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Water management guidelines for agriculture and forestry

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Abstract

The guidelines describe the environment where water management in agriculture and forestry takes place and the societal expectations involved in this, and sets targets for future actions. They also examine the role of water resources management in ensuring sustainable food production and bioeconomy. Based on the results presented by the working group, the guidelines define targets for sustainable water management in agriculture and forestry and the key water management measures to solve challenges brought by the changing environment, climate and water conditions.

The proposed water management measures have been divided into six categories: Governance measures, financing, planning and implementation, research and development, education, training and advice, and digitalisation. They key measures include investments in studies on the level of catchments, understanding the current state of and opportunities offered by water management measures, ensuring the numbers and level of competence of water management planners, contractors, advisers and experts, and new and innovative solutions through research, pilot projects and digitalisation. Financial and other steering instruments must be developed to appropriately promote these targets and measures. The work was carried out in cooperation between the Ministry of Agriculture and Forestry, Finnish Field Drainage Association and Tapio.

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Tiivistelmä

Suuntaviivojen tavoitteena on kuvata maa- ja metsätalouden vesitalouden toimintaympäristöä, siihen kohdistuvia yhteiskunnallisia odotuksia sekä asettaa päämääriä tulevalle toiminnalle. Lisäksi käydään lävitse sitä, mikä merkitys vesitaloudella on kestävän ruoantuotannon ja biotalouden varmistamisessa. Suuntaviivoissa määritetään työryhmän työn pohjalta maa- ja metsätalouden kestävän vesitalouden tavoitteet sekä keskeisiä vesitaloudellisia toimenpiteitä, joiden avulla voidaan ratkaista toimintaympäristön, ilmasto- ja vesiolojen muutosten mukana tuomia haasteita.

Ehdotetut vesitaloudelliset toimenpiteet ovat jaettu kuuteen eri kategoriaan: Hallinnon toiminta, rahoitus, suunnittelu ja toteutus, tutkimus ja kehittäminen, koulutus ja neuvonta sekä digitalisaatio. Keskeisiä toimenpiteitä ovat valuma-aluetason tarkasteluun panostaminen, nykytilan ja vesitaloudellisten toimenpiteiden mahdollisuuksien ymmärtäminen, vesitaloussuunnittelijoiden, urakoitsijoiden, neuvonantajien ja asiantuntijoiden määrän ja osaamisen tason vaaliminen, uudet ja innovatiiviset ratkaisut tutkimuksen, kokeiluhankkeiden ja digitalisaation avulla. Lisäksi taloudelliset ja muut ohjauskeinot tulee kehittää edistämään tarkoituksenmukaisesti edellä mainittuja tavoitteita ja toimenpiteitä. Työ toteutettiin maa- ja metsätalousministeriön, Salaojayhdistys ry:n ja Tapio Oy:n yhteistyönä.

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Syftet med riktlinjerna är att beskriva verksamhetsmiljön för vattenhushållningen inom jord- och skogsbruket och de förväntningar som samhället ställer på den samt att fastställa mål för den framtida verksamheten. Här beskrivs också vattenhushållningens betydelse för en hållbar matproduktion och för främjandet av bioekonomin. Utifrån arbetsgruppens förslag har man satt upp mål för en hållbar vattenhushållning inom jord- och skogsbruket och fastställt de centrala åtgärder inom vattenhushållning som kan lösa de utmaningar som verksamhetsmiljön och förändringarna i klimatet och i vattenförhållandena medför.

De vattenhushållningsåtgärder som föreslås har delats upp i sex olika kategorier: Förvaltningens verksamhet, finansiering, planering och genomförande, forskning och utveckling, utbildning och rådgivning samt digitalisering. De viktigaste åtgärderna är att satsa på granskning av avrinningsområden som helhet, förstå de möjligheter som nuläget och vattenhushållningsåtgärderna erbjuder, säkerställa tillräckliga resurser och kunnande genom vattenhushållningsplanerare, entreprenörer, rådgivare och sakkunniga samt att hitta nya och innovativa lösningar genom forskning, pilotprojekt och digitalisering. Dessutom bör man utveckla ekonomiska och andra styrmedel för att kunna främja ovannämnda mål och åtgärder på ett ändamålsenligt sätt. Riktlinjerna utarbetades som ett samarbete mellan jord- och skogsbruksministeriet, Täckdikningsföreningen rf och Tapio Ab.

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FOREWORD

Forests, fields and water bodies are interconnected by the water cycle and substances transported by the water. Securing the availability of sufficient volumes of water at the right time for growth and production while ensuring that economic activity does not put the preservation or achievement of a good status of waters at risk are preconditions for sustainable food production and forestry. Drainage, ditches excavated for drainage purposes and other means of water management play a key role in achieving these objectives.

The climate and hydrological conditions have been highly variable in recent years, and as a result of climate change, it is obvious that these changes will continue at an increasingly fast pace in the decades to come. Summer 2017 was clearly colder with greater precipitation than normal, summer 2018 was unusually dry and warm, whereas in winter 2019–2020, there was little or no snow in Southern and Western Finland. These years have faced agriculture and forestry with new challenges and reminded us of how important water and water management are. In the meantime, many strategies and action plans related to this theme have expired or are about to finish (including the Objectives of subsoil drainage programme for 2020, Guidelines for reducing harms caused by acid sulphate soils for 2020 and the Water management strategy 2011–2020).

The time was also right for the preparation of these guidelines because growing expectations are placed on water management in agriculture and forestry by different stakeholders in society, while the operating environment of both the public and the private sector has changed in many ways. These growing expectations concern not only aiming for profitability and cost-effectiveness in agriculture and forestry but also achieving environmental and climate targets. The role played by the central government has changed and become less important, while the roles of agriculture and forestry actors and landowners have diversified and grown larger.

These Guidelines discuss the significance of water management for ensuring sustainable food production and bioeconomy as well as the way challenges created by changes in the operating environment, climate and hydrological conditions can be solved by means of water management. Based on the efforts of a working group, the Guidelines specify the objectives of sustainable water management in agriculture and forestry as well as the key measures for achieving these objectives.

The work on the new Guidelines was commissioned by the Ministry of Agriculture and Forestry and carried out in cooperation by the ministry, the Finnish Field Drainage Association and forest management consultants Tapio Oy. Other contributors to the work included representatives of the Ministry of the Environment, the Finnish Forest Centre, the National Land Survey of Finland, the Finnish Environment Institute, the National Resources Institute Finland, the Finnish Wildlife Agency, Metsähallitus, the ELY Centres for Uusimaa, Southwest Finland, Häme, North Ostrobothnia, South Ostrobothnia, Central Finland and Southeast Finland, the Central Union of Agricultural Producers and Forest Owners, ProAgria Southern Finland, Aalto University, the Drainage Foundation, the Pyhäjärvi Institute, the Municipality of Raasepori, the Baltic Sea Action Group as well as OTSO Metsäpalvelut Oy.

We would like to extend our heartfelt thanks for everyone who participated in this work for your contributions!

Helsinki, 22 April 2020

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Introduction

Finland is a land of forests, fields and water bodies whose use, management and protection are closely interlinked. Using natural resources is a precondition for welfare, and their status and the rest of the operating environment must be maintained at a level where sustainable exploitation of natural resources is possible and sociably acceptable. Water management in agriculture and forestry is subject to many types of societal expectations and goals defined in national and international strategies and programmes. Responding to these expectations requires an understanding of causal relationships, overall evaluation of positive and negative impacts, and participatory and cross-sectoral cooperation at the level of catchment areas and also more extensively. For this purpose, we must be able to identify the problems and needs associated with water management and to mobilise the available resources and potential for solving the problems and meeting the needs.

Water management in Finnish agriculture and forestry should be planned and the measures should be carried out with foresight and ensuring that the measures improve these sectors' ability to adapt and respond to the challenges created by a changing operating environment. This means maintaining the production capacity of agriculture and forestry, preparedness for floods and periods of drought, and methods that will simultaneously promote the achievement of water management objectives. By means of sustainable water management not only in agriculture and forestry but also in built-up areas, well-functioning, scenic and biodiverse entities can at best be created in which economic activity, the environment and recreational use go hand in hand, supporting and complementing each other.

A properly functioning drainage system as a key method of water management improves soil productivity and nutrient utilisation, which also helps reduce nutrient leaching. By means of more nature-based drainage channels, improved possibilities of regulating drainage systems, and building wetlands on suitable sites we can prepare for the more frequent extreme weather phenomena brought about by climate change while safeguarding biodiversity, reducing watercourse erosion risk and reducing nutrient leaching.

To achieve these goals, development will be needed across a broad front. The following sections contain a more detailed description of the operating environment, the changes taking place in it and the steps required to move forward.

Key measures include examining water management increasingly at the level of catchment areas; understanding the current status and potential of water management measures; ensuring the availability and competence level of sufficient numbers of water resources planners, contractors, advisers and experts; and creating new and innovative solutions through research, pilot projects and digitalisation. It is also important to ensure that economic and other policy instruments operate appropriately and promote the attainment of the goals listed above.

1 Operating environment

The drainage infrastructure in Finnish agriculture and forestry is quite extensive. Main drains, forest ditches and other small watercourses used to direct surplus water away extend across an estimated distance of over 1.5 million kilometres. It is also estimated that there are nearly one million kilometres of subsurface drains. Whereas directing surplus water away has a significant role in ensuring the productivity of agriculture and forestry, retaining and recycling water will be increasingly important for climate change adaptation and for protecting waters and the environment.

These Guidelines examine the content and the operating environment of water management in agriculture and forestry using the concept presented in Figure 1. The objectives of water management in agriculture and forestry are underpinned by societal expectations arising from national and international policies. The measures which support sustainable water management in agriculture and forestry are divided into six groups.

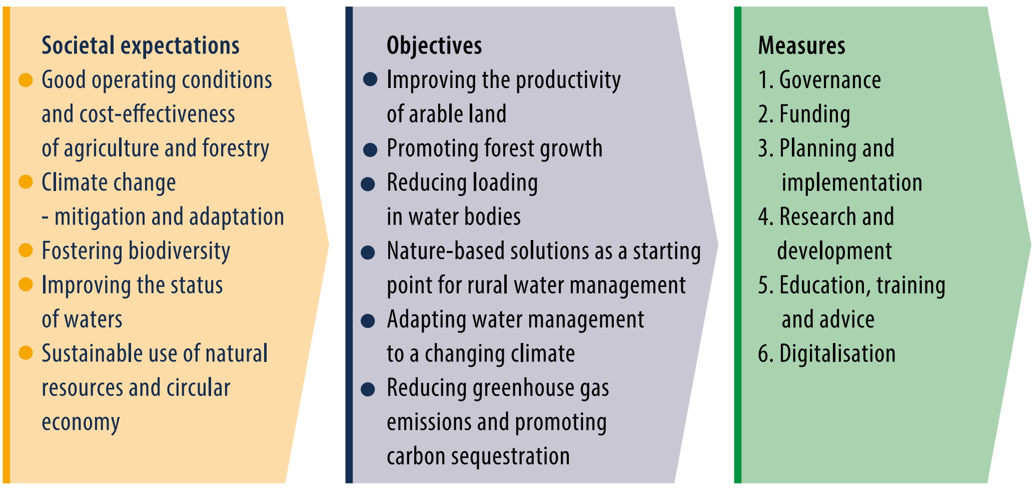


Figure 1. Societal expectations set by the operating environment of sustainable water management in agriculture and forestry, or international and national policies (in orange). The expectations are responded to through objectives set for water management (in blue) and the measures related to them (in green).

1.1 International and national strategies and programmes

Societal expectations are shown in the yellow boxes placed beside the key policies linked to them.

UN Sustainable Development Goals were formulated in 2015 in 2030 Agenda with the purpose of directing global development towards greater sustainability by 2030. The goals include eliminating famine and sustainable development in which the environment, humans and the economy are taken into account equally (UN Association of Finland 2019). The goals are global and they must be accounted for in national work. In spring 2017, the Finnish Government adopted a National implementation plan for the 2030 Agenda. See Figure 2 for the most essential sustainable development goals for water management in agriculture and forestry.

Figure 2. UN sustainable development goals which the Water management guidelines for agriculture and forestry support.

The European Union's Common Agricultural Policy (CAP) (e.g. European Commission 2020) specifies how agriculture, rural entrepreneurs and the entire food chain will be supported with common EU and national funds. Preparations for the next CAP period (2021–2027) are underway. While the CAP stresses climate actions in keeping with EU policies, environmental issues are generally emphasised more in connection with different support forms. The new CAP for Finland will be prepared by the government and must be approved by the European Commission. See Figure 3 for the key objectives of the new CAP regarding water management in agriculture and forestry.

Figure 3. Key objectives of the new CAP from the perspective of water management in agriculture and forestry are a fair income level, competitiveness, environmental care, climate change action and preserving landscapes and biodiversity.

Good operating conditions for agriculture

The Government report on food policy (Food2030, Government 2017) contains the objectives and key priorities of the Finnish food policy well into the future. The objectives of the food policy include responsible and sustainable food production and consumption which create economic and social welfare. Finland's clean soil and air and plentiful water resources lay a good foundation for sustainable food production, and a shortage of clean water does not restrict production methods or prevent new business opportunities in the same way as they do in many regions of the world. In addition to the availability of water resources, the Government report stresses the importance of water management as part of risk management and adaptation to changing conditions in food production.

Good operating conditions for forestry

Climate change mitigation

Climate change adaptation

The common objective of the Finnish Bioeconomy Strategy (2014), **the National Energy and Climate Strategy** (2013), **the National Energy and Climate Roadmap 2050** (2014), **the National Climate Change Adaptation Plan 2022** (2014) as well as **the National Forest Strategy 2025** (2019) is promoting forest use that is socially, economically and ecologically sustainable and welfare based on forests. The volume of current and new bioeconomy investments creates the framework for the needs to use the timber reserves accumulated in peatland forests as a result of ditch drainage. Increased forest use and food production are also associated with challenges, which are linked to safeguarding biodiversity, climate change adaptation and mitigation as well as water protection. Evidence-based solutions will be required to resolve these challenges while safeguarding good operating conditions for agriculture and forestry.

The sustainable and responsible use of mires and peatlands is based on policies contained in a Government resolution adopted in 2012. The objective is halting biodiversity loss in peatlands and developing peatland environments to achieve a favourable conservation status. The policies on mires and peatlands also include the goal of safeguarding the agricultural and forestry benefits produced by these areas as well as energy supply.

Improving the status of waters

The goals of water protection and the measures required to achieve them are determined in water management plans referred to in **the EU's Water Framework Directive** (WFD, 2000/60/EC). Its purpose is achieving at least a good ecological and chemical status of all surface waters and groundwaters, maintaining an excellent and good status of waters, and ensuring that no further deterioration occurs. In agriculture and forestry, this necessitates focusing on improving the quality of runoff waters. In the river basin management plans adopted in 2015, the measures related to water management in agriculture and forestry proposed for 2016–2021 include regulation of drainage conditions to control acidity, wetlands and sedimentation basins, buffer zones, and water protection measures associated with ditch maintenance. An effort is being made to reduce the harms caused by acid sulphate soils through the measures set out in the guidelines published by the Ministry of Agriculture and Forestry and the Ministry of the Environment in 2011. In its feedback provided on Finland's river basin management plans on the second round, the European Commission's DG Environment notes that additional inputs will be needed in managing diffuse pollution. The feedback also pays attention to the fact that the measures in the agricultural sector are mainly voluntary in nature, and recommends the passing of phosphorous legislation to complement the requirements of the **EU Nitrates Directive** (ND, 91/676/EEC).

The Strategy for protecting and restoring small water bodies (Hämäläinen 2015) identifies drainage and the hydromorphological changes caused by it as one of the most important reasons for the deteriorated status of small water bodies. As their number is large and numerous plants and animals depend on them, ditch networks and other small watercourses have high significance for fish, the entire aquatic ecosystem and biodiversity in general. The Strategy for small water bodies focuses particular attention on the need to identify and take into account protected areas and protection needs as well as small water bodies in a natural or close to natural state in drainage activities. Different obstacles to water flow, including dysfunctional culverts, should be examined and removed from watercourses. The significance of river basin specific planning is highlighted in the placement and dimensioning of water protection structures and safeguarding of biodiversity. The objective of the **Strategy for Restoration of Waters** (Olin 2013) is setting multiple goals for water body restoration in order to achieve a good status, to improve the usability of the water, and to support biodiversity. In the future, catchment area level measures should be increasingly taken into account to manage loading.

In addition to these strategies, a number of national and international programmes create challenges and expectations for water management in agriculture and forestry, which concern sustainable use of natural resources and fostering biodiversity. For example, the

Sustainable use of natural resources

Fostering biodiversity

objective of **the Strategy and action plan for the conservation and sustainable use of biodiversity** (Ministry of the Environment 2007, among others) is to safeguard water management in mires and peatlands by restoring drained mires, by protecting, maintaining and developing wetlands, and by increasing border strips and buffer zones on main drains to halt biodiversity loss caused by drainage of fields and forests. Wetlands and mires are also covered by **the international Convention on Biological Diversity (CBD)** (United Nations 1992) and **Finland's game husbandry and wetland strategy (2015).**

The strategic entities of **the Government Programme (Inclusive and competent Finland – a socially, economically and ecologically sustainable society,** Finnish Government 2019) titled 'Carbon neutral Finland that protects biodiversity' and 'Dynamic and thriving Finland' contain clear objectives relevant to water management in agriculture and forestry. The climate programme for the land use sector will strive to strengthen the carbon sinks and stores in land use, for example by means of climate sustainable management of peatland forests, diverse silviculture and forest management techniques and arable farming practices. The Government Programme also stresses the importance of good soil productivity and water economy from the perspective of crop security and adaptation of agriculture to changing natural conditions. As concrete measures are proposed promoting controlled subsurface drainage, introducing a wetland and afforestation programme and wetland cultivation[1]. Additional objectives include reducing the impacts of agriculture on waters by more efficient water protection and nutrient recycling, promoting flood protection and water management in agricultural soils, and increasing cooperation between farmers in solutions concerning water bodies.

1.2 Geographical operating environment

1.2.1 Climate and weather conditions

The geographical operating environment sets its own limitations to the production and environmental considerations in Finnish agriculture and forestry. In the Finnish conditions, drainage is one of the prerequisites for profitable agriculture and forestry.

The country's location between the 60th and the 70th latitude affects Finland's climate, which has features of both a maritime and a continental climate depending on the air flow

1 In this publication, wetland cultivation refers to arable farming in wet conditions, which can be created by such means as controlled subsurface drainage.

direction. The Finnish climate is milder than in continental regions located between the same latitudes.

The average annual precipitation determined by Finland's geographic location is 500 to 750 mm. The month with the greatest precipitation has typically been August, while March is the driest month. In global terms, precipitation in Finland is low, while the proportion of evapotranspiration, which is strongly concentrated in the summer months, is relatively low. Annual variations in precipitation and evapotranspiration are great. High precipitation in autumn and snowmelt in spring may cause flooding, whereas in summer, floods only occur in connection with heavy rain. Due to the low precipitation and strong evapotranspiration, early summer is the most typical period in which droughts occur (Figure 4).

The growing season in Finland is relatively short. The average length of the thermal growing season (period during which the average daily temperature is above +5 degrees centigrade) varies between 105 and 185 days depending on the location, with the longest season in Southwest Finland and the shortest in Northern Finland. Similarly, the accumulated temperature during the growing period varies from 1,400 to 600 degree-days. (Finnish Meteorological Institute 2019)

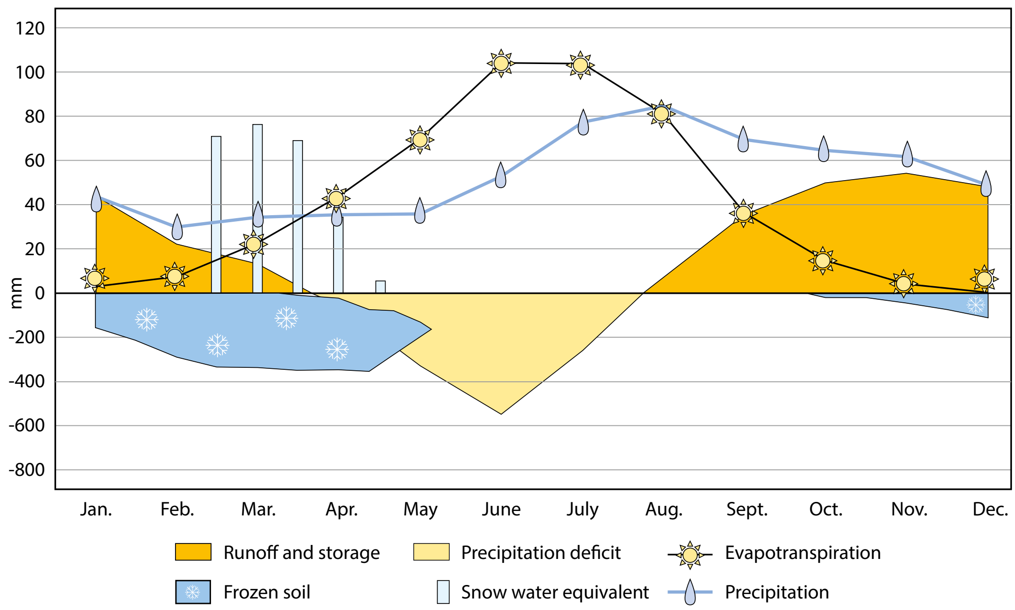


Figure 4. Hydrological conditions in Finland. On average, precipitation exceeds evapotranspiration in Finland in spring and autumn (Finnish Field Drainage Association).

Climate change is predicted to increase temperatures in Finland during all seasons, however more in winter than in summer. According to projections, winter temperatures will rise by 2 to 7, and summer temperature by 1 to 4 °C by the period 2040–2069 compared to 1981–2010. There will be longer warm periods in autumn, and spring will come earlier. The forecasts indicate that the ground will be frozen less often, the ice cover on sea will be thinner on average, and the surface area of ice will decline (Ruosteenoja et al. 2016).

The annual precipitation is expected to increase by 7% to 30% during the same period. Wintertime precipitation is projected to grow clearly, whereas there will be little change in the average precipitation in summer. Rainstorms in summer, on the other hand, are expected to become more powerful. Evapotranspiration is also predicted to increase as a result of shorter winters, rising temperatures and more frequent heatwaves alike, which may lead to worse periods of drought than today (Veijalainen et al. 2010, Ruosteenoja et al. 2016). Changes in precipitation and evapotranspiration will affect the generation and volume of runoff and also flow rates in rivers, water height in lakes, occurrence of floods and groundwater levels. Seasonal changes in runoff, especially increases in autumn and winter (Figure 7), will gradually also change temporal variations of loading in water bodies, reducing the significance of peak loading in spring.

1.2.2 Soil

The occurrence and distribution of soil types in Finland are a consequence of geological processes, topography and land uplift which took place during and following the Ice Age. The most common soil type is moraine. Soil types with a fine grain, including clay and silt, have typically been deposited in low-lying areas, which is why approximately one third of arable lands in Finland have clay soils (Natural Resources Institute Finland 2020a). Organic soil types were created as a result of an incomplete decomposition process of plant parts in anaerobic conditions after the Ice Age. A soil is classified as organic if its organic matter content is at minimum 20 percent of soil weight, and as peat if this content is at minimum 40 percent of soil weight.

Fields with organic soil account for 364,000 ha (15% of the total arable land surface). Of this, 262,000 ha (11%) are peatlands and 102,000 ha (4%) humus soils (Natural Resources Institute Finland 2020a). The proportion of arable peatland becomes higher the further north you go, and of all regions, North Ostrobothnia has the highest proportion of this soil type. A small increase has been recorded in the clearing of peatland for agricultural land in recent years.

Fields with a heavy peat layer of over 60 cm account for 170,000 ha (7% of arable land area), whereas fields with a thin peat layer of 30 to 60 cm account for 194,000 ha (8% of the arable land area).

Approx. 5.7 million hectares of mires and other waterlogged lands have been drained for forestry, of which peatlands account for 4.6 million hectares (VMI11). Approx. 4.2 million hectares of undrained peatland remain in Finland (Hökkä et al. 2002).

It has been estimated that the deposits of acid sulphate soils on the Finnish coast in the area marked by the highest shore of the Littorina Sea are the most extensive in Europe. The layer containing sulphides is saturated with water and usually below the groundwater table. If the sulphide layer extends to the surface, interventions that break the ground surface may promote soil exposure to oxygen and trigger the oxidation of the sulphide layers and the dissolution of metals. Especially in agricultural use, acid sulphate soils may have become oxidised to a depth exceeding one metre as a result of effective drainage. Acidity peaks which cause metals to dissolve may in the worst case result in widespread fish deaths and have a detrimental effect on the chemical and ecological status of water bodies.

1.2.3 Water bodies

Finnish lakes' special features include numerous islands, shallow, oligotrophic and acidic waters, and a low acid neutralising capacity. The damp and cold climate in Finland favours peatland formation, and most lakes are naturally rich in humus. The water quality in water bodies is also affected by the properties of the soil and bedrock in the catchment area, which together with the hydromorphological features of the water body comprise the basis on which Finnish surface waters (rivers, lakes and coastal waters) have been classified into different types. The classification of surface waters lays the foundation for determining their ecological status. The ecological and chemical status of a water body is influenced by human activity and land use in its catchment area.

The aquatic environment is vital for many species, including bacteria, plant and animal plankton, insects, fish, reptiles, mammals and birds. The species richness of lakes and ponds is affected by the climate, the size and depth of the water body and its geographical location. Dramatic seasonal changes, which affect the functions of the aquatic environment and are reflected in the structure of a lake, are a special feature important for aquatic organisms. The functioning of river and stream ecosystems is strongly dependent on the land ecosystem and groundwaters in their surroundings. In running waters, the flow conditions, bottom structure and variation of rapids and areas of a slower flow regulate the structure and number of species in the local ecological communities. Rivers, streams and rivulets are important for biodiversity and the landscape. They form ecological river corridors, which also link the Baltic Sea to the ponds and lakes in its catchment basin.

1.2.4 The Baltic Sea

The Baltic Sea is almost completely enclosed by continents, and its average depth is relatively shallow (54 m). The water in the Baltic Sea basin is brackish and features permanent salinity stratification.

Despite its small capacity, the Baltic Sea has quite a large catchment basin. The surface area of the catchment basin is over 1,600,000 square kilometres, or almost four times the surface area of the sea itself. Due to the extent of the catchment basin and its population density, the shallow water depth, and the slow circulation and stratification of the water, the Baltic Sea is susceptible to the impacts of eutrophication from nutrient leaching caused by human action, including from agriculture and forestry. In terms of biodiversity, the coastal areas are some of the most important habitats in the Baltic Sea, as they offer breeding, growing and feeding sites as well as shelter for a number of species.

1.2.5 Groundwaters

According to the definition used in natural sciences, groundwater is water that fills soil pores and fractures in bedrock in a uniform manner. The most useful groundwater resources in terms of water supply in Finland are found in stratified gravel and sand deposits, including eskers and large terminal moraines. The groundwater table mainly follows the relief of the ground surface. Groundwater is discharged into springs, spring-fed rivulets and streams, mires and other wetlands and water bodies. As groundwater is found close to the ground surface and groundwater areas have good hydraulic conductivity, groundwaters are susceptible to contamination. Land use, including ditch drainage in groundwater areas, affect the volume and quality of groundwater. Groundwater areas are classified and protected on the basis of their suitability for water supply use and their need for protection.

1.3 Water management on agricultural lands

The arable land area in Finland is approx. 2.27 million hectares, which accounts for approx. 8% of the entire land area of the country (Natural Resources Institute Finland 2020b). Water management in agriculture is to a great extent based on drainage. The drainage system built over the years is extensive and covers almost the entire arable land area in Finland. By regulating soil moisture, an effort is made to create as favourable conditions as possible for plant growth and to maintain a good soil bearing capacity and structure, ensuring that efficient use can be made of Finland's short growing season.

The drainage system in agriculture can be divided into arterial and field drainage. The arterial drainage system directs the surplus waters through main drains or cleared natural watercourses to rivers and lakes and further to the sea. Arterial drainage creates preconditions for field drainage, which means directing surplus water away from an agricultural parcel through subsurface drains or open ditches. Based on references in literature, drainage for agricultural needs began in Finland as early as the 18th century (Turunen 2016). However, the majority of arterial drainage projects were carried out in the 1950s and 1960s and subsurface drainage work between the 1960s and 1980s (Figure 5). Approx. 60% of Finnish fields, or about 1.4 million hectares, have subsurface drains and 25% open ditches, whereas 15% can be cultivated without drainage. Based on the area of arable land with subsurface drains, the total length of subsurface drains is estimated to be one million kilometres.

The current arterial drainage activities mainly involve the maintenance and overhaul of watercourses. Subsurface drainage is laid across approx. 10,000 hectares a year, some of which concerns replacement and completion of existing drains and some first-time subsurface drainage in fields that previously had open ditches. While irrigation in agricultural areas is currently rare, it is likely that there will be a growing need to prepare for irrigating fields in the future as climate change progresses.

Central government grants amounting to approx. EUR 2.5 million a year are disbursed for arterial drainage projects. In addition to the state aid rules, eligible projects must meet the requirements of the Arterial Drainage Act (947/1997) and Decree (1419/2011). Grants are only available for overhauls, not maintenance work. The outcomes of a supported project should as a rule benefit agricultural land and more than one holding. In addition, a precondition for eligibility is that the project's costs are reasonable considering the benefits achieved and that it takes into account environmental protection and management perspectives. The current objective is not only to obtain the benefits of drainage but also to reduce the negative impacts of arterial drainage on the environment and to improve the ecological and landscape values of the site. The support may account for no more than 40% of the eligible costs of an arterial drainage project. The maximum support rate may be increased by a maximum of 20 percentage points if the water protection and structural solutions are particularly costly, or if measures taken in the river basin upstream from the project site increase the costs. A full grant may be given for compensation and other costs incurred from discretionary environmental management measures regarded as necessary.

Central government investment aid for agriculture can be granted to subsurface drainage. The support rate for subsurface drainage is 35%, and for controlled subsurface drainage 40%, of the eligible costs. The minimum amount of support is EUR 3,000, and the maximum eligible costs are EUR 4.20/m. A precondition for eligibility is that the plan includes a planning map. The plan must additionally include a cost estimate and building specifications prepared by an expert familiar with subsurface drainage, and it must meet certain technical criteria. In recent years, the total annual amount of investment aid for subsurface drainage projects has varied from three to six million euros.

In connection with land reparcelling, the ditch drainage of fields is also often improved. The budget for ditch drainage and the construction of farm roads carried out in connection with reparcelling was EUR 3.5 million in 2019 and EUR 2.5 million in 2020. In addition, 23 reparcelling reports are being prepared. Significant government grants are currently available for reparcelling. Under Finnish legislation, the central government may grant support covering at most 75% of the fee charged for cadastral proceedings and 50% of the costs of eligible measures (including drainage). However, in recent years the emphasis has shifted towards support for the cadastral proceeding fees.

The status of arterial drainage was most recently investigated in a study on the status of arable land drainage conducted in 1989–1994, which found that one third of Finnish fields suffer from problems related to arterial drainage (Puustinen et al. 1994). An area of 150,000 hectares was in great need of main drain maintenance, and the area of drains needing some degree of maintenance was 225,000 to 300,000 hectares. The number of arterial drainage projects has not returned to the level recorded before the study. At present, around 50 projects are carried out each year. In the early 2000s, the effective areas covered by arterial drainage projects processed in ditch drainage proceedings represented less than 0.2% of the total arable land area in Finland. This suggests that the need for drain maintenance remains great.

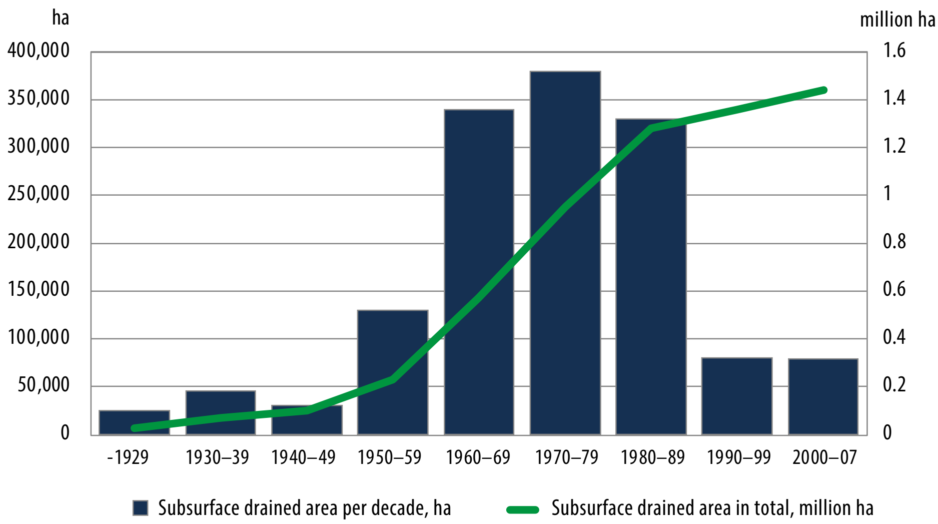


Figure 5. Subsurface drainage by decade as columns and the cumulative total drained area as a graph between the 1920s and 2000s (Finnish Field Drainage Association).

1.3.1 Environmental impacts

Drainage and irrigation alter natural water circulation and affect the quantities of water stored in the soil and the flow paths of water. Drainage related to agriculture has brought about significant changes, especially in running waters. Through watercourse erosion and surface erosion in fields, solids and nutrients end up in water bodies, which causes sludging, cloudiness and eutrophication of surface waters and has a negative impact on the status of the receiving water bodies.

Loading in water bodies can be influenced by controlling the time and intensity of drainage and irrigation. Soil structure and water management go hand in hand and have a significant impact on the soil's agricultural condition and the risk of nutrient loading in water bodies. Soil that is in good agricultural condition will produce good crop yields, which means that nutrients are used by plants and nutrient levels remain lower (PERA project 2020).

Subsurface drainage of fields helps to balance out flow ratios and may reduce the transport of solids to water bodies compared to open ditches as they reduce surface runoff and surface erosion of soil. By means of controlled subsurface drainage and dams in outlet drains, the groundwater table can periodically be maintained at a higher level than in ordinary subsurface drainage, increasing soil moisture and evapotranspiration levels and reducing the loads of nutrients and solids transported by subsurface runoff.

By maintaining the groundwater table higher than usual, environmental loading caused by acid sulphate soils and arable peatland can also be decreased, and soil subsidence in peatlands can be reduced. Drainage of arable peatlands, on the other hand, accelerates the decomposition of organic matter, causing carbon dioxide and nitrogen oxide emissions.

In the past, water construction measures in agriculture2 were often carried out in ways that resulted in more homogeneous or impaired habitats for organisms. Subsurface drainage also reduces the shelter and habitats offered by open ditches for organisms in agricultural environments and consequently has a negative impact on biodiversity. On the other hand, subsurface drainage may indirectly reduce the use of plant protection products by reducing the surface area of border strips along open ditches. Biodiversity in arable fields is enhanced by the current trend implementing nature-based solutions as extensively as possible in the construction and maintenance of channels. The objectives of this operating model include increasing biodiversity and reducing loading in water bodies. The building of wetlands and setting up of buffer zones along water bodies serve the same objectives.

1.4 Water management in forest lands

Systematic forestry drainage activities began in Finland in 1909. Most of the ditch drainage work was carried out between 1955 and 1985 (Figure 6). Drainage can improve the viability and growth conditions of trees, and also the timber yield and financial results of silviculture. There are 26.2 million hectares of forestry land in Finland (86% of the total land area). Approximately 5.7 million hectares of peatland and waterlogged forest land have been drained for silviculture purposes. As a result of drainage, around 25% of the increment currently comes from drained areas. The emphasis of ditch drainage work has now shifted from first-time drainage to maintaining and supplementing existing drain systems, and carrying out a discretionary assessments of the need for drainage is more common. Since the reform of the forest legislation in 1996, no first-time drainage has been carried out in peatlands in a natural state. The drained forestry area comprises 800,000 to 1,000,000 hectares of peatlands where timber production is not feasible.

With the average weather conditions of late summer, keeping groundwater table at a depth of 30 to 40 cm has been assessed to be an ideal state of drainage for tree growth. In these conditions, the stands will not be affected by excessive moisture and anaerobic conditions. Evapotranspiration from trees has a significant impact on the site's water economy. It has been estimated that a stand comprising 120–150 m^3ha^{-2} would be sufficient for maintaining the water economy, even if the ditches were in a poor condition (Sarkkola et al. 2013). Final felling significantly raises the groundwater table, and continuous cover forest management, in which the forest consists of trees of different ages, is emerging alongside traditional forest cultivation cycles. Forest managers are also beginning to consider the possibility of ash fertilisation to help postpone ditch maintenance. Under certain conditions, the additional increment achieved by fertilisation may exceed the levels which could be achieved by maintaining ditches (Ahtikoski and Hökkä 2019).

The group of organisations engaged in the planning and implementation of drainage work is large and scattered: Otso Metsäpalvelut Oy, forest management associations and forestry service entrepreneurs. While drainage in forestry is the responsibility of the landowner, these activities are supported by the central government. National support plays an important role in systematic implementation of drainage. Support referred to in the Act on the Financing of Sustainable Forestry (34/2015) is currently available for the planning and implementation of peatland forest management projects. A peatland forest management project may include ditch clearance or the digging of supplementary

2 Water construction in agriculture refers to structures that enable water management on agricultural land, such as drainage ditches, subsurface drains, dams or embankments.

ditches. In a peatland forest management project, the site must be a continuous area of at least two hectares. The support rate is 60% of total costs when the site comprises a continuous area of at least five hectares, and 30% for other sites. Financial auditors of the Finnish Forest Centre approve the plan and supervise its implementation. A precondition for implementing a drainage project is that a water protection plan has been drawn up for it and that a drainage notification has been submitted to the local ELY Centre. The current Act on the Financing of Sustainable Forestry will be in force until the end of 2020, and a new forestry incentive system is being developed.

Since the early 2000s, forest ditches have been maintained across an average area of 60,000 to 70,000 hectares in Finland. The actual drained area has been well below the estimated need, as in the forest programmes of the time (National Forest Programme), the drainage need was estimated to be approx. 100,000 ha a year. At present, ditches are annually maintained across an average area of 35,000 hectares.

There has been no systematic data collection on the condition of drainage systems in forestry. In the Finnish Forest Centre's districts, regional forest programmes are prepared and reviewed each year. These programmes estimate the annual area in which ditch maintenance is to be carried out at a rough level. Rather than the condition of the ditches, the estimate is based on the time which has elapsed since work was previously carried out on the ditches.

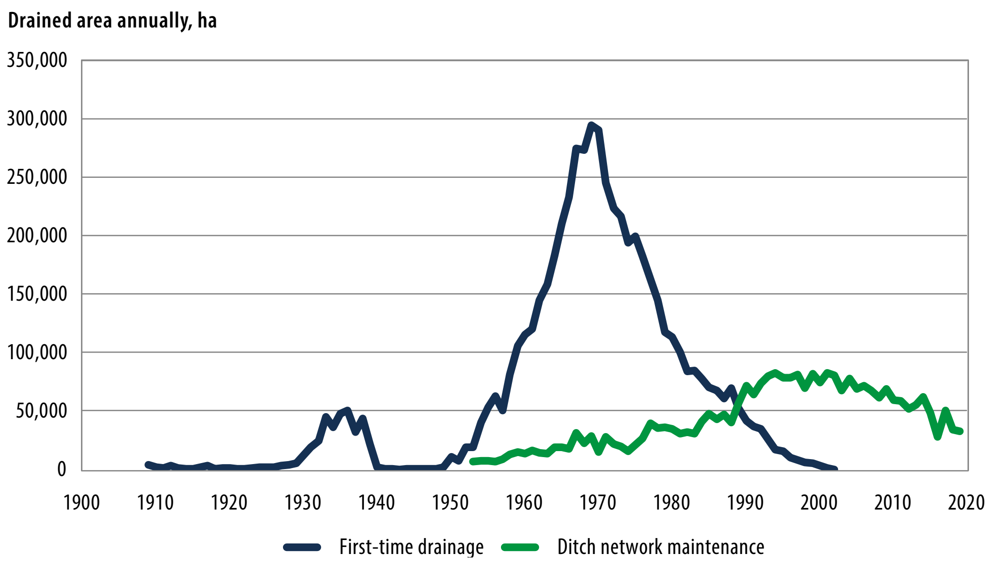


Figure 6. Trends in forest drainage in 1909–2019.

Source: Annual reports of Metsähallitus 1909–1950, annual reports of Tapio 1929–1950, and statistics of the Natural Resources Institute Finland and the Finnish Forest Centre 1950–2019.

Unlike previously, the National Forest Strategy 2025 no longer sets targets per hectare, for example for ditch network maintenance. The National Forest Strategy 2025 is based on upward trends in forest yields, and detail can be added to its different objectives in regional forest programmes. A precondition for achieving the forest yield figures is continued investment in forest management, and especially the management of peatland forests, in order to maintain favourable growth trends.

1.4.1 Environmental impacts

Ditch drainage of peatlands significantly alters their hydrology, usually increasing runoff until evapotranspiration from trees growing in the drained area begins to balance it out. In terms of its impacts on water bodies, ditch maintenance has been found to be the most harmful of forestry measures. Ditch drainage increases loading in the form of solids and nutrients bound in them, especially in areas where excavation reaches down to the mineral soil below the peat layer. On the other hand, lowering of the groundwater table and the resulting aerobic conditions also drive the mineralisation of nutrients, which promotes tree growth but may also increase the leaching of nutrients into runoff waters.

More accurate estimates of phosphorus, carbon and nitrogen loads in water bodies caused by forestry were produced in the MetsäVesi (ForestWater) project launched by the Prime Minister's Office in 2019. Based on the findings of this project, forestry accounts for 25% of the total phosphorus load, 4% of the carbon load and 16% of the nitrogen load in forested catchment areas. The results of the ForestWater project indicate that forestry plays a bigger part in the loading, and natural runoff a smaller one, than was previously estimated. The higher loading caused by forestry is due to the fact that the impacts of forestry drainage continue for a longer period than was previously believed (Finér et al. 2020).

The most common water protection methods used in drain systems are structures designed to slow down the flow rate and thus promote the sedimentation of solids dissolved in the water, while also aiming to reduce nutrient loading. The water protection structures recommended in forest management guidelines include sedimentation basins, sludge sumps, pipe dams, areas left undrained, bottom dams, wetlands and treatment wetlands. The most frequently used structures currently are sedimentation basins and sludge sumps.

1.5 Impacts of climate change

The report **Climate Change and Land** by the IPCC (Intergovernmental Panel on Climate Change, IPCC 2019) notes that the interlinkages between land use and climate change are extensive. The changes taking place in temperature, growing season length and air carbon dioxide content will have direct impacts on the growth of trees and crops as well as the processes occurringin the soil. The groundwater table and soil moisture are essentially linked to both growth and soil processes, such as decomposition and the transport, retention and release of substances.

The increase in atmospheric carbon dioxide and the longer growing season are predicted to improve the carbon binding capacity of plants. On the other hand, the rising temperature has also been projected to accelerate the decomposition of organic matter in the soil and thus reduce or even eliminate the carbon sequestration benefits of climate change in agriculture and forestry. (IPCC 2019)

The projected change in wintertime runoff in 2040–2069 is presented in Figure 7 combined with the area of drained peatland, area of agricultural land and the ecological status of surface waters. The Figure illustrates the challenges to water management brought about by climate change in agriculture and forestry. Climate change is expected to increase the loading in water bodies through higher precipitation in winter, which is likely to increase the leaching of nutrients from snowless and unfrozen land.

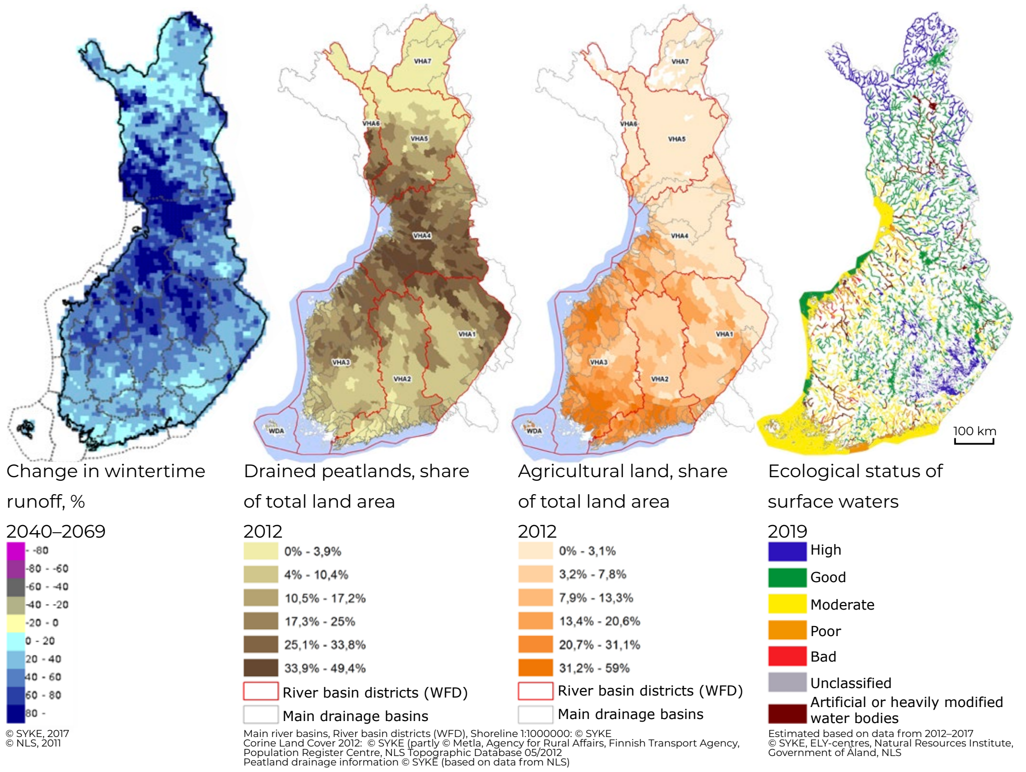


Figure 7. On the left, projected change in wintertime runoff in 2040–2069 according to RCP 2.6 climate scenario. Changes in runoff will take place extensively across agricultural land and forestry areas.

1.5.1 Climate change and agriculture

The lengthening of the frost-free period and increased runoff pose challenges to the functioning of agricultural drainage systems and water protection structures. Excessively moist fields hamper the growth of plants, reduce soil bearing capacity, and increase the risks of soil compaction, erosion and nutrient leaching. On the other hand, longer periods of drought increase the need for irrigation and stress the importance of water storage and retention solutions. Ground frost promotes good soil structure in clay soils, and as it occurs less (both in terms of time and quantity), there is a growing risk of deterioration of soil structure and compaction.

As the snow-free season becomes longer and precipitation increases, the risk of soil erosion and nutrient leaching is exacerbated. Mild winters also increase the risk of plant diseases. Various types of pests can become more common, making it necessary to focus more attention on plant protection. Vigorous plants growing in a soil that is in good condition are also more resistant to pests. This is why looking after the water economy of the soil helps reduce the need for chemical control and decreases the risk of chemical leaching.

To reduce greenhouse gas emissions from agriculture, particular attention should be paid to peatlands. In peatlands, soil moisture affects the decomposition of peat and thus the release of carbon dioxide and nitrous oxide emissions. It has been estimated that in total, cultivation in peatlands accounts for approx. 14% of Finland's annual greenhouse gas emissions, exceeding emissions from cars (Regina 2019).

1.5.2 Climate change and forestry

Climate change also poses challenges to the management of commercial forests. As the cold season becomes shorter, the frost-free period longer, and early rains more frequent, timber harvesting, ditch maintenance and tillage are hampered. Increasing runoff creates challenges to the functioning of water management and water protection structures. The warming of the climate and more frequently occurring winds may also exacerbate the risks of forest damage. Damage caused by some insects may become more common, and new pests may arrive in Finland.

Forests and their management have a significant impact on Finland's greenhouse gas balance. In their natural state, peatlands operate as carbon sinks as a whole, whereas drainage may turn them into carbon sources, depending on land use, soil nutrient content and the climate. The drop in the groundwater table caused by drainage exposes peat to oxygen, accelerating the decomposition of organic matter. As a result, the peat layer grows thinner and carbon dioxide (CO2) is released from the soil. When peat breaks down, nitrous oxide (N2O) is released, which is another greenhouse gas. On the other hand, ditch drainage often promotes the growth of trees in peatlands, and the volume of carbon dioxide (CO2) sequestered in trees goes up. While ditch drainage may also reduce methane emissions (CH4) from peatland, methane continues to be released from the ditches. Even at best, a forestry drained peatland is assessed to be methane neutral (Minkkinen & Laine 2006, Minkkinen et al. 2008, Hyvönen et al. 2013).

During the first cycle after ditch drainage, the impact of forest drainage on the carbon balance is generally positive, as reduced methane emissions and carbon dioxide sequestered in growing trees and forest litter reduce greenhouse gas emissions to an extent that exceeds the emissions from decomposing peat. However, most of the carbon sequestered in trees is released sooner or later after the final felling – depending on the use made of the timber – into the atmosphere as carbon dioxide.

Careful forestry drainage in oligotrophic peatlands and those with a very thin peat layer may also be carbon neutral over the long run. In other cases, reducing or preventing peat decomposition is the most important method of enhancing carbon sequestration also in forestry drained peatland over the longer term.

2 Objectives of sustainable water management in agriculture and forestry

The objectives of water management in agriculture and forestry are underpinned by societal expectations. The boxes below show the objectives against a blue background and the social expectations associated with them in yellow. The symbol used to refer to each objective is shown on the right. Rather than presenting them in an order of priority, the objectives are treated as being of equal value.

Improving the productivity of agricultural land

- Good operating conditions for agriculture
- Climate change adaptation
- Sustainable use of natural resources
- Fostering biodiversity
- Climate change mitigation

The arterial drainage system must be in good condition in order for field drainage to work and flooding to be avoided. Good arterial drainage is one of the most important preconditions for arable farming. The good condition of arterial and field drainage systems should be maintained by methods that prevent solid and nutrient loading in water bodies and promote the achievement of climate and environmental targets. In addition to drainage systems, cultivation techniques can also be used to influence erosion and transport of soil, as well as to reduce silting up and overgrowth of watercourses and the need for ditch clearing.

Sufficient drainage improves the soil's agricultural condition and bearing capacity, which reduces the risk of soil compaction, maintains a good soil structure, makes it easier to carry out cultivation work at the right time, and ensures efficient use of factors of production. By means of drainage planned to a high standard and its regulation, the possibilities of preparing for extreme weather phenomena, such as floods and droughts, can be improved. Optimal drainage creates preconditions for improving the nutrient balance. A suitable soil moisture level is a prerequisite for a good crop yield and thus also for carbon sequestration in fields.

Promoting forest growth

Good operating conditions for forestry | **Climate change mitigation** | **Sustainable use of natural resources**

The objective of the National Bioeconomy Strategy is to create new economic growth and jobs by promoting bioeconomy business as well as high value added products and services and by safeguarding the operating conditions of natural ecosystems. According to the National Forest Strategy, the growth of forests will be increased by means of active and sustainable forest management, ensuring that the forests will remain carbon sinks while sufficient raw material is available for industrial needs and to replace fossil raw materials.

Drainage creates conditions for growing trees in peatlands by improving the soil's oxygen economy and increasing the release of nutrients for the trees' use. As bioeconomy is a growing sector, there will also be a significant demand for timber in the future. In the drainage of peatland forests, the focus should be on better water protection while striving to preserve carbon in the soil, in addition to carbon sequestration in trees. In forestry, forest management methods should also be used to reduce erosion and the transport of soil in order to prevent the silting up and overgrowth of watercourses and to reduce the need for ditch clearing.

Reducing nutrient loading in water bodies

Improving the status of waters | **Sustainable use of natural resources** | **Fostering biodiversity**

Most of the loading in water bodies caused by human activities comes from agriculture and forestry. This loading is mainly carried to the water bodies by drainage systems. The negative impacts on water bodies of different measures in the land use sectors are often the strongest immediately downstream from the source of loading, but the impacts often accumulate and also cause problems in the lower parts of the catchment area.

Even minor reductions reducing the loading in water bodies carried out across large areas may achieve significant improvements in the status of water bodies and coastal waters.

If climate change increases autumn and winter precipitation as projected, the current measures should be targeted more accurately, and new measures should be found to reduce the risk of loading. Reducing the loading in water bodies promotes the preservation of habitats for many species. In order to improve the status of waters, restoration of water bodies may also be needed; if external loading is not prevented, however, the effectiveness of restoration projects will be short-lived.

Nature-based solutions as a starting point for rural water management

Improving the status of waters

Sustainable use of natural resources

Fostering biodiversity

Drainage channels can be cleared following nature-based principles, according to which running waters are examined as catchment areas consisting of the watercourse, river corridor, flood plain and river basin. Key nature-based solutions include flood retention in the catchment area, for example by means of bottom dams and wetlands; erosion protections and flood plains created with vegetation; restoration of cleared watercourses to a natural state; and improving aquatic organisms' possibilities for mobility and reproduction. Maintaining the accessibility of the river corridor and its ecological connectivity preserves and may increase biodiversity in small water bodies and agricultural and forestry areas. Good drainage and water protection methods improve the quality of runoff waters, contributing to the preservation and increase of biodiversity in receiving water bodies.

Adapting water management to a changing climate

Good operating conditions for agriculture

Good operating conditions for forestry

Climate change adaptation

Sustainable use of natural resources

The projected changes in climate and hydrological conditions will affect water management in agriculture and forestry significantly. Drainage systems play a key role in climate change adaptation, and when planning water management, it is essential to account for the impacts of climate change. Drainage must be efficient enough to tackle the higher precipitation and runoff volumes. In the future, preparedness for greater fluctuations in climate and hydrological conditions and drought periods brought about by climate change, for example through better capabilities for water retention and irrigation, should be possible by means of controlling the water economy and improving the agricultural condition of soil.

Reducing greenhouse gas emissions and promoting carbon sequestration

Sustainable use of natural resources | **Climate change mitigation**

Soil carbon is one of the most important growth factors in agricultural and forestry production. Finland is committed to reducing greenhouse gas emissions from agriculture and forestry and increasing soil carbon stocks (including the 4 per 1000 initiative of 2015). The carbon stocks of arable lands have also declined in Finland (Heikkinen et al. 2013), although relatively little in comparison to many other countries.

To turn this trend, decomposition should be slowed down especially in organic soils by changing forms of land use and influencing the groundwater table. As a rule, drainage of organic soils has accelerated decomposition and the release of greenhouse gas emissions. On the other hand, drainage of peatlands creates preconditions for cultivation and tree growth, which binds atmospheric carbon. In forestry drained peatlands, tree growth can compensate for carbon losses from peat during the first cycle. In moderately drained oligotrophic peatlands and peatlands with a very thin peat layer (approx. 10 cm), forestry drainage may also be carbon neutral over the longer term (Ojanen 2019).

In addition to water management measures, carbon sequestration should be promoted by means of cultivation techniques and by developing forest management.

3 Measures

This section discusses measures aiming to improve and develop today's water management practices in agriculture and forestry. The measures discussed here contribute to achieving the objectives set out in Chapter 2. Each measure can influence several objectives, which are marked with the symbol of the objective in question next to the title of the measure. The measures are categorised into six groups on the basis of their main associations. Each measure is only included in a single group, although it could belong to many. The groups of measures are presented in a random order and have no priority value. The blue symbol under the title of a measure indicates the objectives it primarily influences.

Groups of measures

1. Governance
2. Funding
3. Planning and implementation
4. Research and development
5. Education, training and advice
6. Digitalisation

3.1 Governance

Harmonisation of water management matters in agriculture and forestry to promote regional planning

Water management and water protection matters in agriculture are still examined separately from forestry, which has led to dissimilar practices, looked confusing from the perspective of the actors, and undermined the effectiveness of the activities.

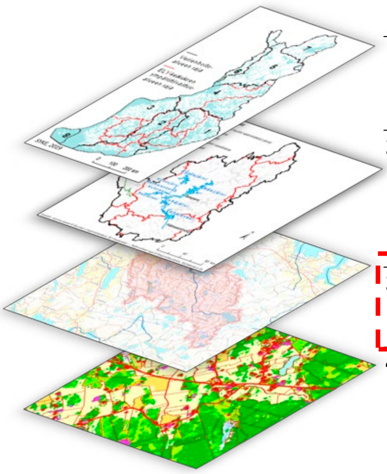
The procedures, policy instruments and requirements related to water management and water protection in agriculture and forestry should be as uniform as possible to facilitate joint planning and implementation. Inter-authority cooperation and dialogue between the authorities and agriculture and forestry actors should be stepped up. Increased dialogue will promote both the definition of common objectives and the equal treatment of actors in different parts of the country, for example in issues related to interpreting statutes.

Coordination in the planning, steering and implementation of land use and water management at catchment level should be developed to create streamlined and effective practices which are sufficiently consistent between the authorities in different land use sectors. For example, this applies to exchanges of information and service use as well as procedures related to ditch drainage, including joint projects, establishment of drainage corporate bodies, ditch drainage of peatlands in a natural state, ditch drainage of acid sulphate soils and groundwater areas, determination of the optimal drainage depth, and the building of water protection structures. Climate and water protection objectives should be included in land use planning and zoning at all levels.

Promoting comprehensive water management in governance

The policies on water management in agriculture and forestry are based on international and national objectives (level 1 in Figure 8). At the regional level, the environmental divisions at ELY Centres are responsible for such aspects as river basin management plans and action plans, whereas the economic development divisions handle implementing tasks related to agricultural and rural development. Similarly, regional forest programmes are drawn up by the Finnish Forest Centre (level 2 in Figure 8). While these programmes are today prepared in broad-based cooperation, they show little interest in issues related to sub-catchments, small catchment areas or drainage areas, even if this is precisely the level at which many solutions should be planned and action should be guided in order to achieve multiple benefits and improve the efficiency of water protection.

In practice, water management planning in agriculture and forestry takes place at parcel or project level and on the initiative of drainage corporate bodies, landowners or farmers (level 4 in Figure 8), and there is little coordination between such projects. Finland lacks a specific party to assume responsibility for these matters, or an operating model for governing the arterial drainage network and the channel network in peatland forests as a whole and for seeing to water resource management planning at the catchment area level, taking water protection into account (level 3 in Figure 8).



Geographical extent	Actors	Steering instruments
1. Country	EU, national government	Legislation, national and international agreements and guidelines
2. Regional	ELY-centres, Finnish forest Centre, Metsähallitus	River basin management plans, regional forest programmes, regional water management plans
3. Catchment	ELY-centres, Finnish forest Centre, Metsähallitus	Common catchment-area water resources management plans
4. Local (water management projects in agriculture, forestry, other)	Project co-ordinators, landowners, farmers, communities	Subsidies, grants, notifications, permits, proceedings

Figure 8. Different governance levels of water management in agriculture and forestry, from the top: 1. national level, 2. regional level (ELY Centres or Metsähallitus' regional administration), 3. catchment area level, 4. parcel and drainage project level. Water management planning should be intensified at levels 2 and 3 marked with a red dotted line.

Source: The Figure was modified from a figure by Turo Hjerppe (Samassa Vedessä project) and it contains background data from the National Land Survey of Finland and the Finnish Environment Institute.

The catchment areas come in many sizes and range from drainage areas belonging to private landowners or drainage corporate bodies and forestry drainage areas to the national river basin division or even the catchment area of the Baltic Sea. Land use in a catchment area is almost always composed of several different forms, not only agriculture and forestry but also built-up areas, which in practice must always be taken into account in planning. The suitable planning level varies from case to case (Figure 9). For example, the areas of the new national river basin division or a suitable combination of these areas can be used as the starting point (Finnish Environment Institute 2019).

In catchment area level planning, the needs and impacts of different land use sectors can be taken into account, thus enabling the implementation of more appropriate drainage systems and the utilisation of more extensive and efficient water protection structures. The larger the area covered, the more effective catchment area planning and water management measures often are

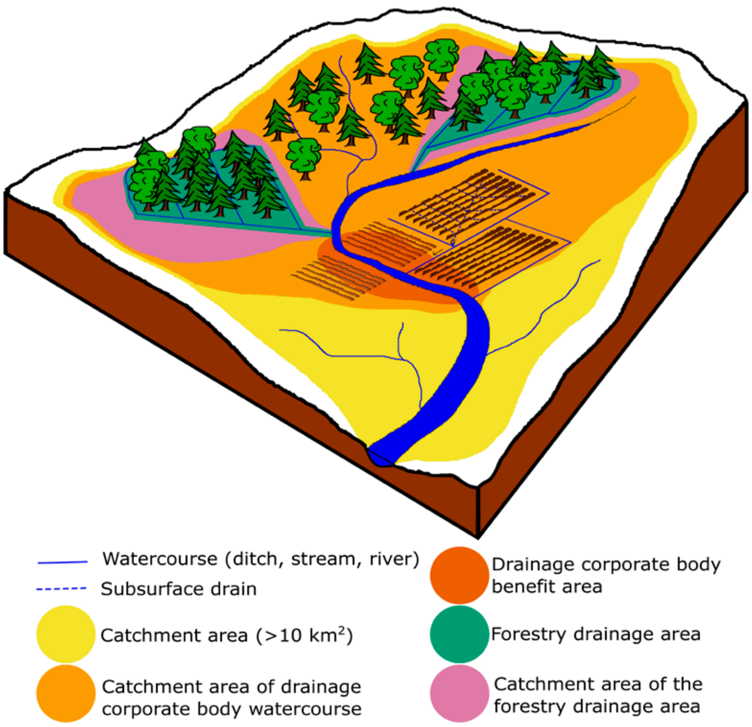


Figure 9. **Catchment area refers to the area from which surface waters and groundwater discharge into the sea, a lake or a certain channel section. The catchment area can be delimited as necessary, for example based on a certain watercourse, lake, watercourse section or the Baltic Sea. In drainage projects, a catchment area is defined for each project, for example the catchment area of a drainage corporate body's watercourse or forestry drainage area. The drainage area (benefit effective area) of a drainage project only covers a part of the watercourse's catchment area.**

Graphics: Olle Häggblom, Finnish Field Drainage Association

The operating models of water management should be reviewed and developed by the central government to meet the needs of more comprehensive water management planning. Water management should be improved especially at regional and catchment area levels (levels 2 and 3 in Figure 8). In the future, better coordination of the planning of measures in the catchment area with objectives related to water management, management of flood and drought risks and biodiversity should be possible.

Developing regional and local planning to promote drainage channel maintenance and overhauls

At present, landowners are responsible for the overhauls and maintenance of drainage channels and watercourses used for drainage purposes. No authority currently examines systematically the status of the drainage network. The drainage network is deteriorating, and maintenance is carried out in areas with active landowners. Regarding agricultural watercourses, the ELY Centres have a general idea of drainage corporate bodies' benefit areas and drain networks in their operating areas, but this information may not be in a consistent form that lends itself to rapid exploitation. While efforts have been made to secure expertise and advice in recent years, the ELY Centres and also municipalities should have better possibilities and resources for promoting the maintenance and overhaul of watercourses in a manner that is as environmentally sustainable as possible.

In the forest sector, estimates of the extent of drained areas in need of overhaul (ha) produced for the regional forest programmes are based on the time period that has passed since the drainage work was carried out. While the Finnish Forest Centre has improved its services in recent years, there is no perception of the need to overhaul forestry drains, either, which would be underpinned by geospatial data or field investigations.

The competence, data and tools of the authorities, especially the ELY Centres, Forest Centres and municipalities, should be used much more effectively in the planning of drained areas, enabling better targeting and implementation of watercourse maintenance and overhauls from the perspective of drainage needs, cost-effectiveness and environmental protection alike. Drainage area planning could be based on the catchment area planning described above, data on water bodies, drainage notifications, and previous water management, water protection and water restoration projects. The aim should be set at making an information product checked by an expert accessible for landowners and project actors.

Regional cooperation network

Closer regional cooperation is a prerequisite for collaboration and common operating practices. By establishing a new cooperation network or using an existing one, the water management needs and problems of the actors in an area could be identified, and the efficiency of information exchanges concerning the available methods, data and requirements could be improved, for example to support the preparation of drainage and water resource management projects.

The ELY Centre could serve as the responsible leader and coordinator of the cooperation network. The networks could also coordinate advice provision for landowners and drainage corporate bodies. The cooperation network members could include representatives from the Finnish Forest Centre, municipalities, lobbying organisations, advisory organisations, water protection associations, forest management associations as well as planners and drainage management officers. One of the objectives would be promoting catchment area planning. The stakeholders participating in the cooperation network would depend on the features and needs of the relevant area. The structure of the network's activities should be as light and dialogical as possible and lead to the launch of concrete projects.

Maintaining water management and protection measures

Water management and protection measures are usually implemented on a voluntary basis, and the responsibility for maintaining and repairing their structures is left to landowners as a rule. Ensuring the continued functioning of water protection structures and, on the other hand, nature-based drainage methods often requires maintenance and repairs at least every few years.

Attention should be paid to maintenance and repairs already in the planning and implementation phase, for example by developing administrative policy instruments, including legislation and support systems. A plan attached to a grant application should indicate how the beneficiary intends to fulfil their obligations and ensure that the benefits of the project will be kept up. In addition, the administration should investigate other new ways of extending the life span of the measures as the operating environment changes. A clearer link between central government support intended for building water protection structures and keeping them in an effective condition would be one way of doing this.

Using reparcelling as a policy instrument of water management in agricultural areas

Reparcelling should also be promoted, and its operating models, funding form and funding level should be developed.

In reparcelling projects, even large areas can be examined and developed at once, which promotes catchment area planning and enables the efficient use of water management and protection structures, taking into account the needs of different parties and environmental perspectives. Reparcelling can set the modernisation of a drainage system in motion and speed up the use of versatile nature-based solutions (meandering watercourses, two-stage channels, bottom dams, wetlands). Reparcelling also helps reduce the proportion of rental fields (Ovaska & Riikkonen 2019).

Facilitating drainage and the building of water protection structures in rental fields

The large number of rental fields (35%, Natural Resources Institute Finland 2018) is problematic as short rental periods do not encourage such long-term investments as drainage or water protection structures. Central government investment aid for agriculture can only be granted to active farmers, which hampers the allocation of drainage costs between the landowner and the farmer.

Clear calculations of how investments in water management increase the value of agricultural land and open information on the history and properties of farmland could encourage landowners to make long-term investments. In addition, the benefits of longer leases should be investigated.

Development of drainage notifications

The submission of drainage notifications became mandatory under a reform of the Water Act in 2012. A notification must be submitted to the local ELY Centre for any drainage project that is larger than minor. The information content of the drainage notifications should be developed, and adequate instructions and training on completing them should be provided for both drainage contractors and authorities. As the drainage notification process has been digitalised, the information contained in the notifications will be more readily available for such purposes as the planning and implementation of water resource management measures.

The concept of minor drainage work, which is the criterion for the obligation to submit a drainage notification, is open to interpretation, and it is not always clear to the actors whether the duty to submit a notification applies or not. A more specific interpretation would clarify and streamline planning work. Actors' ability to identify a watercourse that has developed into a natural state should be promoted by such means as advice, training and open information.

Based on the drainage notifications, the authorities can examine the big picture and provide more detailed instructions for the successful implementation of drainage projects. Sufficient resources should be reserved for the authorities for the cumulative collection and comprehensive examination of this information. The use of data collected from drainage notifications for maintaining situational awareness of drainage systems, developing spatial data on existing water protection structures, water management, and catchment area planning should be promoted.

Avoiding drainage in peatlands in a natural state

Draining peatlands in a natural state to gain farmland or for other purposes should be avoided. Other measures should be used to increase the area of arable land at holding level. New ways of preserving areas in a natural state should also be sought, for example through various voluntary and discretionary land use changes, land exchanges and compensations, and by drawing on previously gathered experiences (including the METSO programme).

Peatlands in a natural state have no longer been drained for forestry use since the reform of forest legislation in 1996. If changing forms of land use in peatlands previously drained for forestry purposes require drainage, the impacts on the groundwater table should be kept to a minimum.

Utilisation of low-productivity areas no longer used for commercial forestry

As the Forest Act was reformed in 2014, the obligation to regenerate forests was abolished in low-productivity drained peatlands and in areas to be restored which originally were open peatlands. Under the Government Decree on the Sustainable Management and Use of Forests (1308/2013), however, at least 20 trunks per hectare shall be left in drained low-productivity peatlands to promote biodiversity.

Where possible, these areas excluded from forestry should be used as treatment wetlands for water protection, for water retention or as wetlands, or they should be allowed to recover naturally to promote biodiversity. In suitable protected peatlands which have been drained and in their marginal areas, using these sites as treatment wetlands should be considered.

3.2 Funding

Coordinating the principles of financial support in agriculture and forestry

The principles of supporting drainage and water protection measures carried out in connection with it differ in agriculture and forestry, even if the runoff from agricultural land and forest land is often interlinked, and the support schemes largely share the same objectives. The administrative procedures and requirements applicable to water protection solutions differ, and the support rates for measures vary between 30% and 100%.

A coherent incentive scheme would promote catchment area planning and cost-effective targeting of measures, for example making it possible to direct waters from forestry areas more extensively to wetlands in agricultural areas. The costs incurred by landowners for these measure should be allocated as equally as possible. The conditions and incentives of the support schemes should also be similar, for example in such special areas as acid sulphate soils.

Coordination of support systems in different land use sectors would also improve the efficiency of managing greenhouse gas emissions and sinks in the land use sector and promoting biodiversity.

Securing and developing the grant for arterial drainage

Currently, the maximum support rate of central government grants for arterial drainage of agricultural land is 40% of the eligible maximum costs. In connection with arterial drainage, it is appropriate to implement and support water protection measures. One of the problems is that reimbursement for planning costs is paid after the support decision has been made. The drainage corporate bodies or planning agencies do not usually have the resources to provide temporary finance. The current operating environment, profitability, more stringent requirements and the landowners' multiple objectives pose a challenge to the implementation of joint projects between several holdings, especially large ones, and result in project implementation that is not necessarily optimal for water management.

While safeguarding the availability of support will also be important in the future, awareness of the support system, its attractiveness, its targeting and the incentive it provides for high-quality work that is in public interest should be improved. It may also be necessary to carry out arterial drainage work in connection with reparcelling, in which case the principles of support should be consistent with other arterial drainage activities.

Use of nature-based solutions and water protection structures should be made a more specific criterion for eligibility for support. The eligible share of planning costs should be increased in central government support, and support for planning should be granted before the plan has been confirmed in cadastral proceedings or by the permit authorities.

Securing and developing investment aid for subsurface drainage

Investment aid for subsurface drainage has been one of the most important, if not the most important, means of managing the water economy of agricultural lands and maintaining the good agricultural condition of soil. The continuation of the aid scheme should be ensured, and the aid should be targeted at sustainable and high-quality subsurface drainage work. In practice, controlled subsurface drainage and irrigation often are the only possibility of controlling the runoff from a field parcel and the recycling of runoff waters, and thus the leaching of substances. First-time controlled subsurface drainage and

irrigation should be supported and otherwise promoted whenever this is appropriate considering the features of the field. Some 77,000 hectares of agricultural land currently has controlled subsurface drainage in place, whereas the total surface area of fields suitable for this method of drainage in Finland is approx. 675,000 hectares (Puustinen et al. 2019).

At present, the eligibility criteria of investment aid for subsurface drainage include no qualification requirements related to planning and few related to implementation, which has resulted in uncertainty among the customers and suppliers of drainage work. The qualification and quality requirements should be incorporated in the terms and conditions of investment aid, or high-quality implementation of supported projects should be ensured by some other means.

Maintaining and developing agri-environment payments related to water management

The agri-environment payment scheme is an important policy instrument which includes a wide range of measures aimed at improving the status of water bodies and the agricultural condition of soil, increasing biodiversity and improving the efficiency of climate change mitigation and adaptation (e.g. Hyvönen et al. 2020). Reducing the loading in water bodies has for long been a key objective of the agri-environment payment scheme.

The recycling of runoff waters, controlled subsurface drainage and irrigation are currently supported in peatlands throughout Finland and in acidic sulphate soils in certain areas. Controlled subsurface drainage and irrigation can reduce runoff through subsurface drains and thus the load of solids and phosphorus, loading in acid sulphate soils, and greenhouse gas emissions from peatlands.

The impacts caused by the recycling of runoff waters, controlled subsurface drainage and irrigation are positive in all areas where these methods are suitable considering the soil type and parcel slope, and they should thus be supported throughout the country. However, the eligibility criteria should be sufficiently stringent, similarly to investment aid for subsurface drainage, ensuring that the measures will be implemented to a high standard and that they will be maintained.

The agri-environment payments should provide a better incentive for the establishment and management of flood plains in so-called two-stage channels. It should be possible to include a flood plain in the area of the buffer zone, or to form a special area consisting of the flood plain, alone or together with other multifunctional ecological areas. Wooded zones between fields and water bodies should also be regarded as buffer zones eligible for support. Riparian forests have a positive impact on the ecological status of running waters (e.g. Turunen et al. 2019).

The support scheme for multifunctional wetlands should be continued; one option for developing the scheme would be strengthening the link between wetland investments and other nature-based water protection methods and catchment area planning, as well as preparedness for changing weather and hydrological conditions.

Targeting forestry subsidies at planning and the selection of water protection structures

The current Act on the Financing of Sustainable Forestry encourages ditch maintenance and water protection.

In the context of reforming the forestry incentive system, the emphasis should be on good planning of water protection measures and deployment of the best available water protection technology. The assessment of economic feasibility should also continue to be part of the eligibility criteria, ensuring that the support is directed at uses where it can improve productivity and where its overall impacts can be considered positive.

The forestry incentive system should guide actors towards more careful planning and implementation in acid sulphate soils. The support scheme should also be developed to provide incentives for planning larger projects, which would enable the use of more comprehensive catchment area level examination in the planning and cost assessment of drainage, and the selection of the most effective water protection methods in each situation. At the moment, the subsidies may in certain situations enable the excavation of oversized drains (Knaappila 2019). A precondition for this development is that the planners and contractors in peatland forest management projects have sufficient competence.

3.3 Planning and implementation

Developing planning at catchment area level

Catchment area planning refers to planning that focuses on the catchment area of a water body or a drainage area. It contains a comprehensive examination of current and future land use in the entire catchment area, its loading and its impact on water bodies. The objective is to identify high-risk sites and plan measures which promote sustainable land use and flood risk management as well as prevent and reduce loading in water bodies as cost-effectively as possible.

In the future, the planning of water management projects should increasingly take place in cooperation between the agricultural and forestry sectors, also taking other actors in the catchment area into consideration. Catchment area planning should primarily target those areas where it is most useful. More attention in the planning should be paid to water resource management priority areas and plans as well as the proximity and status of receiving water bodies. In order for water resource management to be realised, it is important that the priority areas defined in the plans are known to those planning drainage measures.

In addition to areas identified in water resource management planning, catchment area planning should be a requirement in areas which need extensive ditch network maintenance, overhaul of ditches or other water management measures, including wetlands, restoration of water bodies or smaller surface waters, or flood protection structures, and in which the measures may have negative impacts upstream or downstream in the catchment area.

The available open geospatial data sets can be used to assess the need for catchment area planning and to support it, but needs to develop and collect data are associated with such aspects as evaluating the drainage status and the impacts of a drainage project. See also the administrative measure Promoting comprehensive water management in governance and the research-related measure Implementing a study on drainage status and needs.

In addition to producing high-quality and comprehensive plans, attention should also be paid to following the plan when the work is carried out by means of work guidance, supervision while the work is in progress and training provided for contractors.

Nature-based solutions as a starting point for rural water management

While nature-based drainage methods have been developed for a long time, few of them have been deployed in practice.

In addition to drainage, nature-based methods improve the environmental status and landscape of watercourses, prolong the retention time of water and reduce loading in water bodies (e.g. Järvelä & Västilä 2016). These solutions can also reduce the need for watercourse maintenance and thus the maintenance costs. Nature-based methods are additionally used to ensure the accessibility of river corridors and to preserve their ecological connectivity, helping to safeguard and promote biodiversity.

Nature-based solutions should be made the starting point for water management measures in agriculture and forestry. In the education and in-service training of arterial drainage planners, the use of nature-based methods should be emphasised, and landowners and farmers should be informed of them. Nature-based methods are currently not sufficiently competitive in terms of their costs. Efforts should be made to reduce costs by various means, making these methods financially feasible.

Maintaining the quantity and quality of subsurface drainage at a good level

No detailed information is available on the repair backlog of subsurface drainage. Currently, first-time and supplementary drainage is laid across some 10,000 hectares annually. The quality of planning and implementation affects the reliability and life span of the drainage system, its maintenance needs and the ease of using it, as well as the cost-efficiency of the drainage project. Cases with various problems in which a new subsurface drainage system is not working properly come up from time to time in different parts of the country.

As a rough estimate, subsurface drains should be laid in an area of approx. 15,000 hectares per year (both supplementing and replacement drainage) in order to maintain the water economy of fields at a good level.

In field drainage, open ditches are still relied on over approx. 600,000 hectares where subsurface drainage should be laid to improve the profitability of farming. The time elapsed since the construction indicates that there is a great need to supplement and replace old subsurface drains.

Efforts should be made to prevent problems in advance, as determining the cause of the problems and making repairs in subsurface drainage at a later is difficult. Attention should be paid to quality control.

Prolonging the retention of water and improving the possibilities of controlling water in rural areas

Water can be retained in soil, basins, wetlands and watercourses. The retained water can be stored for irrigation purposes or to increase the base flow and level out flood peaks. Controlled retention of waters also reduces the load of solids and nutrients in runoff water. The available geospatial data tools and laser scanning data make it possible to assess the backwater effect achieved by means of different damming techniques upstream from the dam structure. A precondition for using water reserves often is close cooperation between holdings and good organisation of stored water use.

Examining the possibilities of retaining and detaining runoff waters should be included in all planning of water management in agriculture and forestry. However, detention and retention may not cause negative impacts in the form of uncontrolled waterlogging to holdings or their land use forms.

Reducing negative impacts caused by acid sulphate soils

As the sulphide layer in acid sulphate soils becomes oxidised naturally or as a result of drainage, sulphuric acid is formed. It dissolves metals found in the soil, which are harmful to organisms and which are carried to water bodies with the runoff water. Even if their surface area is small, channel excavations that reach deeper down than the sulphide layer may at worst lead to the acidification of water and thus to impaired living conditions for aquatic organisms and, for example, fish deaths. The leaching of acidity and metal compounds can be reduced by controlling the excavation depth. More accurate and open map data on acid sulphate soils should be produced, and methods for interpreting it should be developed and deployed. In addition, sample sites, advisory services and financial policy instruments should be used to increase the number of controlled subsurface drainage projects and perennial grasslands in areas where acid sulphate soil is present.

In agricultural areas, the negative impacts of acid sulphate soils should be mitigated by means of controlled (subsurface) drainage, subsurface irrigation and shallower ditches in suitable areas. In acid sulphate soils, groundwater retained by means of controlled subsurface drainage prevents the oxidation of deeper soil layers that are potentially acidic. This way, less acidity is formed than in a field with normal subsurface drainage. For cultivation in acid sulphate soils, plants requiring a lower drainage depth could be selected.

In forestry areas, increasing the drainage depth and ditches excavated down to mineral soils should be avoided. If the drainage efficiency needs to be improved, this can be done by means of shallow supplementary ditches with a closer spacing than usual. Water protection methods requiring deep excavations, including sedimentation basins and sludge sumps, are not suitable for acid sulphate soils. Instead, bottom and pipe dams and treatment wetland structures can be used.

Sustainable water management in peatland forests and fields

Lowering the groundwater table accelerates peat decomposition and may have a negative impact on the greenhouse gas balance of peatlands. In the longer term, reducing peat decomposition would be the key measure for preventing the release of carbon.

The environmental impacts of peatland fields, both nutrient leaching and greenhouse gas emissions, should be minimised by means of water management measures. Controlled subsurface drainage and irrigation have potential to keep the groundwater table higher, thus maintaining organic soil under anaerobic conditions and slowing down decomposition and subsidence in peatlands. In peatland forests, peat loss should be reduced by carefully considering the need for drainage, avoiding the excavation of unnecessarily deep ditches, and utilising the evapotranspiration effect of trees.

Taking groundwater areas into consideration in drainage

Maintenance of forest ditches is currently not recommended in classified groundwater areas if it is necessary to deepen the ditches as far as the mineral soil underlying the peat layer. In both agriculture and forestry, the established practice is to notify the ELY Centre of ditch drainage work in groundwater areas.

Ditch drainage in groundwater areas may impair groundwater quality and cause harmful discharge of groundwater, especially in areas where the groundwater table is close to the ground surface. Ditch drainage in groundwater areas and their marginal zones may affect the productivity of the groundwater body.

Assessing the impacts of ditch drainage on groundwater is complex and should be done on a case-by-case basis, however, which is why the development and introduction of a risk assessment tool for actors and planners should be promoted.

Adapting drainage systems to changing water volumes

The dimensioning of structures related to drainage and water protection as well as the possibilities of controlling them should be developed to meet the requirements of periods of drought and flooding which are projected to occur in the future.

The drainage systems of agriculture and forestry should be adapted to climate change by increasing the maximum normal flows as necessary, especially at the main bottlenecks of drainage systems, including culverts and bridges. Planning guidelines for drainage and irrigation (Järvenpää & Savolainen 2015) suggest that the maximum normal flows and runoff values should be increased by 20% from their current values and that the functioning of major bridges and culverts should be ensured with maximum floods occurring once every 250 years (HQ1/250).

The adaption of drainage systems to changing water volumes should take place partly by means of reverting water bodies and smaller streams and water formations to a natural state, retention of water, and catchment area level planning and implementation, making it possible to some extent reduce flood peaks by temporarily retaining flood waters in wetlands as well as in peatland and forest areas. These measures would also contribute to drought resilience. If increasing drainage capacity is necessary, this should be done following nature-based principles, or ensuring that any negative impacts on the environment are minimised or compensated for. If necessary, the dimensioning recommendations should be updated and applied for the purposes of the practical work.

3.4 Research and development

Research and development related to water control techniques

More information is needed on the impacts of drainage on crop and timber yields, nutrient leaching and greenhouse gas emissions. Longer term monitoring is needed, which should be intensive in selected areas within the scope of measures.

The possibilities of water retention in agricultural and forest lands should be assessed more accurately, both using computational modelling and by means of field measurements. Sufficient research data are not available on the impacts of controlled subsurface drainage and irrigation, or the damming of arterial drainage channels, on nutrient loading in water bodies from mineral lands and acid sulphate soils as well as greenhouse gas emissions from peatland fields. Techniques for controlling the groundwater table, including controlled subsurface drainage and various damming methods of main drains (for example, pipe dams, bottom dams, stop log dams) and their use should be developed. The usability and effectiveness of measures could be improved by means of automation and remote control.

In subsurface field drainage, suitable coatings for pipes should be developed to replace gravel. The possibilities of using different options should be investigated, as there is little information on the quality and suitability of different coatings for different conditions. The use of recycled plastic products in subsurface drainage should be increased, while a new standard for drainage pipes containing recycled plastic should be adopted.

The possibilities of using shallower forest ditches should be studied and piloted in practice on sites. The excavation of unnecessarily deep ditches poses a risk to water bodies and drives carbon dioxide emissions from peat decomposition. In addition, remote sensing methods should be developed for identifying ditches in need of clearing both on agricultural land and forest land to assess the need for ditch drainage more efficiently and to target it correctly (see also the research measure Implementing a study on drainage status and needs).

Development and impact assessment of nature-based methods

Evidence-based information on the impacts of nature-based methods on hydrology, water quality and the ecological status of waters is only available from individual projects, whereas it is generally believed that these methods would significantly contribute to biodiversity and reduce loading in water bodies compared to such methods as the clearing of main drains carried out in traditional ways.

The suitability of different methods, such as two-stage channels, gravel bars, bottom dams, meandering channels and wetlands for sites with different topography, vegetation and soil types in both agricultural and forestry areas should be examined. The impacts of these methods on water flow, runoff water quality, the ecological status of waters and watercourse morphology should be studied and monitored in greater detail.

Nature-based construction techniques construction techniques for arterial drainage should be improved, and the practical application of information on nature-based methods methods and soil structure improvement should be promoted.

Development and pilot projects eligible for support should always come with adequate monitoring of the measures and their combined impacts. The continuity of monitoring should be ensured by linking it to other research or monitoring carried out by the authorities, or by targeting new development and pilot projects at areas on which previous monitoring data is available.

A critical approach should be taken to cost-effectiveness assessments, and they should be carried out at multiple levels from the perspective of both society and the sector, covering a sufficiently long time period.

Assessing the impacts of optional forest management techniques

Peatland forests favourable for natural seedling growth and fertile drained peatland types have potential for uneven-age forest cultivation, in which the tree volume may be sufficient to maintain an adequate drainage status without repeated maintenance of the ditch network. So far, little is known about the impacts of continuous cover forestry on water bodies, and further research is needed. The water economy of forest land and the carbon balance and climate sustainability of peatland forests can be influenced by developing and using ditch drainage techniques and varying silviculture methods.

The growth condition of trees can also be boosted by ash fertilisation, which can produce long-term additional growth without ditch maintenance. With the help of ash fertilisation, it may be possible to postpone the need for ditch maintenance until the next final felling. Ash fertilisation is not currently known to cause negative impacts on water bodies (e.g. Piiranen et al. 2013), but longer-term studies are needed.

Developing water protection measures

In the future, investments should be made in the development of multifunctional water protection structures both in agriculture and forestry. Wetland-type solutions, for example, can be implemented in connection with watercourses in areas prone to flooding. However, findings concerning the effectiveness of wetlands are inconsistent. The impacts of wetlands of variable sizes on hydrology, runoff water quality and biodiversity should be studied in greater detail.

Most of the runoff water from agricultural lands comes through subsurface drains, which is why new practices should be developed especially to clean and retain these runoff waters.

Water protection methods used in forestry drainage mainly help to retain solids and the nutrients bound to them. Following recommendations, sludge sumps are often used as water protection structures in addition to other methods; there is no research evidence of their effectiveness, however. Models indicate that they may even increase the solids loading in areas with a thick peat layer (Haahti 2018). To verify the usability of sludge sumps, their impact on reducing the loading in water bodies should be investigated.

The methods available for retaining soluble nutrients and humus are currently few. Treatment wetlands can be used to effectively remove solids and probably also soluble nutrients from runoff waters, but as a practical water protection measure, this method is at present used relatively little (Nieminen et al. 2005). The utilisation of treatment wetlands as a water protection structure in forestry should be evaluated more carefully, and applications should be found for it. In addition, wood-based materials have been tested in retaining soluble nutrients and organic carbon, such as biocarbon and bundles of tree stems. The development of these methods should be continued, and their effects on runoff water quality should be monitored more accurately. In forestry, more attention should be paid to regional differences in the loading in water bodies with regard to water protection. In addition, preventing the cloudiness of waters should play a stronger part as a goal in water resources management.

Water protection methods that may be suitable for acid sulphate soils, including ash fertilisation, limestone filter dams and biocarbon filtration, should be developed further.

Developing a model of close cooperation between the agricultural and forestry sectors

Cooperation between agriculture and forestry at the level of water body specific catchment areas should be developed. General planning related to drainage should be piloted, and in this context, an operating model for testing the smooth running of cooperation should be created. The operating model should be tested in different areas, gradually creating a national model which enables the use and combination of water protection solutions and possibilities for directing and storing waters used in the drainage projects of the different land use sectors.

Implementing a study on drainage status and needs

At present, the agricultural and forestry sectors do not have an overall idea of the drainage status of fields and forests.

Information on the current status of the drainage network and drainage needs in agricultural and forest lands is a prerequisite for developing the activities. Methodology development is needed in such fields as geospatial data and remote sensing to identify watercourses, ditches and subsurface drains in need of maintenance. In addition, a study on drainage status covering both sectors should be conducted, and a process should be developed for keeping the drainage status data up to date. As far as possible, this process should be based on digital data sets and data produced by support schemes and other existing processes, ensuring that the situational picture is kept up to date and that the production of information remains simple. The drainage status study together with the river basin management plans should be the starting point for targeting water management and water protection measures in agriculture and forestry through regional planning.

Developing water quality monitoring

The forestry sector has a Monitoring network for water loading from forestry, which continuously measures runoff and monitors water quality in 21 forestry areas and 10 catchment areas in a natural state around Finland. The data produced by the monitoring network is openly accessible (http://kartta.luke.fi/vesidata/). Continued operation of this network should be ensured, and sufficient funding should be guaranteed for it. Preconditions for more accurate impact assessments and targeting of water management measures include developing monitoring data use as well as identifying and filling in gaps in the monitoring network.

Monitoring data on agriculture is available through the monitoring of water management and water quality in general. Improved assessment of the impacts of agriculture on water systems could be supported by means of a more comprehensive monitoring network comprising continuously operating measurement stations with a wider coverage. When selecting areas, sites should be used on which monitoring data is already available, for example data produced by different projects, and on which information on cultivation measures and other properties is available.

Maintaining international cooperation and exchanges of information

International information exchanges and development at the level of research, administration and companies should be maintained in water management issues of agriculture and forestry.

International forums for information exchanges include the International Organisation for Irrigation, Drying and Flood Protection (ICID) and the Nordic Association for Agricultural Science (NJF). Participation in European research and development cooperation also provides good opportunities for influencing EU policy measures.

The protection of the Baltic Sea requires cooperation between all countries in its catchment area. Decisions of the ministerial meetings of the Baltic Marine Environment Protection Commission HELCOM (e.g. HELCOM 2013) refer to developing catchment area level water control to reduce nutrient loading, and the Baltic Sea Action Plan, which is about to be updated, is to specify concrete measures implemented throughout the Baltic Sea area. Finland has been active in water issues related to agriculture, for example during Finland’s HELCOM Chairmanship in 2019–2020, and this work needs to be continued.

Climate change and the need to adapt to changes in weather and hydrological conditions also challenge previous water management practices in agriculture and forestry and the competence associated with them. International cooperation and information exchanges play a key role in the development of new operating methods and competence.

Investigating needs to develop irrigation

Irrigation is currently quite rare in arable farming in Finland. It has been estimated that with the current irrigation equipment, only about 3% of the arable land area in the entire country could be irrigated (Jaakkonen & Mattila 2012). This is due to the availability of other cultivation technology innovations, the high investment costs of irrigation equipment, and the poor profitability of agriculture. What also creates a challenge to irrigation is that when the need for irrigation is the greatest, the water supply often also is restricted. This is particularly true for areas with few lakes or rivers.

The need for irrigation water and the feasibility of irrigation in agriculture at present and in the future should be examined. The possibilities of utilising different water reserves, including lakes, rivers, other water bodies, the soil, arterial drainage channels and forest areas to store irrigation water should be investigated. Preparedness for irrigation in agriculture should be improved by promoting controlled subsurface and open ditch drainage in fields suitable for these methods.

Developing indicators for sustainable water use and carbon balance in agriculture and forestry

Indicators for the sustainability and carbon balance impact of water use in agriculture and forestry should be developed to assess the economic, social and environmental impacts of water use better and to promote responsible water management.

The so-called water footprint concept used in the international ISO standard (ISO 14046: 2014) offers an opportunity to do so. Among other things, the water footprint can be used to make visible the so-called 'hidden water' which is used in the production process but which cannot be directly seen in the actual product or service, as well as to compare water consumption in different stages of the production chain and in different areas. Another method that might be better suited for an indicator of sustainable water use in Finnish agriculture and forestry is water accounting, which would offer more extensive opportunities than the water footprint for utilising the indicator for such issues as the value of water, nutrient loading in water bodies, regulation and economic policy instruments. (Launiainen & Laurén 2012, Salminen et al. 2017).

The development of indicators for the sustainability of water use in agriculture and forestry should continue. In addition to water volumes and the efficiency of water use, the indicators should take into account loading in water bodies and aquatic ecosystems. The development and introduction of indicators would also make possible more effective communication about sustainability of water use to consumers, enabling them to influence the sustainability of agriculture and forestry through their choices.

Similar indicators should also be developed for how water management in agriculture and forestry can influence the carbon balance in these sectors, including the carbon balance of soil. More carbon is bound in soil than in the vegetation above the ground, which is why even a small change in soil carbon content can produce extensive climate impacts.

Additionally, the volume of soil carbon correlates strongly with the soil's good agricultural condition and microbiological activity.

3.5 Education, training and advice

Strengthening education related to water management and environmental protection

Instruction related to water management is mostly provided as part of natural resources education. Water management in agriculture and forestry is often overshadowed by other studies, and not enough attention is paid to its significance for production and the environment.

The instruction and teaching materials related to water management and water protection should be reviewed and, if necessary, developed at all levels of education (especially in upper secondary and higher education).

The educational administration and practical agricultural and forestry advisory services should work together to develop an easy-to-understand, evidence-based information package on water management and water protection using digital tools.

Provision of training for officials, planners and contractors

Training on water management in agriculture and forestry aimed at actors or authorities in these sectors is currently desultory.

Joint in-service training on water management in agriculture and forestry should be organised for public officials, including funding and permit authorities. This training should provide a clear overview of the needs related to water management in agriculture and forestry and update the authorities' knowledge of the latest measures and practices. Training will also help ensure the coherence of practices and interpretations of legislation across the country in both sectors.

There currently are some 50 active water management planners in agriculture and around 60 subsurface drainage contractors, whereas there is only a handful of arterial drainage planners. Education in water management in agriculture which aims for competence in practical water management planning is provided by Sedu Adult Education in Ilmajoki. The students can complete a Specialist Qualification in Agriculture, which comprises the competence area of water management in agriculture. The competence area includes compulsory units in planning subsurface field drainage and the use of surveying equipment and planning software, as well as optional units in planning arterial drainage, runoff water treatment and irrigation, implementation of subsurface drainage, and management of a drainage corporate body. More than 60 planners have completed the module on planning subsurface field drainage. The Finnish Field Drainage Association maintains a competence system for subsurface drainage planners and contractors, which includes almost all key actors in the field.

Education in water management in agriculture is also provided by Aalto University's School of Engineering, the Faculty of Technology at the University of Oulu and the Faculty of Agriculture and Forestry at the University of Helsinki, and to some extent by the Universities of Applied Sciences of Häme, Jyväskylä, Lapland, Oulu, Seinäjoki, Savonia and Novia.

Education in the competence area of water management in the Specialist Qualification in Agriculture should be continued in order to keep up a sufficient number of qualified planners and contractors. The competence system of subsurface drain planners and contractors should be maintained, and the possibilities of improving its utilisation should be investigated, for example as part of the conditions for investment aid for subsurface drainage. Adequate in-service training for planners and contractors should also be ensured.

The estimated number of water management planners in forestry is 100. They work in forest management associations or Otso Metsäpalvelut Oy, or as forest service entrepreneurs. In forestry, training on water management is fragmented and small in scale.

The eligibility criteria for central government support do not currently include qualification requirements for the planners or implementers of agricultural and forestry drainage projects. When developing a new incentive scheme for forestry, a range of measures should be put in place to keep up the professional competence of operators who maintain forest ditches. Planners and implementers of management and ditch maintenance projects in peatland forests should have to give a demonstration of competence. This can be done in a special competence test, which could also be included in vocational education and training.

Raising awareness among and providing more opportunities for landowners and farmers

Carrying out maintenance and overhaul projects of main drains is often experienced as difficult. Ditch drainage may affect dozens of landowners, and no consensus can necessarily always be reached on the need for the measures and their implementation. Problems also arise in connection with leased land, including the division of costs. There may be gaps in farmers' knowledge of the significance of water management and its implementation in agricultural lands. People who have no previous familiarity with these sectors increasingly inherit agricultural and forest land. For this group of owners, advisory material is needed, which should also contain basic information about water management. In this context, knowledge and awareness of the soil type and properties of arable land as well as the prerequisites for good agricultural condition of soil, its impacts, and its promotion as the basis for water management planning should be emphasised.

Through cooperation networks (the measure Regional cooperation network), farmers and landowners can be advised and guided more effectively in water management issues. The ELY Centres, the Finnish Forest Centre and the municipalities should also pay additional attention to advisory services and guidelines, and sufficient resources for this should be reserved. Not only financial resources but also landowners' knowledge of drainage projects play a key role in achieving sustainable water management in agriculture and forestry.

Developing drainage management

Landowners need advice on how to manage common ditch drainage matters. For example, they need information on how an inactive drainage corporate body can be reactivated, how to apply for support, what investigations are needed and how costs are shared. Many are unclear about whether cadastral proceedings are needed in a specific case, whether a permit from the permit authority is required, or whether drainage can be based on an agreement. Since 2019, the competence area of water management in agriculture in the Specialist Qualification in Agriculture has contained a module on managing a drainage corporate body. The adult education division of Seinäjoki Joint Municipal Authority for Education (SEDU) currently organises preparatory training for the qualification and accepts competence demonstrations.

Drainage management activities and their scope should be monitored and developed as necessary. They could also be extended to forestry areas, and even to serving as a catchment area coordinator referred to in the action 'Promoting comprehensive water management in governance', and as a facilitator and convener of the network proposed in the measure 'Regional cooperation network'. Cooperation with the management of roads and other rural infrastructure, such as water supply, should be intensified. Experience gained in Sweden (studiecirklar), Denmark (oplanssulter) or England (Catchment Officers) can be used to develop drainage management.

3.6 Digitalisation

Developing new mapping methods

New mapping methods, including remote sensing (by drones, aircraft, satellites), artificial intelligence and machine learning, should be developed to meet the needs of the water management sector. Continuous development of geospatial data tools ensures more effective utilisation of the more accurate data. Advanced geospatial data tools enable more detailed pre-planning of drainage and also open up possibilities for seeking more extensively for depressions and low-lying areas to which water can be directed in the terrain. Geospatial data sets are particularly useful in advance planning, as they make it possible to examine project details related to drainage technology and water protection by catchment area and go ahead with their planning well before a field visit.

Generation of digital data sets

Documents related to the arterial drainage of agricultural land are stored at the ELY Centres or in regional archives. Some of them have been digitised and imported into the geospatial data system. Forestry drainage and ditch maintenance projects on private lands are currently archived in the files of the Finnish Forest Centre's district offices. Data on forest ditches have been partly digitised, but no detailed information exists on non-digitised projects. The planning of forestry drainage was digitalised at the turn of the 2000s.

Data on completed arterial drainage, forestry drainage and ecological management projects should be converted into a uniform and easy-to-use electronic format as far as possible. While the ELY Centres have guidelines for the digitisation of drainage corporate bodies' documents in the agricultural sector, no similar uniform guidelines exist for the forest sector.

General water protection plans, priority areas of water resource management, and completed water protection measures should be documented more accurately in an electronic format and stored in the geospatial data system. The availability of data in a digital format would facilitate the work of drainage corporate bodies, the authorities and planners, also helping to expand the scope of the planning to larger areas. A precondition for planning based on catchment areas is developing a common planning platform to improve the usability of digital data sets.

Openly accessible hydrographic data (on channel networks) should be developed to also include watercourses smaller than a water body[3], including streamlets and drainage ditches. The conceptual model of the Hydrography theme in the National Topographic Database defines the water bodies to be modelled, such as lakes, running waters, marine areas, rapids and flow paths.

Geospatial data should be compiled on small water bodies with valuable fisheries and other aquatic ecosystems, including obstacles to migration and completed water restoration projects. Existing geospatial data sets should be complemented with data on running waters important for migratory fish.

The database of subsurface drain maps should be kept up to date. Saving subsurface drainage plans to a single location also in the future will support the planning and long-term maintenance of subsurface drains (currently, a subsurface drain database is maintained by the Finnish Field Drainage Association). This database contains almost all subsurface drainage plans in Finland, and it provides easy access to these plans for farmers when necessary.

Using data and promoting its availability

Currently, such stakeholders as the National Land Survey of Finland, the Finnish Environment Institute, the Finnish Meteorological Institute, the Natural Resources Institute Finland and the Finnish Forest Centre produce digital data sets, most of which are openly accessible. To support the planning of peatland forest management, an open map service containing geospatial data on peatland forest management has been compiled on the website of the Finnish Forest Centre. This service includes the data sets of the producers

3 According to the water act (587/2011), water formations with a catchment area smaller than 10 km^2 where water does not flow continuously and the passage of fish is not possible to any significant extent are not classified as water bodies (note: definition differs from Water Body as defined in EU WFD).

listed above. The Finnish Field Drainage Association maintains a database in which are stored most subsurface drainage plans in Finland. While this database is not an open one, it can be accessed by planners and researchers.

In the future, the availability and usability of open data should also be expanded to provide coherent and compatible map and other services for actors in agriculture and forestry, such as planners. Electronic materials should also be utilised to develop the monitoring of drainage status (see the measure Implementing a study on drainage status and needs), among other things.

The ELY Centres are planning a digitalisation project of river basin management plans (eTPO), the implementation of which should be supported. If this project goes ahead, it would be completed in connection with the preparation of the following set of plans by 2021. As a result of the eTPO project, future river basin management plans would be in a more easily readable and accessible format, also benefiting planners of drainage in agriculture and forestry. The use of these plans in drainage planning would promote water protection in agriculture and forestry and, more extensively, also planning related to the catchment areas of specific water bodies.

The priority areas of water resource management should also be included in the geospatial data, making them more extensively available for both planners and the proposed cooperation network. Location data on endangered species are not included in open data sets, and the possibilities of making them available at a rough level, such as the occurrence of endangered species on a certain watercourse section, should be assessed.

Development and wider use of calculation models in planning and impact assessment

Computational models should increasingly be used in the planning of water management in agriculture and forestry as well as for assessing the impacts and cost-effectiveness of various agricultural and forestry measures. They can be used to model water management in different regions and over different periods on a range of scales. The model to be applied in each situation should be carefully selected, ensuring that it is suitable for the site in question and for the Finnish conditions. A precondition for modelling is that versatile measurement data are also available (see also the measures Developing water quality monitoring and Research and development related to water management techniques).

At the national level, models are needed to assess hydrological changes and the extent of loading caused by land use in real time and by river basin. The watercourse model system maintained by the Finnish Environment Institute (VEMALA, Modelling and evaluation system for water quality and nutrient loading, Finnish Environment Institute 2020) is well suited for this purpose and has been in operational use for a long time. The development and maintenance of the VEMALA model should be ensured, and the model should be used more widely. For example, development needs are associated with the calculation of loading figures for different land use forms, the utilisation of calculation results, and the combination of different models in order to get a better overall idea of the transport of water and substances on different scales.

The assessment of plant growth, transport of water and substances, and impacts of measures (including drainage) needs to be supported by models capable of describing physical and chemical processes. The efficiency of developing and using such models should be improved. Research and measurement data should be produced in cooperation between the administration, research institutes and universities, without forgetting the opportunities offered by NGOs and the private sector. There are several potential models that examine hydrological processes and those related to the transport of substances in soil on a smaller scale:

The FLUSH model developed at Aalto University, which describes the hydrology of agricultural lands, can be used to assess the impacts of ditch drainage on water balances and flows, as well as the runoff of solids and nitrogen leaching. The model is currently being developed for assessing the impacts of subsurface drainage. In the future, a description of phosphorus leaching should also be incorporated in the model, and it should be expanded to catchment area level.

Aalto University has investigated the suitability of the DRAINMOD model developed in the United States and the Hapsu model developed by the Finnish Environment Institute for modelling the water economy of acid sulphate soils. In cooperation between Aalto University and the Drainage Foundation, a model is now being developed which combines the HYDRUS and PHREEQC models to facilitate the assessment of loading in water bodies caused by acid sulphate soils with various options for controlling the water economy of a field. The modelling will first focus on the scale of field parcels in agricultural areas causing the greatest loading in water bodies, but the application of the model to forest land should also be assessed.

The KUNNOS risk assessment tool developed by WaterHope Oy can be used to assess the impacts of forest drainage in groundwater areas. The development of this model should be continued, and the possibilities of applying it to agricultural areas should also be assessed.

The Natural Resources Institute Finland has developed a peatland simulator, SUSI, which can be used to model the impact of ditch depth on the growth response of trees. The simulator makes it possible to assess if ditch drainage is necessary for a specific growth site and compartment. The development of the peatland simulator should be continued, also incorporating in it estimates of the impacts on greenhouse gas emissions and water bodies caused by different drainage depths and forest management alternatives.

Digitalisation of administrative processes

The current operating environment requires extensive digitalisation of administrative processes and services based on electronic and, where applicable, automated practices. The usability of the data needed in water management in agriculture and forestry, information flows, smooth delivery of services between the administration and various actors and, ultimately, decision-making and impact assessments would benefit significantly from digitalisation.

Generally speaking, the environmental and geospatial data needed for ditch drainage and other water management projects in agriculture and forestry are relatively freely available in an electronic format. Instead, the digitalisation of information on previous projects (see also the measure Generation of digital data sets) and notification, permit, statement and support processes is not yet sufficiently advanced. The sectors of agriculture and forestry are at different stages when it comes to the digitalisation of administrative processes, and the compatibility and interoperability of their systems are only taking their first steps.

Shortcomings in the digitalisation of administrative processes should be identified, and the processes to be digitalised should be mapped in both sectors jointly and separately. The implementation of projects already identified, including the digitalisation of drainage notifications and application procedures, should be ensured. New cooperation models and practices based on digitalisation between the administration, operators and service providers are also needed.

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