CAP SPECIFIC OBJECTIVES

...explained

– Brief No 5

EFFICIENT SOIL MANAGEMENT

This is part of a series of Briefs summarising the facts and addressing the policy relevance around the 9 proposed specific objectives of the future CAP.

KEY MESSAGES

- ✓ *Soil is one of the most important natural resources, supplying essential nutrients, water, oxygen and support for plants, the soil provides many other essential services in terrestrial ecosystems.*
- ✓ *Although it does not represent a problem that is uniformly felt throughout Europe, soil health raises a significant share of concerns. It absorbs all the consequences of human presence, both in terms of direct activities we perform on it (intensive cropping, irrigation, compaction, contamination building, etc.) and of weakening its ability to react to other natural forces, as in the case of water erosion.*
- ✓ *This is the reason why the contribution of policies to address soil protection becomes more and more relevant, based on an array of mandatory and voluntary measures in the new CAP proposal.*
- ✓ *Alongside with the uptake of integrated sustainable practices, such as agro-ecology, new technologies can bring an important help in this process as well, with precision farming enabling simultaneous improvements in both economic and environmental performance based on a higher degree of knowledge incorporated in best practices.*

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Agriculture and Rural Development

1. The facts about the state of EU soil

a. The relevance of soil management

In addition to the basic functions of supplying essential nutrients, water, oxygen and support for plants, the soil provides many other essential services in terrestrial ecosystems. Soils are a critical part of the carbon, the nutrients and the hydrological cycles. They can moderate flood risk and contribute to water purification, by providing a biogeochemically activated filtration and cleaning service that transforms or retains materials or nutrients that are introduced on the land surface (e.g. nitrogen and phosphorus).

Soil properties can transform and affect the movement of chemicals, thus protecting people and animals from the effects of pollution. Soils host around a quarter of biodiversity on Earth and soil biodiversity is crucial for soil health and good functioning of ecosystem services.

Why does soil matter?

That soil is one of the most important natural resources that provide us with vital goods and services to sustain life is an understatement. Soil being a habitat and gene pool, it serves as a platform for human activities, landscape and heritage, and acts as a provider of raw materials. A healthy, fertile soil is at the heart of food security, thus rendering any threat to these functions a direct threat to food availability.

Soil biodiversity varies from microscopically small bacteria, yeasts, fungi, molds and protists, through nematodes, micro-arthropods and insects that are visible to the eye, to larger animals such earthworms and vertebrates that spend all or part of their life in soil. It influences aboveground biodiversity in containing seed banks of plant species,[1] in regulating plant community composition and above-ground pests, plagues and pathogens,[2] and in controlling plant abundance and invasiveness.[3]

As a carbon sink, soil can sequester CO_2 from the atmosphere thus mitigating global warming. Agricultural soils in EU contain around 14 billion tonnes of carbon in the topsoil (corresponding to 51 billion tonnes of CO_2 equivalent) which is much more than 4.4 billion tonnes of greenhouse gasses emitted annually by EU Member States.[4]

Therefore, releasing just a fraction of the carbon held in EU soils to the atmosphere could easily wipe out any savings of anthropogenic GHG emissions made by other sectors[5]. For example, a loss of 0.1% would correspond to around 1% of the EU GHG emissions, annually.

b. Threats to European soils[6]

A wide range of processes threatens the health of European soils and requires policy responses. An indicative, but non-exhaustive list of these threats includes the following:

- **Soil erosion** (the accelerated loss of soil resulting from anthropogenic activity in excess of accepted rates of natural soil formation) is in farming mainly due to inappropriate land management and overgrazing. Soil erosion by water is one of the most widespread forms of soil degradation in Europe.

- **Soil organic matter (SOM) decline** (the deterioration of the composition of soil's living and dead organic constituents presents derived from residual plant and animal material) impacts soil structure and aggregate stability, water retention, soil biodiversity and the sourcing of plant nutrients. Since the primary constituent of SOM is organic carbon (OC), it is often used as a proxy for SOM as it is easier to measure and can be related to emissions from the land to the atmosphere.

- **Soil biodiversity loss** (the reduction in the diversity of organisms living in the soil) affects the web of biological activity in the soil, which in turn reduces the ability of soil to provide ecosystem services. Many pivotal roles such as releasing nutrients from SOM, carbon sequestration, forming and maintaining soil structure and contributing to soil water entry, storage and transfer, are thus threatened. Soil degradation by erosion, contamination, salinisation and sealing all threaten soil biodiversity by compromising or destroying the habitat of the soil flora and fauna.

- **Soil compaction**, which results from the physical degradation of soil micro- and macro-aggregates, which are deformed or even destroyed under pressure from the passage of heavy machinery or repeated trampling of grazing animals, especially under wet conditions. Compacted soils are less able to absorb rainfall, thus increasing runoff and erosion while root growth and soil air is restricted, affecting plant health.

- **Soil contamination**, which affects the soil fauna and human health through the food chain (through soil-crop-human or soil-crop-animal-human chains), and stems from industrial activity and mining, and from the widespread use of chemicals such as pesticides on agricultural land which accumulate their residues in soils.

- **Salinisation** (the increasing accumulation of salt in soil in excess of its naturally occurring levels), which results from human interventions (such as inappropriate irrigation practices, the use of salt-rich irrigation water, and/or poor drainage conditions), but could also be due to changes in groundwater or rainfall characteristics.

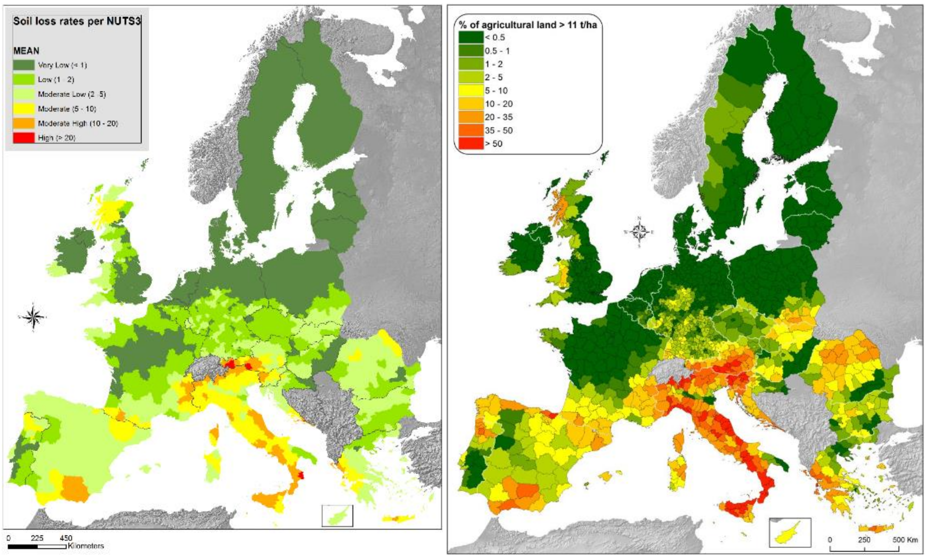
- **Sealed soils**, or the destruction or covering of soils by buildings, constructions and layers of completely or partly impermeable artificial material (asphalt, concrete, etc.), which constitute the most intense form of land take and are essentially an irreversible process.

- **Desertification**, a type of land degradation in dry areas resulting from a combination of climatic variations (such as prolonged droughts and more irregular precipitation) and human activities (e.g. unsustainable agricultural practices) that is manifest by the reduction or loss of the biological or economic productivity of the land.

c. Soil erosion in EU

Soil erosion by water is the main source of erosion in Europe. Other forms of erosion such as wind erosion, gully, and erosion by harvesting crops have less significant effects in EU. Soil erosion by water affects primarily three regions with different intensity of the threat: a southern zone with severe risk, another loess zone with moderate risk and an eastern zone with an overlap of both of these zones.

Figure 1. Soil erosion from water (left) and in farmland (right), EU-28



Soil erosion by water (tonnes per ha per year), 2010, EU-28, NUTS 3 (left) and Severe soil erosion in agricultural lands (right) - % of agricultural land with > 11t/ annually.
Source: Joint Research Centre, European Commission

According to recent studies, approximately 11.4 % of the EU's territory is estimated to be affected by a moderate (up to 5 tonnes per hectare per year) to severe *water erosion* (more than 5 tonnes per hectare per year).[7] This estimate is lower compared to the previous estimations that 17 % of EU's land area is affected by soil erosion,[8] mainly due to the introduction of management practices against *soil erosion* (reduced tillage, cover crops, plant residues, grass margins, stone walls and contour farming), which have been applied in Member States during the last decade.

Yet more than 24 % of the EU lands and almost 1/3 of agricultural areas have erosion higher than the sustainable rates (2 tonnes per hectare per year), and this despite the fact that between 2000 and 2010, erosion has decreased by 20% on arable lands in Western and Central Europe because of erosion control.[9],[10]

A recent quantitative estimate of *wind erosion* shows that around 7% of the EU arable lands have rates higher than 2 tonnes per ha per year.[11] The regions mostly affected by wind erosion are large parts of arable land in Denmark, Netherlands, the northern part of Germany, eastern England and the Iberian Peninsula.

d. Evolution of soil organic matter (SOM) in EU

Soil organic matter can decline due to a combination of factors ranging from a reduction in inputs to an increase rate of soil disturbance. Organic matter decays more rapidly at higher temperatures, so soils in warmer climates tend to contain less organic matter than those in cooler conditions. Well drained soil generally contains less soil organic matter than wetter soils, where less oxygen is available for its decomposition.

Disturbance such as tillage increases the exposure of organic matter to microbial decomposition in topsoil, thereby contributing to a higher decay rate. Loss of organic matter also occurs because erosion affects topsoil, removing sediment enriched in organic carbon. Generally, cropping returns less organic matter to the soil than native vegetation. It is estimated by the JRC that around 75% of all EU croplands are below 2% OC.[12]

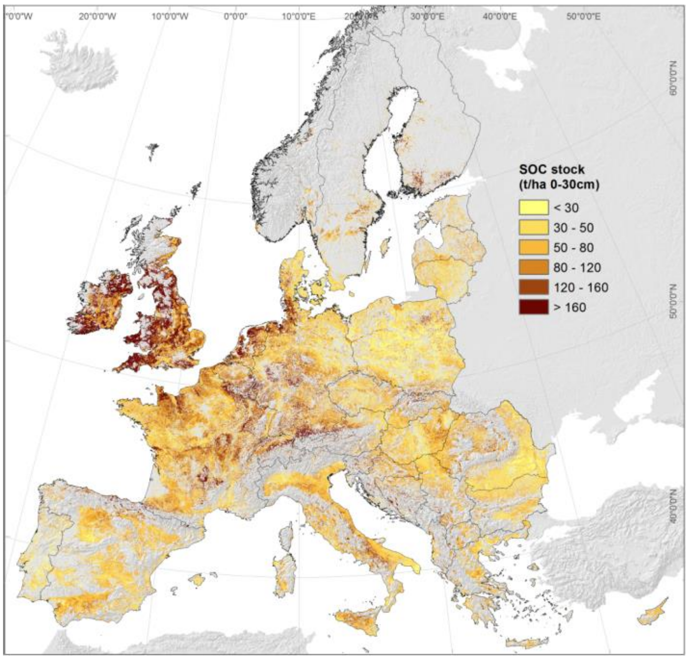
Low levels of organic carbon in the soil are generally detrimental to soil fertility, water retention capacity and resistance to soil compaction. Increases in surface water run-off can lead to erosion while lack of cohesion in the soil can increase the risk of erosion by wind. Other effects of lower organic carbon levels are a reduction in biodiversity and an increased susceptibility to acid or alkaline conditions.

Data from the JRC based on samples collected by the 2015 LUCAS survey shows that cropland exhibits much lower soil organic carbon concentrations compared to grasslands and natural vegetation (eg. 17.8, 40.3 and 77.5 g per kg, respectively).

Comparison of LUCAS data between 2009 and 2015 suggests that cultivated mineral soils generally show stable or low decreases while those under grasslands show slight increases (+1.43 % for grasslands and -0.49% for croplands). Interestingly, 74% of all LUCAS soil points on croplands in are below 2% OC.

Decline in SOM in peat soils (see forthcoming Brief No 4 on greenhouse gas emissions) has been a major degradation process in northern Europe reflecting historical management practices such as drainage, whereas decline in SOM in mineral soils is a European wide degradation process.

Figure 2. Soil organic carbon stocks in agricultural topsoils, EU-28



Soil organic carbon stocks in agricultural topsoils of the EU. (Lugato et 2014)

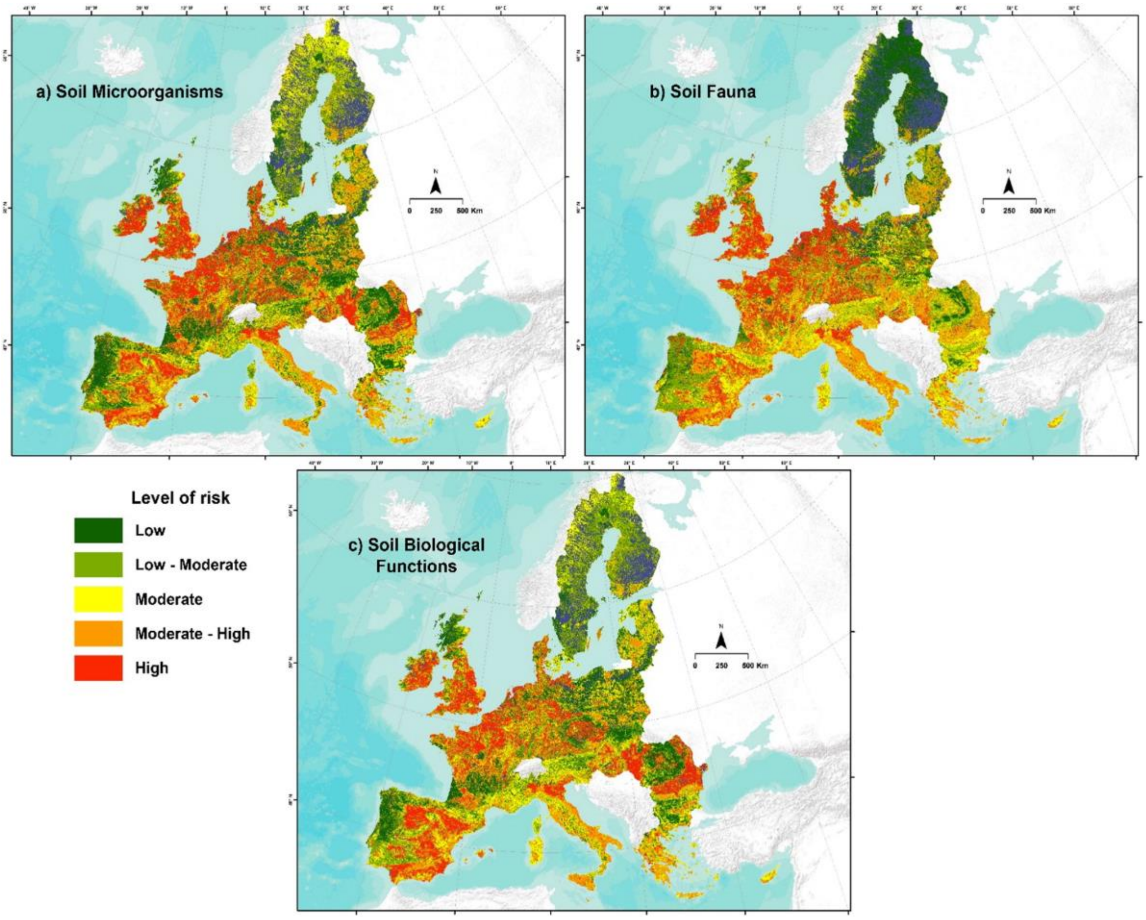
e. Decline in soil biodiversity

A large proportion of the planet's biodiversity within terrestrial ecosystems is hidden belowground in soils. While belowground biodiversity can often be much higher than above ground biodiversity, reductions in that diversity and composition can threaten the performance and functioning of ecosystems. Evidence tends to show that soil biodiversity is declining and that soil communities are changing due to land use intensification, soil sealing, erosion, contamination and compaction.

It is important to note that soil organisms interact within complex food webs, which means that changes in diversity within one group may alter the abundance, diversity, and functioning of another. Soil biodiversity has been well described in the European Atlas of Soil Biodiversity [13] and the Global Soil Biodiversity Atlas.[14]

These Atlases try to address a fundamental problem with soil biodiversity: if we do not know what is out there, how do we know if it is in decline? Even with this resource, it is challenging to gauge at national, European and global scales. However, at local levels, it is clear that biodiversity is decreasing due to changing common threats to soil such as soil sealing, erosion, organic matter depletion, salinisation, contamination and compaction.[15] Furthermore, through the LUCAS 2018 Survey, the JRC are using DNA extraction techniques to undertake the most comprehensive survey of soil biodiversity for EU soils.

Figure 3. Potential risks to EU soil biodiversity



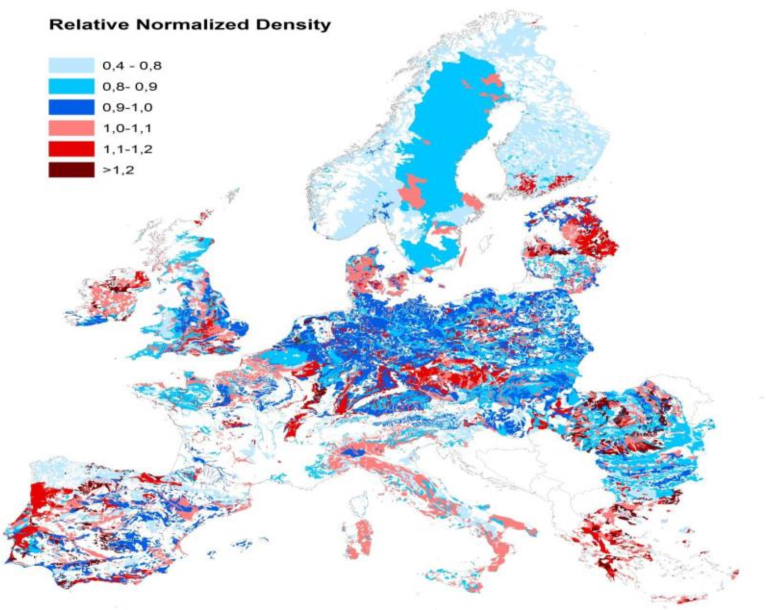
Distribution of the potential threats to (a) soil microorganisms, (b) soil fauna and (c) soil biological functions predicted for 27 European countries (spatial resolution 500 m).[16]

f. Soil compaction

Quantification of soil physical properties is laborious, especially for the subsoil. Hence, there are only few thorough inventories based on measured indicators, and these only cover regional areas. However, a range of soil properties for a total of approximately 900 soil profiles (roughly 3500 soil horizons) across 28 countries in Europe has been compiled, making it possible to estimate the density of subsoil horizons in each of the above-mentioned soil profiles (Figure 4).

White areas on the map indicate that it was not possible to estimate the density. It was found that about 23 % of the total analysed area has critically high densities.[17] This status of soils can be partly explained by the increased use of heavy machinery since the 1960s, resulting in high stress on soils, in particular in the subsoil below the plough layer.

Figure 4. EU relative normalised density (RND)



Relative normalized density (RND) for European subsoil horizons covering the depth 0.25 – 0.7 m as calculated by Eqs. 3ab based on the SPADE8 database. RND>1 may be considered a dense soil.

2. The facts about best soil practices

a. Several farming practices address issues related to soil degradation (drivers)

Protecting soils should acknowledge the effects of different practices. For example, land use intensification can reduce soil biodiversity by physical disturbance, which also hampers soil structure, and depletes soil organic matter (SOM). This in turn can lead to physical soil degradation such as an increase in soil erosion rates. Monocultures and the use of heavy machinery can cause soil compaction, while soil pollution by chemicals such as pesticides and excess levels of nutrients further stress the soil.

Such threats together will result in a reduction of water-holding capacity and aeration of the soil, which increases emissions, the need for larger machinery for cultivating the soil, which further exacerbates soil compaction and erosion. There is a strong feedback between many of these threats to fully functional soils, which means that a holistic and collaborative approach to soil management is crucial.

Agro-ecology and the sustainability of farming systems

Agro-ecology, as a science, studies how different components of the agroecosystem interact in order to develop sustainable farming systems that optimise and stabilise yields against adverse conditions. It helps to understand how nature can reduce crop exposure to natural pests by using landscape complexity, flower strips and inclusion of green manures and cover crops in rotation that may promote mutualists (e.g. pollinators and mycorrhiza), while reducing the spread of pests and pathogens by promoting natural defences. This offers a soil management approach, both aboveground and belowground, based on a more nature-inclusive, ecological intensive agriculture. An appropriate combination of crop rotation, soil cover maintenance and specific tillage management can thus help meet the pressing need to protect natural resources, such as soil, in certain areas while maintaining economically viable agriculture.

Among these farming practices related to land use and cover management, some can be readily influenced by policy makers and farmers in order to help reduce soil degradation. Indeed, in 2017, the Intergovernmental Technical Panel for Soils published a set of voluntary guidelines of scientifically sound approaches for sustainable soil management endorsed by FAO.[18] The following practices, directly or indirectly, form part of the proposed framework of the good agricultural and environmental condition (GAEC) of the land for the period post-2020, which beneficiaries of area- and animal-based payments of the CAP would have to observe.

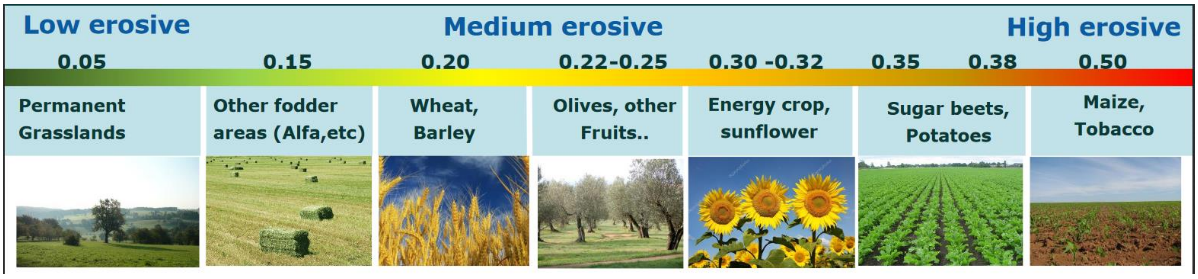
b. Crop rotation

Crop rotation is a farming practice in which different crops are grown in the same field at different times over several years, and which can positively or negatively affect the environmental and economic performance of farms. Crop rotation aims to create favourable conditions for crop development, promoting soil fertility and minimising the development of pests and weeds, as well as ensuring better nutrient management. To achieve this, a balance between the combination of crops and the sequence in which they are cultivated is sought.

Often, the first sequence in a rotation is used to prepare and regenerate the soil — using crops such as legumes and grasslands — while the second sequence takes advantage of the increased fertility of the regenerated soil, ideally leading to a farming practice that is economically more sustainable. In the EU, crop rotations typically last 3 to 5 years in conventional agriculture, and 5 to 10 years in organic agriculture. They can include a number of different plant species and strategies to achieve the desired outcome.

The length of the crop rotation (i.e. number of years of the rotation) is an important issue; however, the overall share of crops at a region level is generally stable in the short term, making the type of the cultivated crops a key factor for soil protection[19]. The annual soil loss from agricultural lands depends on the crop type (Figure 5).

Figure 5. Erosive effect of crops and grasslands by type



The value amounts for the crop factor within the cover-management factor which is used, together with four other factors, to estimate the risk of erosion within the Revised Universal Soil Loss Equation (RUSLE) developed by the JRC. [20]

Benefits of crop rotation may be maximised by the influences of other practises, such soil cover, reduced tillage and organic management low in pesticides and synthetic fertilisers.

Depending on the crop type, crop rotation can significantly reduce the amount of soil loss from water erosion. In areas that are highly susceptible to erosion, farm management practices such as no and reduced tillage can be supplemented with specific crop rotation methods to reduce raindrop impact, sediment detachment, sediment transport, surface runoff, and soil loss.

The use of different species in rotation allows for increased soil organic matter (SOM), greater soil structure, and improvement of the chemical and biological soil environment for crops. With more SOM, water infiltration and retention improves, providing increased drought tolerance and decreased erosion. Crop rotations also increase soil organic carbon (SOC) content.

Highly diverse rotations spanning long periods have shown to be even more effective in increasing SOC, while soil disturbances (e.g. from tillage) are responsible for exponential decline in SOC levels. Rotating crops, such as leguminous crops, adds nutrients to the soil. Increasing the biodiversity of crops has beneficial effects on the surrounding ecosystem and can host a greater diversity of fauna, insects, and beneficial microorganisms in the soil.

c. Soil cover

Soil cover refers to the periods of the year when the soil is covered by residues or crops, including catch or cover crops. It is important for preventing nutrient and pesticide runoff and reducing the risk of soil erosion. In addition, soil cover may improve soil fertility by increasing soil organic matter and soil biodiversity.

Cover crops are a management practice that is efficient in reducing soil and nutrient loss by keeping the land covered with vegetation during the whole year. These crops are not normal winter crops or grassland, but are sown specifically to protect bare soil in winter (and early spring) after the harvesting of summer crops.

Cover crops also reduce soil loss by improving soil structure and increasing infiltration, protecting the soil surface, scattering raindrop energy and reducing the velocity of the movement of water over the soil surface. The economic value of the cover crops is low – its main goal is to protect soil and avoid nutrient leaching.

In EU-28 in 2010 during winter 44 % of the arable area was covered with normal winter crops, 5 % with cover or intermediate crops, 9 % with plant residues and 25 % was left as bare soil. For 16 % of the arable area soil cover was not recorded. Areas for which no soil cover is recorded include areas under grass and areas not sown or cultivated during the reference year (e.g. temporary grassland).[21]

In parallel, maintaining crop residues on soil surfaces also protects the soil from splash erosion, but additionally increases infiltration rates and reduces surface runoff, resulting in less soil loss.

d. Tillage management against erosion

Tillage practices refers to the preparation of land for growing crops and usually involves ploughing operations carried out between the harvesting and the sowing of crops. Tillage management against erosion encompasses various practices ranging from contour farming to conservation and no tillage. The effects of tillage practices on soil degradation are varied.

Contour farming means that farmers apply certain field practices (ploughing, planting) to constant elevations that are perpendicular to the normal flow direction of runoff.

It reduces erosion potential by reducing runoff velocity and the hydraulic forces exerted by the water on the soil surface. The increased surface roughness provides more time for infiltration. The effectiveness of contour farming in reducing soil erosion depends on the slope gradient of the field where it is applied[22].

No-tillage and reduced tillage can diminish run-off and erosion, provided the soil is sufficiently covered. It is assumed that with no-tillage, the number of tractor passages decreases significantly; which is not always true under reduced tillage. Generally, the less the disturbance of vegetation or residue cover at or near the surface, the more effective is the tillage practice in reducing soil erosion by water.

Conventional tillage is the most widespread tillage practice and is applied in 74.4% of the arable sites in EU-28. Reduced tillage or conservation tillage is practiced on around 21.6% of the arable land in EU, while no tillage is applied to only 4% of arable land.

3. The challenges of precision agriculture

a. *Precision farming: Increase productivity and reduce impact on soil*

Precision farming or agriculture is a modern farming management concept using digital techniques to monitor and optimise agricultural production processes, while maximising yields. It involves local soil fertility and crop growth monitoring, remote sensing, global information and positioning systems, computer models, decision support systems, variable-rate technology, and accurate recordkeeping. It offers the opportunity to collect information on environmental conditions at local (parcel) level which could then be further used for monitoring the impact on the environment.

Precision agriculture

Precision agriculture as a modern farming management concept offers farmers more accurate and precise means of optimising crop management according to soil types and properties through the use of new information technology. Examples in arable farming include:

- ✓ *in situ and remote sensors to assess the spatial variability of parameters related to practises such as tillage, seeding, weeding, fertilisation, herbicide and pesticide application, and harvesting;*
- ✓ *in situ sensors that can continually characterise ground and surface water conditions while proximal and remote sensors determine the actual state of soils, crops or natural vegetation, and monitor continually air quality;*
- ✓ *geolocated land management systems with live measurements of soil chemical properties allow farmers to adjust fertiliser supply to the local soil fertility conditions, recognise disease and disease-free spots, and weed presence on cropland.*

Precision farming, which involves the targeted application of nutrients and pest control measures on the basis of location-specific monitoring, offers a means of delivering yield while reducing nutrient losses. Likewise, satellite guidance systems can help improve work organisation, by saving the use of a person to guide the cultivator. But they also make it possible to use permanent pathways, known as Controlled Traffic Farming (CTF), that are beneficial for soil protection.

Due to reduced compaction of the upper soil layer, the water and air regime in the soil improves. Yields from cropping systems become more stable during periods of drought and heavy rainfall. Current test results confirm that CTF systems adapted to local conditions can sustainably improve the efficiency of soil protection and crop production in Europe.[23]

b. The three gaps: knowledge, application and perception

While increasing the uptake of sustainable farming systems (such as agro-ecology) or certain favorable practices is necessary, particularly in certain areas where environmental and climatic challenges are strong, the development of precision farming is inevitable. However, development that is beneficial to the environment and the climate cannot be achieved without filling the three gaps facing precision farming: knowledge, application and perception.

Increasing the use of precision farming by overcoming these challenges not only offers the chance to farmers to save costs and time, produce more and better food, while reducing environmental impacts, but also enhances the knowledge of the natural processes which underpin agro-ecology. For instance, sensing can be used to effectively monitor soil organic carbon for accounting purposes and be central to the adoption of best agronomic practices that also reduce greenhouse gas emissions and allow significant carbon sequestration.[24]

Knowledge gap: farmers are most often lacking the tools or the context to analyse their own data and are mostly unaware of the extent to which their data get stored, traded and analysed for future use. The lack of interoperability standards that would allow communication between machinery and components of the precision agriculture, connectivity and compatibility standards is also a key problem.

Application gap: there is a risk for having a digital divide. Small or less educated farmers may be unable to keep up with new technologies. This could lead to a large digital divide between big and small farmers. Therefore, having independent advisory services in place with sufficient digital knowledge and access to the data is very important to help to minimise the divide. There is a need to develop adapted solutions for all including small farms. There is still a high need for incentivising innovation, to tailor precision agriculture technologies to farmers' needs.

Perception gap: the high start-up costs with a risk of insufficient return on investments pose the challenges with accessibility and affordability. Both on- and off-farm employment will require increasing levels of digital skills. According to the 2017 Europe's Digital Progress Report, 44% of the EU population and 37% of the workforce had 'insufficient' digital skills in 2016.[25] There is a lack of infrastructure, many rural areas lag behind in broadband availability, while 76 % of the EU population has access to fast broadband (>30Mbps), only 40 % of homes in rural areas have such access.

c. What needs to be done to fill these gaps?

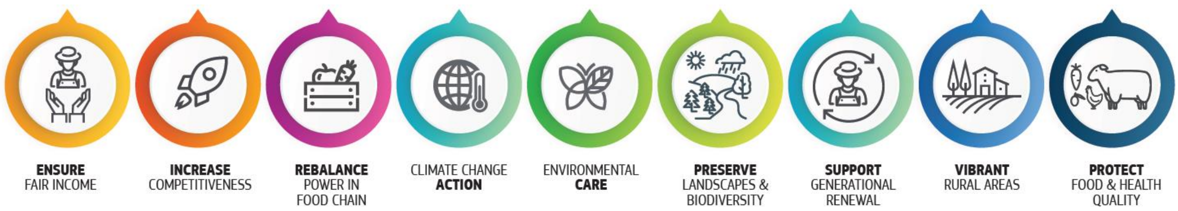
A balanced and appropriate uptake of precision agriculture will require various public interventions ranging from the development of a new farm information management system as the Farm Sustainability Tool for Nutrients (FaST) proposed for the CAP post 2020, supporting cooperation between farmers to foster collective investments to incentivising Producers' organisations to organise access to precision farming for its members, with the support of CAP/CMO funds.

Precision farming also requires adequate advisory system and services. Independent advisors often lack digital skills. As agricultural data management and precision agriculture requires technical competence, a system of support and training for advisers across the EU would be very much desirable. The future role of farm advisory services should include facilitating innovation projects on digital technologies and supporting farmers in orienting themselves in the digital landscape.

From the technical point of view, progress in miniaturisation and development of cost-effective technology will continue, and an innovating industry for machinery and services is already in place. Global Navigation Satellite Systems (GNSS) and remote sensing data sources are improving through upgrade of EU infrastructures (Galileo and Copernicus) and resulting services and applications.

There is also an ongoing project led by the EEA, involving DG AGRI, JRC, ESTAT, the European farmers' association Copa-Cogeca, and CEMA, the European network of national agricultural machinery associations and their member companies aiming at jointly organise the collection of data on precision farming, with two main objectives.

The first one is to better estimate the current and potential use of precision faming tools. Secondary objective is the assessment of (perceived) environmental and economic benefits achieved through the application of certain precision farming practices, the identification of challenges of the uptake and use of precision farming instruments, and the assessment of its potential for environmental monitoring. Lessons learned through this project for developing a module on precision farming in recurring statistical surveys might be drawn to be able to better follow the development of the sector.



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For more information

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