Evaluation support study on the impact of the CAP on sustainable management of the soil

Final report

Alliance Environnement

November 2020

-Alliance Environnement-

European Economic Interest Grouping

EUROPEAN COMMISSION

Directorate-General for Agriculture and Rural Development
Direction C - Strategy, simplification and policy analysis

Unit C.4 - Monitoring and Evaluation
Contact dissemination: AGRI-EVALUATION@ec.europa.eu

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

Evaluation support study on the impact of the CAP on sustainable management of the soil

Final report

Directorate-General for Agriculture and Rural Development

2021

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (http://www.europa.eu).

Luxembourg: Publications Office of the European Union, 2021

PDF ISBN 978-92-76-21411-3 doi: 10.2762/799605 KF-02-20-617-EN-N

The United Kingdom withdrew from the European Union as of 1 February 2020. During the transition period, which ends on 31 December 2020, Union law, with a few limited exceptions, continues to be applicable to and in the United Kingdom and any reference to Member States in Union law shall be understood as including the United Kingdom.

Evaluation support study on the impact of the CAP on sustainable management of the soil

Authors:

This report is presented by the European Economic Interest Grouping:

-Alliance Environnement-

European Economic Interest Grouping

The study was coordinated by Juliette Augier (Oréade-Brèche) assisted by Juliane Papuchon (Oréade-Brèche), with main contributions from Alice Devot (Oréade-Brèche), Vincent Ayral (Oréade-Brèche), Adrien de Pierrepont (Oréade-Brèche), Anne Maréchal (IEEP), Stephen Meredith (IEEP) and Ana Frelih-Larsen (Ecologic). Other contributors to this study were Thierry Clément (Oréade-Brèche), Damien Lisbona (Oréade-Brèche), Emilia Poirier, Eloïse Maire and Dorian Pinsault.

The case studies were conducted by: Juliette Augier and Damien Lisbona (Oréade-Brèche) for Belgium-Wallonia; Filiz Ismetova for Bulgaria; Lukáš Maláč (EACE) for Czechia; Ana Frelih-Larsen and Sophie Ittner (Ecologic) for Germany-Bavaria; Morten Kvistgaard for Denmark; Leonidas Nikolaou for Greece; Stephen Meredith (IEEP) for Ireland; Juliane Papuchon and Vincent Ayral (Oréade-Brèche) for Spain-Aragon; Paola Torcia for Italy-Tuscany; Alice Devot and Adrien de Pierrepont (Oréade-Brèche) for Sweden.

EEIG ALLIANCE ENVIRONNEMENT is formed by the following companies:

ORÉADE-BRÈCHE Sarl
2480 L'Occitane - 31670 Labège, France
Tel. : + 33 5 61 73 62 62
Fax : + 33 5 61 73 62 90
Mail : t.clement@oreade-breche.fr
Represented by:
Thierry CLEMENT

and

IEEP
Rue Joseph II 36-38 – 1000 Brussels, Belgium
Tel. : + 32 (0) 2738 7482
Fax : +32 (0) 2732 4004
Mail : CFroomberg@ieep.eu
Represented by:
Claire FROOMBERG

Date: November 2020

TABLE OF CONTENT

TABLE OF TABLES

TABLE OF FIGURES

TABLE OF BOXES

TABLE OF MAPS

List of acronyms

AECM	Agri-environment-climate measure
AIR	Annual implementation report
AKIS	Agricultural knowledge and innovation systems
BPS	Basic payment scheme
CAP	Common agricultural policy
CD	Crop diversification
CMEF	Common monitoring and evaluation framework
CMO	Common market organisation
CS	Case study
CSA	Community supported agriculture
CUMA	Cooperative for the use of agricultural equipment
EAFRD	European Agricultural Fund for Rural Development
EAP	Environmental action plan
EEA	European Environment Agency
EFA	Ecological focus area
EIP	European Innovation Partnership
ENRD	European network for rural development
EQ	Evaluation question
ESPG	Environmentally sensitive permanent grassland
ESQ	Evaluation study question
ETS	Emission trading system
EU	European Union
FADN	Farm accountancy data network
FAO	Food and Agriculture Organisation
FSS	Farm structure survey
GAEC	Good agricultural and environmental conditions
GHG	Greenhouse gas
GPS	Global positioning system
HNV	High nature value
ICT	Information and communication technologies
IPM	Integrated pest management
JRC	Joint Research Centre
LAG	Local action group
LSU	Livestock unit
LUCAS	Land use and land cover survey
LULUCF	Land use, land-use change & forestry
MS	Member States
NEC	National emission ceilings
NGO	Non-governmental organisation
NVZ	Nitrate vulnerable zone
PG	Permanent grassland
PII	Pillar II
PPP	Plant protection product
RBMP	River basin management plans
RD	Rural development
RDP	Rural development programme
RP	Research papers
RTK	Real-time kinematic
SAC	Special area of conservation
SAPS	Single area payment scheme
SFS	Small farm scheme
SMR	Statutory management requirements
SMS	Sustainable management scheme
SOC	Soil organic content
SOM	Soil organic matter
SPA	Special protection area
SPUD	Sustainable pesticide use directive
SSM	Sustainable soil management
SWOT	Strength weakness opportunity threat
UAA	Utilised agricultural area
UAV	Unmanned aerial vehicle
VCS	Voluntary coupled support
WFD	Water framework directive

ABSTRACT

As part of a series of evaluation of the Common agricultural policy (CAP) against its general objective of sustainable management of natural resources and climate action, the evaluation support study of the impact of the CAP on soil identified the activities impacting soil quality and reviewed the implementation choices at the Member States' and beneficiaries' levels on instruments and measures with an impact on soil quality and productivity. It investigated the effectiveness, efficiency, relevance and coherence and EU added value of the CAP instruments and measures addressing sustainable soil management and soil quality. The analysis covered the period from 1 January 2014 onwards, in all EU Member States. It considered all instruments and measures with a potential direct or indirect effect on soil sustainable management. A focus was made on the CAP instruments and measures explicitly designed to address sustainable soil management, i.e. the horizontal requirement of minimum soil cover and management practices (GAECs 4 and 5), the requirement to maintain soil organic carbon in soil (GAEC 6), the obligation of crop diversification under greening, and the RD support for investments in forests (M08), agri-environment and climate measures (AECM or M10.1) and support for organic farming (M11).

Dans le cadre d'une série d'évaluation de la politique agricole commune (PAC) par rapport à son objectif de gestion durable des ressources naturelles et d'action climatique, l''étude de support à l'évaluation de l'impact de la PAC sur les sols identifie les activités impactant la qualité des sols et examine les choix de mise en œuvre des États membres et des bénéficiaires de la PAC concernant les instruments et mesures ayant un impact sur la gestion durable et la qualité des sols. L'efficacité, l'efficience, la pertinence, la cohérence et la valeur ajoutée des instruments et mesures de la PAC visant la gestion durable des sols est examinée. L'analyse couvre la période démarrant au 1er janvier 2014 et tous les États Membres de l'UE. L'accent est mis sur les instruments et mesures de la PAC visant explicitement à répondre aux enjeux de gestion durable des sols, c'est-à-dire l'obligation de couverture minimale des sols et de pratiques de gestion (BCAE 4 et 5), l'obligation de maintien du taux de matière organique (BCAE 6), l'obligation de diversification des cultures dans le cadre du verdissement, la mesure de soutien aux investissements dans les forêts (M08 des PDR), les mesures agroenvironnementales et climatiques (MAEC ou M10.1), ainsi que les mesures de soutien à l'agriculture biologique (M11).

1. INTRODUCTION

1.1. OBJECTIVES AND SCOPE OF THE EVALUATION STUDY

Soil is one of the most important natural resources and a key resource for agriculture and forestry. Conversely, activities in agriculture and forestry have a direct impact on soil quality in the EU: that impact can include soil erosion, compaction, soil organic matter (SOM) content, soil biodiversity, soil pollution, salinisation, and the balance of nutrients in soils (see Figure 1). To safeguard the natural functions and production of soil, sustainable soil management (SSM) is required. This refers to activities in agriculture and forestry dealing with soil conservation, amendment, restoration, fertilisation and health, with a goal toward protecting, restoring and improving soil quality.

Figure 1: Sustainable soil management and the factors of soil quality

Source: Alliance Environnement

As part of a series of evaluations of the common agricultural policy (CAP) with regard to its general objectives of sustainable management of natural resources and climate action, this evaluation study focuses on the impact of the CAP on sustainable soil management. It assesses the extent to which CAP instruments and measures have contributed, through impacting activities in agriculture and forestry, to fostering sustainable management of soil and have influenced soil quality.

The objective of the study is to provide further understanding of the strong and weak points of the various CAP instruments and measures in terms of addressing the soil challenges in agriculture and forestry, with future policy development and implementation in mind. With that purpose, the study identifies the activities impacting soil quality and reviews the implementation choices, at the Member State and beneficiary levels, for instruments and measures impacting sustainable soil management and soil quality. It then investigates the effectiveness, efficiency, relevance and coherence and EU added value of the CAP instruments and measures addressing sustainable soil management.

The analysis covers the period following the implementation of the 2013 EU common agricultural policy reform, from 1 January 2014 onwards, in all EU Member States. It considers all instruments and measures with a potential direct vs indirect effect on sustainable soil management, including the horizontal measures as set out in Regulation (EU) No 1306/2013, the direct payments support schemes as set out in Regulation (EU) No 1307/2013, relevant sector-specific market support measures as set out in Regulation (EU) No 1308/2013, and relevant Rural Development measures as set out in Regulation (EU) No 1305/2013.

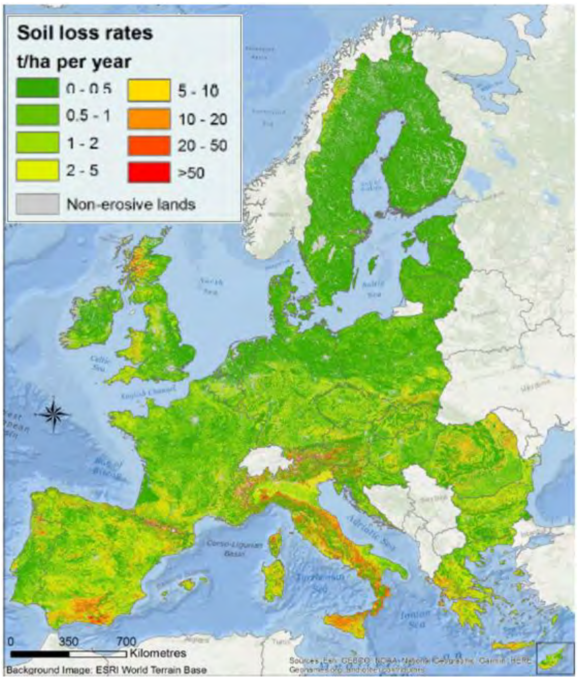
1.2. State of EU soils

Soil is a natural body consisting of layers composed of weathered mineral materials, organic material, air, water and living organisms[1]. As the support of life on earth, soil delivers a variety of ecosystem services, e.g. it provides food, fibre and fuel, carbon sequestration, water purification, climate regulation, nutrient cycle and habitat for microorganisms. However, soil is a hardly renewable resource: it takes 1 000 years on average to produce one cubic centimetre of soil (FAO and ITPS, 2015). Besides, considerable amount of soils is lost every year as a result of erosion and sealing: according to the Food and Agriculture Organisation of the United Nations (FAO), 20 to30billion tonnes of fertile soils or 12 million hectares topsoil are lost every year.

Furthermore, the capacity of soils to deliver the above-mentioned ecosystem services varies according to their properties (e.g. chemical content, physical and biological properties). Most of the soil properties are dynamic and are affected by processes such as compaction, pollution, salinisation, and decrease in organic matter or biodiversity. The following paragraphs provide an overview of the state of soil in the EU with regard to those factors of soil quality.

1.2.1. Soil erosion

Map 1: Soil loss related to erosion by water in the EU (reference year: 2016)



Source: (Panagos *et al.*, 2020) modelled by RUSLE2015

An estimated 12.7% of Europe's land area is affected by moderate to high erosion[2] (EEA, 2020), compromising soil functions and water quality. Water erosion leads to topsoil removal, while wind erosion involves the removal of predominantly the finest soil particles. Agriculture also directly contributes to erosion, in particular through crop harvesting. Soil erosion modelling showed that the mean soil loss rate by water erosion is estimated at 2.45 t/ha/yr in the EU-28 for 2016 (Panagos et al., 2020). In 2010, this rate (which was at 2.46 t/ha/yr) exceeded by 1.6 the average soil formation rates (Panagos *et al.*, 2015b). The total soil loss due to water erosion is estimated at 960 million tonnes per year (Panagos et al., 2020). The rate of soil erosion by water however significantly vary across the EU (see Map 1).

Soil loss due to wind erosion on arable lands is estimated at 62 million tonnes per year, as the mean wind erosion rate is 0.53 t/ha/yr (Borrelli *et al.*, 2017). Regarding soil loss due to harvesting crops, Panagos et al. (2019) estimate that 4.2 million hectares of root crops (out of 173 million hectares of utilised agricultural land in the EU) contribute to 14.7 million tonnes of soil loss (Panagos, Borrelli and Poesen, 2019).

[1] See https://ec.europa.eu/environment/soil/index_en.htm and http://www.fao.org/soils-portal/about/all-definitions/en/

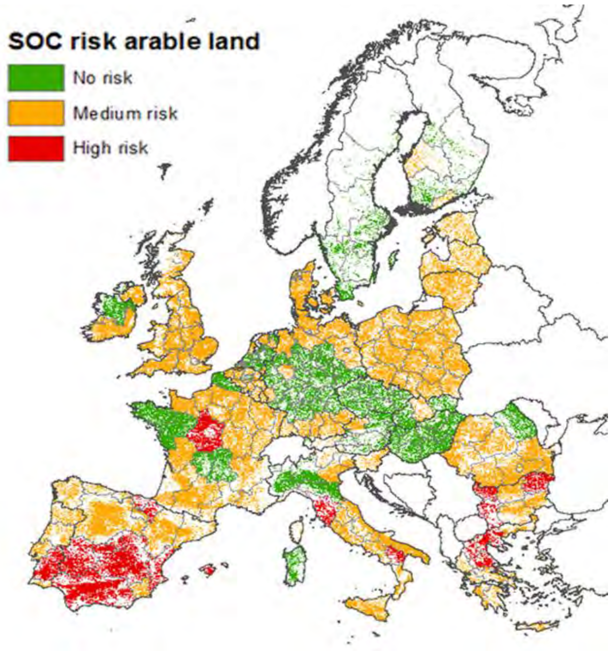
[2] Erosion is considered as moderate when soil loss rates exceeds 5 t/ha per year.

1.2.2. Soil organic carbon

Soil organic matter influences numerous soil properties relevant to ecosystem functioning and crop growth. Even small changes in total C content can have disproportionately large impacts on key soil physical properties (Powlson *et al.*, 2011). Soil organic carbon (SOC) supports the soil's structure, which improves the physical environment for roots to penetrate through the soil, enhances water-retention capacity, and supports drainage (thus reducing runoff and erosion). A loss in organic carbon content can limit soil's ability to provide nutrients for sustainable plant production.

Around 45% of the mineral soils in Europe have low or very low organic carbon content (0–2 per cent organic carbon) (FAO and ITPS, 2015). The highest contents of organic carbon in soil can be found in the northern areas (Estonia, Latvia, Finland, Sweden, the UK), especially in woodlands, wetlands and mountainous areas. The lowest organic carbon contents are found in the Mediterranean zone (Greece, Spain, Italy), but also in some parts of Czechia, Germany, France, Hungary, Poland and Slovakia, where croplands and permanent crops are predominant (De Brogniez *et al.*, 2015). Regions at high risk of decline in soil organic carbon (SOC) stocks in arable lands are mainly located in the Mediterranean zone (mainly Greece, Spain, Italy) and can be found in some parts of Bulgaria and France. The lowest risk regions are mostly located in central and parts of western Europe (Czechia, Germany, France, Hungary, the Netherlands) (Merante *et al.*, 2014) (see Map 2).

Map 2: Soil organic carbon risk classes for arable land in the EU



Source: (Merante *et al.*, 2014) from RothC model using input data from the MITERRA-Europe model

1.2.3. Soil compaction

Compaction causes significant damage to soil infiltration rate, redistribution of water and nutrients, and root development (Noor Shah *et al.*, 2017). It also negatively affects soil organisms, as their presence is determined by the accessible soil pore volume. Two types of soil compaction exist: topsoil compaction and subsoil compaction. The first type is reversible, while the second is persistent, cumulative, and without remediation options (Thorsøe *et al.*, 2019).

The susceptibility of soils to compaction mainly depends on soil texture, with sandy soils being least and clayey soils being most susceptible. It also increases with the soil water content.

An estimated 32-36% of European subsoils have high or very high susceptibility to compaction (Jones *et al.*, 2012a). About 23% of soils in the EU-28 are estimated to have critically high densities in their subsoils, indicating compaction (Schjønning *et al.*, 2015). Soils in the north part of Europe (Denmark, Estonia, Lithuania, the Netherlands, Poland) are the most affected (based on the bulk density sampled in LUCAS 2009), but other regions such as northern Germany, southern Spain, northern France and southern Portugal and UK are also concerned (Ballabio, Panagos and Montanarella, 2016; Orgiazzi *et al.*, 2016).

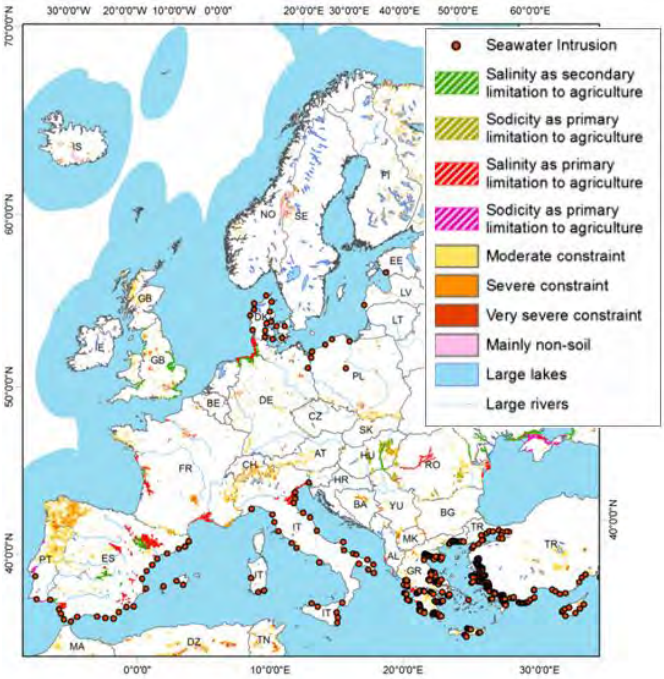
1.2.4. Soil salinisation and sodification

Salinisation leads to an excessive increase of water-soluble salts in the soil, whereas sodification concerns an increased content of exchangeable sodium (Na^{+}). High levels of salinity in soils provoke the withering of plants due both to the increase of osmotic pressure and the toxic effects of salts.

Salinisation also decreases the permeability of soil layers, eliminating the possibility of using the land for cultivation. Excess sodium on the exchange complex results in the destruction of the soil structure, which, due to a lack of oxygen, cannot sustain either plant growth or animal life. The main natural factors influencing soil salinity are climate, the salt contents of the parent material and groundwater, land cover and topography (Louwagie, Gay and Burrell, 2009).

At EU scale, seawater intrusions are concentrated on the Mediterranean (Greece, Spain, Italy) and Baltic coasts, mainly in Denmark and Poland (Daliakopoulos *et al.*, 2016). Saline soils have developed in most arid regions, where climate is the determining driver, e.g. in Spain, Hungary and Romania. Other countries suffer localised occurrence of these conditions, which could have a devastating effect locally.

Map 3: Saline and sodic soils as agricultural constraint/limitation and areas of seawater intrusion in Europe in 2008



Source: (Daliakopoulos *et al.*, 2016)

1.2.5. Soil pollution

The FAO defines soil pollution as 'the presence of a chemical or substance out of place and/or present at a higher than normal concentration that has adverse effects on any non-targeted organism'. There is a broad diversity of pollutants, from heavy metals to agrochemicals, and the list is constantly evolving due to agrochemical and industrial developments. The effects of soil pollution depend on various factors including soil properties, since these determine the mobility, bioavailability and residence time of contaminants. High concentrations of heavy metals can be toxic for living organisms, resulting in biodiversity decline and groundwater pollution. Heavy metals together with excessive nitrogen inputs are main sources of contamination in agricultural soils (Louwagie, Gay and Burrell, 2009). The presence of certain pollutants may also lead to nutrient imbalances and soil acidification (FAO, 2017).

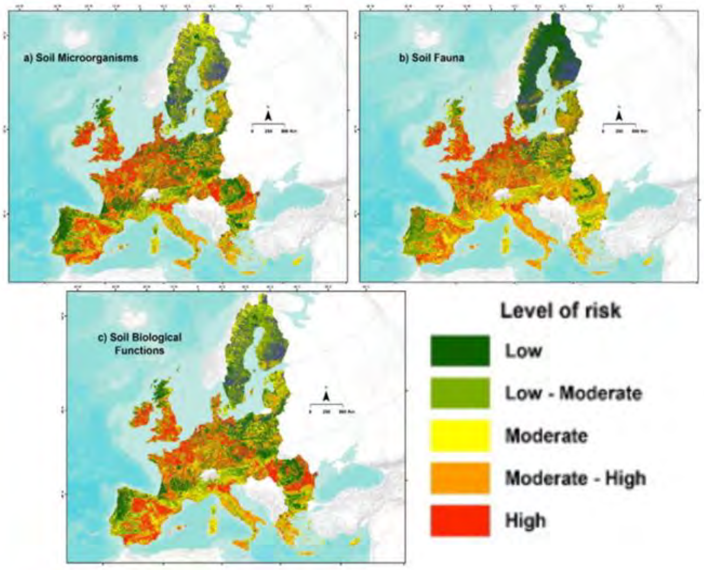
An estimated 6.24% of EU-27 agricultural land needs local assessment and possible remediation action (Tóth *et al.*, 2016). Regional differences can be observed within the EU, with north-eastern Europe and eastern-central Europe less affected by high concentrations of heavy metals, compared to western Europe and the Mediterranean. The presence of microplastic particles in agricultural soils is another growing issue. It alters physical parameters of the soil environment as well as plants' physical and physiological traits. However, there is a lack of information on the extent of the problem and further research is needed (De Souza Machado *et al.*, 2019).

1.2.6. SOIL BIODIVERSITY

Changes in biodiversity alter ecosystem processes and the resilience of ecosystems to environmental change (Louwagie, Gay and Burrell, 2009). The factors that can impact soil biodiversity can be biotic or abiotic (e.g. changes in climate, land use, soil-quality components, etc.).

Most EU soils are at risk for soil microorganisms, fauna and biological functions (Orgiazzi *et al.*, 2016). Only Finland, Poland, Portugal, Slovakia and Sweden have more than 40% of their area in low or low-moderate risk (see Map 4). At EU level, arable soils are the most exposed to pressures.

Map 4: Potential risk to soil biodiversity in Europe



Source: (Orgiazzi *et al.*, 2016) from an additive aggregation model

1.2.7. NUTRIENT BALANCE

A lack of nutrients (nitrogen and phosphorus) may lead to low soil fertility. Conversely, a build-up of surplus nutrients in excess of crop needs can lead to nutrient imbalance in soils which impacts soils' biology communities and soils' functions (Louwagie, Gay and Burrell, 2009).

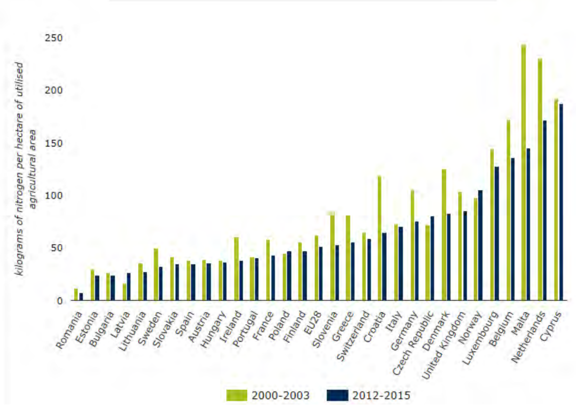
From 2000 to 2015, the gross balance between nitrogen added to and removed from agricultural land in the EU has decreased, which is a positive trend meaning that the potential nitrogen surplus was reduced (EEA, 2018). The surplus of nitrogen applied to agricultural land fell by about 18%, from an average (EU-28) of 62.2 kg/ha in the period 2000-2003 to an average of 51.1 kg/ha in the period 2012-2015[3]. However, the nitrogen balance has not improved further in samples taken since 2010. Even though they are decreasing in most Member States, agricultural nitrogen surpluses are still high in some parts of Europe, in particular in the Atlantic and Mediterranean zones (e.g. Belgium, Cyprus, Luxembourg, Malta, the Netherlands)[4].

Based on the LUCAS soil database, the mean value of nitrogen is estimated at 2.11 g/kg (Panagos *et al.*, 2020). As regards the balance in phosphorus between 2013-2015, data revealed surplus in the majority of the EU Member States (see Figure 3). The mean value of phosphorus is estimated at 27.20 mg/kg (Panagos *et al.*, 2020).

[3] Series of years (3-4 years) are taken as a reference instead of a single year, in order to avoid taking into account the effects of yearly weather conditions.

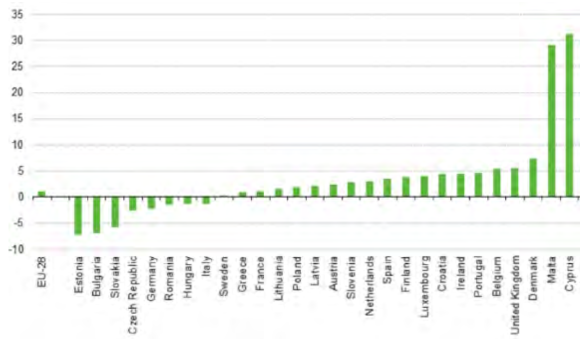
[4] A lower nitrogen surplus at Member State level does not mean that the Member State does not face major issues in relation to nutrient imbalance, as there can be significant heterogeneity at regional level (e.g. in FR-Britany and IT-Emilia Romagna).

Figure 2: Gross nitrogen balance by country



Source: EEA, 2018

Figure 3: Gross phosphorus balance kg P per ha, 2013-2015



Source: EEA, 2018

1.3. GENERAL EU POLICY FRAMEWORK WITH REGARD TO SOIL

In the last 20 years, policy initiatives on soil protection have been undertaken at EU level.

In 2002, following the call of the 6th Environment Action Programme[5], the Commission communication **'Towards a Soil** Thematic S**trategy'**[6] laid down the principles of a future Soil Thematic Strategy to prevent further soil degradation and restore degraded soils in the European Union.

Published in 2006, the Soil Thematic Strategy[7] states that soil should be considered as a non-renewable resource, given its extremely slow formation process. It sets the general objectives for the EU to prevent further soil degradation, preserve soil functions and restore degraded soils to a level of functionality that would be at least consistent with its current and intended use. Its implementation led to the proposal of a Soil Framework Directive[8]. Asa global regulation for soil protection, the proposal included several requirements related to erosion, organic-matter decline, salinisation, compaction and landslides, contamination, sealing and biodiversity loss. However, the proposal was opposed on account of the subsidiarity and proportionality principles, the estimated costs of implementation and related administrative burden, and the existing contradictory national legislations. This put an end to a binding act for soil protection in the EU.

In 2013, the 7th Environmental Action Programme[9], setting the guidance for the EU environment policy until 2020, included the objective to 'protect natural resources and promote a sustainable use of soil'. It establishes the types of degradations to which soil is subject; these include erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline of biodiversity, salinisation, flood and landslides. The 7th Environmental Action Programme provides guidelines towards sustainable land management, suitable land management and ongoing efforts to clean up soils by 2020 in the EU. It encourages Member States to pursue actions for reduction of soil erosion, increase of organic matter in soils and remediation of contaminated sites. The programme covers most soil threats, but its non-binding nature limits its strength and real impact (Ronchi *et al.*, 2019).

---

[5] Decision 1600/2002/EC.

[6] COM(2002) 179.

[7] COM(2006) 231.

[8] COM(2006) 232.

[9] Decision 1386/2013/EU.

The 2014-2020 Common Agricultural Policy (CAP) includes soil as one of the key resources for agriculture and forestry. Its objective of 'sustainable management of natural resources and climate action' includes also the objective of addressing sustainable soil management. Furthermore, the CAP objective of viable food is highly, even if implicitly, linked to the capacity of soil to produce – i.e. to soil productivity. The CAP provides a set of regulatory and financial instruments for the agricultural sector (see their description in Chapter 2), some of which directly aim to address soil quality and foster sustainable soil management. Other instruments, primarily addressing other environmental issues (biodiversity, climate, or water) may also contribute to sustainable soil management.

The protection of agricultural soils is also addressed through various other policies or strategies at EU level. This includes in particular:

- The Water Framework Directive (Directive 2000/60/EC), that indirectly addresses soil pollution (by acting on the reduction of discharges, emissions and losses of pollutants), erosion and soil compaction (by promoting sustainable land use with the objective of water quality and quantity) and salinisation (by working towards sustainable water use).
- The Nitrates Directive (Directive 91/676/EEC), whose implementation involves identification of areas to be classified as 'Nitrate Vulnerable Zones' (NVZs), where good agricultural practices in respect to nitrate management are to be applied by farmers (including compulsory compliance with prohibition of land application of certain types of fertiliser during certain periods, limitation of land application of fertilisers that considers the characteristics of the vulnerable zone concerned, and maximum amount of manure to be used per hectare).
- The Sustainable Use of Pesticides Directive (Directive 2009/128/EC), whose implementation through national action plans involves requirements such as the prohibition of aerial spraying and limitation of pesticide use in sensitive areas, informing about pesticide risks and promoting integrated pest management (IPM). The binding standards set by this directive are reflected in the CAP by the statutory management requirements (SMRs).
- The EU Floods Directive (Directive 2007/60/EC), which states that some human activities contribute to 'an increase in the likelihood and adverse impacts of flood events' and in particular soil sealing and soil compaction. Its implementation through flood risk management plans may promote sustainable land use and management practices, increasing natural infiltration and the retention capacities of soils.
- The Sewage Sludge Directive (Directive 86/278/EEC), which regulates the use of sewage sludge and contributes to limiting soil contamination, for instance by requiring limit values on concentrations of heavy metals in soil, treatment of sludge before its use in agriculture, and record-keeping of sludge use (quantities, composition, type of treatment, etc.).
- The Fertilisers Regulation (Regulation EU 2019/1009) which lays down common rules on safety, quality and labelling requirements for fertilising products. It introduces limits for toxic contaminants which guarantees a high level of soil protection. Among others, it defines thresholds for contaminants presence in fertilising products, notably Cadmium, to minimize soil pollution.
- The Mercury Regulation (Regulation EU 2017/852) which aims, among other things, to restrict the use of mercury in various products and seek to address pollution caused by it. It thus has an indirect effect to reduce soil pollution.
- The legislation on Plant Protection Products (PPP) (Regulation EU 1107/2009) which ensures that industry demonstrates that substances or products produced or placed on the market do not have any harmful effect on human or animal health or any unacceptable effects on the environment. It thus has an indirect effect to address soil pollution.

- The Biodiversity Strategy: in particular, target 3A aiming at 'By 2020, maximis[ing] areas under agriculture across grasslands, arable land and permanent crops that are covered by biodiversity-related measures under the CAP'.
- The Birds Directive (Directive 79/409/EC, amended by Directive 2009/147/EC) and the Habitats Directive (Directive 92/43/EEC), which, by preventing degradation of natural habitats and by preserving habitats including meadows and grasslands, may protect agricultural soils, fight soil biodiversity decline and promote land uses sustainable for soil quality.
- The Effort Sharing Decision (ESD): establishing binding non-CO_2 greenhouse emission targets for the Member States for the periods 2013–2020 for the sectors not included in the EU Emission Trading System, including agriculture and forest, concerned by land-based emissions (such as N_2O); and the Land use, Land use Change and Forestry (LULUCF) Decision (Decision No 529/2013/EU): setting quantified emission limitation for the agriculture and forest sectors. Those decisions however focus on land use and do not set objectives regarding the quality of agricultural and forest soils.

The EU Green Deal proposed by the European Commission in December 2019, followed by the Biodiversity strategy and the Farm to Fork strategy in May 2020, may add additional objectives with regards to soil protection. However, they were not taken into account in this evaluation study, which focused on the CAP implementation following the 2014 reform.

2. CAP INTERVENTION LOGIC WITH REGARD TO SUSTAINABLE SOIL MANAGEMENT

2.1. INTRODUCTION TO THE INSTRUMENTS AND MEASURES ADDRESSING SOIL-RELATED ISSUES

The CAP provides various instruments and measures that may impact activities with an impact on soil quality. Those considered in the evaluation study are presented below.

2.1.1. HORIZONTAL REGULATION, INTRODUCING RULES OF CROSS-COMPLIANCE

First introduced in 2003, cross-compliance sets basic rules for agricultural activities, related to public expectations on the environment, public and animal health, and animal welfare. Regulation (EU) 1306/2013 sets two categories of rules:

- Statutory management requirements (SMRs): these requirements refer to certain provisions of 13 legislative acts (including regulations and directives) that exist independently of the CAP and apply to all farmers (even those not receiving EU support). In particular, SMR1 and 10, although not specifically targeted towards soil, aim at regulating the use of pesticides and fertilisers and may therefore impact soil quality by limiting micro and macro nutrient unbalance.
- Standards of good agricultural and environmental condition (GAEC) provide for Member States establishing, at national or regional level, minimum standards for all farms receiving CAP payments. Farmers who do not comply are penalised by a reduction in or exclusion of the support received under the CAP. As set in Annex II of Regulation (EU) 1306/2013, three GAECs directly target sustainable soil management:
    - The requirements of minimum soil cover (GAEC 4) and of minimum land management (GAEC 5) reflecting site-specific conditions to limit erosion;
    - The requirement to maintain soil organic matter (GAEC 6), through appropriate practices including, as an EU baseline, the ban on burning arable stubble except for plant health reasons.

  Other GAECs do not clearly target sustainable soil management but may impact soil quality. These include:
    - GAEC 1, requiring the establishment of buffer strips along water courses, which could contribute to soil biodiversity and the reduction of soil erosion in these areas.
    - GAEC 3, regulating the protection of ground water and taking into account the indirect pollution brought about by dangerous substances percolating through the soil.
    - GAEC 7, focusing on the retention of landscape features. It has the potential to reduce the risk of soil erosion by disrupting the flow of wind and water, and its provision for the retention of woody features such as hedges, trees and ponds can reduce risk of loss of organic matter and contribute to the carbon pool through soil carbon sequestration.

2.1.2. PILLAR I

2.1.2.1. Direct Payments

Since 2003, direct payments – i.e. area-related payment based on the number of hectares of farmed land and/or coupled payments based on fixed areas, type of crops grown, and yield and/or numbers of animals – have been paid to farmers to support their income. The amount paid per hectare through the basic payment scheme (BPS) may differ depending on the Member State, region and farm, but by 2019 entitlement values should converge completely or at least result in no farmer receiving less than

60% of the relevant national or regional per-hectare average rate. In the Member States which chose to offer it, the small farmers scheme (SFS) payment replaces all direct payments by annual flat-rate support. In addition to the basic payment for farmers, voluntary coupled support (VCS) can be provided to sectors facing particular situations where specific types of farming or specific agricultural sectors are particularly important for economic, environmental or social reasons. The most supported sectors include beef and veal, dairy products, sheep and goat meat, and protein crops.

The 2013 CAP reform introduced the greening payment to support climate and environment-friendly agricultural practices that go beyond cross-compliance, for which Member States are required to use 30% of their direct payments budget. The three greening obligations are:

- Crop diversification, directly targeted at sustainable soil management: farms with arable areas between 10 ha and 30 ha must cultivate at least two different crops, and the main crop cannot exceed 75% of the arable land. Where the arable area is more than 30 ha, farmers must fulfil three cumulated requirements: at least three different crops must be grown, the main crop cannot exceed 75% of the arable area and the two main crops cannot exceed 95% of the arable area.
- The maintenance of permanent grassland, targeting in particular carbon sequestration; this includes the requirement that the ratio of permanent grassland (PG ratio) compared to the total agricultural area claimed must not decrease by more than 5% relative to the reference level established in 2015. In addition, environmentally sensitive permanent grassland (ESPG) should be designated by the Members States, on which ploughing of permanent grassland is prohibited.
- The designation of ecological focus areas (EFAs) with the main objective of protecting biodiversity: the measure requires farms with arable land above 15 ha to allocate 5% of the arable land to EFAs[10].

Requirements apply to the eligible area of the holding, excepting area under permanent crops. Farmers entering the small farmers scheme SFS are exempted from greening obligations (and from cross-compliance requirements).

Except for the greening measures, the regulations did not intend for direct payments to deal with soil-related issues. Nevertheless, direct payments as a whole can have indirect effects on land use and practices, thereby possibly influencing sustainable soil management (e.g. limiting possible soil degradation such as erosion and reduction of soil organic matter).

2.1.2.2. Common Market Organisation

Regulation (EU) No 1308/2013 establishing a common organisation of the markets in agricultural products (CMO) repeals Regulation (EC) No 1234/2007, which had previously grouped together the regulations concerning most of the agricultural sectors, updated after the Health Check in 2009. It establishes support measures *inter alia* for the olive, fruit and vegetables, and wine sectors. In particular, it provides for operational programmes for the fruit and vegetable sector to include two or more environmental actions (Article 33 of Regulation (EU) 1308/2013). However, sustainable soil management is not an objective of the common market organisation.

[10] i.e. fallow (no production), terraces, landscape features, buffer strips, agro-forestry, afforested areas (with RDP support), forest edges (with or without production), short rotation coppice, catch crops, green cover or nitrogen-fixing crops. These elements are subject to different weighting based on their relative duration and environmental value. Some amendments to the initial provision have been introduced with the Omnibus regulation (EU) 2017/2393 of 13 December 2017. These amendments include the implementation of a pesticide ban on EFAs.

2.1.3. PILLAR II

Preventing soil erosion and improving soil management is one of the 18 focus areas of the EU rural development policy, set in Regulation (EU) 1305/2013.

The Rural Development Regulation sets a total of 20 support measures[11], a number of which may contribute to sustainable soil management. Support for investments in forests (M8), commitments into agri-environment and climate measures (AECMs: M10), support for organic farming (M11).

Other rural development (RD) measures, in particular investments in physical assets (M4), may indirectly contribute to fostering sustainable soil management. Considered in the evaluation study were support for knowledge transfer and information actions (M1); advisory services, farm management and farm relief services (M2); restoring agricultural production potential damaged by natural disasters and catastrophic events and introduction of preventive actions (M5); Natura 2000 and Water Framework Directive (M12); support for commitment for the environment and climate in forests (M15), payments to areas facing natural or other specific constraints (M13); and support for animal welfare (M14).

The actions of the European innovation partnerships for agricultural productivity and sustainability (EIP-AGRI) and of the European network for rural development (ENRD) were also taken into account.

The choice of measures to be implemented is established in the rural development programmes (RDPs), designed by managing authorities at either national or regional level.

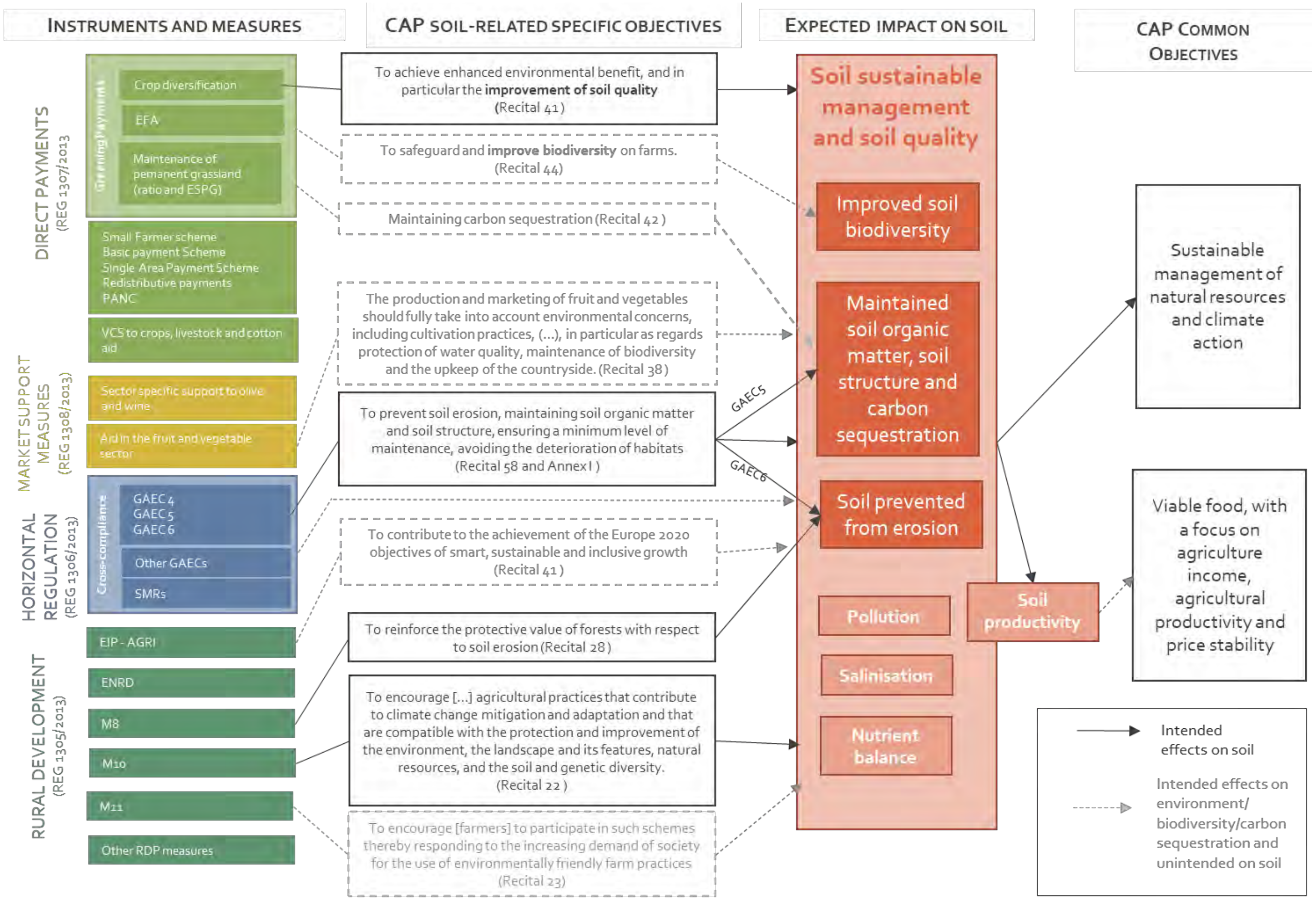
2.1.4. MODEL OF THE CAP INTERVENTION LOGIC

The logic diagram on the next page summarises how the above-described instruments and measures were linked with the CAP soil-related objectives, the expected impact and the CAP common objectives. The diagram includes instruments and measures specifically designed to address sustainable soil management, as well as those designed to address other issues related to the sustainable management of natural resources (e.g. water, biodiversity, climate change mitigation and adaptation) but imply actions with regard to soils.

Arrows with continuous lines show explicitly intended effect on sustainable soil management. Arrows with dotted lines represent intended effects of the measures on the environment, biodiversity and carbon sequestration, with implication for soil management. The expected impacts in the dark orange boxes are those explicitly established by the regulations.

[11] Measure 18 ('financing of complementary national direct payments for Croatia') is not considered in this study.

Figure 4: Intervention logic on the objective of sustainable soil management



Source: Alliance Environnement, based on 1305/2013 (RD), 1306/2013 (Horizontal); 1307/2013 (direct payments) and 1308/2013 (CMO)

2.2. Further analysis of the intended impact and theoretical effect of the instruments and measures in the scope of the study

The instruments and measures in the scope of the evaluation study are analysed in Table 1, based on:

- **their intended impact on sustainable soil management**, according to a strict analysis of the CAP regulations. Doing so distinguishes intended impact on sustainable soil management from intended impact on other issues related to the sustainable management of natural resources (e.g. water, biodiversity, climate change mitigation and adaptation), implying actions with regard to soils.
- **their theoretical effect on soil management**: for that purpose, effects on land use and on management practices were distinguished, by adopting the following definitions:
  - **Land use and land-use change** refer to land use and land cover types including the establishment of landscape elements and their potential changes, e.g. when arable lands are converted to grasslands or when hedges are established. Operations and construction that induce deep changes to soils and landscapes, above or below ground (e.g. drainage installations such as pipes, terracing), were also attached to this category.
  - **Management practices** are the practices and treatments used on farms to manage the agro-ecosystem, in terms of optimisation of production and resource protection. These practices are generally annual (e.g. types of crops grown for a given crop year, ploughing) but they can also be implemented for several years, considering that cropping choices are part of the practices (e.g. the choice in term of perennial crops, or the choices in terms of crop rotation).

Direct and indirect effects are also distinguished. An instrument or measure is considered to have a potential **direct effect** on land use (or management practices) when it sets a rule or supports the establishment of a given land use (or the implementation of specific practices). **Indirect effect** appears when the rule or support provided by the instruments or measure induces changes in land use or management practices.

Table 1: Intended impact and theoretical effect of the CAP instruments and measures on sustainable soil management

		Intended impact		Theoretical effect on soil management	
		Soil quality, Sustainable soil management	Environment/ biodiversity/ sustainable management of natural resources, which could include soil issues	Land use	Management practices
HORIZONTAL					
Cross-compliance	➢ GAEC 1	No	Yes	D	D
Cross-compliance	➢ GAEC 2	No	Yes	No	No
Cross-compliance	➢ GAEC 3	No	Yes	No	D
Cross-compliance	➢ GAEC 4 to GAEC 6	Yes	No	No	D
Cross-compliance	➢ GAEC 7	No	Yes	D	No
Cross-compliance	➢ SMR1 and SMR 10	No	No	No	D
Cross-compliance	➢ Other SMR	No	No	No	No
EIP-AGRI		No	Yes	I	I
PILLAR I					
Greening – crop diversification		Yes	No	D	I
Greening – EFAs, PG Ratio and ESPG		No	Yes	D	I
Payments for areas with natural constraints		No	No	I	No
Other direct payments[12]		No	No	I	I
Voluntary coupled support (VCS)		No	No	D	No
Sector	➢ Fruits and vegetables	No	Yes	I	D
Sector	➢ Olive sector and wine sector	No	No	I	No
Sector	➢ Other specific sector aid	No	No	I	No

[12] Basic payments scheme, voluntary redistributive payment, small farmer scheme, single area payments, payments for natural constraints.

	Intended impact		Theoretical effect on soil management	
	Soil quality, Sustainable soil management	Environment/ biodiversity/ sustainable management of natural resources, which could include soil issues	Land use	Management practices
PILLAR II				
M1: Knowledge transfer and information actions & M2: Advisory farm management and relief services	No	Yes	I	I
M3: Quality schemes	No	No	No	No
M4: Investments in physical assets				
➢ M4.1[13], M4.3[14] and M4.4[15]	No	No	D	D
➢ M4.2 Support for processing and marketing of agricultural products	No	No	No	No
M5: Restoring agricultural production potential damage by natural disasters / prevention actions	No	No	I	No
M8: Forest investments				
➢ M8.1[16], M8.2[17], M8.3[18] and M8.4[19]	Yes	Yes	D	No
➢ M8.5[20]			No	D
➢ M8.6[21]			No	I
M10: Agri-environment-climate				
➢ M10.1 Agri-environment and climate commitment	Yes	Yes	D	D
➢ M10.2 Genetic resources in agriculture			No	No
M11: Organic Farming	Yes	Yes	I	D
M12: Natura 2000 and Water Framework Directive	No	Yes	I	I
M13: Areas facing natural constraints	No	No	I	No
M14: Animal welfare	No	No	No	No
M15: Forest-environment-climate				
➢ 15.1. Payment for forest-environmental and climate commitments	No	Yes	D	D
➢ 15.2. Support for the conservation and promotion of forest genetic resources			No	No
M19: LEADER	No	No	No	I
European Network for Rural Development (ENRD)	No	Yes	I	I

Source: Alliance Environnement, based on Regulation (EU) No 1305/2013, 1306/2013, 1307/2013 and 1308/2013. Legend: Yes = Intended effect, laid down in the regulation; No = No intended effect on soil; D = Direct effects identified; I = Indirect effects identified.

[13] M4.1: Support for investments in agricultural holdings.

[14] M4.3: Support for investments in infrastructure related to development, modernisation or adaptation of agriculture and forestry.

[15] M4.4: Support for non-productive investments linked to the achievement of agri-environment-climate objectives.

[16] M8.1: Support for afforestation/creation of woodland.

[17] M8.2: Support for establishment and maintenance of agroforestry systems.

[18] M8.3: Support for prevention of damage to forests from forest fires and natural disasters and catastrophic events.

[19] M8.4: Support for restoration of damage to forests from forest fires and natural disasters and catastrophic events.

[20] M8.5: Support for investments improving the resilience and environmental value of forest ecosystems.

[21] M8.6: Support for investments in forestry technologies and in processing, mobilising and marketing of forest products.

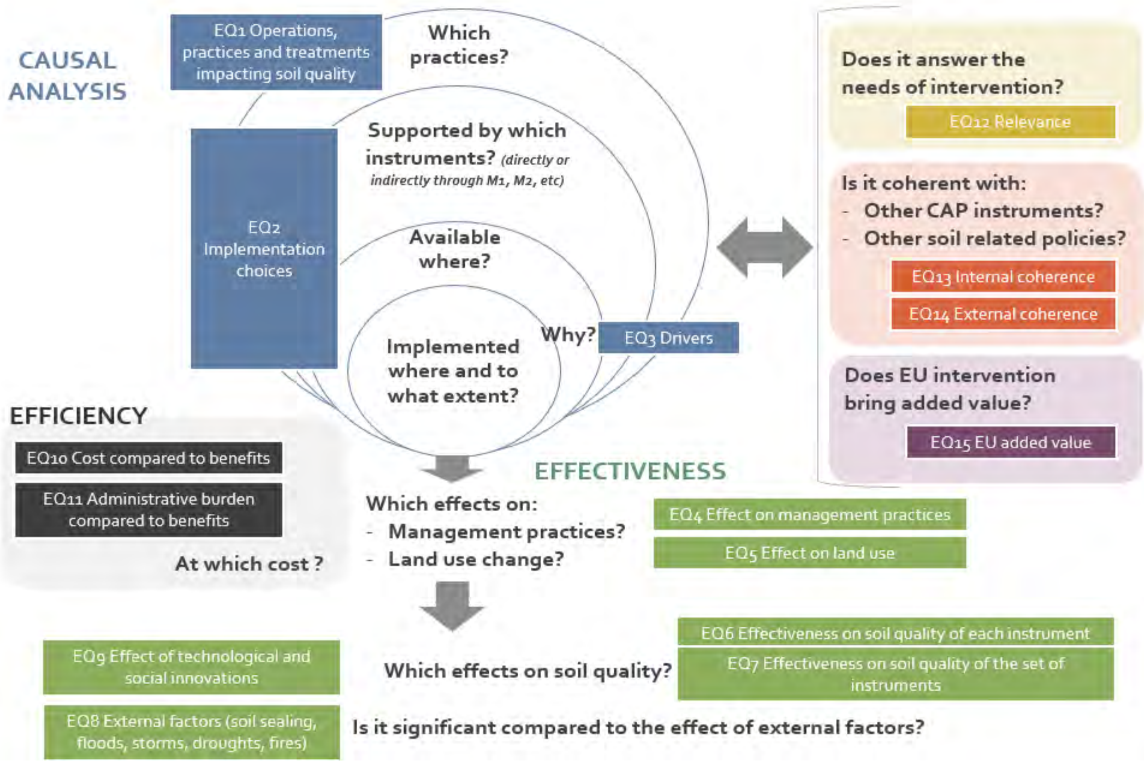
3. GENERAL PRINCIPLES AND METHODS FOR THE EVALUATION

3.1. EVALUATION STRATEGY

3.1.1. EVALUATION STUDY QUESTIONS

The study aimed at answering 15 evaluation questions, which review the implementation of the CAP with regards to sustainable soil management, its effectiveness, efficiency, coherence, relevance and EU added value in addressing soil quality. The EQs and their interrelations are presented in Figure 5.

Figure 5: Overview of the evaluation framework



Source: Alliance Environnement

It must be noted that EQ4 and EQ5 focus on assessing the outputs of the CAP instruments and measures on activities with an impact on soil quality and productivity: EQ 4 focuses on the CAP outputs on management practices and EQ 5 on land use and land-use change[22]. Based on this review of the outputs of the CAP, EQ6 concludes on the CAP contribution of addressing soil quality and soil productivity.

3.1.2. INSTRUMENTS AND MEASURES CONSIDERED UNDER EACH EVALUATION QUESTION

The evaluation methodology was developed on the basis of the intervention logic of the CAP instruments and measures addressing sustainable soil management (described in Chapter 2). The relevant instruments and measures were classified into four categories reflecting their objectives and their potential effects on sustainable soil management (see Table 2).

- Category 1 includes the measures designed to address sustainable soil management, which also have a direct effect on land use and management activities relevant to soil quality. The central focus

[22] See the definitions set in Chapter 2.2.

of the evaluation study was to review their implementation (EQ 2-3), their effectiveness (EQ 4-8) and efficiency (EQ 10-11) to foster sustainable soil management, the relevance of their design to address this objective (EQ 12), as well as their coherence with other EU instruments and policies (EQ 13-14) and their EU added-value (EQ 15).

- Category 2 includes the measures not designed to address SSM, but that have a potential direct effect on SSM. For instance, buffer strips are implemented through GAEC 1 for soil quality, but they can have direct effects on soils. The evaluation study in particular sought to understand the decisions regarding how those measures were implemented in relation to soil quality (EQ 2-3) and to assess their contribution to the implementation of land use and managing activities relevant to soil quality (EQ 4-7).
- Category 3 includes the measures with cross-cutting objectives and a potential indirect effect on the implementation of management practices and land-use change sustainable for soil. Given the cross-cutting objective of those measures, assessing their effectiveness to address soil issues. is not relevant However, the additional contribution they may bring to the effects of the CAP should be reviewed, as well as their contribution on how the instruments and measures acted as a set (EQ 7).
- Category 4 includes the instruments designed to address other objectives of the CAP but which may indirectly impact land cover / land use or intensity of production, e.g. area-based direct payments. For this category of instruments and measures, the main question is whether they have been coherent with the objective of sustainable soil management (EQ 13).

The categories to be considered in each evaluation question can be summarized as follows:

Table 2: Evaluation strategy as regards the instruments in the scope of the study

Instruments and measures		Causal analysis		Effectiveness						Efficiency		Relevance	Coherence		EU added value
		EQ 2	EQ 3	EQ 4	EQ5	EQ 6	EQ 7	EQ 8	EQ 9	EQ 10	EQ 11	EQ 12	EQ 13	EQ 14	EQ 15
1	Measures designed to address SSM, with a potential direct effect on SSM: GAECs 4, 5 and 6, crop diversification, M8.1, M8.2, M8.5, M10.1, M11	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**
2	Measures not designed to address SSM, but with a potential direct effect on SSM: GAECs 1, 3 and 7, SMRs 1 and 10, EFAs, permanent grasslands, F&V environmental measures, M4.1, M4.3, M4.4, M15.1	**X**	**X**	**X**	**X**	**X**	**X**					X	X	X	X
3	Measures with a potential indirect effect on SSM: EIP-Agri, ENRD, M1, M2, M5, M8.3, M8.4, M12, M19						**X**		EIP			X	X	X	X
4	Measures not designed to address SSM, *indirectly impacting land cover / land use or intensity of production:* VCS, basic payments scheme, voluntary redistributive payment, small farmer scheme, single area payments, payments for natural constraints, other sector-specific measures, M13, M14												**X**		

Source: Alliance Environnement

Legend:		
	(dark shading)	The answers to the EQ give primary focus to these measures
	(light shading)	The answers to the EQ give secondary focus to these measures

For each evaluation question, judgement criteria and related indicators were set. The methodological approach and tools chosen for this evaluation took account of the European Commission better regulation guidelines[23] and Toolbox, and the methods and tools encountered in previous evaluation studies of the CAP with regards to its general objectives of sustainable management of natural resources and climate action.

The analysis of each evaluation question cross-checked information from various sources and combined qualitative and quantitative methods to ensure soundness of judgement.

3.2. Information sources and analytical tools

The indicators were informed using a range of qualitative and quantitative data collection tools (see Table 3). The sources used and the methods applied are detailed in the answers to the evaluation questions (Chapters 4 to 9).

Table 3: Data collection and analytical tools used for the evaluation study

	Tool	Type of tool	Description	EQ mainly concerned
Collection tools	Documentary research, Literature Reviews	Qualitative and quantitative	The study encompassed a review of the available bibliography with regards to the implementation and impacts of the CAP. That included in particular previous studies of the CAP at the EU level, as well as previous evaluation studies, rural development programmes (RDPs) and their annual implementation reports (AIRs) in the case-studies areas. Specific literature reviews were performed on key subjects, in particular: • effects of agricultural and forest activities on soil quality; • effects of key soil-relevant practices on soil productivity; • technological and social innovations expected or proven to have a significant impact on soil quality; • effects of operations similar to those supported by the CAP, in the EU member states and abroad. Those literature reviews included peer-reviewed publications and grey literature collected in the case-study areas.	EQ 1-15 EQ2-7 EQ12-13 EQ1 EQ9 EQ6- EQ15
Collection tools	Review of databases	Quantitative	The quantitative analysis conducted in the study were based on existing indicators: • Context indicators provided by Eurostat and by recent publications for the JRC, e.g. agricultural area, area in organic farming, forest and other wooded land, soil organic matter in arable land, soil erosion by water • Additional specific indicators on land use and farming practices from the LUCAS and farm structure surveys, provided by JRC: e.g. area in fallow land; • Common monitoring and evaluation framework (CMEF) outputs indicators on greening, from the ISAMM database (provided by DG AGRI) : e.g. number of farms concerned and hectares declared for greening (OID_05), greening exemptions (OID_06) crop diversification (OID_07), permanent grassland (OID_08), ecological focus areas (OID_09 and OID_10) and greening equivalence (OID_11) • CMEF outputs and results indicators on RDPs, from the AIRs 2018 (provided by DG AGRI): in particular the total public expenditures (OIR_01), total area (OIR_05) and physical areas supported (OIR_06) • Additional RD monitoring data collected from local authorities in the in case-study areas: e.g. physical area supported under specific AECMs.	EQ 4-7, EQ12 EQ4-5 EQ2, EQ 4-12 EQ2, EQ 4-12 EQ2, EQ4-12 EQ3, EQ4

[23] SWD(2017) 350

	Tool	Type of tool	Description	EQ mainly concerned
			• Datasets from the Farm accountancy data network (FADN) (provided by DG AGRI), including in particular indicators related to farms' structure, the CAP payments received by farms on Pillar and Pillar 2, and farms' expenditure on PPP, fertilizers and manures. Datasets were collected from the case-study Member States only, in order to ensure that the statistical analysis could be put in perspective with an appropriate knowledge of the context.	
Analytical tools	Interviews	Qualitative	Used to gather in-depth qualitative information and the opinions of key stakeholders (managing authorities, researchers and other local experts working on agricultural soils, farmer representatives and advisors, NGOs) relative to context, implementation and results. A total of about 200 interviews were conducted as part of the case studies (see below). Some additional interviews were conducted with specific project managers and researchers.	EQ 1-15
Analytical tools	Case studies	Qualitative and quantitative	Case studies were used as an evaluation tool when 'how' and 'why' questions are posed. They allow a detailed examination of specific issues to be carried out in line with the evaluation goals. The content and methodology of the case studies is detailed in Chapter 3.3.	EQ 1-15
Analytical tools	Survey	Qualitative and quantitative	A survey was carried out to farm advisors in the case-study Member States. It collected qualitative information on the drivers and choices made by the farmers regarding their practices and their uptake of innovations, in a standardised way.	EQ 9
Analytical tools	Descriptive analysis	Quantitative	Following the collection of data from various databases, data were analysed using descriptive statistics and comparison of averages.	EQ 2-5, 10-11
Analytical tools	Matrix scoring	Qualitative and quantitative	In order to summarise and give a clear view of the findings, matrix scoring was carried out, for instance: - Effects of agricultural activities on soil-quality components - Soil-related activities enforced, fostered and supported by the CAP, in the case-study areas - Relevance of CAP objectives to the needs in soil quality, etc.	EQ 1, 2, 6, 9-15
Analytical tools	Counterfactual analysis	Quantitative	Used to analyse the effects of measures by comparing situations between beneficiaries and non-beneficiaries of measures.	EQ 4, 15
Analytical tools	Stakeholders analysis	Qualitative	Stakeholder analysis was carried out at each step of the evaluation study, in order to prepare interviews with the relevant stakeholders and to analyse the information they provided in the light of their levels of participation, interests and influence on the CAP implementation.	All EQs except 1,8,9

Source: Alliance Environnement

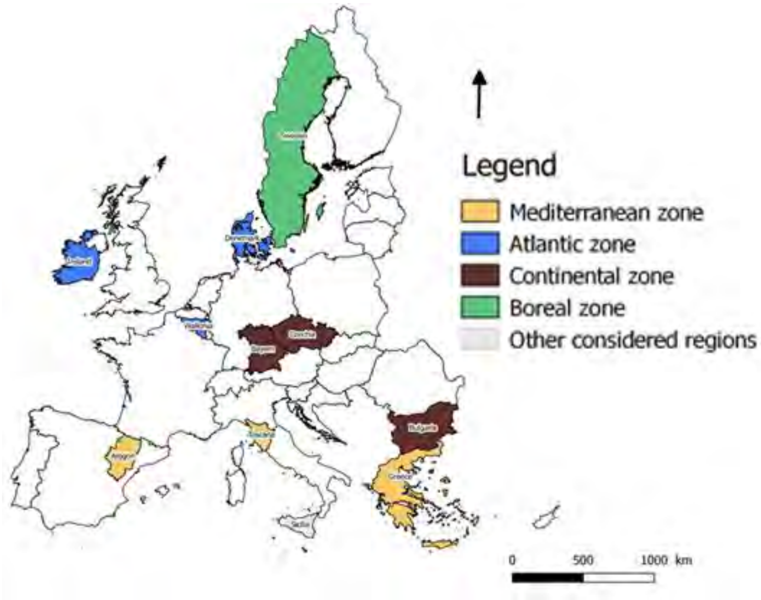
3.3. IMPLEMENTED CASE STUDIES

3.3.1. OVERALL METHODOLOGY FOR SELECTION

A careful selection of case-study areas is key for supplying insight on the implementation and effects of the instruments and measures and for covering as much as possible the variety of contexts across the EU. However, it was decided not to consider the outmost regions, in which soil issues and contexts are very different from those on the EU mainland, in the selection process.

In order to ensure coverage of the largest possible variety of situations across the EU, the following selection criteria were used: biogeographical zone, relevant national regulation, intensity and method of production, implementation of the soil-related CAP instruments and measures, and intensity of soil threats. Based on the review of those criteria and related indicators, the following area were selected (see Map 5).

Map 5: Selected case-study Member States and regions in the EU



Source: Alliance Environnement

- Belgium-Wallonia: Wallonia is representative of a region with significant annual precipitations, which faces significant soil erosion by water and regular mudslides. Both intensive arable farming, in flat lands, and grassing-based farming systems can be found in the area. Organic farming represents 8.8% of the UAA in 2015.
- Bulgaria: Bulgaria, which is in the continental zone presents a low share of farms with more than three crops (9.5% versus 13.6% at the EU level) and one of the lowest shares of UAA dedicated to Organic farming (2.7% versus 7.0% at the EU level). Concerning key-soil related CAP instruments and measures, Bulgaria has the lowest (2.2%) share of agricultural land under contract to improve soil (FA 4C), while a specific AECM dedicated to soil protection is available at the national level. Regarding soil threats, Bulgaria is characterised by a high potential loss by wind, achieving 1.84 t/ha/yr. To a slightly lesser extent, soil threats for biodiversity were identified.
- Czechia: is representative of Atlantic Member State with intensive large arable farming (the average size of farms is 130.2 ha of UAA/holding vs 16.6 ha of UAA/holding at the EU scale). The case of Czechia is of specific interest because of the loss of SOM and biodiversity in soils is particularly significant. Regulatory provisions have been taken to protect the agricultural soils, and the CAP measures have been targeted to this objective. Conservation agriculture and the reduction of fertiliser is promoted to address threats on soils. Besides, even if the region is not identified as mountainous according to EEA, significant areas of croplands are located on slopes, which also makes erosion a significant issue (0.45 t/ha/yr according to JRC).
- Denmark: is representative of an Atlantic Member State with a large share of arable land. Regarding national regulation, Denmark has set soil protection laws but no action plan according to the reviewed sources. The significant problems of compaction on arable lands, fostered by the wet climate, make it an interesting example. Denmark also has the highest soil losses by wind in the EU (3.01 t/ha/yr), as estimated by (Borrelli *et al.*, 2017), as well as a negative trend regarding the content of SOM in soils (-1.69 g/kg between 2007 and 2012).
- Germany-Bavaria: Germany is one of the Member States which decided to implement soil protection laws and regulations, but also soil protection strategies and action plans. Germany is mostly impacted by compaction, decline of soil biodiversity and diffuse pollution caused by heavy metals like Cd, Cu, Hg, Pb and Zn. Consequently, Germany presents an interesting profile to select

it as a case study. Considering that its RDPs are defined at the regional level, the analysis is refined at this scale by focusing on the Bavarian region. This region located in the Continental zone has both cropland in the low land and grassland on mountainous areas. In order to address the above-mentioned threats, the RDP set 2 AECMs targeted to soil in this region.

- Ireland: at the opposite of Denmark, Ireland is characterised by a very high share of grassland. This Member State located in the Atlantic zone has set both a soil protection strategy and an action plan. The share of agricultural land under contracts for soil protection is high, which may reveal a specific will and strategy of intervention to address soil issues through the RDP. It also shows a negative trend regarding the content of SOM in soils (-2.46 g/kg between 2007 and 2012).
- Greece: this case study enables to analyse the implementation of the instruments and measures in the context of Mediterranean climate and production (wine, citrus, etc.), in a context where no action plan on soil was adopted at the national level. Greece has among the lowest share of farms with more than three crops (4.2% versus 13.6% at the EU level), which may also have impacted the implementation of the CAP instruments and measures. The threats on soils are quite significant in Greece: it is the Member State with the highest contents in heavy metals (Cr, Ni, Cd, Cu, Hg, Pb, Zn) according to (Anaya Romero *et al.*, 2016), and other threats such as erosion by wind, compaction, the decline of soil biodiversity decline and salinization also occur. To finish with, the case of Greece will enable to get an insight of the impact of fires on soil, and the related need of intervention from the CAP.
- Spain-Aragon: Like other regions of central Spain, Aragon faces desertification, related to soil erosion by water (Panagos *et al.*, 2015b), high soil erosion by wind (Borrelli *et al.*, 2017), and low organic carbon contents (De Brogniez *et al.*, 2015) in a context of Mediterranean region. Furthermore, this Mediterranean area is also a hot spot for secondary salinization (Daliakopoulos *et al.*, 2016) which has an impact on the quality of soils and also crop's productivity. The RDP of Aragon aimed at promoting sustainable management of resources, including soils: 32% of the budget were to be allocated to area-based payments to farmers using environment/climate friendly management practices, including organic farming. Aragon's agricultural production presents a very few proportions of UAA in organic farming (1.9%). Several AECMs have been specifically targeting soils (10.1.a, 10.b, 10.1.f), with an objective of 1.7 million hectares protected from erosion through the implementation of AECMs.
- Italy-Tuscany: Toscana presents a high share of UAA dedicated to organic farming (19.1%). This Mediterranean region faces some hotspots in terms of erosion both by wind and by water and presents an important risk of loss of organic matter. As regards the implementation of the CAP, this Mediterranean region has a specific AECM (M10.1.1) dedicated to conservation of organic matter in soils, with an objective to cover 8,000 ha. In terms of productions, this case-study enables, like other Mediterranean regions and countries, to investigate the implementation of the CAP instruments in relation to specific productions such as citrus, wine and fruits.
- Sweden: Sweden has a specific approach regarding soil regulation: it has no soil law but a Strategy for sustainable land use, which highlights mostly the importance of soil as a carbon sink. The case of Sweden will be of particular interest to analyse the implementation and effect of the CAP instruments and measures on peatland and forests. Regarding farming systems, Sweden has a very high share of monocropping farms (44.5% vs 27.2% at the EU level) and one of the highest shares of UAA in Organic farming (19.2% vs 7.0 % at the EU level). Finally, this Member State located in the Boreal zone faces significant erosion by wind and diffuse pollution.

3.3.2. Implementation of the case studies: contents and methodology

The case studies enabled collection of primary and secondary information aimed at supporting the answer to each evaluation study questions (statistical data collection at national, regional and local level, and documentary research including literature reviews and interviews). Specifically, they helped to provide a clear view of the CAP instruments and measures implemented in a specific context, with the corresponding effects observed. They also helped to assess the effectiveness of the measures and instruments as well as the coherence between the CAP and other soil-related policies implemented at the same level, such as the 7th Environmental Action Plan.

All case studies followed the same general approach and applied the same methodology. A case-study template and guidelines prepared by the core study team set out the data to be collected to understand the local context and answer the evaluation questions. This ensured the homogeneity of the information presented and the data/information collected within each case study.

3.4. Limitations of the methodology implemented for the evaluation

The first key limitation concerned the difficulty of observing the impact of the CAP implementation. Soil processes are long-term phenomena whose trends cannot be observed on the timescale of the CAP programming period. Despite the extensive monitoring of the CAP and data collection from EU farms, the available databases do not make it possible to assess the effects of the CAP on soil quality at farm nor at local level. Against that backdrop, the study built on the outputs of the CAP (EQ 4 and 5), but its impacts on soil quality (EQ 6) could be approached only through expected effects and changes in general impact metrics.

The second main limitation relates to the high variability, across the EU, of implementation choices with regard to the CAP instruments and measures addressing sustainable soil management: very few requirements and measures are set at EU level (as analysed in Chapter 7). Thus, in spite of the careful selection process behind the case studies, significant outputs in some Member States or regions may have been missed. Furthermore, the state of play at EU level should not be extrapolated or generalised from the situation found in the case-study areas: as stated in Chapter 3.3.1, the case studies are meant to reflect the variety of situations across the EU but do not constitute a representative sample.

The third limitation is related to the fact that the effects of the CAP on soil cannot be isolated from the effects of the other environmental concerns, i.e. water, biodiversity and climate: it is very difficult to break down the CAP budget, costs and benefits that address only sustainable soil management. Also, issues related to agricultural soils not clearly identified by stakeholders and some operations supported by the CAP may be identified as addressing primarily water, biodiversity or climate, even though they may also be very relevant for soil. In that respect, the study encompassed a strict identification of the implementation choices to address soil quality, on the basis of the identification of a clear list of relevant activities in agriculture and forestry (EQ 1).

Other limitations relate to the availability of data. In particular, data on the adoption of soil-relevant practices and innovations (EQ 9) were limited. In this regard, a questionnaire survey on innovations was sent to farm advisors (see also Table 3), but the number of responses received did not provide robust and representative results reflecting the situation in the case-study areas. Some of the analysis based on the FADN data could moreover not be conducted for all the case-study Member States, the samples being too small to run complete statistical analysis. Furthermore, for now, FADN data do not made it possible to distinguish beneficiaries of each RD measure and includes few environmental indicators. In particular, the uses of plant protection products and fertilisers could be estimated only based on the corresponding expenses.

4. Causal Analysis

4.1. EQ 1: What are the operations, practices and treatments impacting soil quality and soil productivity?

4.1.1. Understanding and method

This evaluation question is not directly linked to the CAP: it aims to provide a better understanding of the agricultural and forestry activities impacting (positively or negatively) soil quality.

The first part of the analysis focuses on identification of those activities and the ranking of their effect on soil organic matter content, soil biodiversity, soil erosion, soil compaction, soil pollution, soil nutrient balance and salinisation. The analysis was based on an extensive literature review. The case studies also gathered the key practices impacting soil quality according to the stakeholders at the local level, in order to round out the information collected in the literature.

The second part of the analysis investigates the effect of soil-relevant agricultural activities on soil productivity. Soil productivity refers mainly to the yields of plots. From this angle, management practices[24] improving soil quality may interfere with productivity. For instance, no/reduced tillage may have positive impact on soil compaction and biodiversity but may reduce productivity, especially in the first years of implementation. The short- and middle-term effects of key soil-management practices on yields were reviewed based on existing literature. Technical references and stakeholders' knowledge, gathered in the case studies, made it possible to round out the information collected in the literature.

Soil productivity may also refer to the general capacity of soil to produce biomass, which depends, among things, on soil quality. General information on this relation between soil quality and productivity was collected from the literature.

4.1.2. Typology of the activities impacting soil quality and ranking of their effects

4.1.2.1. Introduction to the typology of activities impacting soil quality

Activities identified as impacting soil quality are as follows (see details in Table 4):

- Regarding activities related to land use and land-use change: the establishment or maintenance of arable land, grassland, wetland, forest and other wooded land, and changes from one type of land use to another should be considered. Activities with significant impact also include choices to establish, maintain or destroy landscape elements (e.g. landscape features, short rotation coppice), as well as operations that induce deep changes to soils and landscapes, above or below ground (e.g. drainage installations such as pipes, terracing).
- Regarding management practices: tillage and traffic management, soil cover and crop management, pest, diseases and fertilisation management, water management, forest management practices and grassland management should be considered.
- Farming systems, referring to farm management which follows (or prohibits) a common set of management practices and land use, also need to be considered: conservation agriculture, organic farming, agroforestry and integrated pest management appear as key farm management orientations impacting soil quality.

[24] This part focuses on management practices only, the link between land use and soil productivity being too indirect and complex to be considered here.

4.1.2.2. Ranking of the effect of the identified activities on soil-quality components

The effects of activities on soil pressures, as found in literature, are summarised in Table 4. Farming systems do not appear as a specific line in the table because they generally combine a set of land use and/or management practices: practices associated with the farming systems under consideration are indicated with asterisks.

The analysis showed that a clustering can be made between:

- Activities having clear positive effects on soil quality: key beneficial practices are those involving permanent soil cover (diversified crop rotation, intercropping, cover crops including catch crops and mulching including crop residues), application of organic amendments (compost, manure), maintenance and creation of permanently covered areas (e.g. forest, grasslands, wetlands), and setting up and maintenance of landscape elements.
- Activities having clear negative effects on soil quality: on the contrary, the major threats to soil quality are land-use changes from forest or grassland to arable land, overgrazing, the use of heavy machinery, chemical inputs, and some forest management practices such as whole tree harvesting.
- Activities having different impacts on soil depending on the context and issues under consideration: other agricultural activities present both positive and negative effects depending on the context, the conditions of implementation and/or the soil pressure considered. In particular the effects of tillage on soil properties are complex and highly depend on its implementation. Under good conditions (no wet soil, correct depth, etc.) tillage has positive impacts in reducing soil compaction and remediating the 'salt crust' of saline soil but has negative impacts on soil biodiversity and erosion risks (Wolkowski and Lowery, 2008; Noor Shah et al., 2017; Roger-Estrade et al., 2010). Conversely, reduced tillage and no-tillage systems lead to a drop in soil erosion and a rise in soil quality (Louwagie, Gay and Burrell, 2009; Martineau et al., 2016). However, the use of heavy machinery under reduced tillage can mitigate these positive impacts.

In addition, it should be noted that:

- soils do not automatically benefit from crop rotation: diversification is needed for soil benefits, and the most beneficial soil rotations appear to be those that involve many different crops, which include at least one leguminous crop and the use of the land as meadow (Alliance Environnement, 2017).
- The effect of grasslands on soil highly depends on the way they are managed. Species-rich permanent grassland has much more significant positive effect on soil structure, biodiversity, organic content and erosion risk than poorly managed or regularly ploughed grasslands.

Table 4: Effects of agricultural activities on soil-quality components

			Organic matter	Biodiversity	Compaction	Erosion		Pollution	Nutrient balance	Salinisation
						Wind	Water			
Land use, land-use change	Afforestation, deforestation and maintenance of forest	Grassland -> forest	0/-							
		Arable -> forest	++	++	++	++	++	++	+	+
		Forest -> arable	-	-	-	-	-		-	
		Forest (long-term maintenance)	++	++	++	++	++	++	++	++
		Agroforestry*	++	++		++	++	++	++	
	Creation, loss and maintenance of grasslands	Forest -> grasslands	0/-							
		Arable -> grasslands	++	++	+	++	++	+	++	
		Grasslands- > arable	-	-	-	-	-	-	-	
		Maintenance of grasslands	++	++	++	++	++	+	++	
	Wetlands management	Creation or restoration of wetlands	++	++	-			++		
		Maintenance of natural wetlands	++	++	++			++		
		Drainage of wetlands	-	-			-		-	
	Other landscape elements	Landscape features	++	++		++	++	++	++	
		Buffer strips	++	++		++	++	++	++	
		Grass strips	++	++		++	++	++	++	
		Short rotation coppice	+	++		++	++	++		
	Operations	Terraces				++	++			
		Drainage	-	+/-	+		+			++
Management practices	Tillage and traffic management	Tillage	+	-	+/-	-	-			++
		Reduced tillage and No-tillage*	+	++/-	+	++	++	+/-		
		Late tillage								
		Subsoiling		-	++/-	-	-			++
		Ploughing**	-	-	+	-	-			++
		Use of heavy machinery			-					-
		Controlled traffic			+					+
	Soil cover and crop management	Diversified crop rotation*/**	+	+	++	++	++	++		
		Intercropping	++	+	++	++	++		++	++
		Cover crops*	++	+	++	++	++			++
		Catch crops	++	0	++	++	++		++	++
		Mulching*	+	++/-	++	++	++			++
		Maintenance of crop residues (no burning)*	++	++/-	++	++	++			++
		Nitrogen-fixing crops*/**	++	0					++	++
		Land lying fallow	+	+	+	++/-	++/-			
		Contour farming				++	++			
	Grassland management	Extensive grazing**	++	+				0/-		
		Intensive grazing	-	-	-	-	-	0/-		
	Pest/weed, diseases and fertilisation management	PPP application*		-				-		
		Mineral fertilisers application	++/-	+/-				-	++/-	+/-
		No synthetic pesticides/herbicides and no mineral fertilisation**	++	++	+	++/-	++/-	++	++	++
		Manuring	+	++/-	++			++/-	+	++
		Compost application	+	++	++			++/-	+	++
		Gypsum application								++
	Water management practices	Irrigation								+/-
	Forest management practices	Physical preparation for afforestation or reforestation	+/-	-	+/-	-	-			
		Prescribed burning	-	-	-	-	-		+/-	
		Clear felling	-	-	-	-	-		-	
		Whole tree harvesting techniques	0/-	-	-	-	-		-	
		Maintenance of forest residues	++	++/-		++	++			
		Harvest compensation application techniques							+	

Positive impact: ++, +; Negative impact: -; Impact depending on the context: +/-, 0/-; Empty cells: no relation found in the literature; *: Practices associated with conservation agriculture. As this farming system is not regulated by the EU, the practices implemented can vary depending on farms. **: Practices associated with organic farming as regulated by the EU.

Source: Alliance Environnement, based on existing literature

Farming systems associated with the above reviewed practices may impact on soil quality. In particular:

- Conservation agriculture, whose three principles are minimum tillage and soil disturbance, permanent soil cover with crop residues and live mulches, and crop rotation and intercropping, increases the accumulation of soil organic matter (SOM) and the soil biodiversity, reduces erosion risks and improves the soil pore system. For now, the use of herbicides is considered necessary to manage soil cover on a large scale by a majority of farmers, which may have negative consequences on soil pollution (Busari *et al.*, 2015; Dumanski *et al.*, 2006; Lal, Reicosky and Hanson, 2007; Pagliai, Vignozzi and Pellegrini, 2004; Piccoli *et al.*, 2016).
- Organic farming tends to improve the SOM contents, biodiversity and soil porosity, while reducing pollution by synthetic chemicals. However, erosion rate improvements are limited due to the increase of tillage practices to control weeds (Gattinger *et al.*, 2012; Hartmann *et al.*, 2014; Seufert and Ramankutty, 2017; Thiele-Bruhn *et al.*, 2012).
- Agroforestry contributes to regulating soil nutrient balance, improving SOM content, reducing soil erosion and significantly enhancing soil biodiversity (Louwagie, Gay and Burrell, 2009; Rigueiro-Rodriguez, McAdam and Mosquera-Losada, 2009; Torralba *et al.*, 2016). Trees' capacity to accumulate heavy metals also enables reduction of soil pollution (Kaur *et al.*, 2017).
- Integrated Pest Management (IPM) leads to a reduced need for phytosanitary products, in turn reducing soil pollution and improving soil biodiversity (Popp, Petö and Nagy, 2015). But this of course depends on the strictness of standards.

The literature review and the interviews with stakeholders involved in soil protection in the case-study areas additionally highlighted that:

- a territorial approach is key to tackling soil degradation risks (e.g. improvement of hedge networks at landscape level to limit wind and water erosion, field sizes, etc.).
- there is no cropping pattern which favours soil quality under any conditions, and cropping choices need to be adapted to the quality soil and local conditions (Alliance Environnement, 2017).

4.1.2.3. Geographical differences to be considered in the case-study areas

Interviews with representatives of farmers, NGOs, local authorities and researchers in the 10 case-study areas[25] confirmed the list of practices presented in Table 4.

Reduced tillage and no-tillage, controlled traffic, manuring, compost application and practices leading to permanent soil cover (diversified crop rotation, intercropping, cover crop and afforestation or agroforestry) were generally presented as the most relevant to protect and improve soil quality. Member States' specificities were also identified, confirming the variability of the effect of 'soil-related' activities depending on the biogeographical conditions, the type of soil and the way practices are implemented.

4.1.3. Effects of sustainable soil management and soil quality on productivity

4.1.3.1. Effect of the implementation of sustainable soil management practices on yields

The analysis focused on the management practices previously identified as clearly positive for soil quality. A total of 66 (mainly European) research papers were reviewed, spanning from 2005-2018. The changes in yields associated with the implementation of the practices available in the publications were collected: they provide estimates on the relevant impact of changes in management practices on yields

[25] The ten case studies areas were: Wallonia (BE), Bulgaria, Czechia, Denmark, Bavaria (DE), Ireland, Greece, Aragon (ES), Tuscany (IT) and Sweden. See Chapter 3.3.

(see Table 5). Interviews with local stakeholders implementing the analysed management practices, in the case-study areas, provided additional references.

Most of the practices or systems with a clear positive effect on soil quality were found to positively impact soil productivity. Nevertheless, the effect depends on implementation conditions, and may vary between the short and long terms.

Reduced tillage and no-tillage show the most uneven effect on yields. In the short term, changes in yields vary depending on the crops and farming conditions under consideration. In particular, increases in productivity occurred under dry conditions in Mediterranean countries (+3% to +35%), as the no-tillage system improves water retention of soil, but no overall trend was observed in other conditions (Lacasta Dutoit, Maire and Meco, 2005; Krauss *et al.*, 2010). However, these practices are not necessarily less profitable, because loss of productivity can be mitigated by drop in production costs (Soane *et al.*, 2012). Over the long term, this farming system is in most cases found to be as productive as a conventional farming.

The maintenance of crop residues and cover crops enabled a rise in productivity when nitrogen-fixing crops were used (Quemada *et al.*, 2013; Greenotec, 2010), but otherwise they had a rather neutral effect on productivity. Diversified crop rotations and intercropping systems led in a vast majority of studies to an increase in yield (up to 67%) (Martin-Rueda *et al.*, 2007). Organic amendment was not found to be more productive than inorganic fertilisation in the short term, but combining both fertilisers generated a gain of productivity of 3-7% (Hijbeek *et al.*, 2017). Studies on mulching also showed a rise of crop yields from 35% to 60% (Fontanelli *et al.*, 2013; Cirujeda *et al.*, 2012; Qin, Hu and Oenema, 2015).

Increases in productivity occurred in agroforestry systems (+20% to +100%) and with the maintenance of harvest residues in forests (+5% to +9%) (Dupraz *et al.*, 2018; Newman, 1986; Achat *et al.*, 2015; Jacobson *et al.*, 2000). The increase was particularly significant (+60%) in the first 20 years of the agroforestry system, when the tree shade was still limited (Dupraz *et al.*, 2018).

The combination of reduced tillage or no-tillage, diversified crop rotation and soil cover in conservation agriculture showed a reduction of yields (-3% to -30%) in the short term (Pittelkow *et al.*, 2014; Wacker, 2018). However, in the long term, this agricultural system is as productive as a conventional one (Perego *et al.*, 2019). It also gave positive results under dry conditions (+2% to +11%) (Camarotto *et al.*, 2018; Calzarano *et al.*, 2018).

Table 5: References found on the impact on productivity of management practices positive for soil, in research papers (RP) and in the case studies (CS)

	Increase in yields	Maintenance	Decrease in yields
Reduced tillage and no-tillage	9 RP; 2 CS short-term; 5 CS long-term - (+3% to +35%)	13 RP; 5 CS short-term; 2 CS long-term	11 RP; 1 CS short-term - (-5% to -13%)
Intercropping	5 RP; 2 CS - (up to +67%)		2 RP - No available estimate
Diversified crop rotation	5 RP; 4 CS - (+5% to +32%)		
Cover crop	7 RP; 4 CS short-term; 6 CS long-term - (+3% to +25%)	6 RP; 1 CS short-term	1 CS short-term
Maintenance of crop residues (used as green manure)	4 RP; 2 CS short-term; 3 CS long-term (+5% to +80%)	5 RP; 1 CS short-term	1 RP (-10%)
Cultivation of nitrogen-fixing plants	9 RP; 1 CS - (+3% to +80%)	4 RP	1 RP – (-10%)
Mulching	4 RP, 4 CS- (+35% to +60%)		
Manuring and compost application	3 RP; 4 CS short-term; 5 CS long-term - (+3% to +7%)	4 RP	1 CS short-term
Maintenance of forest residues	5 RP - (+5% to +9%)	1 RP	
Agroforestry	4 RP - (+20% to +100%)	1 RP	
Conservation agriculture	3 RP; 1 CS - (+2% to +11%)	2 RP	3 RP - (-3% to -30%)

Source: Alliance Environnement, based on the literature and on the knowledge of the interviewed stakeholders in the CS.

4.1.3.2. Estimates linking the components of soil quality to productivity

Soil-quality components are closely interlinked and play various roles in crop-growing. Hence, few studies focused on measuring the individual effects of soil properties. The following information was nevertheless found in the literature:

- Concerning the SOM's impact on soil productivity, a rise of 0.5% of SOM may allow an average rise of productivity of 20% for soils under 2% of SOM (Oldfield, Bradford and Wood, 2019).
- Severe compaction from several tractor crossings led to a 20% loss of barley yield, and compacted soils cause an average 50% loss of production (Wolkowski and Lowery, 2008; Arvidsson, 1999).
- Soil erosion in Europe is responsible for an annual productivity decrease of 0.43% for soils losing more than 11 t/ha/yr (Panagos *et al.*, 2018).
- Severe heavy metal pollution can reduce yields up to 92%, although field conditions rarely reach the phytotoxicity limit (Bhogal *et al.*, 2003).
- Regarding soil salinisation, each salinity unit decreased yield by 4% to 6%, leading to observed yield losses of approximately 25% in saline soils (Slavich, Read and Cullis, 1990; Katerji *et al.*, 1996).
- Soil biodiversity has beneficial impacts on soil productivity (Barrios, 2007), though no estimate was found linking their abundancy with yields.
- Concerning soil nutrient balance, the current agricultural yields are mostly obtained with soil nutrient saturation through the use of mineral fertiliser. Thus, the challenge of nutrient balance revolves around the range and dose of fertilisation to prevent nutrient losses while maintaining yields (Tonitto, David and Drinkwater, 2006).

4.1.4. Answer to evaluation question 1

The analysis confirmed that key beneficial practices are those involving permanent soil cover, application of organic amendments, maintenance and creation of permanently covered areas (e.g. forest, grasslands, wetlands), and the setting up of landscape elements. Land-use changes from forest or grassland to arable land, overgrazing, excess use of heavy machinery and some forest management practices (e.g. prescribed burning, clear felling and whole tree harvesting) have important consequences on soil quality.

The positive or negative effects of other practices highly depend on the context, the conditions of implementation and/or on the soil pressure considered. The effect of tillage is notably complex: under good conditions (no wet soil, correct depth, etc.) tillage has positive impacts on reducing soil compaction and remediating the 'salt crust' of saline soil, but it can also have negative impacts on soil biodiversity and erosion risks. Conversely, reduced tillage and no-tillage lead to a drop in soil erosion and a rise in soil quality. Other practices or systems can also have uneven effects depending on conditions: irrigation, fertiliser application, crop rotation (the most beneficial rotations for soils appear to be those that involve many different crops, which include at least one leguminous crop and/or include grassland). The effect of grassland on soil highly depends on the way it is managed: the situation differs between species-rich permanent grassland and grassland suffering overgrazing conditions. Afforestation of land generally reduces the risk of erosion.

Practices associated with conservation agriculture, organic farming and agroforestry contribute to maintaining or improving soil quality. This is also the case, but to a lesser extent, with integrated pest management, and of course strictness of the standards is a big factor.

The link between soil quality and productivity is complex, both of them being influenced by numerous factors; indeed, scientific papers can show regularly opposite results of a given practice in the short term. Some practices that have a negative effect on soil productivity in their first years of implementation can result in positive effects in the long term.

4.2. EQ 2: What is the architecture of CAP implementation in Member States in relation to CAP instruments and measures having effects on soil quality (i.e. choices and uptake concerning Pillars I and II including market-related measures)?

4.2.1. Understanding and method

This evaluation question aims to provide mapping of which soil-related instruments and measures are available in which areas[26] to support, foster or enforce sustainable soil management practices. The analysis considered the following judgment criteria:

- CAP instruments and measures, as defined in the regulations, have (or not) enhanced positive practices / limited negative practices: the CAP instruments and measures having a potential direct and indirect effect on soil quality were identified in Chapter 2. The first part of this analysis aims at refining this analysis, in the light of the soil-related practices identified in EQ 1.
- The soil-related CAP instruments and measures have (or not) been implemented in the EU Member States: subsidiarity in the implementation of the CAP instruments and measures results in the instruments being implemented in various ways across Member States and Regions. It is based on information available in the CAP monitoring databases (CMEF and ISAMM: see Table 3).
- The soil-related instruments and measures have (or not) supported, fostered or enforced sustainable soil management practices in the case-study areas: parts of the analysis focus on identifying whether soil-relevant practices were supported by the CAP, according to decisions by Members States and managing authorities, and whether they were actually implemented. and the third on the details regarding implementations choices collected in the case studies.

The analysis focused on CAP instruments and measures with a potential direct effect on sustainable soil management (i.e. Category 1 and 2 in Table 2). As regards the instruments and measures with a potential indirect effect on SSM (i.e. Category 3 in Table 2), examples of relevant projects are developed in EQ 7. Concerning the instruments and measures indirectly impacting the land cover / land use or intensity of production (i.e. Category 4), those instruments consist in support for farm income. Their coherence with the objective of sustainable soil management is analysed in EQ 13.

The reasons behind the implementation choices of Member States and beneficiaries are investigated in EQ 3.

4.2.2. CAP instruments and measures, as defined in the regulations, have (or not) enhanced positive practices / limited negative practices

Most activities with a negative effect on soil quality are not directly enhanced by the CAP instruments and measures. Exceptions to be mentioned concern:

- Support for forestry: the preparation of soil for afforestation (aiming at limiting the spread of fires or diseases) can be supported by RD measures (M8.1 and M8.3) in spite of their possible negative effect on soil quality. However, they contribute to the development of forest maintenance, which has an overall positive effect on soil in the long run.
- Support for investments in machinery: productive investments are supported by RD measures both in agriculture (M4.1) and in forestry (M8.6). Investments and the use of increasingly heavy machinery can have a very significant effect on soil compaction. Potential provisions taken by managing authorities to limit those side effects are investigated in EQ 13.

[26] Member States or regions in the case of measures implemented in regional RDPs.

The CAP instruments and measures concentrate on the maintenance of wetland and landscape features, the establishment of cover/catch/winter crops, and limitation on the use of pesticides and fertilisers. Those aims are directly enhanced by effects of the CAP through:

- the baseline set in the Horizontal Regulation (GAEC and SMR), making them compulsory in specific zones;
- the obligations and conditions to declare areas under EFA on greening, which provide an additional incentive for farmers to implement those activities;
- voluntary measures (RD or CMO), enabling local authorities to provide an incentive for voluntary implementation of those practices.

Other activities like the limitation of plot size, no/reduced/late tillage, controlled traffic, diversified crop rotation, compost application, which are among the most relevant activities to tackle erosion and compaction, are not enforced by the CAP obligation or by other EU regulation, in any type of zone (in the sense of NVZ, EFA, Natura 2000, etc.). Fostering those practices is left to the choices of Member States, who can enhance them through GAECs or voluntary measures (see the choices made in the case-study areas, described in Chapter 4.2.4).

4.2.3. THE SOIL-RELATED CAP INSTRUMENTS AND MEASURES HAVE (OR NOT) BEEN IMPLEMENTED IN THE EU MEMBER STATES

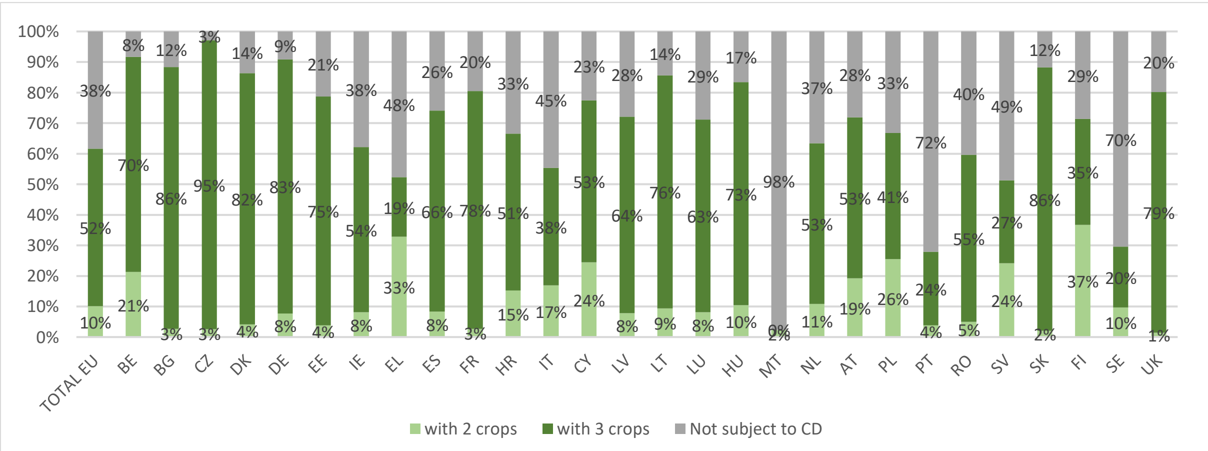
Implementation choices of soil-relevant Horizontal Measures

The standards on minimum soil cover (GAEC 4), prevention of erosion (GAEC 5) and the maintenance of soil organic matter (GAEC 6) are set at Member State level (see Chapter 4.2.4) and implemented by all farmers except those subject to the small farmers scheme. In 2018, non-compliance was detected for less than 2% of the controlled sample of CAP beneficiaries, in 75.8% of the paying agencies for GAEC 4, 86.2% for GAEC 5, and 88.1% for GAEC 6.

Implementation of the greening measures

- At EU level, in 2018, the requirement of crop diversification due to greening applied to 15.3% of the CAP beneficiaries, corresponding to a total of 61.7% of the total arable land at EU level. Exemptions are related to farms with less than 10 ha, organic farms and the small farmer scheme.

Figure 6: Share of arable land subject to crop diversification due to greening, 2018 (%)



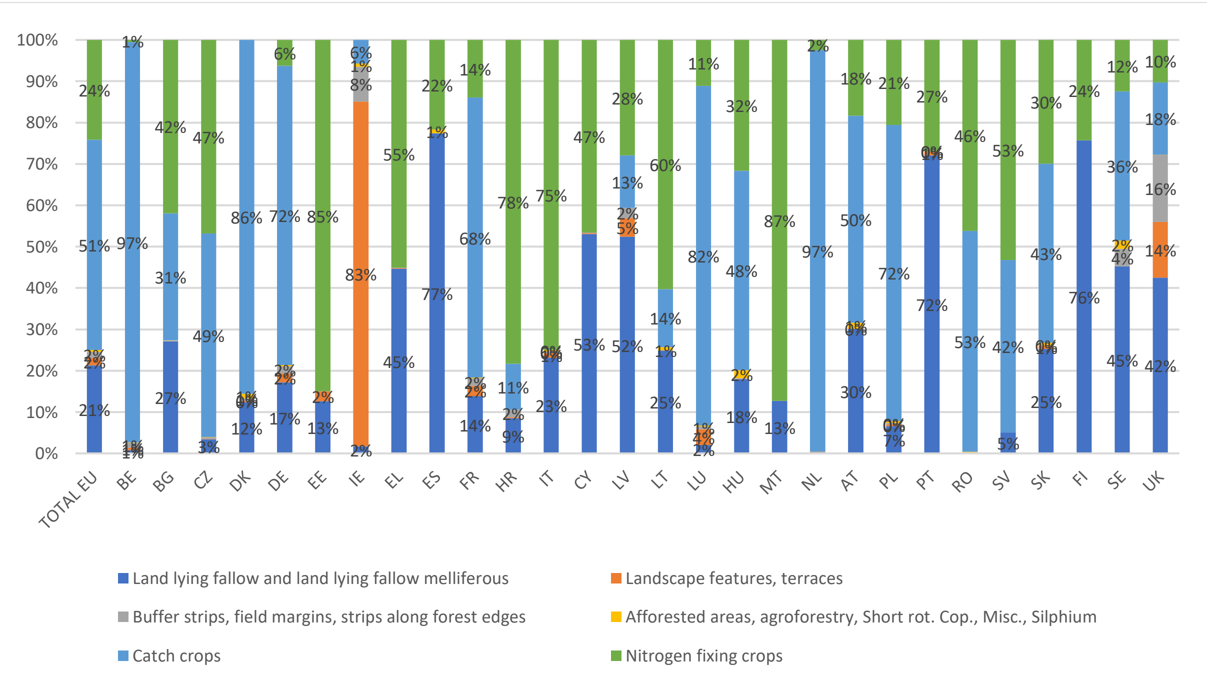
Source: DG AGRI, ISAMM notifications, 2018

- The PG ratio is monitored at regional level in Belgium, Germany, France and the United Kingdom, and at the national level in all other Member States. At the EU level, in 2018, 46.9 million ha of permanent grassland were declared, of which 42.1 million ha count in the calculation of the PG ratio. The ratio of permanent grassland is very uneven among the Member States (see EQ 5, Figure 11) with an EU average of 33.3% permanent grassland.[27] In 2018, Ireland, Portugal and the United Kingdom crossed the -5% authorised threshold on decrease in the ratio.

- In 2018, the greening requirement to declare at least 5% of the utilised agricultural area (UAA) in EFAs concerned 856 458 farms, out of 2.9 million farms subject to at least one greening obligation (in 2018), and 6.8 million beneficiaries of CAP direct payments. It concerned 69.5% of the EU arable land. At EU level, in 2018, the main EFAs are (see also Figure 7):
  - catch crops: 51% of the area declared in EFAs at EU level (main type of EFA in Belgium, Denmark, Germany, France, Luxembourg, the Netherlands and Poland);
  - nitrogen-fixing crops: 24% of the area declared in EFAs at EU level (main type of EFA in Bulgaria, Czechia, Estonia, Greece, Croatia, Italy, Latvia, Hungary, Malta, Austria, Romania, Slovenia, Slovakia and the UK);
  - fallow land: 20% at EU level, main type of EFA in Spain, Cyprus, Portugal and Finland.

Landscape features, strips, short rotation coppice and afforested areas represent a very small share of the EFAs.

Figure 7: Share of EFA, per type, in 2018 (%) (simplified typology)



Source: DG AGRI, ISAMM notifications, 2018

[27] This figure corresponds to the average PG ratio across EU Member States. The EU ratio of permanent grassland (Area in permanent grassland counting in the ratio / Total agricultural land declared, in 2018) is 28.6%.

Implementation of the RD measures[28]

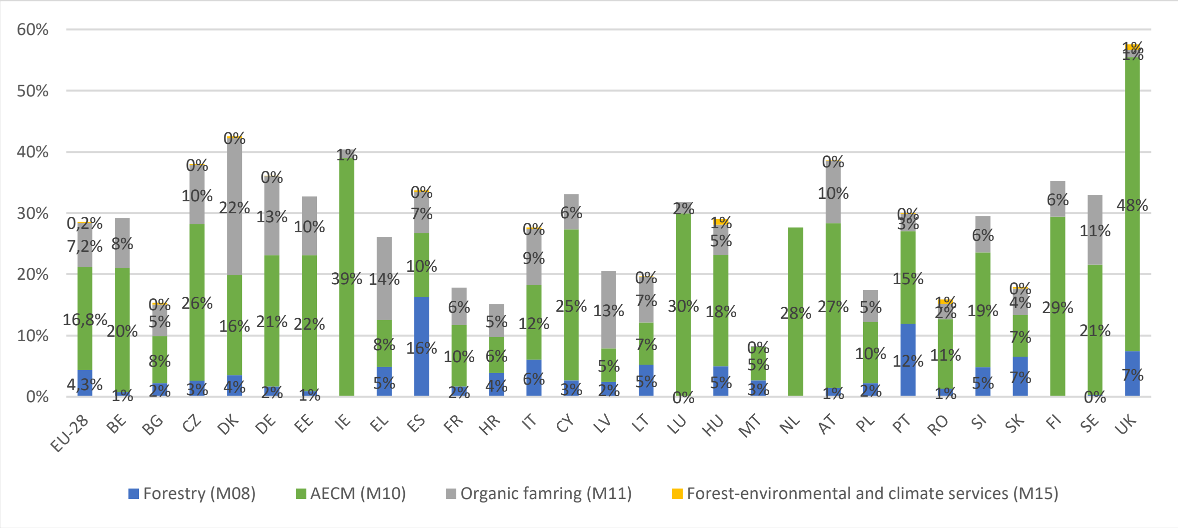
Focusing on the RD measures with an intended and direct effect on sustainable soil management, the choices made by the managing authorities at national and regional level were the following (see Figure 8):

- Support for investments in forestry (M08) was implemented in all the Member States except Ireland, Luxembourg and the Netherlands. At EU-28 level the share of the RDP budget for M08 is EUR 6.5 million, which is 4.3% of the total planned public expenditure on RDPs. Support for afforestation (M8.1), and for the establishment of agroforestry systems (M8.2) are the sub-measures in M8 identified as relevant to contribute to soil quality. M8.1 represents about 30% of the M08 budget. M8.2 was planned in only 22 RDPs and corresponds to a 2% share of M08.
- Agri-Environment and Climate Measures (M10) were programmed in all the Member States and represent 16.8% of the total planned public expenditure in RDPs (EUR 25.294 billion). In 2018, a total of 29 million ha was under AECM contracts (M10.1), i.e. about 20% of the EU total UAA. About 50% of those contracts, representing about 25.5 million ha, are related to the implementation of land use and management practices relevant to contribute to soil quality[29], i.e.:
  - creation and upkeep of ecological features (e.g. field margins, buffer areas, flower strips, hedgerows, trees): concerning a total of 2.2 million ha, of which 1.1 million ha in Austria and 0.6 million ha in the United Kingdom;
  - maintenance of high nature value (HNV) arable and grassland systems (e.g. mowing techniques, hand labour, leaving of winter stubble in arable areas), introduction of extensive grazing practices, conversion of arable land to grassland: on 10.6 million ha, of which 3 million ha in the UK, 1.2 million ha in France and 1 million ha in Spain;
  - crop diversification, crop rotation: on a total of 2.1 million ha, mostly in Germany (0.9), Poland (0.6) and Estonia (0.4);
  - reduction of drainage, management of wetlands: concerning 0.7 million ha, of which 0.6 million ha supported in Poland;
  - soil cover, ploughing techniques, reduced tillage, conservation agriculture: on a total of 3.7 million ha, including 1.7 million ha in Finland;
  - management of inputs including integrated production (reduction of mineral fertilisers, reduction of pesticides): concerning 6.2 million ha, mostly in Finland (1.8), Portugal (0.8) and Austria (0.7).
- Support for organic farming (M11) was programmed and significantly implemented in all the Member States except the Netherlands (as a result of national desire to programme a limited amount of measures). It represents 7.2% of the total planned public expenditure in RDPs. The measure supported operations (i.e. conversion to organic farming, and maintenance in organic farming) that can all be qualified as relevant to contribute to soil quality. Except in Malta where the measure was implemented to a very limited extent, it had significant uptake in all the Member States and concerned a total of 2.1 million ha for conversion and 7.1 million ha for maintenance in organic farming in the 2014-2018 period.
- Forest-environmental and climate services and forest conservation (M15) was programmed in only 25 RDPs, of 13 Member States (see Figure 8). It represents 0.2% of the total RD budget. Among the operations supported by M15, only payments for forest-environmental and climate commitments (M15.1) are relevant to contribute to soil quality, but those represent close to 100% of the operations.

[28] The implementation choices and uptake of the soil-related RD measures are presented below based on the financial data only. The corresponding outputs are presented in EQ 4 and 5 to illustrate the effect of the measures.

[29] Based on Member States' declarations in the annual implementation reports 2018.

Figure 8: Total planned public expenditure on the soil-related RD measures (2014-2020)



Source: DG AGRI, based on AIRs 2018

4.2.4. The soil-related instruments and measures have (or not) supported, fostered or enforced sustainable soil management practices in the case-study areas

Table 6 provides mapping of activities that are strictly mandatory in relation to cross-compliance, or fostered by the greening measures and RD measures, in the case-study areas[30]. In order to draw a precise overview of implementation choices, the table focuses on direct effects only. In particular, the effect of support for productive investment (M4.1) is not included in the table, as this measure may have supported investments both in machinery that reduces impact on soil (e.g. direct-seeding machines in Aragon, equipment for conservative and precision agriculture in Italy-Tuscany) and machinery with a negative impact on soil (e.g. ploughs in Wallonia, heavy specialised machinery in Italy-Tuscany)[31].

The mapping shows the variety of implementation choices from one area to another. Regarding GAECs, it is difficult to judge the more or less strict character of the rules put in place, but it is noticeable that some Member States (e.g. Bulgaria, Czechia, Ireland and Italy) have established many requirements and options for the application of the soil-related GAECs, which suggests a more ambitious approach to soil protection. While cross-compliance was expected to set a regulatory baseline, the mapping shows significant flexibility for farmers in the implementation of GAEC 4, 5 and 6. In some Member States, various alternatives are proposed to fulfil the condition (e.g. on GAEC 5 in Belgium-Wallonia, Bulgaria, Czechia and Italy): in this case GAECs are closer to an incentive to go towards a practice than to a strict obligation.

Practices specifically related to soil protection have been included as compulsory practices in GAECs and/or encouraged by other instruments and measures. In particular, reduced tillage or the no-tillage system was included in GAECs in six out of ten case-study areas (Czechia, Denmark, Ireland, Greece, Spain-Aragon, Italy-Tuscany). Limitation on plot size has also been introduced through the GAECs on areas vulnerable to erosion in Bulgaria and Czechia (since January 2020, see Box 7). In Ireland, GAEC 5 enforces controlled traffic on waterlogged soils or under unfavourable conditions. Compost or manure application is an alternative to GAEC 4 in Czechia. Furthermore, beyond GAECs and the greening

[30] Based on the analysis of Members States' declarations on greening and GAECs, rural development programmes, and additional information on the implementation choices of the instruments and measures collected from national authorities and managing authorities.

[31] Selection criteria established to limit the support to investments with a potential negative impact are reviewed in EQ 12.

requirement, AECMs encourage positive soil-related practices such as crop diversification (Germany-Bavaria and Spain-Aragon) and soil cover (Belgium-Wallonia, Czechia, Germany-Bavaria, Greece and Italy-Tuscany).

Establishing compulsory practices had to be accompanied by determining the areas concerned, in particular by risk of erosion. In general, the slope height was used as a threshold. In some Member States, the implementation was based on a mapping of areas vulnerable to erosion, based on models (Belgium-Wallonia, Czechia, Italy). In Czechia, the rules of GAEC 5 are different regarding the extent of the erosion threat (moderately or severely), with increasing requirements for the most vulnerable areas. A case of geographical definition (based on counties) was found in Sweden for the application of GAEC 4. In Bulgaria, specific requirements were established on GAEC 5 for 'sloped plots', but no corresponding minimum slope was set.

Table 6: Soil-related activities enforced, fostered and supported by the CAP, in the case-study areas

M	Activity strictly mandatory, in relation to cross-compliance	O	Activity taken into account as an option to comply with the requirements of the GAECs	S	Activity to which an incentive is provided through DP (greening measures) or through voluntary measures (RD)

In red: Practices with a generally negative effect on soil quality

		Base-line	BE-Wal.	BG	CZ	DK	DE-Bav.	IE	EL	ES-Ara.	IT-Tusc.	SE
LAND USE, LAND-USE CHANGE AND OPERATIONS												
Forests	Afforestation			S	S	S				S	S	
	Agroforestry		S	S		S				S	S	
Grasslands	Forest > grasslands											
	Arable > grasslands			S	S		S					S
	Maintenance of grasslands	PG ratio, ESPG	S	S		S	S					S
Wetlands manag.	Creation or restoration of wetlands			S		S						S
	Maintenance of natural wetlands			S	M	S						S
Other landscape elements	Landscape features (maintenance and creation)	SMR 2 and 3	S	M, S	S	S	S	S	S	S	S	S
	Buffer strips	GAEC 1	S	O, S	O, S	S	S	S	M, S		S	S
	Grass strips		M, E, S	S	S		S				O	
	Grassed strips between rows of permanent crops		S	O, S						O, S		
	Short rotation coppice		S	S	S	S	S	S			S	S
Opera-tions	Limitation of plot size			M	M							
	Terraces			O, S	S		M, S	S	M, S	O, S	M, S	
	Drainage			S							O, S	S

		Base-line	BE-Wal.	BG	CZ	DK	DE-Bav.	IE	EL	ES-Ara.	IT-Tusc.	SE
SOIL-MANAGEMENT PRACTICES AND TREATMENTS												
Tillage and traffic manag.	Reduced tillage and No-tillage	ESPG	S		O	M	S	M, S	M	O, S	O, S	
	Late tillage						M	M		S		S
	Subsoiling				O							
	Ploughing		S	O	O				M		S	
	Use of heavy machinery										S	
	Controlled traffic		S		S			M			S	
Crop management practices (crop manag./soil cover)	Intercropping			O	O							
	Diversified crop rotation	Crop div.					S		S			
	Cover crops	GAEC 4	M, S	M, S	O, S	M, S	M, S	O, S	M, S	M, O, S	M, S	M, S
	Catch crops	SMR 1			O	S	S	S				S
	Mulching						S					
	Maintenance / no burning of crop residues	GAEC 6			O		M	O		S		
	Cultivation of Nitrogen-fixing crops		S	S	O, S		S	S	S	S	S	S
	Contouring			O, S	O				M	O		
	Fallow land		S	S	S	S	S	S	S	S	S	S
Grass-land manag.	Extensive use of pasture	M11				S	S	M		S		S
Pest, diseases and fertilisation manag.	Ban on PPP application	EFA, M11	M, S		M, S		M, S		S	M, S	S	
	Ban of mineral fertilisers application	M11	S	M, S	M, S		S	S	M, S	M, S	S	
	Manuring				O			S				
	Compost application				O				S	S		
	Liming											S
Water manag.	Irrigation			S					M, S	S	S	

Sources: GAEC database, ISAMM, CMEF, interviews and Alliance Environnement data collection at case-study level

4.2.5. Answer to to evaluation question 2

Some activities which are key for sustainable soil management are not directly included under CAP rules, such as greening and specific GAECs, or under EU environmental legislation (in the EU baseline). In particular, the limitation of plot size, no/reduced/late tillage, controlled traffic, diversified crop rotation and compost application are not enforced by EU regulation in any type of zone (in the sense of NVZ, EFA, Natura 2000, etc.). Fostering those practices is left to the choice of Member States, which can enhance them in the design of the GAECs or through voluntary measures (see the choices made in the case-study areas, described in Chapter 4.2.4). Conversely, the CAP rules including GAECs and intervention are more concentrated on activities relevant for soil but targeting the protection of biodiversity and water foremost, i.e. maintenance of wetlands and landscape features, the establishment of cover/catch/winter crops, and limitations on the use of pesticides and fertilisers.

The implementation of greening concerns a significant share of EU agricultural land. The areas subject to crop diversification and EFAs represent 61.7% and 69.5% respectively of total arable land, with exemptions for small farms and areas under organic farming. The greening requirements were duly implemented on the concerned areas, with few exceptions.

RD measures identified as relevant to contribute to soil quality were allocated with about half the RD budget, but only part of this budget is allocated to operations with an effect on soil quality, which could not be precisely estimated. About 25 million ha are under AECM contracts with an effect on soil quality (mostly related to the creation and upkeep of ecological features, HNV arable and grassland systems, but also the implementation of relevant management practices such as crop diversification, conservation agriculture, etc.).

The mapping of activities strictly mandatory in relation to cross-compliance, greening measures and voluntary measures in the case-study areas illustrated the variety of implementation choices from one area to another. Some Member States (e.g. Bulgaria, Czechia, Ireland, Italy) have established many requirements and options for the application of the soil-related GAECs, which suggests a more ambitious approach to act on soil protection. While cross-compliance should set a regulatory baseline, the mapping also highlighted significant flexibility for farmers in the implementation of GAEC 4, 5 and 6. Nevertheless, practices specifically related to soil protection have been integrated as compulsory practices in GAECs and/or encouraged by other instruments and measures: in particular reduced tillage and cover crops are fostered in most areas.

The definition of vulnerable areas appears as a key element for setting requirements to protect soil, in particular concerning erosion. In general, slope height was used as a threshold by Member States. A mapping of areas vulnerable to erosion was also used in some Member States (Belgium-Wallonia, Czechia, Italy).

4.3. EQ 3: What are the drivers and reasons behind the implementation choices regarding the relevant CAP instruments and measures influencing soil quality?

a. At the level of the Member States and/or regional administrations in terms of CAP instruments and measures and their design, taking into account the range of possibilities for setting compulsory and facultative elements in the requirements for farming practices,

b. At the level of the beneficiaries (farmers/foresters) in terms of land-use patterns, intensity of land use and geographical distribution of production?

4.3.1. Understanding and method

This question examines the reasons for the choices made by Member State and RDP managing authorities as regards implementation of instruments subject to subsidiarity. It also considers the reasons for the choices made by the farmers/foresters to apply to the measures, i.e. technical choices taken to comply with the requirements and decisions to commit into voluntary schemes. Choices associated with soil-relevant CAP instruments and measures have particularly been reviewed, i.e. GAECs 4 to 6, the greening measures and the choices to apply for RD measures 4.1 and 4.4, 8.1, 8.2, 10.1, and 11 (i.e. instruments and measures falling into Categories 1 and 2, as explained in Chapter 3.1).

At the level of Member States and regional administrations, the analysis considered the following judgment criteria:

- Soil-related issues influenced (or not) the choices to implement soil-relevant CAP instruments/measures : this part reviews the relative importance given to soil-related issues among other needs and priorities addressed by the CAP, and their influence on the Member State and RDP managing authorities' choices for setting compulsory and voluntary aspects in the requirements for farming practices. The analysis built on interviews with the stakeholders involved in CAP implementation choices in the case-study Member States and was rounded out by considering the needs and strategies described in the RDPs. Previous evaluation studies of the CAP were also used to crosscheck the opinions collected in the interviews and assess the influence of soil issues compared to other issues and needs.

- Specific factors influenced (or not) the weight of soil-related issues in the implementation choices: this part builds on information collected in interviews with the stakeholders involved in the design of the instruments and measures.

At the level of beneficiaries, the analysis investigated:

- Soil-related issues were considered (or not) **in farmers'** choices to implement the soil-relevant CAP instruments and measures. Identification of farmers' decision-making process builds on interviews with the farmer representatives and other stakeholders involved in the implementation of the CAP (i.e. farm advisers, local authorities, NGOs, etc.) in the case-study areas.
- Specific factors influenced (or not) the consideration given by farmers to soil quality. A statistical analysis of the characteristics of beneficiaries and non-beneficiaries as well as their distribution between different groups was carried out based on FADN data: it provides insight into the link between the implementation of the forestry measure (M8), AECM (M10.1), organic farming (M11) and specific factors (i.e. land-use patterns, intensity of land use, and geographical distribution of farms).

4.3.2. At Member State level – Soil-related issues influenced (or not) the choices to implement soil-relevant CAP instruments/measures

Soil threats have been considered as an important issue in the designing process of the CAP in three case studies (Czechia, Germany-Bavaria and Greece). However, in other case studies, the managing authorities did not specifically target soil issues, even when they were assessed as quite problematic (e.g. Belgium-Wallonia or Italy-Tuscany, see Table 7).

Weight of soil issues in Pillar I implementation choices

The case studies revealed that soil issues influenced the implementation choices of cross-compliance in 2 of the 10 areas of investigation: Czechia and Greece. In Czechia, all stakeholders interviewed indicated that GAECs 4 and 5 and especially GAEC 6 were designed to tackle soil issues.

As for greening payments, previous CAP evaluations highlighted that one of the key drivers to their design was instead avoidance of administrative complexity (Alliance Environnement, 2017b).

Weight of soil issues in Pillar II implementation choices

According to previous CAP evaluations (Alliance Environnement, 2017b; Alliance Environnement, 2018; Alliance Environnement, 2019a; Alliance Environnement, 2019b), other environmental components such as biodiversity, climate and water were significantly taken into consideration in the design of the RDPs. However, soil issues were directly targeted by AECM (M10.1) in only three case-study Member States (Czechia, Germany-Bavaria and Italy-Tuscany). For instance, in Germany-Bavaria, two soil-related AECM (M10.1) were targeted on arable areas most at risk of erosion, which is indeed the most frequent soil issue considered in the SWOT analysis of case-study RDPs (see the table below). In other case-study Member States, soil issues were indirectly considered in the design of RD measures (Belgium-Wallonia, Denmark, Ireland, Spain-Aragon, and Sweden), mostly through AECM (M10.1) and organic farming (M11), even if in three of them (Denmark, Ireland, Sweden) no specific issue was associated with soil according to both case-study interviews and RDPs (Table 7).

Table 7: Identified soil issues in SWOT analyses of case-study RDPs

Soil threats	BE-Wal.	BG	CZ	DK	DE-Bav.	IE	EL	ES-Ara.	IT-Tusc.	SE
Erosion	● *	● ***	● **		● **		● *	● *	● *	
Decline of soil organic content	●	●			●		●	●	○	
Compaction			●							
Salinisation		●								
Pollution	○	○	●	○		○				
Decline of soil biodiversity	○	●	○	○	○		○		○	○
Nutrient balance	●	●	●	○	●	○				○

Source: RDP SWOT analysis.

* Type of erosion not specified; ** water erosion; *** wind and water erosion

● Soil issues directly mentioned ○ Soil issues identified through broader environmental issues

The fruits and vegetables support scheme (under the CMO regulation) was also used to address soil issues in Spain-Aragon and Greece, according to producers' organisations. In Greece for instance, the producers' organisations decided to include soil-related actions into their quality standards (as an environmental action of their operational plans) and promote investments in equipment beneficial for soil (for the plastics used as soil cover for soil disinfection by sun – soil solarisation).

4.3.3. At Member State level – Specific factors influenced (or not) the weight of soil-related issues in the implementation choices

4.3.3.1. Key barriers for consideration of soil issues in the implementation choices

There were two major reasons that hindered consideration of soil issues in the implementation choices at Member State level:

- Economic and political challenges: In half of the case studies (Belgium-Wallonia, Czechia, Greece, Spain-Aragon, Sweden), the majority of stakeholders mentioned that sufficient competitiveness of agricultural holdings generally prevails over environmental issues (including soil issues) when CAP implementation choices are made. This applies to both mandatory requirements from Pillar I (Belgium-Wallonia, Czechia) and voluntary measures under the RDPs (Greece, Sweden). Recent studies (Ecorys et al., 2016; Alliance Environnement, 2017a; Alliance Environnement, 2019a; Alliance Environnement, 2019b ; Brown et al., 2019) confirm this statement for general environmental issues, showing for instance that nitrogen-fixing crops or catch crops were favoured as EFAs as they allow farmers pursue productivity. Researchers and farmer representatives in Greece also pointed out that environmental actions under the fruits and vegetables operational programmes (CMO regulation) were fostered by the marketing of environmentally friendly products. Political challenges can also hinder managing authorities' ambition regarding soil: in Spain-Aragon, the priority of preventing inequality remained after a reorganisation of administrative regions (according to stakeholders other than managing authorities).
- Administrative burden: Limiting the administrative burden associated with the implementation of cross-compliance (Greece) and RD measures (Italy-Tuscany), as well as ensuring the controllability of the measures (Belgium-Wallonia), are also significant drivers hindering further changes in the CAP design for the consideration of soil issues, according to case studies. Previous CAP studies also corroborate this driver in the implementation choices of greening measures (Alliance Environnement, 2017b; Alliance Environnement, 2019b). In this regard, ensuring continuity of the supports with the previous implementation periods is a significant driver. Literature shows that, in local authorities' choices of areas eligible as EFAs, consistency with existing agricultural practices was favoured over environmental effects.

4.3.3.2. Key levers for consideration of soil issues in the implementation choices

However, the following factors led the managing authorities to promote sustainable soil management through their implementation choices of CAP instruments and measures:

- Collective analysis of local needs carried out for the design of the RDP: Analysis of local needs, generally involving concertation with local institutions, was mentioned by managing authorities as a driver towards the consideration of soil issues for RDP implementation choices in Greece and Germany-Bavaria.
- Relevant and shared knowledge of the stakeholders on soil issues: Previous CAP studies show that the level of knowledge of the stakeholders involved in the design process is a significant factor behind the consideration of environmental issues, which influences the design of CAP instruments (notably ESPG) and RD measures (Alliance Environnement, 2017b; Alliance Environnement, 2019b). The case studies of Belgium-Wallonia, Germany-Bavaria and Czechia confirmed the role of institutions working directly on soil for soil-related issue to be taken into considerations in CAP implementation decisions. In Ireland and Italy, the lack of uniform thinking and knowledge at national level was spotted as a weakness, respectively by environmental NGOs and managing authorities. Those studies also revealed that public opinion can act as a lever for the consideration of environmental issues in the design of AECMs. Also, in Germany-Bavaria, recent events played a role in soil erosion being identified as a significant issue[32].
- Other environmental issues: In 3 out of 10 case studies (Germany-Bavaria, Denmark and Sweden), the interviews with the local administration clearly highlighted that other environmental issues such as water quality, climate and biodiversity are given more importance than soil issues but can nevertheless indirectly benefit soil quality.

4.3.4. At beneficiaries' level – Soil-related issues influenced (or not) the choices to implement soil-relevant CAP instruments/measures

The opinions gathered in the case studies indicate that, in most areas (Belgium-Wallonia, Czechia, Denmark, Greece, Italy), soil issues did not influence farmers' choices regarding the areas declared as EFAs and cropping choices to comply with the obligation of crop diversification. However, in Bulgaria and Germany-Bavaria, some farmer representatives mentioned that the awareness of soil-related issues influenced the farmers' choices in the types of area declared as EFAs (e.g. catch crops), together with the fact that their costs of implementation is low. According to farmer representatives, soil issues were also indirectly considered in Spain-Aragon by farmers looking for potential yield increase through the introduction of legumes as catch crops, although managing authorities did not share this view.

Soil issues were mentioned as drivers for the implementation by farmers of soil-relevant RD measures, especially AECM (M10.1) and support for organic farming (M11) (Bulgaria, Czechia, Germany-Bavaria, Spain-Aragon, Italy-Tuscany). Preserving forest soils was also cited as a significant driver for forestry measure (M8) uptake in Czechia.

[32] In Germany-Bavaria, the tragic event of a flash flood causing seven fatalities in 2016 increased consideration of soil erosion issues in the RDP.

4.3.5. At beneficiaries' level - Specific factors influenced (or not) the weight of soil-related issues in the implementation choices

4.3.5.1. Key barriers preventing farmers from addressing soil issues by implementing relevant CAP instruments and measures

Farmers' implementation choices are significantly influenced by two factors that can play against soil-relevant activities:

- Economic drivers: Both case-study findings and previous evaluations of the CAP point out economic drivers that play a key role in the uptake of CAP measures by beneficiaries, sometimes to the detriment of environmental issues. With regard to Pillar I, cases studies showed that economic reasons are often the drivers behind farmers' decisions on greening measure and cross-compliance choices. According to both case studies and literature, farmers have implemented the EFAs that induce the least management change and that are most aligned with their existing production (Czechia, Denmark and Germany-Bavaria), as well as those that meet market demand (Czechia) or maximise agricultural output (Italy).

  Economic drivers were also central in the uptake of RD measures by farmers, as demonstrated by in the literature and the case studies. The premium of AECM (M10.1) was noted as a significant driver (Belgium-Wallonia, Bulgaria, Greece), especially when opportunity costs are low (Germany-Bavaria, Italy-Tuscany). The uptake of organic farming (M11) and environmental measures of the fruits and vegetables support scheme (CMO regulation) is also strongly correlated to market opportunities (in Belgium-Wallonia, Denmark, Germany-Bavaria, Greece, Spain-Aragon, Italy-Tuscany).
- Administrative burden: previous studies shows that administrative requirements and delays are a significant barrier in farmers' decisions (Alliance Environnement, 2017a; Alliance Environnement, 2018; Alliance Environnement, 2019b; Ecorys, 2018). This was corroborated by case studies, in which administrative burden sometimes prevented farmers from applying for RD measures, notably in Italy-Tuscany and Sweden.

4.3.5.2. **Key levers influencing farmers' choices to implement soil**-relevant CAP instruments and measures

There are key levers that positively influence farmers' uptake of CAP environmental measures:

- **Farmers' awareness and knowledge o**f environmental issues: Both evaluations assessing the impacts of the CAP on biodiversity and water highlighted the influence of farmers' awareness on their decision to address environmental issues through CAP instruments/measures. Only half of the case studies (Bulgaria, Czechia, Germany-Bavaria, Spain-Aragon and Italy-Tuscany) mentioned soil issues as potential drivers for the uptake of AECM (M10.1), organic farming (M11) or forestry measures (M8). In other case studies, choices seem to be driven by other environmental issues such as biodiversity and water quality.
- Advisory services and technical support available: the literature shows that advisory services and technical support available can be key drivers of farmers' implementation choices, for instance concerning forestry RD measures (M8) (Alliance Environnement, 2017a) as well as the importance of farmers' knowledge and the quality of advisory service in the uptake of soil carbon management practices (Mills *et al.*, 2019). Case studies as well (Bulgaria, Germany-Bavaria, Spain-Aragon, Italy-Tuscany and Sweden) revealed that farmers' motivation to address environmental issues through CAP measures greatly depends on their awareness and knowledge, which is increased through training and advisory services. In Germany-Bavaria for instance, the programme 'Boden:ständig', a

networking platform that targets areas at risk for soil erosion, increased the uptake of AECM (M10.1) in areas with high erosion risks through tailor-made solutions identified in collaboration with farmers.

- Other EU Regulatory requirements: the case studies also mentioned that soil-relevant measures can sometimes be implemented by farmers to comply with regulatory requirements, i.e. those induced under the Nitrates Directives (Belgium-Wallonia, Denmark).

Other drivers were identified for AECM such as the possibility to apply collectively (Czechia) and the proven effectiveness of the measure through its use by neighbouring farmers (Spain-Aragon).

4.3.5.3. Influence of farms characteristics

The case studies and the FADN analysis show that farmers' choices vary according to their **farms' characteristics**. Regarding geographical situation for instance, FADN data showed great disparities in the percentage of farms applying for AECM[33] (M10.1) or support for organic farming (M11), depending on the regions and/or the Member States. The analysis also revealed that, in all case-study Member States, there is a higher proportion of holdings applying for AECM (M10.1) and support for organic farming (M11) in Areas facing Natural Constraints (ANCs), and that they are also characterised by lower yields and higher production costs. For instance, the proportion of farmers applying for AECM (M10.1) inside ANCs is more than twice than that outside ANCs in Belgium and Czechia. This finding is consistent with those of other analyses on the comparison of average values, which show that low land productivity (based on gross farm income per ha) could be a driver behind adoption of AECM (M10.1), as holdings applying for this measure are on average less profitable than others in all case-study Member States. This finding was also confirmed during case-study interviews.

FADN analysis revealed that the level of diversification could positively influence AECM (M10.1) uptake: in most case-study Member States (Belgium, Denmark, Germany, Greece, Spain, Italy), there is a higher proportion of AECM (M10.1) beneficiaries among highly diversified farms (five arable crops or more).

Interviews (Bulgaria, Germany-Bavaria, Italy-Tuscany and Sweden) also point out farmers' administrative or technical capacities, biophysical conditions of their fields and the availability of the necessary assets (land, labour, capital/machinery) as factors influencing farmers' choices. For instance, in Czechia the optional use of strip-till technology to fulfil the requirements of GAEC 5 was mentioned by researchers as depending on the financial capabilities of the holdings.

4.3.6. Answer to to evaluation question 3

At the level of the Member States and/or regional administrations

Case studies and the literature review show that consideration of soil-related issues had limited influence on the implementation choices of soil-relevant CAP instruments/measures, especially regarding Pillar I. Among 10 case-study Member States, soil issues were mentioned as having impacted the implementation of cross-compliance through strengthened requirements only in Czechia and Greece (e.g. for GAEC 6 on maintenance of soil organic matter). To a limited extent, case studies show that soil-related issues have influenced the implementation choices of Pillar II measures and the fruits and vegetables support scheme. Indeed, 3 out of 10 case-study Member States (Czechia, Germany, Italy) outlined the existence of soil-targeted AECM, whereas most of the others mentioned indirect consideration of soil issues in the design of M10.1 or M11, through wider environmental considerations.

[33] The FADN does not make it possible to distinguish whether the farmers identified were beneficiaries of AECM (M10.1) or animal welfare (M14) or both measures. Results were nevertheless used and interpreted with care as AECM was more widely implemented than animal welfare (around seven times more budget according to CMEF indicators - 2017)

In some case-study Member States (Denmark, Ireland, Sweden), the low level of consideration of soil issues in the implementation choices was justified by the absence of identified soil threats in the assessment of local needs carried out in the RDP. The literature and interviews highlight that other environmental issues (biodiversity, water and climate change mitigation) had been taken into account for the implementation choices of Pillar II measures and, to a lower extent, Pillar I instruments. Water issues and climate change mitigation were also important issues influencing RDP implementation choices. Hence, indirect positive effects on soil can be expected from the implementation of such measures (fostering carbon sequestration or reducing pollutants transferred into soil).

According to the case studies and the literature, ensuring sufficient competitiveness of agricultural holdings generally prevails over environmental issues, including soil issues, when it comes to CAP implementation choices at Member State level. In case studies, efforts to limit administrative burden also limited the consideration of soil-related issues in the implementation choices. On the other hand, case studies and literature show that a key lever for soil-related issues consideration was the influence of relevant institutions (with expertise and knowledge on soil issues).

At the level of the beneficiaries (farmers/foresters)

In 5 out of 10 case-study Member States (Belgium-Wallonia, Czechia, Denmark, Greece, Italy), soil-related issues did not weigh on farmers' choice to implement EFAs or crop diversification (greening). However, case studies show that soil-related issues can sometimes influence the uptake of RD measures, especially AECM (M10.1) and organic farming (M11) (Bulgaria, Czechia, Germany-Bavaria, Spain-Aragon and Italy-Tuscany).

Both case studies and literature show that economic drivers remain central for farmers' implementation choices on Pillar I or Pillar II instruments and measures. Interviews with stakeholders involved in implementing the measures in the case-study areas indicated that the premium delivered under AECM (M10.1) is a significant driver whereas the uptake of the organic farming and fruits and vegetables environmental measures is instead driven by market opportunities (notably in Spain and Greece). Limiting administrative burden and increasing measure continuity between the implementation periods was also mentioned as a driver for farmers' increased uptake in the case studies (Greece, Spain-Aragon, Italy-Tuscany, Sweden) and in the literature. Both the case studies and literature also indicate that farmers' motivation to tackle environmental issues is increased by their awareness and knowledge, notably through advisory services, which can positively influence the consideration of soil-related and other environmental issues in their implementation choices.

The case studies also highlighted that adoption of soil-relevant measures from overall CAP instruments depends on farm characteristics, such as animals or the type of crops grown, the biophysical conditions, yields and available equipment. In particular, the FADN analysis showed that AECM (M10.1) beneficiaries are more often located in ANC (also true for organic farming-M11). Farms which commit into AECMs also have a level of crop diversification above the average, as well as lower land profitability in terms of income/ha (also true for forestry measure-M8). This latter result underlines the importance of opportunity costs for farmers to convert land into AECM (M10.1).

5. EFFECTIVENESS

5.1. EQ 4: TO WHAT EXTENT HAVE THE RELEVANT CAP INSTRUMENTS AND MEASURES CONTRIBUTED OR NOT TO SUSTAINABLE SOIL MANAGEMENT WITH AN IMPACT ON SOIL QUALITY AND SOIL PRODUCTIVITY?

5.1.1. UNDERSTANDING AND METHOD

This evaluation question analyses the contribution of the CAP to the implementation of management practices sustainable for soil[34] identified in EQ 1, i.e. practices related to tillage and traffic management; soil cover and crop management; pest, disease and fertilisation management; water management; forest management; and grassland management.

For each category of management practice, the analysis considered the following judgement criteria:

- CAP instruments and measures contributed (or not) to the implementation of the relevant management practice. The analysis focused on quantifying the contribution of soil-related CAP instruments, reviewing their outputs (e.g. operations supported, number of beneficiaries and impacted area). The analyses concerning instruments and measures with intended effects on soil quality (i.e. Category 1 in Table 2)[35] were based on data covering all Member States when available. In other cases, data were gathered from managing authorities or estimated at case-study level. Output of the instruments and measures without intended effects on soil but having potential direct effects on soil quality (i.e. Category 2 in Table 2) were collected only at case-study level.
- The CAP contribution to the implementation of management practices sustainable for soil was significant (or not), putting into perspective the outputs identified with the overall changes observed in the spreading of the practices. Depending on the information available for the different practices, different methods were used: analysis of the average changes of the use of pesticides and fertilisation[36] or comparison with the general changes of the area concerned by the practice (e.g. for N-Fixing crops and crop diversification). Interviews with stakeholders at case-study level round out these analyses with qualitative information.

Out of need to provide a summary and clear overview of the situation, the analyses below are presented by category of management practices.

5.1.2. CONTRIBUTION OF CAP INSTRUMENTS AND MEASURES TO THE IMPLEMENTATION OF PEST, DISEASE AND FERTILISATION MANAGEMENT

Standard mandatory requirement 1 (SMR1) ensures appropriate application of fertilisers (manure and mineral fertiliser) on all nitrate vulnerable zones (NVZs): those range from 100% of the total UAA in some Member states (e.g. Denmark, Germany, Ireland) to 13% in Italy. It represented 49% of the UAA in the EU in 2015.

Additional regulations on pest, disease and fertilisation management through the GAECs were found in the case-study areas, e.g. ban of PPPs on buffer strip in Belgium and Czechia (under GAEC 1), on fallow lands in Germany (under GAEC 4); mineral fertilisers on buffer strips in Bulgaria and Czechia (GAEC 1) and landscape features in Czechia (GAEC 7). Regarding manuring, manure application

[34] The potential negative impacts of the CAP instruments (i.e. direct payment, VCS), will be investigated in EQ 13.

[35] Among the instruments and measures in Category 2, M8.1 and M8.2 impact only land use and not management practices: thus, they are considered in EQ 5 and not in this chapter.

[36] The expenses in PPP and fertilisation (FADN database) were used to assess their uses.

is an option to fulfil standards of GAEC 6 in Czechia. The areas on which the GAEC regulation applies could not be calculated. However, the majority of the stakeholders interviewed in the case-study areas estimated that the GAECs effect pest, disease and fertilisation management had been rather limited.

Prohibition of PPPs on EFAs which are or may be productive concerned 13% of EU arable land (9.6 million ha). This new provision thus had significant effects looking at the area concerned, but it also resulted in a decrease of the area of N-fixing crops and green fertilisers (-50% in 2018), which may have negative effects on the balance in nutrient and soil quality.

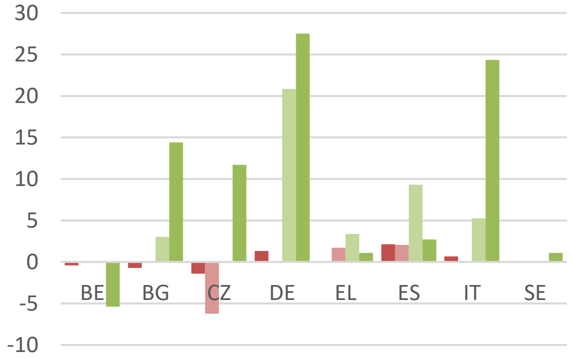
RD significantly contributed to the increase in the area in organic farming (M11), thus inducing restrictions on the use of mineral fertilisers and PPPs[37]. In 2018, support of conversion and maintenance in organic farming (M11) concerned 9.2 million ha (68% of the total area fully converted and under conversion to organic farming). The majority of the stakeholders interviewed in the case-study areas estimated that support for organic farming significantly contributed to the reduction of the use of pesticides. This opinion was confirmed by statistical analysis based on FADN data (counterfactual analysis based on comparison of averages based on the available samples from the case-study Member States): a tendency for decrease in total fertiliser and PPP expenses for farmers converting to organic farming can be observed in all case-study Member States except Italy. Still, the difference between changes in the PPP and fertiliser expenses for organic holdings as compared to the same indicator for non-organic holdings is statistically significant in Germany and Spain only.

The effect of organic farming (M11) on the use of manuring and composting was not often mentioned in the interviews. Nevertheless, the statistical analysis of FADN data also showed a trend towards an increase in the share of manure in fertiliser expenses for organic holdings (Figure 9). The difference with non-organic holdings was found to be statistically significant in six case-study Member States.

Legend:

- Conventional holdings
- Farmers applying organic production methods in 2014 but not in 2016
- Farmers applying organic production methods in 2016 but not in 2014
- Organic holdings

Figure 9: Mean change in share of manure expenses (% of fertiliser expenses) (2014-2016)



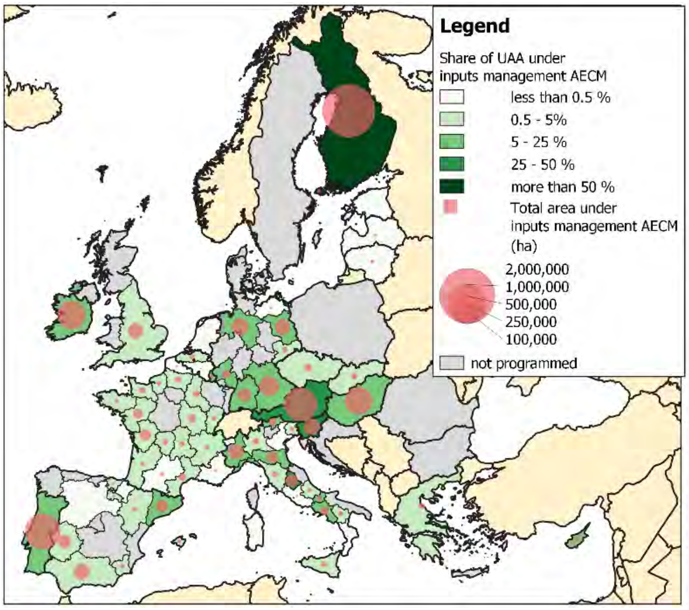
Source: Alliance Environnement, based on FADN. Variable not available for DK and IE.

[37] Article 12 of Regulation (EC) No 834/2007: the use of PPPs is restricted to the case of an established threat to a crop and the use of mineral nitrogen fertiliser is banned.

AECM (M10.1) also supported the management of inputs on 4% of arable and permanent land (almost 7 million ha) in the EU in 2018, with great heterogeneity among Member States (see Map 6). Moreover, some AECMs targeting other soil issues such as biodiversity include a ban on PPPs in their selection criteria (e.g. 80 564 ha, representing 11.2% of UAA)) concerned in Belgium-Wallonia.

However, statistical analysis based on FADN data (comparison of averages based on the available samples from the case-study Member States) show no significant change in fertiliser or PPP expenses for holdings entering an AECM[38]. This statistical result may be explained by a switch toward protection products authorised in organic farming , which are generally more expensive than conventional products.

Map 6: Area under AECM supporting the management of inputs in 2018



Source: DG AGRI, based on AIRs

Looking at expenses in manure, data from the FADN show that the average share of manure in fertiliser expenses increased for farms entering an AECM[38], in all the case-study Member States except Czechia. However, no data is available on the quantity of manure produced and used on farms.

Support for productive investments in agricultural holdings (M4.1) may incentivise farmers to invest in specific equipment to improve the use of fertilisers and PPPs or to change their management practices, thereby developing new techniques that could reduce inputs (equipment for manuring, mechanical weeding, precision farming, etc.). However, few examples of such effects were found in the case-study areas. When conducting a counterfactual analysis comparing changes in the purchase of PPP by M4 beneficiaries and non-beneficiaries, the statistical analysis of FADN data show no overall trend on the 2014-2016 period. There also seems to be no general relationship between M4 support and total fertilisation and manure expenses.

Significant examples of contribution of the fruits and vegetable operational programmes to promote better use of PPPs and fertilisers were found in the case-study areas. In Spain-Aragon, over the current period, there was found to be support for 5 326 ha (2.7% of permanent crops) through 'Generic integrated production' (action 7.16), for 937 ha through the use of methods of biotechnology or biological control instead of conventional ones in fruits and vegetables cultures (7.18.1) and for 1 124 ha through use of the peach-bagging technique as a physical barrier against pests (action 7.20.1).

[38] The indicator used to identify beneficiaries of AECMs (M10.1) actually beneficiaries of AECMs with beneficiaries of support for animal welfare (M14). This indicators was nevertheless considered as representing AECMs beneficiaries, given that AECM was more widely implemented than animal welfare.

5.1.3. Contribution of CAP instruments and measures to the implementation of soil cover and crop management practices sustainable for soil

The soil-relevant CAP instruments and measures involved in the implementation of these management practices are: GAEC 4, GAEC 5, GAEC 6 and SMR1, the greening measures 'crop diversification' and EFA, M10.1 (all soil cover and crop management practices), and the environmental actions of the fruits and vegetables operational programmes, depending on the Member State (see EQ 2).

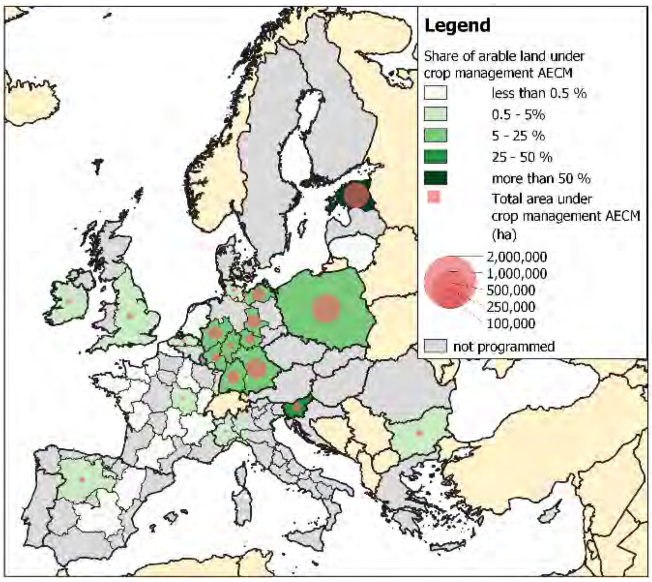
5.1.3.1. Diversification and crop rotation

Statistical analysis based on FADN data showed that almost half of the area corresponding to undiversified arable land (5% of EU arable land) in 2014 was diversified in 2015 to meet the obligation of crop diversification under the greening requirements: it led to an increase in the area under leguminous plants, peas, field beans and sweep lupin, rape and turnip rape, fallow and sunflowers (Alliance Environnement, 2017b)[39]. The case studies confirmed that the measure contributed to alleviating monoculture in Spain-Aragon and Ireland. Leguminous plants were introduced in Spain-Aragon, Bulgaria and Greece, and barley was grown in Spain-Aragon as an alternative to wheat monocropping.

However, the impact of the measure on cropping patterns at EU level is limited: 79% of the arable land subject to the requirement of diversification had already been included in cropping patterns complying with the obligation (Alliance Environnement, 2017b). This limit was also mentioned by numerous stakeholders in Belgium-Wallonia, Czechia, Denmark and Sweden. In addition, at EU level, 12% of arable land has been exempted (some of which has nevertheless been diversified). This was mentioned as a limit in Belgium-Wallonia, Italy and Sweden. Depending on the area, increasing crop diversity on-farm may or not be linked with increases in crop rotation (Alliance Environnement, 2017b).

AECM (M10.1) supported crop diversification and crop rotation[40] in 37 RDPs in 15 Member States in 2018[41] (see example in Box 3). At EU level, this accounts for 2% of arable land (2 159 925 ha: see the breakdown in Map 7). The area under contract reached two-thirds of arable land in Estonia and one-third in Slovenia.

Map 7: Area under AECM supporting crop diversification and crop rotation in 2018



Source: DG AGRI, based on AIRs

[39] Statistics produced in the framework of the evaluation study of the payment for agricultural practices beneficial for the climate and the environment (Alliance Environnement, 2017), based on FADN data from 2014 and 2015 in 10 MS (AT, CZ, FR, RO, DE, PL, NL, UK, LT, ES).

[40] Only commitments going beyond the requirement of cross-compliance and greening can be supported in the framework of AECMs, in order to avoid double funding.

[41] BE, BG, CY, DE, EE, ES, FR, IE, IT, LT, LU, NL, PL, SI, UK (DG AGRI, based on AIRs 2018). As a condition for the greening payment, diversification can be supported in RD only if it goes beyond the greening requirement.

Box 1: Example of AECM supporting diversified crop rotation in Bavaria (DE)

In Germany-Bavaria, 300 000 ha of diversification or crop rotation were supported in 2018, or 15% of arable land. This AECM supported diversified crop rotation with protein plants, large-sized legumes or old cultivars, limiting the main crop to 10% to 30% of arable land (except for grass, small-grained legumes (clover/alfalfa) or their seed as the main crop diversified crop rotation with protein plants (legumes)). In the case of grass, small-grained legumes (clover/alfalfa) or their seed as the main crop, the extent of cultivation may be up to 40%. The proportion of cereals (sweet grasses) may not exceed 66% of the arable land.

Source: Alliance Environnement

5.1.3.2. Cover crops, catch crops and N-fixing crops

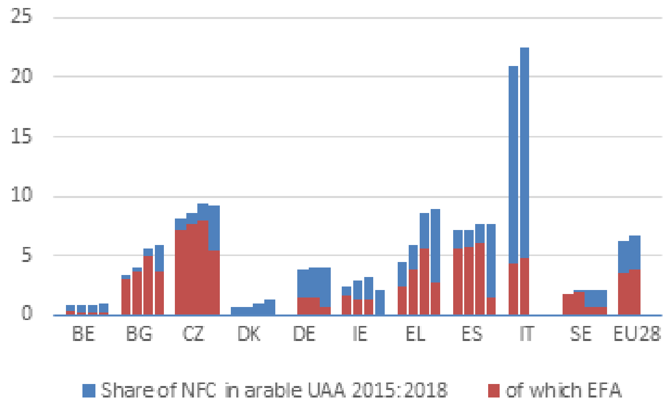
SMR1 resulted in the implementation of catch crops on all NVZs, i.e. 49% of the UAA in the EU in 2015 (see also Chapter 5.1.2). Of the 10 case-study Member States, only Czechia fosters the implementation of catch crops in other areas: on arable land with sloping area > 4% under GAEC 4, and on areas severely vulnerable to erosion (SEO) > 2 ha under GAEC 5 (57 665 ha, or 2.37% of UAA).

GAEC 4 required the implementation of soil cover in all the Member States, but its effect on practices is unclear: the share of arable land subject to this requirement could not be calculated within the framework of this study. It partly corresponds to areas where the soil was already covered as a result of the SMR1. The majority view collected in the case-study area thus points to a limited effect of the GAECs on the cultivation catch crop, but a significant effect was found in some areas: e.g. in Germany-Bavaria, where an increase in winter cover may be due to GAEC 5, and in Denmark and Czechia where the increase in cover crop and catch crop may be attributed to both GAEC 4 and 5.

N-fixing crops were one of the main crops introduced by farmers in their cropping patterns to comply with the crop diversification requirement, partially replacing common wheat, barley and maize (see also Chapter 5.1.3.1). The declaration of N-fixing crops in EFAs also clearly contributed to the spreading of N-fixing crop cultivation, even though upward trends were already existing between 2010 and 2015 (Alliance Environnement, 2017b). In 2017, N-fixing crops were the most declared area in EFAs in terms of area declared.

In 2018, the area of N-fixing crop declared as EFAs decreased by 50% in the EU-28 (from 4.6 million ha to 2.3 million ha) as a consequence of the restriction of pesticide application under the 'Omnibus' Regulation[42] (Alliance Environnement, 2019 a). However, the general trend shows a stabilisation or a small increase in the share of arable land dedicated to N-fixing crops (except in Ireland) (see Figure 10). Thus, farmers have maintained their area in N-fixing crops, but they choose not to declare them under EFAs.

Figure 10: Share of the arable land in N-fixing crops (total and declared in EFA) from 2015 to 2018, in the case-study Member States (in %)



Source: DG AGRI, ISAMM notifications, Eurostat 2015: 2018[43].

[42] Reg (EU, Euratom) 2017/1555

[43] Analyses conducted based on available data on area under protein crops, field peas, sweet lupins, soybean, fresh pulses, fresh beans and leguminous plants harvested green (EUROSTAT), compared with N-Fixing crops allowed to be declared as EFA in each

The declaration of EFAs also indirectly fostered the implementation of catch and cover (accounting for 51% of the total EFAs at EU level in 2018, concentrated in Belgium, Germany, France, the Netherlands and Poland). Comparison between area under catch and cover crops in 2010 and the uptake of the EFA measure in 2016 revealed that their cultivation increased in several Member States (Germany, Hungary, Romania) following the implementation of greening. Though the extension of catch and cover cropping areas could not be entirely attributed to the EFAs at EU level, it may be the key driver of its implementation in some Regions (Czechia, Germany, France, UK-England) (Alliance Environnement, 2017b). In the case-study areas, interviews with local authorities and farmers representatives confirmed this statement, the majority view considering that the EFA measure did not result in significant changes in term of farming management practices and choice of the cover. Nevertheless, technical advisers underlined that the EFA measure contributes to establishing relevant cover crops and to raising farmers awareness of the positive effect of intercrops and started working also on the improved of the mix of species use in the cover.

Half of the case-study areas[44] have implemented AECMs (M10.1) concerning catch crops, cover crops and N-fixing crops (see Box 2). The extent to which AECM (M10.1) have supported the reduction of tillage at EU level could not be quantified: the monitoring of those operations gathers AECM supporting soil cover management and tillage practices (found in 23 RDPs in 2018 and representing 3.8 million ha or 2.4% of the EU arable and permanent land).

Box 2: Example of M10.1 supporting the implementation of catch crops, cover crops and N-fixing crops and uptake in the case-study areas

In Germany-Bavaria, AECM 10.1.05 contributes to fighting soil erosion by maintaining soil cover during the winter months. The soil cover can be obtained either with catch crops or with wild grasses between the rows in hop fields and vineyards. It is accompanied by scheduled land management/tillage and a ban on chemical PPPs. In 2018, this measure supported 48 200 ha (1.5% of arable and permanent land). In addition, AECM 10.1.06 indirectly supported crop cover by promoting mulch sowing or the direct-seeding method for row crops, for a total of 39 477 ha (1.9% of arable land). Likewise, in Italy-Tuscany AECM 10.1.1 supports both cover crops (2 789 ha), direct seeding (728 ha), cover crops with direct seeding (441 ha), and ground cover of specialised tree crops (964 ha). The total of area supported represents 0.65% of the UAA.

Some of these measures are not widely adopted: in Belgium-Wallonia, 76 ha of managed plots were supported by AECM 'MC8' in 2018, representing only 0.01% of the UAA and 61 beneficiaries. This measure aims to guarantee a cover determined by experts, on which fertilisers and PPPs are banned. Moreover, in Spain-Aragon, AECM 10.1.f on conservation agriculture in vineyards aims to maintain plant cover between rows of plantation between 1 June and 28 February. Although they had little data to base their responses on, interviewees agreed that very few farmers are concerned by this measure due to the admissibility criteria. A similar measure has been implemented in Bulgaria through the AECM 'Grassing of vine rows and perennials (AK7)', which supported 17 036.9 ha (0.3% of UAA) and 1 569 beneficiaries in 2018.

Source: Alliance Environnement

No significant effect of the fruits and vegetables operational programmes was found on the implementation of catch, cover or N-fixing crops. Such operations were supported in Spain-Aragon, but the available data show very little result outputs.

5.1.3.3. Fallow lands

The eligibility of fallow land as EFAs[45] significantly impacted farmers' decision on whether or not to put land into fallow, in the first year of implementation of the greening measure (Alliance Environnement

MS (DG AGRI, ISAMM notifications). Data not available for DE 2015 and IT and EU-28 2017 :2018. As NFC EFAs do not include soybeans for IE, EL or SE, soybean areas were not considered as NFC in these Member States.

[44] BE-Wallonia, CZ, DE-Bavaria, ES-Aragon and IT-Tuscany.

[45] Option chosen in all MS except Romania and the Netherlands. At EU level, it represented 2 044 847 ha in 2018 (21% of the area declared under EFA).

2017b): the area of land left fallow increased by 4.9% from 2014 and 2015. However, from 2015 to 2018, there was still a trend toward a decrease in the annual area in fallow at EU level.

Four case-study areas[46] have implemented RD measures concerning fallow lands. Some examples of the supported management practices and their uptake are set out in the box below.

Box 3: Examples of AECMs supporting the implementation of fallow land

In Germany-Bavaria, in 2018, 1 053 ha (0.3% of agricultural area) of fallow land in fields with natural vegetation for reasons of species protection were supported by the measure 'Farmland biotope type 2' (M10.1.17), but mainly for biodiversity purposes. No land management is authorised between 15 March and 31 August. Likewise, in Ireland the operation 'environmental management of fallow land' (M10.1) firstly aims to increase biodiversity by providing food and habitat for ground-nesting birds other fauna and insects

In Spain-Aragon, setting aside fallow land in rainfed plots is part of operations promoting the maintenance of stubble (M10.1.a). Half of the field must be left fallow and the other half dedicated to cereal cultivation. The harvested plot in summer that leaves the stubble on the ground until 31 December will be the plot left fallow the following year. Moreover, a cover has to be established on the fallow. In the Aragon RDP, no precisions are given on the type of fallow (tilled, plant cover seeded or natural). It represents more than 60 000 ha (or 2.8% of agricultural area).

In Greece, implementation of fallow land in at least 30% of the total eligible UAA is supported in the sub-type of operation 10.1.4.a of the TO M10.1.4 'reduction of water pollution from agricultural activities', eligible in all NVZs. It has been adopted by 95% of the beneficiaries (around 3 960 beneficiaries) of M10.1.4.a. All farming activity is forbidden (e.g. tillage, fertilisation, PPP use, irrigation etc.) on the fallows. Moreover, fallow lands adjacent to water surfaces have to be maintained during the entire five-year period.

Source: Alliance Environnement

Furthermore, the case studies highlighted that fallow lands can have either positive or negative effects on soils, according to the bioclimatic context, the way they are managed or how they are defined[47]. For instance, spontaneous fallow land in dry areas in Spain-Aragon does not cover all bare soil, and if they are tilled (a common and traditional practice), it seems to increase the effect of wind and water erosion significantly. Therefore, their effects on soil quality have to be considered with caution.

5.1.3.4. Maintenance of crop residues

Though GAEC 6 set a ban on burning on all EU arable land, it induced no significant changes in management practices in the case-study areas, except in Greece.

Examples of additional fostering of the maintenance of crop residue were found in the case studies. The maintenance of crop residue is a possible option for compliance with GAEC 4 in Czechia and Ireland, and with SMR1 in Ireland. Nevertheless, no information was found enabling assessment of the area under these conditions where crop residue is maintained.

Fruits and vegetables operational programmes supported the maintenance of pruning residues in orchards. In Spain-Aragon, the action 7.2 'Incorporation into the soil or placement on it of pruning remains' is the most implemented (11 426.09 ha or 12% of permanent crops). According to producers' organisations, it incentivised fruits producers to implement new management practices sustainable for soil structure and for the maintenance of SOM; practices which would probably not have carried out otherwise (e.g. crushing residues).

[46] DE-Bavaria, IE, EL and ES-Aragon.

[47] Some Member States such as Bulgaria have defined two types of fallow lands: green fallow and brown fallows, while other do not distinguish between the two types.

5.1.4. Contribution of CAP instruments and measures to the implementation of tillage and traffic management sustainable for soil

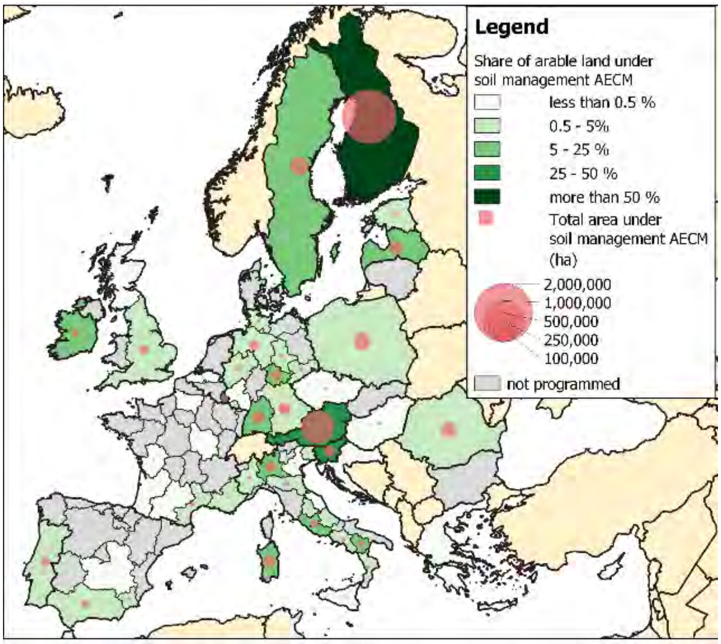
Although no provision was set up in the EU framework regarding late tillage and no-tillage, 4 out of 10 Member States (Denmark, Germany, Estonia and Ireland) introduced it under cross-compliance, on sloped areas (Denmark, Ireland, Spain, Italy) or in specific vulnerable zones (areas vulnerable to erosion in Germany and Czechia, NVZs in Ireland) (see also Table 6. The corresponding area could not be quantified, but available data from case-study reports show that it reaches one-quarter of the total UAA in Germany-Bavaria and Czechia (EVZs). Ireland requires, under GAEC 5, controlled traffic in unfavourable weather conditions (e.g. waterlogged soils).

In most of the case-study areas concerned, the majority view was that cross-compliance had little effect on the implementation of no-tillage or reduced tillage, which had already been implemented by the farmers. Czechia stands out as an exception: the majority view is that GAEC 5, though implemented since 2019 only, contributes to the spreading of strip-till.

The greening requirements on **environmentally sensitive permanent grassland (ESPG)'** resulted in a ban on ploughing on almost 6 million ha, which were declared as ESPG in the EU-28 (13% of the total PG). However, 94% are within the Natura 2000 network[48], where ploughing was already banned or pre-authorisation required. The added value of the greening measure thus lies in more frequent checks, which can allow for better compliance with this rule (Alliance Environnement, 2017b). Outside the Natura 2000 network, the limited area covered by the measure limits its effects (Alliance Environnement, 2017b).

Out of the 10 case-study RDPs, three set an AECM supporting conservative tillage practices, and two set an AECM on late tillage (see Box 4). The exact extent to which AECM M10.1 has supported the reduction of tillage at EU level could not be quantified: the monitoring of those operations gathers AECMs supporting soil cover management and tillage practices together (3.7 million ha).

Map 8: Area under AECM supporting Soil cover, ploughing techniques, low tillage, Conservation agriculture in 2018



Source: DG AGRI, based on AIRs

48 Only five Member States have decided to designate ESPG outside Natura 2000 areas (BE, CZ, IT, LT and UK).

Box 4: AECM supporting the implementation of low, no or late tillage in the case-study areas

In Germany-Bavaria, M10.1.01, M10.1.03 and M10.1.04 include reduced tillage. They represented 266 982 ha in 2018, or 8.5% of the UAA of Bavaria.

Italy developed an interesting AECM programme on soil-conservative practices (sowing on hard land, minimum tillage, strip tillage). Associated AECMs were programmed in 15 Italian RDPs, targeting the adoption of beneficial cultivation practices on 330 000 ha (RRN, 2016).

In Spain-Aragon, M10.1.a involves the no-tillage system on stubble surfaces until 31 December. This measure had been planned for more than 60 000 ha, or 4% of arable land.

In Sweden within the type of operation 'Reduced nutrients leaching from arable land' (M10.1), no early tillage can be carried out during cultivation of catch crops. A total of 96 000 ha were committed to this type of operation (including catch crops and/or late tillage) in 2019.

Source: Alliance Environnement

5.1.5. Contribution of CAP instruments and measures to the implementation of water management sustainable for soil

Water management has a limited effect on soil but must be considered in the context of the implementation of sustainable soil management, particularly when there is a risk of salinisation and when irrigation can lead to soil erosion or compaction. The impact of the CAP on water management was recently investigated in an ad hoc evaluation study (Alliance Environnement, 2019b).

Some examples of the CAP's contribution to rational management of water to limit the impact on the soil are shown in Box 5.

Box 5: Examples of CAP instruments and measures contributing to water management

Greece has implemented standards within GAEC 5 by prohibiting surface irrigation on plots with >10% slopes .

In Bulgaria and Italy-Tuscany, M4.1 has supported investments in water management practices to improve the irrigation equipment on farm. In Spain-Aragon, M.4.3 has supported investments to modernise irrigation systems (M4.3.d): this benefited to 5 638.26 ha.

The fruits and vegetables operational programmes in Greece, Italy-Tuscany and Spain-Aragon have also supported the implementation operation related to the sustainable use of water. For instance, in Spain-Aragon, 128 ha benefited from the action 'modernisation of irrigation'. However, no link with practices clearly contributing to sustainable soil management could be confirmed.

Source: Alliance Environnement

5.1.6. Contribution of CAP instruments and measures to the implementation of forest management practices sustainable for soil

Forest management practices sustainable for soil (ban of clear felling, harvest residues maintenance and harvest compensation application techniques) could be supported by M8.5 and M15.1 (see EQ 2).

Some examples of operations relevant for soil were identified under those measures, in 2 of the 10 case studies (e.g. in Czechia, support for introducing supplementary species in forests with important anti-erosion functions). However, the evaluation study of the forest measure under rural development showed that those measures mostly targeted the protection and enhancement of social and environmental ecosystem services in forests and had little impact on soil management (Alliance Environnement, 2017a). In addition, actions for erosion control on slopes and surface runoff, and erosion control in riverbeds (sowing and padding, construction and maintenance of transverse barriers to the maximum slope line) were supported under M8.4 in Spain-Aragon.

RD measures also target traffic on soil in forest areas. This was the case for example in the RDP of France-Aquitaine which as part of M8.6 related to investments in machinery included the obligation to have low-pressure tyres to protect soil from compaction (Alliance Environnement, 2017a).

5.1.7. Contribution of CAP instruments and measures to the implementation of grassland management practices sustainable for soil

The previous evaluation study of the CAP (Alliance Environnement, 2019) showed that support for organic farming (M11) played a key role in the maintenance of extensive grazing: extensive use of pasture is required in organic farming (livestock density limited to an equivalent of 170 kg.N/ha/year).

Interesting examples of the use of AECMs (M10.1) were found in 3 out of the 10 case studies (see Box 6), though no data are available to assess the uptake of AECM dedicated to the support for extensive grazing at EU level.

It should be noted that, in some areas with natural constraints, areas used for grazing are not appropriate for other types of farming (crops, permanent crops or intensive livestock). Hence, in these areas, support for extensive grazing addresses the issue of land abandonment and maintenance of farming activities (see also

), but not the issues of intensive production.

Box 6: RD measures linked to the implementation of grassland management practices

In Germany-Bavaria, 'Extensive grassland use and forage production for grazing stock' (10.1.1) supports the use grassland for grazing stock, also on mountain pastures and Alpine areas (max. 1.40/1.76 LSU/ha). It supported 199 841 ha in 2018. Moreover the 'Grazing of mountain pasture' (10.1.13) supported 32 676 ha in 2018. In Spain-Aragon, extensive grazing is promoted by the AECM 'Additional extensification of grazing' (M10.1.c) (no data on its uptake could be collected). Its conditions include not exceeding a livestock load of 1 LSU/ha in the areas of regionalised yields below 2 t/ha and 1.4 LSU/ha in the areas of regionalised yields above 2 t/ha.

Source: Alliance Environnement

Other CAP instruments and measures may have an effect on the implementation of grassland management practices sustainable for soil (e.g. voluntary coupled support for livestock and M13). Their effect is assessed in EQ 13.

5.1.8. Answer to evaluation question 4

The extent to which the CAP contributed to the development of soil-relevant management practices is difficult to establish. The CAP instruments and measures introduced provisions on the use of PPPs and fertilisers, which concerned a significant share of the EU arable land: cross-compliance, by sanctioning beneficiaries when not complying with the relevant rules, contributes to limiting the use of fertilisers in NVZs (49% of EU arable land), the ban on PPPs on EFAs (5% of UAA) and support for organic farming (13.4 million ha of which 68% are supported by M11 under RD).

The CAP contributed positively to the establishment of catch and cover crops and significantly to the establishment of N-fixing crops. Tillage practices on arable land were supported by AECMs, but these were limited to specific areas and thus not significant at EU level. However, the ban on ploughing of permanent grassland (set in nine Member States) and on ESPG (as an EU requirement) are paramount for acting on not only carbon storage but also erosion in these areas. Regarding the maintenance of crop residues, but also manuring and compost application, few effects of the CAP were highlighted in the study. In particular, while those practices may have been included in GAEC 6 to maintain soil content in organic matter, the provisions taken under GAEC 6 lacked ambition (though examples of good practices were found in some Member States).

Looking at the individual effect of the instruments and measures targeting sustainable soil management, it appears that GAEC 4, 5 and 6, in spite of being enforced within all the areas eligible for direct payments, triggered changes of practices on limited areas. The requirement of crop diversification (greening), which was one of the most important measures on soil quality, had few effects in the end because it also concerned a small share of land and did not entail the implementation of crop rotation.

AECMs proved to have the capacity of foster very relevant management practices, tailored to the local needs and context. Still the examples of such measures that were found in the case-study area are seldom and benefited to limited areas. Lastly, the organic farming measure has significant effects (confirmed by the FADN analysis) on the reduction of the use of PPPs and thus on soil pollution. Nevertheless, its effect on soil quality remains controversial because the repeated use of machines can affect soil compaction, erosion and soil organic matter.

5.2. EQ 5: To what extent have the relevant CAP instruments and measures affected land use and land-use change with an impact on soil quality and related productivity?

5.2.1. Understanding and method

This question focuses on analysing the contribution of the CAP instruments and measure on land use, land-use change and operations that help boost soil quality and productivity: in other words, the extent to what the CAP instruments foster and/or result in positive changes[49] in land use that promoted implementation of sustainable soil management.

For each category of land use, the analysis considered the following judgement criteria:

- CAP instruments and measures contributed (or not) to the implementation of the relevant land-use change and operations. The analysis focuses on quantifying the implementation of land use and land-use change sustainable for soil[50] resulting from or supported by the CAP instruments (e.g. grassland, or arable land into forest, terracing, etc.). The study covers the outputs and results of the instruments identified as having an intended and direct effect on sustainable soil management (i.e. categories 1 and 2 in Table 2), and which have a potential to impact on land use and land-use changes: i.e. GAEC 5, M8.1, M8.2, M10.1; and GAEC 1 and GAEC 7, greening measures – EFAs and maintenance of permanent grassland.
- The CAP contribution to land-use change relevant for soil was significant (or not): in order to provide tangible insight into the contribution of the CAP to sustainable soil management, those outputs are put into perspective with the overall changes in land-use change at EU or local level and/or the qualitative judgement of the stakeholders, at case-study level.

Out of need to provide a summary and clear overview of the findings, the analyses are presented below per category of land use and land-use change.

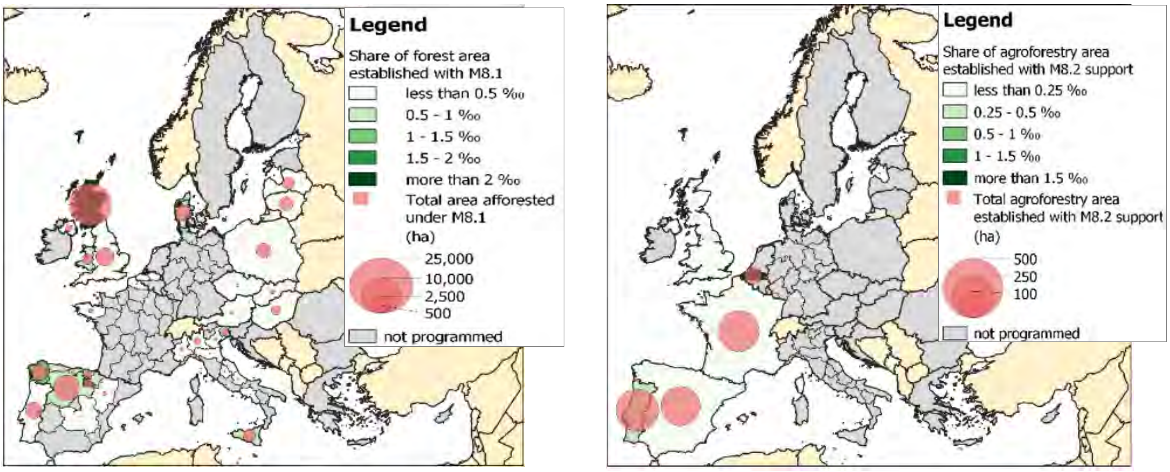
5.2.2. Contribution of the CAP to afforestation and the maintenance of forests

Afforestation and the establishment of agroforestry systems were supported by the RD measures on afforestation (M8.1) and agroforestry (M8.2). Those measures were programmed in a limited number of RDPs (see Map 9).

[49] The potential secondary negative impacts of some CAP instruments (i.e. direct payment, VCS), will be investigated in EQ 13.

[50] Building on the typology of land use impacting soil quality obtained in EQ 1.

Map 9: Area supported for afforestation and agroforestry between 2014 and 2018



Source: Alliance Environnement, based on DG AGRI (data from AIRs 2018) and Eurostat

At EU level, rural development programmes have supported the afforestation (M8.1) of 64 369 ha since 2014[51], or 0.04% of the EU area in forest in 2014. The afforested area represents up to 2% of forest lands in United Kingdom-Scotland but less than 0.5% in most of the other areas.

Looking at the long term, CAP support may significantly contribute to the EU forest increment: over the 10-year period of 2007-2017 the forest area established with CAP support is equivalent to about a third of the EU forest increment over the same period (Alliance Environnement, 2017).

Support for the establishment of agroforestry systems (M8.2) has concerned a total of 1 224 ha since 2014, equivalent to 0.01% of the total area in agroforestry at EU level. This measure, which involves very significant changes in farming systems and targets only the establishment of agroforestry areas(maintenance of former/traditional agroforestry systems is not within the scope of the measure), was implemented in 22 out of 110 RDPs and had a limited effect at EU level.

Areas afforested or established under agroforestry systems with the support of RDPs were eligible as EFAs in 10 and 2 Member States respectively in 2018. However, they represented less than 1% of the declared EFAs in all Member States concerned, with the exception of Luxembourg (1.9%). Analysis carried out as part of the evaluation study of the forestry measures under rural development found that it was not a driver towards afforestation or the establishment of agroforestry systems (Alliance Environnement, 2017). The very limited area under EFAs of this type designated in 2018 and the information collected in the case studies corroborate this result.

5.2.3. Contribution of the CAP to the creation and maintenance of grassland[52]

The creation and maintenance of grassland were fostered by the greening measures (maintenance of the PG ratio), and AECM (M10.1).

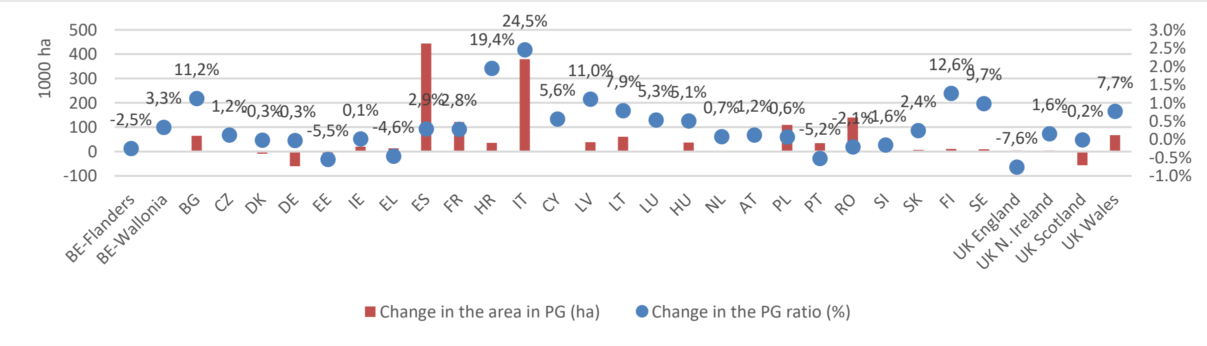
The requirement under greening to maintain the PG ratio is a key instrument to limit conversion of grassland into arable land. From 2015 to 2018, the limit of 5% was surpassed only

[51] This includes areas afforested since 2014 but also areas afforested in the previous programming period, for which a compensation of the loss of income was provided to holders between 2014 and 2018. The compensation of the income foregone may last up to five years after afforestation.

[52] The impact of the CAP on the management of grasslands (ploughing etc.) is analysed in EQ 4. This part focuses only on the potential conversion of grassland into arable land, and vice-versa.

eight times in five Member States or regions (Estonia, Greece, Cyprus, Romania, United Kingdom-England). On areas counting in the permanent grassing ratio[53], a total of +1.46 million hectares were declared as permanent grassland, compared to the reference year. In 14 out of 28 Member States, the share of UAA on permanent grassland increased from 2015 to 2018, though significant variations exist due to changes in the definition of grassland (e.g. +19.4% in Hungary and +24.5% in Italy).

Figure 11: Changes in the area in permanent grassland, by MS, from 2014 to 2018



Source: Greening statistics, 2018

However, limits to the protection of grassland through the permanent grassland ratio were highlighted in the case studies and in previous evaluation studies of the CAP. For instance, in Belgium-Wallonia, opinions diverge regarding the capacity of the instrument to ensure the maintenance of grassland: according to some stakeholders, the tolerance of 5% allows a significant variation. The calculation carried out on a regional scale would also mask a significant decline in grassland in intermediate areas (where the risk of erosion by water is very high) in recent years.

AECM (M10.1) supported both the maintenance and creation of grassland. No precise monitoring data of the area under contract for the creation or maintenance of grassland are available at EU level[54], but monitoring data collected in the case-study areas show significant commitment for the conversion of arable land into grassland or maintenance of grassland in areas where their conversion is not banned (see Table 8).

The case studies also highlighted some limits of the AECM (M10.1) supporting temporary grasslands, e.g.:

- in Sweden, the commitments led to an extension of the period with temporary grassland (three seasons compared to two), rather than their area;
- Czech farmers pointed out that the AECM was mostly implemented on unprofitable land plots such as steep slopes plots (>12°) or plots with natural or physical constraints. Thus, in the absence of the measure, a significant share of these plots would either be left fallow, grassed or abandoned. Moreover, after the five-year commitment, farmers sometimes plough the grassland to prevent its shift into 'permanent grassland' and its resulting decrease of market value[55].

[53] Areas under organic farming are excluded.

[54] The areas under contract in the category "maintenance of HNV arable and grassland systems, introduction of extensive grazing practices and conversion of arable land to grassland" was 10.6 million ha in 2018 (= 35.8% of the total EU surface covered by an AECM). It represented the largest type of AECM support, especially in Denmark (100%), Czechia (95.1%), Hungary (92.4%) and Bulgaria (91.8%).

[55] This observation was also made in Wallonia and France. This is despite the rule that land brought under grassland through AECM is not classify as permanent grassland automatically after the AECM commitments end.

Table 8: Examples of AECM promoting the creation and maintenance of grassland implemented in the RDPs of the case-study areas

RDP	AECM title	Area under contract in 2019 (ha)
BE - Wallonia	Natural grasslands	13 000
	Grasslands with high biological value	13 200
	Fodder autonomy (indirect effect on the maintenance of grassland)	74 000
BG	Conversion of arable land into permanent grassland	11 381
CZ	Management of grasslands	911 731
	Grassing of arable land	13 000
	Grassing of areas of concentrated runoffs	50
DK	Tending of pasture and nature areas	n.a.
DE - Bavaria	Conversion of arable land into grassland along watercourses and other sensitive areas	16 595
	Conservation and improvement of habitats of nature conservation value through extensive grazing	23 808
SE	Maintenance of semi-natural grazing lands and mown meadows	406 000
	Restoration of grazing lands and meadows	6 300
	Extensive ley management (temporary grassland)	220 000

Source: Alliance Environnement, based on data gathered from the managing authorities of the RDPs

Opinions collected in the case studies (e.g. in Belgium-Wallonia, Bulgaria and Sweden), and previous evaluation studies of the CAP (e.g. Alliance Environnement, 2019) showed that support for organic farming (M11) played a key role in the maintenance of grassland, enabling the maintenance of extensive farming systems. However, in of Belgium-Wallonia, several stakeholders also mentioned a negative side effect of M11: the high level of payments for conversion to organic farming, together with the higher added value of organic products, fostered conversion of low-productive plots, previously used as temporary grassland, into arable land.

Other CAP instruments and measures may have an indirect effect on the maintenance of grassland (e.g. voluntary coupled support for livestock and M13) (see EQ13).

5.2.4. Contribution of the CAP to the establishment and maintenance of landscape elements[56] relevant for sustainable soil management

The CAP fostered the creation or maintenance of landscape features and grass strips through cross-compliance (GAEC 1, 4, 5 and 7), the requirement under greening to designate EFAs, AECMs and the environmental actions under the fruit and vegetable operational programmes.

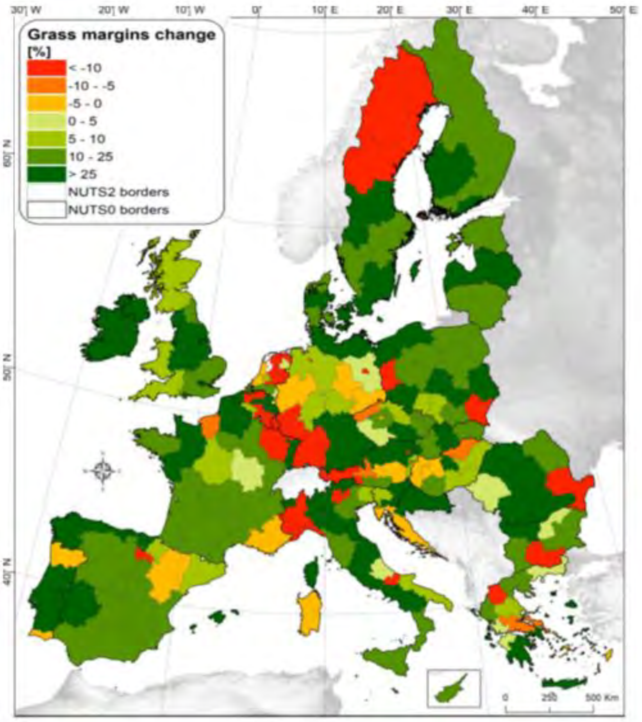
[56] Terraces and stone walls are considered in the following paragraph.

Effects of cross-compliance

Recent work of the JRC showed significant changes in the number of grass margins between 2012 and 2015, in relation to the implementation of GAEC 1 requiring the establishment of buffer strips along all waterways ((Borrelli and Panagos, 2020), based on LUCAS survey, see Map 10).

The establishment of grassed and buffer strips was found to be a common requirement for or alternative to comply with the obligation of preventing erosion (GAEC 5) (e.g. in Belgium-Wallonia, Bulgaria, Czechia, Greece, Italy-Tuscany), and to a lesser extent with the obligation of minimum soil cover (GAEC 4) e.g. in Belgium-Wallonia, and in Spain-Aragon for permanent crops. However, the contribution of GAEC 4 and 5 to the maintenance or establishment of landscape elements could not be quantified within the framework of the study[57].

Map 10: Regional changes (NUTS2) in grass margins between 2012 and 2015



Source: Borelli et al., 2020. (based on LUCAS Survey)

According to all stakeholders in Belgium-Wallonia, Germany-Bavaria, Ireland, Spain-Aragon and Sweden, cross-compliance did not have a significant effect on the introduction of landscape features. In Denmark researchers explained that, while changes in landscape elements were observed, they were not related to the CAP. Nevertheless, in Bulgaria, Czechia, Greece and Italy-Tuscany the establishment of buffer strips has been noted as a possible result of GAEC 4 and 5 by a majority of stakeholders.

Effects of requirement under greening to designate EFAs

The requirement under greening to designate EFAs was found to have very little impact on the establishment and maintenance of landscape features. Landscapes features and buffer strips could be designated in EFAs in most Member States (see details in EQ 2, Chapter 4.2), but represented 1.7% (167 536 ha) and 1.3% (131 562 ha) respectively of the designated EFAs in 2018 at EU level. Notable exceptions are Ireland and the United Kingdom, where landscape features accounted for 83.4% and 13.5% respectively (mostly hedges or trees in line). The opinions collected in the case studies show that the requirement to designate EFA s did not impact farmers' decision to maintain or establish buffer strips and landscape features. When necessary to reach the requirement of 5% of the UAA designated as EFAs, farmers preferred to establish other types of eligible cover, e.g. catch crops or N-fixing crops, whose management is perceived as less constraining (e.g. Belgium-Wallonia, Czechia, Germany-Bavaria and Greece).

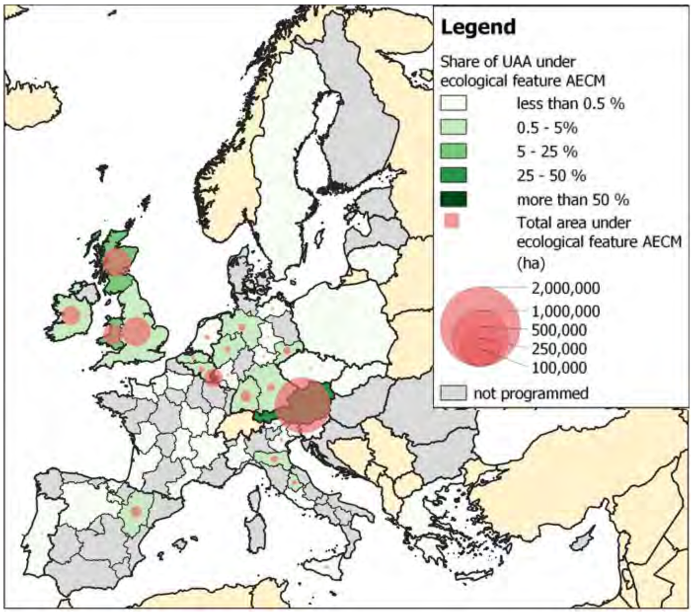
[57] For example, in Belgium-Wallonia, the obligation to establish a grassed strip concerns plots identified as R10 plots (slope>10%) and with root crops, i.e. annually about 10% of total arable land. However, the corresponding area in grassed strips was not found. In Greece, the same obligation applies to all plots in R10, but here as well no estimation of the corresponding area in grassed strips was found.

Effect of AECMs

Various AECMs supported the creation and/or upkeep of landscape elements (e.g. field margins, buffer areas, flower strips, hedgerows, trees). At EU level, a total of 2.2 million ha was under contract in 2018, of which 1.1 million in Austria (42% of the total UAA), 0.6 million in the United Kingdom (3.5% of the total UAA), 120 286 ha in Ireland (2.6%), and 118 435 ha in Luxembourg (89%).

The information collected in the case studies and in previous studies of the CAP highlighted that AECMs supporting for the creation or upkeep of landscape elements are overwhelmingly targeted at providing habitats for biodiversity. Nevertheless, some AECMs with a clear objective to limit erosion by wind and/or water were found in the case studies (see Table 9).

Map 11: Area under AECM contract for the creation or upkeep of ecological features (2018)



Source: Alliance Environnement, based on data from AIRs 2018

Table 9: Examples of AECM promoting the creation and maintenance of landscape features implemented in the RDPs of the case-study areas

RDP	AECM title	Area under contract in 2019
BE-Wallonia	MB1.a Hedgerows and aligned trees	6 750 ha
	MB1.b Isolated trees, shrubs and groves	1 550 ha
	MC7 Grassed plots (choice of location, composition of cover and management method established with a technical advisor to ensure the relevance to the environmental issues)	1 000 ha
	MC8 Grassed strips (idem)	3 250 ha
	of which MC8.b Grassed strips preventing erosive water runoff	n.a.
BG	Soil erosion control	28 000 ha
	Creating and maintaining buffer strips	*29 ha*
	Grassing of vine rows and perennials	*9 890 ha*
CZ	Biocorridors	2 834 ha
DE-Bavaria	Water and erosion protection promoting management schemes on arable land and grassland	50 546 ha
	Allocation of land for the permanent creation of structural and landscape elements	22 212 ha
EL	Reduction of water pollution from agricultural activity	n.a.
ES-Aragon	Conservation agriculture in vineyards of arid areas and steep slopes	1 376 ha
	Creation of biocorridors in Natura 2000 networks	38 358 ha
IE	Laying Hedgerows	350 ha
	Riparian Margins	4 650 ha
	Planting New Hedgerows	6 500 ha
	Arable Grass Margins	2 400 ha
	Coppicing Hedgerows	6 975 ha
SE	Buffer zones along water courses or in the fields to reduce erosion	11 500 ha

In bold-italic: AECMs directly addressing soil erosion; Source: Alliance Environnement data gathered from the managing authorities of the RDPs

To a lesser extent, RD support for investment may have contributed to the establishment of landscape features.

- Regarding support for non-productive investments (M4.4): this measure targeted a very broad range of operations, and the monitoring of the types of operation supported does not provide enough details to quantify the contribution of the measure to the establishment of landscape features. On the previous CAP programming period, an ECA audit on support for non-productive investments found that 71 % of the visited projects contributed to the achievement of agri-environment objectives such as landscape and biodiversity protection. Examples of such projects were looked for in the case-study areas: an interesting example was found in Bavaria where M4.4 supported the 'Renewal of hedges and fields on agricultural land' (44 ha covered in 2018)[58].
- Regarding support for investments in infrastructures (M4.3) : in Czechia, support the land consolidation (M4.3.1) have supported a significant number of landscape features, buffers and field roads with positive impact on erosion and catchment of water in the area (preventing rapid water runoff).

Effects of the fruit and vegetable operational programmes

The establishment of hedges is supported in Spain-Aragon. The uptake of this operation has been very limited: interviews with farmers representatives revealed that this low uptake may be due to the list of eligible species, which is considered as not well-targeted to the local context.

5.2.5. Contribution of the CAP to other land use and land-use change with an impact on soil quality

5.2.5.1. Maintenance of peatlands and wetlands

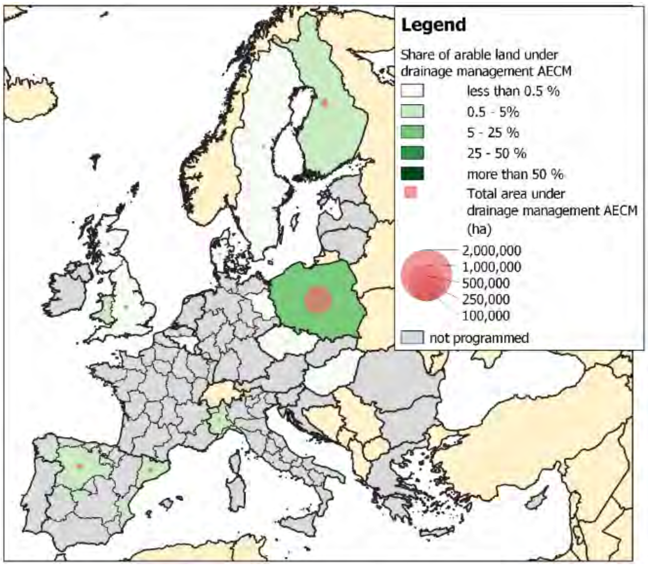
The CAP contribution to the protection of peatlands and wetlands was analysed in the evaluation study of the contribution of the CAP to biodiversity (Alliance Environnement, 2019a). Out of 10 areas investigated in the study, only two (Germany-Baden-Württemberg and the Netherlands) were using CAP instruments (i.e. Support for non-productive investments (M4.4) and AECMs) to implement their strategy of restoration and maintenance of peatlands and wetlands. In four areas (Ireland, Latvia, Portugal, Romania) restoration and maintenance of peatlands and wetlands was a local priority, but the CAP was not used to address this priority.

While GAEC 7, declaration of EFAs and designation of ESPGs were identified (see EQ 2) as potentially contributing to the protection of peatlands and wetlands, their effects were not identified in the above-mentioned evaluation study.

[58] The uptake of the measure was limited, due to complex application procedures, potentially low awareness of the measure, or the fact that the 2007–2013 measure in which former commitments expired by 2017 already covered the eligible structures. Bavarian advisors and technical staff also pointed to the high opportunity costs associated with setting up landscape features as well as the high share of leased land as barriers (Annual Implementation Report 2018 of the RDP of Germany-Bavaria).

Concerning AECMs, a total of 731 504 ha were under contract for the reduction of drainage and/or management of wetlands in 2018 (see Map 12). Information collected in the case studies brings some insight on the effect of AECM support for the maintenance of wetlands: in Denmark, wetlands were supported through an AECM (M10.1.1: maintaining wetlands, natural water level conditions, low-lying soil projects and changed drainage conditions). It was applied on 7 394 ha and only indirectly contributed to the increase of soil-protecting practices, according to the Danish Agricultural agency.

Map 12: Area under AECM contracts for the reduction of drainage and/or management of wetlands



Source: Alliance Environnement, based on data from AIRs 2018 and Eurostat

In Sweden, the maintenance of wetlands and ponds AECM could be considered as effective, as it applied to 10 200 ha, almost reaching the implementation target of 10 900 ha. However, the Swedish 'Forest's environmental values' measure (M8.5) supporting the creation of wetlands among other things had an insignificant effect overall.

Regarding support for non-productive investments (M4.4), Denmark supported 863 operations in 2018 in relation to the establishment of wetlands and water protection. Sweden also had a non-productive investments sub-measure focusing on wetlands, but the details are not available (204 operations in 2018 related to fencing against predators, one-time clearing of pastures, construction and restoration of wetlands and ponds, construction of two-stage ditches, and restoration of cultural environments).

5.2.5.2. Maintenance of stone walls and terraces

In 2012, the stone walls density (number of stone walls divided by total number of observations according to the LUCAS survey) averaged 4.9% in the EU. The density is higher in Mediterranean countries (e.g. 22.6% in Portugal, 13.8% in Spain, 8.1% in Italy, 8.9% in Greece). According to JRC, no significant changes occurred between 2012 and 2015, with the exception of a stone walls increase in Sweden, indicates a steady upkeep of stone walls (Panagos *et al.*, 2015a).

The observed maintenance of stone walls in Spain and Italy can be considered as a result of the implementation of the GAECs: the maintenance of terraces is a requirement of GAEC 5 in Spain and Italy. It is also required in GAEC 7 in Bulgaria, Germany-Bavaria, Greece and Italy-Tuscany. The local authorities in Spain-Aragon and Italy-Tuscany confirmed the requirements under the GAECs had a significant effect on the maintenance of terraces. However, the increase in the occurrence of stone walls observed in Sweden could not be correlated with the implementation of the CAP, on the basis of the information collected in the case study of Sweden.

Although not mentioned in the case-study areas, RD measures (e.g. support for non-productive investments – M4.4) can also have supported the restoration of stone walls and terraces. .

5.2.5.3. Drainage

Examples of support for drainage were found in Sweden (in M4.1 and M4.4) and Czechia. In Sweden very few operations were supported. Representatives of farmers explained that one-third of Swedish farmers are already equipped with a drainage system, one-third should be equipped but are not yet, and that one-third do not need a drainage system. However, this measure was efficient in Czechia.

5.2.5.4. Limitation of the size of plots

Examples of operations supported by the CAP in relation to the limitation of the size of plots were found in Bulgaria (GAEC 5) and Czechia (GAEC 7). In Czechia, the provisions have been implemented since January 2020 only, so no effect can be analysed at this stage (see expected effect in Box 7).

Box 7: Intended effect of GAEC 7 on plot size in Czechia

A significant potential to induce some changes in land use is related to the new GAEC 7d that should be extended to all arable land in January 2021. This new regulation sets a maximum area of one crop to 30 hectares (according to the requirements that were planned to be set at the time the case study of Czechia was managed). There are more than 18 000 plots of land above 30 ha in Czechia, on nearly 3 000 farms. Such a measure is expected to result in the fragmentation of land plots into smaller ones by the means of landscape features and strips.

However, this measure is, so far, perceived rather negatively by the farmers and their associations, and some independent experts, although generally supportive, see their effect as questionable: it may in particular lead to negative trends in soil compaction as machinery will have to turn around more frequently. Also, this measure could further limit the effectiveness of other measures favourable to soil quality, e.g. contour farming combined with striped cultivation.

Source: Alliance Environnement

5.2.6. Answer to evaluation question 5

Even if data are lacking to precisely quantify the effects of GAECs on land use and land-use change with an impact on soil quality, the information collected from the literature and in the case studies confirmed that the GAECs have been key instruments to ensure the maintenance of landscape elements (in particular buffer strips, grassed strips and terraces). However, the analysis could not assess on the extent to which those landscape elements are appropriately located to contribute to limiting erosion (see EQ12 in Chapter 7.1.3). Regarding the standard set by Member States to prevent soil erosion (GAEC 5), the affected areas could not be quantified, but the interviews in the case-study area revealed its limited effect on land use, even though positive effects were reported locally. AECMs supported the creation and/or upkeep of landscape elements on a total of 2.2 million ha, aiming in priority to provide habitats for biodiversity. Still, some AECMs found in the case-study areas had a clear objective to limit erosion by wind and/or water, and thus supported the establishment of landscape feature appropriately located to contribute to limiting erosion.

Afforestation and the establishment of agroforestry systems were fostered by voluntary measures only and implemented to a limited extent, in coherence with the change they involve in land use. However, it is important to consider changes in forests over longer periods than when considering agriculture. Consequently, it can be noted that the total area afforested with the support of the CAP over the 10-year period 2007-2017 corresponded to a significant share (about one-third) of the forest area increment in the EU over the same period (Alliance Environnement, 2017). Regarding agroforestry, the area established in agroforestry with M8.2 support is equivalent to 0.01% of the total area in agroforestry at EU level. The CAP contribution to this land-use change is thus very limited.

Regarding the maintenance of grassland, the support for organic farming (M11) had a key role in addition to the PG ratio requirement. To a lesser extent, some AECMs found in the case-study areas brought an interesting contribution to the maintenance of grassland.

Interesting examples of local design of the instruments and measures fostering land-use change with an impact on soil quality were found in the case studies. For instance, specific AECMs regarding erosion were implemented in Belgium-Wallonia, Bulgaria and Germany-Bavaria. Czechia also recently implemented new requirements for GAEC 7 aiming at limiting the size of plots, which is a key issue at stake for soil erosion. Though implemented on a small scale, those examples show the potential of the CAP to contribute to land-use change of specific interest for sustainable soil management.

5.3. EQ 6: To what extent have the individual relevant CAP instruments and measures contributed to improve or deteriorate soil quality and related productivity?

5.3.1. Understanding of the evaluation question

This EQ aims to assess the effects of the changes in management practices and land use induced by CAP instruments and measures, on soil-quality components and soil productivity[59]. It focuses on direct effects of the CAP, and thus on instruments and measures in Category 1 and 2 (see Table 2).

It is important to keep in mind that soil productivity can be impacted by soil quality improvement/degradation affecting soil fertility, but also by management practices that reduce/increase annual yields. For instance, reduced tillage or no-tillage may have positive impacts on soil compaction and biodiversity; however, it may also reduce productivity, especially in the first years of implementation.

The analysis considers the following judgement criteria:

- Soil-related practices enforced, fostered or supported by CAP instruments have (or not) contributed to changes in soil-quality components. The analysis reviews the contribution of the CAP to the implementation of activities positive[60] on soil-quality components, building on the findings from EQ 1, EQ 4 and EQ 5. It is complemented by the opinions of key stakeholders collected in case studies, as well as by estimates found in key literature.
- CAP instruments and measures have (or not) contributed to changes in soil productivity. The potential change in soil productivity resulting from the implementation of the CAP is assessed by crossing the CAP contribution to management practices related to soil quality (based on the findings of EQ 4 and 5) with the expected impact of the CAP-fostered management practices on soil productivity, on the short and on the long term (based on the findings of EQ 1). It is also complemented by the opinions of case-study stakeholders and literature.

5.3.2. Soil-related practices enforced, fostered or supported by CAP instruments have (or not) contributed to changes in soil-quality components

5.3.2.1. The CAP instruments and measures have (or not) contributed to changes in soil erosion

The main CAP instruments which contributed to implementation of activities that reduce soil erosion are 1) the GAEC 1 requirement to maintain landscape features; 2) the EFAs, among which 53% were cover crops in 2018[61]; and 3) the AECM (M10.1) supporting the maintenance of landscape elements (e.g. in Belgium-Wallonia, the implementation of grassed headlands and buffer strips; in Bulgaria, creating and maintaining buffer strips) and soil cover (e.g. in Bulgaria, grassing of vine rows; in Ireland, cultivation of catch crops; in Spain-Aragon, support for longer soil cover). Regarding the AECMs, the case studies revealed that most were not specifically designed to tackle erosion, but that they had this indirect effect by supporting types of operations leading to soil permanent cover (e.g. in Belgium-Wallonia, the implementation of grassed headlands and buffer strips; in Bulgaria, conversion of arable land into

[59] This EQ does not take into account possible interactions between CAP measures, which have been assessed in EQ 7. The impact of environmental external factors on the effectiveness of CAP instruments and measures has been analysed in EQ 8.

[60] The negative effects are linked to the indirect effect of the CAP instruments and measures and were investigated in EQ 13.

[61] ISAMM_Greenings data.

grassland, grassing of vine rows, creating and maintaining buffer strips; in Ireland, appropriate grazing management, cultivation of catch crops; in Spain-Aragon, support for longer coverage on fields).

Minimal soil cover maintenance (GAEC 4), minimum land management reflecting site-specific conditions to limit soil loss (GAEC 5), SMR1, the maintenance of permanent grassland, EFA, investments measures (M4) and support for organic farming (M11) also contributed, to a lesser extent, to the implementation of practices and land use sustainable for soil erosion (see Table 10). The limited effects of GAEC 4 and 5, which focused on the objective of tackling erosion, suggest stronger provisions should be taken under those instruments (see also EQ 12).

Table 10: Contribution of the CAP instruments and measures to activities reducing soil erosion

		GAEC 1	GAEC 4	GAEC 5	SMR 1	EFAs	PG	M10.1	M11	M4	M8
Key activities related to soil erosion	Afforestation, establishment of agroforestry systems										+
	Maintenance of landscape elements	++	+	+		+		++		+	
	Arable to grasslands						+	+	+		
	Reduced tillage and no-tillage	+	+	+	+		+	+		+	
	Cover crops, winter crops		+	+	+	++		++	+		
Instruments' expected effects on soil erosion		++	+	+	+	++	+	++	+	+	+

Source: Alliance Environnement

++ Positive effects were highlighted at EU level

+ Some positive effects were highlighted in specific areas

Given the complexity of quantifying the effects, the CAP instrument implementation could not be linked to the soil loss rates in the case-study areas. JRC studies found that the GAECs contributed to reducing soil losses on European arable lands by 20% in the past decade (Panagos *et al.*, 2016), but little progress on the 2010-2016 period (-0.4% in all lands and -0.8% in arable land), in particular in the most erosive areas, suggesting that efforts to reduce soil erosion need to be strengthened and that a stronger set of soil-conservation practices is needed to reduce erosion in hotspots (Panagos *et al.*, 2020). This finding is confirmed by the finding of this evaluation study, which showed that the definition of vulnerable areas is key for setting requirements to protect soil, and in particular concerning erosion (see EQ 2) and that tiered approaches are a key way to increase the relevance and effectiveness of the CAP instruments and measures (see EQ 12).

Regarding the greening payments, modelling based on the CAPRI model[62] found that the implementation of the greening payment could not be expected to have significant result on soil erosion: it should result in a minor increase of +0.56% (+0.03 t/ha/year) of soil erosion per hectare in the EU-28, as the result of an increase in the area of uncovered fallow land (this side effect was also highlighted in the case studies of Spain-Aragon and Bulgaria). The model also confirms the positive effect of greening provisions on the maintenance of grassland measure (-0.4%) and the absence of effects of the crop diversification measure on erosion (Gocht A., 2017).

According to the synthesis of the evaluation components of the enhanced AIRs 2019, over the period 2014-2018, the AECM (M10.1) reduced the average soil loss by 4.7 t/ha/yr in Czechia. The managing authorities of Italy-Marche and Italy-Lazio reported a significant reduction of soil erosion on the area that benefited from specific RD support on the 2014-2018 period (by 20.46 t/ha/yr and 1.12 t/ha/yr respectively) (European Evaluation Helpdesk, 2019). In Spain-La Rioja, the AIR mentioned a reduction of almost 30% concerning soil erosion when M8.1 was implemented. This confirms the capacity of RD measures to contribute to tackling erosion. However, results from EQ 4 and 5 also point out key limits

[62] Common Agricultural Policy Regionalised Impact Modelling System. See also: https://www.capri-model.org/.

to the effects of RD measures on soil erosion: the small coverage, the low level of targeting areas with higher erosion risks and sometimes the limited relevance of the prevention of soil erosion (Cyprus, United Kingdom-Northern Ireland and United Kingdom-England).

5.3.2.2. The CAP instruments and measures have (or not) contributed to the changes in soil organic matter content

The main CAP instruments which contributed to the implementation of activities limiting the loss of soil organic matter are the requirements to declare EFAs (of which 53% were cover crops and 25% were nitrogen-fixing crops in 2018), AECMs supporting soil cover (see 5.3.2.1) as well as the support for organic farming (M11) (incentive to apply organic amendments). GAECs 4 and 6, SMR1, crop diversification and operational programmes specific to the fruits and vegetables sector also contributed, to a lesser extent, to the implementation of practices and land use sustainable for soil organic matter (see Table 11).

It can be noted that the GAEC requirements on the maintenance of soil organic matter level through appropriate practices (GAEC 6) do not stand out as contributing to limit the loss of organic matter: the low relevance of the implementation choices set at national level partly explains this result (see also EQ 12).

Table 11: Contribution of the CAP instruments and measures to activities that limit the loss of soil organic matter

		GAEC 4	GAEC 6	SMR 1	F&V	CD	EFAs	PG	M10.1	M11
Key activities related to soil organic matter	Arable > grassland								○	
	Maintenance of grassland							●	○	○
	Reduced tillage and no-tillage		○					○	○	
	Cover crop	○		○			●	●	●	○
	Maintenance/incorporation of crop residues		○		○				○	
	Organic amendments (compost, manure)		○		○				○	●
	Cultivation of nitrogen-fixing crops			○	○	○	●	○	○	
Instruments' effects on soil organic matter		○	○	○	○	○	●	●	●	●

Source: Alliance Environnement

● Positive effects were highlighted at EU level

○ Some positive effects were highlighted in specific areas

The JRC recently established that the soil organic carbon changes cannot be identified within the timeline of policy actions, in particular in the 7-year cycle of the CAP (Panagos *et al.*, 2020). Hence, the link between the implementation of the CAP over the 2014-2020 period and SOM results cannot be established, and the following data should be taken cautiously.

In the case-study areas, AECM M10.1 is the first measure mentioned by a majority of stakeholders as having positive effects in SOM (Bulgaria, Czechia, Germany-Bavaria, Spain-Aragon, Italy-Tuscany, Sweden). For instance, in Czechia, some AECMs foster the production of biomass on soils, thus adding organic matter to soil. In Italy-Tuscany, the case study concluded that the AECM targeting conservation agriculture have been the most effective measure to tackle the loss of SOM, although it hitherto has affected an extremely small share of UAAs (3%). In Spain-Aragon, support to conservation agriculture (M10.1.f) is expected to increases SOC in the upper layer. Support to maintaining soil cover (M10.1.a) may also increase SOC in soils.

According to the synthesis of the evaluation components of the enhanced AIRs 2019, only in a few cases were achievements expressed in terms of an increase in SOM (European Evaluation Helpdesk, 2019). For instance, in 2018, it is estimated that 15 394.73 tonnes of CO_2/year in supported agricultural land were maintained in Spain-La Rioja , idem 134 700 tonnes in Finland-Mainland and idem 68 415 tonnes in Italy-Emilia Romagna (European Evaluation Helpdesk, 2019). Austria reported that the humus contents were kept stable at a favourable level with medians of 2.75% to 3.0%, and in two out of three regions a slight increase of 0.1% of humus content was achieved on supported farms. Support for organic farming was identified as strongly contributing to carbon conservation and sequestration in some EU Member States and regions (e.g. Belgium-Wallonia, Germany-Brandenburg, Estonia, Spain-Castilla la Mancha). For instance, in Italy-Liguria, it was reported that organic farming contributed to an increase in the amount of organic matter by 0.651 t/ha/yr. Support for afforestation (M8.1) is mentioned as having significantly contributed to carbon conservation and sequestration in Czechia, Spain-Andalucía and Slovakia.

The Project MO.NA.CO led in Italy demonstrates the high level of effectiveness of GAEC Standard 4.1, 'Protection of permanent pastureland', in maintaining soil organic carbon content. Moreover, the two main productive EFAs – catch crops and nitrogen-fixing crops – can contribute to improving soil by increasing the levels of soil organic carbon on arable land (ECA, 2017).

The impact of management practices to increase SOC may take longer than 10 years before showing significant changes (Panagos *et al.*, 2020). This highlight that the implementation of relevant practices over the long term should be ensured in order to secure the effect of the CAP instruments or measures like AECMs and support for organic farming on SOM.

5.3.2.3. The CAP instruments and measures have (or not) contributed to the changes in soil biodiversity

The positive effects of the CAP in relation to the protection of soil biodiversity mostly result from specific AECMs promoting reduced tillage (see EQ4) and the creation and maintenance of grassland (see EQ 5), as well as from the support for organic farming measures regulating application of PPPs and promoting compost application. Regarding GAECs 4 and 6, crop diversification, operational programmes specific to the fruits and vegetables sector, the maintenance of permanent grassland and investment measures, these measures and instruments have low impact on the implementation of practices and land use sustainable for soil biodiversity (see Table 12). EFAs of catch crops and nitrogen-fixing crops were found to offer no significant biodiversity benefits (ECA, 2017).

Table 12: Contribution of the CAP instruments and measures to activities contributing to the protection of soil biodiversity

		GAEC 4	GAEC 6	SMR 1	CD	F&V	EFAs	PG	M4	M8	M10.1	M11
Key activities related to soil biodiversity	Afforestation, establishment of agroforestry systems									Specific areas		
	Arable to grasslands							Specific areas			Specific areas	Specific areas
	Reduced tillage and no tillage		Specific areas					Specific areas			Specific areas	
	Compost application		Specific areas			Specific areas					Specific areas	EU level
	Land lying fallow				Specific areas		Specific areas				Specific areas	
	Control of PPP application			EU level			EU level				Specific areas	EU level
Instruments' effects on soil biodiversity		Specific areas	Specific areas	EU level	Specific areas	Specific areas	EU level	Specific areas	Specific areas	Specific areas	EU level	EU level

Source: Alliance Environnement

EU level: Positive effects were highlighted at EU level   Specific areas: Some positive effects were highlighted in specific areas

The result of the CAP implementation on soil biodiversity is not monitored and cannot be established.. The recent evaluation study on the impact of the CAP on biodiversity (Alliance Environnement, 2019a) does not refer to effect on soil biodiversity. However, we should recall that most EU countries have soils facing high levels of risk to soil biodiversity (Orgiazzi *et al.*, 2016).

5.3.2.4. The CAP instruments and measures have (or not) contributed to the changes in soil compaction

The key activities impacting soil compaction are controlled traffic, afforestation and the maintenance of grassland. Reduced tillage and no-tillage are controversial with regard to their impacts on compaction, while subsoiling is a way to decrease compaction.

Table 13: Contribution of the CAP instruments and measures to soil compaction

		GAEC 1	GAEC 4	GAEC 5	SMR 1	PG	CD	F&V	EFA	M4	M8	M10.1	M11
Key activities related to soil compaction	Controlled traffic												
	Afforestation, establishment of agroforestry systems												
	Arable to grasslands												
	Reduced tillage and no-tillage												
	Cultivation of nitrogen-fixing crop												
Instruments' effects on soil compaction													

Source: Alliance Environnement

Positive effects were highlighted at EU level

Some positive effects were highlighted in specific areas

The impact of these measures remains very limited, while soil compaction is a major threat for soil in the EU; mainly in Northern Europe. Indeed, an estimated 32-36% of European subsoils have high or very high susceptibility to compaction (Jones *et al.*, 2012b). However, further research is needed to estimate the soil compaction in EU.. Indeed, an estimated 32-36% of European subsoils have high or very high susceptibility to compaction (Jones *et al.*, 2012b).

5.3.2.5. The CAP instruments and measures have (or not) contributed to the changes in soil pollution

The CAP instruments and measures which contributed to the implementation of activities limiting soil pollution are the provisions regarding EFAs and support for organic farming, which limited the use of PPPs and herbicides. Operational programmes specific to the fruits and vegetables sector and investment measures also contributed to a lesser extent (see Table 14).

Table 14: Contribution of the CAP instruments and measures to soil pollution

		SMR 10	EFAs	F&V	M4	M10.1	M11
Key activities related to soil pollution	Control of PPP application						
Instruments' effects on soil pollution							

Source: Alliance Environnement

Positive effects were highlighted at EU level

Some positive effects were highlighted in specific areas

Several managing authorities reported that RDPs allow significant support for improving the management and reducing the use of pesticides and fertilisers in agriculture. For example, France-Aquitaine assessed that RDPs decreased the use of inputs (93%) and reduced the nitrogen fluxes released to the environment (70%) (European Evaluation Helpdesk, 2019). In Belgium, it has been found that AECMs (M10.1) mainly act in favour of the reduction of the use of fertilisers (WWF Belgique, 2019). Likewise, the Investments measure (M4) also plays a key role (even not directly related to soil) by reducing the loss of input in the environment (WWF Belgique, 2019).

5.3.2.6. The CAP instruments and measures have (or not) contributed to the changes in soil nutrient balance

Similarly to soil pollution, the key CAP instruments impacting soil nutrient balance are SMR1, EFAs and support for Organic Farming requirements to control mineral fertilisers' application, the GAEC 1 requirement to maintain landscape features and AECMs supporting the maintenance of landscape elements. To a lesser extent, GAECs 4, 5 and 6, crop diversification, operational programmes specific to the fruits and vegetables sector and investment measures also contributed to the implementation of practices and land use sustainable for soil (see Table 15).

Table 15: Contribution of the CAP instruments and measures to soil nutrient balance

		GAEC 1	GAEC 4	GAEC 5	GAEC 6	SMR 1	CD	F&V	EFAs	M4	M10.1	M11
Key activities related to soil nutrient balance	Catch crops					■			■		□	
	Cultivation of nitrogen-fixing crops					□	□	□	■		□	
	Control of mineral fertiliser application					■			□		□	□
	Organic amendments application (compost, manure)				□						□	■
	Maintenance and creation of landscape elements	■	□	□					□	□	■	
Instruments' effects on soil nutrient balance		■	□	□	□	■	□	□	■	□	■	■

Source: Alliance Environnement

■ Positive effects were highlighted at EU level □ Some positive effects were highlighted in specific areas

Soil nitrogen (N), phosphorus (P) and potassium (K) were assessed for the first time in the 2009 LUCAS survey. A second assessment was performed in the LUCAS 2015 survey and changes are under evaluation by JRC. Thus, changes in soil nutrient balance and the effect of the CAP implementation cannot be directly established. However, the gross balance between nitrogen added to and removed from agricultural land in the EU has not improved since 2010 (while it had decreased between 2003 and 2015, meaning a reduction of the potential nitrogen surplus) (EEA, 2018). In croplands, no decrease of phosphorus in LUCAS points was assessed between 2009 and 2015 (Fernandez Ugalde *et al.*, 2020). This suggest that, in spite of the fact that the multiple CAP instruments and measures foster the reduction of the use of PPPs and fertilisers (see Chapter 4.2.2 and Chapter 5.1.2), the recent implementation of the CAP did not succeed in providing an additional contribution to the effect of previous policies for the reduction of the use of fertilisers.

According to the CAPRI simulation model, the greening measures do not have a noticeable impact on nutrient balances (Gocht A., 2017). In Germany-Baden-Wurttemberg, catch crops contributed to the decrease of nutrient leaching through three RD measures on 9.4% of the arable land (European Commission, 2019).

5.3.2.7. The CAP instruments and measures have (or not) contributed to the changes in soil salinisation

Soil salinisation significantly occurs in only two case-study areas: Spain-Aragon and Greece. In Spain-Aragon, some potential positive effects of the CAP measures on soil salinisation were highlighted:

- M4.3 (modernisation of irrigation systems) makes it possible to save water and to limit the phenomenon of salinisation by 'washing' the salt, so its effect is particularly positive in areas with salinisation risks. Nevertheless, the programme of modernisation dates back to the 2000s.

- 10.1.g favours rice cultivation in some saline-prone fields that could not support other agricultural production, but it does not solve salinisation issues.

In Greece, where salinisation is also a soil issue, no CAP instruments and measures contributed to control soil salinity.

Although soil salinisation is often concentrated in specific areas, it is expected that the issue is becoming increasingly common. Indeed, salinisation of agricultural soils can be created or aggravated by improper management but also by variations in rainfall and temperature patterns due to climate change (EIP-AGRI Focus Group, 2020).

5.3.3. CAP instruments and measures have (or not) contributed to the changes in soil productivity

First, it should be recalled that most of the soil-related practices supported by the CAP do not reduce soil productivity (see EQ 1). This has been confirmed by the interviews managed in the case-study areas: no stakeholders mentioned negative impact on productivity from the soil-related measures implemented . Conversely, some practices such as intercropping or mulching are deemed to boost yields but were barely supported by the CAP instruments and measures.

The cultivation of nitrogen-fixing crops (whether as a cover crop or as a part of crop rotation) is generally associated with an increase in yields (see EQ 1). This practice is mostly fostered by the EFAs, even if the 'Omnibus' Regulation led to a lower rate of adoption of this type of EFA (see 5.1.3.2). SMR1, operational programmes specific to the fruits and vegetables sector, crop diversification and AEMCs also contributed, to a lesser extent, to the implementation of this practice. Areas of N-fixing crops have an impact on soil nutrient balance, thus improving productivity.

The 2014-2020 CAP programme has not contributed to the expansion of diversified crop rotation (see EQ 4). The generalisation of this practice may however be expected to increase yields, provided it integrates relevant crops for the soils. Thus, productivity issues should not be an obstacle to the mainstream uptake of this measure.

Reduced tillage and no-tillage have mixed results on productivity depending on the timescale or the local context, but the effect of the CAP instruments and measures on this practice is marginal. It is mainly fostered through GAEC 4 and 5 requirements that limit tillage on slopes or areas with risk of erosion. In addition, tillage is also prohibited in areas declared as ESPG. As mentioned before, these practices of reduced tillage and no-tillage have to be implemented in relevant areas to ensure positive effects on productivity. M4 can also foster investment in machines for direct seeding.

EFAs and M10.1 had significant effects on the implementation of cover crops. GAEC 4 and 5, SMR1 and M11 can also foster cover crops to a lesser extent. The use and destruction of cover crops require good knowledge and training, but the implementation of cover crops can be expected to increase productivity, at least when N-fixing crops are used (Quemada *et al.*, 2013). In the case-studies areas where the establishment of catch or cover crops have been enforced by cross-compliance, some farmers took this as an opportunity to improve their management practices and optimise their positive effects on yields. Intercropping and mulching are not significantly supported by the CAP instruments and measures, even though they are promising techniques for increasing productivity in the long run.

The maintenance of crop residues can have an impact on productivity provided it concerns N-fixing crops (Tonitto, David and Drinkwater, 2006). By banning the burning of crop residues through GAEC 6, a practice often already implemented, and by supporting the maintenance of stubble through AECM or fruits and vegetables operational programmes, the CAP contributed to the adoption of this practice. In Aragon, measure 7.2.1 'Incorporation into the soil or placement on it of pruning remains to improve its content in organic matter and fight against erosion' of the fruits and vegetables operational programme also had a significant effect on the implementation of the practice. Nevertheless, although these practices improve the SOM with likely benefits on productivity in the long run, the effect on soil productivity in the short term is unclear. In forests, the maintenance of dead wood and pruning residues is barely fostered by the CAP instruments and measures.

Agroforestry was barely supported by the CAP 2014-2020. In particular, the maintenance of traditional agroforestry systems (in Spain or Portugal for instance) was not supported, even though they protect areas from desertification and thus maintain productive areas in the long term. Moreover, the implementation of such a practice can dramatically increase soil productivity (see Chapter 4.1.3, Table 5).

The principles of conservation agriculture include soil cover, crop rotation, and reduced tillage (according to the definition set by FAO). Hence, every measure fostering one of the three measures can foster the development of conservation agriculture. The best practices to be applied are still to be experimented according to the crops and local conditions, but soil conservation and quality are in any case necessary to maintain or increase productivity.

Table 16: Contribution of the CAP instruments and measures to soil productivity

Key activities related to soil productivity	Short-term effect	Long-term effect	GAEC 1	GAEC 4	GAEC 5	GAEC 6	SMR 1	EFAs	PG	CD	M4	M8	M10.1	M11	F&V
Cultivation of nitrogen-fixing crops	X														
Diversified crop rotation		X													
Reduced tillage and no-tillage	O	O													
Intercropping	X	X													
Cover crops	X														
Maintenance of crop residues (used as green manure)	X	X													
Composting, manuring	X	X													
Maintenance of forest residues		X													
Mulching	X	X													
Agroforestry	O	X													
Conservation agriculture	-	O													
Potential effects on soil productivity															

Source: Previous EQs

Positive effects were highlighted at EU level

Some positive effects were highlighted in specific areas

X Positive effect on soil productivity (increased or equal productivity compared to conventional practices)

O Mixed effect on soil productivity depending on conditions and management practices

\- Negative effect

5.3.4. Answer to evaluation question 6

The direct effects of CAP measures and instruments on soil-quality components have been approached by focusing on the instruments and measures targeting agricultural activities with effects on each soil-quality component. Although many measures of them have a positive impact on soil-quality components, the contribution of the CAP may be limited due to the areas concerned by their implementation.

As shown in EQ 4 and EQ 5, the CAP has favoured agricultural practices limiting soil erosion, i.e. soil coverage and maintenance of landscape elements, which helps to reduce runoff and erosion by wind. The literature and the case studies showed that GAECs 4 and 5, M10.1 and M11 could contribute to reducing soil erosion. However, the fact that there was little progress over the 2010-2016 period (-0.4% in all lands and -0.8% in arable land), in particular in the most erosive areas, suggests efforts to reduce soil erosion need to be strengthened, especially in hotspots. In addition, the effect of the above mentioned RD measures on erosion is limited due to the limited area concerned and its low level of targeting on vulnerable areas.

The EFAs, GAEC 4 and RDP measures (i.e. M10.1 and M11) contribute to practices limiting the loss of SOM by fostering the use of organic fertiliser or soil cover. The link between CAP implementation over the 2014-2020 period and results on SOM cannot be established due to the timescale of the policy implementation, even though managing authorities demonstrated positive effects from RD measures implemented at the local level. It is important to note that the implementation of relevant practices should be ensured over the long term to secure their effect on SOM.

Activities positive on soil biodiversity and nutrient balance were fostered by GAEC 1, AECM and organic farming which promote grasslands, the restriction of PPPs, and landscape features. However, the result of CAP implementation on soil biodiversity is not monitored. Hence, the effect of CAP measures and instruments cannot be established.

Soil pollution is mainly tackled by SMRs, EFAs and M11, which restrict the use of fertilisers and PPPs. The maintenance of landscape features promoted by GAEC 1 and AECM can also contribute to reducing soil pollution. Changes in soil nutrient balance and the effect of the CAP implementation cannot be directly established. Still, the absence of decrease in the growth of nitrogen balance since 2010 suggests that the recent implementation of the CAP did not succeed in providing an additional contribution to the effect of previous policies for the reduction of the use of fertilisers.

The impact of the CAP measures and instruments on soil compaction and salinisation remains very limited, as no instrument clearly addressed this issue.

Most of the soil-related practices supported by the CAP can be expected to improve soil productivity in the long run. They can improve soil productivity either in the short term or the long term. CAP measures and instruments promoting N-fixing crops (e.g. EFAs, RD measures, crop diversification, etc.) are the ones with the greatest impact on productivity. Other practices concern specific cases or small areas and therefore cannot have an impact on productivity at EU level. Conversely, some practices that can improve soil productivity positive for soil are not significantly promoted by CAP instruments and measures. In particular, the CAP has not contributed to the spreading of diversified crop rotation, intercropping, mulching, reduced tillage or agroforestry, even though these can improve soil productivity. Furthermore, it is important to recall that implementing a minimum of conservation practices is necessary to maintain soil fertility in the long run.

5.4. EQ 7: To what extent have the combined relevant CAP instruments and measures overall contributed to the improvement/deterioration of soil quality and related productivity?

5.4.1. Understanding and method

This evaluation question analyses the combined effects of the CAP instruments and measures as a set, highlighting synergies contributing to sustainable soil management. The analysis considered the following judgement criteria:

- Measures and instruments with potential indirect effect on sustainable soil management (i.e. Category 3 in Table 2: ENRD, M1, M2, M5, M8.3, M8.4, M12, M16 (EIP-Agri) and M19 (LEADER) brought (or not) an additional contribution to the effects of the other CAP instruments and measures with a direct effect on sustainable soil management investigated in the previous evaluation questions(Category 1 and 2 in Table 2)[63]. The potential expected effects on soil, based on theory, were cross-checked with evidence collected in case studies, highlighting examples of CAP-supported projects contributing to promote sustainable soil management.
- The CAP soil-related instruments and measures acted in synergy (or not) towards the implementation of sustainable soil management. Here, specific combinations that supported synergetic agricultural practices (e.g. same practices or complementary practices considering their effects on soil) were highlighted, and potential antagonisms identified during the case studies were looked for. A literature review was carried out to complement these analyses, in order to identify synergies, complementarities or antagonisms between practices affecting soil quality and productivity and relevant CAP measures.

5.4.2. Measures and instruments with a potential indirect effect on SSM brought (or not) an Additional contribution to SSM

5.4.2.1. Theoretical additional effects on the implementation of sustainable soil management

Under the CAP framework, M1 Support for knowledge transfer and information (M1) and support for farm advisory service, farm management and farm relief service (M2) can contribute to raise farmer's awareness of soil threats and sustainable management practices, such as reduced tillage or crop diversification for example. Natura 2000 and WFD payments (M12) can be used to compensate for additional costs and income foregone caused by the mandatory introduction of management practices and specific land use required under the WFD and Natura 2000, potentially resulting in the conversion of arable land into grassland, in afforestation or in the establishment of cover crops potentially that could helping to limit soil erosion. M8.3 and M8.4 support the prevention and restoration of damage to forests, that may indirectly contribute to the protection of soil from erosion that can occur when soils are left bare after forests fires and natural disasters. Similarly, support for investment in prevention actions or to restore agricultural land damaged by natural disasters (M5), potentially address water and air erosion. Support to cooperation (M16) provides support for actions with potential indirect effects on soil, implemented by a group of at least two entities (including networks, clusters, EIP operational

[63] The coherence of the category 4 CAP measures having indirect effect on soil, by fostering specific cropping pattern or choices in the crop implementation (e.g. VCS or CMO sector specific aid) will be investigated in EQ 13.

groups and others). In particular, sub-measure M16.5 is designed to support cooperative environmental projects and ongoing environmental practices[64].

5.4.2.2. Identification of specific examples of contributions of CAP measures with potential indirect effects on sustainable soil management

In the case studies, contributions of CAP measures with potential indirect effects on sustainable soil management have been identified for the following measures:

- Support for knowledge transfer and information action (M1): Even though M1 was implemented in 7 out of the 10 case-study areas, it was clearly identified as contributing to the dissemination of activities related to sustainable soil management in only three areas: Spain-Aragon, Ireland and Sweden. In Spain-Aragon, 23% of the training activities supported under M1.1 (training) were related to conservation agriculture, direct seeding, manuring organic farming, fertilisation and precision agriculture (56 activities) and 44% of the activities supported by M1.2 (knowledge transfer) were related to the soil/crop relationship (41 activities). In Sweden M1 helped to foster changes in practices following the implementation of the Greppa project[65], an advisory service focusing on nutrients management, through M1 and M2. Indeed, between 2008 and 2018, beneficiaries from this programme increased by 9% the percentage of grasslands under rotation, stored extra carbon in soils and increased the use of catch crops.
- Advisory services, farm management and farm relief services (M2): The measure is implemented in four of the Member States studied (Bulgaria, Ireland, Spain-Aragon, Sweden). In Bulgaria, the measure consisted in consultancy packages, and, within M2.1, two of the six advisory packages contained subjects related to soil such as improving the storage and application of manure or low-carbon manure processing practices (composting, biogas, etc.). In Spain-Aragon, 31% of the advisory activities were related to organic and mineral fertilisation, soils and irrigation, precision agriculture and minimum tillage (i.e. 889 activities supported). However, in Ireland, is not clear if the activities supported by this measure include also practices that contribute to protect soil quality.
- Support for prevention and restoration of agricultural production potential damaged by natural disasters and catastrophic events (M5): M5 is implemented in only three Member States of the case studies (Denmark, Greece, Italy); no specific example of its contribution to soil quality was found there.
- M8.3 and M8.4 for prevention and restoration of damage to forests from forest fires and natural disasters and catastrophic events: rural development programmes indirectly supported forest maintenance by supporting the implementation of prevention of damage (due to fire, storms, etc.) and restoration programmes (M8.3 and M8.4). Maintaining or re-establishing forest areas contributes to the maintenance of carbon stocks in vegetation and soils and soil stabilisation. Preventing the loss of forests or reinstating them *ex post* thus helps to ensure these functions in the longer term. M8.3 (prevention) is implemented and considered relevant to soil preservation in three Member States studied (Bulgaria, Spain-Aragon, Italy-Tuscany). In Italy-Tuscany, the sub-measure supports the implementation of prevention actions against the risk of natural disasters, degradation and hydrogeological instability (such as stabilisation of slopes affected by landslides) or preventive forestry actions against drought and desertification (such as introducing drought-tolerant tree species and/or shrubs). M8.4 (restoration) is implemented in five of the Member State studied

[64] Regulation 1305/2013 Art. 35(2)(g).

[65] The Greppa project focuses on reducing losses of nutrients into air and water from livestock and crop production. It is a joint venture between the Swedish Board of Agriculture, the county Administration Boards, the Federation of Swedish Farmers and a number of companies in the farming business. See also: http://greppa.nu/.

(Bulgaria, Czechia, Denmark, Spain-Aragon, Sweden), but is considered to have had positive significant effects in only three of them (Bulgaria, Czechia, Spain-Aragon). For instance, in Czechia, forest owners have a legal obligation to reforest these areas after natural calamities, but support provided by M8.4.1 makes it possible to perform this faster. Moreover, the measure also makes it possible to limit the period of uncovered soil and contributes to a higher presence of improved and strengthened trees to prevent erosion, stabilise stands and produce timber and biomass of higher quality, thus adding organic matter to soil and improving nutrient balance (Vopravil, 2010).

- M12 Natura 2000 and Water Framework Directive: The use of the Natura 2000 measure on the 2007-2013 and 2014-2020 periods was very limited in many Member States, accounting for only 0.5% of RDP spending in the EU as a whole[66]. It has been implemented and identified as supporting sustainable soil management by three Member States studied (Belgium, Bulgaria, Spain-Aragon). For instance, the case study in Bulgaria showed that M12 focuses on soil protection from erosion and improvement of soil fertility through its potential indirect effect on the cultivation of N-fixing crops.
- M16 Cooperation: The measure is mentioned in seven Member States studied (Bulgaria, Czechia, Germany, Ireland, Spain-Aragon, Italy, Sweden) as contributing to the promotion of sustainable soil management. For example, in Czechia, M16.1 has been implemented as a set of projects of cooperation with the aim of testing new technologies, practices and other innovations. Thus, the measure is considered to have the potential to spread practices favourable to soil. Projects of precision agriculture, application of integrated production, production of organic fertilisers rich in nitrogen, etc. were supported by M16.1.1. As highlighted by the ENRD, other soil-relevant cooperation projects were supported under Sub-measure M16.5, for example to improve farmers' soil management skills (OSMO project in Finland), to improve local stakeholders' understanding of soil erosion (LESELAM project in France-Mayotte), or to promote sustainable soil management (see Box 8).

Box 8: Contribution of M16.5 to soil quality in Wales (UK)

In Wales, the cooperative Fferm Ifan of 11 farmers, implemented the Sustainable Management Scheme (SMS), under RDP M16.5, to support knowledge exchange and collaborative learning opportunities on sustainable intensification. Many of the farms involved are neighbouring and share access to an area of common land (as part of a grazing association) that is used for summer grazing. The project began in 2017 and is still at an early stage. However, model projections show that for the planned SMS actions the benefits will include:

- 54 tonnes of increased carbon storage in soils and vegetation;
- 94 ha increase in the area managed to mitigate rapid runoff and to diffuse pollution;
- 40 ha reduction in areas with significant accumulation of overland flow.

One of the key findings highlighted by the project is the collaboration needed between farmers and scientist to design schemes at landscape scale and account for local environmental factors.

Source: (ENRD, 2018)[67]

- M19 LEADER: The LEADER measure (M19) was mentioned in only two Member States studied (Belgium and Germany) as having potential indirect effects on soil. In Wallonia-Belgium, for example, local action groups (LAGs) can be indirectly related to soil quality. The case study revealed that one LAG called 'Culturalité' promotes various practices, including soil-related ones (i.e. vegetal cover, compost, no-tillage system, direct sowing, etc.) through initiatives which group together almost

[66] EC 2018. Farming for Natura 2000.

[67] ENRD 2018. Thematic Group on sustainable management of water and soils. Collaborative and multi-actor approaches to soil and water management in Europe.

400 farmers. A relevant example has also been identified in the UK, where the measure supports investment in conservation-agricultural machinery (see box below).

Box 9: Example of the contribution of M19 in spreading sustainable soil management in UK (Cotswolds)

In the UK, The Cotswolds Conservation Board, which works to conserve the local natural environment, has led this Leader project from 2015 to 2020. In this hilly region, the soil is very thin and the risk of soil erosion significant. The Cotswolds LEADER programme allocated 28% of its budget to support 16 farm businesses to invest in a wide range of equipment and machinery (e.g. direct drills, fertiliser spreader, trailing shoe slurry systems). The first objective of the programme was to increase the productivity of farm operations, but significant environmental benefits were also considered, as the conservation board selected only farmers with strong environmental motivations.

Thanks to the programme, more than 7 000 ha have been managed under soil conservation practices while maintaining or improving yield. Using a direct drill decreases disruption to the ground and associated organisms, reducing soil erosion. Trailing shoe slurry systems and the variable rate application system using GPS and connected spreaders has helped improve inputs management and reduce the use of fertilisers, with positive effects on soil nutrient balance. Investments for woodland maintenance were also provided under this scheme and have been assumed to contribute to soil conservation. Another advantage of this LEADER programme was the role played by the LAG, which allowed sharing knowledge on soil preservation practices among local farmers and permitted broader adoption of these practices in the Cotswolds area.

Source: Interview by Alliance Environment (2020)

5.4.2.3. Qualification of the effects of the measures on the implementation of sustainable soil management

The available CMEF indicators on M1, M2, M5, M8, M12, M16 and M19 provide the number of projects implemented with the support of RDPs and the corresponding number of beneficiaries. However, no breakdown is available identifying either the share of soil-relevant projects/activities supported under each measure or their outcomes in addressing the components of soil quality.

The potential contributions of the improvement of soil quality were hence identified based on the analysis of the opinions of the stakeholder interviews[68] in the case-study areas. The table below provides an overview of the contribution of the measure to improvement of soil quality, based on information collected in the case study (examples of projects supported, opinions of stakeholders on the actual contribution of each measure).

Table 17: Contribution to the improvement of soil quality of the CAP measures with potential effects on sustainable soil management in MS studied

	Erosion	Compaction	SOC	Biodiversity	Pollution	Salinisation	Nutrient
M1	ES (Aragon)	ES (Aragon); SE	ES (Aragon); SE	ES (Aragon)	ES (Aragon); SE	ES (Aragon)	ES (Aragon); SE
M2	BG, ES (Aragon)	BG, ES (Aragon), SE	BG, ES (Aragon), SE	ES (Aragon); BG	BG, ES (Aragon), SE	ES (Aragon); BG	BG, ES (Aragon), SE
M8	BG, CZ, ES (Aragon), IT	EL	BG, CZ, ES (Aragon)	BG, ES (Aragon)	ES (Aragon)		ES (Aragon); CZ
M12	BE (Wallonia)	BE (Wallonia)			BE (Wallonia)		
M16	ES (Aragon), IE	ES (Aragon), IE	ES (Aragon), IE	IE	BG, CZ, ES (Aragon), IE	ES (Aragon)	ES (Aragon), IE

Source: case studies

- Positive effects in relation with this soil threat were observed in at least two of the Member States studied (dark green)
- Positive effects in relation with this soil threat were observed in one of the Member States studied (light green)
- The effects in relation with this soil threat varied depending on the activities supported (orange)
- No impact of the measure mentioned by the stakeholders interviewed (grey)

[68] A total of 161 stakeholders were interviewed. They were selected from among the most relevant representatives of farmers, managing authorities, farm advisers, soil experts and researchers.

Those findings were compared to the effects on SSM from literature. Different sources identified farm advisory actions supported under M2 and collaborative approaches under M16 as contributing to the reduction of soil erosion in other areas (e.g. Germany-Schleswig Holstein, Spain-Canarias, Spain-Castilla y Leon, Hungary, UK-Wales). The positive contribution of M16.5 on soil organic content and soil contamination is also consistent with examples of projects found in the literature review (see the examples provided hereinafter). According to the synthesis of the evaluation of the enhanced AIR 2019 led by the European Commission, the Natura 2000 payments (M12) have also been found to significantly contribute to carbon conservation and sequestration in some Member States (e.g. Estonia, Spain-Murcia, Italy-Friuli Venezia Giulia).

5.4.3. The CAP soil-related instruments and measures acted in synergy towards the implementation of SSM

5.4.3.1. Theoretical analysis of the impacts of the combined effects on soil quality and productivity

The CAP provides a set of tools that can be implemented either alone or together to foster the implementation of sustainable soil management. The ENRD highlights examples of possible combinations of RDP measures. For instance, joint projects involving activities funded by M10, M11 and M15 could use M16.5 to cover the costs of coordinating and facilitating the cooperation group implementing the project. In the objective to promote sustainable soil management, support to advice and training services (M1 and M2) may work together with AECMs (M10.1) or support innovation and research under M16[69].

However, as mentioned by Regulation (EU) No 1305/2013, support overlap must be avoided, and the same action cannot be supported twice. The CAP instruments and measures should hence be used to support complementary actions or address different soil threats or activities, contributing to the same overall objective. Furthermore, the stakeholders involved in the implementation of the measures (e.g. local authorities in Belgium-Wallonia) highlighted the difficulties introduced by the reform of the CAP in 2014, which requires to submit one application file for each of the measures, making harder the implementation of combined measures under a single project..

5.4.3.2. Notable cases where the combination of CAP measures and instruments had significant effects on soil quality and productivity

Table 18 presents the sets of CAP instruments and measures focusing on similar activities that were implemented in the case-study areas. They were identified according to findings from EQ 2 (see Chapter 4.2.3).

69 ENRD RDP analysis_M01_M02

Table 18: Example of strategic choices of combined CAP measures to foster soil-relevant practices in the MS studied

Supported Practice	Concerned case-study area	Observed combinations of instruments and measures
Landscape features (maintenance and creation)	BE (Wallonia), CZ, IE, EL	EFA+ M10.1
	DK, IT	EFA+ M4.4
	DE	EFA+ M4.4+ M10.1
	ES (Aragon)	M10.1+ M4.3
Reduced tillage or no-tillage	CZ, ES (Aragon)	GAEC 4+ GAEC 5
	IT	M4.1+ M10.1
	BE (Wallonia)	M4.1+ M12
	SE	M1+ M2
Cover crops	DK, IE, SE	GAEC 4+ EFAs
	BE (Wallonia), CZ, DE	GAEC 4 EFAs+ M10.1
	EL, IT	GAEC 4+ M10.1
	BG	GAEC 4+ CD+ EFAs
	ES (Aragon)	GAEC 4+ GAEC 5
Forest maintenance	BG, ES (Aragon)	M8.5+ M4.3+ M8.4

Source: Alliance Environment

In the case-study area, synergies were found between cross-compliance and RD measures (Belgium, Denmark, Greece, Ireland, Italy) but also between greening payments and RD measures (Czechia, Italy, Sweden). For instance, in Ireland, GAEC 4 requiring appropriate grazing practices and an AECM supporting the management of low-input permanent pasture and traditional hay meadows acted in synergy to prevent soil erosion. In Denmark, the stakeholders interviewed see the Nitrates directive requirements as complementary to the practices supported under M11 Organic Farming to improve soil quality. As for greening payments, they motivate farmers in Czechia to further spreading SSM and RDP measures, especially the environmental ones (M10, M11). In Sweden, farmers can either declare areas in catch crops under Greening, or set an AECMs contract on those area ('Reduced nutrients leaching from arable land'): entering the AECM can be a second step toward sustainable soil management, given that the AECM comes with additional requirements on tillage, i.e. no early tillage of the catch crops and no tillage in fall. In Belgium-Wallonia, it was observed that most of the area declared in EFA is area under catch crop established as a result of the requirement under SMR1: to be declared in EFA the area in catch crop has to be maintained on a longer period and to be sown with specific species. This is an interesting synergy between horizontal and greening measures, which resulted in significant incentive for farmers to implement cover crops. Still, the fact that the areas overlap undermines the additional effect of the greening requirement to declare EFA, compared to cross-compliance.

The case studies also highlighted synergies between RDP measures, in 7 of the 10 studied areas (Bulgaria, Belgium, Czechia, Ireland, Greece, Spain, Sweden). Most of the synergies were observed between AECMs and other RDP measures (notably M1, M2 and M4). For instance, in Ireland, support for machinery to reduce soil disturbance (M4.4) was designed to complement the AECM supporting minimum tillage . In Sweden, M1 and M2 were implemented in the objective to increasing farmers' awareness, and notably their awareness on how to implement the AECMs (several of which are of interest to improve soil quality, e.g. 'Reduced nutrients leaching from arable land' and 'Extensive ley management' . Box 10 presents an example of a project that promotes agricultural activities beneficial for improvement of soil quality and that was supported through several RDP measures used in combination, in Italy-Marche.

Box 10: Example of combined effects of RDP measures (M1, M10, M11, M16.2, M16.5) on soil quality in Italy (Aso Valley)

Launched in 2016, the AEAs support coordinated actions among 103 farmers in 13 municipalities. The purpose is to increase soil and water quality by establishing integrated/advanced agriculture practices and/or organic farming across 1 063 ha. The AEA is supported by a package of measures that includes the agri-environment-climate scheme (M10) and organic farming (M11), which are supported by the measures of knowledge transfer, information and advices to farmers (M1) and cooperation (M16). The latter is used in the form of pilot projects (G.ECO.VALDASO) to assess the economic and environmental sustainability of farming techniques required in the AEA (M16.2), and to support the role of a facilitator (M16.5). The set of CAP measures work in synergy, as soft measures (M1, M16) are necessary to convince farmers to adopt sustainable soil practices, in particular pest management practices (M10), reduced tillage or no tillage, and/or organic farming (M11).

The monitoring phase of the effects of the project has just started, but first results of the 812 ha under pest management (M10) and 251 ha under organic farming (M11) show a significant increase of the soil cover and biodiversity and a decrease in the use of pesticides and herbicides by the farmers. A key point is that the implementation of the new practices makes it possible to improve soil quality while maintaining the same productivity. Stakeholders interviewed also highlighted that AEAs have also ensured positive effects on advisory services, learning and networking. This effect increases the level of trust and reciprocity among farmers, thereby creating both environmental and knowledge effects in the valley. These encouraging results have led to the creation of a similar project in another part of the Marche region.

However, the administrative burden due to the complexity of applying for all CAP measures individually and the delay in the CAP payments have been identified as significant limits to the development of the project, as they discourage the farmers involved. This shows all the more the key role of the facilitator (M16.5) in helping farmers in their efforts.

Source: Interview by Alliance Environment (2020)

The majority of the interviewed stakeholders (e.g. in Belgium-Wallonia, Bulgaria, Czechia, Ireland, Greece, Spain-Aragon, Sweden) confirmed the possible synergies between CAP instruments and measures, which may have indirect but positive effects on soil. However, the case studies also highlighted that those effects are quite limited because soil quality was not the main focus of RD measures (Denmark, Ireland) and because relevant measures have a low level of implementation (Belgium, Greece, Italy).

Conversely, contradictory outcomes were also found. For instance, in the case of Spain-Aragon, farmers' representatives noticed that the combined effects of EFAs, which forbid phytosanitary treatments, and GAEC 4, which requires tillage, tend to promote fallow land with bare soil that is ploughed every year, thus increasing the risk of erosion.

5.4.4. Answer to evaluation question 7

Together with other measures with more direct effect, knowledge transfer (M1), advisory services (M2) and cooperation (M16) measures can achieve significant effects. Indeed, the case studies and the ENRD highlighted examples of projects in which knowledge transfer (M1) and advisory services (M2) measures helped to accompany and foster the adoption of conservation agriculture, organic farming, and precision input management. These operations thus effectively contributed to addressing various soil threats (e.g. erosion, compaction, soil organic content). The cooperation sub-measures were also implemented (e.g. M16.1-EIP Operational Groups, M16.2-Pilot projects and M16.5-Environment and climate change) to support joint actions in various projects facing local soil issues. To a lesser extent, the Natura 2000 payments (M12) and the LEADER (M19) measures may also contribute to the promotion of sustainable soil management. However, the case studies revealed the limited effects of M12 because of its low level of implementation. Support to prevention and restoration of agricultural production potential damaged by natural disasters and catastrophic events (M5) was not identified as having significant effects on soils in the case-study Member States. Regarding forest management, support to preventing or restoring forests from damage due to natural disasters, fires or catastrophic events (M8.3 and M8.4) contribute significantly to the maintenance of soil cover, carbon stocks in soils and vegetation and soil stabilisation, as was shown in four of the case-study Member States (Bulgaria, Czechia, Spain-Aragon, Italy-Tuscany).

Various exemples found in the case-study areas showed that CAP instruments and measures can act in synergy to foster the implementation of sustainable soil activities by farmers. Most of the synergies noticed were between RD measures themselves. In particular, the combination of AECMs and other RDP measures (notably M1, M2 and M4) was highlighted by specific examples identified in the case studies and in the ENRD.

However, according to the majority opinion of the stakeholders in the Member States studied, the effects of these synergies on soil quality and on the promotion of sustainable soil management are limited, because soil concern was not the main objective of the supported projects and because relevant measures with indirect effects (e.g. M1, M2, M16) could be further implemented to better foster the adoption of sustainable soil management. Locally, successful examples of projects involving more than two CAP measures combined to foster implementation of relevant practices by farmers were identified. However, the project leaders outlined the difficulties introduced by the reform of the CAP in 2014, which requires separate applications to be filed for each measure, thereby increasing the difficulty of implementing combined measures under a single project.

RD measures also acted in synergy with the requirement under cross-compliance and greening: in particular, AECMs can be a second step toward sustainable soil management, based on requirements set by cross-compliance or the need to declared EFAs. In Belgium-Wallonia, interesting synergy between the requirement under SMR1 and the greening requirement to declared EFA resulted in significant incentive for farmers to implement cover crops. Still, the fact that the areas overlap undermines the additional effect of the greening requirement to declare EFA, compared to the baseline set by cross-compliance.

5.5. EQ 8: To what extent have external factors (e.g. soil sealing, floods, storms, droughts, fires) affected the impact of the relevant CAP instruments and measures on soil quality?

5.5.1. Understanding of the question and methodology

This question assesses the extent to which factors external to the CAP have affected the impact and results of CAP instruments and measures on soil quality and their implementation. In terms of external factors, the analyses focus on soil sealing as well as climatic and natural events such as floods, storms, droughts and fires, and they consider the impact of those factors on the various components of soil quality.

The analyses considered the following judgement criteria:

- The external events affected (or not) the results of the CAP instruments and measures i.e. the soil benefits achieved through sustainable soil management practices supported by the CAP instruments and measures). The analysis describes the impact these external factors may have on soils and the extent to which they affected the results.
- The external events impacted (or not) the implementation of soil-related CAP instruments and measures. It looks at the changes the case-study Member States/regions have made in the CAP in response to these natural events.
- The external events affected (or not) a significant area compared to the area managed to deliver sustainable soil management under the CAP, in the case studies.

These analyses were carried out based on the literature review and the information collected during the case-study interviews. Some findings were rounded out with statistical or implementation data.

5.5.2. External events affected (or not) the results of the CAP instruments and measures, i.e. the soil benefits achieved through sustainable soil management practices supported with the CAP instruments and measures

5.5.2.1. Review of general types of impact to be expected for the identified external factors on soil quality components

Natural events and soil sealing affect agricultural and forest soils in a variety of ways. Based on literature analysis, Table 19 provides a typology of the impacts that can be expected from the various natural events and soil sealing, which are the main factors assessed in this EQ.

Table 19: Impacts to be expected on soil from external natural factors and from soil sealing

	Floods	Droughts	Storms	Fires	Soil sealing
Soil erosion	Heavy rains and floods lead to topsoil removal by water. On steep slopes, heavy rainfall and floods will cause landslides.	In the event of a drought, the fine soil particles of dry soils become more volatile, which increases erosion by wind or water.	Storms lead to both water and wind erosion caused by heavy rainfall combined with powerful winds. Summer storms may additionally take place over dry soils (e.g. during droughts), exacerbating their impacts.	Forest fires destroy vegetation cover and increase the risk of soil erosion by water or wind.	n.a.
Soil organic matter	These natural events can decrease the level of soil organic matter content in agricultural and forest soils through soil erosion effects.			Fires destroy the vegetation above ground and litter, depriving soils of	n.a.

	Floods	Droughts	Storms	Fires	Soil sealing
				organic matter inputs	
Soil compaction	Soil compaction acts as an exacerbating factor rather than a result of climatic events. For example, the water from floods occurring on compacted soils has a low soil infiltration rate and low capacity of redistribution; this exacerbates the impact of floods, notably with respect to soil erosion damage.			n.a.	Soil sealing results in severe soil compaction due to the pressure exercised on soil by settlement or infrastructure.
Soil salinisation and sodification	n.a.	Dry soils caused by drought increase the water table level in soils, bringing water-soluble salts into the top layers of soil.	n.a.	n.a.	n.a.
Soil pollution	By affecting yields, all these natural events are likely to drive land managers to respond by increasing PPPs and/or fertilisers, both of which increase concentrations of chemical substances in soils.			n.a.	Depending on the activity hosted on sealed soil, soil pollution can be associated with soil sealing trends.
Soil biodiversity	Climatic events can lead to declines in soil biodiversity by affecting the other components of soil quality, on which living organisms in soils depend. For example, droughts leading to soil salinisation or storms leading to soil erosion negatively impact biodiversity in soils.				Soil sealing prevents soil from fulfilling its basic functions and therefore strongly affects soil biodiversity.
Nutrient balance	By affecting yields, all these natural events are likely to drive land managers to respond by increasing nitrogen and/or phosphorous inputs and contribute to excessive presence of these nutrients in soils. In addition, heavy rainfalls, floods and storms lead to nutrient leaching, which decreases the availability of nutrients in soils but increases their unwanted presence in the wider environment (e.g. water courses).			n.a.	n.a.

Sources: soil erosion (Louwagie, Gay and Burrell, 2009), (Panagos et al., 2016); soil organic matter (Louwagie, Gay and Burrell, 2009); soil compaction (Thorsøe et al., 2019); soil salinisation and sodification (Louwagie, Gay and Burrell, 2009); soil pollution (Silva et al., 2018), (Louwagie, Gay and Burrell, 2009); soil biodiversity (Orgiazzi et al., 2016); nutrient balance (Louwagie, Gay and Burrell, 2009).

5.5.2.2. Analysis of the impact of recent natural events and soil sealing, on agricultural and forest soils and subsequent agricultural management

Description of the impacts of recent natural events on agricultural and forest soils and subsequent agricultural management in the case-study areas

Study was made of a range of major natural events having occurred in the case-study areas and their consequences on agriculture and forests there. Six of the case studies (Czechia, Germany-Bavaria, Ireland, Greece, Spain-Aragon, Sweden) reported yield losses due to the climatic events studied, notably of fodder crops, with knock-on effects on the livestock sector. In Greece-Crete, floods led to yield losses in the olive and Fruit & Vegetable sectors. In a number of case studies (Belgium, Germany-Bavaria, Spain-Aragon), farmers and farmer representatives indicated they were more concerned by the impact of gradual climatic changes on their businesses than by one-off extreme weather events. In Germany-Bavaria, extremely heavy rainfall in 2016 caused significant damage to maize production.

Case-study authors overall found it difficult to identify the specific soil impacts of these events, but a few clear examples were identified, as follows:

- Natural events contributing to soil erosion:
  - In Belgium-Wallonia, increase in the frequency of spring storms is the phenomenon with the most effect on erosion, and this frequency is expected to increase by 40% by 2050 (Panagos et al., 2017)). Droughts exacerbated soil erosion issues due to reduced vegetation cover.
  - In Greece, annual summer fires, and in particular those of 2007, led to soil erosion in forests in mountain areas, as the absence of trees and vegetation meant that there was no protection against storms/landslides.
  - In Germany-Bavaria, the increased occurrence of small-scale heavy rainfall events as the consequence of climate change has increased the risk of soil erosion. Extremely heavy rainfall in 2016 increased visibility of land use and crop cultivation choices as drivers of erosion in Bavaria, where 500 000 ha (25% of arable land) are at risk from water erosion, 96 000 ha of which at high risk.
- Natural events contributing to increased fertiliser use and nutrient imbalance:
  - In Ireland, severe snowfall and ice in winter 2018 were followed by a summer drought. As a result, fertiliser use increased significantly due to the demand for late season grass and silage (Dillon et al., 2019).
  - In Sweden, the impact of the 2018 drought and associated yield losses, especially in spring crops, drove farmers to use more nitrogen fertilisers than normal, in the hope of boosting yields. This led to strong nutrient imbalance.
- Gradual changes in climate patterns impacting soil-quality components:
  - In Czechia, gradual changes in climate patterns are also having an impact on the effectiveness of winter catch crops and their benefits for soil. Due to an insufficient number of days when the temperature falls below zero, catch crops do not die due to freezing and are not able to perform the positive functions expected in terms of nutrient balance and organic matter release.
  - In Greece, climate change has been reported as important factor affecting the infestation of certain crops by plant pests (more generations and earlier appearance); this has led to increased use of PPPs and thus soil contamination.
- Soil sealing driven by renewable energy infrastructure on agricultural land:
  - In Greece, there is a growing trend of agricultural soil sealing caused by the expansion of renewable energy infrastructure, such as photovoltaic equipment in plains and wind turbines in mountain pastures.

Impact of external events on CAP instruments and measures' efforts towards sustainable soil management

While extreme natural events occurred in all case-study areas, sometimes at significant scales, they have not, overall, hampered the effectiveness of CAP measures aiming to support sustainable soil management.

In two cases (Germany, Greece), negative impacts were experienced, but only very locally in some areas, and it could not be concluded that the performance of CAP measures was hampered overall in these case-study areas. Evidence of a few links was nonetheless found in a number of case studies, as follows:

- Catch crops in Czechia are the preferred option to comply with the EFA obligation, but the impact of warm winters on the effectiveness of catch crops has hampered the effectiveness of CAP measures supporting their use, notably GAEC 5 and EFAs.
- In Greece, according to forest advisors, there had been significant soil slides due to storms in mountainous areas previously devastated by forest fires. Some of these forests had been

protected by soil stabilisation and anti-erosion works funded by M8 and/or the Green Fund (national funding).

- In Greece-Crete, in the Chania area where floods occurred in 2018, the sectoral Fruit & Vegetable Operational Programme included measures to protect soil quality. The significant soil erosion which was triggered by the floods had a negative impact on these efforts.

Some of the case studies also highlighted the two-way interlinkages and influence between the damage caused by external events and the practices supported through policies. In Spain, some 633 169 ha of fallow land were declared as EFAs in 2018. No provisions are set regarding the tillage and covering of fallows, and the common practice is that soil is generally tilled and left bare, thus making them highly vulnerable to soil erosion brought about by droughts and heavy summer rainfall. Hence, CAP implementation has not been able to prevent such poor management practices from happening, thereby leaving soil vulnerable to erosion caused by natural events. On the contrary, in another case (an organic farm in Germany-Bavaria), by supporting the implementation of soil protection practices (through EFA catch crops, M10.1 and M11), the CAP is seen as having helped to reduce the negative impacts of heavy rainfall in spring 2019. This case was compared to a similar event in 2013 on the same farm where impacts had been much more damaging.

External natural events may act as an obstacle to farmers carrying out specific soil protection practices. For example, in Belgium, when soils are too humid because of exceptional rainfall, direct seeding as practised in conservation agriculture (which is generally focused on achieving high soil quality) is not possible.

Extreme natural events occurred in all case-study areas, sometimes at significant scales. While the examples above show concrete ways in which the effectiveness of CAP measures aiming to support sustainable soil management has been affected, overall in the case studies examined for this study it cannot be said that the CAP efforts towards sustainable soil management have generally been hampered due to damage caused by natural events. This is because either the information was unavailable to draw a conclusion (Belgium-Wallonia, Denmark, Ireland, Spain-Aragon, Italy, Sweden) or because the impacts were severe but too localised to conclude that they affected the CAP effectiveness as a whole in the case-study area (Germany-Bavaria, Greece).

5.5.3. External events impacted (or not) on the implementation of soil-related CAP instruments and measures

5.5.3.1. Identification of changes in the implementation of the CAP soil-relevant instruments and measures related to natural events

The most frequent changes made to CAP implementation in the case-study areas have been ad hoc responses in the form of temporary derogations to current rules. Of most relevance to agricultural soils are the derogations to the Pillar I greening rules to maximise the area of land which could be used to produce fodder for livestock. The drought had severely affected the production capacity of grassland and yields of fodder crops, with wide-scale knock-on effects on livestock farms.

The case studies indicate that derogations were made to allow the grazing/mowing of EFA fallow land and other non-productive options such as catch and cover crops (in Germany-Bavaria, Sweden and Denmark), to delay the establishment date for EFA cover crops (Denmark), to allow winter crops to qualify as EFA catch crops if grazed or harvested for fodder production (Ireland), or to permit more relaxed verification/enforcement of the greening measures (Spain-Aragon). In Czechia, ad hoc exceptions from cross-compliance rules were allowed on the basis that the 2018 drought constituted a case of force majeure.

- In Denmark, because of the 2018 summer drought, the authorities agreed to postpone the deadline for cover crops to be established, some of which land counted as EFA. A total of 400 000 ha of cover crops was affected. EFA fallow land was also allowed to be used for animal feed.
- In Germany-Bavaria, following the 2018 drought and damage from hail, exemptions to EFA greening were introduced: EFA fallow land was allowed to be used for grazing or for fodder production, and the same derogation applied to other areas taken out of production (GAEC areas). In 2019, continued drought led to further exemptions, in particular affected areas of Bavaria, and EFA areas were once again allowed to be used for catch crops and undersown crops for animal feed.
- In Spain-Aragon, when floods occurred, verification of greening rules was relaxed.
- In Ireland, greening derogations were introduced for the rules on winter catch and cover crops.
- In Sweden, following the 2018 drought, the authorities allowed farmers to harvest the grass from fallow registered as EFA, to feed animals.

These case-study examples fall within a wider set of derogations that were taken in a number of Member States and approved centrally by the European Commission (See Box 11).

Box 11: Derogations to greening rules granted by the European Commission to some Member States following the summer 2018 drought

In the face of the 2018 drought, requests for derogations to the greening rules were granted centrally by the European Commission to Member States which requested them[70]. One of the main challenges faced by farmers dealing with the impact of drought has been to cope with the scarce availability of fodder resources for livestock. The derogations to the greening rules mostly aimed at enabling more land to be used for fodder production because of the shortage experienced. Derogations were adopted in two packages, as follows:

- First package:
  - Derogations on crop diversification and EFA rules on the non-productive requisites of land lying fallow, to allow such land to be used for the production of animal feed.
- Second package:
  - Possibility to consider winter crops which are normally sown in autumn for harvesting/grazing as catch crops (prohibited under current rules) if intended for grazing/fodder production;
  - Possibility to sow catch crops as pure crops (and not a mixture of crops as currently prescribed) if intended for grazing/fodder production;
  - Possibility to shorten the eight-week minimum period for catch crops to allow arable farmers to sow their winter crops in a timely manner after their catch crops;
  - Extension of the previously adopted derogation to cut/graze fallow land to France.

The derogations apply to Member States which requested it. For the derogation on land lying fallow, these were: Belgium, Denmark, Estonia, France, Latvia, Lithuania, Poland, Portugal, Finland and Sweden. For the derogation on catch crops and winter crops, these were: Belgium, Denmark, Germany, Ireland, France, Latvia, Lithuania, the Netherlands, Poland, Sweden and the United Kingdom (England and Scotland).

Note: other actions were taken by the Commission but with no impact on agricultural soils.

Source: European Commission press releases in September 2018

With respect to CAP implementation changes in Pillar II, most case studies indicate that the RDPs often do not explicitly address extreme events, and no changes to RDP programmes were made in response to climatic events or soil sealing in the case-study areas, although specific rules exist regarding the implementation of the RD measures in case of force majeure. Only in a few cases were changes made in CAP implementation in terms of the type of RDP measures programmed or in the budget assigned to them. In Bulgaria, as a result of natural events, it was decided to open the disaster risk reduction measure (M5) for the year 2020, with a budget of EUR 31 million, funded with the unused budget rather

[70] https://ec.europa.eu/info/news/adoption-greening-derogations-farmers-impacted-drought-2018-sep-19_en

than through a budget transfer. M5.1 (prevention) was due to open for applications in December 2019 and M5.2 in May 2020. At the time of writing (August 2020), however, M5.1 had not been opened yet. In Czechia, following the 2018 drought, the eligibility criteria for Measure 4 (investments) were broadened to include the construction of water-retention tanks (basins). Some administrative deadlines were also adjusted ad hoc in order to allow more potential beneficiaries to submit applications.

5.5.3.2. Opinion of the stakeholders on the impact of any change in the CAP implementation

Overall, the actions taken in response to natural environmental events or soil sealing have not resulted in a major systematic change in CAP programming or implementation, although a number of ad hoc and targeted changes in RDP implementation have been taken in two Member States. That said, according to the relevant case study, external factors such as extreme climatic events have gained prominence in driving RDP programming in Czechia for the next period (both as a result of extreme weather events and gradual changes in climate).

5.5.4. External events affected (or not) a significant area compared to the area managed to deliver sustainable soil management under the CAP, in the case studies

This section intends to put into perspective the CAP's contribution to the implementation of management practices and land use sustainable for soil compared to the area affected by natural events and soil sealing. Three relevant examples of such comparisons were identified, where it was possible to estimate the geographical boundaries of the area impacted by external factors.

In Belgium-Wallonia, the agricultural area estimated to have been impacted by the 2018 summer droughts was about 145 000 ha[71]. In Wallonia, the total area under permanent grassland and arable land is 727 920 ha (source: Eurostat[72]), which means that the 2018 drought impacted about 20% of arable land and grassland in Wallonia. This compares with the area of land under management contracts under Pillar II of the CAP to improve soil management and/or prevent soil erosion, which in Belgium-Wallonia is 10.05% (AIR 2017 data[73]). While it should be noted that this is an imperfect comparison, the scale of the natural event in this case has been about twice greater than the area receiving support for soil under Pillar II of the CAP.

In Czechia, some 400 000 ha of cover crops were estimated to have failed to perform their function for soils (nutrient release, input of organic matter), as they did not die off naturally during the unusually warm winter of 2018. Czechia reports that 6.96% (about 250 000 ha) of its agricultural land is under CAP management contracts to improve soil management and/or prevent soil erosion (AIR 2018 data[74]). This again shows that the scale of CAP measures available and taken up by farmers to improve soils in Czechia did not match, by a significant order of magnitude, the impacts of the natural event examined.

---

[71] For Belgium, Alliance Environnement calculations based on subsidy envelopes received in response to the drought, including both permanent grassland and arable land (https://www.rtbf.be/info/economie/detail_31-5-millions-d-euros-pour-indemniser-les-agriculteurs-wallons-touches-par-la-secheresse-de-l-ete-2018?id=10391671).

[72] 2016 data extracted from the Eurostat database [ef_lus_main] in May 2020.

[73] Result indicator R10_PII.

[74] Result indicator R10_PII.

With respect to soil sealing, a 2015 JRC study estimated that for 21 of the then 27 EU Member States[75], agricultural land take (soil sealing) was 752 973 ha for 1990–2000 and 436 095 ha for 2000–2006. This compares with a total UAA for the EU-27 of 173 million ha[76] but represented 70.8% and 53.5%, respectively, of the total EU land take for these periods.

5.5.5. Answer to evaluation question 8

Natural events (droughts, floods, storms, droughts) and soil sealing can affect agricultural and forest soils in a variety of ways, impacting the seven components of soil quality. For two of the case studies it has been possible to carry out a comparison of the area affected by external natural events with the area supported under the CAP for sustainable soil management. Although imperfect, this comparison helps to put into perspective the efforts currently made available and taken up by farmers under Pillar II of the CAP in relation to soils. It is noticeable that those events may impact very large areas and may thus very significantly impact soil quality in comparison to the impact that can be expected from the CAP. It is also important to note that degraded and bare soils are more affected by storms and droughts than sustainably managed soils, and that the frequency of extreme natural events is expected to increase in the future. This suggests that the CAP measures and instruments need to scale up to counterweight, as much as possible, the effects of these events.

The study also investigated the extent to which the CAP implementation was affected by natural events: external factors have, generally, not significantly affected the outputs of soil-related CAP measures. However, a few examples identified showed that external events and land managers' responses to them have led to increased soil erosion, greater fertiliser use and nutrient imbalance, and soil contamination through increased usage of PPPs. A growing soil sealing trend was noted in Greece, caused by renewable energy infrastructure on agricultural land.

In terms of the policy response by local authorities, neither natural events nor soil sealing resulted in major systemic changes in the CAP programming or implementation of soil-related CAP instruments and measures. That said, a number of ad hoc and temporary changes were made, especially in the form of derogations to the non-production rules of the greening obligations to allow more land to be used for the production of fodder for livestock. In two Member States, some changes were made in the RDP programmes in response to climatic events, but no changes were made in the other case studies in response to the external factors they faced.

[75] Croatia not included. Gardi, C., Panagos, P., Van Liedekerke, M., Bosco, C. and De Brogniez, D. (2015) 'Land take and food security: assessment of land take on the agricultural production in Europe', *Journal of Environmental Planning and Management,* 58(5), pp. 898-912.

[76] 2013 data extracted from Eurostat database [ef_oluft] in May 2020.

5.6. EQ 9: To what extent have technological and social innovations in the agricultural sector contributed positively or negatively to soil quality?

5.6.1. Understanding and method

Innovation is one of the seven flagship priorities of the Europe 2020 strategy for a smart, sustainable and inclusive economy. The emergence and dissemination of innovation in agriculture is a cross-cutting objective of the common agricultural policy and a specific objective of Pillar II.

The analysis considered the following judgement criteria:

- Technological and social innovations may have (or not) a significant effect on soil quality. To assess this, a (non-exhaustive) list of the technological and social innovations[77] that have contributed over the last few years positively or negatively to soil quality was drawn up and their impacts (positive or negative) on EU soils characterised. This list was developed from an ad hoc literature review and interviews conducted as part of the case studies and some additional interviews with researchers.
- Soil-related technological and social innovations have (or not) been widely adopted by the relevant stakeholders. Indeed, the impact of innovations on EU soil depends on the extent to which they are disseminated across the EU and used by farmers. The level of adoption of soil-relevant technologies was approached based on data available in relevant literature and from the case-study interviews.
- Specific factors are impacting (or not) the development and adoption of technological and social innovations by farmers and relevant stakeholders. In order to understand the level of adoption of these innovations, the analysis looks at the specific factors encouraging or hindering the adoption and development of these innovations. Findings are based on the literature review, previous evaluations, interviews carried out during the case studies or with EIP group leaders, and on an ad hoc survey carried out by Alliance Environnement targeting farms advisors[78], on technological and social innovations.

5.6.2. Technological and social innovations may have (or not) a significant effect on soil quality.

5.6.2.1. Inventory and typology of soil-related innovations and their expected or observed effects

Focusing on technological innovations that facilitate the work of farmers while improving soil quality and the environment, the study identified four relevant categories of innovations: agroecological practices and biological, mechanical and ICT-based technologies. They are identified in Table 20.

[77] Technological innovations can be defined as 'new products and processes and significant technological changes of products and processes' (OCDE (2015) *Frascati Manual 2015.*). Social innovations are characterised by processes of co-design or co-construction of innovation involving various stakeholders (e.g. politicians, farmers, citizens, scientists, etc.) and responding to societal demands that are not fully addressed by traditional markets and/or institutions; (Bock, B. B. (2012) 'Social innovation and sustainability; how to disentangle the buzzword and its application in the field of agriculture and rural development', *Studies in agricultural economics,* 114(2), pp. 57-63, Hubert, A. 2010. Empowering people, driving change: Social innovation in the European Union. BEPA-Bureau of European Policy Advisors, European Union.)

[78] This survey was sent to 264 farm advisors in the 10 case-study Member States. With the COVID-19 pandemic as a backdrop, the response rate was only 12%, with no respondents in one case study.

Table 20: Technological innovations positively contributing to sustainable soil management

TECHNOLOGICAL INNOVATIONS		DESCRIPTION
Agroecological practices[79]	Soil covers	Improvements of soil cover and crop rotations can lead to better soil quality without requiring specific technological innovations. Deep-rooting crops can limit subsoil compaction.
	Crop rotations	
	Deep rooting crops (e.g. alfalfa)	
Biological technologies	Soil eco-activators	Substance(s) and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance/benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality.
	Pest control	Reduces the amount of pesticide used, through the spraying of biological substances (e.g. hormones) to prevent pests from growing or reproducing.
	Nitrification inhibitors in soil	By limiting the microbial conversion of NH4 to NO_2 in soil, nitrification inhibitors decrease direct N_2O emissions and nitrate leaching. They also limit fertilisation needs.
	Selection of resistant crops	Improving the capacity of crops to resist pests and/or to adapt their agrophenology to the climatic conditions, crop selection can reduce the pollution linked to fertilisers and chemicals. Deep-rooting crops can limit soil compaction.
Mechanical technologies	Polyvalent/Flexible tyres / Caterpillar	Tyres with an ultra-flexible sidewall cause a larger footprint, generating less ground pressure.
	Rubber track systems for farm machines	Agricultural machinery equipped with rubber tracks to limit ground pressure.
	Automatic tyre pressure control system (Central Tyre Inflation System)	System allowing for specifically adapting tyre pressure according to the type of soil and situation.
	Soil decompaction technology (shanks subsoiler, Rotary subsoiling, etc.)	Equipment used to loosen and break up soil at depths below the level of a traditional plough.
	Reduced-till equipment / Soil working and seedbed preparation: seedbed combinations (strip-till and direct-seeding equipment, etc.)	Agricultural machinery making it possible to sow and prepare seedbeds under plant cover or residuals, or to create channels between rows.
	Low-ground-pressure machine (wide-span vehicle) / High speed operations while keeping vibrations low	Agricultural machinery with a specific design/capacity thought to reduce ground pressure and thus reduce soil compaction.
	Combined harvesters and planters, combined fertilisers and planters	Combined equipment making it possible to carry out several operations at the same time (planting and spraying and dripping, bringing seeds into direct contact with fertiliser)
	Slurry management technologies (e.g. tractor-trailer machinery used for slurry application)	Slurry application with trailers reduces GHG emissions. However, modern tractors used in slurry application have stand-alone weights of about 12 tonnes, and with trailer attached the rear axle alone may carry >14 tonnes.
ICT-based technologies (information and communication technologies)	Controlled Traffic Farming (CTF)	System that enables machinery to drive along repeatable tracks with accuracy using GPS/RTK technologies.
	Sensors (optical, airflow, electrochemical, electromagnetic, mechanical, tec.)	Sensors collect information on soil properties (soil nutrient levels, soil moisture, organic matter, salinity, etc.) to adapt field treatments.
	Variable Rate Application (VRA) technologies	Sensors that are mounted on the applicator measure the soil properties or crop characteristics at the same time. The information is then streamed in real-time and the exact localised dose of input (e.g. fertilisers, herbicides, pesticides, etc.) is calculated and applied. Data can also be obtained via airborne mapping devices.
	GPS monitoring of livestock	Technology that facilitates grassland management and avoids overgrazing.
	Airborne mapping devices (drones, satellites)	Imagery to create maps (e.g. nutrient map, crop biomass, plant stress, pests and diseases, soil properties, etc.) to plan localised and precise land management.
	Drone pulverisation (herbicide, fertiliser)	System to spray on localised area and with precise dose.
	Decision Support System	Models used via smartphone app or computer which take into account the complexity of many parameters and their implications to help decision-making.
	Robotics (Swarm or individual robots)	Swarm of robots or individual robots that reduce soil compaction and help in agricultural activities (e.g. weed control, ploughing, etc.).

Source: Alliance Environnement based on literature review, case studies and interviews within the framework of case studies and with researchers

[79] Agroecological practices are described in the literature review associated with EQ 1, and the contribution of the PAC to the development and level of adoption of these technologies is studied in EQ 2 and EQ 4 (based on the data available).

Though a large range of 'positive' technological innovations can be identified, there is also a trend of increasing size and weight load of machinery[80], posing a great risk to soil structure and soil health, as compaction of subsoil is primarily determined by wheel load (P. Schjønning et al., 2018)

Agroecological practices directly target the broadest range of soil threats, such as erosion by maintaining crop cover. This has been confirmed by the respondents of the survey, as well as by the stakeholders (e.g. farmers, researchers, farmer representatives) interviewed during the case studies. They view these practices or productions systems such as cover crops, intercropping, conservation agriculture as positive innovations for soil.

Other technological innovations focus on specific soil components. In particular, mechanical technologies tackle compaction and erosion. They aim at limiting pressure on the ground by modifying tyres and design of machinery, or by limiting tracks and tillage on the fields. Biological technologies focus more on nutrient balance and soil organic matter and pollution. Moreover, ICT-based technologies mainly target soil pollution by helping farmers to properly use the right amount of fertiliser and PPPs. The indirect effect on soil will depend on how farmers modify their practices accordingly. The innovations limiting inputs of fertiliser mostly have an impact on water quality, rather than on soil, due to the nitrate leaching process (Schröder et al., 2004).

The impacts of these innovations are highly dependent on timing, management skills and territory. For instance, slurry trailers used at the wrong time (e.g. high-water saturation in soil) can prompt more damage than without the technology.

Most of the current social innovations involve the sharing of soil-related knowledge, skills and equipment through social networks, online platforms or exchange groups. These innovations contribute to building better Agricultural Knowledge and Innovation Systems (AKIS[81]) and make it possible to create and/or share knowledge with a bottom-up approach (Dargan and Shucksmith, 2008). Innovations in governance, funding and relations with consumers also promote sustainable soil management. When implemented, these innovations come a variety of forms, specific to the local context and to the needs of the stakeholders involved: examples for each category are provided in Table 21. It is noteworthy that private initiatives (such as labels, platforms, etc.) play a significant role in their implementation.

Table 21: Social innovations positively contributing to sustainable soil management

SOCIAL INNOVATIONS	DESCRIPTION
Online forums or platforms on management practices for soil conservation	This concept takes advantage of the internet to connect farmers and stakeholders beyond the neighbourhood scale, allowing them to share ideas and knowledge and to discuss their agricultural activities. Some social networks have been identified as contributing to the sharing of knowledge on SSM between farmers and researchers (Mills et al., 2018).
Groups of farmers or mix stakeholders (e.g. farmers, advisers, citizens, policy maker, etc.) working on local challenges linked to soil quality	The actions of the groups are taken towards 'shared interests'; they involve multiple stakeholders to discuss common challenges and raise the awareness of farmers. There are various forms of collective approaches, depending on the issue to be addressed and the local situation: bottom-up initiatives (coming from farmers or other local stakeholders, community-led and bringing a variety of stakeholders together to generate action); top-down initiatives (coming from public authorities) or a combination of both (where actions are coordinated between practitioners and authorities). According to (Reed *et al.*, 2017), the Field Labs initiative is 'as much about being given the tools and the confidence to go away and try things, as it is about acquiring specific knowledge, skills and practices.'

[80] From the 1960s to 2009, wheel loads of combine harvesters have increased by one ton every seven years, and those of tractors shifted from 1Mg in 1955 to 4Mg in 2009. Keller, T., Sandin, M., Colombi, T., Horn, R. and Or, D. (2019) 'Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning', *Soil and Tillage Research,* 194, pp. 104293.

[81] The term Agricultural Knowledge and Innovation Systems (AKIS) is used to describe the whole knowledge exchange system: the ways people and organisations interact within a country or a region. AKIS can include farming practice, businesses, authorities, research, etc. and can vary a lot, depending on the country or sector. (https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_knowledge_systems_2018_en_web.pdf).

SOCIAL INNOVATIONS	DESCRIPTION
Groups of consumers ensuring the purchase of the production of small local farmers enacting environmentally friendly practices	Community supported agriculture (CSA) is a partnership between farmers and consumers in which the responsibilities, risks and rewards of farming are shared. CSAs around the world share common principles, one of which is agroecological farming methods (sometimes requiring organic certification).
Groups of farmers sharing equipment for optimised soil management (e.g. direct-seeding equipment)	Groups of farmers organised in a specific body in order to share investment and operating costs of agricultural machinery. This type of initiative promotes innovation and practice change in agriculture.
Financing of sustainable management of the soils through crowdfunding and sponsorship	Crowdfunding refers to raising capital through large numbers of small contributions for a specific project. The financial support can be a donation, a donation with something in return (the consumer obtains local products or small services from the farmer) or a loan paid with low rates. For example, since 2015 a French crowd funding platform dedicated to agricultural and food projects has helped 2 500 projects. The plat form has 160 000 members and an 85% success rate.
Label or private brands promoting sustainable soil management	The label can guarantee some sustainable soil management practices, and it can foster the providing of ecosystem services from landscape and agricultural activities by by obtaining real market recognition thanks to inter-sectoral cooperation. In Austria, the label 'Healthy soil for healthy food', started in 2015, introduced soil conservation practices over 1 200 ha in 2017 with 59 farmers involved[82]. In France, the 'low carbon' label launched in 2019 encourages the increase of SOC through various agriculture practices[83].
Organisations which purchase land of particular interest (e.g. environmental or social) in order to conserve it.	The organisation can lease or lend these areas to farmers, applying specific management rules. In England, the task of the Soil Association Land Trust established in 2007 is to acquire and manage organic farms, to promote access to land for future organic farmers, and to allow citizens to reconnect to agriculture, in particular thanks to activities and open days on the farms.
Land stewardship	A strategy to involve landowners, civil society and users (e.g. farmers, foresters, shepherds, hunters, passive recreationalists) in the conservation of nature and landscapes, often with the support of a voluntary contract (Sabaté et al., 2013). For example, the 'Grazing in Sønderup stream valley' project was led in Denmark between 2012 and 2014, with the aim of developing coordinated management of the stream-side meadows through grazing (ENRD, 2018).
Crowdsourcing of soil data / Bottom-up participatory research to be discussed	Uses the potential of the population to collect data on soils through apps or websites. For instance, a free mobile app provides 'regional information on soil depth, texture, pH and organic-matter content, and on vegetation habitats. The users can upload photos and descriptions of their local soils. More than 500 entries have so far contributed to this valuable data bank of soil properties in different localities' (Shelley, Lawley and Robinson, 2013).

Source: Alliance Environnement based on literature review, case studies and interviews

It is difficult to assess the effects of social innovations. Indeed, although these innovations help to spread soil-friendly practices, their effects are essentially indirect, and they depend hugely on stakeholders' will and how they apply what they may learn. Moreover, the soil threats addressed by social innovations are as diverse as the sustainable soil management practices and innovations that are promoted by the platforms, the labels, the groups of farmers and any other social innovations. The effect of these innovations will also depend on the local area's characteristics, soil issues, biogeographical zones or the farming system on which the social innovation is applied.

5.6.2.2. Soil-related technological and social innovations have (or not) been widely adopted by the relevant stakeholders.

Few studies have investigated the level of adoption of innovations in agriculture in the EU. Literature (e.g. Barnes et al., 2019) and the survey carried out by Alliance Environnement agree on the fact that most technological innovations are not widely adopted. Indeed, current adoption rates of machine guidance and Variable Rate Nitrogen Application in the EU remain low (SOTO EMBODAS et al., 2019). Within the EU, the levels of adoption of precision farming technologies can vary among Member States. They are more widespread in central and northern Europe, where farm size is greater (EIP-AGRI, 2015).

Data on social innovation is more difficult to obtain, given it concerns many local initiatives. Data are available, however, for some initiatives: the study of 62 LIFE projects throughout the 28 Member States, for example, reveals that there were 16 269 land stewardship organisations in 2015 in Europe and that in 2019 45% of French farmers were members of an equipment-sharing cooperative.

[82] https://ec.europa.eu/environment/soil/news_en.html

[83] https://agriculture.gouv.fr/quest-ce-que-le-label-bas-carbone

5.6.3. Specific factors impacted (or not) the development and adoption of technological and social innovations by farmers and relevant stakeholders

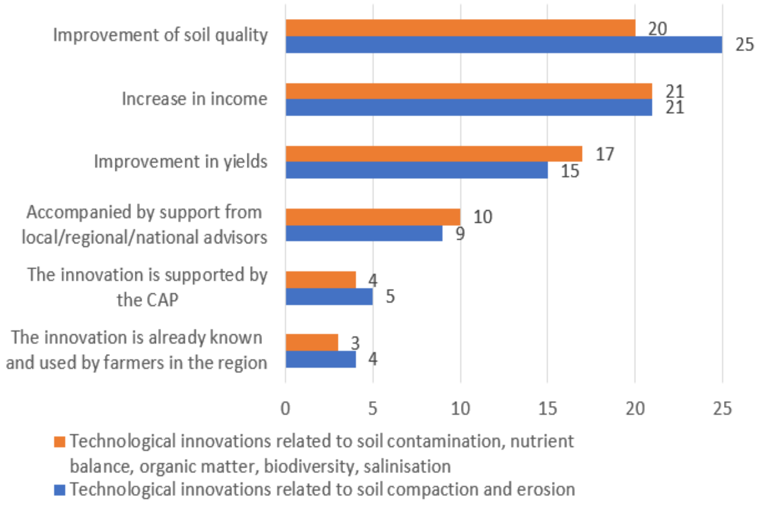
5.6.3.1. Factors impacting the emergence of soil-related innovations

The level of adoption on innovations depends on factors that can be both economic, structural or linked to the awareness of the agricultural stakeholders on soil issues. Among the factors encouraging their adoption, the literature shows that an enabling environment is needed for farmers to adopt innovations. Indeed, farmers are often subject to a broad web of influencers and that their learning about new technologies and new practices occurs in a complex social learning system (Oreszczyn, Lane and Carr, 2010). This enabling environment especially involves peer-to-peer exchanges (Knook et al., 2020), access to quality information and advisory services (Baumgart-Getz, Prokopy and Floress, 2012; Mills et al., 2019; Barnes et al., 2019) and access to ICT (Kiiza and Pederson, 2012) that that help remove some geographical and time constraints. The partiality of the advice may also be significant, because nowadays, in some Member States, farmers rely mostly on private companies for consultancy services (Swanson and Rajalahti, 2010). Indeed, a recent study showed that advisory services give low priority to sustainable soil management (Ingram and Mills, 2019).

To a limited extent, the CAP can contribute to the development and dissemination of innovation through exchange groups such as EIP groups (see Chapter 5.6.3.2).

The results of the survey of advisors carried out as part of this evaluation study show that the improvement of soil quality and income are the two main reasons for adopting the technological innovations mentioned in the survey. The CAP support does not appear to be a motivation to adopt these technologies. Care is necessary when observing these findings, because of the limited pool of respondents.

Figure 12: **Farmers' motivations to adopt technological innovations**



Source: Survey of farm advisors, answers to the question: 'what are the main motivations to adopt these innovations?'

However, the results are confirmed by an in-depth analysis of drivers and barriers governing soil management by farmers carried out by the CATCH-C project (Pronk et al., 2015), which shows that for agroecological practices (e.g. catch and cover crops, green manure, etc.), the main drivers concern soil quality (e.g. reduced erosion, more soil humus, better soil structure, etc.) rather than financial reasons.

Regarding social innovation, given that these innovations often require collaboration among stakeholders, strong leadership can lead to better adoption of the innovation (Pahl-Wostl et al., 2007).

As for the barriers to the adoption and diffusion of technological innovations, a recent study focusing on climate-smart agriculture technologies in Europe, including sustainable land management practices, showed that barriers exist on both the demand and supply sides (Long, Blok and Coninx, 2016). Among users, the main barriers are low awareness of climate-smart agriculture and technologies, high costs and long return on investment periods, and lack of verified impact on technologies. Farm size can also be an obstacle. These findings corroborate the results of the survey sent to farm advisors as well as the findings from the CATCH-C project (Pronk et al., 2015).

In addition, some soil-related technological innovations are adopted at a low rate because they are still at the design level and are not fully available in European markets. Indeed, there is often a time span between the start of the research and its mainstream application.

Finally, policy instruments and regulation can hinder the spread of the innovation. For instance, legislation on drone use is not the same in each EU Member State (Reger, Bauerdick and Bernhardt, 2018). In order to address EU regulatory obstacles to innovation, in 2016 the EU launched the 'Innovation Deals', which act as a cooperation bridge between innovators, authorities and commission services. However, so far, no soil-related initiative has been supported by this EU instrument.

5.6.3.2. Examples of the use of the EIP and other RD measures to support soil-related innovations

The European Innovation Partnership (EIP-AGRI)[84] supported by Measure M16, encourages cooperation among farmers, researchers, advisors, businesses, environmental groups, consumer interest groups and other NGOs to share knowledge and disseminate innovative solutions.

EIP-AGRI focus groups bring together 20 experts that collect the best practices in a specific field as well as challenges and opportunities, and then suggest and prioritise innovative actions and ways to disseminate good practices. This can lead to the establishment of EIP Operational Groups in order to advance innovation in the agricultural and forestry sectors.

On the EIP-AGRI website, systematic research based on key words[85] has identified 221 operational groups directly or indirectly linked to soil issues. Some examples are shown in Table 22.

Table 22: Examples of EIP-AGRI Focus or Operational Groups focusing on soil issues

Project	Soil issue addressed	Objectives
Moving from source to sink in arable farming	SOC	Determine which cost-effective farm management practices and tools could foster and ensure long-lasting carbon storage in arable farming,
Soil salinisation	Salinisation	Determine how to maintain agricultural productivity by preventing, reducing or adapting to soil salinity
Using 'Internet of Things' (IoT) technology to improve slurry management on farms (2020-2021)	Soil nutrient balance	This project will test a range of sensors implementing various parameters: soil condition, water table level, rainfall levels and air temperature. The farmers are hoping that gaining real-time information on the conditions of the land will allow them to make decisions on slurry management quickly and safely.
Development of robotic weed management equipment (2019-2020)	Soil pollution	This project includes plans to develop weed management equipment that would be able to move autonomously on a field and identify weeds and crops, as well as a high-power laser or precisely positioned mechanical tool that would be used to destroy weeds or considerably hinder their further growth.

Source: Alliance Environnement based on EIP-AGRI website

[84] EIP-AGRI is a policy framework and networking initiative designed to support agricultural productivity and sustainability through the interactive innovation model. It is mainly supported by Measure M16.1 and Sub-measure M16.5. In some Member States, the Operational Groups are financed under measures other than M16, such as M1 in Bulgaria and Finland, M2 in Croatia and Slovakia, and M4 in Finland and Sweden (Alliance Environnement, 2017). The objectives, tasks and issues that can be addressed by the EIP group are detailed in Article 53 of Regulation (EU) No 1305/2013.

[85] Key words: Biological health of soil; Soil biodiversity; Soil microbial biomass; Soil management technology; Soil management; Soil; Soil aeration; Soil compaction; Soil degradation; Soil fertility; Soil health; Soil moisture content; Soil organic matter; Soil quality; Soil respiration; Soil sealing; Soil water availability.

Box 12: EIP-AGRI action supporting innovations for soil erosion risk mitigation and better management of vineyards on hills and in mountain landscapes_SOiLUTION SYSTEM in Italy (Verona)

The SOiLUTION SYSTEM project (2019-2021) intends to develop innovative and sustainable integrated systems of actions and technologies, with the aim of reducing the risk of soil erosion – and, in general, soil instability – in a context of high hydrogeological risk, and to maintain the landscape value of hillsides and mountain vineyards in terraces. The EIP action, through the cooperation measures (M16.1 and M16.2), supports 100% of the project (EUR 447 700). The project is thus enabling development of some soil-related innovations: an unmanned aerial vehicle (UAV) survey and a linked algorithm to understand and monitor erosion processes (mapping and 3D modelling); a new light and cheap system for runoff sampling at field scale; mechanised electric and track-equipped prototypes able to operate on steep slopes, with low environmental impact; a new low-cost and low-impact technique for consolidation and restoration of terraces; soil conservation techniques to reduce risk of erosion and increase soil biodiversity.

The first results from the ongoing project reveal that the mapping and 3D modelling based on the UAV survey are accurate and promising for reaching better adapt soil management. According to the stakeholders interviewed, the most important action has been the cooperation between the two wineries and the consortium of researchers and companies, thereby making it possible to share knowledge and experience – in particular in the wine sector, which is traditionally very discreet about its production system.

The project also supported a large-scale national and international strategy of dissemination through seminars and events to share the discoveries, as well as through social media to raise the awareness of citizens about soil concerns.

Source: Interview by Alliance Environment (2020) and project website[86].

Support for productive investments (M4.1) can contribute to the spreading of innovation by helping farmers to invest in soil-related technologies. For example, since 2019 in Spain-Aragon, M4.1 can be used by young farmers for the purchase of direct-seeding machines.

The LEADER Programme can contribute to innovation in the EU, and local action groups (LAGs) are required to take innovation into consideration in their Local Development Strategies (LDS). Although social innovation is encouraged by LEADER (Dargan and Shucksmith, 2008), soil-related issues are not widely addressed.

Other European programmes or instruments (LIFE[87], Horizon 2020[88], etc.) may also contribute to the adoption of soil-related innovations.

5.6.4. ANSWER TO EVALUATION QUESTION 9

The lack of data available to answer the question is a barrier to a clear vision of how innovations contribute to soil quality. However, the findings suggest that soil-related innovations have up to now contributed to soil quality improvement slightly.

First of all, the literature review identified a set of technological and social innovations with a potential positive effect on soil. Few technologies have direct effects on soil issues, and there is a huge disparity in the scope of soil issues addressed by the current technological innovations. Soil compaction is by far the most tackled soil issue, while SOM, salinisation and soil biodiversity are barely targeted by these innovations. However, agroecological practices (e.g. cover crops and intercropping) make it possible to complement, with direct effects, the scope of soil issues addressed by high-end technological innovations. The effects of innovations as a whole are highly dependent on timing, management skills, climate and territory.

On the other hand, the survey to farm advisors and the case-study interviews suggested that the levels of adoption remain very low across the EU because of several factors: economic reasons, lack of evidence of their effects on soil and lack of knowledge. The low priority given by advisory services to

[86] http://www.soilutionsystem.com

[87] The LIFE programme is the EU's funding instrument for the environment and climate action.

[88] Horizon 2020 is a EU Research and Innovation programme spanning from 2014 to 2020.

the protection of soil-quality, as well as the heterogenous quality and partiality of advisory services, can also hamper the uptake of these innovations.

As for social innovations, data are even sparser, but such initiatives are often an option for disseminating innovation by implementing knowledge-sharing systems through multi-stakeholder groups or social media platforms. Their indirect effects on soils depend on the extent to which farmers appropriate the knowledge learnt. Social innovation initiatives remain a useful tool for spreading innovative managing practices, by involving consumers through labels or crowdfunding and by involving landowners through land stewardship. Indeed, it both raises awareness among farmers and consumers on soil issues specific to their local context and financially rewards some practice changes. In the long term, these social innovations may help to increase the adoption rate of soil-related technological innovations.

Against this backdrop, the EU may participate in the dissemination of sustainable soil practices and innovations thanks to various CAP measures (M1, M2 and especially M16) that encourage investments (under M4). The CAP also spurs cooperation among stakeholders through EIP-Agri Focus and Operational Groups. Other European non-CAP mechanisms can be used, such as research programmes (e.g. Horizon 2020) but they were not developed in the analysis.

6. EFFICIENCY

6.1. EQ 10: TO WHAT EXTENT HAVE THE RELEVANT CAP INSTRUMENT AND MEASURES AS IMPLEMENTED BY THE MEMBER STATES GENERATED THE BEST POSSIBLE RESULTS ON SOIL QUALITY WITH ITS AVAILABLE BUDGET?

6.1.1. UNDERSTANDING AND METHOD

The question investigates the relationship between the budget invested for implementation of soil-relevant CAP instruments and measures, and the results achieved in soil quality. The analysis focuses on the measures with a direct and intended effect on sustainable soil management, i.e. Category 1 in Table 2. The following judgement criteria are considered:

- The crop diversification measure provided (or not) the best results on soil-quality improvement with the budget spent. This criterion The analysis built on previous findings of the evaluation study on the payment for agricultural practices beneficial for the climate and environment (Alliance Environnement, 2017b) was rounded out by considering the effects of the measure on soil (previous EQ 4 and 5), as well as by the opinions of local authorities and farmer representatives in case-study Member States.
- Payment rates granted under the relevant RDP measures[89] were adequate to foster change/maintenance of soil-relevant practices[90]. Indeed, RD measures are voluntary, and their results will be expanded if largely implemented. However, their uptake by farmers or other stakeholders depends on their attractiveness, i.e. whether the payment rate/unitary amount granted is sufficient to offset the opportunity cost[91] incurred by farmers. Information sources for the analysis were extracted from interviews and monitoring data, to determine whether RD measures implemented in case-study Member States/regions were sufficiently attractive to achieve the best possible effects on soil quality.
- CAP instruments and measures were (or not) necessary to foster change/maintenance in practices beneficial for sustainable soil management. Based on stakeholders' opinions, the analysis appraises to what extent the agricultural practices would have been changed or maintained by farmers in the absence of support. Potential deadweight effect[92] associated with the implementation of the soil-relevant CAP instruments and measures is also investigated.

The costs related to implementation of GAECs 4, 5 and 6 are associated to the control of the CAP beneficiaries' compliance: they are considered in EQ 11, which examines the administrative burden arising from the management and control of the soil-relevant measures. Therefore, no analysis on the efficiency of GAECs 4, 5 and 6 is presented in the chapter below.

[89] i.e. measures with an intended effect on soil sustainable management (M8.1, M8.2, M8.5, M10.1) and measures with potential direct effects on soil (e.g. M4.1, M4.3, M4.4).

[90] The targeting of measures toward specific areas/beneficiaries helps increase the measures' efficiency (by focusing the payments where they are most needed). This was examined in EQ 12 assessing, which assessed the relevance of the measures.

[91] In this evaluation, the opportunity cost for farmers (beneficiaries) is defined as a combination of the cost incurred by not enjoying benefits from the changed practice (e.g. income foregone) and the cost of all investments necessary to carry out the new practice. Thus, it excludes costs related to delays in payments and administrative costs (addressed in EQ 11).

[92] Deadweight effect refers to costs which yield no benefit or could have been avoided. Cases of deadweight indicate that the available budget could have been used to fund other measures or support other practices.

6.1.2. THE CROP DIVERSIFICATION MEASURE PROVIDED (OR NOT) THE BEST RESULTS ON SOIL-QUALITY IMPROVEMENT WITH THE BUDGET SPENT

Previous evaluation studies of the CAP concluded that insufficient targeting of greening measures impacted their efficiency (Alliance Environnement, 2017b) and that crop diversification specifically did not lead to significant positive results (Alliance Environnement, 2019b)[93]. Findings from EQ 4 support this statement, as they show that effects of the crop diversification measure were low at EU level. In most areas, farms were already diversified (e.g. Belgium-Wallonia, Czechia, Denmark and Sweden) or exempted from crop diversification requirements when smaller than 10 ha of arable land (e.g. Italy and Sweden). Managing authorities interviewed in Ireland and Greece, as well as NGOs and farm advisors in Greece, also believed that crop diversification requirements would have been met in the absence of the measure. Therefore, in 7 out of the 10 case studies (Belgium-Wallonia, Bulgaria, Czechia, Germany-Bavaria, Spain-Aragon, Italy-Tuscany, Sweden), the majority of the stakeholders interviewed (from beneficiaries to managing authorities) confirmed the low level of efficiency of the crop diversification measure, as regards its low level of effects on sustainable soil management[94].

In the effectiveness analysis (see EQ 4), however, it was shown that the crop diversification measure fostered sustainable soil management practices in some Member States; for example, in Spain-Aragon, a researcher and a farmer representative stated that the crop diversification measure had put an end to monocropping and promoted the introduction of leguminous plants, thereby improving soil. In Bulgaria as well, managing authorities stated that the crop diversification measure could be considered as efficient with regard to its positive effects on soil quality.

6.1.3. THE PAYMENT RATE WAS ADEQUATE (OR NOT) TO FOSTER CHANGE/MAINTENANCE OF SOIL-RELEVANT PRACTICES

According to Article 28 of Regulation (EU) No 1305/2020, payments delivered under AECM must 'compensate beneficiaries for all or part of the additional costs and income foregone resulting from the commitments made'. Payment can also cover transaction costs up to a value of 20% of the premium paid (30% in the case of commitments undertaken by groups of farmers/land managers). Transaction costs are defined as all costs related to the various stages of the measure's implementation, such as set-up, running, management and control stages (Alliance Environnement, 2019b). In addition, the report on administrative burden (Ecorys, 2018) reminds that the administrative cost of agricultural policy is mostly related to transaction costs. Supports delivered under the AECM (M10.1) shall not exceed max. amounts laid down in Annex II (i.e. EUR 600/ha for annual crops; EUR 900/ha for specialised perennial crops; EUR 450/ha for other land uses; EUR 200/livestock units) but those amounts 'may be increased in duly substantiated cases taking into account specific circumstances to be justified in the rural development programmes'.

Table 23 shows examples of payment amounts granted under the soil-relevant RD measures in case-study Member States and stakeholders' opinions on its ability to foster change/maintenance of soil-relevant practices.

---

[93] Negotiations prior to 2014 on the design of greening measures had resulted in a lower level of requirements than those initially set at EU level under these measures and granted greater flexibility to Member States to decide how to implement the greening measures on their territory.

[94] From a budgetary point of view, crop diversification is one of the three greening measures that farmers must comply with to receive the associated share of 30% of the direct payments budget. Farmers who do not comply with greening obligations receive reduced payments. Hence, the relative budget delivered to farmers complying with the crop diversification requirements is significant compared to the effects achieved in soil.

Table 23: Examples of payments granted to support specific practices under soil-relevant RD measures in case-study Member States

CS	Measures	Support rate	Source
Land use			
Maintenance and creation of landscape elements			
Sweden	M10.1 Basic and adapted buffer zones	Construction and maintenance of buffer zones on arable land, either along water courses (basic) or on erosion spots (adapted): EUR 258/ha for both (0.3 ha minimum)	Managing authorities
Wallonia (BE)	M10.1.B1A hedgerows	Support for planting and maintaining hedgerows notably with an objective to fight against erosion and mudflows: EUR 25/200 m of hedgerows or 20 trees	All stakeholders
Creation, loss and maintenance of grasslands			
Sweden	M10.1 Ley management	Increasing the area and the lifespan of temporary grasslands: €47/ha (2 ha minimum), up to €57/ha if the plot doesn't count for greening payments	Managing authorities Farm advisor
Wallonia (BE)	M10.1.B2 Natural pasture	Support for maintenance of natural pasture: €200/ha to €220/ha	All stakeholders
Management practices			
Crop management practices (crop management/soil cover)			
Tuscany (IT)	M10.1.1 Soil and organic matter conservation	Direct seeding: EUR 220/ha Introduction of cover crops: EUR 240/ha Direct seeding and introduction of cover crops: EUR 350/ha Grassing of specialised tree crops: EUR 130/ha Sowing on autumn winter cereal with legumes: EUR 200/ha	Farmers representative and managing authorities
Aragon (ES)	M10.1.a Stubble maintenance	Maintaining the stubble surface until December 31, leaving the remains of the crop on the ground and performing fallow in rainfed plots: EUR 50/ha	Most stakeholders
Ireland	M10.1 Catch crops	Establishing catch crops annually using light cultivation techniques: EUR 155/ha	Farmers representative and managing authorities
Greece	M10.1.4 Reduction of water pollution from agricultural activity	Different sets of commitment involving fallows, crop rotation and buffer zones: EUR 600/ha	All stakeholders
Pest, diseases and fertilisation management			
Wallonia (BE)	M11.1 Conversion to organic farming	Grassland and forage crops: 350 (<60 ha) and 270 (>60 ha) EUR /ha Other annual crops: 550 (<60 ha) then 390 (>60 ha) EUR /ha Fruits vegetable and seeds: 1 050 (<3 ha) then 900 (<14 ha) then 550 (>14 ha) EUR /ha	All stakeholders
Bavaria (DE)	M11.1 Conversion to organic farming	Grassland and arable land: EUR 350/ha Land used for gardening: EUR 915/ha Permanent crops: EUR 1 250/ha	Environmental associations
Tillage and traffic management			
Wallonia (BE)	M4.1 investment in agricultural holdings (no soil related type of operations explicitly mentioned in the RDP)	Basic rate at 10% of the eligible cost (20% for CUMA) but up to 40% depending on farm features (including organic production for instance)	Managing authorities
Aragon (ES)	M4.1.a Modernisation of farms including conservation agriculture	Notably investments in conservation agriculture machinery: Basic rate at 40% but up to 60% of the eligible cost depending on farm features (young farmers, organic farming, collective investments, etc.)	Farmers representative
Ireland	M10.1 Minimum tillage	Establishing a crop using minimum tillage equipment: €40/ha	Farmers representative and managing authorities

Alliance Environnement, based on the case studies

Legend (cell colour in the Source column):
- Green: Payment rate high enough
- Orange: Payment rate not high enough in some cases
- Red: Payment rate not high enough in most cases

Source: case-study RDPs and case-study interviews

The table illustrates that, in Belgium-Wallonia, Ireland and Sweden, the payment levels set under certain AECMs (M10.1) may not be high enough to cover the opportunity cost for highly productive farms (e.g. in Sweden, AECMs on ley management and buffer zones; in Wallonia, the AECM on pasture). Managing authorities considered that it impacted the uptake of the measure in Ireland. In Italy-Tuscany, farmers' representatives considered AECM (M10.1) payment rates to be inadequate as regards the high administrative burden involved. In Greece and Spain-Aragon, all the interviewed stakeholders agreed that the premiums delivered under AECMs (M10.1) are quite incentive to adopt the practices encouraged in the AECMS. .

In Germany-Bavaria, environmental associations regretted the low appeal of support for organic farming (M11) especially because of the impossibility (decided by the regional authority) of combining this payment with AECMs (M10.1) (e.g. on diverse crop rotations). Conversely, in Belgium-Wallonia, payment could be added, and the support is considered as sufficient for a change of practices.

Investment support for soil-relevant machinery equipment was not often provided under the investment measure (M4.1) across case-study Member States and regions. In Greece and Spain, soil-relevant investments were supported under the forestry measure (M8) and the fruit and vegetable environmental measures (CMO regulation); the former was assessed as having a sufficient payment rate by the stakeholders interviewed in Greece, and the latter was assessed so in Spain.

As shown in Table 23, AECMs (M10.1) and the investment measure (M4.1) were often mentioned as not providing sufficient payment rates or reimbursements to foster changes by some farmers (i.e. highly productive farms with high opportunity costs in the case of AECMs) or most farmers (i.e. payments are generally not sufficient to attract farmers according to the stakeholders interviewed). There is, however, a trade-off between increasing payment rates of AECMs to cover opportunity costs for highly productive farms and keeping payment rates to a suitable level for less productive beneficiaries, in order to avoid overfunding. Indeed, payments for management commitments are calculated at regional level and not at farmer level, embracing a variety of farming systems and environmental conditions. The use of this method may imply a limited undercompensation or overcompensation of the farmer.

The CAP framework provides the possibility to target specific crop types or areas with different payment rates, either within the same type of operation (examples provided in the table above) or by supporting different types of operations oriented towards a specific farming system or farmland type. Doing so enables to give a compensation not too far from the right value.

6.1.4. THE CAP INSTRUMENTS AND MEASURES WERE NECESSARY (OR NOT) TO FOSTER CHANGE IN PRACTICES BENEFICIAL FOR THE SUSTAINABLE SOIL MANAGEMENT

To appraise the extent to which the budget allocated to the soil-relevant CAP instruments and measures had generated the best possible results on soil quality, the analysis considered whether the various types of support were necessary for achieving the positive effects on soil, i.e. whether the beneficial activities would have been implemented in the absence of support.

- Implementation of non-profitable activities

The case studies have shown that support has been necessary to foster non-profitable practices beneficial for soil protection or to target specific types of farmers, e.g. farmers not aware of soil issues (Belgium-Wallonia, Czechia) or small- and medium-size farmers with less investment capacity (Italy-Tuscany). In Sweden, the farmer representative highlighted that the AECM (M10.1) on buffer zones, which does not generate direct economic gains, was a very cost-effective measure as regards its positive results on soil erosion. In Greece, the activities having the most positive impacts on soil quality (i.e. fallows, green covers or buffer zones) would not have been implemented without CAP support.

- Maintenance of traditional activities

The analysis distinguished between the activities already implemented by farmers and that would have been carried out by them in the absence of CAP support (deadweight effect) and the activities traditionally implemented by farmers and at risk of being stopped for economic reasons when not supported.

The stakeholders interviewed during the case studies outlined several practices beneficial for soil that would have, according to them, been implemented in the absence of CAP support, e.g. ley management under AECMs (M10.1) in Sweden[95]. As mentioned earlier, the introduction of the crop diversification measure under Pillar I did not lead farmers to significantly improve their practices (Czechia, Denmark, Ireland, Greece, Sweden). This was also pointed out in the evaluation of the greening measures (Alliance Environnement, 2017b), which indicated that 70% of arable land and 53% of farms already met the requirements for crop diversification in the case-study Member States. Concerning forestry measures relevant for soil, the evaluation of forestry measures (Alliance Environnement, 2017a) showed that operations to prevent and restore damage to forests (M8.3 and M8.4) would have been carried out without the RD support, but with less magnitude.

Nevertheless, CAP support also contributed to preventing a trend towards decrease in sustainable practices, as mentioned in Spain-Aragon. In this region, for instance, sainfoin cultivation and inter-row plant cover for woody crops supported under AECMs (M10.1) are practices considered as traditional. This was also a significant statement of the evaluation of the greening measures (Alliance Environnement, 2017b). The effectiveness analysis also outlined the importance of AECMs (M10.1), organic farming (M11) and permanent grassland (greening) to prevent the decline of grassland areas. In these cases, the CAP instruments and measures are necessary for maintaining beneficial practices for sustainable soil management.

6.1.5. Answer to evaluation question 10

According to the previous evaluations and the stakeholders interviewed in the case-study Member States, the efficiency of the crop diversification measure is limited, mostly because it did not foster significant changes in agricultural practices (Czechia, Denmark, Ireland, Greece, Sweden).. Although the effectiveness analysis (EQ 4) has shown that crop diversification locally promoted sustainable soil management practices (e.g. crop rotation or introduction of nitrogen-fixing crops), these positive one-off effects remained limited. The analysis revealed the low level of requirements set for farmers under the measure that hindered its effects and related efficiency, and it highlighted potential improvements: the stakeholders interviewed suggested that types of crops could be imposed (Spain-Aragon, Italy-Tuscany, Sweden) or that the requirement could be increased to a higher number of crops (Bulgaria).

Regarding soil-relevant RD measures, the information collected during the case studies have shown that the payment levels provided under these measures sometimes hindered their attractiveness (and therefore their effectiveness). This is especially true for AECMs (M10.1), for which the payment rate granted under a specific operation may not be attractive enough for highly productive farms (Belgium-Wallonia, Czechia, Germany-Bavaria, Ireland, Sweden). However, for most of the stakeholders interviewed, the payment rate of RD soil-relevant measures was found high enough to offset opportunity costs, but sometimes too low to cover the administrative costs further incurred by beneficiaries as part of transaction costs (e.g. M10.1 in Italy-Tuscany). Therefore, the payment rates of AECMs (M10.1) were not systematically sufficient to achieve the uptake necessary to address the needs

[95] A farm advisor considered one of the key AECMs addressing soil issues (ley management) to be adopted only by farmers already cultivating hay.

identified, to generate positive results and to foster the implementation of soil-relevant activities. On the other hand, payments rates under forestry measures (M8), the fruits and vegetables support scheme environmental measures (CMO regulation) and organic farming (M11) were generally found to be set at an appropriate level to encourage application by farmers.

As previously described, the CAP payments were not always necessary to foster the implementation of practices beneficial for soil protection. However, the analysis demonstrated that support has been necessary to foster unprofitable practices and land use (e.g. buffer zones (Sweden)) and to prevent decline in traditional practices beneficial for soil protection, such as sainfoin cultivation and inter-row plant cover for woody crops, as mentioned in Spain-Aragon.

6.2. EQ 11: To what extent are the administrative burden and administrative costs, also created through monitoring and reporting mechanisms, proportionate to the given support and the results achieved?

6.2.1. Understanding and method

This question investigates the administrative burden generated by the implementation of the soil-relevant measures and its proportionality with the support provided and results achieved in sustainable soil management. The analysis focused on the CAP instruments and measures designed to address sustainable soil management (i.e. Category 1 in Table 2).

As a preliminary step, the amount, types and sources of administrative burden associated with the implementation of soil-relevant CAP instruments and measures were identified based on data from other studies and case-study findings.

The analysis considered the following judgement criteria:

- Administrative procedures and increased control costs can be justified (or not) when compared to the budget granted for the implementation of the measure. The analysis looked at the area concerned (when available), as administrative burden can indeed arise from large-scale implementation and the budget involved in the implementation of soil-relevant measures/types of operations characterised by high administrative burden and costs.
- Additional costs and administrative burden can be justified when the heaviest measures are also the most effective. The analysis looked at the effects of the instruments/measures on sustainable soil management (investigated in EQ 4, 5 and 6) to assess whether the administrative costs associated with their implementation are proportionate to the effects achieved.
- Additional costs and administrative burden can be justified when they arise from procedures t**hat are necessary to ensure/assess the measure's effectiveness**. The analysis of the effects achieved by the measures characterised by significant administrative burden, as well as the opinions of the stakeholders interviewed, have helped to determine whether the administrative burden is necessary and justified by their effects.

6.2.2. Preliminary analysis of the administrative burden associated with soil-relevant measures

At the managing authorities level

Table 24 below provides a synthesis of the opinions collected in case studies as regards the administrative burden associated with the management, controls and monitoring of the measures. It shows that managing authorities reported high administrative burden arising from the monitoring and reporting obligations set by the EU regulation[96].

The implementation of EU requirements related to controls also generated administrative burden, especially for greening measures (Sweden), GAEC 6 (Greece, Sweden) and AECMs (M10.1) (Belgium-Wallonia, Greece, Italy). It was mentioned in Italy-Tuscany and Sweden that EU provisions related to controls are burdensome to implement, especially as they are time-consuming. On-site inspections in particular are considered costly for administrations in Czechia. For greening measures, high control costs were mainly explained by the necessity to build a new control IT system (Land Parcel Identification System) during the first years of implementation and on-farm checks obligations (Alliance Environnement, 2017b). Previous evaluations also outlined high control costs of the forestry measure (M8) and especially AECMs (M10.1) (Ecorys, 2018; Alliance Environnement, 2017a, Alliance Environnement, 2017b; Alliance Environnement, 2019b). It should be noted that soil-relevant measures do not generate extra administrative burden when compared to other CAP measures (according to managing authorities in Czechia, Denmark, Bavaria-Germany, Greece). The cost of controls was found to be higher for RD measures than for direct payments, as these measures often require several on-the-spot controls when most of Pillar I controls can be performed through remote sensing (Ecorys, 2018).

Table 24: Synthesis of case-study findings on administrative burden incurred by local authorities for measures designed to address sustainable soil management (Category 1)

Soil-relevant measure	Administrative management	Controls	Monitoring and reporting
GAEC 4	-2 (EL, SE)	0 (IT)	1 (SE)
GAEC 5	-2 (EL, SE)	0 (IT)	1 (SE)
GAEC 6	-1 (SE)	2 (EL, SE)	2 (EL, SE)
Crop diversification	-1 (EL)	0 (EL)	NA
AECMs (M10.1)	3 (ES, IT)	5 (BE, EL, IT)	2 (BE, SE)
Support for Organic farming (M11)	-1 (BE)	NA	2 (BE, SE)

Source: Conclusions of geographical experts, based on interviews with the authorities in charge in Belgium-Wallonia, Bulgaria, Czechia, Greece, Spain, Italy, Sweden. No information is available for Denmark, Germany-Bavaria and Ireland. Methodology of the scoring: the geographical experts provided information on the level (low, medium, high or very high) of administrative burden associated with the CAP instruments and measures. In each Member State, administrative burden was assessed using the following scoring: low=-1, medium=0, high=1 and very high=2; then adding the scores from the case studies to get a score for all case studies.

Legend: Low administrative burden → High administrative burden

As mentioned by the managing authorities interviewed, the administrative management of the measures was easy, except for AECMs characterised by the highest administrative burden (in Belgium-Wallonia, Spain-Aragon, Italy-Tuscany, Sweden). Previous studies of the CAP indicated that high implementation and control costs of AECMs arise from the complexity associated with specific types of operations and changing eligibility requirements, which require verification of many eligibility and selection criteria.

Additional national/regional complexities have sometimes increased administrative burden associated with controls and administrative management of the measures, e.g. in Italy-Tuscany for controls of multiyear commitment measures such as AECMs (M10.1) or support for organic farming

[96] As managing authorities do not see direct benefits in carrying thorough monitoring and reporting of the measures implemented and the effects achieved, these obligations from the EU regulation appear for them as very burdensome.

(M11) (according to paying agencies); in Greece, controls on the ban on burning crop residues (GAEC 6) were strengthened, which resulted in a feeling of additional complexity from the stakeholders.

At the beneficiaries level

According to case studies (Table 25), most of the administrative burden on the farmers' side emerges from controls, whether it is for GAECs, AECMs (M10.1) or support for organic farming (M11). Controls imposed by EU requirements lead to constraints and financial risks that some farmers are not ready to bear (even though control rate is set at 1% under cross-compliance): indeed, as stated by farmer representatives and organisations involved in the implementation of the measures, the number of controls is higher for voluntary farmers applying for 'environmental schemes', and this also increased the corresponding financial risks associated with the potential penalties in case of non-compliance (Belgium-Wallonia, Czechia, Italy-Tuscany, Sweden). For AECMs (M10.1), filling in the farm register under a strict timeline further increases administrative burden (Italy-Tuscany).

Table 25: Synthesis of case-study findings on administrative burden incurred by beneficiaries for measures designed to address sustainable soil management (category 1)

Soil-relevant measure	Administrative management	Controls	Montoring and reporting
GAEC 4	-1 (CZ)	1 (CZ, SE)	-2 (CZ, ES)
GAEC 5	-1 (CZ)	1 (CZ, SE)	-2 (CZ, ES)
GAEC 6	-1 (CZ)	1 (CZ, SE)	-2 (CZ, ES)
Crop diversification	-1 (CZ)	0 (ES)	-2 (CZ, ES)
AECMs (M10.1)	1 (ES, IT, SE)	4 (BE, CZ, IT, SE)	-2 (CZ, ES)
Support for Organic farming (M11)	1 (SE)	2 (BE, SE)	NA

Source: Case studies. Same methodology as previous table. The colours are a graduation from green to red indicating:

Legend — Low administrative burden → High administrative burden

Administrative management of CAP measures is not mentioned as being burdensome for farmers, except for AECMs (M10.1) (Spain-Aragon, Italy-Tuscany and Sweden) and support for organic farming (M11). In Italy-Tuscany, AECMs (M10.1) were mentioned as requiring farmers to rebuild an entire production system, i.e. changing networks of relationships, with suppliers of equipment and knowledge, which involves considerable effort (according to an expert from the National Rural Network in Italy-Tuscany). High administrative management costs of these measures therefore reflect their higher ambitions in terms of production system redesign and environmental benefits (see Section 6.2.4).

National implementation choices can sometimes increase administrative burden on beneficiaries. For instance, the fragmentation and management of control by several public authorities causes complications due to the multiplication and redundancy of those controls (Czechia, Spain-Aragon). Also, some AECMs (M10.1) require the establishment of an environmental plan, e.g. AECMs in NVZs in Greece (which aims to ensure effective and efficient management of inputs used at the farm scale) or AECMs on wetlands in Sweden (due to national legislation).

6.2.3. The administrative burden of soil-relevant CAP instruments is proportionate (or not) to the public expenditure related to each instrument and measure

GAEC 6 was mentioned as difficult to control and monitor in Sweden and Greece. However, no specific budget is delivered under GAECs and its efficiency should be assessed as compared to the results achieved (see Section 6.2.4).

The administrative management and controls of greening measures generated high administrative burden for the national authorities. However, this complexity is considered as proportionate to the share of direct payments associated with such commitments (30%). Hence, the crop diversification payment delivered to farmers is estimated here as one-third of greening support, representing around EUR 29 000 million.

The AECMs (M10.1) are perceived as the most burdensome RD measures. The relationship between the complexity associated with their management on the one hand and the controls and related budget involved on the other hand varies significantly depending on the types of operation supported. For instance, one AECM (M10.1) related to the maintenance of hedges in Belgium-Wallonia represented only 3.7% of RDP expenditures but, required time-consuming controls due to EU requirements (on-the-spot checks to be carried out for at least 5% of beneficiaries)), resulting in a significant cost compared to the given support (EUR 25/250 million/year). The example of conservation agriculture in vineyards in arid areas and on steep slopes in Spain-Aragon also shows that high administrative burden (arising from national choices, according to the stakeholders interviewed) can be generated by AECMs (M10.1) with a small budget (0.3% of RDP expenditures) and reaching a limited area (1 376 ha committed). In Sweden however, and according to the managing authorities, the most burdensome AECM (M10.1) (maintenance of semi-natural grassland and meadows) was also the one with the highest budget (among soil-relevant RD measures, 2.4% of RDP expenditures). Therefore, in this case the burden could be considered as proportionate to the budget involved.

It should nevertheless be kept in mind that, although it increases administrative burden, applying AECMs (M10.1) in operations that may be complex to design, manage and control may also increase the efficiency of the support by making it possible to have a more targeted action in respect to soil quality and limit deadweight effects (see section 6.2.4)

6.2.4. The administrative burden of soil-relevant CAP instruments is proportionate (or not) to their effectiveness

Efficiency of an instrument/measure must be assessed with regard to the effects achieved. Table 26 provides a synthesis of the administrative burden experienced at the level of managing authorities and beneficiaries, and indicates the corresponding effects on soil erosion, soil organic matter and other soil-quality components, taking into consideration the potential of these measures to address soil issue when applied.

Table 26: Estimated administrative burden and effectiveness of CAP measures designed to address sustainable soil management (Category 1) at EU level

Soil-relevant CAP measures with administrative burden	Administrative burden on national/managing authorities	Administrative burden on farmers	Effectiveness in tackling erosion issues	Effectiveness in tackling SOM issues	Effectiveness in tackling other soil-quality issues
AECMs (M10.1)			++	++	++
Support for Organic farming (M11)			0	+	++
GAEC 4			+	0	0
GAEC 5			+	0	0
GAEC 6			0	+	0
Crop diversification			0	+	+

Source: Case-study results[97] and EQ 4, EQ 5 and EQ 6 results ,. The colors are a graduation indicating

[97] The score for administrative burden was calculated based on scores from previous sections (scores added up for each administrative burden component), and the effectiveness score is based on the findings from EQ 6.

Administrative burden: Low – High

Effectiveness: Low, Medium, High

Table 26 shows that AECMs (M10.1) contributed to soil protection, whether it concerns protection against erosion, soil organic matter or other soil-quality components such as nutrient balance, soil pollution and soil biodiversity. Indeed, this support was successfully implemented locally to target specific issues that were addressed by fostering the implementation of beneficial practices/land uses by farmers and foresters. This diversity of commitment and payment levels generated high administrative burden for AECMs, which was justified by the ability of this measure to address soil issues, making AECM an efficient instrument in this regard.

Support for organic farming (M11) was also put forward for its contribution to limit soil pollution and improve soil organic matter. As organic farming (M11) was easier to manage (despite controls having been mentioned as burdensome and costly for farmers and managing authorities), it is comparatively more efficient (when looking at the ratio between effectiveness and administrative burden) than AECMs.

Regarding cross-compliance, interviews with the local authorities revealed that controllability and its easy management have been major concerns at the administrations level, due to the high costs associated with controls at that level and the high financial risks for farmers in case of non-compliance. Although it resulted in high administrative burden in Greece and Sweden, GAEC 6 contributed to only a limited extent to the issue of soil organic matter conservation in case-study Member States. In comparison, GAEC 4 was assessed as effective on erosion and was associated (when information was available) with a smaller administrative burden.

6.2.5. Obligations in monitoring and control has (or not) ensured the effectiveness of the instruments and measures

Soil-relevant instruments and measures that were highlighted as difficult to control were GAEC 6 (Greece, Sweden), greening measures, AECMs (M10.1) and support for organic farming (M11) (see 6.2.3).

Controls obligations were sufficient to ensure effectiveness of the studied instruments and measures according to managing authorities in Bulgaria and Denmark (and Greece for GAECs 4 and 5). In Spain-Aragon, stakeholders agreed on the effectiveness of the risk analysis to control a sample of farmers that benefit from area-based payments.

However, in Belgium-Wallonia and Italy-Tuscany, managing authorities considered that controls are too scarce to ensure full effectiveness of cross-compliance, and they mentioned the advisability of satellite controls to improve and facilitate controls when relevant (such as for GAEC 4). This would reduce the administrative burden while increasing the control's effectiveness, as suggested in the report of the ECA on imaging technologies (ECA, 2020). Also, despite local strengthening of control obligations for GAEC 6 (ban on burning crop residues), burning of arable stubble is very hard to restrain in Greece.

Although they may ensure effectiveness to some extent, controls conditions and planning are sometimes found irrelevant by some stakeholders. As pointed out in Belgium-Wallonia, the need to support "controllable practices" can constrain the design of the instruments to address soil quality issues. The idea that commitments and controls could focus more on eligible actions supported rather than results to be achieved can lead to counterproductive effects, such as in Czechia where famers using modern and effective approaches to soil protection (contour farming) may not claim some payments because they would often not be able to meet the conditions established by GAEC 5. Examples of irrelevant controls mentioned in case studies can refer to dates for commitments that do not take into consideration meteorological conditions (Czechia, Tuscany, Italy), or fields considered abandoned if pluriannual plants are present under GAEC 4 (farmer representatives in Spain-Aragon). A shift towards result-oriented controls was mentioned as more efficient to guarantee positive results and lower administrative burden, by both managing authorities and farmer representatives in Czechia and Sweden.

6.2.6. Answer to the evaluation question

Case-study results show that, on the side of managing authorities, most of the administrative burden comes from monitoring and reporting and from control obligations. As for beneficiaries, controls were also the most important source of administrative burden mentioned during interviews. The EU requirements for the implementation of the control system (notably on-site inspections), often necessary to guarantee the effectiveness of the CAP support granted., indeed created heavy costs for both administrations and beneficiaries Nevertheless, the impact of national or regional implementation choices are more ambiguous, as they can either ease or strengthen the administrative burden of soil-relevant CAP instruments, both on the farmers side and managing authoritiesy side.

Comparison of administrative costs and total budget spent on each studied instrument shows that proportionality between administrative costs and budget allocation varies not only according to the instrument/measure at stake, but also to national/regional implementation choices. AECMs (M10.1) represent a significant share of the total CAP budget but is also associated with more administrative burden than other soil-relevant CAP instruments, although local choices and the nature of the operations supported influence administrative burden. Administrative costs related to the crop diversification measure may be deemed to be justified considering the considerable budget involved.

Based on the assessed effectiveness of the instruments studied in EQ 4, 5 and 6, the low administrative burden of soil-relevant CAP instruments seems to be proportionate to their limited effectiveness. AECMs (M10.1) are the most demanding soil-relevant measure in terms of administrative burden, but they also appear to be the most effective CAP instrument for soil protection, and therefore an efficient instrument with regard to this cost-effectiveness ratio. Support for organic farming (M11) generates the same pattern of high administrative burden and high level of effectiveness, but to a lesser extent. Meanwhile, crop diversification generates both moderate administrative burden and moderate effectiveness.

The case studies highlighted that control obligations are not always sufficient to ensure the effectiveness of the measures and instruments. Although the procedures of monitoring and controls seem to be sufficient in some Member States (e.g. Bulgaria, Denmark, Spain), they appeared to be too scarce in others (e.g. Belgium, Italy). The use of satellite controls to tackle this issue could be relevant, especially for GAEC 4 controls. In addition, case studies and literature show that administrative burden could be optimised, especially for controls which do not always appear to be relevant. A shift towards result-oriented controls was mentioned as more efficient to guarantee positive results and lower administrative burden by both managing authorities and farmer representatives in Czechia and Sweden.

7. Relevance

7.1. EQ 12: To what extent do the CAP objectives related to sustainable management of natural resources and climate action and the relevant CAP instruments/measures correspond to the actual needs within the EU at European, Member State and farm level in respect to soil quality?

7.1.1. Understanding and method

This evaluation question focuses on the extent to which the policy objectives and measures in place are appropriate to address the needs. The underlining questions vary depending of the level of focus that were asked to be considered in the answer to the evaluation question: EU level, Member States level and farm level.

As a preliminary step, the needs at each level were identified. In a second step, the analysis considered the following judgement criteria:

- At the EU level, CAP objectives and implementation cover with sufficient ambition (or not) the various needs at European level with respect to soil-quality issues. The analysis builds on the needs identified in literature, our own review of the regulations, and on the results from previous studies assessing the EU response to soil issues.
- At the level of Member States, local implementation choices were (or not) in line with the threats on soil quality in the concerned area. The relevance of the CAP instruments/measures at the level of Member States relates to their capacity to meet the local needs. A focus was made on the instruments and measures with a direct effect on sustainable soil management (i.e. Category 1 in Table 2), but the potential contribution provided by other instruments and measures was also considered. Given the challenges in identifying local needs and in understanding the authorities' strategies, the analysis was carried out for case-study Member States and regions. Priorities and needs for each soil-quality issue were identified based on interviews with key stakeholders (e.g. local experts, farm advisers, etc.), soil indicators and the local RDP's SWOT analysis. The relevance of the implementation choices draws on a review of local choices and the analysis of their adaptation to local needs, compared with our own observations on the stakeholders' knowledge, as gathered in the interviews.
- At farm level, the design of the instruments/measures was adequate (or not) to enhance positive changes in practices. Farmers' prerequisites to implement activities sustainable for soil were drawn from the causal analysis (EQ 1-3). The CAP instrument/measure appropriateness to those needs was analysed on a qualitative basis, building on the views collected in interviews and on results from the previous EQs.

7.1.2. Analysis at EU level

7.1.2.1. Needs at EU level in respect to soil quality

Deriving from the key soil threats that are widespread in the EU (see also Chapter 1.2), the key needs to maintain and improve soil quality at EU level are:

- To avoid soil erosion: 24% of land shows unsustainable soil water erosion rates (> 2 t/ha), and 12.7% of arable lands (or 4 million hectares) are estimated to be affected with more than 5 t/ha of annual loss (Panagos et al., 2015b).

- To maintain and enhance soil organic matter: this is the main challenge for both mineral soils (i.e. soils containing low levels of organic matter, between 1% and 6%), and organic soils which contain high levels of soil organic carbon (e.g. above 60% in peatlands). Given the historical and ongoing losses of existing soil organic carbon stocks in mineral soils, preventing further losses of carbon from mineral soils is essential, as a large share of arable soils would continue losing C without improvements in management (Wiesmeier et al., 2020).
- To avoid soil compaction: subsoil compaction is estimated to affect approximately 29% of subsoils across Europe, as a result of increasing size and weight of field machinery applied in European agriculture[98]. Using historical data, researchers have shown that typical wheel loads of combine harvesters increased from 1.5 tonnes to 9 tonnes in the period 1960 – 2010, or by 600%, leading to as much as a fivefold increase in mechanical stress reaching deep subsoil layers and thereby to subsoil compaction risk even at moderately wet soil conditions (ibid.).

As already stated in Chapter 1.2, reducing the risk of salinisation, preventing and remediating soil pollution, reversing decline in soil biodiversity, as well as improving the nutrient balance in arable soils are regionally important needs.

7.1.2.2. CAP objectives and implementation cover (or not) the various needs at European level with respect to soil-quality issues

The need to limit erosion, to increase carbon content in mineral soils and to protect grasslands to ensure the maintenance of their carbon content are explicitly addressed in the CAP framework. Various objectives point to those needs (e.g. Recitals 28 and 41 of Regulation (EU) No 1305/2013 and Recital 58 of Regulation (EU) No 1306/2013) as do CAP priorities for rural development and in particular focus area 4C preventing soil erosion and improving soil management and focus area 5E fostering carbon conservation and sequestration in agriculture and forestry. As previously analysed, specific tools were designed to achieve those objectives, i.e. GAEC 4, 5, 6, the requirement of crop diversification under greening, RD support for operations in forests (M8), agro-environment and climate measures (M10.1) and support for organic farming (M11). Other regulatory tools, though not strictly designed in that sense, directly address those needs (EFA, permanent grassland, support for knowledge transfer and information actions (M1), advisory services, farm management and farm relief services (M2), restoring agricultural production potential damaged by natural disasters and catastrophic events and introduction of preventive actions (M5), support for commitment for the environment and climate in forest (M15.1).

However, the actual capacity of those tools to address the measures depends on their capacity to adapt to local situations and on the way they are implemented at Member State and at farm level. For example, the GAEC 4 – 6 standards are very broadly defined in the CAP EU level framework. Their impact depends on how Member States establish the requirements to be applied at farm level. On the other hand, the relevance of greening measures 'protection of permanent grassland' and the EFA measure depend on the area to which these are applied. These issues are examined in the following paragraphs.

The current CAP framework does not clearly address the maintenance of soil organic matter on peatlands. Although peatland restoration can be supported under the RDP objectives, the scale of this implementation is limited. Moreover, the CAP sets no restrictions for the receipt of direct payments on peatlands. Instead, the CAP direct payments in effect provide a barrier to the implementation of reduced

[98] https://www.ecologic.eu/sites/files/publication/2018/2730_recare_subsoil-compaction_web.pdf

drainage and rewetting of peatlands because crops grown in paludiculture are not eligible as agricultural activity for direct payments[99].

Although it mentions the need to address soil structure, the CAP framework does not point to the issue of soil compaction, despite the fact that this issue affects one-third of arable land in the EU. While GAEC standards, greening obligations and RDP support soil quality and thus increase resilience of soils to soil compaction, the major need to limit the impact of heavy machinery is not identified or taken into account in the design of the instruments.

Soil biodiversity and nutrient balance could be said to be captured by the broader objectives on biodiversity and limitation of pollution, but the issue of excess fertiliser use and pesticide residues in soils is not explicitly addressed. In particular, in the rural development framework, fertilisers and pesticides management is addressed along water management in focus area 4A 'improving water management'. Moreover, microplastics pollution (which for example includes plastic mulching used in agriculture) is a neglected issue and not given explicit attention in the CAP framework. The threat of salinisation is also not explicitly addressed by the CAP objectives.

7.1.3. Analysis at MS level

7.1.3.1. Needs at MS level

The following table presents a review of the level of threats on soil components in the case-study areas.

Table 27: Local soil-related stakes in the case-study areas by biogeographical zone

	Atlantic zone			Continental zone			Mediterranean zone			Boreal zone
	Wallonia (BE)	DK	IE	BG	CZ	Bavaria (DE)	EL	Aragon (ES)	Tuscany (IT)	SE
Soil erosion										
Soil organic matter										
Soil biodiversity										
Soil pollution[100]										
Soil compaction										
Soil nutrient balance										
Soil salinisation										

Legend:

	Major soil threats: the quality component is significantly at threat in the area: there is a significant need to take action to tackle this threat.
	Secondary soil threats: this threat exits in the area, but it is not a key issue, or it is less significant than in other places.
	This threat does not occur or occurs to a limited extent in the area.

Source: Eurostat, European Environment Agency, JRC, DG Agri (CMEF context indicators), RDPs (Section 4: Description of the needs), (Ronchi et al., 2019)

The loss of soil organic matter and decrease in soil depth are major issues, although Sweden and Ireland with their respectively high share of forests and grasslands avoid these substantial soil losses. Diversity of soil microorganisms and fauna is at risk in 7 out of 10 case-study areas, but it is not a priority of the RDPs compared to the more easily observable biodiversity. Pollution from the accumulation of heavy metals in the soil as well as soil compaction are also significant threats in half of the case studies. Salinisation is more limited and concerns only Greece and Spain-Aragon. The high rate of nitrogen and phosphorus surplus caused by the overuse of fertilisers is threatening the soil nutrient balance in most EU Member States. Across the case-study areas, only Sweden is preserved from unbalanced inputs.

[99] Wetlands International: https://europe.wetlands.org/news/paludiculture-presents-the-necessary-paradigm-shift-towards-sustainable-peatland-use-with-global-climate-benefits/

[100] The measures targeting water pollution were not taken into account.

7.1.3.2. Local implementation choices were (or not) in line with the issues at stake

At Member State level, the analysis of the local implementation choices in the case-study areas reveals that implementation choices by Member States and managing authorities are unevenly aligned with the threat identified at local level (see Table 28). It especially highlights gaps in the CAP implementation at national level concerning soil compaction, soil biodiversity and soil salinisation: very few or no instruments were set to prevent these soil threats in the case-study areas.

Table 28: Scoring matrix of the relevance of the local implementation choices in the case-study areas to the threats identified at local level.[101]

	Wallonia (BE)	BG	CZ	Bavaria (DE)	DK	EL	Aragon (ES)	IE	Tuscany (IT)	SE
Prevent soil erosion	Orange	Green	Orange	Green	Grey	Green	Orange	Grey	Green	Grey
Maintain soil organic matter	Red	Red	Green	Orange	Red	Green	Orange	Grey	Green	Grey
Protect soil biodiversity	Grey	Red	Red	Green	Red	Red	Red	Red	Grey	Grey
Reduce soil pollution	Green	Green	Green	Grey	Green	Green	Grey	Green	Grey	Green
Avoid soil compaction	Grey	Grey	Red	Red	Red	Red	Grey	Orange	Grey	Grey
Achieve reasonable soil nutrient balance	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey
Avoid soil salinisation	Grey	Grey	Grey	Grey	Grey	Red	Red	Grey	Grey	Grey

Source: Alliance Environnement

Green	The CAP measure objectives sufficiently address the need	Red	The CAP measure objectives do not address the need
Orange	The CAP measure objectives partially address the need	Grey	Not identified as a need

While erosion was to be addressed through the requirement of minimum soil cover (GAEC 4) and minimum land management practices (GAEC 5), ambition towards implementation of those GAECs at the national level was limited. In some cases, various options given to farmers to comply with GAEC 4 and 5, without requirements for them to justify that their chosen option was the best agronomic solution for soil protection (in all the observed cases), resulted in limited relevance of the actions taken under the GAEC to address erosion (e.g. Belgium-Wallonia, Czechia). In addition, the establishment of grassed strips was a commonly offered option under GAEC 5 (in Belgium-Wallonia, Czechia, Greece and Italy). The relevance of this practice to limit soil erosion highly depends on good localisation of the strips. Furthermore, while the practice helps limit runoffs, it does not improve the soil's capacity to resist erosion. Some activities also appeared to be requiring better regulation through the GAEC, i.e. establishment of black fallow (though promoted through EFAs), and bare inter-rows for permanent crops. It appeared that permanent crops are not always concerned by the GAEC 4 and 5 requirements, even though they are highly subject to erosion by wind and water.

The analysis of the RDP and complementary information collected through interviews with the managing authorities showed that RD measures were implemented to tackle erosion in all the concerned case-study areas. AECMs (M10.1) narrowed the gaps that were left by lack of ambition for GAEC 4 and 5 (e.g. in Germany-Bavaria, Spain-Aragon and Italy-Tuscany). However, in most case-study areas the stakeholders involved in soil protection judged the implementation choices to be not proportionate to the level of threat. For instance, in Belgium-Wallonia, only one sub-measure of the AECM programme directly focused on soil erosion, even though mudflows are a significant issue in the region.

[101] If a major need was associated with a constraining GAEC, the CAP was considered as sufficient to address the need. Though, if the GAEC was not very convincing, the relevance of the RDP's implementation choices was considered before concluding on the CAP response to the soil quality needs. For secondary needs, the implementation of a relevant instrument was sufficient to assume that the need was met by the CAP.

Although maintenance of soil organic matter was to be addressed through GAEC 6, few case-study areas implemented the necessary GAEC rules or RD measures to meet their needs. The EU minimal requirement consisting in the ban of burning of crop residues was the only provision set under GAEC 6 in 8 case-study areas out of 10 (of which five present high risk related to SOM). The case studies highlighted that this requirement is inappropriate to address the maintenance of SOM in most areas: burning of residues does not occur in those areas. Thus, the activities impacting SOM (e.g. tillage, absence of winter cover) are not regulated by the GAEC 6. The ban on ploughing of permanent grasslands, introduced by nine Member States (Bulgaria, Germany, Greece, Spain, Italy, Cyprus, Lithuania, Hungary and Slovakia), provides an additional contribution to tackling the loss of SOM.

Soil pollution and soil nutrient balance were tackled though provisions related to other objectives, i.e. water quality and biodiversity, both on a regulatory and voluntary basis. However, the implemented measures aim mostly at water protection and have indirect positive effects on soil, although soil pollution is an issue in itself. In particular, though the requirement to declare EFAs was not targeting sustainable soil management, the potential to designated crop, catch and N-fixing crops in EFA proved relevant to increase in the area under cover crops and nitrogen-fixing crops, and to raise farmers' awareness on the benefits and management of cover crops (e.g. Belgium-Wallonia, Czechia). Regarding RD measures, the identification of measures explicitly aimed at reducing soil pollution confirmed that very few measures have been implemented in this respect. Biodiversity is considered in all RDPs, but the implemented measures rarely target the protection of soil biodiversity.

Mainly occurring in the arable crops located in the northern half of Europe, compaction is hardly covered in the RDPs, and there is no measure with an objective to reduce soil compaction in case-study Member States. Salinisation concerns the case-study areas of Greece and Spain-Aragon. Greece and Spain-Aragon only had AECMs indirectly targeting soil salinity.

Interviews with the local authorities and local stakeholders involved in soil protection highlighted that the need to ensure the controllability of the GAECs heavily weighed on how they are defined, sometimes limiting the relevance of the requirements that were set to address soil protection (e.g. in Belgium-Wallonia, Czechia) (see also EQ 3 on drivers). In order to limit those negative effects, several stakeholders (e.g. in Belgium-Wallonia, Czechia, Italy) recommended the implementation of result-oriented approaches, with more flexibility given to farmers on how to achieve the objectives set by the regulations.

Box 13: Result-oriented approaches for the maintenance of SOM: relevant alternatives for determining the requirements under GAEC 6

In Belgium-Flanders, GAEC 6 requires farmers to conduct a minimum number of soil organic content and pH tests annually, the numbers of which increase according to the area of the plot farmed – from no tests on fields smaller than five hectares, to one test on plots between 5 and 10 hectares and up to 10 tests on plots larger than 100 hectares. If the pH is too low, the plot has to be limed. If the carbon content falls below soil-favourable levels, the farmer has to take actions from among the following: follow advice, apply farmyard manure, apply compost, incorporate straw or grow cover crops.

In Germany, the cross-compliance regulation requires a minimum level of crop rotation at farm level (at least three types of arable crops, each representing at least 15% of the arable area). If it is not complied with, farmers must conduct either (i) a farm humus balance for the entire arable area (including set-aside) by March 31 of the following year, or (ii) a test for soil humus contents at least every six years on uniform farmed plots with similar properties. In each case, the humus balance must not fall below a threshold value of minus 75 kg/ha/year of humus carbon material.

Source: Alliance Environment based on (Turpin *et al.*, 2015) and(Cebrián-Piqueras, 2019).

Furthermore, it may have been difficult for local authorities to set strong rules at the Member State level, on account of the need for competitiveness of the local farming sector, in particular, on GAEC 4 and 5 for which no minimum requirement was established at EU level.

Regarding RDP, various factors explain those implementation choices; these include the facts that the RD strategy was designed against a backdrop of limited financial resources (e.g. Spain-Aragon, Italy-Tuscany), that actions may be proportionate to the degree to which production suffered from soil loss, and that economic aspects and other environmental issues often prevailed. (See the analysis of the drivers behind the implementation choices at the level of managing authorities, in EQ 3.)

The analyses suggest that a more specific/targeted design of the CAP instruments would be needed to address soil erosion and the loss of SOM. In this regard, interesting examples of selection/eligibility criteria ensuring that the operations supported address soil quality needs were found (see Table 29).

Table 29: Eligibility and selection criteria ensuring the relevance of the AECMs and support for investments to contribute to sustainable soil management

	Identified eligibility / selection criteria	AECM	Investments
Location criteria	Plots/beneficiaries located in zones with a high risk of erosion	BG, DE-Bavaria, EL, SE	BG for M8.1; CZ for M8.5; EL for M8.3 and on non-productive investment (M4.4.2)
	Beneficiaries located in ANCs	DE-Bavaria, ES-Aragon, IT-Tuscany	
Approach-related criteria	Farms under a management plan or quality scheme	BE-Wallonia, DE-Bavaria and IE	CZ for M4.1
	Applicants trained in soil protection practices	IE, EL	
	Applicants beneficiaries of AECMs		M4.4 in BG; M4.4.2 for the fencing of pasture lands in EL
Practice-related criteria	Plots seeded with species relevant for soil quality	BE-Wallonia, ES-Aragon	
	General assessment of the sustainability of the project		BE-Wallonia for M4.1
	Investments contributing to protect soil (reasonable size, low-pressure tyres, precision farming, etc.)		CZ for M4.1; DE-Bavaria for M8.5; ES-Aragon for M4.1

Colour code: criteria found in 2, 3 or 4 case-study areas; Source: Rural Development Programmes 2014-2020, call for projects and interviews with Managing Authorities, in the case-study areas

The interviews with local stakeholders highlighted the relevance of a tiered approach focusing on erosion sensitive areas. The lack for an approved erosion risks map is a key limit to be to the establishment of such criteria in the current programming period (mentioned by local authority and researcher in BE-Wallonia, by NGO in IT-Tuscany; see also answer of EQ 2).. The condition that farms should be located in ANCs was used as an alternative to a more precise definition of areas at risk for erosion (see examples in Table 29). 'Approach-related' criteria also proved to be very relevant to implement targeted operations. For investments, criteria on applicants to be beneficiaries of AECMs also aimed at fostering integrated approaches.

Regarding investments, the relevance of the investment in term of sustainable soil management was very marginally considered: examples of a focus on investments contributing to protect soil (reasonable size, integration of technologies such as low-pressure tyres, precision farming, etc.) as selection criteria for M4.1 were found in two case studies (Czechia and Spain-Aragon).

The analysis also confirmed the limited relevance of the requirement of crop diversification under greening to address soil quality in the Member States. As found in EQ 4, the requirement on the number of crops to be established implies that rotations be implemented. In Spain-Aragon, Italy-Tuscany and Sweden, stakeholders (managing authorities, farmer representatives and advisors, farmers) also outlined the weakness of the requirements regarding the type of crops to be used.. In Sweden, all interviewed stakeholders highlighted the need to introduce more grasslands, set-aside and/or catch crops to improve soil quality.

Furthermore, the requirement of crop diversification is more difficult to meet for small farms, in relation to the limited UAA available to establish new types of crops. Small farms with sustainable cropping patterns (e.g. in Sweden) or grass-based cattle farms with a small UAA dedicated to the production of supplementary concentrate feed (e.g. maize in Belgium-Wallonia) could not necessarily comply with crop diversification and had to cease their activity. Then, their arable lands may be purchased by larger farmers (that meet the crop diversification requirements) and covered by one single crop.

7.1.4. Analysis at farm level

7.1.4.1. Levers for the implementation of sustainable soil management at farmer and forester level

Farmers and foresters have specific needs to take action on sustainable soil management, which can be identified from the answers to EQ 3, EQ 10, EQ 11, the analysis at Member State level in this EQ, and interviews in the case studies. These needs are presented below.

- To access economic support: Economic and competitiveness considerations significantly influence farmers' willingness to invest in soil management. In some cases, direct impact on production or environmental considerations foster the sustainable soil management implementation by farmers. However, the implementation of relevant practices such as cover crops, reduced tillage, agroforestry, crop diversification and rotations, etc. results in opportunity costs as well as risks to be borne by farmers. Besides, marketing opportunities can also significantly influence farmers' choices and must be taken into account in their technical decisions. As a consequence, to foster sustainable soil management practices, economic support must be granted to farmers to guide their production choices, reduce the economic risks associated and offset the opportunity costs arising from their implementation.
- To be provided with awareness raising and technical guidance: sustainable soil management requires complex agronomic reasoning tailored to local conditions: plot history, soil type and annual weather conditions should be included in the decision parameters. Hence, their implementation requires precise technical guidance. The interviews showed that awareness of soil issues and of solutions for sustainable management of soil is shared by a limited number of farmers.
- To be given flexibility to adapt practices, together with limited administrative burden: previous analyses have shown the importance of flexibility for farmers to implement practices that effectively protect the soil under local conditions, while ensuring continuity in production and economic viability of operations. Fear of administrative burden may be an obstacle preventing farmers from applying for CAP measures supporting the implementation of relevant practices. This

aspect was also found to counteract the incentive effect of voluntary measures (see EQ 10 and EQ 11).

7.1.4.2. The CAP implementation addresses (or not) the levers for sustainable soil management at **farmers' and foresters' level**

Analyses from EQ 10 show that the measures cover to a limited extent the needs for economic support of farmers wishing to engage in soil conservation agriculture. In particular, payments under AECMs (M10.1) are not enough compared to the risk taken by farmers who start to implement practices related to conservation agriculture. In addition, the interviews point to economic limits in relation to the difficulty of finding outlets for crops of interest for soil quality (e.g. ley). In that sense, market-driven approaches may be needed as a complement to the CAP support. Furthermore, in countries where a high proportion of land is rented (e.g. Belgium-Wallonia, Bulgaria, Czechia), the interviews also highlighted that while land tenants tend to focus on yearly profitability (Belgium-Wallonia, Bulgaria, Spain-Aragon). AECMs with low incentives and long-term commitments are thus not the right tool.

With regard to awareness raising and technical support, EQ 7 shows that, when implemented, knowledge transfer (M1), advisory services (M2) and cooperation (M16) measures can achieve significant effects. Indeed, the case studies and the ENRD highlighted examples of projects in which knowledge transfer (M1) and advisory services (M2) measures helped to support and foster the adoption of conservation agriculture, organic farming and precision input management, thereby effectively helping to address various soil threats (e.g. erosion, compaction, soil organic content). Cooperation sub-measures were also implemented (e.g. M16.1-EIP operational Groups, M16.2-Pilot projects and M16.5-Environment and climate change) to support joint actions in various projects facing local soil issues. To a lesser extent, the GAECs, the crop diversification and the EFA measures were also mentioned (e.g. in Belgium-Wallonia, Bulgaria, Ireland) to contribute to indirectly raise farmers awareness: some farmers took the new requirement as an opportunity to experiment and implement new agronomical practices. However, the need to develop more training and information tools stands out: as found in EQ 9, there are many agronomical and technological innovations that may contribute to improve soil quality, and lack of evidence of their effects on soil and of knowledge are, along with economic reasons, the main factor limiting their adoption by farmers.

7.1.5. Answer to the evaluation question

At EU level, the CAP objectives and the CAP framework primarily address the issues of soil erosion and the loss of soil organic matter in mineral soils. Various objectives point to those needs, and specific instruments and measures were designed to achieve those objectives. However, the design of the relevant instruments and measures does not set a sufficiently high level of ambition to address the scale of these challenges. In particular, the actual capacity of those instruments and measures (e.g. GAEC 4, 5, 6, the requirement of crop diversification under greening, RD support to operations in forest (M8), agro-environment and climate measures (M10.1) and support to organic farming (M11)) to address the soil-related issues depends on the way they are implemented at Member State and farm levels. Other soil threats are not sufficiently addressed. While it mentions the need to address soil structure, the CAP framework does not point to the issue of soil compaction, which affects one-third of arable land in the EU. There is no explicit link in the CAP objectives with soil biodiversity, although this could be said to be captured by the broader biodiversity objectives. The issue of pesticide residues in soils is not explicitly addressed.

Analysis of the CAP response to the needs at the Member State/regional level confirms the gaps in the CAP implementation concerning soil compaction, soil biodiversity and soil salinisation, which are addressed by very few or no instruments. Concerning the maintenance of SOM, while this threat was considered through GAEC 6, the case studies highlighted that this requirement is inappropriate to address the maintenance of SOM in most areas. Burning of residues does not occur, except in Greece and Spain, but the loss of SOM results from other activities not regulated by the GAEC. Few case-study Member States / regions implemented the necessary GAEC rules or RD measures to meet their needs. The soil erosion concern was more significant and resulted in more appropriate CAP response. In particular, AECMs narrowed the gaps left by lack of ambition for GAEC 4 and 5 (e.g. in Germany-Bavaria, Spain-Aragon and Italy-Tuscany). Regarding soil pollution and soil nutrient balance, the SMRs in relation to the nitrate and water directives contribute to addressing the needs.

At farm level, information from the previous evaluation questions and the interviews reveals that the CAP measures may support voluntary commitments, but the risks taken by farmers implementing conservation practices cannot be supported. However, the CAP instruments and measures proved relevant to address the need for awareness raising. The GAECs and the crop diversification and EFA measures were also mentioned (e.g. in Belgium, Bulgaria, Ireland) as helping to raise farmers' awareness on sustainable soil management. When implemented, knowledge transfer (M1), advisory services (M2) and cooperation (M16) measures can achieve significant effects and address the need of technical support. Nevertheless, the CAP is perceived to entail complicated and burdensome regulations.

8. Coherence

8.1. EQ 13: To what extent have the relevant CAP instruments and measures delivered a coherent and complementary contribution to achieving the CAP objectives of sustainable management of natural resources and climate action, and in particular the issues related to soil quality?

8.1.1. Understanding and method

Coherence investigates the extent to which the intervention under investigation does not contradict other interventions with similar or related objectives (i.e. the interventions are not in conflict with one another, act neutrally together or are in synergy).

The analysis considers the following judgement criteria:

- CAP instruments and measures directly and indirectly addressing sustainable soil management acted in synergy (or not) to address issues related to soil quality. (i.e. Categories 1, 2 and 3 in Table 2). Synergies between the instruments and measures with a direct effect on sustainable soil management were investigated in EQ 7, in order to evaluate the capacity of the instruments and measures to act as a set. The findings were used to inform this judgement criteria.
- Instruments and measures designed to address other CAP objectives were coherent (or not) with the CAP objectives related to soil quality: this judgement criteria investigates the contributions to the objective of sustainable soil management, and/or negative effects of the instruments and measures in Category 4 in Table 2. The analysis encompassed a review (theory-based matrix analysis) of the potential indirect effects of each of the concerned instruments and measures on soil on the activities contributing to sustainable soil management identified in EQ 1. The potential effects were cross-checked with the observations of stakeholders, thereby providing on-the-spot examples of synergies and conflicts gathered during case studies. Information from the literature review rounds out the analysis.
- CAP instruments and measures targeting SMM delivered a coherent and complementary contribution to achieving the CAP objectives of sustainable management of natural resources and climate action: it is important to examine whether instruments and measures designed to address soil issues (i.e. Category 1 in Table 2) contribute to (or may interfere with) other CAP objectives of sustainable management of natural resources and climate action, such as the protection of water, biodiversity, mitigation of climate change and adaptation. The analysis was based on the findings of the effectiveness of the CAP instruments and measures to foster relevant activities (EQ 4-5), and on previous studies of the CAP focusing on the above-mentioned objectives.

8.1.2. CAP instruments and measures directly and indirectly addressing sustainable soil management acted in synergy (or not) to address issues related to soil quality

Examples of synergies between the CAP instruments and measures were found in the case-studies areas (EQ7) : RD measures, cross-compliance and greening measures can act together to foster sustainable soil management. Most synergies occur between RD measures themselves and especially between AECMs and RD measures which support knowledge transfers (M2), technical advisory services (M1) and cooperation (M16). Still, synergies between regulatory and mandatory instruments remain limited.

Significant synergies between the requirement under SMR1 and the greening requirement to declared EFA resulted in significant incentive for farmers to implement cover crops. Still, the fact that the areas overlap undermines the additional effect of the greening requirement to declare EFA, compared to the baseline set by cross-compliance.

8.1.3. CAP INSTRUMENTS AND MEASURE NOT TARGETED AT SUSTAINABLE SOIL MANAGEMENT WERE (OR NOT) COHERENT WITH THE CAP OBJECTIVES RELATED TO SOIL QUALITY

8.1.3.1. Theory-based analysis of the effect of the considered instruments and measures on sustainable soil management

A very limited range of soil-related activities may be impacted by the investigated instruments. In particular, the theory-based analysis found no potential link between the investigated instruments and measures on the one hand and some categories of management practices on the other, such as tillage and traffic management and management of pests, diseases and fertilisation management. The indirect effects to be foreseen are the following:

- The basic payment scheme (BPS) and single area payment scheme (SAPS) are hectare-based payments that may have important effects on land use and land cover. In particular, the fact that landscape features and newly established forests are not always eligible for payment may limit the maintenance or establishment of landscape features by farmers. Similarly, by granting payments on drained peatlands, it also does not incite farmers from restoring peatlands. The direct payment system may have negatively impacted the diversity of local production in specific cases[102]. Paludiculture, which consists in growing crops on rewetted peatlands, thus limiting or reversing drainage, is not eligible for CAP direct payments. Cross-compliance constitutes provisions that limit the potential negative effect of the BPS and SAPS[103]. However, potential negative indirect effects on land use and cover remain. They may be significant given the importance of the schemes from a financial point of view (on average, about 40% of the payment perceived by farmers).
- Voluntary redistributive payments and the small farmer scheme (SFS) may contribute to the maintenance of small farms. It might thus indirectly contribute to the limitation of plot sizes. Small fields are more diversified and have more landscape features such as hedgerows, contrary to larger fields that are managed in order to mechanise the production and which have historically decreased the number of landscape features through this arable intensification and its associated simplification (Stoate et al., 2001). Moreover, on arable land, the machinery used may be much less heavy in the case of small fields, thus reducing the risk of compaction. SFS farmers are exempted from greening obligations and from cross-compliance penalties, but, given their average size, the effect of those exemptions on soils may be limited.
- Voluntary coupled support concentrates on beef and veal, milk and milk products, sheep meat and goatmeat (73% of the payment distributed for VCS in 2017). Support for those sectors may indirectly foster the maintenance of grassland. Conversely, animal-based production can be harmful for soils if grazing and manure/slurry use are not properly managed. VCS for protein crops (11% of VCS) may directly foster the establishment of N-fixing crops, which are of interest for the soil

[102] This effect was found in the case of Lithuania over the 2004-2016 period. Volkov, A., Balezentis, T., Morkunas, M. and Streimikiene, D. (2019) 'Who Benefits from CAP? The Way the Direct Payments System Impacts Socioeconomic Sustainability of Small Farms', *Sustainability,* 11(7), pp. 2112.

[103] Article 99 of Regulation (EU) No 1306/2013 sets the following rules: In the event of non-compliance due to negligence, the percentage of reduction shall not exceed 5% and, in the event of reoccurrence, shall not exceed 15%. In the event of intentional non-compliance, the percentage reduction shall in principle not be less than 20% and may go as far as total exclusion from one or several aid schemes and may apply for one or more calendar years.

structure and nutrient balance (see Box 2). Moreover, direct support for sugar beets (4.3% of VCS) and starch potatoes encourage those crops, whose cultivation practices promote significant soil loss due to their crop harvesting (Panagos, Borrelli and Poesen, 2019).

Box 14: Impact of VCS on the establishment of protein crops

In 2015, 16 Member States decided to grant support for several protein crops (including soya bean) and two Member States to oilseeds other than soya bean.

Member state implementing VCS on Protein crop, and supported crop, in 2015

Member States	Chickpea	Soya bean	Oilseeds (other than soya bean)	Lupine	Alfalfa	Pea	Fava bean
BG	X	X		X	X	X	X
CR		X		X	X	X	X
CZ		X		X	X	X	X
FI		NS		X		X	X
FR		X			X	X	X
GR	X	NS		X		X	
HU	X	X		X		X	X
IE				X		X	X
IT	X	X		X		X	X
LV		X	X	X	X	X	X
LT				X	X	X	X
LU	X			X	X	X	X
PL	X	X		X	X	X	X
RO		X			X		
SL		X		X	X	X	X
ES	X	X	X (until 2017)	X	X	X	

X	VCS (Voluntary Coupled Support)
NS	No information on whether coupled support has been implemented within VCS framework

VCS has probably been a driver of the increase of field pea, soya bean and lupine area in the EU in 2015-2016 (Alliance Environnement, 2017b). As for broad and field beans, it seems rather unlikely that the measure had significant impacts at EU level, since similar trends can be observed in Member States with and without coupled support available.

Source: (Agrosynergie EEIG, 2018)

Income support in areas facing natural or other specific constraints (M13 and Payment for Natural Constraint) may contribute to the maintenance of agricultural activities in marginal areas, and in particular to the maintenance of grassland in those areas[104]. However, one alternative to the maintenance of grassland is land abandonment, which may result in a general improvement of soil properties (see

). On the contrary, land abandonment occurring on terraces or in semi-arid areas can generate erosion.

Box 15: Effect of land abandonment on soil quality according to literature

The vegetation recovery following land abandonment results in a general improvement of soil properties compared to agricultural soils (Romero-Díaz et al., 2017). Overall, in the long term, agricultural land abandonment helps decrease the erosion rates but in the short term (two years) can result in increased soil losses (Cerdà et al., 2018), suggesting the importance in some areas of planned and managed land use to ensure soil protection (Rodrigo-Comino et al., 2018; Cerdà et al., 2018). Notably, the development of spontaneous vegetation triggers a reduction of soil erosion, in particular in sloping mountainous areas (Latocha et al., 2016; Cerdà et al., 2019). However, the effect may be the opposite in some specific zones, such as in abandoned terraced areas (Agnoletti et al., 2019) or in semi-arid areas where vegetation recovery is slower (Rodrigo-Comino et al., 2018).

Land abandonment tends to result in an increase in SOC stock (Novara et al., 2017; van Hall et al., 2017; Romero-Díaz et al., 2017), and in deeper soil horizons (Campo et al., 2019). However, there is no global trend regarding the effects of land abandonment on soil biodiversity, which is influenced by various factors (type of soil, geographical area, management of vegetation recovery, etc.). Land abandonment appears to result in an increase in total microbial biomass and richness compared to what occurs on agricultural land (Susyan et al., 2011; Zornoza et al., 2009).

The vegetation recovery following land abandonment contributes to water penetration into the deeper soil layers due to the flow paths via plant roots and stem flow; this in turn helps to avoid or reduce soil water repellency. It improves soil water-retention capacity and hydraulic conductivity, thus increasing infiltration and decreasing runoff (Lucas-Borja et al., 2019; Romero-Díaz et al., 2017). At the same time, the growth of above-ground biomass potentially increases the risk of fire, especially in dry areas (Benayas et al., 2007), although no evidence of increased fire risk was found in some studies (Ricotta, Guglietta and Migliozzi, 2012).

104 In France, a study showed that the payments for ANCs introduced in 2015 led beneficiary farms to increase their grassland areas by around 3% in 2016 (Gallic and Marcus, 2019).

As for grassland areas, their abandonment can promote litter decomposition and lead to an increase in soil microbial biomass, soil organic carbon, C:N ratio, and inorganic N supply (Bohner *et al.*, 2019). Another study in Poland showed that the content of soil organic matter, moisture, total nitrogen and exchangeable forms of potassium, calcium and magnesium were significantly higher in mown grasslands than in grassland systems unmown for 10 years. (Swacha *et al.*, 2018).

Source: Alliance Environnement's own compilation, based on the literature

- RD support for Animal welfare (M14) includes potential support to improve access of animals to the outdoors. However, the measure is unlikely to have resulted in a decrease of livestock density.
- Within the Wine CMO, the Restructuring and conversion measure[105] largely supported replanting of vineyards[106], which involves significant perturbation on soil and may lead in particular to a decrease in soil organic content in the short term (Gianelle et al., 2015), and thus increase the risk of erosion. Although no details on the concerned area are available, the measure also supported operations of land improvement, such as ground levelling (supported in Greece, Spain, Italy, etc.), which may have had negative effects. However, it also supported operations that limit soil erosion, such as installation of erosion-control facilities (in Bulgaria and Croatia), construction/reconstruction of dry stonewalls (in Cyprus, Germany, Portugal) and construction of terraces (in Austria, Germany, Greece). Between 2014 and 2017, the measure impacted more than 5% of the vineyards in 13 out of the 15 Member States that implemented the measure, and even reached levels above 10% for 4 of them. At EU level, the measure concerned a total of 323 683 ha over the same period, equivalent to 10% of the EU vineyard area.

8.1.3.2. Synergies and conflicts identified in the case studies

BPS/SAPS, voluntary redistributive payment and small farmer scheme

Regarding BPS/SAPS, the case studies confirmed that the land eligibility criteria for direct payments prevent encroachment of semi-natural vegetation on agricultural land, sometimes discourage the establishment of landscape features, or encourage farmers to remove landscape features (Belgium-Wallonia, Spain-Aragon). However, the corresponding areas were eligible for direct payment in Ireland, thereby making it possible to avoid these side-effects.

Numerous interviewees (i.e. farmers' representatives, organisations involved in the implementation of the measures, local NGOs, researchers) pointed out the failure of the CAP to tackle the trend towards fewer and bigger farms (e.g. in Belgium-Wallonia and Sweden), despite the establishment of the voluntary redistributive payment and the small farmer scheme. They argue that the area-based system results in most of the payments going to the biggest farms, which is confirmed by the fact that 20% of the biggest beneficiaries (in terms of amount received) receive about 80% of direct payments[107].

Voluntary coupled support (VCS)

Controversial points of views were collected in the case studies regarding the coherence of the VCS with the objective of sustainable soil management. On the one hand, VCS are considered to have supported the maintenance of sustainable activities in terms of land use (e.g. maintenance of grassland in relation to the VCS for beef in Belgium-Wallonia and maintenance of paddy fields through VCS for rice in Spain-Aragon). On the other hand, other stakeholders pointed out that VCS encourages intensive farming. Indeed, in Belgium-Wallonia, according to representatives of managing authorities and farmers, the VCS

[105] Article 46 of Regulation (EU) No 1308/2013.

[106] With the objectives of varietal conversion, relocation, change of density to adapt to meet the requirement of PDO/PGI, and restructuring to enable mechanisation of practices in vineyards.

[107] DG Agriculture and Rural Development 2018. Direct payments. https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/direct-payments_en.pdf

for cattle is inconsistent with some AECMs (grass subsidies and fodder autonomy) in terms of livestock density. In Spain-Aragon, according to farmer representatives, the VCS dedicated to protein crops concerns only very productive areas and ignores regions facing soil issues (semi-arid regions and high wind erosion).

Furthermore, for all the examples of VCS found in the case studies, no example of provisions taken to limit negative effects of the supported production on soil were found.

Payments to areas facing natural or other specific constraints

The RDP measure 13 'Payments to areas facing natural or other specific constraints' was highlighted by all categories of stakeholders in seven case studies, as a means to maintain rural agricultural activities in difficult areas and avoid land abandonment (Bulgaria, Germany-Bavaria, Ireland, Greece, Spain-Aragon, Italy-Tuscany, Sweden). Despite the synergies underscored by many Member States (see Box 16), limits were mentioned in Italy-Tuscany, where the measure helps soil preservation in mountainous areas, even though the greatest soil threats are located in hilly areas (where olives and cereals are grown). In Ireland, it has been highlighted that, regarding ANCs, there is a lack of management prescriptions that apply to soil protection or soil quality, even though biophysical and soil characteristics are taken into account to determine ANCs.

Box 16: Examples of synergies with M13 in case-study Member States

In Germany-Bavaria, 66% of UAA is classified as disadvantaged area. Payments differ according to the degree of handicap and farm size. In mountain areas, the first 10 ha are given a EUR 25/ha premium (9 500 farms concerned). There is good uptake of the measure due to lengthy experience of the CAP, a relatively limited administrative burden and good knowledge among farmers. Since 2018, the new delimitation of the eligible area has expanded the area and therefore the benefits to soils (a lower altitude and a lower slope are required). It has been shown that the measure supports areas where grassland management dominates, thus favouring soil quality. An increase in forage has been observed for all M13 area categories.

In Sweden, managing authorities emphasised the synergy between M13 and M10.1 on temporary grassland because they each promote ley management in a complementary way within and outside ANCs. Therefore, when promoting grassland management, Measure M13 maintains an agricultural activity with positive effects on soil quality.

Source: case-study reports

Animal welfare (M14)

Regarding animal welfare (M14), potential synergies were identified in two case-study areas: in Sweden, the representative of organic farmers stated that M14 contributes to improving the economic viability of organic livestock breeders and thus to producing more organic manure needed for organic farming (M11).

8.1.4. CAP INSTRUMENTS AND MEASURES TARGETING SUSTAINABLE SOIL MANAGEMENT DELIVERED (OR NOT) A COHERENT AND COMPLEMENTARY CONTRIBUTION TO ACHIEVING THE CAP OBJECTIVES OF SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES AND CLIMATE ACTION

Previous evaluation studies on the CAP showed that the instruments and measures addressing sustainable soil management with direct effects on sustainable soil management can also positively contribute to other objectives of sustainable management of water, biodiversity and climate. Examples are shown below.

- Cross-compliance standards (GAEC 4, GAEC 5 and GAEC 6) contribute to improving water quality (Alliance Environnement, 2019b) and to a lesser extent present benefits for aquatic ecosystems and soil fauna (Alliance Environnement, 2019a). These instruments are also beneficial regarding climate mitigation and adaptation, as they contribute to improving water retention and increasing SOC levels (Alliance Environnement, 2018).

- The crop diversification requirement entailed by greening may lead to a reduction of inputs applied on land, meaning it could have positive impact on water quality (Alliance Environnement, 2019b). Despite limited overall biodiversity benefits, it may have slowed the general trend towards simpler cropping patterns (Alliance Environnement, 2019a). Introducing N-fixing crops can reduce emissions of N2O, but its impacts on climate mitigation remains low (Alliance Environnement, 2018; Alliance Environnement, 2017b).
- Regarding RD measures: support for afforestation (M8.1) contributes to water quality by limiting soil erosion and surface runoff and indirectly contributes to increasing water retention in soil (Alliance Environnement, 2019b). Measure M10.1 promoting conservation tillage makes it possible to increase water retention in soil and positively impact water quantity. It is also a significant driver for encouraging the adoption of practices beneficial to water quality and quantity, especially to promote systemic changes (Alliance Environnement, 2019b). Moreover, most of the actions included in AECM schemes have the potential to provide significant biodiversity benefits for one or more taxon groups (Alliance Environnement, 2019a). M11 can also contribute to improving water quality and biodiversity by avoiding PPP and fertiliser use, but it can increase soil erosion because of ploughing.

Potential trade-offs between the environmental objectives can also be mentioned:

- Conservation agriculture that avoids ploughing the soil and promotes soil cover as well as crop rotation has up to now relied on phytosanitary products that can damage biodiversity or affect water quality. There is increasing interest in combining no-till and organic farming, but this raises challenges for farmers.
- N-fixing crops often require greater use of pesticides compared to cereals, thus negatively impacting biodiversity and water quality (Alliance Environnement, 2017b).
- The increasing inputs of organic material to improve SOC levels may lead to increase in groundwater nitrate levels, depending on climate and regional soil characteristics (Alliance Environnement, 2018).
- Support for afforestation may promote diversification of habitats but may also replace them, in particular grassland and semi-natural habitats (Alliance Environnement, 2019a)

8.1.5. Answer to the evaluation question

Examples of synergies between the CAP instruments and measures were found in the case-studies areas: in particular, RD measures often can act together to foster sustainable soil management. Still, synergies between regulatory and mandatory instruments remain limited.

Based on the data available, the analysis of the coherence of the CAP instruments and measures not targeting sustainable soil management showed that a very limited range of soil-related activities may be impacted by the investigated instruments. The basic payment scheme and single area payment scheme were identified as potentially limiting the maintenance or establishment of landscape features and wetlands, as well as diversity of production at local level. The case studies confirmed that the land eligibility criteria for direct payments prevent encroachment of semi-natural vegetation on agricultural land, sometimes discourage the establishment of landscape features, or encourage farmers to remove landscape features. Conversely, based on the assumption that maintaining small farms limits restructuring to larger fields, there may have been some indirect positive synergies regarding sustainable soil management with the redistributive payments and small farmer scheme.

The voluntary coupled support can provide complementary contribution to achieving the objective of sustainable soil management. In particular, 16 Member States (in 2016) granted support for several protein crops, thereby encouraging the establishment of N-fixing crops. Coupled support for animal husbandry indirectly fosters maintenance of grassland, but it may also promote intensive use of pastures. Direct support for sugar beets (4.3% of VCS) and starch potatoes encourages those crops, whose cultivation practices promote significant soil loss due to their crop harvesting. Some examples in case studies showed that VCS could also promote intensive farming.

Payments to ANCs aim to limit land abandonment and contribute to the maintenance of grassland and agricultural activities. However, with regard to the sustainable soil management, it is noteworthy that spontaneous reforestation or afforestation due to land abandonment may have a positive effect on soil protection and may thus be considered as an alternative for soil protection in areas with severe risks of erosion.

The national support programme in the wine sector, through the restructuring and conversion measure, has had mixed impact on soil quality. Indeed, this specific measure may lead to perturbation of soils (e.g. during grubbing up of old vines or deep tillage before replanting), but it can also limit erosion (e.g. by establishing or reconstructing terraces with or without stonewalls).

Support for animal welfare (M14) was found to be neutral towards sustainable soil management and to have some potential synergies with organic farming (M11) in the case studies.

Previous evaluation studies of the CAP showed that the instruments and measures addressing sustainable soil management with direct effects on sustainable soil management can also contribute positively to other EU objectives of sustainable management of water, biodiversity and climate. Nevertheless, conflicts can occur between soil conservation and other environmental objectives demanding potential trade-offs.

8.2. EQ14: To what extent have the relevant CAP instruments and measures delivered a coherent and complementary contribution to achieving the soil-related objective of EU environmental and climate-change legislation and strategies?

8.2.1. Understanding of the question and methodology

This question evaluates the extent to which the CAP instruments and measures addressing sustainable soil management have been coherent with the EU's environmental and climate change legislation and strategies, and brought about a complementary contribution to those policies, on soil-related issues.

The assessment considers the following judgement criteria:

- Soil-related objectives were (or not) set in EU and national/regional policies: the analysis encompasses a review of the soil-related objectives in EU environmental and climate-change policies. Policies set by Member States or regions are also reviewed, in order to then analyse their potential link with the action taken within the CAP framework.
- The CAP instruments and measures were coherent (or not) with the objectives of EU environmental and climate change legislation and strategies: based on the EU environmental and climate policies identified in the first part of the analysis, the assessment considers the relationship between the soil-related EU policies and CAP instruments and measures with direct and indirect impact on sustainable soil management (i.e. Categories 1, 2 and 3 in Table 2) in terms of their coherence. This takes into account the rationale of the CAP instruments and measures and draws on findings on the previous evaluation questions.
- The CAP instruments and measures delivered (or not) a complementary contribution to achieving the objectives of EU environmental and climate change legislation and strategies: this analysis reviews how the CAP intervention interacted with other tools in addressing sustainable soil management. It considered the complementarity of the CAP with other EU policies but also with actions taken at the national or regional level.

8.2.2. Soil-related objectives were (or not) set in EU and national/regional policies

8.2.2.1. Soil-related objectives in EU environmental and climate change policies

The Soil Thematic Strategy issued in 2006 is the cornerstone of EU-level policy on soil. The overall objective is the protection and sustainable use of soil, based on the following guiding principles:

- Preventing further soil degradation and preserving its functions
- Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of soil restoration.

The 7th Environmental Action Programme 2012-2020 (7th EAP), which aims to protect, conserve, and enhance the EU's natural capital, set the following soil-related objectives:

- Land is managed sustainably in the EU, soil is adequately protected and the remediation of contaminated sites is well underway.
- Forest management is sustainable, and forests, their biodiversity and the services they provide are protected and, as far as feasible, enhanced, and the resilience of forests to climate change, fires, storms, pests and diseases is improved.

Other EU policies addressing diffuse pollution and water, biodiversity and nature, and air and climate set legally binding objectives according to their primary focus area. They do not set specific requirements for Member States to programme specific soil actions, but the uptake of relevant practices to achieve the primary objectives of these policies can also help to deliver improvements toward sustainable soil management, as identified in Table 30.

Table 30: Key EU environmental and climate policies with soil-related objectives

Policy Instrument	Soil focus	Soil threats addressed	Relationship with CAP
Diffuse pollution and water policies			
Water Framework Dir. (2000/60/EC)	I	Compaction, pollution, erosion, soil organic matter, nutrient balance	Programmes of measures (PoM) in river basin management plans (RBMPs) can be supported by the CAP, particularly through RDP measures (including those related to soils).
Sewage Sludge Dir. (86/278/EEC)	E/I	Pollution, soil organic matter, nutrient balance	No explicit link to CAP support
Floods Dir. (2007/60/EC)	I	Compaction, erosion	Actions set out in flood management plans (FMPs) can be supported by the CAP particularly through RDP measures (including those related to soils).
Nitrates Dir. (91/676/EEC)	I	Compaction, pollution, nutrient balance	Nitrate action programmes set actions which farmers in nitrate vulnerable zones (NVZs) must comply with in order to receive CAP support (including those related to soils).
Sustainable Pesticide Use Dir. (2009/128/EC)	I	Pollution, soil biodiversity	Actions set out in action plans can be supported by the CAP, particularly RDP measures (including those related to soils).
Marketing of Fertiliser Products Reg. (2019/1009/EU)	E/I	Pollution, nutrient balance	No explicit link to CAP support
Biodiversity and nature policies			
Habitats Dir. (92/43/EEC) & Birds Dir. (2009/147/EC)	I	Compaction, pollution, erosion, soil biodiversity, soil organic matter	Actions set out in Priority Action Frameworks (PAFs) can be supported by the CAP, particularly through GAEC 7, the EFA measure and RDP measures (including those related to soils).
EU Biodiversity Strategy (COM(2011)0244)	E/I	Compaction, pollution, erosion, soil biodiversity, soil organic matter	Direct reference made to the role of the CAP in supporting farmland and forestry biodiversity measures, in particular soil biodiversity
Air and climate policies			
National Emission Ceilings Dir. (2016/2284/EU)	E/I	Pollution, erosion, soil organic matter, nutrient balance	Actions in national action programmes can be supported by the CAP, particularly through RDP measures (including those related to soils).
Land Use, Land-Use Change & Forestry (LULUCF) Dec. (529/2013/EU)	E/I	Soil organic matter, nutrient balance	Mandatory reporting requires Member States to demonstrate what measures are contributing to limiting or reducing CO_2 emissions and maintaining or increasing removals. Very often, these refer to CAP instruments and measures (including those related to soils).
Effort Sharing Dec.(406/2009/EC)	I	SOM, nutrient balance	Actions for reducing non-CO_2 emissions can be supported through the CAP as a means of contributing to overall non-ETS reduction targets (including those related to soils).

Notes: E=Explicit, i.e. directly relevant to SSM; I=Implicit, i.e. indirectly relevant to SSM

Source: AllianceEnvironnement analysis of identified EU policies, Ronchi et al. (2019); Frelih-Larsen et al. (2016) and Louwagie, et al. (2011)

8.2.2.2. National/regional strategies, actions plans or programmes relevant to the protection of agricultural and forest soils

Few policies are set at national or regional level to specifically address issues related to agricultural and forest soils: such regulations or action plans were found in three case-study areas only (Box 17).

Institutional efforts to develop a policy or strategy have been initiated in the past in other case-study areas: e.g. in Ireland, a discussion paper was produced by the Irish Environmental Protection Agency (2002) calling for a national soil protection strategy, and in Greece a legislative proposal was developed on the protection and sustainable use of soil (2014). However, no specific soil policy has been adopted at present.

Box 17: Member States and regions with detailed soil protection policies

- Belgium-Wallonia has a decree that addresses SSM broadly, but with a specific focus on diffuse pollution/water management, industrial/localised contamination of land and erosion. It also implicitly addresses other soil threats including compaction and loss of SOM and soil biodiversity.
- Bulgaria has a Soil Act (2007), which sets out requirements relevant to soil degradation and damage to soil functions. This is complemented by a Soil Strategy for the period 2014-2020. It focuses on the sustainable use of soil as a natural resource, preserving and improving soil fertility, reducing the harmful effects on soils caused by natural processes and phenomena and anthropogenic factors, thereby preventing and reducing the risk to human health and environment.
- Germany has a Soil Protection Act at federal level (since 1998 and revised in 2015) that regulates the management of contaminated sites and the prevention of soil degradation across different sectors. It also sets out the principles for good agricultural practices. This is complemented at regional level with the Bavarian Soil Protection Act, which implements the federal legislation (since 1999 and revised in 2019), in addition the Bavarian Soil Protection Programme (since 1991 and revised 2016) sets out instruments, objectives and measures to keep soils healthy and productive.

Source: Case studies

8.2.3. The CAP instruments and measures delivered (or not) a coherent contribution to achieving the identified EU soil-related objectives

The analysis summarised in Table 31 shows that the CAP instruments and measures are generally coherent with the EU's soil-related objectives. Those which are designed or have the potential to deliver direct effects for sustainable soil management have the greatest possibilities for securing synergies, whereas those which have indirect effects on sustainable soil management deliver largely neutral or limited outcomes, but remain coherent.

Table 31: Coherence of CAP instruments and measures with the EU soil-related objectives

	CAP instrument or measure		
EU environmental and climate policies	Designed to address SSM (1)	With potential direct effects on SSM (2)	With potential indirect effects on SSM (3)
Cross-cutting policies (non-binding)			
7th Environmental Action Plan (7th EAP)			
Soil Thematic Strategy			
Diffuse pollution & water management policies (binding)			
Water Framework Dir.			
Sewage Sludge Dir.			
Floods Dir.			

	CAP instrument or measure		
EU environmental and climate policies	Designed to address SSM (1)	With potential direct effects on SSM (2)	With potential indirect effects on SSM (3)
Nitrates Dir	[yellow]	[blue]	[yellow]
Sustainable Use of Pesticides Dir.	[green]	[blue]	[yellow]
Marketing of Fertiliser Products Reg.	[yellow]	[yellow]	[yellow]
Biodiversity & nature protection policies (binding)			
Habitats (92/43/EEC) and Birds Dir.	[green]	[green]	[yellow]
EU Biodiversity Strategy	[green]	[green]	[yellow]
Air & climate policies (binding)			
NEC Dir.	[green]	[blue]	[yellow]
LULUCF Dec.	[green]	[blue]	[yellow]
Effort Sharing Dec.	[green]	[blue]	[yellow]

Notes: green = synergetic, yellow = neutral/limited, blue = mixed/conflicting

(1) GAECs 4, 5 & 6; Greening – Crop diversification; M8.1, M8.2, M8.5, M10.1, M11, (2): GAECs 1 & 3 and SMR1 & SMR10, Greening – EFAs & the maintenance of permanent grassland & the fruits & vegetables environmental measures; M4.1, M4.3, M4.4,; (3): Other sector-specific measures, M1, M2, M5, M8.3, M8.4, M12, M15.1 & EIP-AGRI

Source: Alliance Environnement analysis

The analysis shows many synergetic interactions betwen the CAP instruments and measures and the EU's soil-related objectives. For example, cross-compliance standards and particularly GAECs 4, 5 and 6 are complementary with the EU's soil-related objectives, as they have an explicit focus on sustainable soil management, wherein Member States are required to establish GAEC standards according to their specific national or regional characteristics including soil and climatic conditions. However, while potential synergies are evident, effective synergies depend on the relevance of the implementation choices made at national or regional level. For instance, as found in the previous chapters, limited requirements under GAEC 6 resulted in a limited contribution of this instrument to the maintenance of organic matter in soils. Under greening, crop diversification also has the potential for beneficial impacts on sustainable soil management, by shifting away from monoculture. However, the extent to which synergies with the soil-related objectives of EU policies can be achieved is again dependent on the Member States' implementation choices, e.g. application of rotation, the type of crops, when they are grown etc. Evidence from the case studies suggests that soil-related issues were not a major influencing factor in farmers' crop diversification choices (e.g. Wallonia-Belgium, Czechia, Denmark, Greece, Italy). However, in others it was considered to have encouraged diversification (e.g. Bavaria-Germany, Denmark, Ireland, Sweden). Other management actions also contribute to sustainable soil management. This includes appropriate grassland management (e.g. Wallonia-Belgium, Bulgaria, Czechia, Bavaria-Germany, Ireland, Sweden), arable practices such as cover crops (e.g. Czechia, Bavaria-Germany, Aragon-Spain, Ireland, Tuscany-Italy) and the use of N-fixing crops (e.g. Aragon-Spain, Tuscany-Italy, Sweden), which have been widely supported under AECMs (M10.1) and organic farming (M11) (all case studies).

The analysis shows some instances where relevant CAP instruments and measures have neutral or limited interactions with the implementation of EU's soil-related objectives. This largely concerns CAP instruments and measures that have an indirect effect on soil quality. As they do not have to have a specific focus on soil, they often deliver neutral or limited outcomes, but remain coherent. For instance, the Farm Advisory Service must provide information on the complying with certain provisions under the

Water Framework Directive and the Sustainable Pesticide Use Directive. However, there is no instrument to ensure enforcement of requirements relevant to soil-related objectives under these Directives (e.g. using cross-compliance) and no evidence of such enforcement was not found in the case studies. At the same time support is offered in some case studies for knowledge transfer and information actions related to nutrient management designed to support the implementation of the Water Framework Directive as well as the Nitrate Directive (e.g. Ireland and Aragon-Spain). The analysis also shows there are some instances where mixed/conflicting outcomes could occur as a result of Member States' implementation choices. For instance, investment support is also used to purchase specialised equipment to reduce the use of inputs or improve efficient use such as equipment for direct sowing, mechanical weeding, precision farming, and slurry and manure spreading. The use of this equipment can have positive effects for soil quality (e.g. Wallonia-Belgium, Aragon-Spain, Ireland, Tuscany-Italy). However, certain tilling and heavy spreading equipment can have negative effects in terms of damaging soil structure and compaction (e.g. Wallonia-Belgium, Ireland, Tuscany-Italy). An overview of the key interactions between the CAP and EU policies addressing diffuse pollution and water, biodiversity and nature, and air and climate with soil-related objectives is explored in the next section in terms of complementarity. There is currently no legal obligation for Member States to demonstrate how CAP instruments and measures are making an active contribution to these soil-related objectives.

8.2.4. The CAP instruments and measures delivered (or not) a complementary contribution to achieving the soil-related EU objectives

8.2.4.1. Complementarity between the CAP and the implementation of the diffuse pollution and water management policies

The CAP and Nitrates Directive largely interact with each other, as farmers located in Nitrate Vulnerable Zones (NVZs). In particular, farmers must fulfil SMR 1 and GAEC 1 with relevant actions that help to mitigate nutrient runoff and reduce erosion risk (e.g. buffer strip creation). SMR 1 sets a maximum limit on livestock manure of 170 kg/N/ha per year in NVZs, which can help to address erosion and compaction. However, relevant actions are only required in NVZs, which range from 100% of UAA in some Member States (e.g. Denmark, Germany, Ireland) to 13% (e.g. Italy). Moreover, farmers can apply for a derogation of up to 250 kg/N/ha per year, which could lead to greater risks of erosion and compaction due to higher stocking densities. This issue was signposted in one case study by environmental stakeholders (Ireland). At the same time, managing authorities in other case studies cited the relevance of the Nitrates Directives in stimulating the uptake of N-fixing crops under greening (e.g. Wallonia-Belgium) and organic farming (M11.1) (e.g. Denmark) with potential benefits for soil quality. Landscape elements are used to fulfil GAEC 4 and 5 requirements and are tailored specifically to address nutrient leaching and soil erosion (e.g. Belgium-Wallonia, Bulgaria, Czechia, Greece, Spain-Aragon, Italy-Tuscany).

The objectives to fulfil in the Sustainable Use of Pesticides Directive and the Water Framework Directive led in some cases to additional requirements for the GAECs and strengthened their capacity to address soil contamination and soil biodiversity issues. For instance, a ban is set on the use of PPPs on buffer strips under GAEC 1 (e.g. Belgium- Wallonia) and on fallow land under GAEC 4 (e.g. Germany-Bavaria). There is also a ban on mineral fertilisers on buffer strips under GAEC 1 (e.g. Bulgaria, Czechia) and landscape features under GAEC 7 (e.g. Czechia). Cover crops which can address water objectives and soil issues such as erosion, nutrient loss and soil organic matter are also supported using GAEC 4 and 5 (e.g. Belgium-Wallonia, Bulgaria, Czechia, Germany, Greece, Spain-Aragon, Italy-Tuscany) as well as using the EFA measure (e.g. Belgium-Wallonia, Bulgaria, Czechia, Germany-Bavaria) and the AECMs (e.g. Belgium-Wallonia, Czechia, Germany-Bavaria, EL, Italy-Tuscany).

The maintenance of landscape elements which act as a buffer to prevent soil erosion are also linked with the Water Framework Directive objectives to catch nutrients and other chemicals. The Sustainable Use of Pesticides Directive may also intensify actions that promote the uptake of integrated pest management or conservation agriculture programmed under AECMs (M10.1) (e.g. Wallonia-Belgium, Czechia, Bavaria-Germany) or the fruit and vegetable operational programme (e.g. Aragon-Spain), and support for organic farming (M11).

The Sewage Sludge Directive has influenced several Member States (particularly in the Mediterranean) to promote the use of waste water for irrigation purposes (Alliance Environnement, 2019) which is relevant to soil contamination and nutrient balance. However, the Directive focuses primarily on contamination issues applicable to sewage companies. Similarly, the Marketing of Fertiliser Regulation, while relevant to soil contamination, is focused more on upstream industries, as it only sets limits on the content of persistent chemical elements such as cadmium and does not state how such fertilisers should be used. For both policies there was no definitive evidence from the case studies of the CAP instruments and measures being used to support relevant soil-related objectives.

8.2.4.2. Complementarity between the CAP and the objectives and implementation of the biodiversity and nature protection policies

Setting binding objectives for the Member States, the Habitats and Birds Directives and the EU Biodiversity Strategy contributed to the setting of relevant provisions in the implementation of the CAP.

In particular, SMR2 and 3 and GAEC 7 on landscape features can help to reduce erosion risk and improve nutrient retention. The ESPG designation under the permanent grassland measure (greening) also supports soil protection in grassland habitats, which are of high biodiversity value. However, the decisions as to what constitutes ESPG do not necessarily fully take soil issues into account, with only a few Member States designating it outside Natura 2000 (e.g. Belgium, Czechia, Italy, Latvia, UK-Wales) (Alliance Environnement, 2019). EFA elements – particularly fallow land, multiannual fodder crops (e.g. alfalfa) and landscape features – also support practices relevant to address soil quality, together with the objectives of the biodiversity and nature protection policies. However, the practices applied often lead to few management changes (Alliance Environnement, 2018).

AECMs can also be designed to support the appropriate management of land features (e.g. hedgerows, trees and ponds) which can address soil erosion. The maintenance or restoration of extensive grassland semi-natural pastures can also prevent soil erosion and compaction and benefit soil biodiversity. Finally, support to organic farming (M11) can have positive impact on soil organic matter and soil biodiversity through the application of crop rotation and the prohibition of synthetic pesticides and fertilisers (all case studies), also with positive effects for soil quality.

8.2.4.3. Complementarity between the CAP and the objectives and implementation of the air and climate policies

Many relevant CAP instruments and measures were also found to be complementary with the soil-related objectives identified in these policies. However, while both the LULUCF and Effort Sharing Decisions can be considered largely coherent with soil issues, the NEC Directive has greater potential to for complementarity, as it has specific objectives and targets that are directly attributable to the agriculture sector. Nevertheless, the implementation of these CAP instruments and measures can contribute, broadly speaking to sustainable soil management. For instance, GAEC 6, which covers the maintenance of crop residues and the ban on the burning stubble, can have a positive impact on preventing GHG and ammonia emissions and on supporting SOM, including greater opportunities for carbon sequestration. While this applies to all arable land, it has not induced significant changes in most Member States (except Greece). Synergies with soil-related objectives can also be achieved with more advanced management practices incentivised under AECMs (M10.1) and the forest measures (M8.1, M8.2, M8.5), such as the conversion of arable land to grassland, minimum tillage and conversation agriculture, the establishment of native woodlands and agroforestry systems and paludiculture – all of which can support carbon sequestration.

8.2.4.4. Complementarity between the CAP and national policies

Very few policies for the protection of the quality of agricultural and forest soil were found at national/regional level. The case studies show that soil-related objectives set out in EU environmental policies have some influence on how the CAP is used to address soil issues relevant to the agriculture and forestry sectors. The breath of the policies that influence CAP choices concerning soil varies significantly within the case studies. In particular, the case study reports identified the nitrates action programmes as the most relevant, followed by climate mitigation and adaption plans. Beyond the EU policies outlined above, the relevance of action plans combating desertification (e.g. Bulgaria, Spain-Aragon, Greece), forestry (e.g. Bulgaria, Greece, Sweden), and peatlands (e.g. Ireland) as well as broader national or sectoral development or sustainability programmes (e.g. Bulgaria, Czechia, Germany -Bavaria, Ireland) were also highlighted.

8.2.5. Answer to the evaluation question 14

In conclusion, the overall analysis shows that most of the relevant CAP instruments and measures are theoretically and practically coherent with the soil-related objectives of EU environmental and climate-change policies. CAP instruments and measures designed to have direct benefits or with the potential for direct effects on sustainable soil management and have the greatest potential of delivering the EU soil-related objectives. Instruments and measures with an indirect effect on sustainable soil management generally deliver neutral or limited outcomes but largely remain coherent. However, the extent to which they play a complementary role is very much dependent on Member States' implementation choices. In terms of theoretical coherence, many soil-related objectives set out in the key EU environmental and climate policies identified can be addressed using CAP instruments and measures. They can therefore play a significant role in supporting sustainable soil management. Moreover, in the absence of a legal EU framework on soils, EU soil-related objectives can help to guide Member States' CAP implementation choices on how to address sustainable soil management. However, despite this potential, there is no specific requirement for Member States to programme specific soil protection actions in order to reach the overall objectives of key EU environmental and climate policies. Moreover, the lack of a legally binding EU framework for soil means that the coherence and complementarity of CAP actions and EU environmental and climate legislation with respect to soils remain highly dependent on binding EU environmental and climate legalisation where sustainable soil management is a secondary rather than a primary goal. In terms of practical coherence evidence from the case studies shows that the majority of them do not have a national specific soil policy targeted directly at sustainable soil management in the agriculture and forestry sectors. As a result, the EU soil-related objectives play an important role in addressing soil issues in the Member States in the absence of a specific soil policy at national or regional level. Soil-related EU objectives also continue to influence CAP implementation choices in Member States where a national or regional soil policy is in place. However, currently there is no specific requirement for Member States to demonstrate how the relevant CAP instruments and measures are designed to make an active contribution to the EU soil-related objectives. This could impede a coordinated approach to sustainable soil management at both national and regional level.

9. EU ADDED-VALUE

9.1. EQ15: TO WHAT EXTENT HAVE THE RELEVANT CAP INSTRUMENTS AND MEASURES CREATED EU ADDED VALUE WITH RESPECT TO SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES AND CLIMATE CHANGE AND IN PARTICULAR THE ISSUES RELATED TO SOIL QUALITY?

9.1.1. UNDERSTANDING AND METHOD

EU added value relates to actions and achievements that would not have happened if Member States had acted on their own, in other words in the absence of EU regulation and support measures. The answer focuses on reviewing the compliance with the principle of subsidiarity[108], i.e. analysing whether sustainable soil management can (or not) be sufficiently achieved by the Member States and the value provided (or not) by EU-level policy intervention compared to national actions independently taken by Member States.

Translating this principle within the framework of the CAP intervention on sustainable soil management, the analysis considered the following judgement criteria:

- The level of ambition set by Member States in relation to soil-quality issues would be equivalent (or not) in the absence of the CAP. This hypothetical situation was approached based on the drivers of implementation of soil-related measures (EQ 3), the review of the presence or absence of non-CAP soil-related measures and strategies, stakeholders' opinions (managing authorities, farm advisors, farmer representatives, experts), previous evaluation studies and literature.
- Sustainable soil management was (or not) more effectively and efficiently implemented than it would have been in the absence of the CAP. The study encompassed a review of operations taken outside the framework of the CAP in EU and non-EU countries, providing counterfactual situations. The effectiveness and efficiency of the identified 'non-CAP' initiatives were qualitatively compared to those of the CAP instruments and measures found in the previous Chapters 4 and 5. Opinions from stakeholders and information from the literature provided complementary sources.
- The CAP framework provided (or not) additional coordination within or between regions and Member States. This analysis is based on the outcomes from external coherence (EQ 14) and stakeholders' opinions regarding gains in coordination for soil protection between EU Member States and regions. It looks at the cooperation between managing authorities but also between stakeholders such as researchers, farmers or companies.

9.1.2. THE LEVEL OF AMBITION SET BY MEMBER STATES IN RELATION TO SOIL-QUALITY ISSUES WOULD BE EQUIVALENT (OR NOT) IN THE ABSENCE OF THE CAP

Recent inventories and assessments of soil protection policy instruments in the EU Member States (Frelih-Larsen et al., 2017) shed light on the limited ambition of those policies to tackle issues related to soil. Examples are shown below.

[108] Under the principle of subsidiarity, in areas which do not fall within its exclusive competence, the Union shall act only if and insofar as the objectives of the proposed action cannot be sufficiently achieved by the Member States, either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level (Article 5 of the Treaty of European Union).

- Few Member States have an overarching soil protection policy (e.g. the Soil Act in Bulgaria at national level or the Bavarian Soil Protection Act at regional level).
- Likewise, not all soil threats are addressed with the same level of requirements and, when addressed, sustainable soil management appears to be in most cases an outcome derived from policies and legislation focusing on other environmental issues (water, biodiversity, peatlands, desertification, etc.).
- In addition, national strategies directly targeting soil issues are not always allocated means for concrete intervention (e.g. according to a researcher in Spain, the Spanish national programme to combat desertification dating back to 2008 has not been allocated a budget for actions).

The choices of Member States and RDP managing authorities (see EQ 3) reveal the general low level of ambition of local authorities to tackle issues related to soil quality: other issues (i.e. ensuring competitiveness of agricultural holdings and addressing biodiversity and water) are predominant in local strategic choices. Still, some ambitious and relevant initiatives have been taken locally. Previous studies of the CAP suggest that EU regulations raised the level of ambition regarding soil protection, as follows:

- The introduction of the measure obliging crop diversification connected to greening payments set requirements that go beyond the rules previously in force in the Member States (Alliance Environnement, 2017b).
- Member States' choices for the implementation of EFAs suggest that, without the greening measures, there would not have been further action to enhance environmental protection (Alliance Environnement, 2017b).
- As for forest measures, it has been shown that the quality and quantity of funding would decrease without EU support (Alliance Environnement, 2017a).

The general opinion from all categories of local stakeholders tends to confirm this result. Moreover, results from an online survey of European soil experts and practitioners concluded that, in absence of some key EU policies including the CAP, the ambition for soil management would be weaker among the 13 Member States studied (Frelih-Larsen et al., 2017). Interviews in the case-study areas confirm this opinion as predominant in 6 out of the 10 case studies (Belgium-Wallonia, Bulgaria, Czechia, Greece, Spain-Aragon, Italy-Tuscany). This hypothetical weaker local commitment to tackle soil issues is linked to the following facts:

- In the absence of a level-playing field set by EU regulations, market forces and the need to remain competitive in the European market would probably prevail over environmental concerns.
- Policies established at EU level avoid limits to requirements on soil protection due to local electoral objectives or local groups' interests.
- SoilSoil protection measures and instruments would not be implemented at national level because soil is not considered as an emergency.

On the contrary, the general opinion from Denmark, Ireland and Sweden is that the level of ambition would be the same. This hypothetical *status quo* is based on the fact that actions are already taken outside the framework of the CAP (e.g. Denmark protects its aquatic environment against nitrates; Ireland funds most of its promotion of Snationally via Teagasc, the Irish state agency in agriculture; Swedish national regulations were already promoting catch crops and practices preventing phosphorus leaching).

Regarding the budget allocated to tackle soil issues, in areas where reduced ambition was foreseen, the interviewed representatives of local authorities estimate it would have been lower in the absence of the CAP (Bulgaria, Czechia, Greece, Spain-Aragon, Italy-Tuscany). This was also the case in Germany-Bavaria and Sweden: though significant ambitions for soil protection were set at the local level, the CAP framework enforced the allocation of financial means to encourage the implementation of sustainable practices (i.e. green payment, 30% ring-fencing in EAFRD).

9.1.3. Sustainable soil management was (or not) more effectively and efficiently implemented than it would have been in the absence of the CAP

In the Member States, national and EU-funded projects are often linked, via integrated approaches. Hence, no strict comparison could be made between the effectiveness and efficiency of national projects (see some examples in Table 32) versus similar CAP-supported projects. EU 'soft' measures (M1, M2, M16), where implemented, provide significant added value to support integrated approaches based on farmers training. National initiatives are sometime coordinated with the CAP to support larger scale projects requiring significant financial capacities, while smaller scale projects may be supported locally to lower administrative burden.

Table 32: Examples of projects supporting sustainable soil management funded at the national or regional level

Germany-Bavaria	'Bodenständig' is an initiative funded by the Bavarian Ministry of Food, Agriculture and Forestry (launched in 2014). It supports cooperation farmers, advisors, agricultural technical services and local communities in areas at risk for soil erosion. The initiative is currently financed entirely by state funds, although some implemented measures, such as the creation of new landscape elements, conversion of arable to grassland, or setting up erosion grass strips are supported through agri-environment measures that have been targeted in areas where 'Bodenständig' projects are implemented. In addition to solutions to cope with nutrient load in lakes or flooding, etc., the initiative increasingly promoted greater uptake of conservation tillage, intercropping, improved soil organic matter management, contour cultivation and winter cover crops. There are currently 93 ongoing projects, some of which are on hold due to lack of local commitment from stakeholders. The entire Bodenständig project area covers over 125 000 ha.
France	The Water Board of Artois-Picardie launched a programme to promote soil cover, through a system of reverse auction. Between 2010 and 2013 it represented 36 farm holdings of a total of 163 ha. However, it was not that effective because fewer people were applying for the aid, which does not concern the whole farm but only some plots (Duval et al., 2016).
Sweden	The LOVA programme[109] (Local water quality projects) provides grants to projects aiming at improving water quality and in particular supports soil structure liming to improve soil structure in clay soils. Because this mitigates the risk of phosphorous leaching, it became popular among farmers. The grant from the LOVA programme helps farmers start with this practice and compensates for any opportunity costs. In comparison with the support under the RDP measures, the administrative burden is lower and the timespan between the application for funding and receiving the financial support is much shorter (Frelih-Larsen et al., 2017).

Source: see sources mentioned in the table

Nevertheless, the limits of the EU framework to meet needs at Member State and farm levels (as developed in EQ 12) result in frequent negative opinions on the effectiveness and efficiency of the effects of the CAP, compared to what may have been carried out by the Member States acting on their own.

The comparison with soil-related policies in non-EU countries (Switzerland and Norway: see Table 33) reveals that their effectiveness does not hinge on their level of implementation, but on key success factors similar to those identified for CAP-funded projects: the actions taken for soil seem to be strict cross-compliance for direct payments, a tiered approach based on mapping of vulnerable zones and availability of highly qualified technical advice.

[109] https://www.havochvatten.se/hav/vagledning--lagar/anslag-och-bidrag/havs--och-vattenmiljoanslaget/lova.html

Table 33: Examples of soil-related policies in non-EU countries

Switzerland
Requirements similar to CAP cross-compliance standards, called 'proof of ecological performance' (PEP), are mandatory to benefit from direct payments, and some of them have effects on soil protection. This cross-compliance for direct payments is stricter in Switzerland than in other OECD countries, including those taking part in the CAP (OCDE, 2017). Conservation agriculture is also encouraged through financial support given to farmers applying the conservation tillage a method, whose rate of use amounted to 23% in 2017 (Schwilch et al., 2019). Moreover, in 2017soil erosion protection measures implemented a cut in payments to farmers experiencing recurrent soil erosion and who do not have a site-specific action plan. The six-year action plan includes suitable prevention measures of the farmer's own choice, adapted to both local environmental and socioeconomic contexts. In this way, the farmer's own solutions are encouraged rather than prescribed measures (Schwilch et al., 2019). And in May 2020, the Swiss Federal Council adopted the 'Swiss Soil Strategy for sustainable soil management'[110], which establishes specific objectives with regard to agriculture, in order to avoid compaction, erosion and loss of organic matter in the soil, as well as to reduce the risks linked to the use of PPPs, fertilisers and other means of production. The example of the canton of Bern also shows holistic and integrated approach to soil management thanks to the implementation of training programmes, monitoring tools and policy instruments.
Norway
Since the early 1990s, farmers have received annual subsidies through the Regional Environmental Programme to encourage more sustainable agricultural production. The most significant financial support is the subsidy for no autumn tillage, which is higher in areas where erosion risk is higher (based on a risk map defining four erosion risk classes). In Spring, ploughing is still authorised because of problems of crop residue and weed management. Results from a study focusing on the trend in nutrient and sediment losses in Norway (Bechmann et al., 2008) demonstrate changes in farmer behaviour, driven by economic incentives combined with the promotion of environmentally friendly management practices by advisory services. Thanks to the subsidy supporting no autumn tillage, cereal area ploughed in autumn covered 46% of the total cereal area in the country in 2013, compared to approximately 86% in 1990 (Barneveld et al., 2019). Also, on a national scale, the area ploughed in autumn in Norway decreased from 82% to about 50% during the 1989–2004 period. In 2004, undersown catch crops represented 8% of the total grain area in Norway (Bechmann et al., 2008).was not one ofrates and or the no-tillage system

Source: mentioned in the table

9.1.4. Additional coordination within or between regions and Member States was brought about (or not) by the CAP framework

From a political perspective, the opinion most commonly raised by stakeholders is that the CAP brings little gain in coordination among authorities for soil protection across EU Member States and Regions (Belgium-Wallonia: managing authorities; Czechia: all stakeholders; Denmark: researchers; Greece: managing authorities, NGO, researchers; Spain-Aragon: managing authorities). There was no coordination with neighbouring regions (e.g. Belgium-Wallonia, Czechia), or coordination was limited to specific zones (e.g. in Greece, between regions for exchanges concerning NVZs). Therefore, internal coordination is not improved by the CAP. Nevertheless, the ENRD Evaluation Helpdesk was cited in two case studies (Greece, Italy-Tuscany) as a useful tool to transfer knowledge between the EU and governments.

From a technical perspective, the CAP framework and especially M16/EIP groups encourage coordination among European researchers, civil society and companies at EU level (Spain-Aragon, Sweden). As shown in EQ 9, this measure fosters EU-wide projects involving a wide range of stakeholders, such as researchers and farmers, who tackle common soil issues. Furthermore, EU-funded projects via LIFE and H2020, such as Re-Care or Soilcare, have contributed to improving exchanges between Member States (Denmark, Greece). Except for these research projects, there have not been any soil-related transboundary initiatives cited by the case-study interviewees.

[110] Stratégie Sol Suisse.

According to recent studies, one of the main obstacles to coordination among authorities in Member States is the lack of an explicit definition of soil and soil threats[111] (Paleari, 2017; Ronchi et al., 2019). Without a common definition of soil-related terms established at EU level, there is a risk of inconsistent implementation of EU soil provisions across the EU. This current situation motivated Member States to act independently, adopting and implementing sectoral policies and strategies.

9.1.5. Answer to evaluation question 15

According to the literature reviewed, the management of agricultural soils in the EU Member States remains mainly influenced by the CAP and its implementation by the Member States. Indeed, few Member States have a comprehensive national soil strategy, and sustainable soil management appears to be in most cases an outcome derived from policies focusing on other environmental issues (water, biodiversity, peatlands, etc.). Thus, in most Member States, the CAP provides EU added value by increasing the level of ambition for sustainable soil management and the corresponding means for action (budget and measures).

National initiatives are nevertheless often coordinated with the CAP to support larger scale projects requiring significant financial capacities. Though no strict comparison could be made with the CAP intervention, it is notable that strict cross-compliance for direct payments, a tiered approach based on mapping of erosion risk, and the availability of highly qualified technical advice appear to be key success factors behind action taken for soil, both inside and outside the CAP framework. Furthermore, the CAP makes for a level playing field and prevents any competition across the Member States that may lead to a race to the bottom regarding environmental and soil-related actions.

Coordination within or between regions and Member States regarding soil issues, through CAP measures and instruments, remains limited. The absence of a legally binding framework that clearly determines soil threats and monitoring indicators is an obstacle to better coordination and gains in effectiveness. So far, the CAP has enabled gains in technical cooperation among European stakeholders (e.g. farmers, scientists, etc.) on specific soil issues through research programmes for instance, but no case study has underlined an effect on cooperation between government and regions.

[111] For example, the definition of soil in force in Germany includes the upper layer of the earth's crust only as far as it fulfils soil functions and to the exclusion of groundwater; that in force in the Flanders Region (Belgium) also covers groundwater; and the broad definition of soil adopted by Italy includes land, subsoil, settlements and infrastructure works.

10. Conclusions and recommendations

10.1. Conclusions of the evaluation study

The conclusions of the evaluation support study are presented below. The numbering indicates the evaluation study question on which each statement is based; e.g. 1.a-c are based on EQ 1.

10.1.1. Conclusions on the causal analysis

1.a The identification of the activities impacting soil quality showed the range of land use, land-use change and management practices in agriculture and forestry that may impact soil quality. It confirmed the need for a specific approach that takes into account soil properties and climate conditions in order to identify the changes in land use and/or management practices that are best suited to local conditions.

1.b Some activities – i.e. targeted application of manure, maintenance of cover on arable land, maintenance and creation of permanently covered areas (e.g. forest, grasslands, wetlands), and the establishment of landscape elements (hedges, buffer strips, etc.) – have a positive impact on soil quality in any context and could thus be fostered at EU level.

1.c The collected information on the potential impact of those practices on productivity (see Chapter 4.1.3) showed that little negative impact can be expected on yields when farmers are appropriately trained. In the long term, the benefits of those practices on soil quality can be expected to result in a positive effect on productivity.

2.a The analysis of the CAP framework showed that it provides a broad range of instruments and measures to foster sustainable management of soil: nearly all the activities contributing to sustainable soil management can be fostered by some (at least one) CAP instruments or measures.

2.b Still, few of the activities necessary for soil protection are enforced at EU level. Furthermore, key activities, such as controlled traffic, no/reduced/late tillage diversified crop rotation and compost application, as well as the limitation of plot size are in no cases enforced by the EU regulation; i.e. vulnerable areas in terms of soil quality (or susceptibility to erosion) do not benefit from specific provisions set at EU level.

2.c Regarding cross-compliance, the exhaustive mapping of activities enforced under the requirements of minimum soil cover (GAEC 4), minimum land management (GAEC 5) and maintenance of soil organic matter (GAEC 6) highlighted that significant flexibility is left to farmers on how to comply with those cross-compliance requirements: various options can be taken at farm level to comply with the GAEC, without having to select the option most suitable at the local level.

2.d Regarding Pillar II, the study found that numerous AECMs (M10.1) were designed to support conservation agriculture (including no or reduced tillage, crop diversification and covers crops). However, the resources allocated specifically to address sustainable soil management could not be estimated precisely.

3.a Looking at the decisions by Member States and managing authorities to implement instruments and measures fostering activities for sustainable soil management, the study found that soil quality was given less importance than other environmental concerns (i.e. biodiversity and water, which benefit from legally binding EU objectives and dedicated institutions or services). This level of priority given to addressing soil quality seems to result mostly from the level of awareness among national and local authorities of the threats to soil and of their possible consequences.

3.b As a consequence, when addressing sustainable soil management, Member States predominantly choose to enforce or support activities that bring positive effect both for soil and biodiversity and/or water: e.g. establishing/maintaining landscape features, establishing cover/catch/winter crops, and limiting the use of pesticides and fertilisers.

3.c At the beneficiaries level, economic drivers are key in farmers' decisions to implement measures addressing soil quality. Conversely, the lack of technical knowledge and support appears as a key factor hindering the implementation of management practices addressing soil quality.

10.1.2. Effectiveness of the CAP to foster sustainable soil management practices and land use

4.a As regards the development of soil-relevant management practices, the CAP instruments and measures introduced provisions on the use of PPPs and fertilisers, which concerned a significant share of EU arable land: cross-compliance, by sanctioning beneficiaries when not complying with the relevant rules, contributes to limiting the use of fertilisers in NVZs (49% of EU arable land), the ban on PPPs on EFAs (5% of UAA) and support for organic farming (13.4 million ha of which 68% are supported by M11 under RD). Statistical analysis of the changes in expenses in fertilisers and PPP of conventional, converting and organic farms over the 2014-2016 period (based on FADN data) were performed: a tendency for decrease in expenses in fertiliser and PPP for farmers converting to organic farming was observed in all case-study Member States except Italy. Still, the difference between changes in the expenses in PPP and fertiliser for organic holdings as compared to the same indicator for non-organic holdings is statistically significant in Germany and Spain only.

4.b Evidence was found for the CAP having contributed to durable changes in farmers' practices, by helping to introduce the use of catch, cover and N-fixing crops. Conversely, regarding the maintenance of crop residues, manuring and compost application, few effects of the CAP were highlighted in the study.

4.c Reduced tillage on arable land was supported by AECMs (M10.1), but this was limited to specific areas and thus did not lead to significant coverage at EU level. However, the ban on ploughing of all ESPG and of the permanent grasslands of Member States was paramount to act on carbon storage and erosion on those areas.

4.d The effects of the CAP on diversified crop rotations seem to be rather insignificant at EU level: in particular, the requirement of crop diversification under greening, which was one of the key CAP instrument targeting soil quality, had few effects because it concerned a small share of land and did not entail implementation of crop rotation. Still, positive effects were observed in some Member States (e.g. reduction of monoculture in Spain).

5.a Regarding land use and land-use change, afforestation and the establishment of agroforestry systems were fostered by voluntary measures only and implemented to a limited extent, in coherence with the change they involve in land use.

5.b Regarding maintenance of and conversion to grassland, the requirement to maintain the PG ratio, support for organic farming (M11) and AECMs played a key role in avoiding conversion of grassland to arable land. AECMs also supported the conversion of arable land into grassland, though to a limited extent.

5.c The GAECs have been key instruments in ensuring the maintenance of landscape elements (in particular buffer strips, grassed strips and terraces). However, the analysis could not assess how appropriate the locations of those landscape elements were in order to limit erosion. Some examples of AECMs which had a clear objective of limiting erosion by wind and/or water were found in the case-study areas: they supported the establishment and maintenance of landscape features appropriately located for limiting erosion. However, GAEC 4, 5 and 6, which specifically targeted sustainable soil management, did not provide significant effects: even if they were enforced within all the areas eligible for direct payments, they triggered changes of practices on limited areas.

10.1.3. Effectiveness of the CAP instruments and measures to address soil quality

6.a Looking at the expected impact of the CAP instruments and measures (EQ6) on erosion, though the study concluded that GAECs 4 and 5, M10.1 and M11 could contribute to reducing soil erosion, the scarce progress over the 2010-2016 period (-0.4% in all land and -0.8% in arable land) suggests efforts to reduce soil erosion need to be strengthened, in particular in hotspots. In addition, the effect of the relevant RD measures on erosion is limited due to the limited area concerned and its low level of targeting vulnerable areas.

6.b The EFAs, GAEC 4 and RDP measures (i.e. M10.1 and M11) have contributed to practices limiting the loss of SOM by fostering the use of organic fertiliser or soil cover. The link between the implementation of the CAP over the 2014-2020 period and results on SOM cannot be established on the timescale of the policy implementation, even though some Member States and regions demonstrated positive effects of the RD measures as implemented at the local level.

6.c Activities positive on soil biodiversity and soil pollution were fostered by the provisions on EFAs, AECMs and support for organic farming which promote the maintenance of grasslands and restrictions on PPPs. However, the result of the CAP implementation on soil biodiversity and soil pollution cannot be established with the existing data.

6.d Changes in soil nutrient balance and the effect of the CAP implementation cannot be directly established. Still, the absence of decrease in the growth nitrogen balance since 2010 suggests that the recent implementation of the CAP did not succeed in providing an additional contribution to the effect that previous policies had on reducing the use of fertilisers.

6.e The impact of the CAP measures and instruments on soil compaction and salinisation remains very limited, as no instrument clearly addressed those issues.

7.a Looking at how the instruments and measures may have acted as a set (EQ 7), the study confirmed the very significant potential of RD support for knowledge transfer (M1), advisory services (M2) and cooperation (M16) to act in synergy with the measures directly targeting sustainable soil management.

7.b Significant synergies between the requirement under SMR1 and the greening requirement to declare EFA, resulted in significant incentive for farmers to implement cover crops. Still, the fact that NVZ established with catch crops and area of cover crops declared in EFA can overlap undermines the additional effect of the greening requirement to declare EFA, compared to the baseline set by cross-compliance.

10.1.4. Effect of other factors on sustainable soil management and soil quality

8.1 Looking at storms, droughts, fires and soil sealing as other factors that may impact soil quality (EQ 8), it can be observed that those events may impact very large areas and may thus very significantly impact soil quality in comparison to the impact that can be expected from the CAP. It is also important to note that degraded and bare soils are more affected by storms and droughts than sustainably managed soils, and that the frequency of extreme natural events is expected to increase in the future:

this suggests the CAP measures and instruments need to scale up to counterweight, as much as possible, the effects of these events.

8.2 The study also investigated the extent to which the CAP implementation was affected by natural events: no major change in the implementation of the CAP was found over the observed period, except for some RD measures.

9.1 Soil-related technological and social innovations have hitherto slightly contributed to soil quality improvement (EQ 9). Although there is a wide range of innovations tackling almost all soil issues, they unevenly address each soil issue, and their level of adoption remains too low to have an impact at EU level. Agroecological practices are the innovative practices with the most direct and most positive effect on soil quality.

9.2 Barriers to adopting technological and social innovations are based not only on economic reasons, but also on the absence of an enabling environment that improves farmers' awareness and knowledge. Some EU research programmes and RD support for knowledge transfer (M1), advisory services (M2) and cooperation (M16) can promote training, knowledge transfer and cooperation among stakeholders and can help in the dissemination of these technologies.

10.1.5. Efficiency of the instruments and measures targeting sustainable soil management

10.1 Looking at the ratio between distributed payments and the observed benefits (EQ 10), the study concluded that the efficiency of the crop diversification measure is low: the greening payment represents 30% of direct payments, and the measure did not result in significant changes in agricultural practices. As for cross-compliance, as no budget spent can be associated with their results, their payments/benefits ratio were not assessed.

10.2 Regarding RD measures, soil-oriented AECMs can have more specific effects on soil quality for a lower cost/ha than does support for organic farming. The payment rates of AECMs were not always sufficient to motivate farmers to commit to the implementation of the supported soil-relevant activities. On the other hand, payments rates under support for activities in forests (M8), the environmental measures of fruits and vegetables operational programmes (CMO regulation) and support for organic farming (M11) were generally found to be set at an appropriate level to encourage application by farmer and forest holders.

10.3 The analysis also demonstrated that support is necessary to foster non-profitable practices and land use (e.g. buffer zones) and that it prevents decrease of traditional practices beneficial for soil protection such as sainfoin cultivation or inter-row plant cover for woody crops, as mentioned in Spain-Aragon.

11.1 Looking at the ratio between benefits and indirect costs (administrative costs and associated administrative burden), support for organic farming was found less difficult to manage for administrations and farmers than were AECMs, because of its 100% area-based management and clarity in the specifications to be applied. The design and management of tailored AECMs can be heavily burdensome, but they appear proportionate to their results.

11.2 Regarding the soil-related GAECs, interviews with the local authorities revealed that controllability and easy management have been a major concern at the level of administrations, because of the high costs associated with controls by the administration and the high financial risks for farmers in the event of non-compliance. In some case studies, this concern was clearly found to have hindered the relevance of the requirements set under GAECs 4, 5 and 6.

10.1.6. Relevance of the CAP instruments and measures

12.a The needs to limit erosion, to increase carbon content in mineral soils, to protect grasslands and to ensure the maintenance of their carbon content are explicitly addressed in the CAP framework (EQ12). However, the rules set at EU level are not very ambitious, and the CAP contribution to mitigate those soil threats thus depend on implementation choices taken at the level of Member States or regions.

12.b The CAP framework does not clearly address the other threats to soil. Though it mentions the need to address soil structure, the CAP framework does not point to the issue of soil compaction, even though it affects one-third of arable land in the EU. Soil biodiversity and pollution are captured in the broader biodiversity and water objectives, but specific issues such as pesticide residues, heavy metal pollution (e.g. herbicides), excess of fertilisers, and microplastics in soils are not explicitly addressed.

12.c The analysis of the local implementation choices in the case-study areas reveals uneven alignment in the implementation choices of Member States and of managing authorities with regard to soil threats at local level. The results suggest the actions stemming from those choices may be proportionate to the impact that soil erosion and desertification have on production, but that soil quality as a specific environmental aspect was often not considered.

12.d While the requirements of minimum soil cover (GAEC 4) and minimum land management practices (GAEC 5) addressed erosion, ambitions for the implementation of those GAECs at national level was weak. RD measures were implemented to tackle erosion in all the concerned case-study areas, so that the issues were addressed on a voluntary basis. Still, this strategy does not ensure erosion is appropriately addressed in areas where the risk is high.

12.e As for GAEC 6 requiring the maintenance of soil organic matter, 8 out of the 10 case-study Member States did not set additional requirements to the EU ban on burning of crop residues, even though the burning of residues does not occur in their areas. Thus, the loss of SOM results from other activities, which are not regulated by the GAECs. Few RD measures addressing SOM were found to fill in this gap. Soil pollution and soil nutrient balance were tackled though provisions related to other objectives, i.e. water quality and biodiversity, both on a regulatory and voluntary basis. Compaction is hardly identified in the RDPs, and there is no measure with an objective to reduce soil compaction in case-study Member States.

12.f Regarding the design of the RD measure by managing authorities, the analysis confirmed the relevance of a tiered approach. In most of the case-study areas, very interesting examples of selection and/or eligibility criteria ensuring that the operations that were supported address the needs were found. However, concerning support for investments (e.g. in machinery), their impact on soil was very marginally considered in the selection of projects to be supported.

12.g At farm level, the 'in-real' capacity of instruments to address the needs also depends on their capacity to adapt to local situations. In this regard, the analysis confirmed that the requirement of crop diversification under greening to address soil quality in the Member States had limited relevance. Indeed, the measure did not induce implementation of diversified crop rotations, and it was also more difficult for small farms to meet the requirements, due to the limited UAA available to establish new types of crops.

12.h As for the 'soil-related' GAECs, the observed limits suggest the need for result-oriented approaches, with more flexibility given to farmers on how to achieve them. They also highlighted difficulties for local authorities in setting strong rules at the Member State level, on account of the need to keep the agricultural sector competitive at EU level.

12.i The CAP was not able to address farmers' needs for a safety net so that they could take the risk to switch to conservation farming practices. Thus, many initiatives for soil conservation are developed without any individual support from the CAP. The need for awareness raising and technical support can be met by the RD 'soft measures' (knowledge transfer (M1), advisory services (M2) and cooperation (M16)), when implemented.

10.1.7. INTERNAL AND EXTERNAL COHERENCE OF THE CAP

13.a Examples of synergies between the CAP instruments and measures were found in the case-studies areas: in particular, RD measures often can act together to foster sustainable soil management. Still, synergies between regulatory and mandatory instruments remain limited. Conversely, there are no incoherencies among the various CAP instruments and measures that may impact on soil quality.

13.b Eligibility rules for decoupled direct payments affect the establishment or maintenance of landscape elements. Conversely, Voluntary Coupled Support who fostered N-fixing crops and animal husbandry (which contributes indirectly to the maintenance of grassland and to the use of manure) may indirectly have a positive effect on soil management.

13.c Payments to areas under natural constraints have contributed to the maintenance of grassland and avoided land abandonment. However, it is noteworthy that spontaneous reforestation or afforestation may have a positive effect on soil protection and may thus be considered as an alternative for soil protection in areas with severe risks of erosion.

13.d Instruments and measures targeting sustainable soil management can also contribute positively to other EU objectives of sustainable management of water, biodiversity and climate. Nevertheless, conflicts can occur between soil conservation and other environmental objectives, demanding potential trade-offs.

14.a Looking at the external coherence of the CAP with regard to sustainable soil management (EQ14), the study highlighted that the Member States are not required to demonstrate the CAP contribution to the EU soil-related objectives. The Soil Thematic Strategy and the 7th Environmental Action Programme both set objectives to prevent soil degradation and promote sustainable soil management. However, there are no clear quantified targets or binding requirements in relation to the objectives set.

14.b Other EU environmental policies strongly articulate with the CAP and strengthen the CAP contribution to addressing the EU soil-relevant objectives: as already mentioned, SMR 1 and SMR 10, set in application of the Nitrates and Sustainable Use of Pesticides Directives, played a significant role in the CAP contribution to address pollution and nutrient balance. Furthermore, the binding objectives set by EU environmental strategies encourage the setting of more ambitious CAP implementation, with an indirect impact on quality.

14.c The study also investigated the articulation of the CAP with national policies addressing the protection of agricultural and forest soils. Few examples of relevant specific policies were found: the CAP thus plays a key role in addressing soil-related issues in the Member States.

10.1.8. EU ADDED VALUE

15.a Few Member States have an overarching soil protection policy, which sheds light on the limited capacity of national policies to tackle issues related to soil. In this regard, EU regulations seem to have raised the level of ambition regarding soil protection, but assessing what would have been carried out by the Members States in the absence of an EU framework is very hypothetical (EQ15). Still, the study confirmed that Pillar II contributed to ensuring the allocation of resources to take action on soil and other environmental concerns.

15.b In the Member States, national and EU-funded projects often articulate with CAP-supported projects via integrated approaches. Hence, no strict comparison could be made between national and

EU-funded projects in terms of their effectiveness and efficiency. However, the comparison with soil-related policies in non-EU countries (Switzerland and Norway) revealed that their effectiveness does not hinge on their level of implementation (i.e. national), but on key success factors similar to those identified for CAP-funded projects, e.g. strict cross-compliance on direct payments and a tiered approach based on the mapping of areas vulnerable to erosion.

15.c The CAP framework and especially M16/EIP-AGRI groups and ENRD focus groups encourage coordination among European researchers, civil society, companies at EU level. That said, one of the main obstacles for coordination among Member States is the lack of common definitions of soil and soil threats.

10.2. Recommendations

10.2.1. Recommendations on policy design and implementation

Based on the findings of the evaluation study, the evaluation team recommends that the following suggestions should be followed in order to improve the design and implementation of the CAP addressing sustainable soil management.

- To establish an EU framework that ensures common definitions of soil and soil threats are adopted across the Member States and sets common definition for sustainable soil management and soil conservation agriculture. Ensuring the adoption of common definitions of soil, sustainable soil management, conservation agriculture and soil threats is a prerequisite to fostering coordination among Member States or regions and for facilitating the spread of conservation practices in the EU, but also research on those practices and the design of instruments to support conservation practices.
- To establish binding requirements for Member States to achieve the objectives set in the soil-related EU legislation. These requirements should be accompanied with quantified targets. In line with this recommendation, the development of monitoring tools at appropriate geographical scale would be necessary to ensure an appropriate follow-up, as well as to assess the contribution of the various soil-related EU policies and of relevant national policies toward those objectives.
- To raise awareness among all stakeholders on the issue of soil quality and include it in the CAP objectives overall, so that it can be addressed on an equal footing with other environmental issues (e.g. biodiversity, water quality, etc.).
- To establish an EU mapping of vulnerable areas, in particular in relation to sensitivity to soil erosion and the loss of soil organic carbon. This mapping (that may be based on the data available from JRC) could then be used in defining the requirements of future soil-related GAEC at EU level, thus ensuring that relevant actions are taken to tackle soil degradation in vulnerable areas. Such an approach is already implemented in relation to soil erosion in Czechia.

In order to scale up the contribution of the CAP to sustainable soil management, the following suggestions should be considered:

- To ensure the large-scale implementation of the 'first line' activities that are necessary for avoiding soil degradation and beneficial in any context: cover crops, establishment of landscape features, maintenance and creation of permanently covered areas. The requirements set for cross-compliance should ensure their implementation in vulnerable areas, through the GAECs, and specific measures should be designed at the EU level to provide incentive toward their large-scale adoption at the EU level.

- To better support the implementation of 'second-line' activities that are crucial for soil conservation: tillage reduction, diversified crop rotation and agroforestry. Guidance and examples of good practices, provided at EU level, on how to design instruments and measures targeting sustainable soil management (e.g. requirements for the GAECs relevant to addressing local soil-related issues, AECMs for soil conservation) may contribute to the implementation of this recommendation.
- To support the consolidation of knowledge and its transmission to farmers through quality advice on sustainable soil management. The choice of practices and appropriate innovation requires tailored agronomic expertise, taking into account the specific context at farm level. A broader implementation of the measures supporting training, knowledge transfer and cooperation among stakeholders can be a key to removing barriers to innovations and allowing farmers to implement sustainable soil management practices while limiting economic risks.
- To enhance long-term and result-oriented approaches to the implementation of both regulatory and voluntary schemes, in particular with regard to soil organic matter, for which the results can be proven in the long term only. Ensuring technical support for farmers, to help them achieve expected results, seems crucial for guaranteeing the effectiveness of such approaches.
- To address harmful practices and on-going trends (e.g. use of plastic in fields, use of continuously heavier machinery, land abandonment occurring on terraces, enlargement of field size) whose impact is increasingly significant. New CAP instruments or measures should be designed to address those issues.

Lastly, in the context of climate change, the following is recommended:

- To swiftly anticipate, prevent and mitigate the growing impact of natural events. The agricultural practices implemented should be resilient to the recurrence of natural events. Authorities should be prepared to react accordingly so that, as soon as the events occur, the actions taken can be fully operational in order to limit impact on soil quality.

10.2.2. RECOMMENDATIONS ON DATA, MONITORING AND EVALUATION

Based on the findings and limitations on data encountered during the evaluation, the following recommendations are proposed:

- To improve the monitoring per type of operation supported under the RD measures, notably the information on actions undertaken under the support for knowledge transfer and information actions (M1), for advisory services, farm management and farm relief services (M2), for non-productive investments (M4.4), for operations improving soil management under agri-environment and climate measures (M10) and for support for EIP groups implementing innovative collaborative actions (M16).
- To further use the opportunity of the FADN sample to monitor environmental impact, such as the quantity of plant protection products / fertiliser used, or the area ploughed. The FADN is a powerful database, which can provide very useful information on changes in the implementation of agri- and environmentally friendly management practices and the impact of the CAP support. It could also be worth including data on the practices implemented or agrienvironment and climate indicators. It would also be interesting to have a variable for the payment received under each RD measure/ sub-measure. Moreover, coherence of data among Member States (notably regarding variables on N, P, K quantity) should be ensured.
- To develop the monitoring of administrative costs related to the implementation of CAP instruments. This would allow for better understanding of the cost efficiency of the measures, for further evaluation studies.

REFERENCES

Achat, D. L., Deleuze, C., Landmann, G., Pousse, N., Ranger, J. and Augusto, L. (2015) 'Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis', *Forest Ecology and Management,* 348, pp. 124-141.

Agnoletti, M., Errico, A., Santoro, A., Dani, A. and Preti, F. (2019) 'Terraced Landscapes and Hydrogeological Risk. Effects of Land Abandonment in Cinque Terre (Italy) during Severe Rainfall Events', *Sustainability,* 11(1).

Agrosynergie EEIG (2018) *Market developments and Policy evaluation aspects of the plant protein sector in the EU*.

Alliance Environnement 2017a. Evaluation study of the forestry measures under Rural Development.

Alliance Environnement 2017b. Evaluation study of the payment for agricultural practices beneficial for the climate and the environment ('greening measures'). European Commission.

Alliance Environnement (2018) *Evaluation of the impact of the CAP on climate change and greenhouse gas emissions*.

Alliance Environnement 2019a. Evaluation of the impact of the CAP on habitats, landscapes, biodiversity. European Commission.

Alliance Environnement (2019b) *Evaluation of the impact of the CAP on water*: European Commission.

Anaya Romero, M., Arvidsson, J., Bampa, F., Berglund, K., Berglund, Ö., Bernet, L., Breuning-Madsen, H., Borrelli, P., Bruggeman, A., Cabrera, F., Camerra, C., Claringbould, H., Daliakopoulos, I. N., Djuma, H., Fleskens, L., Frelih Larsen, A., Geissen, V., Giannakis, E., Greve, M. H., Hessel, R., Hlavcova, K. and Karatzas, G. P. (2016) *Soil threats in Europe*. Available at: https://esdac.jrc.ec.europa.eu/public_path/shared_folder/doc_pub/EUR27607.pdf.

Arvidsson, J. (1999) 'Nutrient uptake and growth of barley as affected by soil compaction', *Plant and Soil,* 208(1), pp. 9-19.

Ballabio, C., Panagos, P. and Montanarella, L. 2016. Mapping topsoil physical properties at European scale using the LUCAS database. Elsevier ed.: Geoderma.

Barnes, A. P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T. and Gómez-Barbero, M. (2019) 'Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers', *Land Use Policy,* 80, pp. 163-174.

Barneveld, R. J., van der Zee, S. E. A. T. M., Greipsland, I., Kværnø, S. H. and Stolte, J. (2019) 'Prioritising areas for soil conservation measures in small agricultural catchments in Norway, using a connectivity index', *Geoderma,* 340, pp. 325-336.

Barrios, E. (2007) 'Soil biota, ecosystem services and land productivity', *Ecological Economics,* 64(2), pp. 269-285.

Baumgart-Getz, A., Prokopy, L. S. and Floress, K. (2012) 'Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature', *Journal of Environmental Management,* 96(1), pp. 17-25.

Bechmann, M., Deelstra, J., Stålnacke, P., Eggestad, H. O., Øygarden, L. and Pengerud, A. (2008) 'Monitoring catchment scale agricultural pollution in Norway: policy instruments, implementation of mitigation methods and trends in nutrient and sediment losses', *Environmental Science & Policy,* 11(2), pp. 102-114.

Benayas, J. R., Martins, A., Nicolau, J. M. and Schulz, J. J. (2007) 'Abandonment of agricultural land: an overview of drivers and consequences', *CAB reviews: Perspectives in agriculture, veterinary science, nutrition and natural resources,* 2(57), pp. 1-14.

Bhogal, A., Nicholson, F. A., Chambers, B. J. and Shepherd, M. A. (2003) 'Effects of past sewage sludge additions on heavy metal availability in light textured soils: implications for crop yields and metal uptakes', *Environmental Pollution,* 121(3), pp. 413-423.

Bock, B. B. (2012) 'Social innovation and sustainability; how to disentangle the buzzword and its application in the field of agriculture and rural development', *Studies in agricultural economics,* 114(2), pp. 57-63.

Bohner, A., Karrer, J., Walcher, R., Brandl, D., Michel, K., Arnberger, A., Frank, T. and Zaller, J. G. (2019) 'Ecological responses of semi-natural grasslands to abandonment: case studies in three mountain regions in the Eastern Alps', *Folia Geobotanica,* 54(3), pp. 211-225.

Borrelli, P., Lugato, E., Montanarella, L. and Panagos, P. (2017) 'A New Assessment of Soil Loss Due to Wind Erosion in European Agricultural Soils Using a Quantitative Spatially Distributed Modelling Approach', *Land Degradation and Development,* 28(1), pp. 335-344.

Borrelli, P. and Panagos, P. (2020) 'An indicator to reflect the mitigating effect of Common Agricultural Policy on soil erosion', *Land Use Policy,* 92, pp. 104467.

Busari, M. A., Kukal, S. S., Kaur, A., Bhatt, R. and Dulazi, A. A. (2015) 'Conservation tillage impacts on soil, crop and the environment', *International Soil and Water Conservation Research,* 3(2), pp. 119-129.

Calzarano, F., Stagnari, F., D'Egidio, S., Pagnani, G., Galieni, A., Di Marco, S. t., Giorgia Metruccio, E. and Pisante, M. (2018) 'Durum Wheat Quality, Yield and Sanitary Status under Conservation Agriculture', *Agriculture,* 8(9), pp. 140.

Camarotto, C., Dal Ferro, N., Piccoli, I., Polese, R., Furlan, L., Chiarini, F. and Morari, F. (2018) 'Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain', *CATENA,* 167, pp. 236-249.

Campo, J., Stijsiger, R. J., Nadal-Romero, E. and Cammeraat, E. L. H. (2019) 'The effects of land abandonment and long-term afforestation practices on the organic carbon stock and lignin content of Mediterranean humid mountain soils', *European Journal of Soil Science,* 70(5), pp. 947-959.

Cebrián-Piqueras, M. A. (2019) 'Measures to Safeguard and Enhance Soil-Related Ecosystem Services', in von Haaren, C., Lovett, A.A. and Albert, C. (eds.) *Landscape Planning with Ecosystem Services: Theories and Methods for Application in Europe*. Dordrecht: Springer Netherlands, pp. 341-358.

Cerdà, A., Ackermann, O., Terol, E. and Rodrigo-Comino, J. (2019) 'Impact of Farmland Abandonment on Water Resources and Soil Conservation in Citrus Plantations in Eastern Spain', *Water,* 11(4).

Cerdà, A., Rodrigo-Comino, J., Novara, A., Brevik, E. C., Vaezi, A. R., Pulido, M., Giménez-Morera, A. and Keesstra, S. D. (2018) 'Long-term impact of rainfed agricultural land abandonment on soil erosion in the Western Mediterranean basin', *Progress in Physical Geography: Earth and Environment,* 42(2), pp. 202-219.

Cirujeda, A., Anzalone, A., Aibar, J., Moreno, M. M. and Zaragoza, C. (2012) 'Purple nutsedge (Cyperus rotundus L.) control with paper mulch in processing tomato', *Crop Protection,* 39, pp. 66-71.

Daliakopoulos, I., Tsanis, I., Koutroulis, A., Kourgialas, N., Varouchakis, E., Karatzas, G. and Ritsema, C. (2016) 'The threat of soil salinity: A European scale review', *Science of the Total Environment,* 573, pp. 727-739.

Dargan, L. and Shucksmith, M. (2008) 'LEADER and Innovation', *Sociologia Ruralis,* 48(3), pp. 274-291.

De Brogniez, D., Ballabio, C., Stevens, A., Jones, R. J. A., Montanarella, L. and Van Wesemael, B. 2015. A map of the topsoil organic carbon content of Europe generated by a generalized additive model. European Journal of Soil Science.

De Souza Machado, A. A., Lau, C. W., Kloas, W., Bergmann, J., Bachelier, J. B., Goerlich, A. S. and Rillig, M. C. (2019) *Microplastics alter soil properties and plant performance, Germany*.

DG Agriculture and Rural Development 2018. Direct payments.

Dumanski, J., Peiretti, R., Benetis, J., McGarry, D. and Pieri, C. 2006. The paradigm of conservation tillage.

Dupraz, C., Lawson, G. J., Lamersdorf, N., Papanastasis, V. P., Rosati, A. and Ruiz-Mirado, J. (2018) 'Temperate Agroforestry Systems, 2nd Edition'.

Duval, L., Binet, T., Dupraz, P., Leplay, S., Etrillard, C., Pech, M., Deniel, E. and Laustriat, M. (2016) 'Paiements pour services environnementaux et méthodes d'évaluation économique. Enseignements pour les mesures agro-environnementales de la politique agricole commune'.

ECA (2017) *Special Report n°21/2017: Greening: a more complex income support scheme, not yet environmentally effective*: European Court of Auditors.

ECA (2020) *Using new imaging technologies to monitor the Common Agricultural Policy: steady progress overall, but slower for climate and environment monitoring*: European Court of AuditorsReport No 4/2020).

Ecorys 2018. Analysis of administrative burden arising from the CAP. *In:* And International, W.E.c.E. (ed.).

EEA (2018) *EEA greenhouse gas - data viewer*. Available at: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

EEA 2020. State and Outlook of the European Environment. *Knowledge for transition to a sustainable Europe.*

EIP-AGRI (2015) *EIP-AGRI Focus Group on Precision Farming: Final report*: European Commission. Available at: https://ec.europa.eu/eip/agriculture/en/publications/eip-agri-focus-group-precision-farming-final.

EIP-AGRI Focus Group 2020. Soil salinisation : Final report.

ENRD 2018. Thematic Group on sustainable management of water and soils. *Collaborative and multi-actor approaches to soil and water management in Europe.*

European Evaluation Helpdesk 2019. Voluntary coupled support: Review by the Member States of their support decisions applicable as from claim year 2019.

FAO (2017) *Soil organic carbon : the hidden potential*.

FAO and ITPS 2015. Status of the World's Soil Resources.

Fernandez Ugalde, O., Ballabio, C., Lugato, E., Scarpa, S. and Jones, A. 2020. Assessment of changes in topsoil properties in LUCAS samples between 2009/2012 and 2015 surveys.

Fontanelli, M., Raffaelli, M., Martelloni, L., Frasconi, C., Ginanni, M. and Peruzzi, A. 2013. The influence of non-living mulch, mechanical and thermal treatments on weed population and yield of rainfed fresh-market tomato (Solanum lycopersicum L.).

Frelih-Larsen, A., C. Bowyer, S., Albrecht, C., Keenleyside, M., Kemper, S., Nanni, S., Naumann, R., Mottershead, D., Landgrebe, R., Andersen, E., Banfi, P., Bell, S., Brémere, I., Cools, J., Herbert, S., Iles, A., Kampa, E., Kettunen, M., Lukacova, Z., Moreira, G., Kiresiewa, Z., Rouillard, J., Okx, J., Pantzar, M., Paquel, K., Pederson, R., Peepson, A., Pelsy, F., Petrovic, D., Psaila, E., Šarapatka, B., Sobocka, J., Stan, A., Tarpey, J. and Vidaurre, R. 2017. Updated Inventory and Assessment of Soil Protection Policy Instruments in EU Member States - Final Report.

Gardi, C., Panagos, P., Van Liedekerke, M., Bosco, C. and De Brogniez, D. (2015) 'Land take and food security: assessment of land take on the agricultural production in Europe', *Journal of Environmental Planning and Management,* 58(5), pp. 898-912.

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., Mäder, P., Stolze, M., Smith, P., El-Hage Scialabba, N. and Niggli, U. 2012. Enhanced top soil carbon stocks under organic farming.

Gianelle, D., Gristina, L., Pitacco, A., Spano, D., La Mantia, T., Marras, S., Meggio, F., Novara, A., Sirca, C. and Sottocornola, M. (2015) 'The Role of Vineyards in the Carbon Balance Throughout Italy', in Valentini, R. and Miglietta, F. (eds.) *The Greenhouse Gas Balance of Italy: An Insight on Managed and Natural Terrestrial Ecosystems*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 159-171.

Gocht A., C. P., Bielza M., Terres J-M., Röder N., Himics M., Salputra G. 2017. EU-wide Economics and Environmental Impacts of CAP Greening with High Spatial and Farm-type Detail. Journal of Agricultural Economics.

Greenotec (2010) *Tillage or no tillage? That's the question*. Available at: http://www.greenotec.be/medias/files/labour-or-not-labour.pdf.

Hartmann, M., Frey, B., Mayer, J., Mäder, P. and Widmer, F. (2014) 'Distinct soil microbial diversity under long-term organic and conventional farming', *Multidisciplinary Journal of Microbial Ecology*.

Hijbeek, R., van Ittersum, M. K., ten Berge, H. F. M., Gort, G., Spiegel, H. and Whitmore, A. P. (2017) 'Do organic inputs matter – a meta-analysis of additional yield effects for arable crops in Europe', *Plant and Soil,* 411(1), pp. 293-303.

Hubert, A. 2010. Empowering people, driving change: Social innovation in the European Union. BEPA-Bureau of European Policy Advisors, European Union.

Ingram, J. and Mills, J. (2019) 'Are advisory services "fit for purpose" to support sustainable soil management? An assessment of advice in Europe', *Soil Use and Management,* 35(1), pp. 21-31.

Jacobson, S., Kukkola, M., Mälkönen, E. and Tveite, B. (2000) 'Impact of whole-tree harvesting and compensatory fertilization on growth of coniferous thinning stands', *Forest Ecology and Management,* 129(1), pp. 41-51.

Jones, A., Panagos, P., Barcelo, S., Bouraoui, F., Bosco, C., Dewitte, O., Gardi, C., Erhard, M., Hervás, J., Hiederer, R., Jeffery, S., Lükewille, A., Marno, L., Montanarella, L., Olazábal, C., Petersen, J.-E., Penizek, V., Strassburger, T., Tóth, G., Van Den Eeckhaut, M., Van Liedekerke, M., Verheijen, F., Viestova, E. and Yigini, Y. (2012a) *The State of Soil in Europe*, Luxembourg: Publications Office of the European UnionA contribution of the JRC to the European Environment Agency's Environment State and Outlook Report - SOER 2010). Available at: http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2012_02_soil.pdf.

Jones, J. I., Murphy, J. F., Collins, A. L., Sear, D. A., Naden, P. S. and Armitage, P. D. (2012b) 'THE IMPACT OF FINE SEDIMENT ON MACRO-INVERTEBRATES', *River Research and Applications,* 28(8), pp. 1055-1071.

Katerji, N., van Hoorn, J. W., Hamdy, A., Karam, F. and Mastrorilli, M. (1996) 'Effect of salinity on water stress, growth, and yield of maize and sunflower', *Agricultural Water Management,* 30(3), pp. 237-249.

Kaur, B., Singh, B., Kaur, N. and Singh, D. (2017) 'Phytoremediation of cadmium-contaminated soil through multipurpose tree species', *Agroforestry Systems*.

Keller, T., Sandin, M., Colombi, T., Horn, R. and Or, D. (2019) 'Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning', *Soil and Tillage Research,* 194, pp. 104293.

Kiiza, B. and Pederson, G. (2012) 'ICT-based market information and adoption of agricultural seed technologies: Insights from Uganda', *Telecommunications Policy,* 36(4), pp. 253-259.

Knook, J., Eory, V., Brander, M. and Moran, D. (2020) 'The evaluation of a participatory extension programme focused on climate friendly farming', *Journal of Rural Studies,* 76, pp. 40-48.

Krauss, M., Berner, A., Burger, D., Wiemken, A., Niggli, U. and Mäder, P. (2010) 'Reduced tillage in temperate organic farming: implications for crop management and forage production', *Soil Use and Management,* 26(1), pp. 12-20.

Lacasta Dutoit, C., Maire, N. and Meco, R. (2005) 'Evolución de las producciones y de los parámetros químicos y bioquímicos del suelo, en agrosistemas de cereales, sometidos a diferentes manejos de suelo durante 21 años'.

Lal, R., Reicosky, D. C. and Hanson, J. D. (2007) 'Evolution of the plow over 10,000 years and the rationale for no-till farming', *Soil and Tillage Research,* 93(1), pp. 1-12.

Latocha, A., Szymanowski, M., Jeziorska, J., Stec, M. and Roszczewska, M. (2016) 'Effects of land abandonment and climate change on soil erosion—An example from depopulated agricultural lands in the Sudetes Mts., SW Poland', *CATENA,* 145, pp. 128-141.

Long, T. B., Blok, V. and Coninx, I. (2016) 'Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy', Available: Journal of Cleaner production.

Louwagie, G., Gay, S. H. and Burrell, A. (2009) *Addressing soil degradation in EU agriculture: relevant processes, practices and policies*: European Commission JRC-IPTSJRC Scientific and Technical Reports). Available at: http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR23767_Final.pdf.

Lucas-Borja, M. E., Zema, D. A., Plaza-Álvarez, P. A., Zupanc, V., Baartman, J., Sagra, J., González-Romero, J., Moya, D. and de las Heras, J. (2019) 'Effects of Different Land Uses (Abandoned Farmland, Intensive Agriculture and Forest) on Soil Hydrological Properties in Southern Spain', *Water,* 11(3).

Martin-Rueda, I., Muñoz-Guerra, L. M., Yunta, F., Esteban, E., Tenorio, J. L. and Lucena, J. J. (2007) 'Tillage and crop rotation effects on barley yield and soil nutrients on a Calciortidic Haploxeralf', *Soil and Tillage Research,* 92(1), pp. 1-9.

Martineau, H., Wiltshire, J., Webb, J., Hart, K., Keenleyside, C., Baldock, D., Bell, H. and Watterson, J. (2016) *Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming*, Didcot, UK: Ricardo-AEA & IEEPReport for European Commission DG CLIMATE ACTION under specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027). Available at: https://ec.europa.eu/clima/sites/clima/files/forests/lulucf/docs/cap_mainstreaming_en.pdf.

Merante, P., Dibari, C., Ferrise, R., Bindi, M., Lesschen, J. P., Kuikman, P., Sanchez, B. and Iglesias, A. (2014) *Report on critical low soil organic matter contents, which jeopardise good functioning of farming systems*.

Mills, J., Ingram, J., Dibari, C., Merante, P., Karaczun, Z., Molnar, A., Sánchez, B., Iglesias, A. and Ghaley, B. B. (2019) 'Barriers to and opportunities for the uptake of soil carbon management practices in European sustainable agricultural production', *Agroecology and Sustainable Food Systems*, pp. 1-27.

Mills, J., Reed, M., Skaalsveen, Kamilla and Ingram, J. 2018. The use of Twitter for knowledge exchange on sustainable soil management.

Newman, S. M. (1986) 'A Pear and Vegetable Interculture System: Land Equivalent Ratio, Light Use Efficiency and Productivity', *Experimental Agriculture,* 22(4), pp. 383-392.

Noor Shah, A., Tanveer, M., Shahzad, B., Yang, G., Fahad, S., Ali, S., Bukhari, M., Tung, S., Hafeez, A. and Souliyanonh, B. (2017) 'Soil compaction effects on soil health and cropproductivity: an overview', *Environmental science and pollution research international,* 24.

Novara, A., Gristina, L., Sala, G., Galati, A., Crescimanno, M., Cerdà, A., Badalamenti, E. and La Mantia, T. (2017) 'Agricultural land abandonment in Mediterranean environment provides ecosystem services via soil carbon sequestration', *Science of The Total Environment,* 576, pp. 420-429.

OCDE (2015) *Frascati Manual 2015.*

OCDE (2017) *The Political Economy of Biodiversity Policy Reform.*

Oldfield, E. E., Bradford, M. A. and Wood, S. A. (2019) 'Global meta-analysis of the relationship between soil organic matter and crop yields', *SOIL,* 5(1), pp. 15-32.

Oreszczyn, S., Lane, A. and Carr, S. (2010) 'The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations', *Journal of Rural Studies,* 26(4), pp. 404-417.

Orgiazzi, A., Panagos, P., Yigini, Y., Dunbar, M. B., Gardi, C., Montanarella, L. and Ballabio, C. (2016) 'A knowledge-based approach to estimating the magnitude and spatial patterns of potential threats to soil biodiversity', *Science of The Total Environment,* 545-546, pp. 11-20.

P. Schjønning, M. Lamandé, M.H Thorsøe and Frelih-Larsen, A. 2018. Subsoil compaction –a threat to sustainable food production and soil ecosystem services. RECARE Policy Brief.

Pagliai, M., Vignozzi, N. and Pellegrini, S. (2004) 'Soil structure and the effect of management practices', *Soil and Tillage Research,* 79(2), pp. 131-143.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., T abara, D. and Taillieu, T. (2007) 'Social learning and water resources management', *Ecology and Society,* 12(2).

Paleari, S. (2017) 'Is the European Union protecting soil? A critical analysis of Community environmental policy and law', *Land Use Policy,* 64, pp. 163-173.

Panagos, P., Ballabio, C., Meusburger, K., Spinoni, J., Alewell, C. and Borrelli, P. (2017) 'Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets', *Science Direct,* 548, pp. 251-262.

Panagos, P., Ballabio, C., Scarpa, S., Borrelli, P., Lugato, E. and Montanarella, L. 2020. Soil-related indicators to support agri-environmental policies. *Soil erosion, soil carbon, soil nutrients and fertility.*

Panagos, P., Borrelli, P., Meusburger, K. and Vand der Zanden, E. H. (2015a) 'Modelling the effects of support practices (P-factor) on the reduction of soil erosion by water at European Scale', *ScienceDirect,* 51, pp. 23-24.

Panagos, P., Borrelli, P. and Poesen, J. (2019) 'Soil loss due to crop harvesting in the European Union: A first estimation of an underrated geomorphic process', *Science of The Total Environment,* 664, pp. 487-498.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L. and Alewell, C. (2015b) 'The new assessment of soil loss by water erosion in Europe', *Environmental Science & Policy,* 54, pp. 438-447.

Panagos, P., Imeson, A., Meusburger, K., Borrelli, P., Poesen, J. and Alewell, C. (2016) 'Soil Conservation in Europe: Wish or Reality?', *Land degradation & development,* 27(6).

Panagos, P., Standardi, G., Borrelli, P., Lugato, E., Montanarella, L. and Bosello, F. (2018) 'Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models', *Land Degradation & Development,* 29(3), pp. 471-484.

Perego, A., Rocca, A., Cattivelli, V., Tabaglio, V., Fiorini, A., Barbieri, S., Schillaci, C., Chiodini, M. E., Brenna, S. and Acutis, M. (2019) 'Agro-environmental aspects of conservation agriculture compared to conventional systems: A 3-year experience on 20 farms in the Po valley (Northern Italy)', *Agricultural Systems,* 168, pp. 73-87.

Piccoli, I., Chiarini, F., Carletti, P., Furlan, L., Lazzaro, B., Nardi, S., Berti, A., Sartori, L., Dalconi, M. C. and Morari, F. (2016) 'Disentangling the effects of conservation agriculture practices on the vertical distribution of soil organic carbon. Evidence of poor carbon sequestration in North- Eastern Italy', *Agriculture, Ecosystems & Environment,* 230, pp. 68-78.

Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, K. J., Lee, J., Lundy, M. E., Van Gestel, N., Six, J., Venterea, R. T. and Van Kessel, C. 2014. Productivity limits and potentials of the principles of conservation agriculture.

Popp, J., Petö, K. and Nagy, J. 2015. Pesticide productivity and food security.

Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W., Whitmore, A. P., Hirsch, P. R. and Goulding, K. W. T. (2011) 'Soil management in relation to sustainable agriculture and ecosystem services', *Food Policy,* 36, pp. S72-S87.

Pronk, A., Bijttebier, J., Ten Berge, H., Ruysschaert, G., Hijbeek, R., Rijk, B., Werner, M., Raschke, I., Steinmann, H. H., Zylowska, K., Schlatter, N., Guzmán, G., Syp, A. T., Bechini, L., Turpin, N., Guiffant, N., Perret, E., Mauhé, N., Toqué, C., Zavattaro, L., Costamagna, C., Grignani, C., Lehninen, T., Baumgarten, A., Spiegel, H., Portero, A., Van Walleghem, T., Pedrera, A., Laguna, A., Vanderlinden, K., Giráldez, V. and Verhagen, A. (2015) *List of drivers and barriers governing soil management by farmers, including cost aspects*: irstea. Available at: https://hal.inrae.fr/hal-02601397.

Qin, W., Hu, C. and Oenema, O. (2015) 'Soil mulching significantly enhances yields and water and nitrogen use efficiencies of maize and wheat: a meta-analysis', *Scientific reports*, 5, pp. 16210. PubMed. DOI: 10.1038/srep16210 (Accessed 2015/11//).

Quemada, M., Baranski, M., Nobel-de Lange, M., Vallejo, A. and Cooper, J. (2013) 'Meta-analysis of strategies to control nitrate leaching in irrigated agricultural systems and their effects on crop yield', *Agriculture, Ecosystems & Environment,* 174, pp. 1-10.

Reed, M., Ingram, J., Mills, J. and Macmillan, T. (2017) *Taking farmers on a journey: experiences evaluating learning in Farmer Field Labs in UK.*

Reger, M., Bauerdick, J. and Bernhardt, H. (2018) 'Drones in Agriculture: Current and future legal status in Germany, the EU, the USA and Japan', *Landtechnik,* 73.

Ricotta, C., Guglietta, D. and Migliozzi, A. (2012) 'No evidence of increased fire risk due to agricultural land abandonment in Sardinia (Italy)', *Natural Hazards and Earth System Sciences,* 12(5), pp. 1333.

Rigueiro-Rodriguez, A., McAdam, J. and Mosquera-Losada, M. R. (2009) *Agroforestry in Europe: Current status and future prospects.*

Rodrigo-Comino, J., MartÍNez-HernÁNdez, C., Iserloh, T. and CerdÀ, A. (2018) 'Contrasted Impact of Land Abandonment on Soil Erosion in Mediterranean Agriculture Fields', *Pedosphere,* 28(4), pp. 617-631.

Roger-Estrade, J., Anger, C., Bertrand, M. and Richard, G. (2010) 'Tillage and soil ecology: partners for sustainable agriculture', *Science Direct*.

Romero-Díaz, A., Ruiz-Sinoga, J. D., Robledano-Aymerich, F., Brevik, E. C. and Cerdà, A. (2017) 'Ecosystem responses to land abandonment in Western Mediterranean Mountains', *CATENA,* 149, pp. 824-835.

Ronchi, S., Salata, S., Arcidiacono, A., Piroli, E. and Montanarella, L. (2019) 'Policy instruments for soil protection among the EU member states: A comparative analysis', *Land Use Policy,* 82, pp. 763-780.

RRN 2016. Documento di analisi - Sullo stato di attuazione delle misure PSR a sostegno de no-till.

Sabaté, X., O'Neill, C., Mitchell, B. and Basora, X. (2013) *Caring together for nature. Manual on land stewardship as a tool to promote social involvement with the natural environment in Europe*: LandLife documents.

Schjønning, P., Akker, J., Keller, T., Greve, M., Lamandé, M., Simojoki, A., Stettler, M., Arvidsson, J. and Breuning-Madsen, H. (2015) 'Driver-Pressure-State-Impact-Response (DPSIR) Analysis and Risk Assessment for Soil Compaction - A European Perspective', *Advances in Agronomy,* 133, pp. 183-237.

Schröder, J. J., Scholefield, D., Cabral, F. and Hofman, G. (2004) 'The effects of nutrient losses from agriculture on ground and surface water quality: the position of science in developing indicators for regulation', *Environmental Science & Policy,* 7(1), pp. 15-23.

Schwilch, G., Corsin, L., Michael, Z., Prasuhn, V. and Derungs, N. (2019) *Soil erosion policy in Switzerland.*

Seufert, V. and Ramankutty, N. (2017) 'Many shades of gray - The context-dependent performance of organic agriculture', *Science advances*.

Shelley, W., Lawley, R. and Robinson, D. (2013) 'Technology: Crowd-sourced soil data for Europe', *Nature,* 496, pp. 300.

Silva, V., Montanarella, L., Jones, A., Fernandez-Ugalde, O., Mol, H. G. J., Ritsema, C. J. and Geissen, V. (2018) 'Distribution of glyphosate and aminomethylphosphonic acid (AMPA) in agricultural topsoils of the European Union', *Science of the total environment*.

Slavich, P. G., Read, B. J. and Cullis, B. R. (1990) 'Yield response of barley germplasm to field variation in salinity quantified using the EM-38', *Australian Journal of Experimental Agriculture,* 30(4), pp. 551-556.

Soane, B. D., Ball, B. C., Arvidsson, J., Basch, G., Moreno, F. and Roger-Estrade, J. (2012) 'No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment', *Soil and Tillage Research,* 118, pp. 66-87.

SOTO EMBODAS, I., BARNES, A., BALAFOUTIS, A., BECK, B., SANCHEZ FERNANDEZ, B., VANGEYTE, J., FOUNTAS, S., TAMME, V. D. W., VERA, E. and MANUEL, G. B. 2019. The contribution of precision agriculture technologies to farm productivity and the mitigation of greenhouse gas emissions in the EU. Publications Office of the European Union.

Stoate, C., Boatman, N. D., Borralho, R. J., Carvalho, C. R., Snoo, G. R. d. and Eden, P. (2001) 'Ecological impacts of arable intensification in Europe', *Journal of Environmental Management,* 63(4), pp. 337-365.

Susyan, E. A., Wirth, S., Ananyeva, N. D. and Stolnikova, E. V. (2011) 'Forest succession on abandoned arable soils in European Russia – Impacts on microbial biomass, fungal-bacterial ratio, and basal CO2 respiration activity', *European Journal of Soil Biology,* 47(3), pp. 169-174.

Swacha, G., Botta-Dukát, Z., Kącki, Z., Pruchniewicz, D. and Żołnierz, L. (2018) 'The effect of abandonment on vegetation composition and soil properties in Molinion meadows (SW Poland)', *PloS one,* 13(5), pp. e0197363-e0197363.

Swanson, B. E. and Rajalahti, R. (2010) 'Strengthening agricultural extension and advisory systems'.

Thiele-Bruhn, S., Bloem, J., De Vries, F. T., Kalbitz, K. and Wagg, C. (2012) 'Linking soil biodiversity and agricultural soil management', *Science Direct*.

Thorsøe, M. H., Noe, E. B., Lamandé, M., Frelih-Larsen, A., Kjeldsen, C., Zandersen, M. and Schjønning, P. (2019) 'Sustainable soil management - Farmers' perspectives on subsoil compaction and the opportunities and barriers for intervention', *Land Use Policy*.

Tonitto, C., David, M. B. and Drinkwater, L. E. (2006) 'Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics', *Agriculture, Ecosystems & Environment,* 112(1), pp. 58-72.

Torralba, M., Fagerholm, N., Burgess, P. J., Moreno, G. and Plieninger, T. (2016) 'Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis', *Agriculture, Ecosystems & Environment,* 230, pp. 150-161.

Turpin, N., Perret, E., Ten Berge, H., Guzmán, G., Vanderlinden, K., Giraldez, J.-V., Laguna, A., Werner, M., Raschke, I., Kruger, J., Steinmann, H., Grigani, C., Zavattaro, L., Costamagna, C., Siebielc, G., Ruysschaert, G., Spiegel, A., Schlatter, N., Berthold, H., Lehtinen, T. and Baumgarten, A. (2015) *Policy bundles framing agricultural soil protection in EU and selected member states. Deliverable 524 CATCH-C*: irstea. Available at: https://hal.inrae.fr/hal-02606351.

Tóth, G., Hermann, T., Da Silva, M. R. and Montanarella, L. (2016) 'Heavy metals in agricultural soils of the European Union with implications for food safety', *Environment International,* 88, pp. 299-309.

van Hall, R. L., Cammeraat, L. H., Keesstra, S. D. and Zorn, M. (2017) 'Impact of secondary vegetation succession on soil quality in a humid Mediterranean landscape', *CATENA,* 149, pp. 836-843.

Volkov, A., Balezentis, T., Morkunas, M. and Streimikiene, D. (2019) 'Who Benefits from CAP? The Way the Direct Payments System Impacts Socioeconomic Sustainability of Small Farms', *Sustainability,* 11(7), pp. 2112.

Vopravil, J. 2010. Soil and its evaluation in the Czech Republic. *Part I.* Research institute of soil amelioration and protection (Prague).

Wacker, T. (2018) *Can Conservation Agriculture Improve Earth's Ability to Keep Nitrogen?* Available at: https://gmsr.dk/conservation-agriculture-og-kvaelstof/.

Wiesmeier, M., Mayer, S., Burmeister, J., Hübner, R. and Kögel-Knabner, I. (2020) 'Feasibility of the 4 per 1000 initiative in Bavaria: A reality check of agricultural soil management and carbon sequestration scenarios', *Geoderma,* 369, pp. 114333.

Wolkowski , R. and Lowery, B. 2008. Soil compaction: causes, concerns and cures.

WWF Belgique 2019. CAP 2021-2027: paths to encourage and support the ecological transition of the Walloon agriculture.

Zornoza, R., Guerrero, C., Mataix-Solera, J., Scow, K. M., Arcenegui, V. and Mataix-Beneyto, J. (2009) 'Changes in soil microbial community structure following the abandonment of agricultural terraces in mountainous areas of Eastern Spain', *Applied Soil Ecology,* 42(3), pp. 315-323.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service: – by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls), – at the following standard number: +32 22999696, or – by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

KF-02-20-617-EN-N

Publications Office
of the European Union

doi: 10.2762/799605
Isbn: 978-92-76-21411-3