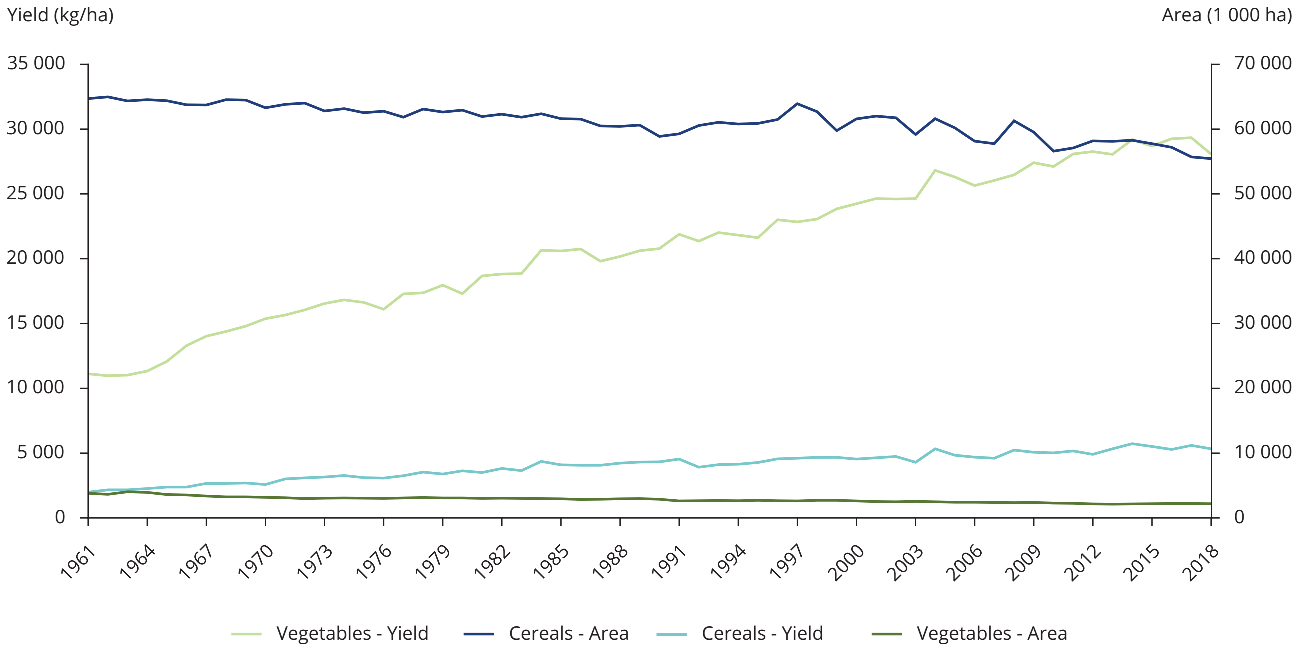
European agriculture is highly influenced by meat production. An estimated 46 % of the UAA of the EU-28 is used as arable and grass-based fodder areas to produce feed for livestock (ESTAT, 2020c). Around 333 million pigs, bovine animals, sheep and goats were farmed in the EU-28 in 2018 (ESTAT, 2020c). Poultry accounted for 14 billion animals. In addition to the feed produced in Europe, livestock production relies heavily on imported feed. The consequences of this import is discussed in Chapter 5.

Current production levels are the result of macro-economic trends, technological change and a long-term post Second World War policy paradigm based on increasing agricultural productivity, securing food supplies to European nations and increasing the competitiveness of European agriculture in international markets. A combination of structural adjustments and strong market incentives were used across Europe until the 1980s.

Cereal, vegetable and livestock production has increased considerably. Cereal production has tripled since 1960, while the area harvested has decreased by about 10 % (Figure 2.2). The area under vegetable production has decreased by 44 %, while the yield per hectare has more than doubled. Increases in yields can be attributed to a combination of factors, including the introduction of new varieties and new cropping techniques, the use of machinery, specialisation, and increased use of inputs such as nutrients, pesticides and irrigation water. In 2011, average crop yields in Europe were 60 % more than the global average (Erisman et al., 2011). Livestock units in Europe more than doubled between 1960 and 2014 with poultry and pig production showing the greatest increases, more than six times and more than twice, respectively (Figure 2.3).

The increase in livestock production slowed in the 1980s because of macro-economic changes, in particular oversupply on the European market and changed incentives offered by the CAP, including the introduction of milk quotas in 1984 (Martín-Retortillo and Pinilla, 2015). As a consequence of adopting intensive livestock production methods, livestock production continued to increase in the Mediterranean countries, while it decreased by more than 50 % in eastern Europe between the 1980s and 2000s. Recent years have seen stable populations of pigs and bovine animals, while goat and sheep numbers have gone down (ESTAT, 2019a).

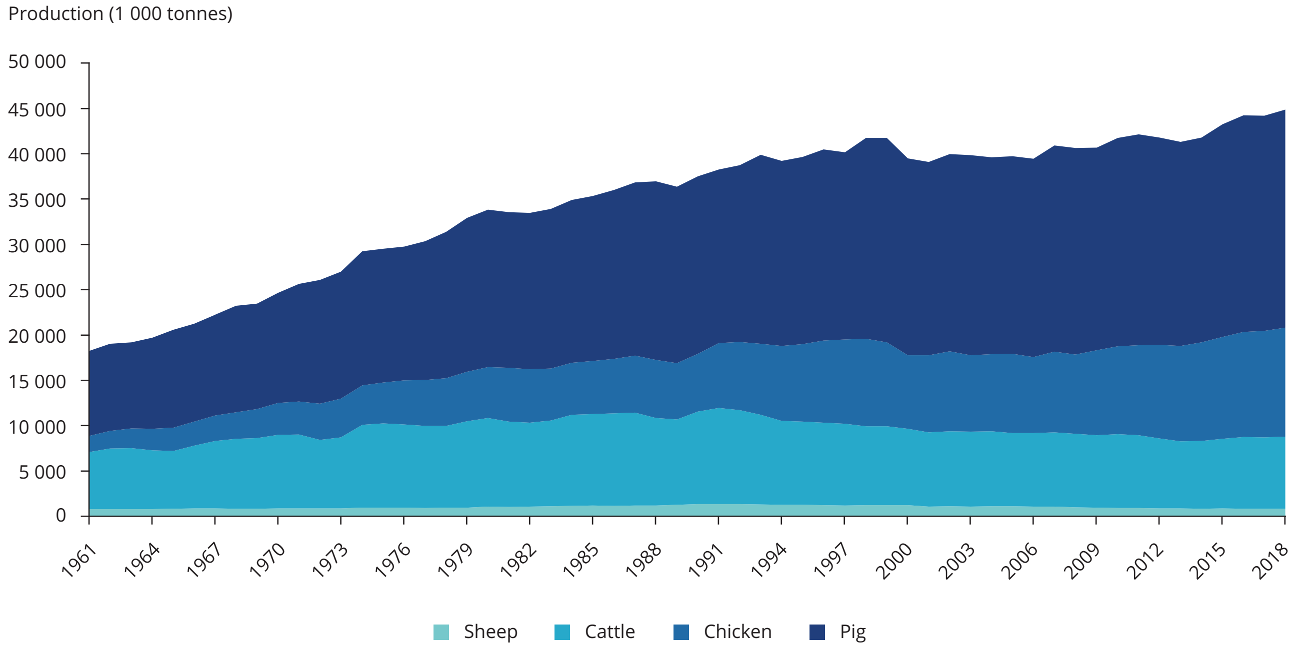
Figure 2.2 Development of cereal and vegetable production



Note: Data for EU-28.

Source: FAO (2020).

Figure 2.3 Development of livestock production



Note: Data for EU-28.

Source: FAO (2020).

Photo: © Jaime Hoogesteger, Flickr

2.2 Types of farming systems

Although the intensification of agriculture has been the predominant trend for several decades and trends vary between countries, farming systems in Europe today are very varied. More intensive forms of agriculture co-exist with more sustainable forms. Three characteristics are relevant to protecting the water environment: (1) the intensity of the use of inputs; (2) the level of specialisation at farm holding and regional levels; and (3) the wider use of sustainable farming practices and standards.

2.2.1 Intensity of the use of inputs

In Europe, the intensity of farm systems has been measured in terms of the expenditure on inputs such as fertilisers, pesticides and feedstuffs per hectare of land (EC, 2018a). In 2016, it was estimated that 61 % of the total UAA is managed by farms of high to medium intensity, and 39 % by low-input farming systems. The highest share of total UAA managed by high-intensity farms is found in the Netherlands (88 %), Belgium (76 %) and Malta (61 %), followed by Denmark, France and Luxembourg (between 47 % and 50 %). In contrast, low-intensity farms were found more extensively in Estonia (79 %), Portugal (73 %), Latvia (70 %), Romania (69 %) and Lithuania (66 %).

The intensity of livestock production can be measured through livestock density. Higher stocking densities can result in greater soil compaction and erosion and higher nutrient emissions. At EU level, average stocking density was at 0.8 livestock units per hectare in 2016 (ESTAT, 2020c). The highest densities could be found in the Netherlands (3.8 livestock units per hectare), followed by Malta and Belgium (2.9 and 2.8 livestock units per hectare, respectively).

High livestock densities were also found in Ireland, north-west France, northern Italy, Denmark and parts of Austria. The lowest livestock densities were found in Bulgaria, Slovakia and the Baltic countries (all below 0.3 livestock units per hectare). However, the highest increases in livestock densities between 2013 and 2016 were also observed in Bulgaria, as well as Portugal, Hungary, the Netherlands, Ireland and Luxembourg (> 5 %).

Intensification of the use of inputs to enhance production in European agriculture has led to impacts on multiple environmental dimensions, such as biodiversity, air quality, climate, soils and water (Matson, 1997; Stoate et al., 2009; Ruiz-Martinez et al., 2015). The use of inputs such as fertilisers, pesticides and irrigation water translates into pollution, abstraction and hydromorphological pressures on water resources and aquatic ecosystems. Patterns of intensive and more extensive farming systems will thus put varying pressure on the water environment (Box 2.1).

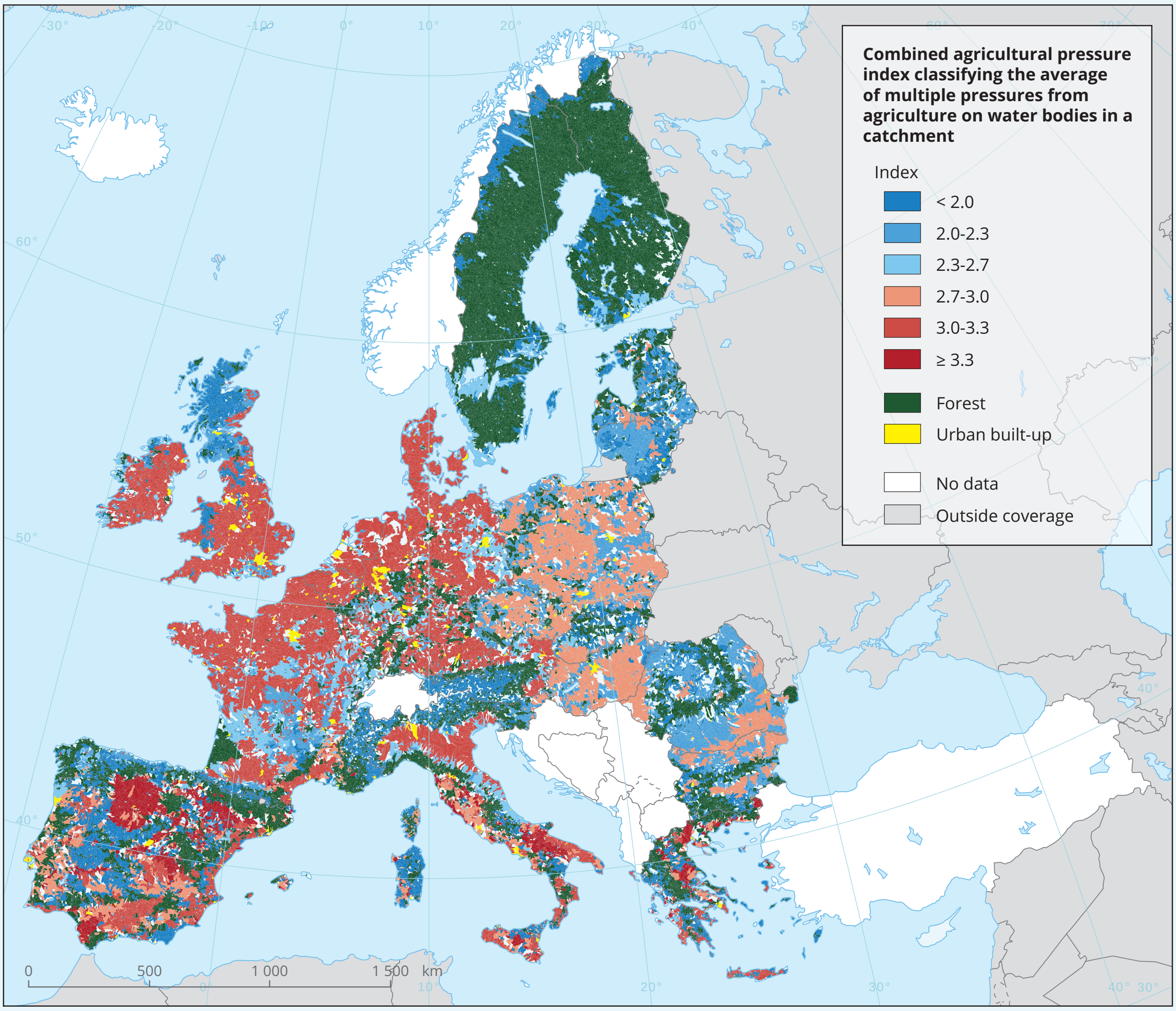
Box 2.1 Agricultural land use intensity

Surface waters are often subject to several pressures stemming from agriculture at the same time. The second river basin management reports indicated that 50 % of water bodies were affected by two or more pressures (EEA, 2018b). While each pressure has a very specific environmental impact, which in itself can be serious, a combination of several pressures may point to a greater range of environmental impacts on aquatic ecosystems as well as a wider range of management strategies being necessary to improve surface water status.

To highlight this issue, the combined intensity of agricultural pressures on water was calculated for Europe. This calculation was based on the spatial distribution of land system archetypes and the levels of four indicators of pressures within each of these types. The four pressure indicators considered in the analysis were nitrogen surplus, a chemical impact indicator, and proxies for irrigation intensity and for hydromorphological pressures. The underlying indicators are introduced and discussed in Sections 3.1, 3.2, and 3.3.

The results show a clear east-west divide with lower intensities in eastern Europe and much higher intensities in western Europe. The areas with the highest intensities are located in the Mediterranean region because the archetype related to intensive and large-scale permanent cropland is associated with high levels of water abstraction, the use of land for agriculture in the floodplains and pesticide impacts, although the nitrogen surplus is lower in these areas. Western land systems, which include intensive cropland and intensive livestock farming, also show multiple pressures acting: here, nitrogen surplus, pesticide impact and the use of land for agriculture in floodplains are high, whereas water abstraction levels are lower. The analysis further shows that a high-pressure intensity is associated with around half the agricultural area of Europe. These areas are also associated with the highest yields or the highest value crops.

Map 2.1 **Combined agricultural pressure index classifying the average intensity of multiple pressures from agriculture on water bodies in a catchment**



Reference data: ©ESRI

Note: Data for the EU Member States in 2012.

Source: Schürings et al. (forthcoming).

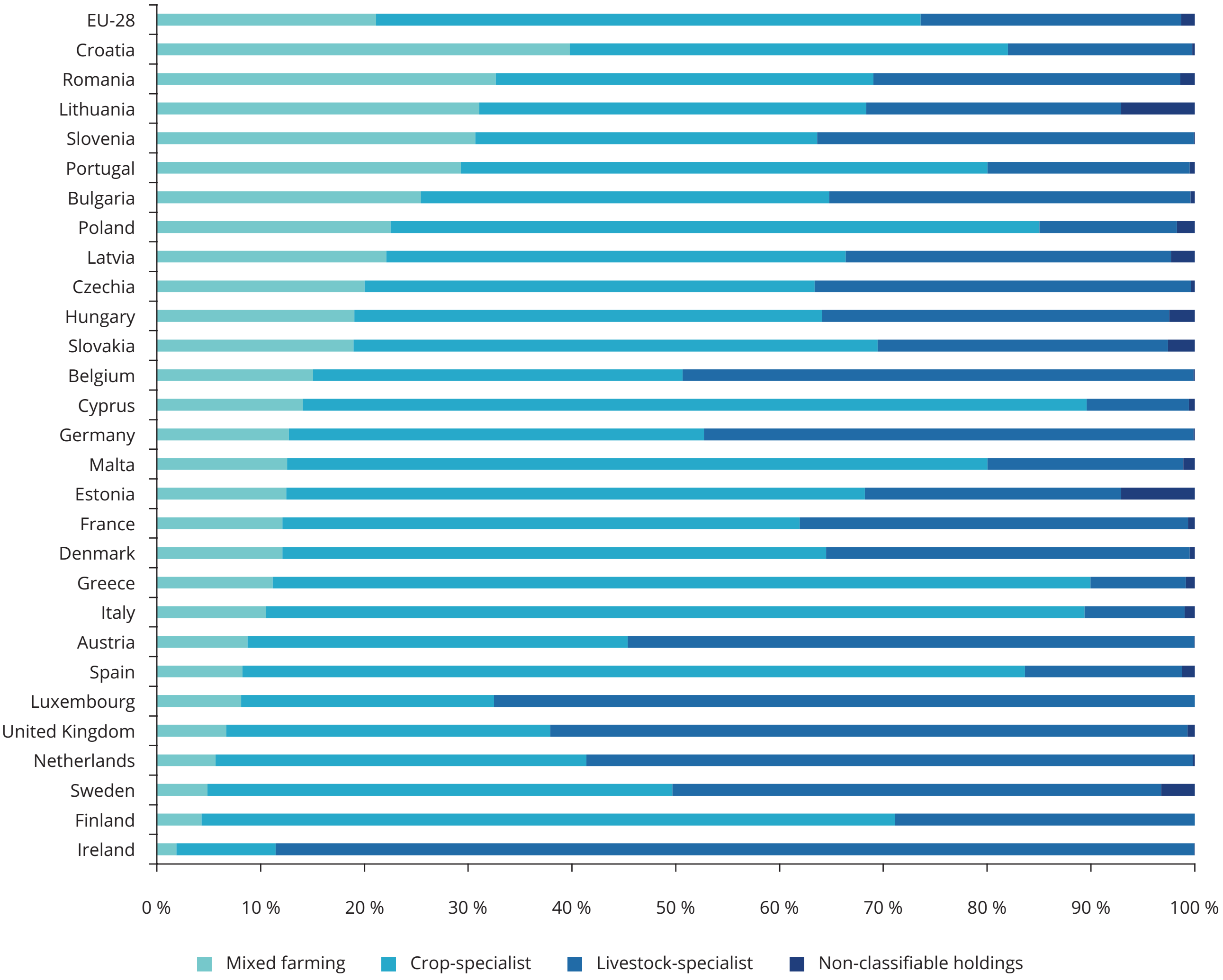
2.2.2 *Specialisation of farming systems*

The level of specialisation can considerably increase the pressure on water (Le Noë et al., 2018). Specialised regions present less diverse livestock and cropping patterns. Regions highly specialised in producing crops lack available manure and rely on synthetic fertilisers. Regions highly specialised in livestock production are more likely to have nutrient surpluses because it is not possible to spread all of the manure produced on the farm. The nutrient surplus from livestock specialists is less where specialisation is not accompanied by high livestock density. This situation arises particularly in extensive livestock farming systems in mountainous areas. Mixed farming usually builds on the synergies of livestock and crop production to increase nutrient recycling.

Overall, agriculture in the EU-28 is highly specialised, and the majority of agricultural holdings are either crop or livestock specialists, representing 52 % and 25 % of all agricultural holdings, respectively (ESTAT, 2020i). Crop and livestock specialists manage 84 % of UAA. Only 21 % of all holdings are mixed crop-livestock farms, managing 16 % of UAA. Since 2005, the share of crop specialists has increased in all Member States, except Cyprus, mainly due to a decline in mixed farming (Figure 2.4).

Alongside specialisation, Europe has seen a decline in the number of farms, while their size has been increasing. Between 2005 and 2016, a farm size of over 100 ha was the only farm size category with increasing numbers and UAAs. Such a trend can result in reduced diversity of the agricultural landscape, with vast areas and increasingly larger fields where only a few crops such as wheat or maize are grown (EEA, 2019d). The loss of landscape elements and increasing field sizes may contribute to greater soil erosion and pressures on the water environment, as well as negatively affecting biodiversity.

Figure 2.4 Farm specialisation



Note: Data for EU-28.

Source: ESTAT (2020f).

2.2.3 Sustainable forms of agriculture

Although there is no agreed definition of sustainable agriculture, five principles of sustainable agriculture and food systems have been proposed (FAO, 2014a):

1. improving efficiency in the use of resources;
2. conserving, protecting and enhancing natural ecosystems;
3. protecting and improving rural livelihoods and social well-being;
4. enhancing the resilience of people, communities and ecosystems; and
5. promoting good governance of both natural and human systems.

A large number of terms have been used to describe different forms of sustainable agricultural systems, such as conservation agriculture, regenerative agriculture, agroecology, organic farming, biodynamic farming, high nature value farming, permaculture, carbon farming and climate-smart agriculture. Table 2.1 presents some of these terms.

Sustainable agriculture refers to many different types of farming systems. Organic farming is the most regulated form of the more sustainable forms of agriculture, but it is also rapidly expanding in response to consumers' demand for healthy and sustainable food (Box 2.2). The concept of agroecology has received increased attention in recent years, as it encompasses many principles that underpin the idea of sustainable agriculture. Agroecological practices aim to optimise the use of natural resources, enhance biological processes in the soil and improve biomass, nutrient, carbon and water cycles (Wezel et al., 2014; FAO, 2018a; EIP-AGRI, 2020; Oberč and Arroyo Schnell, 2020). They also aim to reduce the reliance on off-farm resources and synthetic inputs and increase resilience to external disturbances and shocks, such as climate change, notably by diversifying farm activities and production.

In Europe, the network of protected sites under the Birds and Habitats Directives (the Natura 2000 network) is home to some of the least intensive forms of agriculture (EC, 2017b). These include livestock systems that rely mostly on forage from semi-natural vegetation, as well as low-intensity arable systems, often in rotation with semi-natural fallow vegetation, low-intensity permanent crops such as traditionally managed orchards, and land under mixed farming systems with a mosaic of low-intensity agriculture and valuable landscape features. Around 9 % of agricultural land is part of Natura 2000 sites and around 30 % of agricultural land is classified as high nature value farmland in Europe (EEA, 2017a).

Sustainable agriculture emphasises the need to adopt a range of range of more natural resource-efficient practices and alternative crop, soils and livestock management practices (Oberč and Arroyo Schnell, 2020). It may rely on innovations in the field of genetic improvements, precision farming and integrated farming tools, together with nature-based and ecosystem-based solutions across the agricultural landscape. These various practices in sustainable agriculture, and their relevance to water management, are presented in more detail in Chapter 4.

Table 2.1 Key terms and definitions related to sustainable farm production systems

Conservation agriculture	A farming system that promotes minimum soil disturbance (e.g. minimum tillage or no tillage), permanent soil cover (e.g. mulching), incorporation of crop residues (increasing organic matter content) and diverse crop rotation to increase water and nutrient efficiency, increase water infiltration and thus reduce run-off. Conservation agriculture promotes the reduction of inputs (pesticides in particular) but does not exclude them. Farmers benefit from the stabilisation of crop production and lower costs for machinery and labour.
High nature value (HNV) farming	Farming based on the conservation of biodiversity by continuing farming with an emphasis on extensive management practices (i.e. low inputs, minimum tillage, low stocking levels and landscape elements). HNV farming practices contribute to soil conservation and improvement by minimising disturbance and increasing soil organic matter, thus having a positive impact on water storage capacity. The lower fertiliser and pesticide use associated with HNV farming also protects water quality.
Agroecology	A farming concept that takes into account both ecological and social concepts and principles to optimise the interaction between plants, animals, humans and the environment. This farming concept thus provides the basis for a sustainable and fair food system and promotes recycling and planned use of natural resources, including water.
Organic farming	A farming concept that aims to preserve natural resources, protect the environment, maintain biodiversity and apply high animal welfare and production standards. The principles of this farming system encourage the protection of biodiversity, enhancement of soil fertility and maintenance of water quality. This is achieved by prohibiting the use of artificial fertilisers, herbicides and pesticides and promoting crop rotation and the cultivation of nitrogen-fixing plants.

Box 2.2 Organic farming in the EU

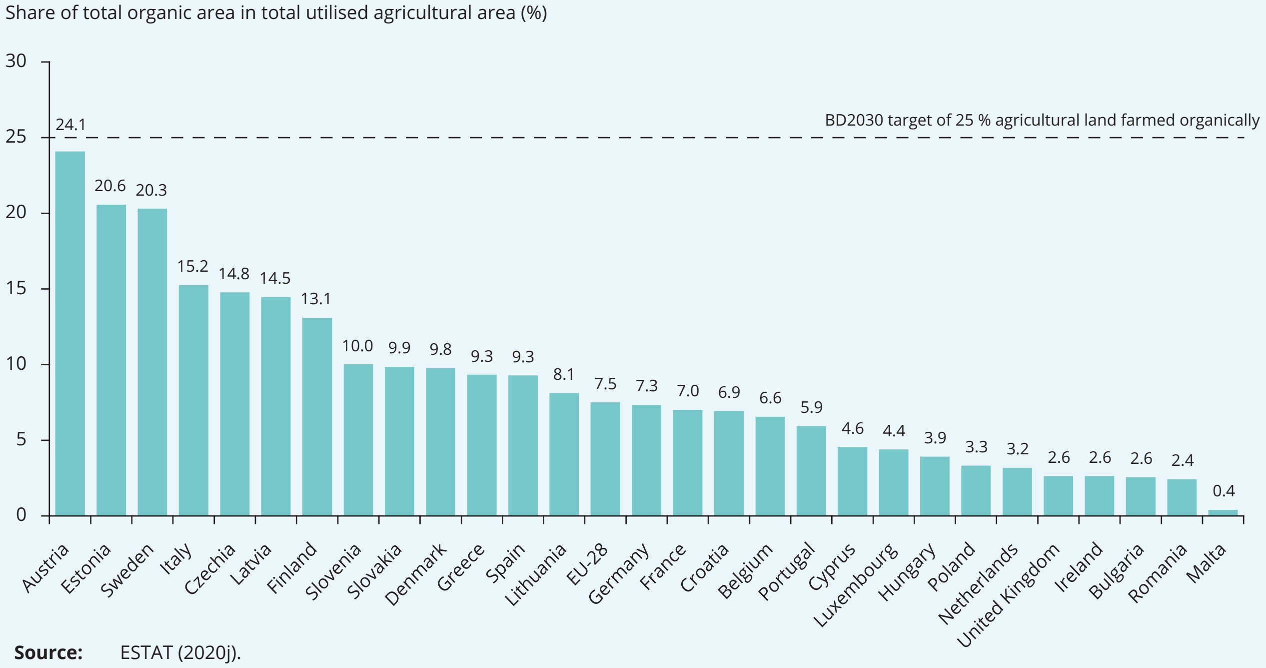
In the EU, organic farming is defined as 'an approach to producing food by using natural substances and processes'. It is a well-established approach in the EU, in terms of both its regulation and its marketing, and all food system actors who wish to market their food under the organic label have to register with a control agency or body that is responsible for verifying that the operator complies with the rules of organic farming.

The principles, aims and overarching rules of organic production, along with its labelling, were first regulated at EU level under Council Regulation 834/2007. Because of the rapid expansion of organic farming, the EU passed new legislation in 2018 to strengthen the control system, establish new rules for producers, expand organic labelling to a wider range of products, and better regulate imported organic food. The legislation will enter into force in 2022.

In 2018, organically farmed land (converted and under conversion) covered 13.4 million hectares of agricultural land in the EU-28, corresponding to 7.5 % of the total utilised agricultural area. This is managed by nearly 250 000 farm holdings, 68 % of which were fully organic. The share of organic farming area is highly variable across the EU. The countries with the highest shares of organically farmed land are Austria, Estonia and Sweden. In each of these countries the share of organic land was above 20 % of the total agricultural area (ESTAT, 2020j).

The area covered by organic farming increased by 34 % at EU-28 level between 2012 and 2018 and is expected to continue increasing. With retail sales amounting to EUR 34.3 billion in 2017, Europe is now the world's second largest consumer of organic goods.

Figure 2.5 Organic farmed area



Source: ESTAT (2020j).

Photo: © Sylwia Pietruszka, Unsplash

3 Pressures from agriculture on the aquatic environment

Key messages

- Diffuse pollution of nutrients from high livestock density and intensive arable farming is the most significant agricultural pressure reported under the Water Framework Directive (WFD). Despite improving trends over the last 30 years, agricultural nitrogen surpluses remain unsustainable over large areas of Europe. Nutrient concentrations in groundwater have not shown significant reductions since the 1990s and no further improvements have been seen in rivers in the last 10 years.
- Diffuse pollution of chemicals such as pesticides, metals and veterinary medicines are less well documented. Consumption of pesticides at EU level has not reduced in the last 10 years. Significant differences in trends exist between Member States, with the largest increases in Cyprus, Austria, France and Slovakia, and the largest decrease in Portugal, Ireland, Czechia and Italy.
- Agriculture is the largest net water user in the EU-28, accounting for up to 60 % of net water use at EU level. The level of agricultural water consumption as a percentage of renewable freshwater resources is particularly high in Cyprus, Greece, Malta, and Spain. Agriculture is also responsible for local and seasonal water stress incidents, which can have severe impacts on environmental river flows.
- Water storage for irrigation and agricultural land drainage and land reclamation projects, and livestock trampling river banks are linked to hydromorphological pressures. About 17 % of arable and permanent crop areas, as well as considerable areas of grassland are drained. Drainage is particularly extensive in northern Europe. Large irrigation infrastructure projects are more often present in Mediterranean countries, but smaller reservoirs exist across Europe, although statistics are lacking.
- Climate change increases temperature and alters the supply and demand of water regionally, increasing the risks of floods and droughts and of larger and less predictable seasonal variations. These additional climate impacts exacerbate pollution and abstraction pressures. These changes will impose considerable additional challenges for managing the pressures from water abstraction, nutrients and pesticides, hydromorphology, floods and droughts.

Pressures on the aquatic environment from agricultural production can be roughly split into three categories: (1) pollution from diffuse sources; (2) water abstraction; and (3) hydromorphological pressures. Across Europe, climate change is exacerbating those pressures, albeit with large regional variability. In this chapter, we discuss the impact of historical agricultural intensification on pressures on the water environment, the current situation and trends in the four pressures, together with their impacts, and the likely consequences of climate change. More sustainable approaches to agriculture are discussed in Chapter 4, and the role of systemic responses is discussed in Chapter 5.

3.1 Diffuse pollution

Agriculture is considered a main contributor of nutrients, pesticides and some metals to the aquatic environment. Other substances, such as veterinary medicines, also reach the aquatic environment, but in comparison very little is known about the quantities or their impacts. Diffuse pollution of nutrients and pesticides remains a significant pressure on one third of surface water and groundwater bodies in Europe, and they are a main pressure on Europe's seas.

3.1.1 Diffuse nutrient pollution

Background

Nitrogen and phosphorus are, together with potassium, the primary nutrients and key for plant growth and metabolic processes. Nutrient application to agricultural land contributes to higher crop yields and maintaining soil fertility. Increased use of fertilisers has contributed, together with other changes in farm practices (see Chapter 2) to increased agricultural yields. It is estimated that one hectare of agricultural land in Europe can now feed 4.3 people as opposed to 1.9 people in 1908 (Erisman et al., 2008). However, not all nitrogen and phosphorus is taken up by plants. Their excessive use can lead to contamination of land, the atmosphere, rivers, lakes and groundwater.

Excess nitrogen and phosphorous pollution causes widespread environmental and human health problems. These nutrients stimulate plant growth and, when in excess, they can lead to widespread eutrophication of Europe's rivers, lakes, transitional and coastal waters, and seas. Eutrophication promotes undesired algal and plant growth, ultimately disturbing the diversity and balance of aquatic food webs. As plants die and decay, anaerobic conditions may develop in lakes, transitional or coastal waters or seas, with further impacts on aquatic biodiversity. Therefore, the ecological status of water bodies is highly sensitive to nutrient pollution.

An excess of nitrates in drinking water can affect human health, such as by causing methaemoglobinemia, which prevents the normal transport of oxygen by the blood to the tissues, causing cyanosis (EC, 2018b). Where excess nitrates occur, drinking water is treated or a different source needs to be found. Both are associated with additional costs to the consumer. High nutrient concentrations and eutrophication also affect human economic activities linked to tourism, fisheries or drinking water quality. Toxic algal blooms or fish kills can have severe economic consequences.

Nutrient pollution is a widespread issue in Europe. The second river basin management plans compiled under the Water Framework Directive (WFD) showed that significant pressures linked to diffuse emissions were identified for 33 % of surface water and 22 % of groundwater bodies in the EU and Norway, and the pressures in close to 70 % of those water bodies were specifically linked to agriculture (EEA, 2018d). This assessment is made when surface water bodies fail to achieve good ecological status or when groundwater bodies fail to achieve good chemical status. Groundwater bodies primarily fail to achieve good chemical status because of elevated concentrations of nitrates in groundwater.

Mineral and organic fertiliser use

Various types of fertiliser are used in agriculture. Synthetic fertilisers contain mainly nitrogen, phosphorus and potassium, followed to a lesser extent by other elements such as calcium, magnesium, sulphur, copper and iron. Synthetic mineral nitrogen fertilisers are manufactured, through a catalyst-based technology called the Haber-Bosch process, and mined from phosphate rocks for phosphorus-based fertilisers. The cost of producing nitrogen fertilisers such as ammonia, urea and ammonium nitrate is highly dependent on energy prices. Phosphorus is considered a critical raw element for Europe due to its limited supply (EC, 2020g).

Organic fertilisers are based on organic matter from animal or plant waste and are typically derived from manure and crop residues. Human sources include sewage sludge from wastewater. While synthetic fertilisers focus on providing the necessary nutrients for plant growth, organic fertilisers can also improve soil structure and microbial activity. The use of organic fertilisers aims to recycle the nutrients encapsulated in organic waste, and therefore it can contribute to the circular economy. Manure may nevertheless contain various chemicals, in particular metals such as copper, as well as livestock feed additives and residuals from antibiotics and anti-parasitic medicines.

Nutrients can also be added to fields through biological fixation of nitrogen, for example through nitrogen-fixing crops, such as legumes. To allow the soil to replenish its nitrogen stocks, farming practices can let land lie fallow or plant legumes between harvesting one crop and sowing the next.

In 2014, overall nitrogen inputs to soils in the EU-28 largely consisted of mineral fertilisers (45 %) and manure input (38 %), followed by atmospheric deposition (8 %) and biological nitrogen fixation (6 %), (ESTAT, 2020b). Mineral fertilisers and manure accounted for more than 93 % of the phosphorous input to agricultural areas in Europe between 2010 and 2014. Other organic fertilisers, such as compost, sewage sludge and industrial waste, accounted for little more than 5 % of total phosphorous inputs (ESTAT, 2020e).

Europe's use of mineral fertilisers represents 12 % of global consumption (FAO, 2019), and its use has increased dramatically in the 20th century (Figure 3.1). It is estimated that the use of mineral fertilisers per hectare increased five-fold between the 1950s and the 1980s at European level, with eastern and central Europe seeing the largest increase (26 times). Between the 1980s and 1990s, mineral fertiliser use decreased by about 30 %, following a drop in the early 1990s as the political system changed in eastern Europe.

Around 75 % of the agricultural area in Europe is fertilised using mineral fertilisers (ESTAT, 2020b). The application rate varies significantly between crops. For example, wheat is grown on 15 % of EU agricultural land but accounts for 26 % of the fertiliser use, oilseeds are grown on 6 % of the agricultural land but account for 11 % of the fertiliser use, while fertilised grassland represents 18 % of the land use and 16 % of the fertiliser use (EC, 2019b).

Nitrogen fertiliser consumption per hectare of fertilised utilised agricultural area (UAA) currently stands at 77.2 kg per hectare of fertilised UAA (ESTAT, 2020d), with the highest use in the Benelux countries, Czechia and Denmark at more than 100 kg/ha. Phosphorous fertiliser consumption stands at 8.6 kg/ha, with the highest use in southern and eastern Europe, in particular Cyprus, Croatia and Hungary.

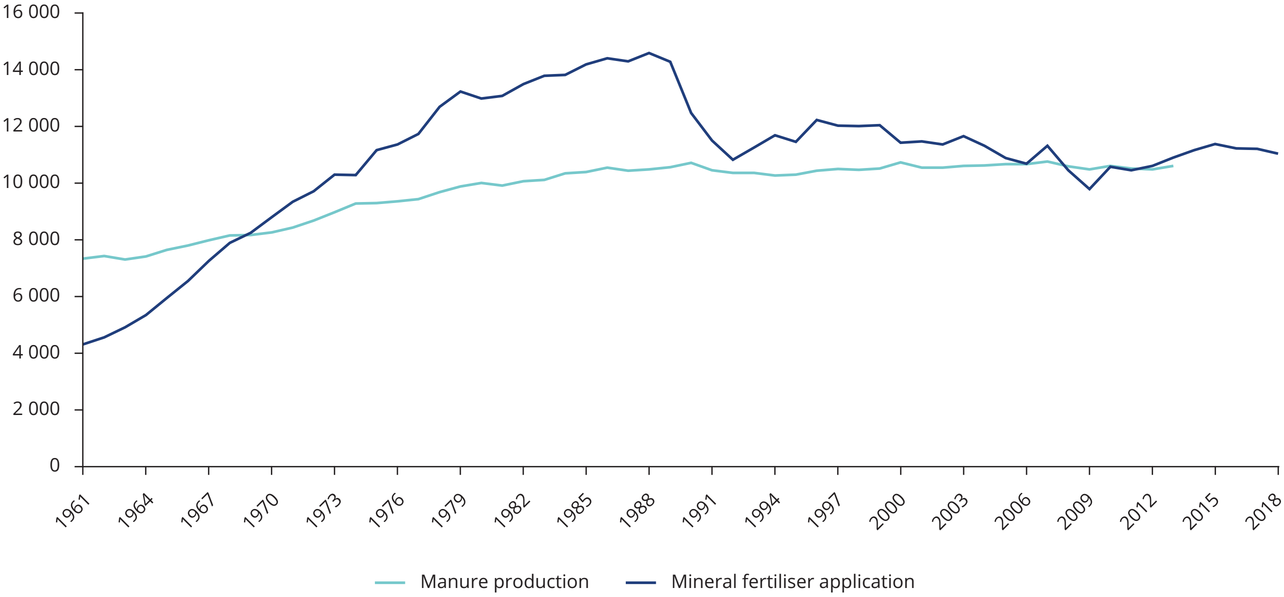
At EU level, trends in mineral fertiliser use have remained stable since 2008, except for yearly fluctuations mostly due to the price of fertilisers (ESTAT, 2020d). This masks large differences between countries. The biggest increase in nitrogen fertiliser consumption (> 40 %) occurred in Bulgaria, Romania, Latvia, Spain and Malta, while a decrease was observed in Croatia, Germany, Finland, France, Greece and Italy. The consumption of phosphorus has increased by more than 100 % in Denmark, Cyprus, Bulgaria and Lithuania, while a decrease of more than 30 % can be observed in the Netherlands, France, Luxembourg, Germany and Finland.

Organic fertiliser use has also increased significantly throughout the 20th century, in particular through the increase in manure production from a growing livestock population (see Figure 2.4) (Sutton et al., 2011). The use of manure is higher in countries with large livestock populations. Countries with high livestock densities such as Malta, the Netherlands, Belgium, Denmark, Cyprus and Ireland, also show the highest rates of manure inputs in relation to their agricultural area (over 98 kg N/ha per year) (ESTAT, 2020c). In contrast, Bulgaria, Estonia, Latvia, Lithuania and Slovakia have the lowest livestock densities and are also among the countries with the lowest rates of manure input per hectare (less than 30 kg N/ha per year).

Data on organic fertilisers (except manure) are lacking in many countries and the significance of these fertilisers in agriculture could be underestimated (ESTAT, 2017). For example, the reuse of nitrogen from sewage sludge from wastewater treatment

Figure 3.1 **Fertiliser use**

Total nitrogen fertiliser and manure in Europe (1 000 tonnes N)



Note: Data for EU-28.

Sources: Lassaletta et al. (2014, 2016).

plants can be significant. It was estimated that nearly 50 % of sewage sludge was reused on agricultural land in 2011 in the EU-28 (Pellegrini et al., 2016).

Nitrogen and phosphorous surplus

Nutrients enter the water cycle by multiple pathways, such as erosion, surface run-off and leaching, or by inflow from polluted groundwater to surface waters. The amount of nutrients that ends up in surface water and groundwater and the rate at which this occurs, depends on many factors. In addition to the amount of nutrients applied, other factors are crop rates of nutrient uptake, specific nutrient application strategies and a wealth of local geographical factors, such as soil type, drainage capacity, water availability, groundwater residence times, catchment topography, presence of natural and constructed buffers and wetlands, and climate.

Together these factors determine how long nutrients remain within the catchment and the specific nutrient transformations that take place. One of these, denitrification is particularly important, as it returns reactive nitrogen (such as nitrate) to atmospheric nitrogen (N_2), which may account for considerable nitrogen removal. Ultimately, these processes determine the share of nutrients that end up in rivers, lakes, transitional and coastal waters, and Europe's seas.

In the EU, the average nitrogen surplus from excess fertilisation of agricultural areas was 49 kg N/ha per year in the period 2013-15 (ESTAT, 2017). However, as agricultural production is not evenly distributed and agricultural systems also differ widely across Europe, nutrient inputs are also highly variable in space. The geographical distribution of nitrogen surplus was calculated using the CAPRI modelling system (Map 3.1). Above average nitrogen surpluses, which are associated with the most intensive agricultural production methods, are located in central Europe, Germany and the Netherlands in particular, but also in Denmark, the United Kingdom and Ireland, and parts of France, Spain, Italy and Hungary.

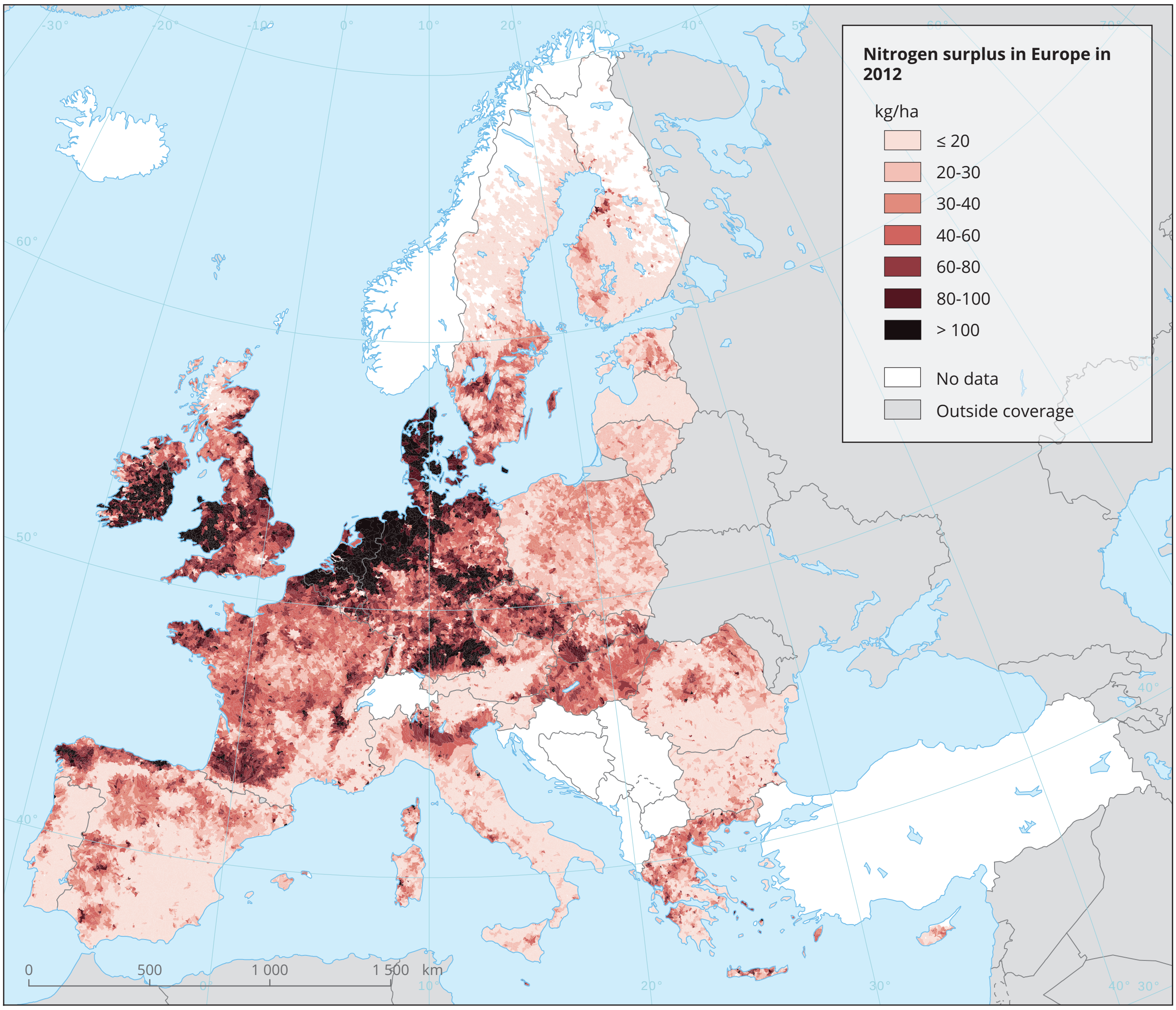
Nitrogen surpluses decreased by 10 % between 2004 and 2015, although nitrogen fertiliser use increased during the same period. This is possible because more optimal fertilisation approaches came into use, securing inputs that are much more in line with the timing of plant uptake, i.e. nitrogen use efficiency has improved (ESTAT, 2017). In the same period phosphorous surpluses on agricultural land also decreased from 4 kg P/ha per year to 1.2 kg P/ha per year (ESTAT, 2017). As phosphate is effectively stored in soils, a surplus can be reduced without short-term impacts on crop productivity (provided that the soil is saturated). At the same time, phosphorous pollution is also a long-term legacy because of its accumulation in soils and sediments and its slow mobilisation.

Nutrient concentration in surface water and groundwater bodies

According to data reported under the Nitrates Directive, 64 % of all monitoring stations of surface water bodies recorded below 10 mg nitrate per litre (annual average between 2012 and 2015), while 2 % recorded concentrations between 40 and 50 mg/L and 1.8 % exceeded 50 mg/L. The highest proportion of stations recording at 50 mg/L or above were reported in Malta, while Sweden, Ireland and Greece reported the highest proportion of stations recording less than 2 mg/L. For groundwater bodies, 13.2 % exceeded 50 mg nitrate per litre and 5.7 % were between 40 and 50 mg/L. Ireland, Finland and Sweden had on average almost no groundwater stations exceeding 50 mg/L, while Malta, Germany and Spain had, respectively, 71 %, 28 % and 21.5 % of their groundwater stations exceeding 50 mg/L on average. The comparability of data between Member States is limited by differences in their monitoring networks and strategies.

Significant efforts have been made to reduce point source emissions, and in particular implementing urban waste water treatment has led to declining concentrations in rivers of phosphates and nitrates, phosphate being associated with industrial and urban waste water pollution (EEA, 2019b). In contrast, concentrations of nitrates more closely linked to diffuse agricultural pollution are declining much more slowly in rivers and on average not at all in groundwater (Figure 3.2). This masks regional disparities: a total of 33 % of the groundwater bodies have shown decreasing nitrate concentrations since 1992 and a further 33 % have shown increasing concentrations (EEA, 2020g).

Map 3.1 **Nitrogen surplus in Europe in 2012**

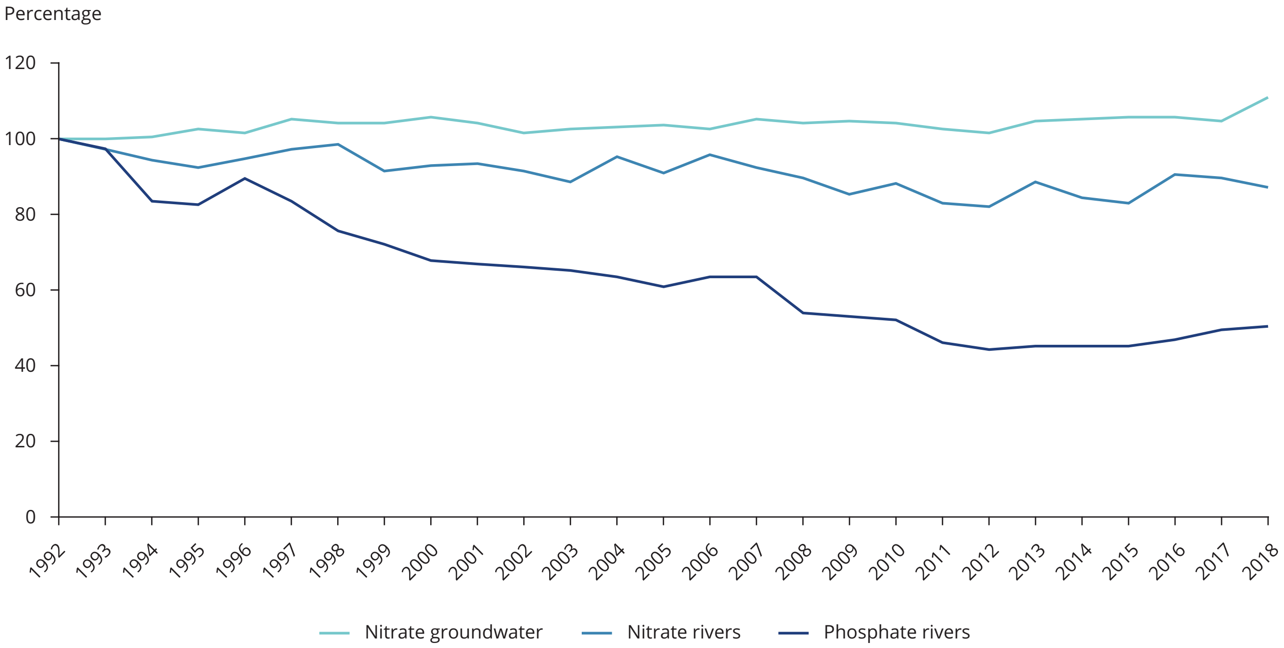


Reference data: ©ESRI

Notes: The CAPRI nitrogen balances were estimated on (1) export of nutrients by harvested material per crop, depending on regional crop patterns and yields, (2) output of manure, depending on the animal type, (3) input of mineral fertilisers, based on national statistics at sectoral level, and (4) a model for ammonia pathways (Leip et al., 2011). 'Nitrogen surplus on agricultural areas' is a proxy for nutrient pollution pressure, aggregated at functional elementary catchment level for the year 2012.

Source: Common Agricultural Policy Regional Impact Analysis (CAPRI) modelling system (Britz and Witzke, 2014).

Figure 3.2 **Trends in nutrient concentration in rivers and groundwater in the EU**



Notes: Concentration in 1992 = 100 %; The data series are calculated as the average of annual mean concentrations for groundwater bodies and river stations in Europe. Only complete series after inter-/extrapolation are included; number of stations included for Europe: groundwater 552, nitrate rivers 846, phosphate rivers 799.

Source: EEA (2020g).

Coastal and marine pollution

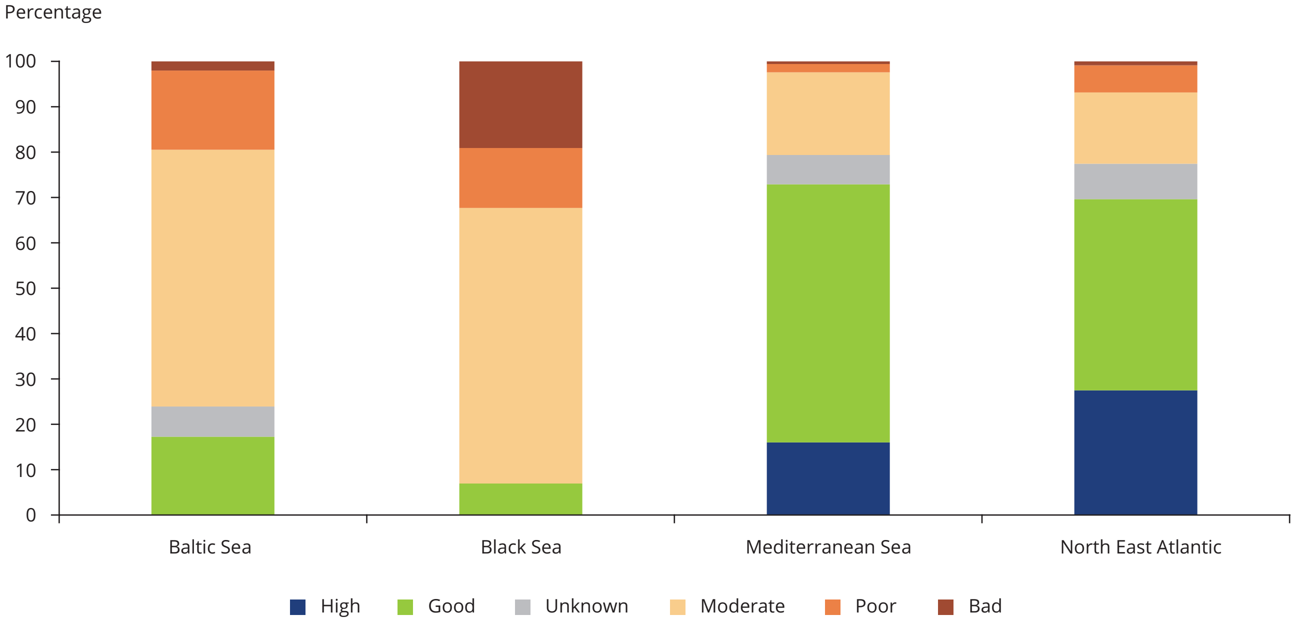
Diffuse pollution from agriculture and the associated eutrophication is a major environmental pressure in Europe's coastal waters and seas, especially in the Baltic and Black Seas where only 10 % and 15 % of coastal waters achieve good ecological status (Figure 3.3). A recent assessment of eutrophication in Europe's seas showed that 99 % of the Baltic Sea area, 53 % of the Black Sea area, 12 % of the Mediterranean area and 7 % of the North East Atlantic area were assessed as problem areas with respect to eutrophication (EEA, 2019f). The Baltic and Black Seas are semi-enclosed and highly stratified seas with hydrodynamic conditions that hamper the exchange of water with surrounding water bodies. Both have extensive dead zones as a consequence. The large problems linked to eutrophication in the Baltic Sea have led to international collaboration in the context of the Baltic Sea action plan, also adopted as a European regional strategy (Box 3.1).

3.1.2 Pesticides, metals and veterinary medicines

The use of pesticides, metals and veterinary medicines may have impacts on the environment and on human health through their spread in water and uptake by aquatic organisms. Some examples are pesticide residues found in agricultural products for human food consumption, fish reproductive capacity compromised by antibiotics, or heavy metal contamination entering the food chain (Fatoki et al., 2018). Specific impacts of some substances on aquatic organisms are better understood than the overall impacts on the aquatic environment or ecosystems or the combined effects of several chemical substances (mixtures).

Important impacts that depend on the substance and the aquatic organism include death, cancers, reproductive failure or, for some substances, bio-accumulation in the food web (FAO, 1996). Soil, with the help of various organisms, filters and buffers contaminants in the environment. Substances that are not readily degradable will eventually leach into

Figure 3.3 Ecological status in coastal waters, by regional sea



Notes: Data coverage is EU-28 and Norway.

Source: EEA (2018d).

Box 3.1 The Baltic Sea action plan

In addition to the obligations linked to the EU Marine Strategy Framework Directive, the Baltic Sea coastal states (which include several EU Member States and Russia) collaborate to achieve specific targets for nutrient emissions as part of the Baltic Sea action plan. The plan was adopted in 2007. It incorporates the latest scientific knowledge and innovative management approaches into strategic policy implementation around the topics of eutrophication, biodiversity, hazardous substances and maritime activities.

Improving the Baltic Sea's eutrophication status continues to require reductions in nutrient loads. Nutrient emissions to the Baltic Sea declined by 22 % for phosphorus and 25 % for nitrogen between 1995 and 2014. Load reductions have primarily been attributed to reductions in point source pollution.The 2014 assessment also indicated that diffuse sources from mainly agricultural activities constitute the major part, making up 46 % of the total riverine nitrogen load and 36 % of the total riverine phosphorous load to the Baltic Sea.

While the load reductions are considerable, they have not been sufficient to achieve the desired environmental improvement of the sea, and further reductions are needed. This is because negative feedback mechanisms in the sea continue to release phosphorus from sea floor sediments under anoxic conditions, slowing down its environmental improvement. Phosphorus in the sea floor stems from historical anthropogenic releases.

Sources: EC (2009b); Sonesten et al. (2018).

surface waters and groundwaters or be dispersed by wind erosion (Sandin, 2017; Silva et al., 2018). In this section, we discuss the use and impact of pesticides, heavy metals and veterinary medicines. However, the information available for a European overview is limited.

Pesticides

Pesticides are substances or mixtures of substances intended for preventing, destroying or controlling any pest, including unwanted species of plants or animals and vectors of animal disease. They include a wide range of chemicals, such as herbicides, fungicides, insecticides, acaricides, nematicides, molluscicides, rodenticides, growth regulators, repellents, rodenticides and biocides.

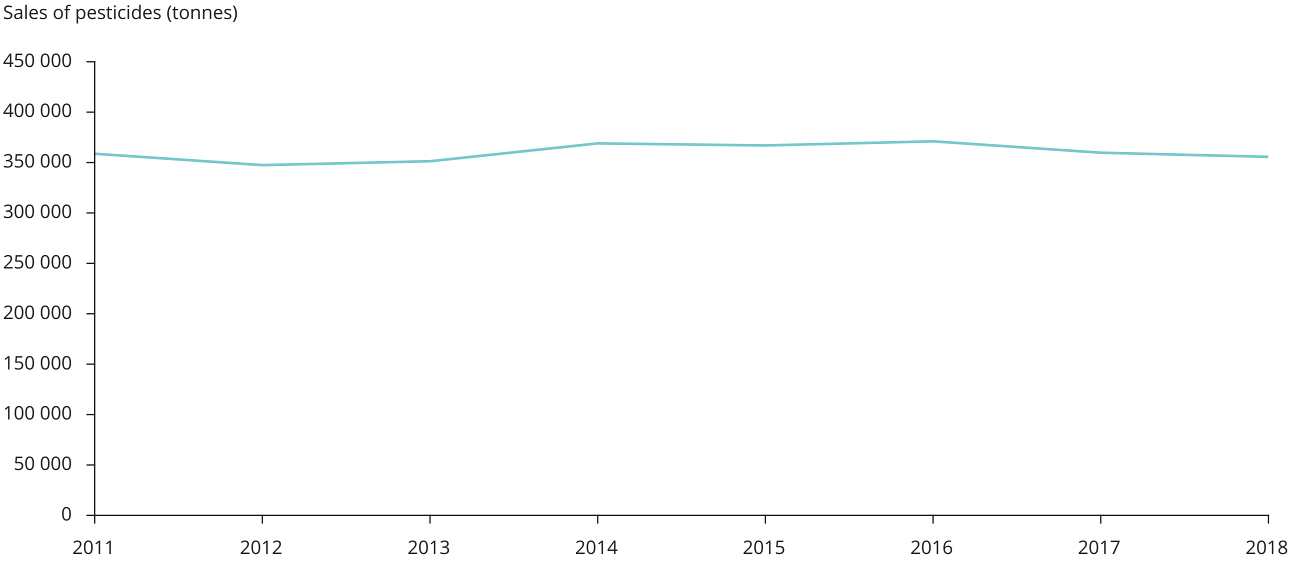
Pesticides differ from many other pollutants, as they are designed to act against organisms (plants, insects) and thus inevitably have an effect on the environment. These products contain at least one active substance and have one of the following functions:

- to protect plants or plant products against pests/diseases before or after harvest;
- to influence the life processes of plants;
- to preserve plant products;
- to destroy or prevent the growth of undesired plants or parts of plants.

When concentrations of pesticides are above critical thresholds, individually or as mixtures, they can be harmful to humans and/or the environment by contaminating soil, surface waters and groundwater (ETC/ICM, 2020a).

Current information on the application of pesticides across Europe remains very limited, which is why the total volume sold (or its value) is usually used as a proxy for quantifying application. In the EU-27, the total amount of pesticides sold is around 360 000 tonnes per year (Figure 3.4), with the biggest consumers in the EU-27 being France, Spain, Italy and Germany (ESTAT, 2020a).

Figure 3.4 Sales of pesticides 2011-2018



Notes: This figure does not take into account confidential values. They represent < 3 % of the total sales over the entire time series. For Denmark, reference year 2017 data were used in place of 2018 data. Data coverage is EU-27.

Source: ESTAT (2020a).

Total pesticide consumption in the EU-27 did not change between 2011 and 2018, although significant differences exist between Member States: the largest increases were in Cyprus, Austria, France and Slovakia, and the largest decreases were in Portugal, Ireland, Czechia and Italy (ESTAT, 2020a).

Pesticides can harm the environment by contaminating soil, surface water and groundwater. Aquatic organisms are directly exposed to pesticides resulting via surface run-off or indirectly through trophic chains (Maksymiv, 2015). The number of approved active pesticide substances in Europe is around 500. Among those, around 25 % are microorganisms, insect pheromones and plant extracts, considered low risk (EC, 2017c).

Active substances used in both plant protection products and biocides are approved at EU level and refer to products such as herbicides, insecticides and fungicides. While thresholds apply to single active substances, knowledge of their combined effects (in mixtures) is rare. Mixtures could reach harmful levels, even if the concentrations of individual substances are below a given threshold (EEA, 2018a; ICF et al., 2019). Furthermore, the toxicity of metabolites or transformation products from a pesticide substance may pose a higher risk to organisms and humans than the pesticide itself.

EU countries authorise active substances in their territories and ensure compliance with EU rules, such as the Sustainable Use of Pesticides Directive. Agriculture is the primary user of pesticides, but they are also used in forestry and horticulture and in gardens.

Although pesticide pollution is recognised as a major problem in European countries and many studies have documented the presence of excessive pesticides in the environment, data with European coverage are scarce. The information currently reported on pesticides in Europe differs among countries and substances, making it insufficient to support an assessment of the risk posed. According to data reported for the second river basin management plans under the WFD, 533 surface water bodies (0.4 %) are still failing to achieve good chemical status due to pesticides among the priority substances; for groundwater, 6.5 % of the whole area failed to achieve good ground water status (ETC/ICM, 2020a).

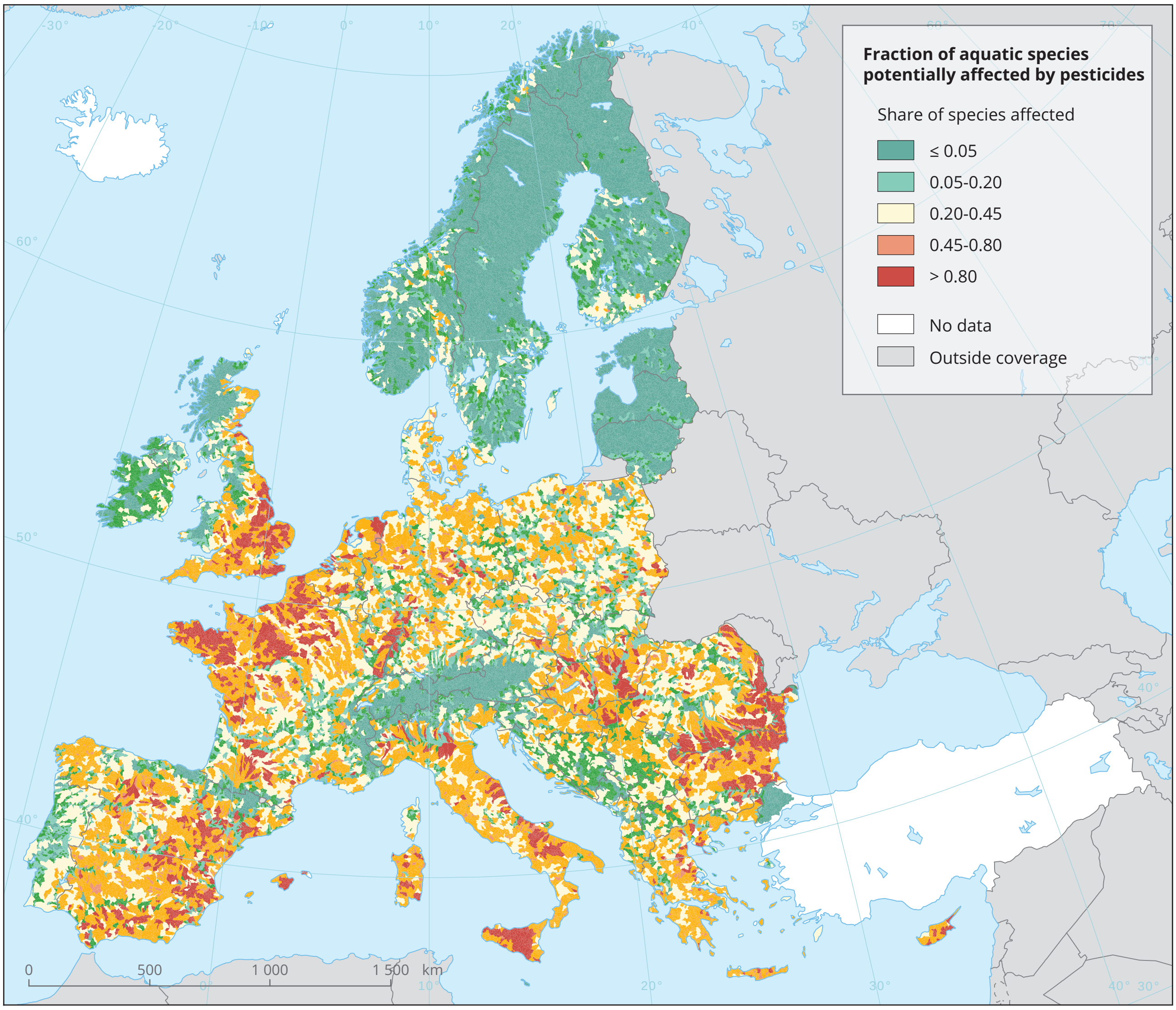
Pesticide substance concentrations reported to the Water Information System for Europe (WISE) database, suggest that exceedance rates could be higher than captured by the 2nd river basin management plans. In surface waters, exceedance rates caused by herbicides and insecticides were found for 5-15 % and 3-8 % of observations, respectively, between 2007 and 2017, using a precautionary lowest value national environmental quality standard to assess exceedance. For groundwater, exceedances occurred mainly for herbicides in 7 % of observations, and less than 1 % of observations for insecticides. Fungicides seem to be of lower importance (ETC/ICM, 2020a).

According to drinking water reporting in the period 2014 to 2016, compliance rates for reporting pesticides are high and vary between 99.8 % and 100 %. However, this does not necessarily represent pesticide contamination in raw water, and reported information hints at exceedances, mainly for metabolites (ETC ICM, 2020a).

Data on pesticide residues in food showed that 95.5 % of all samples fell below maximum residues levels with 4.2-4.6 % exceedances on vegetables, fruits and nuts and fewer exceedances on cereals, animal products or infant food (EFSA, 2019)

Modelling is one way to quantify the effects of pesticides on freshwater ecosystems. The chronic multi-substance potentially affected fraction (msPAF) of aquatic species can be used as a proxy for the intensity of pesticide pressure (Map 3.2). The msPAF specifies the potential share of the biological community affected by pesticide toxicity (van Gils et al., 2019; Posthuma et al., 2020). It was derived by modelling the cumulative impact of individual substances, aggregated according to their specific modes of action. The highest msPAF for aquatic species is found in the western part of France, Belgium, the Netherlands, north-western parts of Germany, south-eastern United Kingdom, Spain, Italy, Romania, Bulgaria, Malta and Cyprus. Low values of msPAF are found in the northern parts of Europe and in alpine regions where agriculture is less intensive.

Map 3.2 **Fraction of aquatic species in Europe potentially affected by pesticides**



Reference data: ©ESRI

Source: van Gils et al. (2019).

Metals

The anthropogenic contamination of the environment with heavy metals is also a serious problem arising from agricultural activities. Application of metal-containing fertilisers, sewage sludge and liquid manure is common practice in agriculture. Metals accumulate in and contaminate arable soils. Cadmium, copper and zinc are among the more common metal contaminants.

Cadmium, mainly originating from mineral phosphorous fertilisers, accumulates in 45 % of agricultural soils, mainly in southern Europe (EEA, 2019h). Cadmium is grouped as a priority hazardous substance in the Environmental Quality Standards Directive (EU, 2008b), i.e. among the most toxic environmental chemicals. Cadmium is, however, rarely transferred from soil to water, and so is of less concern in water.

Copper and zinc are added to animal feed and introduced into the environment through manure spreading or with copper- and zinc-containing pesticides. Furthermore, copper has been widely used as a fungicide spray because of its bactericidal and fungicidal properties in both conventional and organic farming (Kuehne et al., 2017). Results from the Land Use and Coverage Area Frame Survey (LUCAS) soil sampling 2009-2012 show elevated copper levels in the soils in the olive- and wine-producing regions of the Mediterranean (EEA, 2019h). Copper-containing materials are also applied as anti-fouling agents on fish farm cages and nets (Burridge et al., 2010).

Box 3.2 Small stream monitoring for veterinary medicines and pesticides in Europe

Based on a scientific study, pesticides and veterinary drugs were monitored in 29 small streams in 10 EU countries. The results showed that all the European rivers sampled in this investigation were contaminated with mixtures of pesticides, and in most cases with several veterinary drugs, but without any clear national or regional pattern. In total, 103 different pesticides, 24 of them banned in the EU, and 21 veterinary drugs were found in the samples analysed. Herbicides were the main contributor to the total amount of pesticides found in the samples, with terbuthylazine present in all the samples. The majority of the veterinary drugs detected were antibiotics.

Source: Casado (2019).

Veterinary medicines

Veterinary medicines reach agricultural soils, surface waters and groundwater directly from grazing animals or aquaculture or indirectly from applied manures. The most used veterinary drugs are antimicrobials, antibiotics in particular (Casado et al., 2019) To decrease the use of and the risk from antimicrobials in veterinary medicines, it is recommended to stay within the safe limits for residues of veterinary medicines used in food-producing animals and of biocidal products used in animal husbandry (EMA, 2016). Although Europe-wide measures address the issues of veterinary medicines in food and the environment, a number of veterinary medicines are known to enter the water cycle (see Box 3.2).

3.2 Water abstraction

3.2.1 Background

Water is an essential resource for agricultural crops, especially during flowering, seed formation or ripening. Due to better management of water application, and combining the management of water with that of nutrients and chemicals, crops grown under irrigated conditions usually achieve higher yields than the same crops grown under rainfed conditions. Irrigation can substantially increase the value of agricultural production. In the drier climate of much of Spain, for example, more than 60 % of the total value of the country's agricultural output comes from the 14 % of irrigated agricultural land (Expósito and Berbel, 2017).

Irrigation relies on water abstracted from surface or groundwater during the main growing season in the spring and summer months. During this period, abstraction puts particular pressure on the hydrological regime of surface water and groundwater. Natural hydrological regimes are key to maintaining healthy aquatic habitats and ecosystems. Surface water abstraction can reduce river flow to below critical levels, affecting aquatic ecosystems, increasing concentration of pollutants and damaging wetland habitats. Exploitation of groundwater lowers water tables and modifies groundwater flow patterns, reducing rivers' base flow and spring discharges and causing deterioration of aquatic and terrestrial ecosystems depending on groundwater flows.

Intensive exploitation of groundwater can lower aquifer levels permanently, in particular in dry climates such as the Mediterranean where groundwater recharge is low and in fossil aquifers where there is no recharge. Changes in groundwater flow patterns increase the risk of infiltration of pollutants and displacement of saline and low-quality groundwater into previously protected aquifers, or saline intrusion from seawater in coastal aquifers.

In the second river basin management plans under the WFD, water abstraction was reported as a significant pressure on 6 % of surface water and 17 % of groundwater bodies. The countries with the highest proportion of surface water bodies significantly affected by agricultural abstraction are Cyprus, Spain, France, the Netherlands and Bulgaria. For groundwater bodies, the most affected countries are Cyprus (where up to 71 % of groundwater bodies are affected), Hungary, Spain, Greece, Malta, Italy and France (EEA, 2018d).

In addition to the pressures caused by water abstraction, poor irrigation management in itself can lead to several pressures. They include increased erosion on slopes, pollution run-off into surface water bodies, leaching into groundwater bodies, and increased soil salinity from salt-rich irrigation water and/or insufficient drainage. Soil salts can affect the aquatic environment when washed away.

Irrigated agriculture relies on the timely delivery of water, especially during spring and summer, and thus relies on a wide range of water works diverting, pumping, storing and conveying water to farms across river basins, and between river basins in the form of cross-basin transfers. The infrastructure for storing and transferring water for irrigation purposes has created substantial hydromorphological pressures (Section 3.3).

3.2.2 Current level of agricultural water abstraction

In the EEA-39, total agricultural abstraction was 92 billion m^3 per year on average between 2008 and 2017, with the EU-28 abstracting 50 billion m^3 of water per year on average and Turkey alone about 40 billion m^3. Agriculture accounts for 24 % of total water abstraction in the EU-28 (EEA, 2019e). Spain, Italy, Greece, France, and Portugal alone accounted for 96 % of water abstracted for agriculture in the EU-28 between 2008 and 2017 (EEA, 2019e).

About 37 % of water abstracted for agriculture in the EU-28 between 2008 and 2017 is from river water bodies, followed by groundwater (36 %) and reservoirs (27 %). The share of abstraction between surface water and groundwater differs between countries. Groundwater abstraction for irrigation exceeds 50 % of total water abstraction for irrigation in 17 out of 27 EU-28 countries, including Malta, Denmark, Lithuania, Cyprus, the Netherlands and Germany (Zal et al., 2017). Some of these countries, such as Cyprus and Malta, have more than 50 % of their groundwater body area in a poor quantitative status (EEA, 2018d). In Malta, groundwater is the only source of water.

Countries such as Cyprus, Malta, Spain and Poland use reclaimed water to irrigate crops. Water reuse reduces the need for additional freshwater abstraction, as this is covered from water resources that have already been abstracted and used in other economic sectors. Because of its residual nutrient content, reclaimed water also decreases the need for fertilisation.

Unlike water abstracted for power plant cooling or household water use, most of the water abstracted by agriculture is consumed by the crop or lost as evapotranspiration (Box 3.3). As a result, agriculture is the largest net water user in the EU-28, accounting for 40-60 % of net water use depending on years (EEA, 2019e).

Box 3.3 Accounting for water use in irrigation

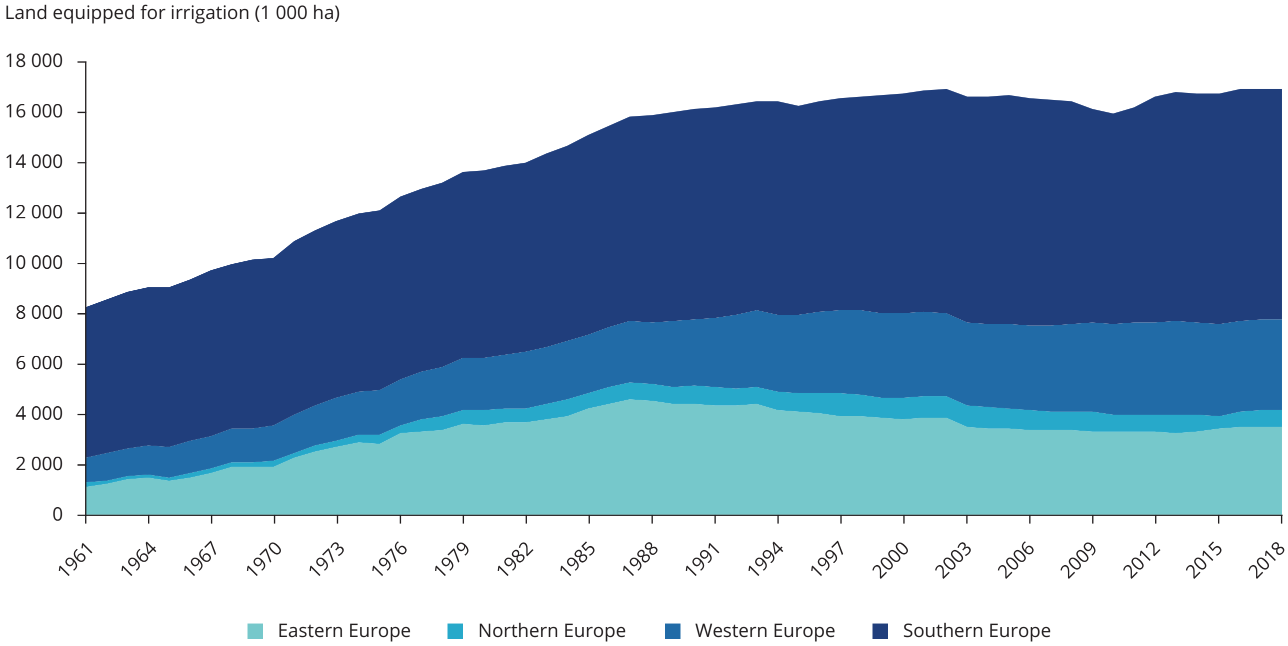
Water abstraction refers to the withdrawal of water from a water source, e.g. pumping water from groundwater, harvesting water from a spring, or extracting water from a river, lake or reservoir. In contrast, water use refers to water consumed by the crop. The difference between water abstraction and water use is dependent on many factors, including unintended conveyance losses and losses at the field level.

Conveyance losses may occur through leakage and seepage in the canals and pipes bringing water from the abstraction point to the field. In the field, losses may occur through evapotranspiration into the atmosphere and infiltration and seepage to groundwater. Water lost through leakage, seepage, infiltration, percolation and run-off may return to surface water and groundwater bodies as return flows.

Irrigation management aims to reduce losses at field level by adopting water-efficient spraying technology and improving irrigation scheduling, optimising water application to meteorological and agronomic conditions.

In agriculture, a large share of abstracted water is not returned to the environment, as it is consumed by the plant or evaporates into the atmosphere. This contrasts significantly with other large water users in Europe, such as public water supplies, which return most of the abstracted water as waste water discharges, usually downstream from the abstraction point.

Figure 3.5 Development of irrigation in the EU-28



Note: The figure presents estimates from the Food and Agriculture Organization of the United Nations (FAO), which differ from data reported through Eurostat. For instance, according to Eurostat, the total irrigable area in the EU-28 in 2016 was 15.5 million hectares (ESTAT, 2019b). This compares with 18.5 million hectares according to FAO estimates. Such discrepancies highlight the need for better monitoring and reporting of agricultural irrigation data.

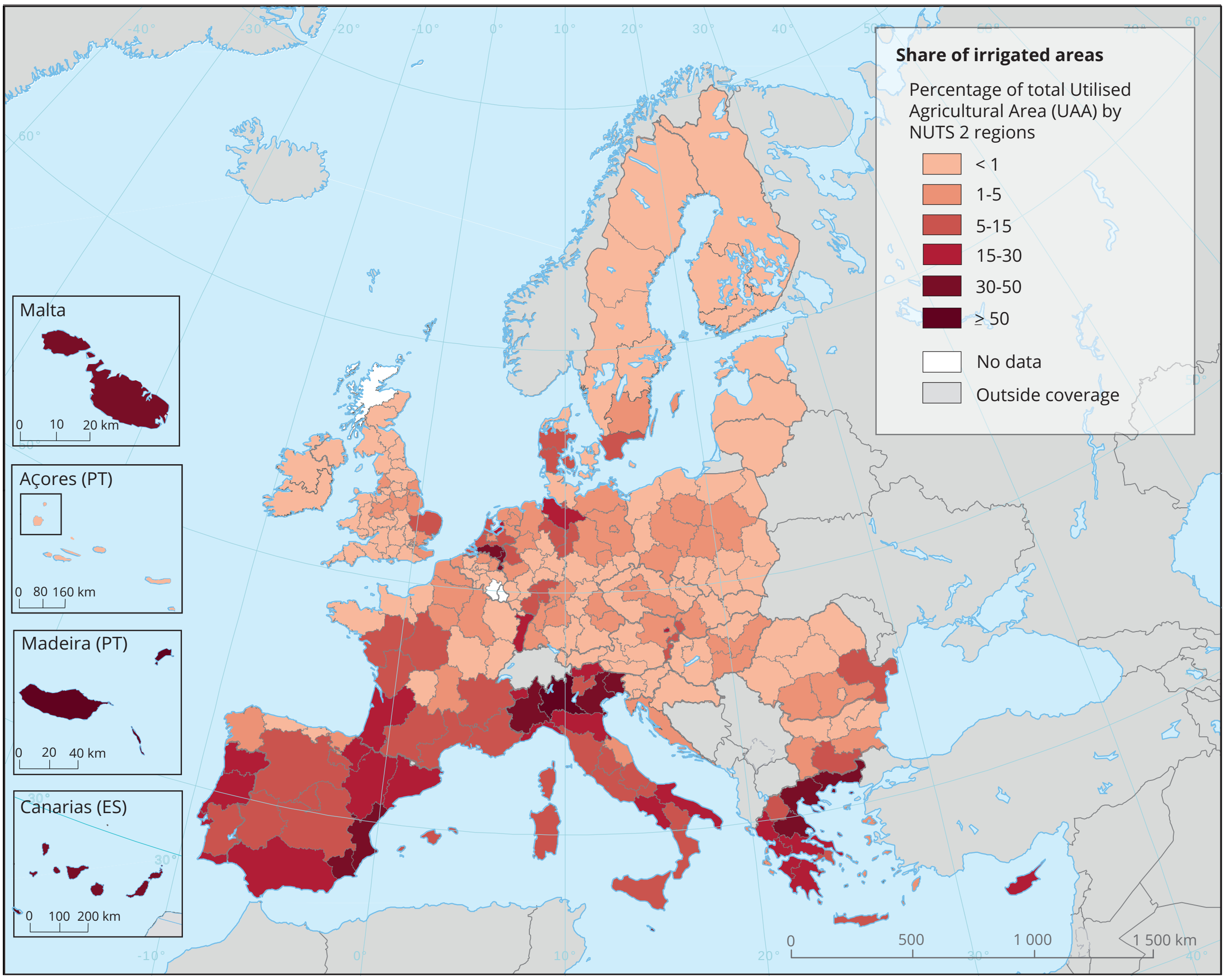
Source: FAO (2020).

3.2.3 Trends in irrigation

Irrigable area is an indicator of farmers' investment in irrigation. The area of irrigable agricultural land across the EU-28 has increased significantly since the 1960s (Figure 3.5). For example, the area has doubled in Italy and tripled in Spain during that time (FAO, 2020). Since the 1990s, at European level, the growth in the area of land equipped for irrigation has slowed. At the same time, total abstraction from agriculture is estimated to have reduced from 73 billion m^3 in 1990 to 48 billion m^3 in 2017 in the EU-28 (EEA, 2019e). In the EEA-39 countries, Turkey has seen a significant rise in its agricultural abstraction, from 27 billion m^3 in 1990 to nearly 46 billion m^3 in 2017(EEA, 2019e). Caution is needed when interpreting these estimates because of the lack of robust monitoring and reporting of abstraction levels from agricultural abstraction points.

Irrigated area — the actual amount of land irrigated — is usually smaller than irrigable area, and it can vary significantly from year to year due to interannual variability in weather conditions, selected crop species (e.g. to meet market demand), the farmer's irrigation strategy, crop and soil management practices, energy prices, and the presence of legal restrictions. Around 7-8 % of the UAA in the EU-28 was irrigated annually on average in the last 10 years (ESTAT, 2019b). High shares of irrigated areas are found in southern European countries, especially in Greece, Spain, Italy and Malta, but also in France, Cyprus, Portugal and the Netherlands (Map 3.3). Between 2005 and 2016, the irrigated area reduced by 6 %, although trends in irrigated areas and water abstraction vary widely across Europe.

Map 3.3 **Share of irrigated areas per NUTS 2 regions in the EU-28**

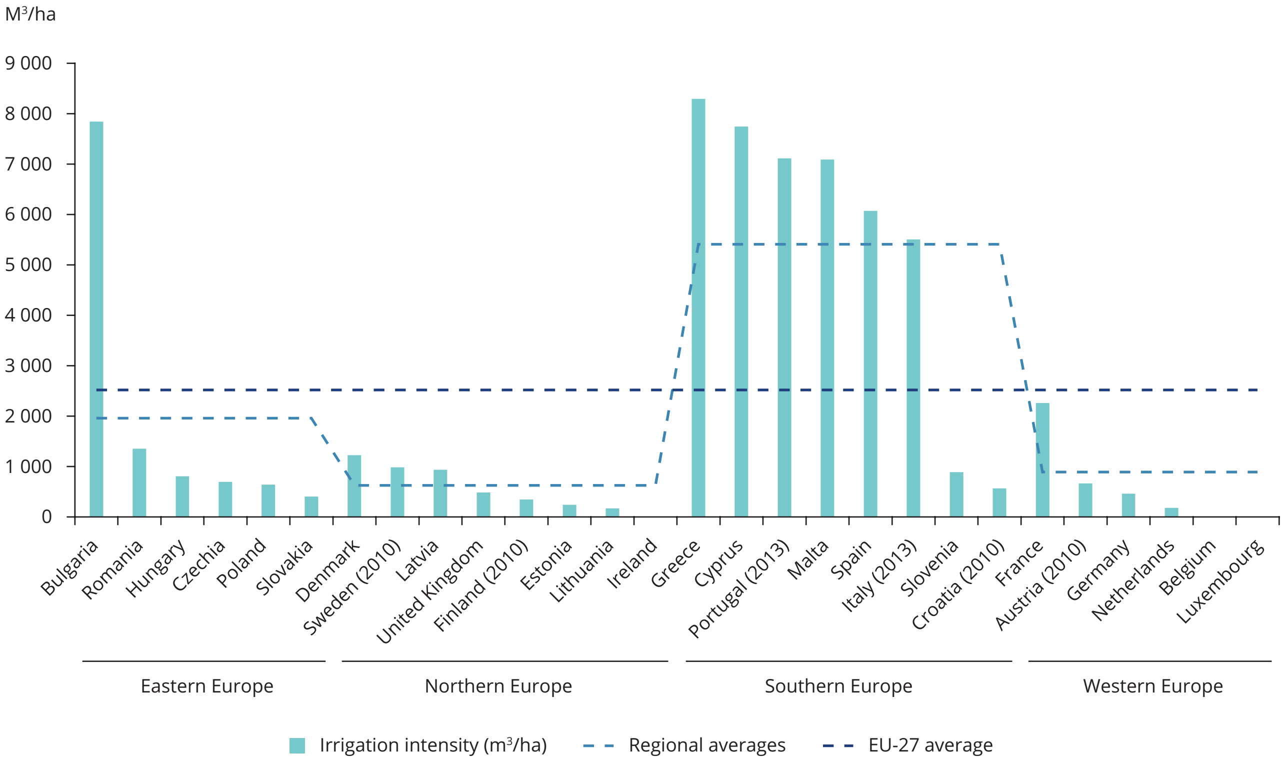


Administrative boundaries: © EuroGeographics © UN-FAO © Turkstat. Source: Eurostat

Source: ESTAT (2019b).

Southern Europe has seen the largest increase in irrigation since the 1960s. Irrigated crop production is extended because the regional climate is warmer and drier, evaporation and transpiration losses are higher, and the cultivated crop types include many commercially valuable but water-demanding crops (e.g. cotton, lucerne, maize, sugar beet, fruit and citrus trees, nuts, berries and vegetables). The average annual intensity of irrigation in these countries (i.e. volume of water used per unit of irrigated land, expressed as m^3/ha) is approximately three times higher than the European average (Figure 3.6).

Figure 3.6 Irrigation water abstraction intensity across Europe (m³/ha)



Source: Zal et al. (2017).

Water use by agriculture (Box 3.3), has decreased by 20 % in southern Europe since 1990 (Figure 3.7). Some countries have now achieved a high irrigation efficiency thanks to significant public and private investment in the irrigation infrastructure. For instance, 80-85 % of agricultural holdings in Cyprus, Malta and Slovenia use drip and sprinkler irrigation. However, investments in irrigation efficiency do not always result in water savings at the river basin and country levels (see Section 4.2). Furthermore, there are continued issues with the low transport efficiency of traditional irrigation water infrastructure, because of significant leakages and evaporation losses from irrigation networks (e.g. earthen and open trenches, ageing pipes), and less efficient irrigation technologies, such as surface irrigation, which still have significant shares in some countries such as Croatia, Greece, Italy, Portugal and Spain (> 30 % of agricultural holdings).

The fragmentation of land ownership is common in southern European countries (ESTAT, 2018), and the 2008 financial crisis limited the investment capacity of farmers and public authorities. These factors have contributed to delays in further modernising the agricultural sector in southern Europe.

Crops in western and northern Europe remain largely rainfed thanks to more humid and temperate climate conditions. However, a significant increase in irrigation has occurred since the 1960s, especially in western Europe, which has levelled off since 2005 (Figure 3.7). Irrigation is used to increase yields of certain water-demanding crops, such as maize. Pockets of intensively irrigated areas exist, for example in the Netherlands, which has specialist vegetable and horticultural production.

Photo: © Ina Krüger

Agricultural water use in western and northern Europe decreased by 50 % and 40 %, respectively, between the 1990s and 2010, and has remained stable since then (Figure 3.7). The Netherlands alone has seen its agricultural water use drop by around 70 % between the periods 1990-1995 and 2000-2005 (i.e. from an estimated 230 million m^3 to 80 million m^3). Since then, water use has reduced further (to an average 60 million m^3 between 2012 and 2017), although large yearly variations can occur. For instance, during the 2003 drought, agriculture abstracted an estimate 170 million m^3. Understanding and explaining changes in agricultural water use is complex because of the lack of data and its context in each country and region. Relevant factors include the uptake of more water-efficient irrigation practices and technologies, changes in crop production, climatological factors and changes in the area of irrigated land.

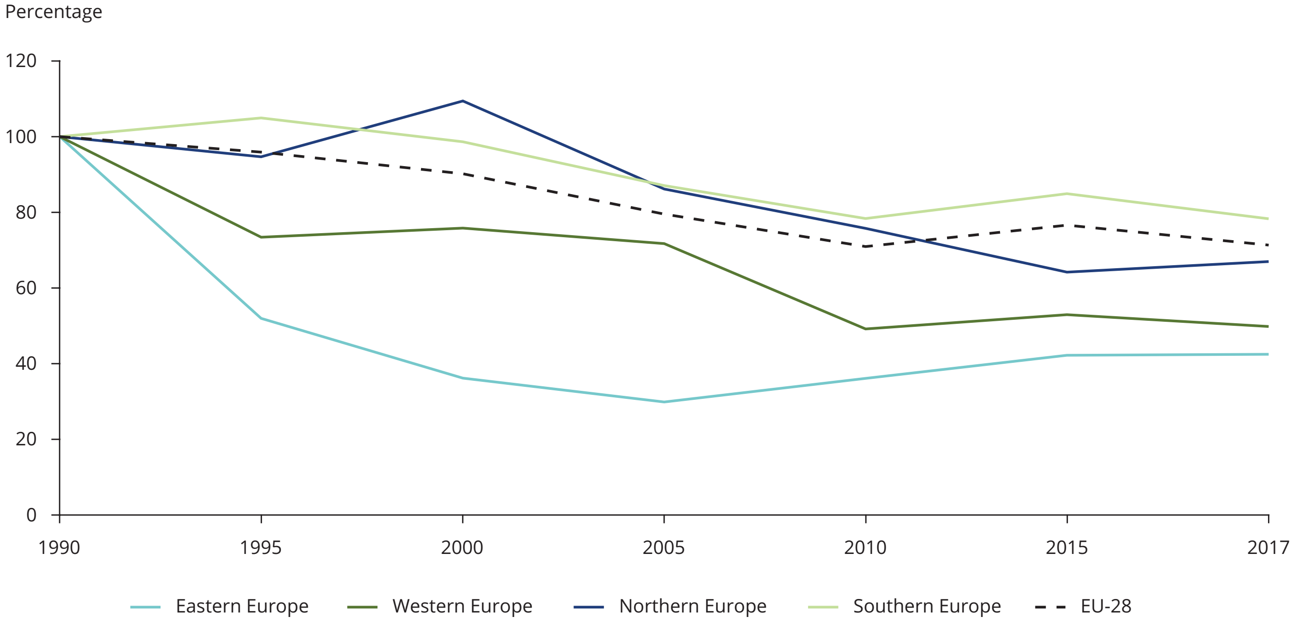
According to Eurostat, between 2005 and 2016, irrigated areas increased in several countries, such as the Netherlands, Belgium and most Baltic countries, while a decrease was observed in Denmark, France and the United Kingdom (ESTAT, 2019b). In France the reduction in irrigated areas can be explained by shifts in agricultural subsidies (especially following reforms in the 1990s and early 2000s) and prices, e.g. favouring less water-demanding cereals instead of more water-demanding maize, as well as stricter abstraction controls imposed by the WFD to protect ecosystems during droughts, and loss of agricultural land to urban area (Martin, 2013).

In eastern Europe, the area of land equipped for irrigation has reduced since the 1990s and agricultural water abstraction has decreased from 8 billion m^3 in 1990 to 1 billion m^3 in 2017. The area of cultivated land and the level of agricultural production fell sharply during the 1990s. In the same period, the water infrastructure was poorly maintained, the renewal of ageing agricultural equipment delayed and farmer training was less frequent. Large investments were launched after 2000, during the pre-accession period, and especially after 2004 and 2007, when most countries in the region joined the EU. In Romania, it is estimated that 53 % of its irrigated land switched to more efficient irrigation systems, as a result of common agricultural policy funding (Devot et al., 2020) In recent years, most eastern European countries have seen significant increases in their irrigated areas, in particular Romania, Poland, Hungary and Bulgaria (ESTAT, 2019b). This recent increase can also be seen for agricultural abstraction, as shown in Figure 3.7.

3.2.4 *Agricultural water abstraction and water stress*

Despite a reduction in agricultural water abstraction, it remains at unsustainable levels in many European regions, a situation that is likely to worsen under climate change due to the declining water resources available during the crop-growing period (Section 3.4). The level of water stress can be calculated as the imbalance between renewable water resources and

Figure 3.7 Trend in agricultural water abstraction in the EU-28

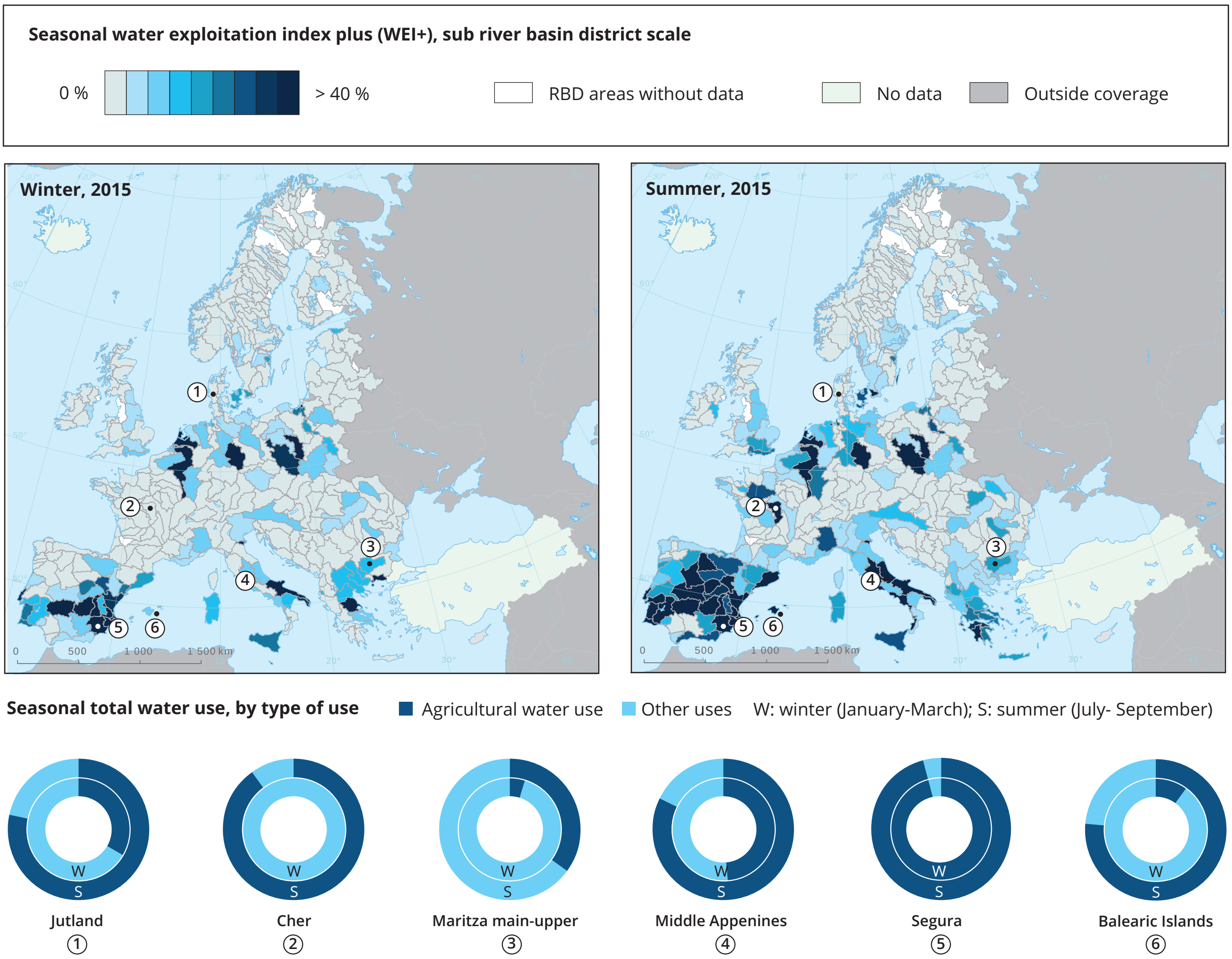


Source: EEA (2019e).

water demand (EEA, 2019e). It is expressed by the water exploitation index (WEI+) as the total water use from surface water and groundwater systems as a percentage of the renewable freshwater resources for a specific area and time. A WEI+ above 20 % implies that a water resource is under stress, and more than 40 % indicates severe stress and clearly unsustainable use of the resource. It is not only related to water demands from agriculture but also to the demand from all the sectors that rely on water: households, industry and energy.

Currently, 10 % of the European territory is under permanent water stress due to pressures from socio-economic and climate change on renewable freshwater resources. In addition, water stress affects up to 30 % of the European territory at least seasonally. This issue becomes more serious during the driest months of the year, when the demand for water from agriculture increases sharply. The seasonal variation in the WEI+ has been calculated for Europe (Figure 3.8). Water scarcity associated with agricultural activities has a strong seasonal variation, especially evident in southern European countries such as Spain, Italy and Greece, but also in many sub-basins of western, eastern and northern Europe.

Figure 3.8 **Seasonal water stress in European sub-basins expressed through water exploitation index (WEI+) results for the winter and summer of 2015. Difference between winter and summer is primarily due to agricultural water use**



Notes: Assessments of the sustainability of water abstraction at the European level remain limited by data availability and the approach to interpretation of water returns. This may lead to large differences in the European WEI compared to national datasets. An example of this occurs in the south-western subbasin of France along the Atlantic Coast, an important maize production area. There the national estimate of WEI is around 50% because it adopts no water returns from agriculture, whereas the European estimate, which is based on 31 % returns ratio from agriculture, is below 10%.

Source: EEA (2019e).

In 2017, the level of agricultural water consumption as a percentage of renewable freshwater resources was particularly high in Cyprus (43 %), Greece (35 %), Malta (34 %), Spain (20 %), Turkey (16 %), Portugal (11 %) and Italy (9 %), whereas in the remaining European countries it was significantly lower (< 3 % in each). Caution is needed in interpreting annual and country-level results in the latter cases. Agriculture is also responsible for local and seasonal water stress incidents. In countries such as France, large seasonal and regional variations can be observed, and spring and summer water abstraction for irrigation can have severe impacts on river flows and aquifer levels in western and northern regions such as the Atlantic catchments.

3.3 Hydromorphological pressures

3.3.1 Background

Many lowlands, such as floodplains and coastal areas, have been reclaimed for agriculture, often over centuries. Typical land reclamation situations include the modification of a river with multiple channels into a river with one single channel, or combining floodplain drainage with dikes for flood protection. Land reclamation also occurs around lakes, typically by lowering the mean water level to gain land for agriculture, forestry or urbanisation (Vartia et al., 2018). In addition, it was common practice in the past to channelise or straighten the streams meandering through agricultural land. Straightening of smaller channels was mainly done to drain land to increase crop yields. Straightening the channel also made growing crops more efficient because they could be farmed along a straight waterway. Other agricultural practices that have strongly influenced changes made to the river network include storing water needed for irrigation, flood control structures and livestock grazing on river banks (Images 3.1, 3.2, and 3.3).

Such changes to the river channel and to the hydrology of the river are known as hydromorphological pressures. Hydromorphological pressures are assessed as part of the WFD, requiring Member States to monitor and manage the effects of changes in physical characteristics on surface water body ecology. Hydromorphological pressures are one of the main reasons for failure to reach good ecological status in European water bodies. Agricultural activities, such as crop cultivation and livestock production, affect floodplains and riparian vegetation when carried out immediately adjacent to the river or in the floodplain. As a result, the edges of many rivers are directly in contact with agriculture and river floodplains have been fragmented and often reduced to narrow strips or isolated trees on the river banks (REFORM wiki, 2015).

Hydromorphology is a term used in river basin management to describe the water and sediment

Image 3.1 **Multipurpose water storage reservoir in Spain**

Photo: © Ina Krüger

flows and geomorphological processes and characteristics of surface water bodies, which in combination play a key role for aquatic ecosystems, habitats and species. Good hydromorphological functioning, in particular river-floodplain dynamics, is an essential element of ecosystem health and underpins the delivery of many ecosystem services and benefits for society (EPA Catchment Unit, 2016; Houlden, 2018). In particular, river-floodplain dynamics are highly relevant for the development of natural hydromorphological conditions (EEA, 2019c). Hydromorphological pressures include physical changes in natural water bodies to control flow, erosion and floods, as well as land reclamation through drainage and river straightening. As an example, flood protection schemes have been installed across Europe to protect agricultural land from damaging floods among others things.

These pressures are largely responsible for the widespread loss of wetlands that has occurred in past centuries and are linked to many different human activities, including agriculture, urbanisation, energy production and transport. In some cases they also contribute to altering the catchment hydrological cycle.

The physical impact of agriculture on surface water bodies has to a large extent resulted from the drainage needed to increase the area of land with conditions appropriate for crop production and from the need to store water for irrigation (Section 2.2.3). Impacts include changes in flow, changes to river banks, riparian zones and floodplains, alterations to the hydrological cycle, increased erosion and sedimentation and disruption of the continuity of the river's flow. Table 3.1 provides an overview of the key hydromorphological pressures and impacts caused by agricultural activities on water bodies and their surrounding floodplains.

3.3.2 Current status

According to the second river basin management plans (RBMPs), 34 % of surface water bodies across the EU are affected by hydromorphological pressures. Such pressures have been identified in almost all Member States, albeit to a different extent, with some countries having more than 60 % of their water bodies affected. In the majority of countries, between 10 % and 60 % are affected by hydromorphological pressures and only a few countries have reported a share of affected water bodies lower than 10 % (EEA, 2018d).

The share of water bodies affected by hydromorphological pressures which are directly linked to agriculture is approximately 7 % of total water bodies (EEA, 2018d). The lack of hydromorphological assessment methods and monitoring data appropriate for understanding the nature of hydrological and morphological modifications from agricultural activities may have led to an underestimation of these pressures.

Image 3.2 Diversion weir of Carcaixent on the river Júcar, Spain

Photo: © Carles Ibor Sanchez, Flickr

Table 3.1 Hydromorphological pressures from agriculture

Pressure	Explanation
Drainage	Across Europe, about 17 % of arable land and permanent crop area is drained to optimise crop production. In addition, grasslands, especially those more intensively managed, are also frequently drained. Drainage has also been a key element of large historical land reclamation projects. Drainage is one of the most common reasons for designating water bodies as heavily modified in the second river basin management plans. Drainage is done by installing drainage pipes in fields, which take water to nearby streams or drainage ditches faster than natural drainage. Although drainage is beneficial in achieving optimal conditions for plant growth and keeping the correct balance between available soil pore water and available pore air, it is also related to several hydromorphological pressures. These pressures include increasing the inflow of fine sediments in the water or changing the hydrological regime. A secondary negative effect of drainage on hydromorphology and ecological status comes from maintaining and operating the drainage facility (Vartia et al., 2018).
Irrigation	Across Europe, on average 7-8 % of the arable land area is irrigated every year. Securing water for irrigation requires water storage and irrigation channels. Dams and impoundments disrupt the river's continuity and migration routes for fish and cause significant changes in river flow and sedimentation patterns (Halleraker et al., 2016). In addition, pumping water directly from rivers during times of low water flow may exacerbate low flows and damage aquatic life. Irrigation channels distribute water within a basin and sometimes between basins. Water transfers between basins to secure a water supply for irrigation are known to have significant hydrological and hydromorphological impacts (WWF, 2009). The magnitude of transfers within Europe is not known.
Flood control	Protecting agricultural land from flooding has required river straightening and channel deepening, constructing weirs to reduce flow velocity and flood defence structures that disconnect rivers from floodplains (EEA, 2019c). Because of such engineering work, less water is infiltrated into the floodplain soil and the groundwater level declines.
Livestock	Overgrazing and trampling by livestock affects river banks, especially where fencing is inadequate. Overgrazing leads to the loss of riparian vegetation, and trampling damages the river bank's stability and leads to increased sedimentation and soil compaction (O'Callaghan et al., 2018).

Image 3.3 Animal trampling and drainage ditch, Netherlands

Photo: © Ina Krüger

Some countries, such as Germany, Hungary, Croatia and Spain, reported a substantial share of water bodies affected by agricultural hydromorphological pressures; however, according to the assessment of the second RBMPs by the European Commission, for most Member States, the hydromorphological pressures identified have not yet been clearly apportioned to specific sectors (including agriculture) in the WFD reporting (EC, 2019a). Nonetheless, awareness of the importance of hydromorphological pressures and impacts from agriculture is growing. For example, a study in Sweden has shown the impacts of intensive agriculture on hydromorphology to be a major barrier to achieving good ecological status (Box 3.4)

In addition, drainage for agriculture is the third most common reason for designating water bodies as heavily modified in the EU, leading to the designation of about 3 700 water bodies out of 18 000 as heavily modified in the second RBMPs. The highest numbers designated are in Germany and the United Kingdom.

Figure 3.9 gives an overview of the proportion of arable land and permanent crops that is drained. Drainage occurs in all countries, but there is a strong north to south gradient. In the Netherlands, Latvia, Lithuania and Finland almost all agricultural land is drained (Herzon and Helenius, 2008). More than 40 % of farmland is drained in 15 countries. In Denmark, for instance, 52 % of the

Box 3.4 Agricultural impact on hydromorphology in Sweden

In Sweden's second river basin management plans, 63 % of surface water bodies failed to achieve good ecological status. The main pressures affecting surface water bodies were atmospheric deposition of pollutants, hydromorphological pressures and diffuse source pollution. Agricultural activities, which are concentrated in southern Sweden and in the central plains, are partly responsible for physical alterations to rivers and lakes. The need to balance good water status in agricultural areas with the objective of competitive and sustainable agricultural production is on the Swedish government's agenda.

To this end, action coordinated between national water and agricultural agencies was initiated in 2014 to develop a national strategy for prioritising measures that can reduce the physical impact of agriculture on water.

In the first phase of this action (2014-2015), the relationship between hydromorphological pressures and ecological status was investigated, and it was concluded that a high share of arable land close to water bodies and their floodplains reduces the quality of their morphology and, with this, the quality of ecologically important structures and functions of the water bodies is also reduced. The result was based on a cluster analysis of 50 800 sub-basins in Sweden. The analysis showed that sub-basins with a high share of arable land and intensive farming, including livestock, seldom achieve good ecological status under the Water Framework Directive, while achieving good ecological status is much more common in sub-basins with a high share of meadows and pastures. In Sweden, intensive farming takes place in only 2.7 % of the sub-basins. This production is characterised by special crops, pig production, laying hens, beef cattle and milk production.

In the second phase (2017-2019), efforts were concentrated on further improving the knowledge base to support Swedish county boards and water authorities in identifying measures to reduce physical impacts in agricultural waters. Up to the second river basin management plans (RBMPs), measures to reduce the physical impacts of agriculture were implemented only to a limited extent and their inclusion in the RBMPs was not clearly defined. Thus, a report on relevant measures was developed for consideration in the preparation of the third RBMPs. In addition, some of the measures presented, e.g. two-stage ditches (reconstructed ditches that give more space to water courses), are already supported by the Swedish rural development programmes and should be considered more widely in agricultural areas in the future (K. Vartia & J. Svensson, Swedish Agency for Marine and Water Management, 19 March 2020, personal communication).

Part of the action was dedicated to describing buffer strip types that are suitable for farmed areas, including an assessment of their effects on the environment and on drainage, in order to support their broader application in Sweden in the future. Buffer strips are not yet widely implemented in practice in Sweden and this type of measure was not included in the second RBMPs (Swedish Agency for Marine and Water Management, personal communication). Finally, the significance of the adverse effects of mitigation measures on agriculture was assessed, in terms of the amount of arable land that can actually be set aside for mitigation measures in farmed areas.

Overall, the action has allowed an intensive dialogue and enhanced cooperation between the Swedish Agency for Marine and Water Management and the Swedish Board for Agriculture to develop jointly a roadmap for reducing hydromorphological pressures from agriculture.

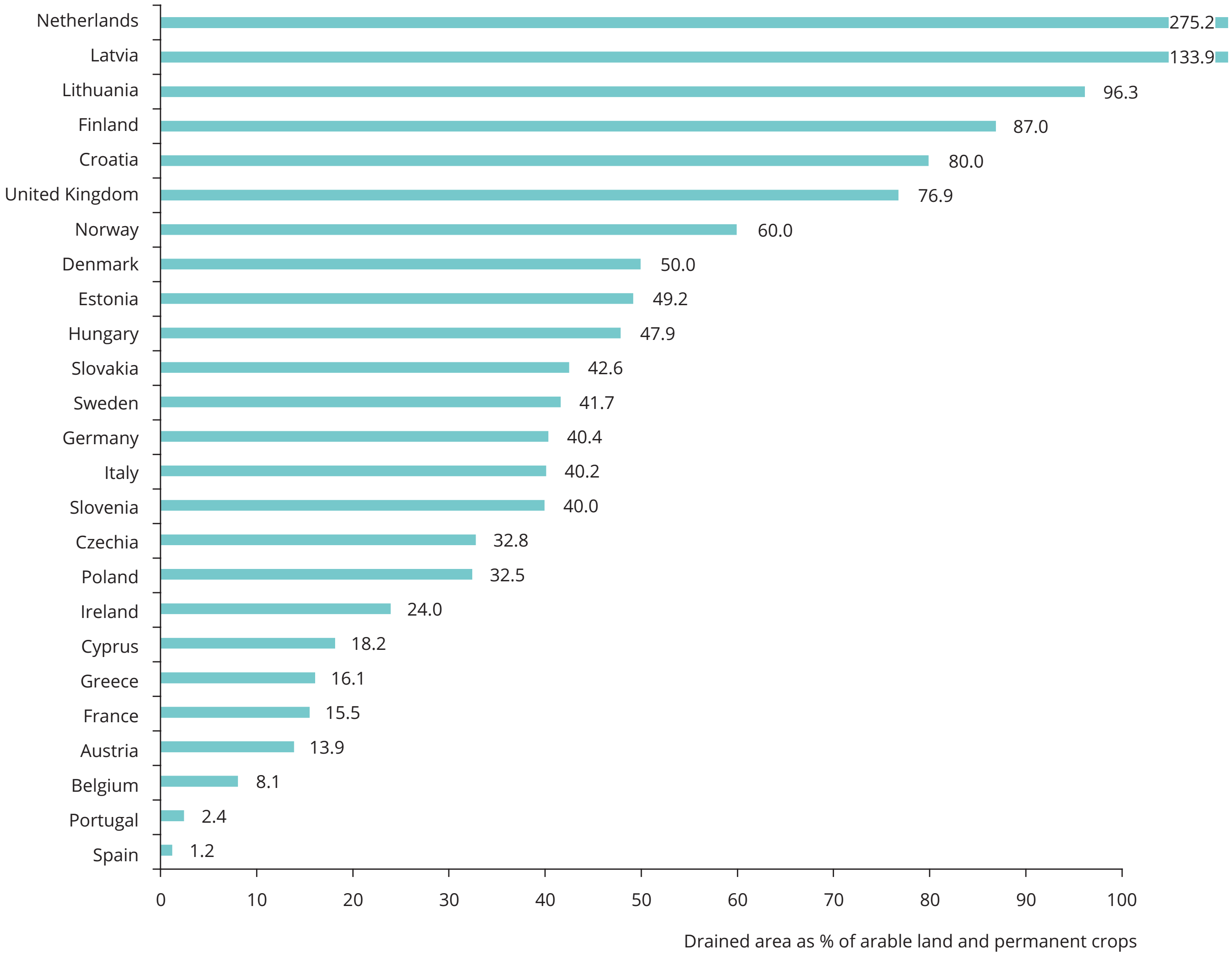
Sources: Swedish Board for Agriculture and Swedish Agency for Marine and Water Management (2015); Bölenius et al. (2019).

agricultural area was drained in the 20th century (Møller et al., 2018). In other countries with a large area of arable land, the share of drained land is high, e.g. 77 % and 40 % in the United Kingdom and Germany, respectively. In southern European countries, drainage is lower, probably because agriculture is mostly irrigated.

In addition to putting a hydromorphological pressure on water bodies, drainage also leads to biodiversity loss, and, when peatlands are drained, large quantities of greenhouse gases are emitted. For example, in Denmark, drained peatlands have been estimated to be responsible for 6 % of the country's greenhouse gas emissions.

In total, 1 500 heavily modified water bodies have been designated because of physical modifications to the water bodies that serve irrigation, with the highest numbers designated in Spain, Poland, Italy and Hungary (EEA, 2018d). The countries with the highest percentage of reservoirs used for irrigation (as single- or multi-purpose reservoirs) are located in southern Europe (i.e. Cyprus, Greece, Bulgaria, Portugal, Spain, Italy, France) (ICOLD, 2020). Spain has the largest number of large reservoirs in Europe, while Cyprus has the highest density. The majority of dams were developed between 1960 and 1990, facilitating extensive river water abstraction, mainly for irrigation (Zogaris et al., 2012). These statistics do not include the large numbers of smaller reservoirs used by one or a small group of irrigators. For instance, an estimated 19 000 small reservoirs were dedicated to agricultural irrigation in France between 1995 and 2000, a number which is likely to be higher nowadays (Carluer et al., 2016a).

Figure 3.9 **Drained area in European countries as a percentage of arable land and permanent crop area**



Note: Shares greater than 100% occurs where the drained area is greater than the area of arable land and permanent crops.

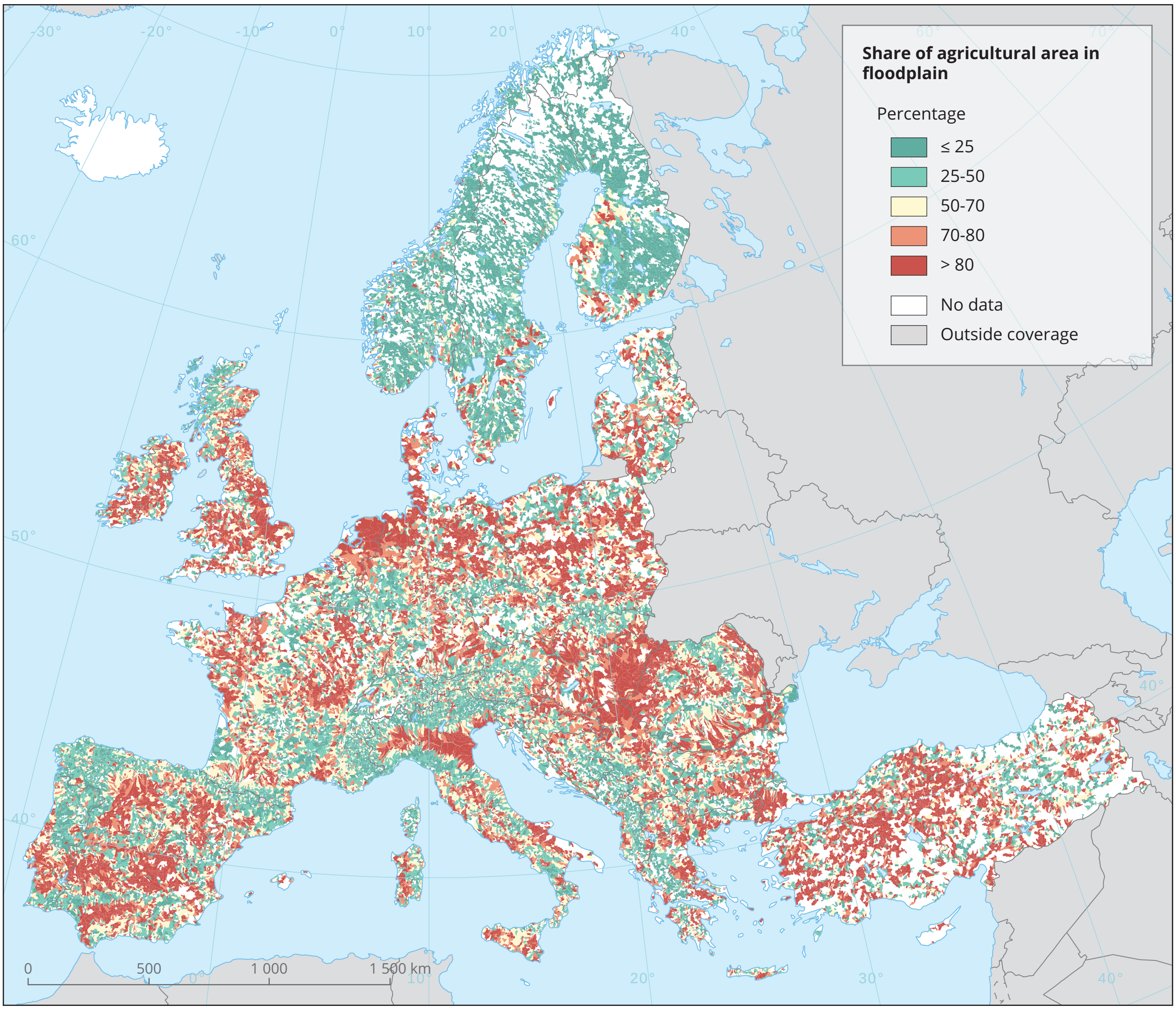
Source: ICID (2018).

3.3.3 *The share of agricultural land in floodplains as a proxy indicator*

Across the EEA-39, an analysis based on the main ecosystem categories used for mapping and assessment of ecosystems and their services (MAES) showed that on average 35 % of croplands and 15 % of grasslands are found in floodplains (EEA, 2019c). Both of these are associated with agricultural activities. To assess the potential hydromorphological pressure from agriculture in the floodplain, agricultural land use has been used as a proxy indicator. The underlying assumption of this proxy indicator is that the larger the share of cropland and grassland in the floodplain, the more an area is likely to be affected by hydromorphological pressures from agriculture. By making this assumption, we have calculated a proxy for the geographical distribution of hydromorphological pressures associated with agriculture in floodplains. The analysis was done by calculating the share of cropland and grassland in small catchment units (functional elementary catchments).

Map 3.5 illustrates that, in most functional elementary catchments, the share of cropland and grassland in floodplains is substantial in lowland areas. In contrast, it is low in mountainous regions such as the Alps and in large parts of Scandinavia.

Map 3.5 Geographical distribution of the share of agricultural land in floodplain areas, calculated by functional elementary catchment



Reference data: ©ESRI

Note: The floodplain extent is based on the potentially flood-prone areas (EEA, 2020b).

Source: ETC/ICM (2020b).

3.4 Water, agricultural pressures and climate change

3.4.1 Impacts of climate change on agricultural pressures on the water environment

Climate change is an ongoing process, already influencing temperature and precipitation patterns in Europe. In return, these changes have multiple impacts on the hydrological cycle, which then affect both crops and natural vegetation. The recently published Peseta IV study analysed the consequences of three different temperature increases by 2050 (Feyen et al., 2020). This study found distinct differences in climate change impacts between northern and southern Europe. Northern Europe is projected to get warmer and wetter (in particular in winter), whereas southern Europe is projected to get warmer and drier. In both northern and southern Europe, the crop growing season will become drier, exposing crops to higher water deficits.

These patterns will affect agriculture differently in the two regions (Feyen et al., 2020). The same study found that agricultural production will need major adaptation in southern Europe, where the most severe consequences of increased temperature and reduced water supply will be experienced. Across Europe, increasing temperatures will cause a northwards movement of crops suited to the area and increase the length of the growing season. Higher temperatures and drier conditions will increase evapotranspiration during the growing season, which may increase crops' demand for water. There is, however, considerable variation among crops in how strong this response is (EEA, 2019a).

The adaptation of the European agricultural sector to a changing climate is and will continue to be critical to its long-term viability. It will also have an important role in the adaptive capacity of society more generally, as, without adaptation, the impacts of climate change may exacerbate existing or create new conflicts, for instance regarding water use, pollution and biodiversity protection. In Section 4.2 some of the long-term sustainable solutions that could be considered to improve resilience to climate change are discussed.

Agriculture is both highly exposed to the impacts of climate change and a net driver of climate change through the emission of greenhouse gases. Overall, agriculture is the fifth largest emitter of greenhouse gases and accounts for 10 % of all EU emissions (EEA, 2019a). It is the largest contributor of non-CO_2 greenhouse gas emissions, in particular CH_4 and N_2O. Livestock in particular are a major contributor to these emissions, as 38 % of agricultural emissions are linked to enteric fermentation in ruminant livestock. The management of agricultural soils is responsible for 32 % of emissions, while other agricultural practices contributing to emissions include the use of mineral and organic nitrogen fertilisers (EEA, 2019a).

The agricultural sector can contribute to removing carbon from the atmosphere through photosynthesis into living biomass, converting between land cover types and managing agricultural soils to increase carbon sequestration. Protecting organic soils from intensive use would be beneficial from the perspective of climate action in the agricultural sector.

Agriculture is facing an increasingly challenging climatic context, for instance increased soil moisture deficits during the growing season, which indicate increased risks that crop will be exposed to drought (Box 3.5). The combined effects of changes in temperatures, rainfall and the frequency of extreme events, such as very strong winds, hailstorms, intense heat and frosts, are already being observed and affecting productivity and yields in Europe. More indirect effects include increases in pests, diseases and invasive species.

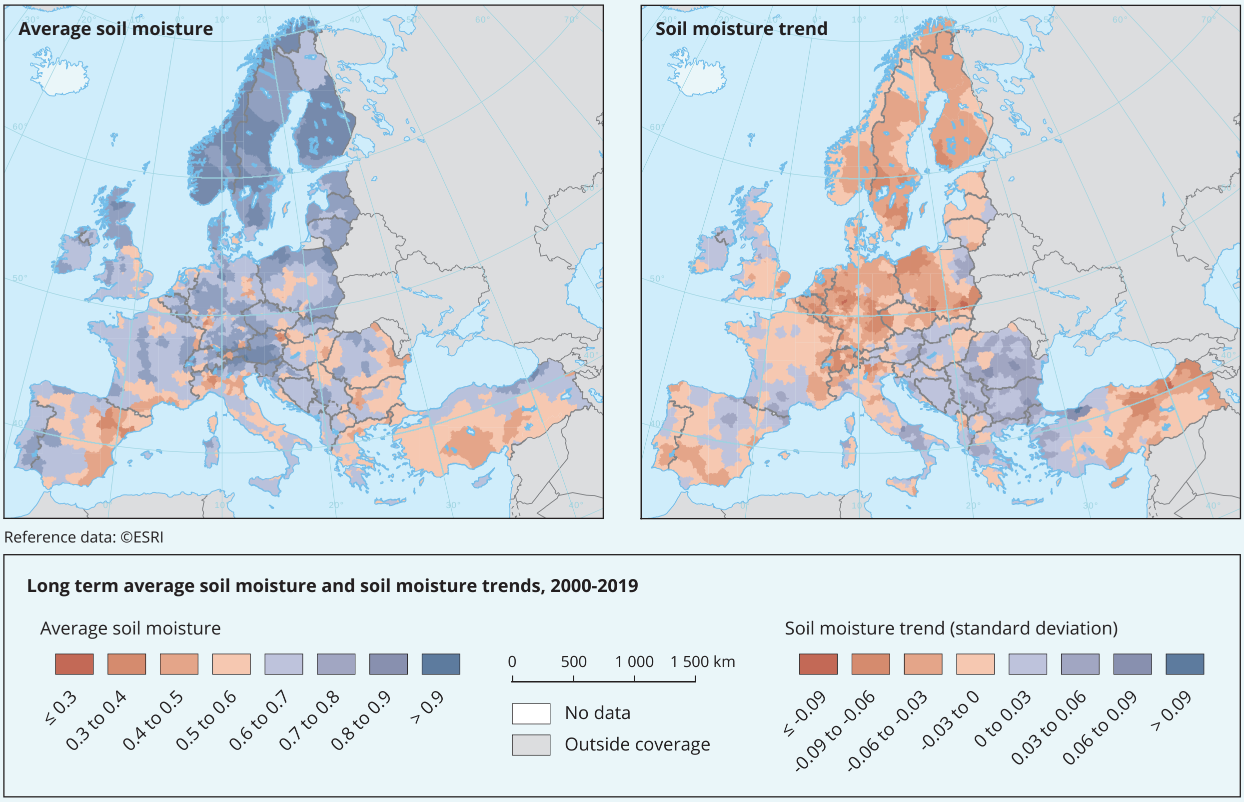
Box 3.5 Short-term changes in soil moisture deficit 2000-2019

Soil moisture is essential for the development of plants: it regulates groundwater levels, soil structure, soil temperature, salinity and the presence of toxic substances, it contributes to preventing soil erosion and it affects crop production and the need for irrigation. Soil moisture content also affects the carbon and nitrogen cycles and drives physical and microbial processes.

The EEA has developed an indicator of growing season soil moisture content for the EEA-39 and the years 2000-2019. During this period, the growing season soil moisture content in the EEA-39 countries was on average low in many European countries, and over this 20-year period it also exhibited a strong negative trend. Apart from 2003, the highest soil moisture deficits have occurred in the last 9 years, indicating an increase in the frequency of drought. Furthermore, the area affected by growing season soil moisture deficits has increased.

Although the Mediterranean experienced frequent and intense drought events, it is the continental and Fennoscandinavian regions of Europe that experienced the largest changes in soil moisture deficit, and in these areas the declines are greater. In eastern Europe, soil moisture appears to be increasing.

Map 3.6 Long term average soil moisture per NUTS 3 region (left). Soil moisture trends per NUTS 3 region (right)



Reference data: ©ESRI

Source: EEA (2020c).

Southern Europe

In Mediterranean regions, the average summer temperatures have already increased by 2.3 °C and precipitation is predicted to decrease. For the most extreme temperature scenario used in the Peseta IV study (3 °C increase by 2050), summer precipitation is projected to decrease by 30 %. As a consequence, the availability of water resources would drop by up to 40 % in southern regions of Europe and droughts would happen more frequently in most of southern and western Europe. As a consequence, the duration and intensity of water scarcity will grow in already existing water-scarce areas (Feyen et al., 2020).

In addition to the gradual change, precipitation extremes are expected to become larger and less predictable (EEA, 2019h; Feyen et al., 2020). In combination, these conditions will lead to lowering maize potential yield by 11 %, and wheat potential yield by 12 %, with crop losses up to 80 % in some southern European countries (Portugal, Bulgaria, Greece and Spain) (Feyen et al., 2020).

A dryer climate is likely to increase demand for irrigation. Currently, rainfed crops will change to needing more water for irrigation, and irrigation will be needed for a longer part of the growing season (EEA, 2019a; Feyen et al., 2020). Droughts can also compromise plant growth and uptake of nutrients from fertilisers. These nutrients will then ultimately end up in the environment — and mainly in waters. The combined effects of a longer growing season and an increased demand for water will have several knock-on effects on pressures on the aquatic environment, which are summarised in Table 3.2.

In southern Europe, and in the shorter term, the potential increase in demand for irrigation water will, if no other adjustments are made, lead to increased demand for and abstraction of water. This will reduce recharge rates and lower surface and groundwater levels. In the context of the WFD objectives, this may result in a failure to achieve good groundwater quantitative status in more water bodies. The increased abstraction levels increase the risk of saline intrusions into groundwater, thereby increasing the risk of failure to achieve good groundwater chemical status. It may also increase water storage demands, potentially increasing hydromorphological pressures.

The longer growing season is likely to increase nutrient demands, which will increase the risks of polluting the aquatic environment. Similarly, the higher temperatures may lead to new or increased levels of pests, demanding more pesticides (Lavalle et al., 2009; Feyen et al., 2020). Hydromorphology and nutrient pollution can both affect the ecological status of surface water, whereas increased pesticide use could alter the chemical status of either surface waters or groundwaters. Nutrient pollution can also reduce groundwater chemical status.

Most processes responsible for soil degradation, including soil organic matter mineralisation and erosion, are enhanced by higher temperatures and more intense precipitation (Balkovič et al., 2018). Furthermore, as stated above, this might increase water pollution, leading to a failure to achieve good ecological status or reducing status further.

In the longer term, towards 2050, the combined effects of agricultural water demands and water supply are expected to be large. In southern Europe, irrigation needs are expected to increase and may reach a level that requires changing to species of crop more tolerant of the new conditions, or it may render agricultural production unprofitable altogether. At the same time, the conditions for profitable growth of certain crops may migrate out of their current zones (EEA, 2019a; Feyen et al., 2020). Overall, it is important to note that the conflicts over the use of water in the agricultural sector and between agriculture and other sectors are expected to grow, increasing the challenge of managing water scarcity.

Northern Europe

In northern Europe, climate change has increased average temperatures, and precipitation is expected to increase. In the short term, the increased precipitation would lead to more water resources being available. Especially in summer, water availability would also drop in western parts of Europe and at higher latitudes. As a result, new areas that face periods of water scarcity will emerge in countries such as Belgium, Bulgaria, Denmark, France, Germany, the Netherlands, Romania, and the United Kingdom.

The increased precipitation will also lead to increased flooding of both agricultural land and populated areas. The increased flood risk will lead to increased demand for structural flood control measures, increased conveyance of rivers and further drainage of agricultural land, all with the potential to increase hydromorphological pressures (Abdelbaki, 2015; Feyen et al., 2020). Furthermore, the Peseta IV study suggests that increased precipitation may lead to increased

Table 3.2 **Southern Europe: a summary of the links between climate change, impacts on agriculture, pressures and impacts on the environment and WFD objectives if no adaptation takes place**

Variable	Climate impact	Impact on agricultural inputs	Pressure	Environmental impact linked to risk of not meeting WFD objectives	WFD status and quality elements (QEs) affected
Water quantity	Reduced precipitation overall and particularly in summer Increased temperatures More frequent droughts in summer	Increased water scarcity Increased demand for water for irrigation	Reservoir, aquifer and groundwater recharge rates are reduced and overabstraction may take place Potential increase in illegal abstractions	Reduction in surface and groundwater levels with negative impacts on aquatic ecosystems Saline intrusion in groundwater aquifers Deterioration of water-dependent ecosystems and non-compliance with the requirements of the WFD	Groundwater quantitative status Groundwater chemical status due to saline intrusion Surface water status due to increased frequency and duration of low-flow conditions
Hydromorphology	Reduced precipitation overall, particularly in summer	Increased demand for water	Increased demand for water storage	Reduced hydromorphological quality and depletion of water-dependent ecosystems	Ecological status through hydromorphological and biological QEs
Nutrients	Increased temperatures Increased precipitation Increased drought frequency	Increased demand for fertiliser Increased demand for water to make nutrients available for plants	Higher fertilisation rates Reduced water quality	Increased nutrient pollution in water, with negative impacts on aquatic ecosystems	Ecological status through physico-chemical and biological QEs GWB chemical status
Pesticides	Increased temperatures	Increase in spraying of pesticides to combat pests and diseases	Increased spread of pests and diseases. (Impacts on both crops and livestock)	Increased chemical pollution with negative impacts on aquatic ecosystems	Ecological status through biological QEs SWB chemical status GWB chemical status

Note: GWB, groundwater body; SWB, surface water body.

Source: Climate impacts based on Feyen et al. (2020).

fertiliser and pesticide pollution, due to greater run-off, and reduced capacity to grow winter crops designed to secure continued nutrient uptake and reduce erosion over winter. This could decrease ecological and chemical status (Lavalle et al., 2009). The relationship between pressures, climate change impacts, environmental impacts and the WFD objectives is summarised in Table 3.3.

In the longer term (towards 2050), agricultural production may be favoured in northern Europe, but, unless production methods change, this would be associated with a further increase in environmental pressures linked to nutrients and pesticides. As an example of changes in agricultural yields, wheat production could increase by 5 %, whereas the more water-sensitive maize production could decrease by 5 %, without irrigation (Feyen et al., 2020). There is also a question over whether further expansion of the agricultural area is possible. Land take of agricultural land (converting agricultural land into urban fabric) is a significant process in northern Europe.

3.4.2 Socio economic impacts of climate change on European agriculture

Agricultural income in Europe is expected to be affected by climate change. The large changes anticipated will not only affect the environment but also generate a cascade of socio-economic impacts with effects on the price, quantity and quality of products and consequently on trade patterns.

Several climatic events have affected crop harvests and livestock feed supplies in recent years. The drought resulting from the heatwave in 2018 resulted in significant losses in the agricultural sector in many countries. For instance, the economic impact of the drought on agriculture was estimated to be in the range of between EUR 375 million and EUR 1.9 billion in the Netherlands and between EUR 1.5 billion and EUR 2 billion in France (Dantec and Roux, 2019). The crisis led to EU and national support for farmers, including derogations on meeting crop diversification and ecological focus area rules on land lying fallow in order to produce feed for livestock.

The actual costs associated with agricultural production may also increase. For example, farmers might be adversely affected if a drought or flood damages their crops. They may spend more on increasing irrigation costs, drilling new wells or feeding and providing water for their animals. Industries linked to farming activities, such as companies that make tractors and food, may lose business when drought damages crops or livestock (Cammalleri et al., 2020).

Agricultural intensification could take place in northern and western Europe, while in southern Europe and especially in the Mediterranean a reduction in the relative profitability of agriculture could result in agricultural extensification and land abandonment (EEA, 2019a). As water scarcity increases in southern Europe, conflicts between water uses may arise. The water supply for human consumption will have the highest priority, which may not allow enough water for irrigation (Godot, 2013) or environmental minimum flows to be secured. In such cases, a balance between environmental, social and economic goals needs to be found (GWP, 2019).

At the global level, climate change affects agricultural production in all parts of the world and, therefore, food supply and global markets, although specific impacts are subject to uncertainty (Wallach et al., 2015; Porfirio et al., 2018). While there are high levels of uncertainty over how global markets will develop, there is a common understanding that production patterns will change, which will also have impacts on EU production (FAO, 2018b). EU production could still slightly increase because of the interplay of different market forces. This is because the negative effects in Europe are projected to be lower than those other world regions. This provides the EU with a comparative advantage in terms of climate change impacts on agricultural productivity, which could positively affect its competitiveness (Feyen et al., 2020).

The agricultural sector in Europe will need to significantly adapt to these changes to secure sustainable agricultural production but also to limit environmental pollution. Farm-level adaptation can reduce losses caused by extreme events, but knowledge of all the impacts of climate change on agriculture is still limited, especially when impacts are multiplied or combined with other socio-economic consequences of climate change (EEA, 2019a).
In Chapter 4 we point to some of the long-term sustainable solutions that could be considered to improve resilience to climate change.

Table 3.3 **Northern Europe: a summary of the links between climate change, impacts on agriculture and impacts on the environment and WFD objectives if no adaptation takes place**

Variable	Climate impact	Impact on agricultural inputs	Pressure	Environmental impact	WFD status and quality elements (QEs) affected
Water quantity	Increased precipitation Increased flood risk Less water available in summer Less frequent droughts Increased temperatures	Increased water scarcity in summer Increased demand for water for irrigation	Hydromorphological pressures from flood protection and drainage	Increased erosion	Flood mitigation measures could affect ecological status through hydromorphological and ecological QEs
Hydromorphology	Increased flood risk	Land conversion to intensive agriculture	Increased area under agricultural production	Mitigation measures linked to flood defence and increased drainage	Ecological status through hydromorphological QE and biological QE
Nutrients	Increased temperatures and precipitation	Due to longer growing season more fertiliser might be needed	Increased leaching of excess nutrients	Increased nutrient pollution	Ecological status through physico-chemical QE and biological QE GWB chemical status
Pesticides	Increased temperatures and precipitation	Due to new pests/invasive species more or other pesticides could be needed	Increased flushing of soils	Increased pesticide pollution	Ecological status through physico-chemical QE and biological QE SWB chemical status GWB chemical status

Note: GWB, groundwater body; SWB, surface water body.

Source: Climate impacts based on Feyen et al. (2020).

Photo: © Patrick Zhang from Pixaba, Flickr

4 Sustainable solutions

Key messages

- A wide variety of management measures exists to tackle agricultural pressures on the water environment, and new ones are being developed through research and innovation. Key design principles include increased resource use efficiency, increased circularity (e.g. nutrient recycling) and increased diversity in agroecosystems.
- The EU has a comprehensive environmental policy framework, developed over decades, that has contributed to tackling agricultural pressures on the water environment. In the future, a more integrated approach to tackling pollution of water, soils and air is needed to ensure more efficient and cost-efficient actions in line with the European Green Deal and its zero pollution ambition.
- Reducing agricultural pressures to improve water quality, water quantity and hydromorphological conditions will be dependent on the more widespread uptake of sustainable soil, crop and livestock management practices. Implementing landscape approaches and nature-based solutions on agricultural land will also play an important role in restoring a more natural catchment hydrology.
- The upcoming common agricultural policy (CAP) strategic plans 2021-2027 have a central role in facilitating the transition towards sustainable agriculture. They will need to be more ambitious than previous programming periods on the environmental obligations associated with CAP payments and on the financing of measures beneficial for the water environment.
- With their targets on organic farming, high-biodiversity landscape features, and reducing nutrient losses and pesticide use, the farm-to-fork and biodiversity strategies provide renewed impetus to reduce agricultural pressures on the water environment. The implementation of these strategies needs to be supported by additional regulatory action, financial resources and mobilisation of stakeholders.

4.1 Introduction

Pressures from agriculture on the water environment contribute to a range of impacts on surface water and groundwater bodies, such as pollution and poor water quality, alteration of water flow regimes and modifications to channel morphology. These challenges must be urgently addressed in order to sustain ecosystems and livelihoods and to build resilience against the impacts of climate change.

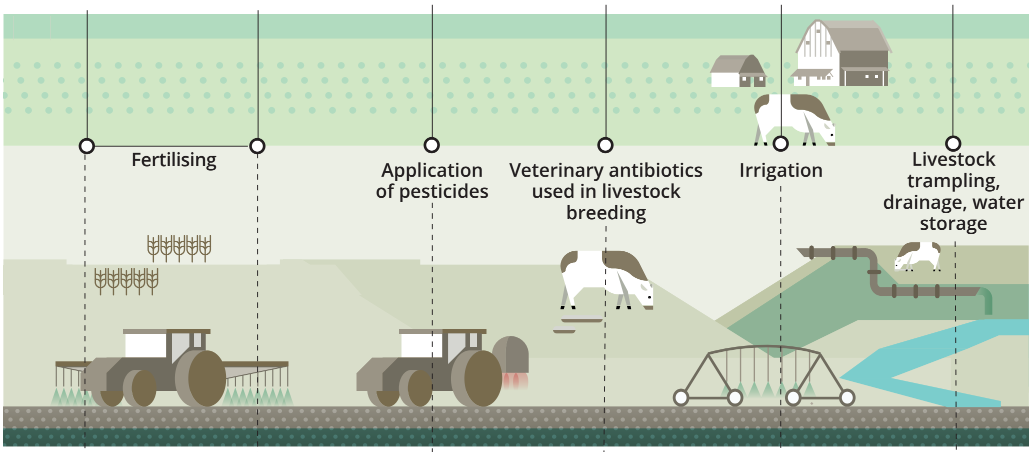
The breadth and variety of management measures, strategies and policies to respond to current agricultural pressures are wide in Europe and increase with ongoing research and innovations (Figure 4.1). However, the measures implemented so far have not been sufficient to tackle agricultural pressures contributing to the failure to achieve good ecological status (EEA, 2018c; EC, 2019). Reducing agricultural pressures and improving the condition of the European water environment will require further efforts and uptake of sustainable solutions.

European policies have a key role in enabling the transition towards sustainability. While the framework of environmental targets and policy instruments at European level is well developed, better implementation of environmental policies and greater coherence of sectoral policies, such as agriculture, food and energy policies, with environmental requirements are needed.

The European Green Deal provides an opportunity to improve the implementation of existing environmental legislation, raise ambitions for the future environmental performance of agriculture and support more systemic change towards sustainable consumption patterns. The farm-to-fork strategy and biodiversity strategy need

Figure 4.1 **Agricultural pressures on the water environment and responses to pressures in Europe**

Pressures	Nitrogen surplus	Phosphorous surplus	Pesticide	Veterinary medicines	Water use	Hydro-morphological pressures
Extent of current agricultural pressure	49 kg N surplus/ha of agricultural land	1.2 kg P surplus/ha of agricultural land	335 870 t active substance	72.6 t active ingredient	50 km^3 of water abstracted by agriculture	34 % of SWB affected
Main sources and activities	Fertilising		Application of pesticides	Veterinary antibiotics used in livestock breeding	Irrigation	Livestock trampling, drainage, water storage



Measures

	Nitrogen surplus	Phosphorous surplus	Pesticide	Veterinary medicines	Water use	Hydro-morphological pressures
Efficient nutrient use	○	○				
Pest and disease management			○	○		
Water use efficiency					○	○
Soil management	○	○	○		○	○
Crop management	○	○	○		○	○
Livestock management	○	○	○	○	○	○
Landscape approaches	○	○	○	○		○

Selected policies

	Nitrogen surplus	Phosphorous surplus	Pesticide	Veterinary medicines	Water use	Hydro-morphological pressures
Water Framework Directive	●	●	●	●	●	●
Nitrates Directive	●					
Floods Directive						●
Drinking Water Directive	●		●			
Marine Strategy Directive	●	●	●	●		
Water Scarcity and Drought					●	
Sewage Sludge Directive	●	●				
Regulation for Water Reuse					●	
Regulation of Fertilising Products	●	●				
Circular economy action plan	●	●			●	
A Resource Efficient Europe	●	●			●	
Common Agricultural Policy	●	●	●	●	●	●
Plant Protection Products			●			
Sustainable Use of Pesticides			●			
Organic Production Regulation	●	●	●	●		
Farm-to-fork strategy	●	●	●	●	●	
Biodiversity strategy for 2030	●	●	●	●	●	●
A zero pollution action plan	●	●	●			
Sustainable Development Goal 2	●	●	●	●	●	
Sustainable Development Goal 6	●	●	●	●	●	●

● Environmental policies ● Circular economy ● Agricultural policies ● European Green Deal ● Global policies

Note: See Table 1.3 for overview of policies.

Source: EEA.

to be translated into existing and new implementing instruments, in particular the future common agricultural policy (CAP) strategic plans 2021-2027. They will require significant financial and technical resources to induce the necessary behavioural changes.

This chapter presents an overview of measures that can be taken to manage agricultural pressures on the water environment, and it provides an overview of the present and upcoming changes to the European environmental and agricultural policy framework. The need for structural reforms of agricultural value chains to support the uptake of sustainable agriculture, including within the food and energy systems, are discussed in Chapter 5.

4.2 Measures to reduce agricultural pressures on water

4.2.1 A consolidated list of farm- and landscape-level measures

Table 4.1 presents a consolidated list of measures that can be used at farm and landscape level to reduce agricultural pressures on the water environment. It focuses on measures that are commonly considered more sustainable (Section 2.2.1). Guiding principles include the need to increase resource use efficiency, increase circularity (e.g. nutrient recycling) and build diversity and resilience in agroecosystems by exploiting ecosystem dynamics and synergies (FAO, 2018a).

Three groups of measures contributing, individually or in combination, to reducing pressures on the water environment, can be distinguished.

Resource use efficiency

One group aims to enhance the efficiency of resource use in agriculture to reduce the emissions of nutrient and chemical pollutants and reduce abstraction pressure, while preserving agricultural productivity. More efficient resource use is an essential first step in decoupling production from resource use and can also have broader environmental benefits such as benefits for air and soil quality and reduced greenhouse gas emissions.

Precision farming has a major role in arable production and grassland systems to support more balanced nutrient management, optimal application of plant protection products and improved piloting of irrigation applications (Box 4.1). In livestock systems, there is scope to improve manure storage and application, for instance by slurry injection, to avoid ammonia emissions and improve the assimilation of nutrients in soils. Improved feeding through more balanced nitrogen and phosphorous levels in livestock diets can also decrease total nitrogen and phosphorous emissions in manure (Klootwijk et al., 2016).

It is important to highlight that efficiency gains do not always translate into cost savings or reduced use of inputs. Precision farming, for instance, can reduce the need for input such as synthetic fertiliser, manure, plant protection products or irrigation water, but it entails investment and operational costs that can be prohibitive for small farms. In addition, resources saved through efficiency gains may be redirected to other uses, offsetting savings and, in some cases, resulting in higher net resource consumption. This is known as the rebound effect or the Jevons paradox.

There is substantial evidence of rebound effects in agriculture, in particular following investments in efficiency improvements in irrigation infrastructure (Ward and Pulido-Velazquez, 2008; Dumont et al., 2013; Gómez and Pérez-Blanco, 2014; Berbel et al., 2015). Saved water may, for instance, be used for more water-intensive crops or to expand the area of irrigated land. The rebound effect may also be led by changes in consumer behaviour, resulting in higher demand and use of resources (Paul et al., 2019). Although less well-documented, the rebound effect may also exist for other resources consumed by agriculture, such as nutrients, pesticides or energy (Paul et al., 2019).

Key tools to mitigate the impact of the rebound effect in the use of irrigation water include adopting adequate accounting procedures for resource flows and putting clear limits on abstraction levels at hydrologically relevant spatial scales.

Table 4.1 **Consolidated list of measures that can contribute to reducing agricultural pressures on the water environment**

Group of measure measures		Technical measures	Benefits for water			Other multiple benefits on			
			Water quality	Water quantity	Hydro-morphology	Biodiversity	Soils	Greenhouse gases	Air quality
Resource use efficiency	Efficient nutrient use	Improved organic and inorganic fertilisation (e.g. control fertiliser use according to risk areas, and climatic, soil and plant conditions)	x			x	x	x	x
		Manure management (e.g. improved storage capacity, air scrubbing for housing, rapid uptake into the soil)	x			x	x	x	x
		Improved inorganic fertiliser (e.g. reducing P content)	x			x	x		
		Improved feed (e.g. reducing content of N and P in dairy nutrition)	x			x	x	x	x
	Pest and disease management	Improved handling of equipment, scheduling and frequency	x			x	x		x
		Mechanical control (e.g. hand-picking, housing, hygiene measures, quarantine)	x			x	x		
		Biological controls (e.g. predators of pests, more resistant breeds/varieties)	x			x	x		
	Water use efficiency	Water-efficient equipment and irrigation scheduling		x			x	x	
		Improved infrastructure (e.g. lining of canals, repair leaking pipes)		x					
Soil, crop and livestock management	Soil management	Appropriate machinery and field operations to reduce soil compaction	x	x	x	x	x		
		Mulching and crop residues	x	x	x	x	x	x	
		Reduced tillage or no till	x	x	x	x	x	x	x
		Contour farming, terraces and strip cropping	x	x	x	x	x	x	
	Crop management	Managing crop water demand (e.g. crop selection, drought-resistant varieties, timing of sowing and harvesting, deficit irrigation)		x					
		Improved crop rotation (e.g. diversification, intercropping, catch, cover and N-fixing crops)	x	x	x	x	x	x	x
		Conversion of arable land into fallow or permanent grassland	x	x	x	x	x	x	x
		Silvo-arable agroforestry	x	x	x	x	x	x	x
	Livestock management	Reduced stocking density	x	x	x	x	x	x	x
		Livestock fencing			x	x			
		Grassland management (e.g. choice of grass varieties, grazing patterns)	x	x		x	x		
		Silvo-pastoral agroforestry	x	x	x	x	x	x	x

Table 4.1 **Consolidated list of measures that can contribute to reducing agricultural pressures on the water environment (cont.)**

Group of measure measures	Technical measures	Benefits for water			Other multiple benefits on			
		Water quality	Water quantity	Hydro-morphology	Biodiversity	Soils	Greenhouse gases	Air quality
Landscape approaches	Buffer strips, field margins and riparian vegetation	x	x	x	x	x	x	x
	Hedgerows and wooded strips	x	x	x	x	x	x	x
	Constructed wetlands, ponds and sediment traps	x	x	x	x			
	Improved drainage management (e.g. reduced drainage in low-lying areas and peatlands)	x	x	x	x	x	x	
	River and floodplain restoration (e.g. reduced dredging, re-meandering)	x	x	x	x	x	x	

Improved soil, crop and livestock management

A second group of measures involves improving the management of soils, crops and livestock to enhance biological synergies and natural biogeochemical cycles, primarily to enhance soil functions, improve nutrient cycling at the field, farm and regional levels, control the spread of pests and diseases, and increase rainfall infiltration and soil water retention. Measures are drawn from techniques and strategies that are common in organic farming and agroecological farming (Section 2.2.1).

Adopting organic production and agroecology in farming systems can have a wide range of benefits for water management. For instance, the use of animal manure and nitrogen-fixing crops and the enhancement of soil structure — as promoted in agroecology — can reduce the consumption of synthetic fertilisers, especially in specialised arable systems, which would in turn reduce the risk of nitrates leaching into surface water and groundwater bodies. Integrated pest management — which would reduce the use of synthetic plant protection products — promotes diversification of plant, grassland and animal species at the farm and regional levels to reduce the risks of pest and disease transmission and vulnerabilities arising from monocultural practices and farm specialisation (Box 4.2).

Sustainable soil management can enhance soil fertility, reduce dependence on inorganic fertilisers, and enhance soil water retention and reduce vulnerability against dry spells and droughts, as well as contributing to reducing the risk of flooding. Avoiding soil compaction and minimising soil disturbances are relevant strategies, for instance through practising zero or conservation (minimum) tillage. Reducing the use of tillage can reduce soil erosion risks and loss of nitrogen and phosphorus as well as reduce fuel consumption, but it can also increase the use of herbicides, as mechanical weed control associated with ploughing is no longer possible. Conventional tillage is a more widespread practice in the EU-28, applied on two thirds of the total arable area, while conservation tillage is practised on 20 % and no till on 4 % (ESTAT, 2020g). Some countries experience increases in conservation tillage (e.g. Portugal), while others report an increase in conventional tillage (e.g. Germany, France, Poland).

Other sustainable soil and crop management techniques include soil cover through cover crops (to reduce soil erosion), green manure crops (to enhance soil organic matter and fertility) and catch crops (to retrieve residual nutrients after a commercial crop). However, trade-offs are possible, for instance when a cover crop increases water use and reduces groundwater recharge (OECD, 2014).

There are wider environmental benefits for biodiversity and habitat protection, air quality and climate mitigation (Murrell, 2017; EEA, 2019a; Smith et al., 2019), as well as positive economic and social outcomes. For instance, the diversification of revenue streams, thanks to more diverse crop and livestock production, can reduce the vulnerabilities of farms and rural economies to climate and economic shocks.

Box 4.1 Precision agriculture

Precision agriculture (PA) or precision farming is a management approach based on observations of temporal and spatial variations in crops, fields or animals. PA aims to optimise agricultural output using less inputs of labour, fuel, agrochemicals, antibiotics or feed.

Agricultural inputs, such as fertilisers, pesticides, water, feed and veterinary medicine, are optimised to the real-time needs of plants and animals, as are agricultural practices such as tillage, sowing and harvesting. Technologies including remote sensing systems, new sensors, drones and robots are used to optimize inputs of fertilisers, pesticides or water. Observations on soil type, soil moisture, nutrient availability and plant health are used to provide precise location-specific input recommendations to the farmer.

PA has the potential to reduce the environmental impact on soil and surface water contamination. With regard to protecting water bodies and reducing water consumption, PA technologies can contribute as follows:

- Automatic machine guidance and individual section control of sprayers and fertiliser applicators can help to keep fertilisers and pesticides at the recommended distances from waterways.
- Automatic steering systems reduce field traffic and thus have the potential to reduce soil compaction, soil erosion and the run-off of surface water, sediments and fertilisers.
- Sensors, remote sensing data and geo-mapping can be used to evaluate soil and crop health and adapt input and farming practices to local conditions. Therefore, these techniques reduce the inputs of fertilisers and pesticides, prevent compaction and erosion and thus reduce the risk of water pollution and sedimentation.
- Robots can help to optimise inputs (fertilisers, pesticides, insecticides) and reduce the impact on soils and water tables. In addition, robots are flexible and able to intervene only where they are needed. This minimises soil compaction by heavy machines.

With precision irrigation, an exact amount of water can be applied to plants at precise times to optimise crop yield and water productivity. As a result, this technique leads to a reduction in water use. Water metering and measuring water use can be considered the basis for precision irrigation. PA can increase farmers' profitability due to increased yields with lower inputs and labour force requirements and furthermore provide farmers with information on the status of crops and animals to improve yield forecasts.

Some disadvantages from the further expansion of PA, especially for small farmers, are expected. Compared with large farms, they often lack the investment capital or the knowledge to acquire PA technologies. This can lead to increased competitive pressures on small farms. Furthermore, the number of jobs on farms is expected to decrease if human labour is increasingly replaced by robots and computers. In some rural areas, applying PA technologies is still hampered by the lack of a suitable IT infrastructure.

Apart from these negative impacts, PA has the potential to contribute to the sustainability of the agri-food sector under a growing demand for agricultural products and to actively contribute to food security and food safety. Monitoring of crops and livestock will allow better predictions of agricultural product quality, making the food chain easier to monitor for producers, retailers and customers. Furthermore, the digitalisation of agriculture makes the environmental impacts more measurable and verifiable and supports true cost accounting.

Source: EIP-AGRI (2015).

Box 4.2 Integrated pest management

Integrated pest management (IPM) encourages improved crop and livestock management to reduce the use of chemical methods against pests and diseases.

In cropping systems, it promotes crop diversification through spatial diversity (e.g. intercropping) and temporal diversity (e.g. longer crop rotations) to break pest and disease cycles. Improved tillage practices and avoiding soil compaction can reduce erosion and support healthy soils, increasing chemical breakdown of pollutants before leaching and run-off into surface water and groundwater bodies.

Preserving and supporting important beneficial organisms that fight pests and diseases, without damaging crops or livestock, are encouraged, as is the development of more resistant seed and crop varieties and animal breeds. In livestock systems, appropriate hygiene and housing can reduce risks, as well as lower livestock densities.

Crop and livestock management should be complemented by efficient monitoring of pest and disease development. In the event of a pest or disease outbreak, biological and physical methods should first be used, and, when necessary, suitable chemical methods may be adopted to protect crops and livestock.

Source: Meissle et al. (2009); Lamichane et al. (2015); FAO (2018a).

Implementing organic farming or agroecological practices in conventional arable and livestock systems can be associated with immediate reductions in grassland or crop yields, mainly due to the phasing out of, or reduced used of, mineral fertilisers (De Ponti et al., 2012; Seufert et al., 2012), plant protection products (Popp et al., 2013) or irrigation water. In Europe, estimates put observed organic farming yields at between 70 % (northern Europe) and 81 % (southern Europe) of conventional farming yields (De Ponti et al., 2012). Yield shortfalls differ considerably between regions, soils and crops. They can be can be as low as 1 % for oilseed crops and 5 % for legumes (Wilbois and Schmidt, 2019). The shortfalls are larger for crops such as olives, potatoes and cereals (Ponisio et al., 2015) and for countries that rely on high levels of external inputs, such as the Netherlands and Denmark (De Ponti et al., 2012).

Over time, the yield shortfall may nevertheless decrease because of improvements in soil fertility (Schrama et al., 2018). Furthermore, the loss of income due to the reduction in yields may be compensated for by lower input costs (e.g. fuel, nutrients, pesticides, irrigation), more stable yields and higher prices, together with higher employment levels in the rural economy (Seufert and Ramankutty, 2017).

Implementing improved soil, crop and livestock management must take account of local conditions in soils, climate, slope and other physical, technological, social or economic factors influencing farm management and field operations. It is important to note that a large-scale transition to organic farming and agroecology may reduce total consumption of fertiliser, pesticides and irrigation water and be beneficial for the water environment. However, it would also reduce total crop and livestock production in Europe. Unless consumption patterns change, in particular diets and meat consumption, such structural changes in agricultural production could push food prices up and increase the need to farm marginal land or import food. These issues are discussed further in Chapter 5.

Landscape approaches

A third group relates to broader landscape approaches contributing to restoring a more natural catchment hydrology across the rural terrestrial landscape and within water bodies, so as to increase nutrient recycling, pollutant breakdown and water storage. It regroups several measures commonly referred to as natural water retention measures (Box 4.3), nature-based solutions (Trémolet et al., 2019) and green and blue infrastructures (EC, 2020h). These measures typically have multiple environmental benefits, for biodiversity protection, flood risk reduction, and climate mitigation and adaptation.

Buffer strips and hedgerows can work as barriers to overland run-off from agricultural land and can contribute to reducing nutrients leaching into surface water. Wetland and floodplain restoration can improve nutrient recycling and water quality downstream of agricultural areas. By restoring surface-groundwater exchange flows, water and floodplain restoration can also enhance local groundwater recharge and water storage. This can be valuable in irrigated regions relying on groundwater or groundwater-fed surface water bodies.

Landscape approaches also include measures to reduce the impacts of agricultural drainage on

Box 4.3 Natural water retention measures and agriculture

Natural water retention measures (NWRMs) are multifunctional measures that aim to protect and manage water resources using natural means and processes, for example by restoring ecosystems and changing land use. Their main focus is to enhance and preserve the water retention capacity of aquifers, soil and ecosystems with a view to improving their status. The European platform on NWRMs (NWRM, 2015) offers an overview of these solutions, including technical specifications and case studies on their application across Europe.

A wide diversity of measures are classified as NWRMs. In areas affected by agriculture, they may include on-farm measures (e.g. buffer strips, soil conservation practices such as crop rotation, intercropping, conservation tillage, incorporation of crop residues) and landscape-wide measures (e.g. floodplain and wetland restoration).

NWRMs have the potential to provide multiple benefits, including reduced greenhouse gas emissions, habitat improvement, flood risk reduction, water quality improvement, groundwater recharge and drought management. For example, riparian buffer zones in agricultural areas primarily aim to reduce nutrient losses and/or increase biodiversity, but they may also reduce peak flooding. However, as the area covered by NWRMs is currently generally small with respect to managed (agricultural or forest) land area, their individual impact on downstream flooding is usually relatively minor.

Overall, NWRMs are still far from being applied in all cases in which they would be an option or the best option and there is a need for a change in thinking to ensure that NWRMs are duly considered in planning processes. More knowledge is required to support the optimisation of NWRMs and their combination with other measures, to quantify their impacts on a large scale and to estimate all of their benefits. Such knowledge may be achieved by improving farm advice in terms of adaptation/resilience to climate change impacts such as floods.

The effectiveness of NWRMs for different objectives, including reducing flood risks and hydromorphological pressures from agricultural use, could be enhanced if they were implemented at a larger scale. If many farms adopt this type of measures, such as riparian buffers or soil conservation practices, at the same time in the same catchment, the effect could be larger compared with that of single applications of measures on a few farms.

Sources: NWRM (2015); Collentine and Futter (2018); EEA (2019c).

water quality and hydromorphological conditions in surface water bodies (see Section 3.3). Appropriate water table management can reduce the impacts of agricultural drainage on the water environment while maintaining yields. Sediment traps or constructed wetlands can be installed at the outlets of agricultural drainage ditches to reduce pollution from drainage outflows (Vartia et al., 2018).

Blocking drainage ditches and rewetting drained agricultural land can be beneficial in reducing pollution risks from drain discharges and in reducing sediment loads. It also can have other benefits for flood risk reduction, soil conservation and reducing carbon emissions from agriculture, in particular on peatland and other carbon-rich soils (Greifswald Mire Centre et al., 2020). However, rewetting of peatland can reduce crop and grassland productivity. Rewetting agricultural peatland would require significant changes in farming operations and possibly in the types of crops and livestock raised on the affected farms. For instance, reed and peat mosses, instead of grassland and livestock, would be more suitable for higher water levels (Greifswald Mire Centre et al., 2020). This would require developing new value chains to support such transitions at farm level (see Chapter 5).

Photo: © Ina Krüger

4.2.2 Facilitating the transition towards sustainability in agriculture: key factors and policy considerations

Transitioning towards more resource-efficient and lower intensity agriculture by adopting organic production and agroecology often requires fundamental changes in farm operations as well as in the types of crops and animals raised (species and varieties) (Ponisio et al., 2015). Such transformation is costly and time consuming for the farmer. It also runs against dominant production models. Radically altering production systems in sectors such as agriculture disrupts established investments, jobs, consumption patterns and behaviours, knowledge and values, inevitably provoking resistance to change (EEA, 2019h).

Careful planning at farm level is needed, taking into account the local environmental, economic and social contexts (Giller et al., 2015). Public policy has a major role in facilitating this transition, and setting an enabling institutional environment with sufficient support and incentives to enhance farmers' willingness and ability to change farm operations. Authorities need a good understanding of what drives particular ways of farming, and should design policy interventions accordingly.

Farmers' decisions are shaped by a complex array of biophysical, economic, technical, social, political and institutional factors (Dwyer et al., 2007; Blackstock et al., 2010; Mills et al., 2017). Figure 4.2 provides a schematic overview of factors influencing farmers' decision-making, as commonly reported in the research literature. These system elements, and their evolution, create both opportunities for and barriers to changing practices towards more sustainable solutions.

Several factors influencing farmers' decision-making are related to their social environment, such as peer pressure, community values and local social norms. Interventions acting at group and community levels — for instance redefining what is collectively perceived as good or bad farming practices in relation to, for example, good-quality drinking and bathing waters — can have a role in changing willingness to adopt change at an individual level. This would require engaging farmers and other local stakeholders in more inclusive processes to build social capital and facilitate collective learning and action (Blackstock et al., 2010).

The experience of farm advisory bodies has shown that providing information is more effective in facilitating uptake of measures when it is part of a process that tailors scientific knowledge to the particular local farm conditions. Creating networks between farmers to share experience and spread innovations are essential tools (FAO, 2018a; EIP-AGRI, 2020).

Scaling up regulatory action and incentives will be needed to overcome economic and political barriers. Theoretically, there is a wide range of relevant instruments to influence the uptake of more sustainable agricultural production. The remainder of this chapter presents those set out in environmental and agricultural policies at EU level.

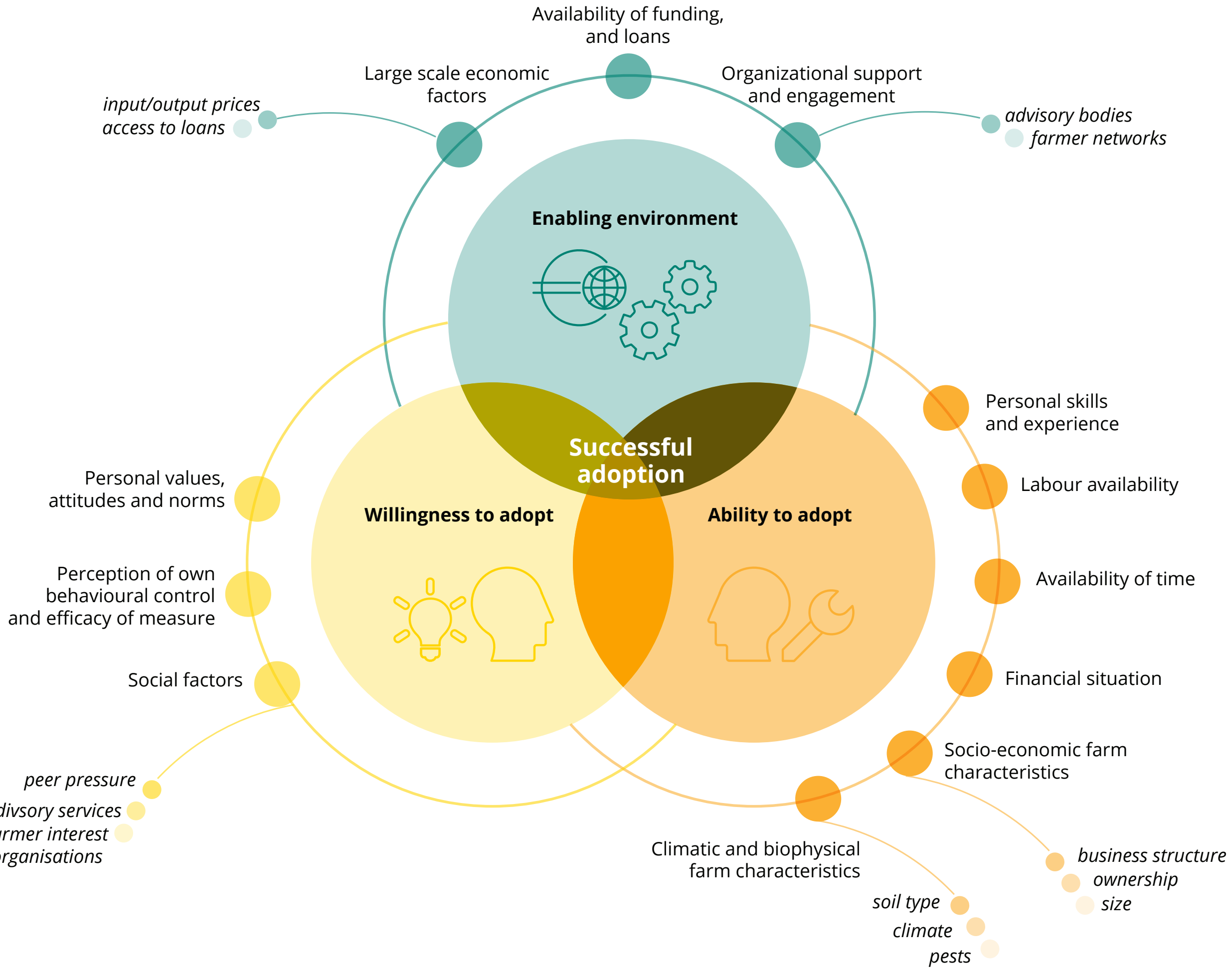
4.3 Implementation of environmental policies

The EU has adopted several pieces of environmental legislation and regulations that require agricultural pressures on the water environment to be tackled in order to achieve their objectives (Chapter 1; Table 4.2). Each piece of legislation has its own intervention logic and instruments, which together form a complex but comprehensive policy framework for tackling nutrient and chemical pollution, water abstraction and hydromorphological alterations arising from agriculture.

The Water Framework Directive (WFD) has been a key driver of defining and implementing measures tackling agricultural pressures. Under the WFD, river basin management plans (RBMPs) are the main instrument to support achieving good status in all of Europe's surface water and groundwater. RBMPs provide a comprehensive planning approach to identify agricultural pressures and present an integrated set of measures, optimising the use of existing mandatory measures required by other EU legislation and selecting supplementary measures to meet good status. Recent evaluations of RBMPs show that many measures have been adopted to tackle agricultural pressures from diffuse pollution, water abstraction and hydromorphological modifications (EC, 2019a).

The following sections focus on the implementation of existing EU environmental policies, including recent ones encompassed by the European Green Deal.

Figure 4.2 Factors influencing farmers decision-making



Source: Modified from Mills et al. (2017).

Table 4.2 Objectives, instruments and measures tackling agricultural pressures on water in European environmental policies

Policy and key target	Goals and targets relevant for water and agriculture	Instruments	Example of technical measures
Water Framework Directive	Good status in all water bodies by 2015	RBMPs	Manure management Application of pesticides and nutrients based on soil/plant conditions, buffer strips, crop rotation Sediment traps, improved drainage, river and floodplain management, etc.
		Controls on abstraction	Water metering
		Controls of discharges, emissions and losses of priority and priority hazardous substances into the aquatic environment	Quality standards on pesticides (see daughter directive on environmental quality standards)
		Incentive pricing and cost recovery	Charges on water abstraction
		Drinking water protected areas	Codes of practice for e.g. manure, nutrient and pesticide application, or fencing'
Nitrates Directive	Reduction and prevention of agricultural pollution with nitrates	Good agricultural practices	Minimum storage capacity for animal manure Crop rotations Winter soil cover Catch crops
		Nitrate vulnerable zones	Cap on fertiliser application Cap on use of livestock manures
Floods Directive	To reduce the adverse consequence of floods	Flood risk management plans	Natural water retention measures
Drinking Water Directive	Protection of drinking water from contamination	Quality standards on several substances	Codes of agricultural practice in WFD drinking water protected areas Denitrification
Sewage Sludge Directive	Enable the disposal of sewage sludge in a manner safe for humans and the environment	Threshold limits for sludge treatment and safe use	Ban spreading sludge above threshold limits Monitoring
Regulation on water reuse	Ensure the safe reuse of reclaimed water for irrigation	Water reuse risk management plans, permit systems, information and awareness campaigns	Infrastructure development
Regulation on the authorisation of plant protection products	Avoid adverse effects on human and environmental health	Risk-based approach to the approval of substances	Authorisation and permitting system

Table 4.2 **Objectives, instruments and measures tackling agricultural pressures on water in European environmental policies (cont.)**

Policy and key target	Goals and targets relevant for water and agriculture	Instruments	Example of technical measures
Sustainable use of Pesticides Directive	Reduce risks posed by pesticides to human and environmental health	National action plans, integrated pest management	Certified training, information and awareness-raising on the handling of pesticides, inspection of equipment, requirements for application (e.g. strict restriction of aerial spraying), handling and storage
		Integrated pest management	Non-chemical methods of pest control (e.g. hand-picking, housing, hygiene measures, quarantine) Biological methods: predators of pest, more resistant crop varieties Crop rotation and intercropping
Biodiversity strategy	25 % of land organically farmed	Action plan on organic farming	No use of mineral fertiliser and pesticides Long crop rotations, fallow land
	10 % of agricultural area as high-diversity landscape features by 2030 and create ecological corridors as part of trans-EU nature network	High-diversity landscape features	Buffer strips, hedges and ponds
	Reduce by 50 % the overall use of and risk from chemical pesticides and reduce the use of more hazardous pesticides by 50 % by 2030 (is also part of Farm-to-fork strategy)		Crop rotation, intercropping and mechanical weeding, uptake of organic farming practices and application of integrated pest management
	Restore 25 000 km of free-flowing rivers		Removal of barriers Adaptation of dams to allow fish passage Removal of water storage infrastructure
Farm-to-fork strategy	Reduce by 50 % the sales of antimicrobials for farmed animals	Regulations on veterinary medicinal products and medicated feed	Lowering stocking densities
	Reduce by at least 20 % the use of fertilisers by 2030, including animal manure, and reduce nutrient losses by at least 50 % by 2030, while ensuring no deterioration in soil fertility	Integrated nutrient management action plan	Sustainable nutrient management, nutrient balances, precise fertilisation techniques

4.3.1 Tackling diffuse pollution

Diffuse nutrient pollution from nitrogen and phosphorus is the main reported pressure from agriculture. Other pollution pressures are linked to chemical pollution from pesticides, sediments, and microbiological/bacteriological and other pollutants such as veterinary products (Section 3.1). However, diffuse pollution from agriculture has been notoriously difficult to address because of the number of farmers that need to be involved to have a noticeable impact on water quality.

Tackling nutrient pollution

Action on nutrient pollution has a long history in Europe, starting in the 1970s with several major international conventions tackling the issue of air pollution and eutrophication of freshwater and marine waters (ETC/ICM, 2016). Diffuse nutrient pollution is the most extensively covered agricultural pressure in the RBMPs, as many water bodies across Europe do not achieve the nutrient levels consistent with good status.

The main instrument to tackle agricultural diffuse nutrient pollution in the EU is the Nitrates Directive (EU, 1991b), although Member States and river basin authorities have also adopted their own national and river basin measures to achieve good status under the WFD. Meanwhile, the National Emission Ceilings Directive ((EU) 2016/2284), which aims to reduce national emissions of certain air pollutants addresses, for example, ammonia emissions to the air. In addition, the Marine Strategy Framework Directive promotes the protection and restoration of the environmental status of marine waters. Some of the pressures on the marine environment originate from agricultural activities, in particular nutrient pollution and eutrophication (see Section 3.1). Coordinating marine and water policies can result in more effective responses.

Under the Nitrates Directive, Member States must establish codes of good agricultural practice, which specify periods when the application of fertilisers and animal manure is prohibited, conditions for fertiliser application, minimum storage capacity for animal manure and beneficial crop management practices (rotations, winter soil cover, catch crops). Member States must also monitor water quality, identify waters polluted by nitrates, designate nitrate vulnerable zones (except when a Member State decides to take a whole territory approach, in which case measures apply to the entire country) and develop nitrate action programmes.

In nitrate vulnerable zones, the codes of good agricultural practice become compulsory, together with additional measures relating to limitations on fertiliser application (mineral and organic) and all nitrogen inputs to soils and on the maximum amount of livestock manure that can be applied. Derogations on the 170 kg/ha ceiling for organic manure are possible, when it can be shown that the additional level of manure to be applied can be absorbed by crops and grassland. The waters in derogated areas must not have a lower quality than those in in other areas. More requirements may be imposed on derogated farms. In Ireland, for instance, around 7 000 farms constituting over 500 000 ha benefit from the manure derogation, allowing higher stocking rates. They are required to perform soil testing and prepare nutrient management plans, including compulsory liming to improve the efficiency of nutrient use and reduce fertiliser needs. Six countries were granted derogations at the end of 2015 (EC, 2018b).

There has been a net improvement in the EU towards reducing nitrogen surpluses from agricultural land (Section 3.1), which is usually attributed to the adoption of the Nitrates Directive. Restrictions on fertiliser application and stricter application standards have contributed significantly to these improvements, together with improved manure application and storage techniques (Webb et al., 2010; van Grinsven et al., 2012). Landscape features, such as buffer strips, constructed wetlands and sediment ponds, have also helped to reduce the risk of leaching and run-off. Manure surplus management has been used to export excess nitrogen and phosphorus to areas with manure deficits where they can work as a substitute for mineral fertiliser. The increased use of manure can be supported by an adequate definition of nitrogen fertiliser equivalencies (van Grinsven et al., 2012).

Full implementation of the Nitrates Directive will certainly be needed in the future to support the achievement of the WFD objectives (EU, 2019a). At EU level, infringement cases have been initiated against several European countries (EC, 2020b). At national level, some countries report that up to 30 % of site controls result in infractions of the Nitrates Directive, in particular regarding manure storage and application near rivers (EC, 2018b).

Nitrate vulnerable zones now cover 61 % of the EU's agricultural area (EC, 2018b). Some Member States (i.e. Austria, Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, Poland and Slovenia) have decided to take a whole-country approach. Other Member States have opted for designating nitrate vulnerable zones. In some cases, designated areas do not include the entire area draining into waters where pollution is caused (EC, 2018b). This will limit the effective implementation of the action programmes.

Further progress in reducing nutrient pressure may be achieved with the wider use of nutrient budgeting at river basin and catchment scales to establish transparent nutrient load reduction targets. Accompanying measures would include river basin and catchment caps on fertiliser and manure use, or livestock density, as well as stricter restrictions on the use of fertilisers and manure.

Regulation (EU) 2019/1009 on the placing on the market of fertiliser products opens up new possibilities for organic fertiliser production and marketing on a large scale. It also harmonises the requirements for fertilisers produced from phosphate minerals and from organic or secondary raw materials in the EU. These new rules aim to ensure that only fertilisers that meet EU-wide requirements and standards for quality and safety can be sold freely across the EU. The contaminants in EU phosphate fertilising products, such as cadmium, can potentially pose a risk to human, animal or plant health, to safety or to the environment (accumulation of cadmium in soils) and, for this reason, the content of such contaminants is limited by the new rules.

The new circular economy action plan (EC, 2020d), biodiversity strategy for 2030 (EC, 2020f) and farm-to-fork strategy (EC, 2020e) call for an integrated nutrient management action plan to tackle nutrient pollution at source, in particular in the livestock sector. The biodiversity and farm-to-fork strategies set an ambitious target of reducing nutrient losses by at least 50 %, without any deterioration in soil fertility and with a reduction in fertiliser use of 20 %. They support better implementation of existing legislation, identifying the reduction in nutrient load needed, wider use of balanced fertiliser application, and better management of nitrogen and phosphorus throughout their lifecycles, all in keeping with the zero pollution ambition.

Tackling pollution from pesticides, heavy metals and veterinary medicines

Contamination caused by chemical pollutants from agricultural activities is highly varied and a major concern in many European countries (Section 3.1). The WFD requires the adoption of measures to control the discharges, emissions and losses of priority and priority hazardous substances into the aquatic environment. Emissions of priority substances should be reduced, while emissions of priority hazardous substances should be ceased or phased out. The list of priority and priority hazardous substances, published under the Environmental Quality Standards Directive 2008 and amended in 2013, includes several pesticides and heavy metals. Pollution from veterinary products is an emerging concern, as is plastics in agricultural soils.

Under the European Green Deal, a zero pollution action plan for air, water and soil will be adopted in 2021, which will target the release of nutrients, chemical pesticides, pharmaceuticals, hazardous chemicals and other waste, including litter and plastics.

Since 1991, EU action against pesticide contamination has gradually strengthened over the years, first by establishing greater control on the authorisation of active substances on the EU market, then by establishing provisions for the safe collection and disposal of waste and more recently by targeting consumption levels. The regulatory area is strongly intertwined with human health policy. For instance, Regulation (EC) No 396/2005 concerns maximum residue levels in or on food or feed, which are mainly intended to protect consumers.

Currently, the placing of pesticides on the market is regulated by Regulation (EC) No 1107/2009, which takes a risk-based approach to authorising pesticides, considering the precautionary principle. Among the 476 approved active substances in the EU, only 18 are considered low risk. However, there have been concerns regarding the robustness of the approval process (Buckwell et al., 2020).

The use of pesticides is regulated through the Sustainable Use of Pesticides Directive (EU, 2009a), which sets out a framework to achieve sustainable use. It promotes integrated pest management (IPM) (Box 4.2), and envisages mandatory inspection of pesticide application equipment, training of pesticide users, advisers and distributors, prohibition of aerial spraying, limitation of pesticide use in sensitive areas, mitigation of risks through improved spraying technology and application of buffer zones, along with proper management and cleaning of equipment after spraying.

Progress in reducing pesticide use has nevertheless been very limited at European level (Section 3.1). The farm-to-fork strategy and biodiversity strategy for 2030 have focused renewed attention on pesticide use, and they aim to reduce the overall use of and risk from chemical pesticides at European level by 50 %, and the use of more hazardous pesticides by 50 %. In addition, the farm-to-fork strategy has set a goal to reduce overall EU sales of antimicrobials in farmed animals and aquaculture by 50 % by 2030. Achieving these ambitious objectives will need significant changes in farm practices.

At Member State level, national action plans must be developed to show how the risks from and impacts of pesticide use will be reduced. To date, measures have focused on establishing systems for training and certifying operators, a range of measures to ensure the safe handling and storage of pesticides, and technological improvements in the efficiency of spraying pesticides (EC, 2020i). Initiatives exist on increasing the awareness of IPM among farmers, such as the Lithuanian labelling system for pesticides, as well as its monitoring and reporting by farmers (ECA, 2020).

Implementation of IPM has been slow, with little evidence of widespread uptake by farmers (Lefebvre et al., 2015). Practical and measurable guidelines and criteria at farm level should be developed to improve the monitoring of progress and increase awareness (ECA, 2020). Although farmers are required to adopt IPM, they are not always required to keep records of how they apply it and penalties for non-compliance are weak.

Systemic change is required by stakeholders throughout the value chain — including pesticide retailers, farm advisory bodies and the food industry — to move away from existing standards and requirements locking farmers into current practices. This lack of broader support for the value chain has been a major factor in explaining the lack of progress, despite ambitious national policies such as the first Ecophyto plan in France (Guichard et al., 2017).

Full implementation of the IPM principles set out in the Sustainable Use of Pesticides Directive is necessary, but so too are other measures. The definitions of non-chemical and low-risk plant protection products should be clarified, as should the recording of and reporting on the use of plant protection products at national and European levels to better measure progress (ECA, 2020). Given the continuous emergence of new chemicals, methods of detection must be strengthened alongside authorisation procedures supported by scientific evidence. The cumulative risks must be considered. Adopting precision farming and other innovations in pesticide application techniques can also improve the efficiency of fertiliser use (Dean et al., 2011).

Regarding the management of heavy metal contamination arising from agriculture, threshold limits for key substances in sludge applied to agricultural land have been set by the Sewage Sludge Directive, which is currently under evaluation. The sludge and the receiving soil require monitoring to take into account cumulative concentrations. The directive bans the spreading of sewage sludge when the concentration of certain substances in the soil exceeds these values. In addition, the directive sets restrictions on when sludge can be applied to protect against potential health risks from residual pathogens.

Reductions in the total amount of metals in sludge has been observed for regulated metals, with the largest decreases for cadmium, chrome and mercury (Fijalkowski et al., 2017). Member States have added substances to be controlled other than those listed in the directive and have implemented stricter limit values.

Diffuse pollution and protecting drinking water

The Drinking Water Directive (EU, 1998), currently under revision, establishes quality standards for drinking water at EU level. Several substances regulated by the directive relate to substances emitted by agriculture (e.g. nitrates). Under the WFD, Member States must establish drinking water protected areas and safeguard zones, in which human activities such as agriculture can be subject to more stringent controls.

Much of the implementation of the Drinking Water Directive has focused on mitigation and remediation actions for nitrates and pesticides, usually by treating pollution during the production of drinking water or by displacing drinking water wells (EC, 2016). The upcoming revised Drinking Water Directive will integrate a risk-based approach from abstraction to tap, with the intention of encouraging further preventive action to safeguard abstraction areas from pollution, including from agriculture. The new Drinking Water Directive will also establish a watch list of substances in response to growing concerns over the effects on human health of pesticide metabolites and emerging pollutants, such as endocrine disruptors, pharmaceuticals and microplastics (EC, 2018a).

Drinking water utilities and bottled water companies across Europe have increasingly engaged with the agricultural sector to find cost-effective ways of reducing pollution risks (Box 4.4).

4.3.2 Tackling pressures from agricultural water use

The EU's response to abstraction pressures has been mostly cross-sectoral, formalised through the WFD, 2000, and supported by the EU action on water scarcity and droughts, 2007, the *Roadmap to a Resource Efficient Europe*, 2011, the *Blueprint to Safeguard Europe's Water Resources*, 2012, and the new circular economy action plan, 2020.

Under the WFD, the classification of the ecological status of surface water bodies relies on biological methods sensitive to hydrological pressures, and Member States are required to assess hydrological regimes when assigning high ecological status (EC, 2015). In addition, the WFD requires that good quantitative and chemical status of groundwater bodies is attained, at the same time ensuring that alterations to groundwater levels do not affect surface

Box 4.4 Cooperation between farmers and drinking water utilities in North Rhine-Westphalia to reduce pollution of drinking water sources

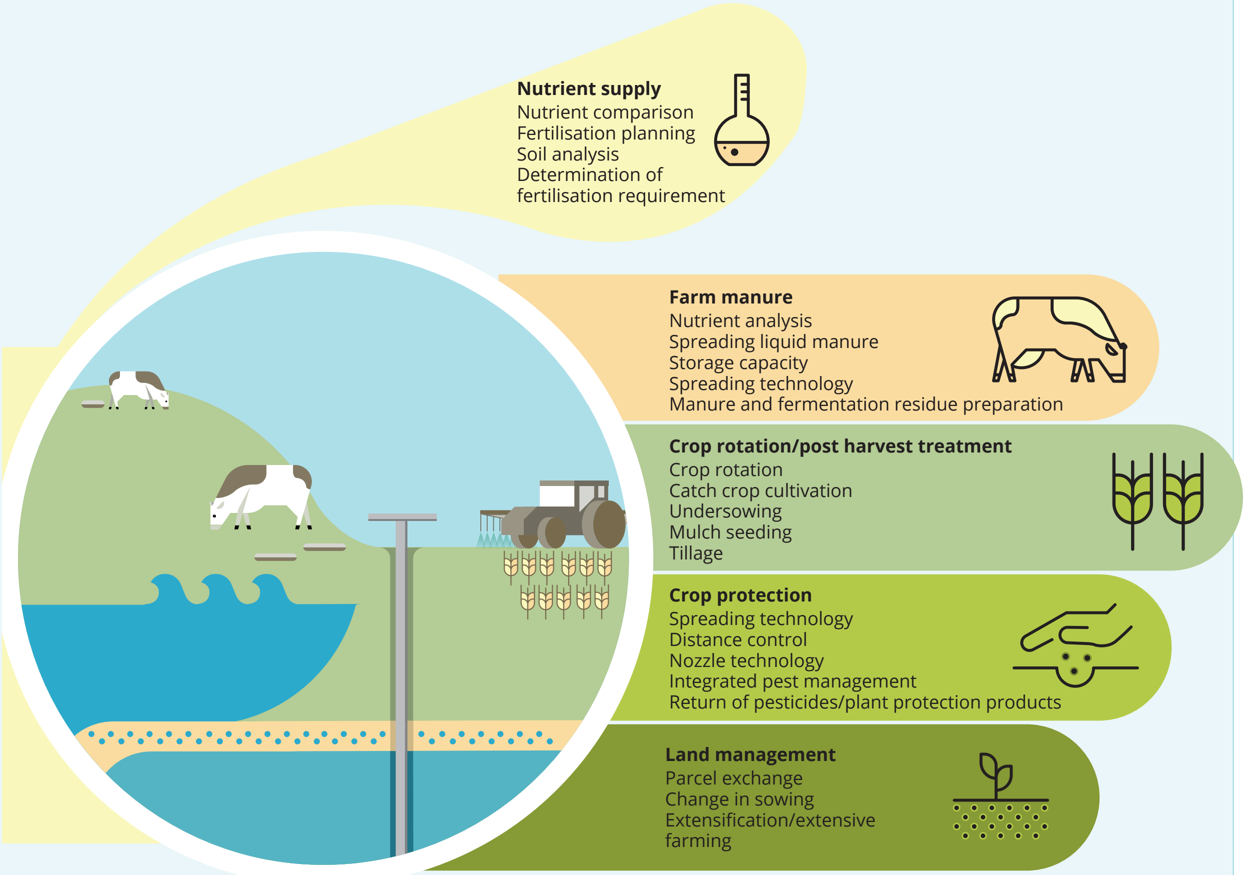
Pressures and impacts on water quality from agriculture are reported in all river basin districts of the second river basin management plans in Germany and include pollutants such as nutrients (and associated eutrophication) and pesticides, as well as morphological modifications. Water pollution from unsustainable agricultural practices poses a serious risk to drinking water.

In North-Rhine Westphalia, 114 voluntary cooperation agreements have been developed with the aim of finding sustainable solutions under the motto 'Cooperation instead of Confrontation'. Around 11 600 farmers and gardeners work together in close cooperation with 160 water supply utilities and the advisory staff of the Chamber of Agriculture of North Rhine-Westphalia.

Solutions incorporate the latest scientific findings on production processes and techniques. Together, the parties develop a catalogue of funding measures, which is adapted every year in consultation with water utility companies, to account for changes in farming practices (e.g. increases in livestock density, expansion of the area under cultivation, production of biogas), climate change and agricultural policy.

The progress of the programme is monitored through water and soil samples from a variety of cooperating areas in spring and autumn, which are analysed to determine their concentration of mineralised nitrogen. These results and those from analysis of other nutrients in the soil and the soil humus content are included in fertiliser balances and serve as basis for advice on optimising fertiliser application. The results of monitoring indicate that the cooperative water conservation programme achieved significant fertiliser savings at farm level. As a result of this programme, reductions in nitrate concentrations in groundwater and surface water were observed in many places.

Figure 4.3 Catalogue of measures drawn up under agreements



Sources: Heinrich Spitz, AquaAgrar 04 February 2020, personal communication; Landwirtschaftskammer Nordrhein-Westfalen (2016).

waters and groundwater-dependent ecosystems (EC, 2006b).

Irrigated agriculture is a major driver of abstraction pressure in the EU's water bodies (Section 3.2). At river basin level, the implementation of RBMPs has therefore led to the uptake of a wide variety of management measures to tackle abstraction pressure, including pressure arising from agricultural irrigation (EC, 2019a).

Prior-authorisation and abstraction control

The WFD requires controls of surface and groundwater abstractions through registration, prior authorisation and regular revision of permits. Member States should inspect abstractions and enforce penalties on unauthorised users who do not comply with the specification of the permit requirements. The latest assessment of the RBMPs (EC, 2019a) indicates that authorisation procedures are generally in place in all Member States.

There remain significant implementation issues regarding abstraction control. Illegal abstraction in the form of unauthorised, unregistered, unmeasured or unmetered abstraction, also continues to be a major challenge (Schmidt et al., 2020). Half of the wells in European Mediterranean countries may be unregistered or illegal (EASAC, 2010). Not all abstraction points are reported, and volumes are not systematically metered.

The multitude of abstraction points makes it particularly difficult for authorities to regulate water use. However, river basin authorities are developing sophisticated strategies to improve the recording of agricultural abstraction and its monitoring (Schmidt et al., 2020). Metering of all abstraction points is challenging on a technical and economic basis.

Most Member States apply exemptions to permitting and registering small abstractions, and the analysis of abstraction may not consider the cumulative impact of abstraction points. This is a major concern for groundwater but also for surface water bodies from which farmers abstract water through individual pumping systems. The lack of consideration of, and control over, small abstraction points in some Member States lead to an underestimation of abstraction levels from agriculture. Further investment in developing indirect methods, such as remote sensing, may be useful to estimate the cumulative effect of small abstractors at the basin level and/or groundwater body level. For example, high-quality data are being made available through the Copernicus Sentinel programme.

The majority of countries and river basin districts have conducted assessments of water balances (EC, 2019a). Water balances provide an overview of the volume and flow of water within a specified hydrological unit (e.g. a river catchment or river basin), occurring both naturally and as a result of human-induced water abstractions and return flows. Water balances provide a sound basis for establishing sustainable abstraction levels based on renewable freshwater resources and environmental flow requirements (EC, 2015).

Further work is needed to harmonise the use of water balances across river basins (Buchanan et al., 2019). To realise their full potential, water balances must give careful consideration to the interconnectivity between surface water and groundwater bodies, the relationship between water flow, quality and ecological status, the effect of climate change and assumptions about water consumption and return flows. Some countries use water balances when reviewing abstraction permits (Box 4.5). Further guidance is planned on how to better link the review of abstraction permits with the aim of restoring ecological flows under the WFD as part of the recent biodiversity strategy for 2030 (EC, 2020f).

Water use efficiency and crop productivity

European policies aim to promote water use efficiency in agriculture, an approach reinforced by the European Green Deal and new circular economy action plan goal to achieve a resource-efficient economy. At the global level, Europe is usually considered to be more efficient in in its use of irrigation water (e.g. Jägermeyr et al., 2015). However, studies have suggested that up to 43 % of water used in agriculture in Europe could be saved (Dworak et al., 2007).

Implementing incentive pricing for the use of water and increasing the cost recovery of abstracting, storing and delivering irrigation water is part of the WFD (Box 4.6). It is expected that cost recovery and incentive pricing can support greater efficiency of water use and encourage a shift to crops, irrigation technologies and practices that reduce wastage and ensure that water is used efficiently.

Cost recovery and volumetric pricing in irrigated agriculture have been more widely adopted in recent years, although many Member States do not yet implement it fully for several social, economic and political reasons (Giannakis et al., 2016; Expósito, 2018; EC, 2019a). It is important to note that incentive pricing does not necessarily result in water savings because of low water prices. Other factors, such as fertiliser or energy costs, may in reality have a stronger impact on water use (Bogaert et al., 2012).

Member States have made significant investments in efficiency programmes, including improved irrigation scheduling and provision of advice, reducing water

Box 4.5 Volumetric control on abstraction for agricultural irrigation in France and Spain

Limits on total agricultural abstraction have been adopted in some river basins in Europe. In France, the Water Law 2006 required caps on abstraction in priority catchments and aquifers, where resources are deemed overexploited. Once the cap is set by authorities, together with users, the portion allocated to agriculture is managed by an agricultural collective management organisation called Organismes Uniques de Gestion Collective (OUGC). The OUGC was conceived as an administrative (relay) institution to improve local knowledge of agricultural abstraction, pool individual water demands annually, decide allocations between farmers and report use after the irrigation season. Policing and compliance remain in the control of public administrations. This co-management between authorities and agricultural users has contributed to improving knowledge of agricultural abstraction in basins and aquifers and to reinforcing local control of agricultural abstraction.

In Spain, user associations have also been created to manage overexploited aquifers. The management of some aquifers, such as the Mancha Oriental, present some elaborate forms of monitoring and controls on abstraction based on Earth observation information. Farmers are required to prepare an irrigation plan specifying which crops will be irrigated, the location and the area to be cultivated. Based on this, the user association carries out continuous Earth observation to detect potential cases of overabstraction and target field inspections. This is assisted by calibrated flowmeters on wells. This has significantly improved controls and the water table level has been stabilised.

While the French and Spanish cases present advanced experiences of controlling abstraction, there are many challenges in implementing such schemes. Ideally, water permits should be reviewed to reduce overexploitation. However, historical water use rights and entitlements pre-dating the WFD may persist, and authorities usually face significant legal and political constraints on modifying them. In France, for example, the definition of abstraction caps imply that agricultural extractions have to be reduced by 10-20 % compared with historical use in most priority catchments and by over 50 % in some cases. These reductions are to be achieved without financial compensation. Ambitious reforms are needed to overcome these barriers and engage in a full and wide-ranging review of existing permits.

Sources: Playán et al. (2018); Ortega et al. (2019); Arnaud (2020); Rouillard and Rinaudo (2020); Schmidt et al. (2020).

losses during conveyance, and water-saving irrigation technologies (Giannakis et al., 2016). Drip and sprinkler irrigation methods, which have the highest water efficiency (85-95 % and 70-85 %, respectively) generally prevail in Europe, while many gravity-fed and surface irrigation systems with lower efficiency (40-60 %) remain in use across Europe, in particular among small farm holdings in the Mediterranean, where surface irrigation has traditionally been used. Moving to more efficient irrigation, for instance by improving the lining of canals or switching to pressurised and drip irrigation systems, could make further water savings.

Performance in irrigation water use can be measured by estimating the water intensity of crop production, which relates to the amount of water used to produce a crop to realise its economic value. The water intensity of crop production in Europe reduced by 12 % between 2005 and 2016 (EEA, 2020f). The biggest reduction occurred in eastern Europe (nearly 32 %) due to increases in the gross added value generated by crops and a reduction in abstraction per hectare. Southern European countries also reduced the water intensity of crop production by about 10 %, although some countries, such as Cyprus, Greece, Italy and Malta, experienced an increase due to an increase in abstraction per hectare and a decline in added value of crops, possibly as a result of climate change.

The idea that moving to more efficient use in irrigation systems and increasing crop water productivity is always beneficial in environmental, social and economic terms warrants some words of caution (Zoebl, 2006; Berbel et al., 2018). More efficient irrigation infrastructures require larger investments and have higher operational and running cost (such as energy costs), placing an additional burden on smaller farm finances (Dumont et al., 2013; Masseroni et al., 2017). Drip irrigation can cause salinisation, as the salts are not leached out of soils. Excess water from inefficient irrigation systems also has environmental benefits. It can return surface water to rivers, increasing base flows that are beneficial to downstream uses and sensitive ecosystems. Higher irrigation efficiency, without reallocating the saved water resources to the water environment, can thus lead to reduced base flows, and exacerbate the impact of abstraction (see also Section 4.2.1).

Investments in water efficiency programmes should therefore be accompanied by careful consideration of water balances at farm, basin and aquifer level, including surface water-groundwater exchanges and dynamics and the impact on groundwater-dependent ecosystems (EC, 2015; Expósito and Berbel, 2017). Attention needs to be given to potential rebound effects (see Section 4.2.1) and ensuring that the water saved is reallocated to environmental needs.

Box 4.6 Cost recovery and incentive pricing in agriculture under the Water Framework Directive

Cost recovery of water services is a general principle in the directive, which Member States should apply (except where it does not compromise the purposes and achievement of the objectives of the directive). Cost recovery and incentive pricing principles under the directive in agriculture can be outlined in the following way:

- Element 1 — there is an incentive pricing policy to use water resources efficiently.
- Element 2 — there is an adequate contribution from the agricultural sector (including self-abstraction for irrigation) to the recovery of the costs of water services, including environmental and resource costs reflected in pricing policy.

Operationally, this would require that all abstractions from surface waters and groundwaters (and reservoirs) by farmers are subject to a fee (i.e. a price). This fee should include not only costs linked to infrastructure management, such as maintenance and energy costs, but also environmental and resource costs to reflect the impact that such abstraction has on the environment and other users.

The price paid for water would be based on the volume of water abstracted for individual agricultural uses, as measured by an individual farm-level meter. Set at the appropriate level, such a pricing policy would provide incentives for the agricultural sector to shift to crops, irrigation technologies and practices that ensure efficient use of water or, in water-scarce areas, to crops requiring less water .

Source: Berglund et al. (2017).

Reducing demand and enhancing rainfed agriculture

As river basins adopt more water-efficient irrigation techniques, technological improvements may reach their full capacity to deliver new value and reduced water use. Findings suggest that gains in water productivity may have reached a ceiling in some southern European river basins, as various innovations, such as new crops, deficit irrigation, and wate-saving and conservation technologies, have reached their full capacity (Expósito and Berbel, 2017). Hence, other measures may be needed to match total water demand with water availability.

As river basins progress towards limitations on total resources, the full impact of agriculture on the basins' hydrology should be accounted for, including its use of both rainfall water stored in soils and supplementary irrigation water. This would require managing water in rainfed and irrigated systems in an integrated way, looking at ways to maximise water savings by managing evapotranspiration and crop water demand, enhancing soil water retention capacity and increasing the productivity of rainfed agriculture (Molden et al., 2007; Rockström et al., 2010). This would also contribute to increasing farms' resilience to water scarcity and droughts.

There is evidence that farms practising organic farming and agroecology have greater resiliency because they can maintain higher yields than non-organic farms during droughts (e.g. Milestad and Darnhofer, 2003; Altieri et al., 2015). In particular, crop diversification reduces exposure to a single crop failure, while the use of soil conservation techniques, such as mulching and incorporating crop residues, promotes carbon-rich soils, which have higher water retention capacities (Adhikari and Hartemink, 2016).

Various techniques can be used to reduce crop water demand, such as modified cropping calendars and crop rotations (to maximise the use of rainfall and stored soil moisture content), rotational fallowing and selecting varieties and species more resistant to water stress (Debaeke and Aboudrare, 2004; EIP-AGRI, 2016, 2020). Deficit irrigation has potential in cropping systems to optimise and reduce water use under drought conditions (Fereres and Soriano, 2006). Combining crops or pastures with trees in agroforestry systems can also buffer exposure to climate change extremes such as storm damage, heatwaves and droughts (OECD, 2014).

Water management measures

Water management measures can contribute to reducing agricultural pressures, such as 'offline' storage, water harvesting, groundwater use and use of unconventional water resources. They are discussed separately here to highlight their potential contribution to enhancing the sustainability of agriculture, if implemented with the right safeguards.

Some countries, such as France, are currently building 'offline' storage schemes, i.e. reservoirs built outside river beds to reduce their hydromorphological impacts. They are filled by pumping into the water bodies during the high-flow season (winter) from rivers or shallow, unconfined groundwater, thereby lowering the direct impact of pumping on environmental flows. Storage is used only to substitute for summer pumping and cannot result in an increase in the irrigated areas. They must be accompanied by metering and cancellation of licences to abstract during seasonal low-flow periods. Priority is given to projects involving several farmers and must be specifically designed to support the WFD targets. Their implementation is widely debated, and further adoption will need to take into account their potentially large visual and environmental impacts (i.e. affecting winter flow dynamics) (Granjou and Garin, 2006).

Rainwater and run-off harvesting in small ponds and reservoirs (with storage capacities of 100-10 000 m^3) is being promoted in many countries to increase farms' resilience to droughts and reduce abstraction pressures. However, their multiplication in catchments can cumulatively lead to major modifications to hydrological regimes (Carluer et al., 2016b). Their impact on the water balance of the catchment and river basin and linked aquifers should be considered.

The second half of the 20th century has also seen a major growth in the use of groundwater by agriculture, in particular in southern European countries, such as Spain and often contributes to increasing water imbalances at catchment level (Llamas and Martínez-Santos, 2005; De Stefano et al., 2015). It also takes place in northern countries such as the Netherlands and the United Kingdom (Foster and Custodio, 2019).

There is a growing interest in more coordinated ('conjunctive') use of surface water and groundwater, in which surface water is used in wet years and groundwater in dry years to maximise the availability of water during dry years (i.e. groundwater is used as an underground reservoir). Managed aquifer recharge may be used to maximise benefits of the storage capacities of groundwater bodies and better regulate groundwater-surface water exchanges. Managed aquifer recharge is increasingly used to improve supplies for drinking water purposes, but there is scope to expand its use across Europe (Sprenger et al., 2017), including by combining it with wastewater reuse schemes (Zuurbier et al., 2018). Although studies of conjunctive use have been done at local and regional level (e.g. Pulido-Velazquez et al., 2008; Guyennon et al., 2017), the potential at EU level is as yet unknown.

The use of alternative water resources, such as desalinated water and treated waste water, is poorly documented, but limited available evidence suggests that it is minor at European level (BIO by Deloitte et al., 2015). Some countries nevertheless have implemented reuse on a large scale, such as Cyprus, which reuses up to 90 % of its waste water. The EU recently published Regulation (EU) 2020/741 on the minimum requirements for water reuse (EU, 2020a), with the objective of stimulating and facilitating water reuse across Europe. In particular, the regulation sets out minimum water quality requirements for the safe reuse of treated urban waste water in agricultural irrigation. Where water is scarce, the benefit of reuse is to alleviate pressure from agricultural abstraction on surface water and groundwater bodies and from pollution from waste water discharges.

Greater use of unconventional water sources will encounter acceptability issues, design and technological challenges, and various financial, environmental and climate risks (Kirhensteine et 0al., 2016). Furthermore, waste water reuse should account for existing uses, including environmental needs, which have to date been dependent on the steady flow of waste water discharges. Redirecting waste water discharge to reuse instead of receiving water bodies might negatively affect ecological conditions during low-flow periods. Hence, not all waste water is available for reuse, and careful catchment balances are needed to assess the real potential (Drewes et al., 2017).

4.3.3 Tackling hydromorphological pressures from agriculture

The hydromorphological conditions of surface water bodies are an essential consideration under the WFD, including when assessing the objectives and status of surface water bodies and designing restorative measures. Agriculture is a major pressure on the hydromorphology of surface water bodies in Europe, because of, for instance, historical and current land drainage, irrigation storage infrastructure, livestock trampling and soil erosion (Section 3.3).

These activities have long been the target of environmental policy measures in Europe. Environmental impact assessments of water management projects in agriculture, including those for land drainage and irrigation, are required under the Directive on assessment of the effects of certain public and private projects on the environment (2011/92/EU). Impoundments must obtain prior authorisation (licensing) under the WFD.

Tackling hydromorphological pressures from existing and historical land management, drainage and irrigation practices requires measures to restore aquatic and linked terrestrial habitats. Restorative measures have been identified under the WFD to address pressures specifically from agricultural land drainage (Vartia et al., 2018) and on storage schemes, including those for irrigation purposes (Halleraker et al., 2016).

The Birds and Habitats Directives (EU, 1992, 2009b) and the green infrastructure strategy (EC, 2013b) do not include any statements of direct relevance to agriculture and water; however, the conservation measures that must be put into place for specific ecosystems may involve actions in this area. More explicitly, the biodiversity strategy for 2030 sets out to restore the longitudinal connectivity of 25 000 km of rivers across the EU and calls for a dedicated EU-wide nature restoration plan.

Other nature-based solutions are promoted by the biodiversity strategy for 2030. It sets out to manage at least 10 % of Europe's agricultural land as high-diversity landscapes, which include riparian buffer strips, rotational or non-rotational fallow land, hedges and ponds. These can help reduce agricultural pollution and soil erosion and mitigate the effects of climate change. The strategy also includes promoting sustainable forest management and a target to plant 3 billion additional trees in the EU by 2030. The upcoming 2021 EU forest strategy could propose strategies to restore catchments heavily deforested by agriculture.

A Europe-wide overview of measures tackling hydromorphological pressures from agriculture is complex because of a lack of data. Evidence exists of countries implementing river restoration measures to remeander river courses, enhance riparian habitat, remove embankments, weirs and barriers (e.g. dams) and reconnect rivers and floodplains. Other measures target agricultural land to promote a landscape-wide restoration of hydrological processes and reduce sediment flow, for example by changes in crop and soil management to reduce erosion. The EU thematic strategy on soils, with a planned update in 2021, sets out measures to prevent soil degradation and enhance soils across the EU (Box 4.7).

Box 4.7 Protecting water resources through European action on sustainable soil management

Soils deliver a wide range of ecosystem services related to the water cycle. Healthy soils play a key role in agricultural productivity and protecting water resources from nutrient and pesticide pollution. Healthy soils have the capacity to support multiple functions, including regulating water, sustaining soil biodiversity, filtering and buffering pollutants, cycling nutrients and providing physical stability for plants. Healthy soils have a high water retention capacity, retaining and slowing down water flows, minimising surface evaporation and making water available to crops during the growing season. Functional and healthy soils have a key role in food security, and the supply of good-quality water, and they alleviate the impact of water deficits and enhance our resilience to floods and droughts.

European soils are under multiple threats from intensive agricultural practices. Intensive field operations, ploughing and cultivation practices on arable land and grazing areas can reduce soil organic matter, affect soil structure and expose soils to wind and rain erosion. Soil erosion leads to pollution of surface water bodies and hydromorphological pressures through sedimentation from fine particulates in rivers and lakes. An estimated 18 % of agricultural areas and natural grassland, equivalent to 35 million hectares, were affected by soil erosion in the EU-28 in 2017, at an average rate of 3.4 t/ha per year, and 25 % of land in the EU is at high or very high risk of desertification. Several countries have significantly higher erosion rates, in particular Italy, Slovenia, Malta, Greece, Spain, Cyprus and Romania.

Soils are also under threat from salinisation (e.g. from irrigation practices), contamination by pesticides and heavy metals and loss of soil biodiversity. It is estimated that 83 % of EU soils have residual pesticides and that 65-75 % of agricultural soils have nutrient inputs at levels risking eutrophication of soils and water.

Coordinated action on soils at EU level was initiated through the EU soil thematic strategy, which sets out common principles for protecting soils across the EU (EC, 2006a). More recently, the EU has committed to implementing the Sustainable Development Goals, including Land degradation neutrality and halting desertification (target 15.3). However, recent evaluations of EU soil-relevant policies highlight the lack of a common strategic framework setting out common targets and soil-specific delivery mechanisms.

Further action to promote sustainable soil management is planned under the European Green Deal in 2021, through the upcoming zero pollution action plan for air, water and soil and a revised EU soil thematic strategy. Tackling soil threats can protect agricultural production and contribute to food security, while contributing to preserving and restoring healthy rivers and lakes.

Sources: Frelih-Larsen et al. (2017); ESTAT (2020h); Veerman et al. (2020).

As awareness of the importance of hydromorphological pressures from agriculture is growing, coordinated efforts between water and agricultural agencies to identify appropriate measures are increasingly needed. This is essential, as measures on drainage and irrigation infrastructure can have significant impacts on the viability of farming systems.

4.3.4 Adapting to climate change

Climate change will bring severe challenges for European agriculture and water management in the form of increased water scarcity and drought risk, flood risks and poorer water quality (Section 3.5.1). Climate change adaptation should be considered in the design of RBMPs under the WFD (EC, 2009a). A climate check would consider whether measures tackling agricultural pressures on the water environment would be cost-effective in the long term under different climate scenarios (EC, 2009a)). EU guidance (EC, 2009a) calls for prioritising measures that are flexible and contribute to enhancing resilience, such as increasing water efficiency, reducing demand for irrigation water, preserving soils and building resilience in agroecosystems.

Under the WFD, RBMPs may be supplemented by drought management plans, which outline management measures when precipitation is significantly below average values. These usually consist of emergency controls whereby water users, including irrigated agriculture, undergo increasing, pre-defined restrictions on their water use when rivers and aquifers reach pre-set levels. Drought forecasting and preparedness should alleviate the problem, as well as mechanisms to optimise water allocations during droughts (Kampragou et al., 2011; Rey et al., 2017).

The Floods Directive provides the framework for flood risk assessment and management in the EU. The flood risk management plans (FRMPs) set out measures to achieve the objective of reducing potential adverse consequences from flooding in their territory. FRMPs should include measures to improve water retention by maintaining and restoring floodplains and promoting sustainable land use practices. EU guidance on natural water retention measures (Box 4.3) sets out measures for agricultural land that have multiple benefits for flood risk reduction and achieving the WFD objectives, including improvements in water quality and hydromorphology.

The EU strategy on adaptation to climate change aims to make Europe more climate resilient (EC, 2013c). Taking a coherent approach by complementing the activities of Member States, it supports action by promoting greater coordination and information-sharing and by ensuring that adaptation considerations are addressed in all relevant EU policies and funding programmes. The new adaptation strategy (to be published in 2021) will represent another chance to address the water and agriculture nexus, ensuring that both can withstand the changing climate, as this is critical for achieving many objectives, including preserving ecosystem services (Trémolet et al., 2019).

Adapting to climate change while ensuring a thriving agricultural sector and high-quality water resources will be a major challenge for Europe in the upcoming years. Agriculture being one of the sectors most exposed to climate change, adaptation measures should enable farming in Europe to become sustainable and more resilient in the long run. Improved resource efficiency to increase the environmental performance of farms, and the uptake of sustainable farming practices that preserve and enhance soils and improve water management, are important adaptation measures. In addition, farm-level adaptation will need support from a wider and more systemic change, not only in the agricultural sector but also in the drivers of agricultural production, i.e. in the societal systems that consume agricultural commodities (see Chapter 5).

4.4 Coherence of European agricultural policies with water policy objectives

The CAP is the main policy that influences the development of the agricultural sector in the EU and that influences how individual farmers choose to manage their land, crops and livestock. Thus, the CAP is a key EU instrument for reducing agricultural pressures on the water environment. Close integration is needed between the objectives, regulations and incentives set by the CAP and the environmental objectives of water-related legislation.

In its preamble, the WFD highlights the importance of close integration with the CAP, and RBMPs have relied on funding from rural development policies to implement measures on agricultural land (Buchanan et al., 2019). While the CAP and other sectoral policies have been in existence progress has been made on streamlining environmental objectives. Yet, there is a need for much more ambitious and far-reaching integration, given the slow progress towards good status, and continued pressure from agriculture on the water environment (ECA, 2014; EEA, 2018b; EC, 2019a).

A new delivery model has been proposed for the next CAP (2021-2027), based on greater subsidiarity. Each Member State will prepare a CAP strategic plan, which will outline a set of objectives and interventions reflecting identified environmental, social and economic needs. Member States' CAP strategic plans will need to be coherent with the specific objectives and interventions set out in environmental planning instruments such as the RBMPs and nitrate action programmes. In addition, the current proposal for the CAP requires greater environmental and climate ambition to avoid any backsliding in its contribution to the environment and climate.

To achieve increased coherence with water targets, Member States will need to ensure that their strategic plans avoid any incentives conflicting with requirements under the WFD and other water legislation and that they increase support for environment and climate action contributing to water policy objectives.

4.4.1 Avoiding policy incentives leading to pressures on water

Most of pillar 1 in the CAP 2014-2020 was oriented towards direct payments to farmers in the form of income support. Direct payments in the 2014-2020 programming period consisted of several schemes, the main one being a basic income support scheme. Other direct payment schemes had more specific objectives, such as supporting young farmers and smaller farms, modernising specific sectors and maintaining production in specific sectors facing economic difficulties.

The influence of the current CAP pillar 1 on the production and use of inputs (e.g. fertilisers, pesticides, irrigation water), and the resulting impact on the water environment, is subject to debate. On the one hand, most direct payments are now decoupled from production, hence removing an incentive to intensify production. Furthermore, direct payments can represent a substantial share of the income of farming systems that have a lower impact on water, for example diversified farms with grass-fed livestock production or extensive farms in areas of natural constraints (Devot et al., 2020). This may maintain their economic viability and prevent their conversion to more specialist arable farming systems.

On the other hand, the CAP provides support payments that can contribute to increasing pressures. For instance, Member States can implement voluntary coupled support in specific sectors that are experiencing certain economic difficulties. These payments do not necessarily take into account the impact of the sector on the water environment, and thus they can support a level of production that leads to damage to the water environment. To limit this effect, some Member States have set conditions on payments from voluntary coupled support. For instance, France and Romania have set a maximum number of animals for the beneficiaries of voluntary coupled support schemes linked to livestock production, thereby setting a limit on the intensity of pressure on water quality (Devot et al., 2020).

Under pillar 1's common market organisation, Member States can implement sector-specific aid schemes to support the competitiveness and modernisation of agricultural holdings. This instrument is often used to support investments in irrigation in sectors such as fruit and vegetables, apiculture, wine, hops, cotton and olives. To ensure that such investments lead to a reduction in pressure on the water environment, and not to its intensification, some Member States, such as Croatia, France, Romania and Spain have set minimum water saving targets on investments benefiting from the aid scheme (Devot et al., 2020).

It is important to note that the impact of voluntary coupled support and sectoral market interventions on farming practices and pressures on the water environment is dependent on many factors, varying with Member States' implementation choices, the characteristics and location of the farm, market conditions and choices made by farmers themselves.

To increase the environmental performance of these policy instruments, the current proposals for the CAP 2021-2027 require Member States to allocate at least 20 % of the sectoral market interventions to improving the overall performance and climate performance of farmers involved in the operational programmes of the fruit and vegetable producer organisations. The future design of pillar 1 payments in the next CAP beyond 2020, in particular the voluntary coupled support and the common market organisation schemes, should integrate ambitious limits and conditions to avoid agricultural intensification and incentives that conflict with water protection targets.

4.4.2 Supporting the transition to sustainable farming

The successive CAP reforms in 1992, 2003, 2014 and the current proposals for the CAP 2021-2027 have resulted in establishing a 'green' architecture composed of various instruments for promoting environmental and climate-friendly farming practices. They can be separated into:

- Instruments mainstreaming environmental standards, i.e. 'cross-compliance' in the CAP

2014-2020, and 'conditionalities' in the current proposals for the CAP 2021-2027;

- Instruments encouraging the uptake of more sustainable farming practices, i.e. 'greening practices' in the CAP 2014-2020 (included as environmental standards in the new set of conditionalities in the upcoming CAP beyond 2020), and the proposed 'eco-schemes' in the CAP 2021-2027;

- Instruments providing financial assistance for the transition towards sustainable farming, i.e. pillar 2 payments under rural development.

Linking direct payments to respect for environmental standards

The CAP reform in 2003 established a series of 'cross-compliance' rules on environmental protection, food safety, animal and plant health and animal welfare, which farmers across Europe must comply with to receive CAP payments (Table 4.3). Statutory management requirements (SMRs) relate to existing environmental legislation. Good agricultural and environmental conditions (GAECs) are additional requirements attached to most direct and rural development payments.

In the CAP period 2014-2020, two SMRs (i.e. SMRs 1 and 10) integrated the requirements of the Nitrates Directive and the Sustainable Use of Pesticide Directive, as well as several GAECs that are also relevant to water targets, directly and indirectly. They include those requiring the establishment of buffer strips along watercourses, groundwater protection measures, soil and land management practices to limit erosion and maintain soil organic matter, and retention of landscape features such as hedgerows. One GAEC required compliance with authorisation procedures for abstraction for irrigation purposes.

Despite the role of cross-compliance to enforce minimum standards beneficial to the water environment on a wide number of European farms, evaluations have shown limited environmental effectiveness (ECA, 2009, 2016; Devot et al., 2020).

One issue commonly reported relates to the generic nature of cross-compliance requirements and their lack of spatial targeting. Under the current system, CAP management authorities set out standards following an approach that can be applied across a region or a country uniformly, usually to minimise the administrative burden. Two notable exceptions are the SMR related to the Nitrates Directive, which accounts for nitrate vulnerable zones, and the GAEC on land management to limit erosion, which integrates the need to account for site-specific conditions.

There are also issues relating to the varying level of ambition between Member States. For instance:

- The specification of GAEC on buffer strips vary widely across Europe, including minimum width, obligations and restrictions on the use of fertilisers and pesticides, and the type of vegetation that can constitute a buffer strip. The most ambitious requirements take into account key compounding factors, such as the slope of the land upstream, to enhance buffer strips' effectiveness in tackling nutrient and pesticide pollution.

- Cross-compliance relating to the use of pesticides has so far been limited to respecting procedures regarding the buying of products, their handling and application (ECA, 2020). Reducing pesticide pressure will require going beyond and implementing an integrated approach to managing pest and diseases that considers alternative methods and reducing the application rate and frequency, as set out under the Directive on the Sustainable Use of Pesticides.

- Abstraction pressures were tackled by GAEC 2, which requires that the farmer comply with authorisation procedures. Considering the large number of unreported abstraction points, this GAEC has considerable potential to improve monitoring of water use. A requirement to install a water meter and report water use could further improve GAEC 2. Potential additional measures could include the uptake of water-saving measures and efficient irrigation systems.

Cross-compliance requirements did not apply to sectoral market interventions nor all direct payments. This exempted certain polluting sectors, such as cotton production, wine and vegetables, from meeting these standards when receiving these payments. In the current proposals for the CAP 2021-2027, some of these payments will remain under different environmental requirements as direct and rural development payments.

Finally, there are issues of implementation and compliance. According to the European Court of Justice, about 20-30 % of spot checks found infringements of cross-compliance standards between 2011 and 2014: 15 % of infringements related to failure to comply with the requirements of the Nitrates Directive.

The new CAP2021-2027 green architecture proposes to integrate cross-compliance requirements and greening measures (Table 4.3) into a set of new conditionalities on all pillar 1 payments. New proposed standards include controls on diffuse phosphate pollution, the new Farm Sustainability Tool for Nutrients, and the protection of wetland and peatland, all of which would contribute to tackling pressures from agriculture on water.

No conditionality requirement has yet been proposed regarding mitigating the impact of hydromorphological changes from drainage schemes and irrigation infrastructure, nor have measures tackling emerging chemical pollution from, for example, pharmaceutical and cleaning products used in livestock rearing.

Encouraging sustainable farm practices

Under the CAP 2014-2020, farmers could receive a 'green direct payment' for implementing three types of measures: (1) crop diversification; (2) maintenance of permanent grassland and (3) ecological focus areas (EFAs). Member States and farmers had significant leeway in implementing greening measures.

Table 4.3 Cross-compliance and conditionalities attached to CAP payments in each programming cycle, focusing on mandatory water-relevant requirements

CAP 2014-2020 (Cross-compliance)	SMR1 Protection against water pollution by nitrates SMR 10 Placing of plant protection products on the market GAEC 1 Buffer strips along water courses GAEC 2 Authorisation for abstraction GAEC 3 Protection of groundwater against pollution caused by certain dangerous substances GAEC 4 Minimum soil cover GAEC 5 Land management to limit soil erosion GAEC 6 Maintenance of soil organic matter GAEC 7 Retention of landscape features
CAP 2021-2027 (Enhanced conditionality)	Use of farm sustainability tool for nitrates Establishment of buffer strips along water courses Maintenance of permanent grassland based on ratio of permanent grassland in relation to agricultural area Appropriate protection of wetland and peatland Ban on burning arable stubble except for plant health reasons Tillage management reducing the risk of soil degradation, including slope consideration No bare soil in most sensitive periods Crop rotation Minimum share of agricultural area devoted to non-productive features or areas: Retention of landscape features or areas Ban on cutting hedges and trees during bird breeding and rearing season As an option, measures for avoiding invasive plant species Ban on converting or ploughing permanent grassland in Natura 2000 sites.

Notes: GAEC, good agricultural and environmental condition; SMR, statutory management requirement.

Experience indicates that farmers preferred to implement 'productive' EFAs, including nitrogen-fixing crops and catch crops, which are deemed beneficial for water (Devot et al., 2020). Since 2018, the use of pesticides on these productive EFAs was forbidden under Regulation (EU) 2017/1155. Other relevant EFAs were offered, such as landscape elements (e.g. hedgerows and wooded strips), afforested areas, agroforestry and maintenance of permanent grassland, but they were less popular among farmers.

Recent evaluations indicate that conditions attached to greening measures were also often not ambitious enough. Many EFAs, for instance, did not always go much beyond existing cross-compliance requirements (Devot et al., 2020; ECA, 2020). The European Court of Auditors (ECA, 2017) concluded that Member States used the flexibility in greening rules to limit the burden on farmers and themselves, rather than to maximise the expected environmental and climate benefits. Hence, no major changes at the farm level were required to receive the payment (Chartier et al., 2016; EC, 2017a). Furthermore, their full potential were not always achieved because of lack of targeted advice to position them optimally at the farm and landscape level (BIOGEA, 2020).

The new CAP 2021-2027 green architecture proposes a pillar 1 payment in the form of an 'eco-scheme' to encourage more sustainable land management through direct payments. This intervention is planned to be mandatory for all Member States, but it will be voluntary for farmers. Because eco-schemes tap into the CAP pillar 1 budget, Member States can mobilise more funding to encourage sustainable farm practices and reach a much larger number of farmers (Lampkin et al., 2020).

Financing the transition to sustainable farming

The CAP 2014-2020 included funding to support a range of rural development and agri-environment-climate measures under its pillar 2 (Table 4.4). Because of the high cost involved in transforming whole production systems, rural development has been a pivotal instrument in supporting the adoption of sustainable farm practices, from the adoption of new technologies to soil conservation practices, crop diversification, organic farming and agroforestry.

Under the WFD planning process, authorities have largely relied on rural development plan (RDP) funding for implementing measures reducing pressures from the agricultural sector that go beyond other environmental legislation such as the Nitrates Directive (EC, 2019a). Box 4.8 presents the level of integration of water issues in the current RDPs 2014-2020).

In the new CAP 2021-2027, rural development payments will remain an important mechanism to increase the adoption of sustainable farming practices. The Commission proposals include an obligation on Member States to earmark at least 30 % of their CAP pillar 2 for funding for the environment and climate, excluding compensation payments for farming areas with natural constraints.

The farm-to-fork strategy and biodiversity strategy for 2030 call for an increase in the area of organic farming to 25 % of utilised agricultural area (UAA) by 2030. Organic farming is undergoing significant growth, but the total area remains at 7 % of UAA in Europe. In January 2021 a new EU Regulation on organic farming will come into effect and replace the existing legislation. The main benefit of the new regulation will be a further alignment of the rules for the production and control of goods produced in the EU with those for imported goods. While this will further protect the standards upheld in Europe, greater policy support will be needed if the ambitious objectives of the biodiversity strategy are to be realised.

Drawing on the lessons from the 2014-2020 programming period, a number of observations can be made on good practice for designing RDP measures (Berglund et al., 2017):

- Some RDPs, such as the one from North Rhine-Westphalia in Germany, prepared an in-depth initial 'gap assessment' synthesising water challenges and drawing on the latest data and information from the RBMPs and FRMPs. This provided a good basis for selecting relevant priorities and measures for the RDP.

- Some RDPs financed innovative approaches to dealing with agricultural pressures. For instance, the Northern Ireland RDP (United Kingdom) financed the modernisation of manure storage as well as nature-based solutions such as constructed farm wetlands.

- When drafting their measures, some RDPs went further than the minimum legal requirements. More ambitious requirements include the requirement to save at least 25 % of water if receiving support for improving irrigation efficiency (in Croatia), the establishment of buffer strips 20 m wide or more or the prohibition of pesticide application in targeted areas.

- Some countries included explicit criteria for preventing investments harmful to water bodies. For example, Latvia funded drainage schemes if they complied with the procedures of the WFD for assessing and preventing the deterioration of water bodies. Furthermore, it prioritises projects that include mitigation measures such as sedimentation ponds and wetlands.

- Some RDPs integrated climate adaptation and the need to build resilience in farming systems through appropriate crop diversification (e.g. in Greece) and adopting drought-resistant crops (in Romania).

Safeguards are particularly important to avoid counterproductive RDP investments in areas of greatest pressure. For instance, in the RDP planning period 2014-2020, it was still possible to invest in irrigation schemes that could lead to an increase in irrigated areas or the uptake of more water-intensive crops in catchments with water bodies failing to achieve good status under the WFD (Devot et al., 2020). Safeguards are needed that prevent damaging agricultural investments (e.g. in irrigation, drainage, the construction of reservoirs and flood risk prevention measures) in areas with water failing to achieve good status.

Achieving uptake at basin levels

The targeting of CAP payments towards areas in greater need of improving their water status has generally been limited until now. Direct payments were not targeted, while farmers were free to choose their greening measures and where they implemented them. RDP

Table 4.4 Measures funded by Rural Development Programmes in each programming cycle

Programming cycle	Measures in rural development plans
CAP 2014-2020	M1 Knowledge transfer and information actions
	M2 Advisory services, farm management and farm
	M4.1 Investments in agricultural holdings
	M4.3 Investments in infrastructure
	M4.4 Non-productive investments linked to the achievement of agri-environment climate objectives
	M5 Natural disasters
	M7 Basic services
	M8 Investments in forest area development and improvement of the visibility of forests
	M10.1 Payment for agri-environment-climate commitments
	M11 Organic farming
	M12 Natura 2000 and WFD payments
	M15 Forest-environmental and climate services and forest conservation
	M16 Cooperation
	M19 Leader
CAP 2021-2027	Environmental, climate and other management commitments
	Natural or other area-specific constraints
	Area-specific disadvantages resulting from certain mandatory requirements
	Investments
	Installation of young farmers and rural business start-up
	Risk management tools
	Cooperation
	Knowledge exchange and information

Box 4.8 Water-relevant measures under the 2014-2020 rural development plans

The 2014-2020 programming of the CAP rural development plans (RDPs) offered a wide choice of measures to farmers wanting to reduce the pressures of their farm operations on the water environment. These included investments in assets (e.g. modernisation of manure storage, water saving technologies, wetland and river restoration), agroforestry, agro-environment and climate operations (e.g. soil conservation techniques, conversion of arable land into grassland) and organic farming. In addition, some Member States, such as France, used compensation schemes for the compulsory uptake of measures supporting water policy (e.g. Water Framework Directive, Drinking Water Directive) objectives.

At European level, the 2014-2020 RDPs planned the following:

- 46 % of the RDPs' budget was allocated to priority 4 'Restoring, preserving and enhancing ecosystems related to agriculture and forestry'
- 8 % of RDPs budget was allocated to priority 5 'Promoting resource efficiency and a low carbon and climate resilient economy'.
- 15 % of the agricultural land within the RDP areas, equivalent to 21 million hectares, was planned to be brought under land management contracts to improve water management during the planning period. This varied greatly between Member States, with some planning to target up to 80 % of agricultural land.
- 9 % of irrigated land, equivalent to 776 842 ha, was planned to be switched to more efficient irrigation systems.
- 36 % of the RDPs' budget was to fund agro-environment and climate operations, with some RDPs allocating up to 83 % of their budgets.
- Most RDPs planned to fund organic farming.

Overall, most measures tackling water pollution from crops focused on more efficient use of fertilisers and pesticides through improved product application. Some measures put a limit on total use, sometimes targeting specific crop types, such as fruit and vegetable crops, olive groves and vineyards. More ambitious measures ban the use of pesticides. Measures for livestock focused on improving fertilisation practices for grassland and feed crops and improving manure storage and waste water treatment on farms. More ambitious measures, proposed in few RDPs, aimed to reduce stocking density.

RDPs aimed to reduce abstraction pressures predominantly by improving the efficiency of water use in irrigation systems and increasing rainwater harvesting. However, this was rarely accompanied by ambitious water-saving targets, risking the potential that most water saved would serve to irrigate more crops or more water-intensive but more valuable crops.

Few RDPs supported the conversion to less water-intensive crops, selection of crops or varieties/hybrids with a lower water demand and more resistance to droughts, or implementing water-saving crop and soil management, which are all important for adapting to climate change.

Less than half of RDPs supported changes in crop and soil management practices, such as crop rotation and low- and no-till agriculture. Few promoted more profound changes in land use, such as flood management measures, creating wetlands, remeandering rivers or converting land to agroforestry — although these measures could have multiple benefits in terms of reducing pollution, abstraction and hydromorphological pressures.

Source: Rouillard and Berglund (2017).

measures were voluntary and fewer farmers participated. However, to achieve a successful and environmentally effective transition, changes in land management need to be targeted to areas creating pressure and, where necessary, should be coordinated across whole basins. Although good practice in spatial targeting does exist, incoherence and overlaps have been observed in the types, ambition and targeting of measures under pillar 1 and 2 instruments (Devot et al., 2020).

The new CAP delivery model provides an opportunity to improve the targeting of pillar 1 payments through the eco-scheme (Lampkin et al., 2020) and with better synergies between conditionality, eco-schemes and RDP instruments. This may be effectively reinforced thanks to the obligation to involve competent authorities for the environment and climate and the obligation to show greater ambition than at present with regard to care for the environment and climate (EC, 2020c).

Box 4.9 A sustainability assessment using data from the Farm Accountancy Data Network

The farm-to-fork strategy has a proposed a Farm Sustainability Data Network. Useful insight for designing this network comes from the Horizon 2020 MAGIC project on marginal land for growing industrial crops, which analysed the feasibility of using the Farm Accountancy Data Network (FADN) data set for 2014-2017 to analyse sustainability questions. A key result of this analysis was that more environmental data in the FADN needs to be captured in terms of biophysical quantities in addition to the current focus on farm finances.

FADN is a data set based on a survey of sample farms across the EU, chosen to represent the mix of land covers (e.g. crops vs grass), land use (dairy cattle using the grass as fodder) and land management (e.g. stocking rates or the intensity of agricultural chemical use — fertilisers or crop protection). The FADN provides insight into the mix of agricultural production systems (farm types), their extents (e.g. geographical and physical outputs) and the potential pressures they can exert on water systems (e.g. from diffuse pollution or water abstraction). FADN data — if combined with spatial indicators of the state of the environment or with mathematical models — could be used to assess the environmental impacts of current agricultural practices and to enable more in-depth analysis of policy effectiveness.

However, the project also found that it will be necessary to critically review the limitations of the FADN to improve the quality of environmental indicators. Key limitations were found to be the level of aggregation of the reported data and the inability to link resource use on farms and environmental impact. The data should enable better attribution and spatialisation of environmental impacts to different farm types and systems, instead of working at a general NUTS 2 level. Furthermore, quantification in physical terms of the bulk and nature of inputs, such as the nature and origin of livestock feeds, would also provide a better indicator of the specific pressures generated within production systems. Some relevant topics were not sufficiently covered, such as crop protection data where it was not possible to assess which products were used, the rates per hectare, attribution to land covers and crucially their relative ecotoxicity and thus potential to affect water systems.

In a future monitoring system, it will be important to overcome such limitations or addressing the sustainability of future farming systems will remain challenging.

Source: Matthews et al. (2020).

The use of more water-relevant indicators in the common monitoring and evaluation framework could support a better assessment of the contribution of RDPs to water policy objectives — a task that has been challenging under the current monitoring approach (Devot et al., 2020) (Box 4.9). The current proposal for the CAP beyond 2020 emphasises a results- and performance-based approach. Quantified targets in the CAP strategic plans will need to be defined using the targets set out by water and environmental planning instruments such as the RBMPs and the nitrate action programmes. Such indicators could track progress in reducing nutrient and pesticide loads, improving morphological conditions, reducing water imbalances and meeting environmental flows.

Using a results-based approach to eco-schemes and rural development payments, whereby controls are made based on results (instead of whether particular management actions have been implemented), should increase transparency in the delivery of objectives and encourage farmers to be more innovative in the processes that they use (Lampkin et al., 2020). This should be supported by appropriate farm-level support and expert advice and peer-to-peer networking to share information and positive experiences.

Collective action and multi-stakeholder approaches are supported under RDPs, and Member States have supported them in various ways, sometimes going beyond cooperation between farmers by integrating researchers and value chain operators (ENRD, 2018). The importance of integrating value chain actors is increasingly highlighted as a critical success factor in sustaining the uptake of crop diversification and leading to reduced water pressures (Menet et al., 2018; Zakeossian et al., 2018). In Slovenia for example, beneficiaries of collective action measures include producer groups and agricultural cooperatives aiming to tackle diffuse pollution in catchments where water bodies fail to meet the WFD objectives (Berglund et al., 2017). Chapter 5 examines in more detail the role of the value chain in transforming agriculture towards more sustainable practices.

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5 The need for more systemic responses

Key messages

- Agricultural pressures on the aquatic environment have in part been resistant to policy interventions because insufficient attention has been given to the underlying drivers of agricultural production
- Increasing resource efficiency and circularity in food and energy systems are essential strategies for reducing agricultural pressures on the water environment. Yet, larger transformations of agricultural production and food and energy systems may be required to progress towards sustainability.
- Meeting Europe's sustainability goals in terms of nutrient flows and freshwater use from agriculture is possible by taking a systemic approach involving the widespread adoption of agroecology and organic production systems, combined with changing diets and cutting food waste across Europe.
- Such a systemic sustainability transition will mean mobilising value chain stakeholders throughout the production and consumption systems, from agricultural producers to retailers and consumers. Public policies at EU and Member State levels have an important role in facilitating such collective action.
- There has been a shift towards greater policy coherence and integration in recent years. The European Green Deal and its instruments, such as the farm-to-fork strategy, are examples of such systemic policy thinking. Their implementation will be key in making progress in future.

5.1 Introduction

Across Europe, pressures from agriculture on the water environment have been resistant to policy interventions (see Chapters 3 and 4). Some of the barriers to further improvements can be found in the underlying drivers of agricultural production that have not been sufficiently tackled. These drivers are diverse, and include socio-economic pressures from the need to maximise profit and secure income for both farmers and the agricultural product industry, as well as wider drivers of population growth, societal demand for food, energy and fibre, and a changing climate. Without addressing these drivers, and the social, economic, political, institutional and technological systems that shape consumption patterns, it is likely that policy interventions will continue to fix the symptoms rather than the root causes of environmental degradation, which is likely to increase under a changing climate if no adaptation measures are taken.

The European Green Deal recognises the importance of taking a more systemic approach to tackling environmental issues. In the area of food policy, the farm-to-fork strategy published in 2020 aims to make food systems more sustainable, environmentally friendly, fairer and healthier. Transitioning towards sustainability in the food system should bring new opportunities for farmers to become more sustainable and resilient and reduce the overall impact of agricultural production on the water environment.

This chapter presents the systemic linkages between food, energy and other drivers of agricultural production and the water environment. It explores the trade-offs involved in meeting societal demand and achieving sustainability of water resources, and it illustrates how taking an integrated and systemic approach offer new opportunities to tackle agricultural pressures on the water environment, while offering a more sustainable and resilient future for European citizens and businesses.

5.2 A systems perspective on water and agriculture

5.2.1 Food systems

A food system can be defined as all the elements (environment, including climate, people, inputs, processes, infrastructures, institutions) and activities that relate to the production, processing, distribution, preparation and consumption of food and to the outputs of those activities, including socio-economic and environmental outcomes (HLPE, 2014).

European food systems evolved greatly during the 19th and 20th centuries, from predominantly local systems of exchange into complex international networks of production, consumption and trade. Today, they exhibit widely diverse characteristics across the continent. Small-scale family-based producers supplying short supply chains operate alongside large-scale globalised food companies and suppliers (EEA, 2017b). Transforming European food systems towards sustainability therefore requires taking account of local drivers of, as much as global demand on, the food commodity markets.

Demography and diet are central drivers of the food system. Between 1950 and 2015, the EU-28 population increased from 380 million to 505 million (EEA, 2019b). The average per capita consumption of animal protein is 50 % higher now than it was in 1950, and it is double the current global average (Westhoek et al., 2011). Globally, population growth and dietary change towards more meat- and dairy-based diets are expected to increase the demand for food in 2050 by 70 % (FAO, 2009) or 56 % more crop calories equivalent (Searchinger et al., 2018).

Under current trends, meeting the growing global demand for food would require either an increase in the area of farmland or an increase in agricultural productivity on the existing land area, achieved in part through more intensive use of inputs such as fertilisers and pesticides (Searchinger et al., 2018). However, these developments would contribute to further loss of forest, wetland, peatland and other natural habitats, more leaching of pollution and consumption of irrigation water, and additional drainage to bring land into production (Wirsenius et al., 2010; Gerten et al., 2020). If the present global trends in food production continue, it is estimated that two out of every three people on Earth will live in water-stressed conditions as soon as 2025 (WRI, 2019).

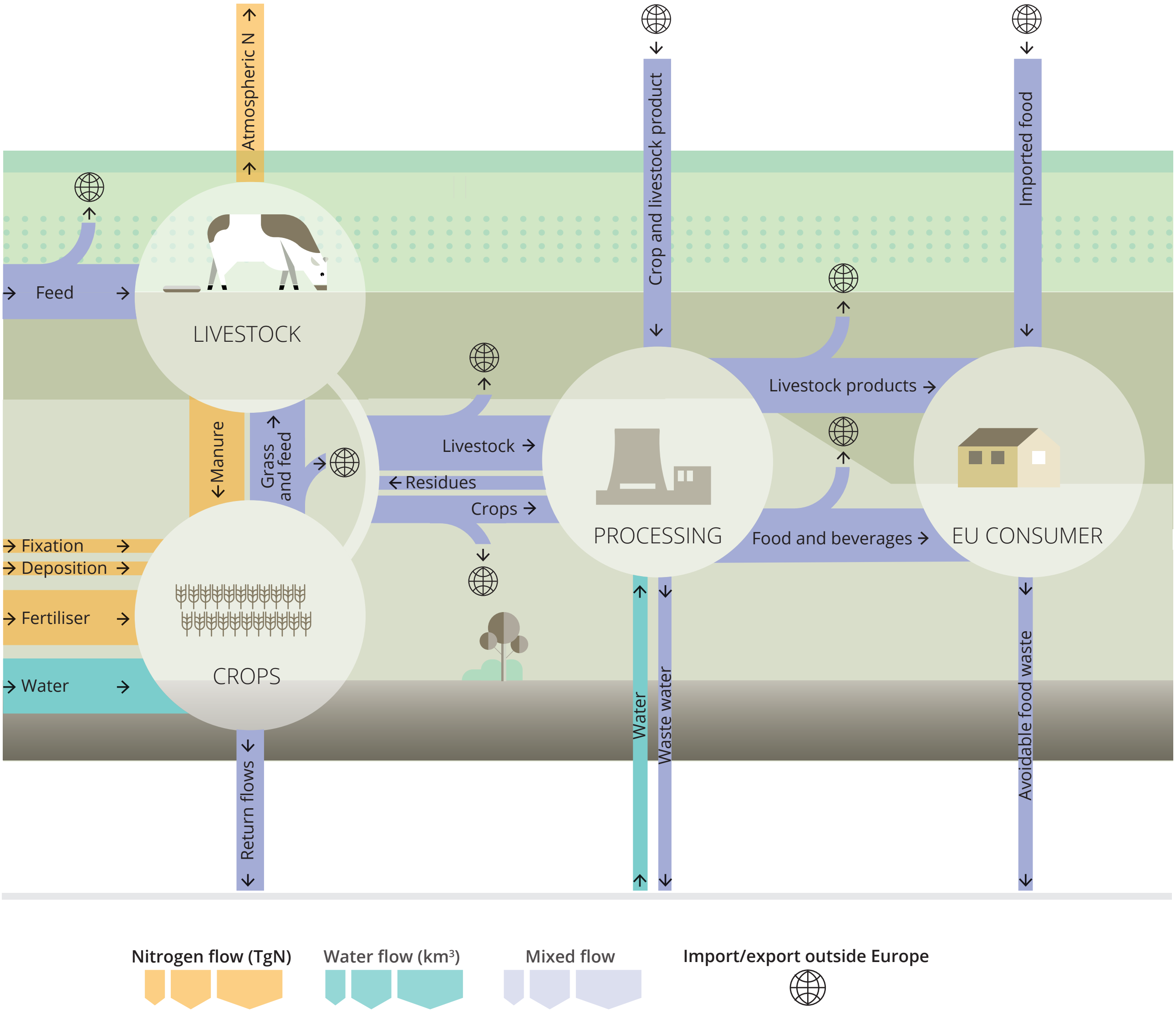
Climate change itself will significantly impact the distribution of natural resources essential for food production, such as water, and will impose drastic changes in climatic conditions in many world regions. Soil erosion, land degradation and desertification rates will put further constraints on global agricultural production (Shukla et al., 2019). Productive land may be lost, putting more pressure on the most productive areas and driving the further expansion of farmland into natural and semi-natural areas.

Without a fundamental change in food systems, the impacts of food production and consumption on the water environment are likely to increase. Food systems are linked to the emission of pollutants and the abstraction of freshwater during crop and livestock production, food and drink processing, and consumption at household level (Castellani et al., 2017). Major losses of nutrients and other pollutants occur throughout the food system. Of the total input in the form of nitrogen and phosphorous fertilisers used in crop and livestock production, only 20-30 % is actually embedded in the food that reaches consumers (Figure 5.1).

Studies have shown that large proportions of nutrient losses into water and air and agricultural water use are related to the expansion of the livestock sector to meet demand for meat and dairy products (Sutton and UNEP, 2013; Buckwell and Nadeu, 2016). About 88 % of the nitrogen embedded in EU crops is used to feed livestock, and the majority of this nitrogen is added to crops as synthetic fertilisers and animal manure (EEA, 2017b). At the same time, nearly 98 % of the water needed to raise livestock is used on feed crops and grazing land. Overall, animal products represent 53 % of the water consumed to grow food in Europe, followed by cereals and beer (11 %) and vegetables, fruits, nuts and wine (9 %) (Vanham et al., 2013).

In addition, the livestock sector in Europe relies not only on feed produced in Europe but also on imported feed, for instance soybean from the Americas. This represents a net import of nutrients into the European environment (embedded in feed). Feed production abroad also exerts large pressures on natural resources in export countries, driving diffuse pollution and unsustainable water use in export countries (Rosa et al., 2019) and externalising the associated pollution from raising livestock in Europe.

Figure 5.1 Nutrient and water flows in the European food system



Source: Vanham and Bidoglio (2013).

5.2.2 *The wider bioeconomy*

Agricultural products are used in the broader bioeconomy for non-food purposes such as energy, textiles, paper, chemicals and pharmaceuticals. Bio-based products can be made from cereal, oil, sugar and fibre crops, straw and organic waste. These products respond to drivers different from those for food products, and have in recent years received significant attention at EU level. In Europe, around 10 million hectares or 5 % of the agricultural area is used to grow non-food agricultural products (Fischer et al., 2017; Bruckner et al., 2019).

Bioenergy refers to a range of energy sources based on biological matter. Bioenergy from agricultural sources is typically produced as liquid biofuels that work as a substitute for diesel and petrol from maize, rapeseed, palm oil, sugar beet and sugar cane. Bioenergy is part of the EU's energy portfolio for its decarbonisation efforts and expansion of its use of renewable energy (EC, 2019d).

By 2030, the EU aims to have at least 32 % of its energy from renewable sources, and by 2020 it aimed to have 10 % of its transport fuel coming from renewable sources such as biofuels. Fuel suppliers are also required to reduce the greenhouse gas intensity of the EU fuel mix by 6 % by 2020 in comparison to 2010. The average share of renewable energy in transport in the EU-28 was 8 % in 2018 (EEA, 2019i) and was mostly met through consumption of biofuels.

Europe's production and consumption of bioenergy, in particular biofuels, has raised concerns about their environmental impacts in Europe and worldwide, for example through the expansion of agricultural land into biodiversity-rich and high-carbon stock land, such as forests and peatlands (EC, 2019d; Strapasson et al., 2019).

Levels of concern are high regarding fertiliser and pesticide pollution of water and the significant demand for water associated with biofuel production. For instance, European production of bioethanol is associated with irrigated maize grown under water-scarce conditions in Mediterranean regions in France and Romania (Vanham et al., 2019). Assessments indicate that, of all the energy sources used in Europe, biofuels generate the highest net consumption of water (Vanham et al., 2019). Overall, it is estimated that the majority of maize consumed for biofuel in Europe is produced under severely water-scarce conditions (Vanham et al., 2019).

In 2012, about 62 % of the feedstock used in biodiesel and 79 % used in bioethanol originated in the EU, mostly from rapeseed, wheat, maize and sugar beet (Hamelinck et al., 2014). The remaining was imported as, for example, palm oil, soybeans and maize feedstock or as final product, from various regions, including Argentina, Australia, Indonesia, Malaysia and the United States. It is estimated that imports of biodiesel account for 64 billion m^3 of water compared with 1 billion m^3 for European sources, due to less efficient production methods (Vanham et al., 2019).

Other bioeconomy value chains are based on a variety of crops and agricultural by-products. The fibre crops grown include cotton, flax, hemp and bamboo for making textiles, but plants are also used for building materials, cosmetics, medicines and chemicals. Cotton is by far the most cultivated fibre crop worldwide, with more than 30 million hectares corresponding to 80 % of the global natural fibre production. However, cotton is a highly water-intensive crop. Europe imports most of its cotton, putting pressure on water resources outside Europe.

A range of new fibre crops is being grown in Europe with the aim of reducing the environmental impact of non-food agricultural production. Such crops include, for instance, *Miscanthus*, giant reed, switchgrass and bamboo, which are low-input, high-yield crops and can be used for paper-making, building, biopolymers and bioenergy purposes.

The demand for non-food agricultural products is likely to grow in response to the drive towards a more circular bioeconomy. Under the EU's bioeconomy strategy, the flagship initiative for a resource-efficient Europe, and the circular economy package, the EU's industrial policy aims to increase the bio-based product industry's share of the EU's gross domestic product (GDP) from 15 % to 20 % in 2020, stimulating primary production and conversion of waste into value-added products.

Demand is thus expected to grow for biodegradable and recyclable materials based on agricultural production that work as substitutes for chemicals based on fossil fuel resources. However, the impact of growing non-food agricultural products on the water environment will need to be taken into account when developing their production, and we need to seek coherence between growing a bioeconomy and protecting natural resources.

5.3 Tackling systemic challenges

5.3.1 Sustainability transitions

The EU has a long-term sustainability vision of 'living well, within the limits of our planet' by 2050. This means that consumption systems driving agricultural production should optimise outcomes taking into account the need for affordable products, social well-being and fairness, and the protection of natural resources, while maintaining and enhancing ecosystem health and resilience (EEA, 2017b). To achieve such sustainable outcomes, a fundamental transformation of agricultural production systems and the linked consumption systems needs to occur.

Over recent years, there has been a multitude of innovations aiming to transform agricultural production systems and the linked food and energy systems and the wider bioeconomy, which have the potential to benefit water sustainability goals. In agriculture, incremental innovations include, for instance, precision farming, which contributes to the more efficient use of fertilisers or water. Others are more radical, such as no-tillage and organic farming, which involve a more fundamental change in farming practices. In food systems, the widespread adoption of vegetarianism or the development of alternative food networks are examples of behavioural and social sustainability innovations (EEA, 2019h).

Yet, sustainability transitions are highly complex and uncertain processes and occur at different speeds in different places and at different levels (EEA, 2019h). They cannot be pre-designed by governments and cannot involve implementing a single solution for all. Instead, sustainability transitions can be facilitated by nurturing the emergence and dissemination of innovations, ideas and approaches. Experimentation, learning and adaptation are essential ingredients of sustainability transitions (EEA, 2019h).

The growing demand for food, energy and other non-food agricultural products in a resource-limited world will bring unavoidable trade-offs between the three pillars of sustainability, i.e. the economic, social and environmental dimensions. To manage these trade-offs in a fair and equitable way, increased collaboration and designing appropriate institutional, social and political responses will be essential.

5.3.2 Managing trade-offs

Progress in reducing agricultural pressures on the water environment is ongoing, and a number of efficiency gains in nutrient and water use have been achieved in the past 30 years (Chapter 3). Some studies indicate, for instance, some decoupling between yields and nitrogen application in Europe, with an observed increase in yields and a reduction in mineral nitrogen application of around 10 % between 1990 and 2007 (Levers et al., 2016). It is estimated that further efficiency gains are still possible without affecting agricultural productivity, for instance by implementing more widely balanced fertilisation techniques and by increasing water productivity through more efficient water use and appropriate crop selection. Technological innovations are ongoing, for instance with progress in genetic research and precision farming (Capper and Bauman, 2013)

Much of the emphasis of EU policies focuses on fostering technological innovation to enhance efficiency and circularity in the use of natural resources, including water, as emphasised in the recent circular economy action plan to 2030. A more circular economy can help to reduce waste, pollution and water abstraction in agriculture and the linked food and energy systems. For example, the recent adoption at EU level of the Regulation on water reuse aims to facilitate waste water reuse in irrigated agriculture to reduce freshwater demand from agriculture. Other initiatives aim to design out waste and pollution, for instance by exploiting food waste and agricultural residues as second-generation biofuels and bioenergy sources.

Yet, the scale of change needed to reduce pressure on the water environment from agriculture is large and the benefits of efficiency gains not always clear. Reductions in pressures from agriculture on the water environment have been incremental so far and are insufficient to reach the EU's sustainability goals. Efficiency improvements are often offset by growth in demand, as observed in irrigated agriculture (see Section 4.2.1).

More fundamental changes in agricultural production, by adopting agroecological principles or organic farming, have considerable potential to reduce pressures on the water environment. For instance, extensifying agriculture or promoting the large-scale adoption of agroecology in Europe has the potential to bring nutrient flows to sustainable levels (van Grinsven et al., 2015; Poux and Aubert, 2018). However, this would entail trade-offs with crop productivity and livestock production, which could decline by up to 30 % and 40 %, respectively (Poux and Aubert, 2018). Such levels of reduction in production and yields would disrupt existing farm systems and value chains and could entail an increase in the price of agricultural products, which would affect the consumer. It could also encourage further imports of animal feed or meat and dairy products from outside Europe (Poux and Aubert, 2018).

Studies at the global level have concluded that reaching key planetary boundaries in nutrient flows, freshwater use and other environmental criteria is possible with changing farming practices. However, diets would need to change and food waste be cut (Wirsenius et al., 2010; Westhoek et al., 2014; Muller et al., 2017; Poore and Nemecek, 2018; Searchinger et al., 2018; Gerten et al., 2020).

In particular, a reduction in meat and dairy product intake in favour of plant-based proteins is key to avoiding competition for arable land and grassland and to avoiding other negative side effects, such as an expansion in the area of farmland to compensate for the lost productivity.

Systemic transitions towards agroecology or organic farming are more radical, but they are also closely aligned with the increasing calls from citizens for healthy food and organic produce. They also have a range of other benefits, such as increasing the diversity of agricultural production, reducing farm input costs and farmers' financial risk, reducing greenhouse gas emissions, and preserving wildlife and biodiversity (van Grinsven et al., 2015; EEA, 2017b; FAO, 2018a; Poux and Aubert, 2018; EIP-AGRI, 2020).

The global need for changes in global production and consumption patterns are at the heart of the United Nations Sustainable Development Goals, which underscore the interdependencies among many different societal factors, together with the potential gains of a more sustainable development trajectory. To reduce trade-offs and manage sustainable transitions, policy action needs to be systemic across production and consumption systems. In food systems, for instance, this calls for solutions that involve not only producers but also food chain actors and consumers and for reorganising the whole food value chain (Westhoek et al., 2014).

5.4 Transitioning towards sustainability in food systems

While the EU food system has been very successful in achieving its past objectives of food security and food safety, it has to date failed to deliver sustainability (EEA, 2017b; GCSA, 2020). The recent EU farm-to-fork strategy (EC, 2020e) is the first step towards tackling the impact of agricultural production and food consumption in an integrated and systemic way. It envisages action on several dimensions, focusing on enhancing the capacity of Europeans to make informed, healthy and sustainable choices about their food environment, while increasing the efficiency of the food system. The strategy takes into account targets for sustainable water management in its overarching objectives of reducing nutrient and pesticide use and boosting the development of sustainable agriculture, in particular organic farming.

Stakeholders at multiple levels of a food system can take numerous strategies to enable a transition towards sustainability in agriculture (Figure 5.2). This section discusses three strategies that have been highlighted in the farm-to-fork strategy and other publications on reforming food systems to achieve sustainability (GCSA, 2020) in the light of agricultural production and its impact on the water environment:

- changing supply chains to promote sustainable and more resilient agricultural systems;
- stimulating more sustainable diets to reduce the demand for water-intensive food products;
- reducing food loss and waste and encouraging their reuse and recycling.

5.4.1 Changing food supply chains to promote sustainable agriculture

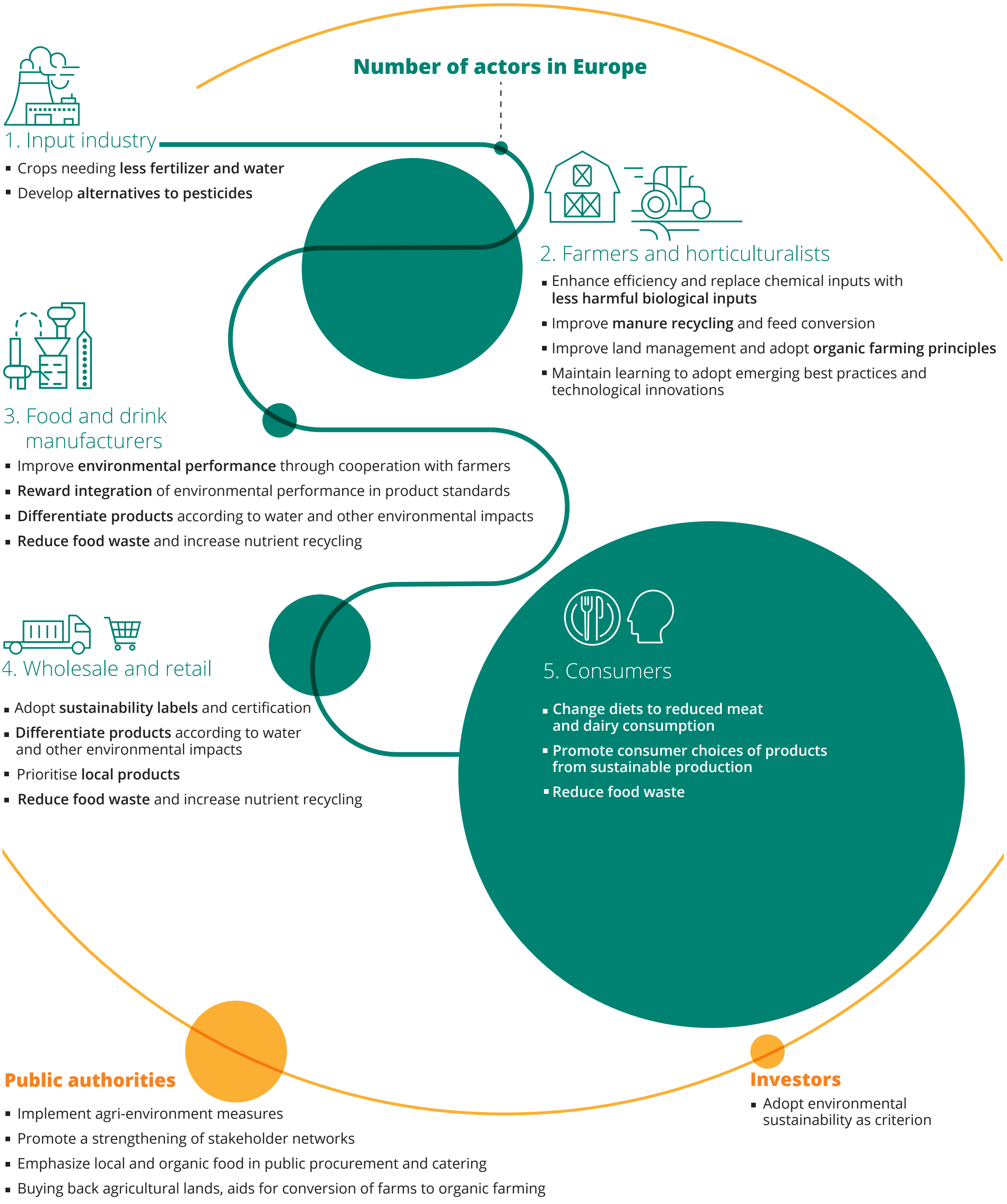
The structure of the value chain has significant implications when designing responses to enhance the sustainability of agricultural production in Europe (Meynard and Messéan, 2014; GCSA, 2020). It also has a role to play in increasing the food system's resilience to climate change by planning adaptation pathways not only for the production sector (farming systems) but also for investments into infrastructure for collecting, storing and transforming agricultural commodities (ADEME, 2019). The risks and opportunities of adopting agroecological practices, diversifying production and adapting to climate change must be shared between farmers and value chain stakeholders.

Value chain operators have optimised the collection, storage and processing infrastructure in accordance with the cost reduction targets and economies of scale needed to compete in national, international and global markets (IPES Food, 2016; EEA, 2017b). Diversifying crops or switching to organic farming implies upfront costs to adapt and expand the specific supporting infrastructure as well as higher running costs for lower volumes of agricultural commodity. These difficulties can represent a major barrier for expanding organic farming or diversifying farm production in specialised regions (Meynard and Messéan, 2014).

The importance of enabling changes in agricultural production through a value chain logic is increasingly emphasised (Meynard and Messéan, 2014; IPES Food, 2016). It calls for a high level of collective action between relevant stakeholders and better structuring between the agri-food sectors (Zakeossian et al., 2018). EU rural development programmes have in some cases supported such collective action. In Greece for example, the authorities supported greater coordination between durum wheat processing plant operators and local cotton-producing farms to initiate a transition from cotton production to durum wheat production, leading to a reduction in water consumption. In Cyprus, potato farmers were encouraged to switch to less water-intensive fodder production in response to increasing demand from livestock farmers faced with rising prices of imported feed.

Other strategies are possible to overcome the cost of creating the infrastructure for the collection, storage and transformation of diversified crop production or organic farming. For example, preferential loans or subsidies on investments in infrastructure supporting diversification in specialised regions or to facilitate the development of organic farming have been provided, for example through rural development programmes (Zakeossian et al., 2018).

Figure 5.2 Measures or actions that can be taken by food chain actors



1. Input industry

- Crops needing **less fertilizer and water**
- Develop **alternatives to pesticides**

2. Farmers and horticulturalists

- Enhance efficiency and replace chemical inputs with **less harmful biological inputs**
- Improve **manure recycling** and feed conversion
- Improve land management and adopt **organic farming principles**
- Maintain learning to adopt emerging best practices and technological innovations

3. Food and drink manufacturers

- Improve **environmental performance** through cooperation with farmers
- **Reward integration** of environmental performance in product standards
- **Differentiate products** according to water and other environmental impacts
- **Reduce food waste** and increase nutrient recycling

4. Wholesale and retail

- Adopt **sustainability labels** and certification
- **Differentiate products** according to water and other environmental impacts
- Prioritise **local products**
- **Reduce food waste** and increase nutrient recycling

5. Consumers

- **Change diets to reduced meat and dairy consumption**
- **Promote consumer choices of products from sustainable production**
- **Reduce food waste**

Public authorities

- Implement agri-environment measures
- Promote a strengthening of stakeholder networks
- Emphasize local and organic food in public procurement and catering
- Buying back agricultural lands, aids for conversion of farms to organic farming

Investors

- Adopt environmental sustainability as criterion

Sources: EEA, (2017b); Magrini MB. et al. (2019).

Cities and municipalities have also created their own collection and storage food cooperatives to supply organic food to public canteens.

The value chain can play an important role in changing agricultural practices in other ways. The food industry has increasingly established product specifications that farmers must follow to access markets (Fresco et al., 2016). These standards, in the form of production contracts and labels, typically include assurances that specific crop and livestock operations will be carried out and that final product delivery meets the desired quantity and quality. Integrating results-based, environmental performance in these standards, and rewarding it accordingly to account for potentially higher production costs, can act as a major leverage on agricultural production. Some food operators have integrated ambitious programmes. The common agricultural policy (CAP) could support further expansion of such private schemes (Fresco et al., 2016).

CAP support schemes have encouraged the adoption of more environmentally friendly practices, and such support schemes could go further in supporting the transition. However, the uptake of more sustainable farm practices will only last if the market takes over from public interventions. The higher costs of producing more sustainably can be covered through product differentiation and the use of certification and labels (ADEME, 2014; Meynard and Messéan, 2014). Alternatively, the greater use of minimum sustainability standards on food products can support a broader and more systematic market uptake by levelling the playing field. The farm-to-fork strategy (EC, 2020e) proposes to progressively raise the sustainability standards of all food products placed on the EU market and to support certification and labelling initiatives.

A number of public and semi-public interventions are increasingly used to provide alternatives to compensation schemes provided under the CAP (Chapter 4) or to overcome the lack of intervention from private food chain operators. This includes, for instance, drinking water providers across Europe, and food boards, such as Bord Bia (Bord Bia, 2020), which have initiated schemes based on payments or on the buying and leasing of agricultural land to encourage more sustainable forms of production (Thomson et al., 2014; Cook et al., 2017).

Under the EU farm-to-fork strategy, the Commission plans to determine the best modalities for setting minimum mandatory sustainability criteria in public procurement. This represents a significant leverage for expanding the supply of more sustainably produced food and promoting sustainable diets in schools, public institutions and collective canteens (Renting and Wiskerke, 2010; IPES Food, 2016). Some cities seek co-benefits to preserve the quality of their drinking water supplies by targeting public food procurement contracts at producers in drinking water protected areas, thereby encouraging the uptake of more sustainable forms of agriculture.

5.4.2 Moving to sustainable diets to reduce water use and emission of pollutants

Demand from consumers is a fundamental driver in the food system. Recent years have seen an acceleration of the adoption of less water resource-intensive diets, by reducing meat consumption and increasing the share of vegetables and plant-based products. To reduce nutrient emissions and the water used in growing feed crops and rearing livestock, diets should contain less meat and dairy products overall, small amounts of high-quality meat and an increased share of plant-based protein types.

Estimates suggest that a switch to a vegetarian diet could reduce the use of water needed to meet the demand for food from southern European countries by 41 % and by 32 % in the case of northern countries (Vanham et al., 2013). Studies on the effect of diets on nitrogen emissions suggest that halving meat, egg and dairy consumption in the EU could achieve a 40 % reduction in reactive nitrogen emissions into water and air and a 25-40 % reduction in the emissions of greenhouse gases, assuming corresponding changes in livestock agricultural production (Westhoek et al., 2014).

Consumer preferences are shaped by the food system and constrained by norms and conventions, cost, convenience, habit, and the ways in which food choices are presented (EEA, 2017b). Influencing the food environment could be an important lever for change with regard to dietary composition and supporting more environmentally sustainable production. Awareness-raising campaigns and food labelling have roles in influencing choices and behaviours, but a food environment conducive to sustainable diets would shift costs on to unsustainable choices and make sustainable choices the easiest option (GCSA, 2020).

The EU's farm-to-fork strategy does not commit to stopping stimulating the production or consumption of meat, but it offers support for alternative proteins and a move to a more plant-based diet. It proposes to strengthen food labelling standards to support consumers in making sustainable diet choices, including high-quality meat production but also diets based on alternative protein sources such as plant products.

Additional targets could also be set to support greater adoption of sustainable diets in public and private catering centres, such as hospitals, schools and large companies. For example, the Law on trade relations in the agricultural and food sector in France aims to achieve a 50 % share of good-quality and sustainable food products in catering centres, including 20 % of organic food by 2022. Other instruments have been proposed, such as taxing animal products (Vinnari and Tapio, 2012) or expanding short supply chains (Box 5.1).

Although the capacity of short supply chains and alternative food networks to meet the challenges of feeding the European population is often questioned, their role in fostering more sustainable eating habits and well-being is well acknowledged. Recently, with the global pandemic due to SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2), short supply chains have played a role in maintaining food deliveries to customers, showing their capacity to innovate and take advantage of online digital tools (RMT Alimentation Locale, 2020). Short supply chains have several advantages, from supporting the emergence of new local outlets and more diversified agricultural production to increasing the value of agricultural products, improving producers' incomes, enhancing social cohesion and reducing CO_2 emissions because of the reduced need for transport (IPES Food, 2016).

5.4.3 *Reducing food waste to increase the efficiency of water use across the supply chain*

An estimated 20 % of food is wasted in the EU, of which as much as half is lost at household level (Vittuari et al., 2016). The remainder is lost in processing (19 %), food services (12 %), production (11 %) and wholesale and retail (5 %). Reducing food waste thus requires tackling losses that occur during separate steps of the food system, involving different actors and very different waste processes. The recent farm-to-fork strategy (EC, 2020e) calls for cutting per capita food waste at retail and consumer levels by half by 2030 and reducing food losses along the food production and supply chains. Global water savings of approximately 250 km³ of water each year may be achieved by reducing food waste (FAO, 2013).

Waste reduction is tackled at EU level by the Waste Framework Directive (Directive 2008/98/EC) (EU, 2008a). The EU circular economy policy (EC, 2020d) encourages the adoption of a circular model, which, if applied to food systems, would encourage not only a reduction in waste based on lower production and consumption levels but also the reuse and recycling of irreducible food waste. Valuing food waste in this way aims to reintroduce food waste into the production cycle, which could further reduce the demand for additional primary commodities.

This integrated approach to food waste management should take account of a number of critical issues from a water and agriculture perspective. First, there needs to be an emphasis on the recovery of nutrients. An estimated 80 % of nitrogen and 70 % of phosphorus are wasted across the food system. Most of these losses occur at production level and warrant adequate measures for reducing the leaching and recycling of nutrients at farm and local levels. Increasing the efficiency of nutrient use is also possible by recycling food waste as animal feed or as compost at the food processing and retailing stages. Reusing waste water

Box 5.1 Short food supply chains

Short food supply chains, such as the direct distribution of agricultural products, collective direct sales and partnerships, lead to regionalisation of markets and can reduce farmers' dependence on large-scale, powerful retailers. Short food supply chains can reduce competition and increase farm income. Furthermore, short food supply chains can strengthen the local economy and help to keep small and family operated farms in business.

There is a great diversity of short food supply chains and local food systems in the EU. Short food supply chains and local markets have flourished here in recent years in both rural and urban areas. On average, 15 % of EU farms were selling more than half of their production directly to consumers through these short supply chains in 2015. In the same year, local food systems provided food for almost half a million Europeans, in particular in France, Belgium and Italy. Short food supply chains tend to be characterised by full or partial organic farming, but they are not always certified.

The rural development programme 2014-2020 puts more emphasis on short food supply chains. Several measures are co-financed by the European Agricultural Fund for Rural Development to help in setting up and developing short food supply chains and local food systems through support for investment, training, adopting the Leader approach and organising producers.

Sources: Kneafsey et al. (2013); IPES Food (2016).

can exploit household losses after consumption as sewage sludge for field application and as irrigation water. The Sewage Sludge Directive (EEC, 1986) and Water Reuse Regulation (EU, 2020a) encourage these practices.

Alternative approaches would enhance the synergies between food and energy systems. Technologies for producing biogas exist to exploit crop waste and manure and to increase nutrient recycling at farm and local levels. This solution can also reduce farm energy costs and represent an additional source of income. Waste along the food chain could also be exploited by larger units.

5.5 The need for policies supporting systemic responses

To move towards sustainability, future policy responses will need to be systemic and maximise opportunities for positive environmental change along the whole agricultural production system and linked consumption systems (EEA, 2019h). In the past, much of the European policy framework tackling agricultural pressures on the water environment has focused on regulating agriculture, and less so on tackling drivers in food and energy systems and in the broader bioeconomy. Integrated responses should aim to align water, agricultural, food, energy, climate, trade, and other environmental and sectoral policies, considering transversal and cross-cutting dimensions (FAO, 2014b; Venghaus and Hake, 2018).

In recent years, there has been a shift towards greater policy coherence and integration and to tackling Europe's challenges in a systemic way. The European Green Deal, and its instruments, such as the farm-to-fork strategy, are examples of such systemic policy thinking. Sustainable finance is also essential to boost financial resources for implementing sustainable farming practices, as progress made under the Taxonomy Regulation (EU, 2020b) shows. Decoupling environmental degradation and economic development — and moving to a greener and more resource-efficient economy — has become a priority, but it requires implementation and more needs to be done to become more sustainable. This transformation will also be needed to adapt to the impacts arising from climate change.

Photo: © Erik Witsoe, Unsplash

6 The way forward

The transition towards sustainability at the interface between water and agriculture will be a challenging task that will not be solved only by traditional policy interventions. Responding more effectively to sustainability challenges will require a better understanding of the conditions and mechanisms that drive agricultural production, with particular focus on consumption systems around food, energy and fibre. As this report documents, an elaborate system of management measures is in place across Europe to manage the pollution, water abstraction and hydromorphological pressures associated with agricultural production. The report also points to potential improvements in management and policy. Responding to these challenges is becoming urgent, since climate change impacts in parts of Europe are becoming severe enough to potentially jeopardise water availability for crops and to increase pollution and hydromorphological pressures, putting agricultural production itself at risk.

In recent decades, more resource-efficient farming practices have been adopted in European farming systems, which has contributed to declining pressures on water. However, the system remains far from sustainable. Less resource-intensive farming systems are needed to further reduce pressures on water, and, although not a subject discussed in this report, they would also benefit air quality, by reducing air pollution, biodiversity and soils and help mitigate climate change. Such systems would also further enhance the resilience of agricultural production to climate change.

The uptake of more sustainable farming systems depends critically on their being attractive to the individual farmer and the operators of the value chains benefiting from agricultural production, and thus they must take account of farmers' incomes, societal lifestyles, consumer demands and overall market forces. The European and global consumer preferences of citizens and industries are extremely important drivers of food production and prices. These interlinkages are complex to apprehend and manage. However, holistic responses taking account of water, agriculture and food systems are needed to make progress towards achieving the objectives of the European Green Deal.

With its ambitious policy initiatives, including the proposed European Climate Law and the adaptation strategy, biodiversity strategy, farm-to-fork strategy and zero pollution action plan, the European Green Deal has articulated the ambition to move Europe on to a more sustainable development path in line with the Sustainable Development Goals.

Sustainability is a central concept in these policies, but, although the messages are clear in terms of targets, a better understanding of how to reach them is needed. For example, reducing fertiliser use by at least 20 % and pesticide use by 50 %, and expanding organic farming to encompass 25 % of the agricultural land area are powerful and clear objectives set in the biodiversity strategy for 2030 and farm-to-fork strategy, but a better understanding of the systemic challenges that need to be overcome to achieve the targets is needed. Sustainable solutions will not be realised by targeting change in one area but by a large-scale and probably also long-term effort to jointly restore nature, reduce pollution to air, water and soil in an integrated approach, improve efficient resource use, incentivise and implement more sustainable farming practices, and change consumer demand and other drivers of consumption systems.

As part of making progress towards achieving more sustainable agriculture, this work points to three areas of improvement: (1) more resilient management actions; (2) improved implementation and integration of EU policies; and (3) more holistic and global approaches through systems thinking.

6.1 More resilient management actions at farm and basin level

This report has shown that a wide variety of management measures exists to tackle agricultural pressures on the water environment. To date, most measures implemented have sought to improve water management and increase the efficiency of resource use in agriculture. As a result, the exponential growth in agricultural pressures observed in the 20th century has stabilised. Nevertheless, while some reduction in pressures has been observed, the current level of resource use in agriculture (water, nutrients and pesticides) remains unsustainable. In addition, hydromorphological pressures need to be reduced.

In coming decades, the impact of global warming on water resources is likely to become stronger. It will result in increased levels of unpredictability and uncertainty for farmers and public authorities alike. This makes more urgent the need to develop resilient agricultural systems to buffer both the impacts of climate change on agricultural production and farmers' livelihoods, and its impacts on aquatic ecosystems.

Three areas of improvement for management at farm and basin levels are highlighted: (1) developing more sustainable and resilient systems; (2) setting out clear limits for resource use in agriculture; and (3) establishing knowledge systems. Many of these recommendations are already being implemented, but they need wider uptake and streamlining across Europe.

Developing more sustainable and resilient agricultural systems:

- **Expand the area of sustainable agriculture, such as agroecology and organic farming.** Sustainable agricultural systems increase resource use efficiency and circularity (e.g. nutrient recycling, storing rainfall water in soils) and build diversity and resilience in agroecosystems by exploiting ecosystem dynamics and synergies. They enhance farm resilience by reducing reliance on inputs and diversifying farm production. Policies and market forces need to acknowledge the upfront costs of these strategies for farms. This is discussed in Sections 6.2 and 6.3, respectively.

- **Promote multifunctional options.** In an uncertain future, it is important to avoid costly investments that may not provide the anticipated levels of return. Measures such as ecosystem restoration, nature-based solutions and natural water retention measures, such as restoring floodplain dynamics or restoring landscape-wide natural infiltration, are no-regret measures that can contribute to reducing pollution pressure, restoring hydrological cycles and enhancing river basin resilience, for instance by increasing water storage in soils and groundwater. They also contribute to multiple environmental objectives, such as reducing flood risk, increasing biodiversity and reducing greenhouse gas emissions.

Setting limits on resource use:

- **Further specify critical thresholds at river basin and farm levels.** Each river basin and aquifer and their agricultural land management have unique biophysical, social and economic conditions. There is not a one-size-fits-all response — hence general sustainability principles must be transcribed into local conditions to make them operational for river basin authorities and farmers. This implies defining river basin carrying capacities and setting targets for water management and agricultural practices. Water management targets could include limits for maximum nutrient loads or maximum volumes and rates of water abstraction in a particular basin, considering too the future impacts of climate change.

- **Set out sustainability standards.** Targets for sustainable agricultural practices could include those at river basin level in terms of the area under organic or low-intensity farming, and standards for nutrient, pesticide and irrigation application rates. Solutions of this nature are addressed by the farm-to-fork and biodiversity 2030 strategies.

Establish effective knowledge systems:

- **Make best use of new technologies.** The agricultural sector is changing rapidly in response to the development of new technologies, from robots to information and remote sensing, improving forecasts, crop monitoring and the responsible use of resources. Member States and the EU fund a broad range of research and development activities. Programmes such as Horizon 2020, LIFE+, Interreg and the European innovation partnerships promote innovation and knowledge creation and exchange across the EU. Authorities may also benefit from improved monitoring of agriculture, for instance to improve understanding of the scale and spatial variability of agricultural pressures (e.g. application of nutrients and pesticides, metering and monitoring of water use) and of the performance of different responses.

- **Accompany transformations at farm level**. Farmers will need support to identify how to diversify production effectively, reducing pressure while increasing their physical, economic and social resilience to global change. In this regard, farm advisory services and peer-to-peer networks are essential for spreading innovation and promoting exchange of ideas. They will also need adequate finance and incentives from private market operators in the food system and broader bioeconomy (Section 6.3).

6.2 Improved implementation and integration of EU policies

The EU has a comprehensive environmental and climate policy framework, developed over decades, that has contributed to tackling agricultural pressures on the water environment. However, a lack of implementation has impeded their successful realisation, and implementation needs to be accelerated. At the same time, the farm-to-fork and biodiversity 2030 strategies have established ambitious new targets:

- to reduce fertiliser use by at least 20 % and nutrient losses by 50 % while ensuring that there is no deterioration in soil fertility fertility, among others building on an integrated nutrient management action plan;
- to reduce by 50 % the overall use of and risk from chemical pesticides and the use of the more hazardous pesticides by 50 % by 2030;
- to reduce by 50 % the sales of antimicrobials used in farmed animals and aquaculture;
- to have 25 % of agricultural land organically farmed by 2030;
- to have 10 % of the agricultural area designated as high-diversity landscape features by 2030;
- achieve EU commitments on land degradation neutrality.

To achieve these targets, greater coherence is also needed between EU environmental policies and the common agricultural policy (CAP). Recent decades have seen improved integration of water targets in the CAP. However, future agricultural policies need to be more ambitious on the scale of change needed in production systems. More systemic attention needs to be given to how CAP regulatory and incentive instruments support a transition in farming production systems that is coherent with environmental goals. The main tools available for managing this challenge for water are a combination of the river basin management plans (RBMPs) and the new CAP strategic plans.

Better implementation of existing EU policies:

- **Better enforcement of minimum requirements.** Regarding diffuse nutrient pollution, Member States that opted to designate nitrate vulnerable zones under the Nitrates Directive should make sure that they capture all of the agricultural land contributing to the identified water pollution. Nitrate action programmes should include systematic measures such as calculating nutrient balances and planning fertiliser application. They should also be reinforced with mitigation measures, such as restricting and prohibiting fertilisation in high-risk zones and during high-risk periods. For diffuse chemical pollution, greater uptake of integrated pest management is needed under the Sustainable Use of Pesticides Directive, which could be supported by strengthening requirements in future CAP conditionalities. Regarding agricultural water use, there needs to be more systematic registration, licensing and monitoring of agricultural water abstraction.
- **More coherent implementation between CAP and environmental legislation.** Environmental legislation is not always fully reflected in agricultural policy. The preparation of new CAP strategic plans and their implementation should fully integrate the information, indicators, priorities and measures stemming from the relevant RBMPs. Support for farming systems posing risks to the water environment should be avoided so as not to become locked into particular intensive production methods. For instance, investments in improving irrigation efficiency should be made conditional on uptake of water-efficient crops and safeguards to avoid increases in net water consumption.

More ambitious design of support instruments in the CAP:

- **Consider efficient resource use as the baseline requirement for any farming system.** Efficiency standards in the use of nutrients, pesticides and water are needed and could be integrated into the framework of CAP conditionalities. This would help support more ambitious measures in CAP eco-schemes and rural development plans.
- **Increase CAP support for sustainable agriculture.** In Member States' CAP strategic plans, eco-schemes and rural development plans should

fund the large-scale uptake of agroecology, organic farming, green infrastructures and nature-based solutions. The budgetary envelope of eco-schemes and rural development plans should match the scale of the water challenges. Results-based payments schemes could ensure that needs, ambitions and results are aligned.

Strengthen policy areas that currently lack a strategic approach:

- **Managing agricultural water use, now and in the future, in the context of climate change.** The EU does not yet have an overarching strategy to reduce pressures from agricultural water use and to strengthen the resilience of agriculture to water scarcity and droughts. An overarching strategy would ensure that carrying capacities and resource limitations are properly established at river basin level (see Section 6.1) and promote adaptation of farming practices and production systems, notably through the uptake of more sustainable farming practices such as agroecology and organic farming.

6.3 More holistic and global approaches through systems thinking

Reducing pressures from agriculture to achieve water and other environmental targets will need to be underpinned by a combined approach to change both agricultural practices and consumer demand and be supported by a transition in food and energy systems. Food and energy systems are important drivers of agricultural production and farmers' specific choices and ultimately of our ability to achieve environmental targets. Managing sustainably in this context requires balancing the need for affordable food, health and social well-being, fairness to farmers and protection of the natural resource base.

The newly adopted farm-to-fork strategy provides leverage towards achieving a sustainable food system, and it calls for changing systemic drivers such as consumer preferences and diets, but further attention needs to be given to other drivers linked to energy and the demand for natural fibres.

Support the transformation of production systems through the food chain:

- **Integrate a systems perspective into the implementation of water, agriculture and food policies.** Collective approaches between farmers, food chain operators, authorities, and consumers and citizens are needed. For instance, at the local level, public procurement contracts for supplying food to public institutions (e.g. public canteens, schools, hospitals) could be used to encourage local production of organic products in areas of benefit for important local freshwater systems, such as drinking water protected areas or areas protected under the nature directives.

- **Prepare a coordinated policy to increase the production of, and market for, plant-based proteins and sustainably farmed products**. This requires investing in infrastructure in the food chain (storage, food product transformation) to scale up and reduce the costs of collecting and delivering sustainable food products.

- **Scale up private finance for sustainable and resilient agriculture.** Sustainability criteria guiding private investments, such as those under the EU Taxonomy Regulation, should direct investments into infrastructure and facilities that will enable the collection, processing and marketing of more sustainable agricultural products. Public funding such as grants available through the CAP can also be used to leverage private finance into sustainable food systems.

Re-orient demand towards sustainable consumption patterns:

- **Stimulate consumer demand for products from sustainable farming.** Increasing awareness of the links between diet, health and lifestyle, on the one hand, and sustainable production and environmental quality, on the other, can have an impact on choice of food products. Labelling schemes and regulations can promote green products that minimise the impacts on water and land.

- **Reduce food waste, promote the safe reuse of organic waste and enhance circularity in the food chain.** Options should be sought to use food waste for bioenergy instead of using intensively grown crop products for energy production.

- **Align agricultural, trade, environmental and climate policies**. It is essential to avoid displacing the environmental impacts of EU consumption to countries outside the EU while seeking high environmental standards in EU agriculture.

6.4 Closing remarks

Achieving sustainable development at the interface of agriculture and water will be complex. It requires a much deeper understanding of large-scale links — those between the food and energy systems, the agricultural sector and in this case the objectives of water policy — than is available at present. To achieve a sustainable transformation in the water and agriculture domain, decision-making will need to be supported by robust monitoring, data collection, knowledge systems and innovation to improve understanding of the scale of changes needed and to create incentives for new responses. Experimentation and learning will be essential.

The scale of challenges facing Europe if it is to achieve sustainability at the interface between water and agriculture is enormous. The same ambition that underpinned the modernisation of agriculture in the post-Second World War period is needed to achieve a more sustainable agricultural system. Conventional techniques have benefited from 70 years of mainstream research and development. Sustainable farming systems including agroecological practices will need to be supported financially and technically to achieve the large-scale uptake required to reduce agricultural pressures on European water resources, biodiversity, soils and climate. Time will be needed to reach the full potential. The European Green Deal, together with the biodiversity 2030, farm-to-fork and climate adaptation strategies, and the upcoming restoration and zero pollution action plans provide fresh opportunities to engage in this transition. If fully implemented and operationalised, the ambitious new targets should provide the renewed impetus needed to move towards a more resilient and sustainable future.

Abbreviations

EEA	European Environment Agency
EEA-39	The 39 member and cooperating countries of the EEA (including the United Kingdom up until 31 January 2020)
EU	European Union
EU-28	The 28 EU Member States (including the United Kingdom up until 31 January 2020
GAEC	Good agricultural and ecological condition
GDP	Gross domestic product
GWB	Groundwater body
IPM	Integrated pest management
RBMP	River basin management plan
RDP	Rural development plan
SMR	Standard management requirement
SWB	Surface water body
UAA	Utilised agricultural area
WFD	Water Framework Directive

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