POLICY BRIEF 1

SUSTAINABLE SOIL MANAGEMENT

Content

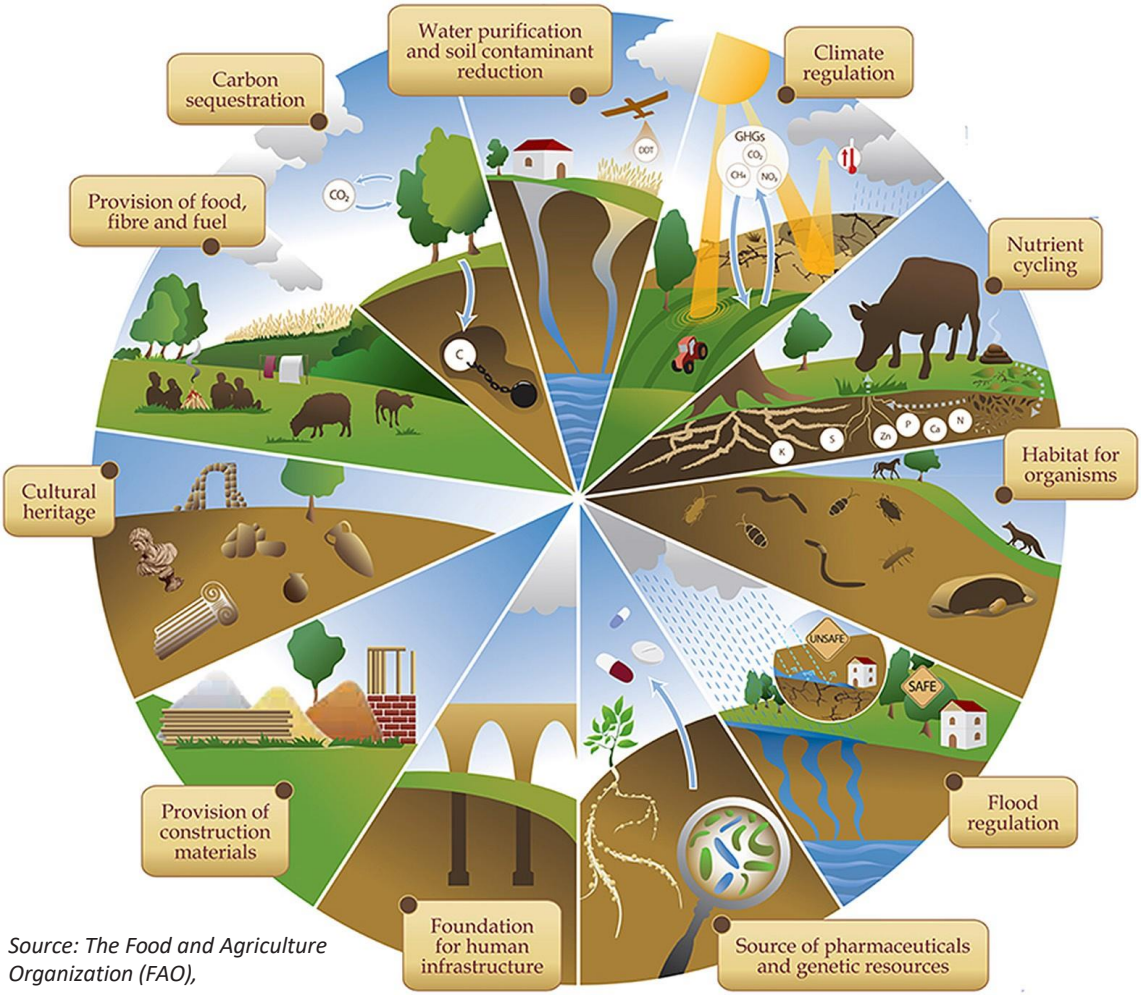
1. THE IMPORTANCE OF SOIL

Soil, the thin skin of the Earth, is one of the most important elements of any ecosystem and the basis of life. It takes a vast amount of time until one meter of soil is formed through physical and chemical weathering and biotic processes. For example, in Europe it takes around 100 years to produce only 1 cm of soil. In the human perception of time, soil is considered a non-renewable resource.

Currently more than 7 billion people live on our planet and almost all our daily food is dependent on the crop production on our soils. Soil is under continuous pressure due to an increasing global population, which will only become more and more dependent on the availability and fertility of soil. Besides food production, soils provide other functions and services, such as holding water, providing biomass, as well as grounds for construction and recreation, all of which often compete with each other. Therefore, it is necessary to manage soils sustainably.

The purity of groundwater and drinking water clearly depends on soils acting as filters and a buffer for contaminants. Furthermore, without the retention of precipitation water, surface run-off would cause flooding after each major rainfall. Soil has the capacity to store carbon and reduce GHG emissions and to hold nutrients for crops. Soil is also a habitat for a multitude of soil organisms and is considered the most important reservoir of biodiversity. Soil biodiversity plays a crucial role in the functioning of ecosystems.

Numerous soil ecosystem services have only been recognised relatively recently and shall be getting increasing attention. Among those are various provisional (food, fuel, fiber, fresh water), regulative (air quality maintenance, climate regulation, erosion control, regulation of human diseases, water purification) and even cultural services (spiritual enrichment, cognitive development, self-reflection, recreation, aesthetic experiences).



Source: The Food and Agriculture Organization (FAO),

2. SOILS ARE INCREASINGLY UNDER PRESSURE

A quarter of the total global land is estimated to be highly degraded (FAO) and half of agricultural land is moderately or severely affected by soil degradation. At the EU level soil degradation is also an important issue: according to "The European environment — state and outlook 2015" of the European Environment Agency (EEA SOER 2015), "the main problems for soils in the EU are irreversible losses due to increasing soil sealing and soil erosion, and continuing deterioration due to local contamination and diffuse contamination (acidification and heavy metals). Other degradation forms are also present".

But soil degradation is not always irreversible: with an appropriate sustainable management of the soil it is possible to prevent the degradation process and remediate degraded land. By increasing soil fertility and soil health, **sustainable soil management (SSM)** offers multiple benefits, e.g. for food production and food quality, human and animal health and other ecosystem services. Good examples and recommendations for sustainable soil management exist. However, they are still not sufficiently implemented at the local level.

3. A NEW MOMENTUM FOR SUSTAINABLE SOIL MANAGEMENT IN THE POLICY AGENDA

There is a growing recognition of the importance of sustainable soil and land management, as well as an increasing awareness of the need for improved soil management and limiting soil degradation at the European and global levels. This new momentum is reflected in the global policy agenda**:** The **Sustainable Development Goals (SDG) of the United Nations (UN)** have set new global sustainability benchmarks, and achieving a number among them is in fact largely dependent on SSM and appropriate land management. Such SDGs include SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 6 (access to clean water), SDG 11 (sustainable cities), SDG 13 (combating climate change), as well as SDG 15 (life on land). SDGs draw attention to the need of protecting soil quality, so as to increase the production potential of soil in terms of the quantity and quality of food. One of the objectives is also to improve degraded soils.

Sustainable soil and land management is duly enshrined in the SDG target 15.3 on **Land Degradation Neutrality**: "Achieving land degradation neutrality – by preventing land degradation and rehabilitating already degraded land, scaling up sustainable land management and accelerating restoration initiatives – it is a pathway to greater resilience and security for all".

Moreover, in 2012 the UN General Assembly decided to initiate the **Global Soil Partnership** (GSP) under the auspice of the FAO[1]. Another initiative was to declare the International Year of Soil in 2015.

One of the main pillars of action of the GSP is to promote sustainable management of soil resources for their protection, conservation and productivity. Urgent action is needed in order to reverse the degradation of soils and thus ensure the necessary food production for future generations, mitigate climate change and provide clean water. An important achievement was the revision of the **World Soil Charter** and the publication of the **Voluntary Guidelines for Soil Sustainable Management (VGSSM)**[2] by the GSP and FAO in December 2016. Itwasthefirstattemptevertodefinesustainablesoilmanagementpracticesatthegloballevel. Those guidelines now need to be promoted and implemented at regional, national and local levels. The implementation of the VGSSM would also require mainstreaming when designing soil and agricultural policies. Those principles are closely linked to the concepts of agro-ecology or equivalent practices such as conservation agriculture, organic farming, permaculture etc., which receive an increasing attention at global level (in particular FAO is promoting agro-ecology and organized in 2018 the second international symposium on agro-ecology).

The **VGSSM** present generally accepted, practically proven and scientifically established principles to promote SSM and provide guidance to all stakeholders on how to translate the principles into practice, through farming, pastoralism, forestry and other forms of natural resources management. The VGSSM focus mainly on agricultural SSM. A number of other international initiatives support the sustainable use of soils, but nevertheless the **implementation of the sustainable soil management** is still insufficient.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[3] published a global assessment of land that has raised awareness on the scale of global land degradation. The importance of soil has also been recognised in the Climate Agenda, in particular the **4p1000 initiative**, which was launched at the COP21[4] with the objective to increase soil carbon sequestration by 4‰ per year. Several events at the COP24[4] in Katowice focused on agro-ecology and the need to promote sustainable soil management.

At the EU level, few policies explicitly mention sustainable soil management, but some policy instruments addressing soil protection promote (at least partly) SSM practices. This is the case for the Common Agriculture Policy (CAP) and the Industrial Emission Directive (IED). With regard to soil sealing specifically, the European Commission developed and released **guidelines on best practice to limit, mitigate or compensate soil sealing**[5]. Soils provide a wide range of vital ecosystem functions in urban areas. The guidelines combine the best management practices to limit soil sealing and to protect fertile soils against it.

4. DEFINITION OF SSM

SSM must be coherent with sustainable development principles: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987)

---

[1]Food and Agricultural Organization of the United Nations, http://www.fao.org/global-soil-partnership/en/

[3]http://www.fao.org/3/a-bl813e.pdf

[3]Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

[4]http://www.cop21paris.org/, http://www.cop24.katowice.eu/

[5]http://ec.europa.eu/environment/soil/pdf/guidelines/pub/soil_en.pdf

There is not a single definition of SSM (even within agriculture) but the revised World Soil Charter provides a commonly agreed and generic definition of sustainable soil management included in the Voluntary Guidelines for Sustainable Soil Management (VGSSM) and adopted by the FAO member countries:

"Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The balance between the supporting and provisioning services for plant production and the regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern".

TARGETS OF SSM

- **Wind and water soil erosion is limited**
- **Contaminant inputs to soil are low and levels are non-toxic to human and animals**
- **Contaminant levels in soil enable the production of healthy crops**
- **Net sealing is reduced and spatial development responsible**
- **Soil carbon in mineral soils remains at a stable level at least**
- **Decline of organic matter in peat soils is reduced**
- **Soil biodiversity is sustained to enable biological processes of energy and nutrient cycling**
- **Soil capacity for retaining water in soil is sustained**
- **GHG emissions from soil are low and counteracted by C sequestration**
- **Good soil structure and low compaction**

5. OVERVIEW OF MOST IMPORTANT SUSTAINABLE SOIL MANAGEMENT MEASURES

PREVENTING SOIL EROSION

What is it?

Erosion is a physical process involving the removal of soil particles by water or wind and their transportation to sedimentation sites. Two groups of drivers can be distinguished, i.e. natural factors (landform, soil, precipitation, wind and vegetation) and anthropogenic factors (land use, tillage, management system). The structure of land and crops, the size and layout of plots, roads and landscape structures in the catchment, shaped as a result of human space management are among the basic factors affecting erosion. Among land use types, arable lands are the most threatened by erosion.

The situation at the European level

Recent evaluations revealed that the EU has a mean annual soil loss rate of 2.46 t ha^{-1} and that annual soil loss is estimated at 970Mt. This significantly exceeds the average soil formation rate (Panagos et al., 2015). Soil protection measures should be implemented on the 24% of European lands that experience mean annual soil loss rates of over 2 t ha^{-1}, while special protection measures are required on 12.7% of arable lands, suffering rates of soil loss of over 5 t ha^{-1} per year.

Process of water erosion (*Photo: R. Wawer*)

Wind erosion of barren land (*Photos: L. Maring*)

Good practices:

A vegetation cover reduces water erosion through reducing surface runoff and increasing infiltration. Plant root systems stabilise soil aggregates. Therefore, planting grass, shrubs and trees helps to manage extremely disturbed areas and stabilise soil. Arable lands susceptible to erosion should be properly cropped, e.g. by way of contour cropping, which involves growing crops along a contour line of the slope (in rows or strips perpendicular to the slope).

Mulching soil through the application of plant residues in order to cover the soil surface effectively protects soil against erosion. Mulching also helps to retain water in the soil. Leaving plant residues on soil can protect it from both water and wind erosion. Residue covers soil particles making them less susceptible to water and wind erosion.

Terracing as a measure to limit soil erosion (*Photo: B. Podolski*)

Crop residue mulch stops soil erosion (*Photo: J. Smagacz*)

Terracing is the practice of building mechanical structures in order to change the slope profile and reduce runoff and related erosion. Terracing combined with a permanent plant cover can be especially effective in reducing the risk of erosion. A similar effect is achieved by hedges or grass strips.

Conservation tillage, represented by reduced tillage or no-till, reduces soil susceptibility to erosion through limiting the disturbance of the soil profile.

Wind erosion can be successfully combated through vegetation practices such as planting shelterbelts or windbreaks perpendicularly to the prevailing wind directions. The application of permanent grasses, crop rotations with legumes and conservation tillage also help to manage wind erosion.

Erosion can also be reduced through avoiding such land use changes as deforestation and the conversion of grassland to cropland.

Level of implementation: farmer.

ENHANCING SOIL ORGANIC MATTER IN MINERAL SOILS/STIMULATING SOIL ORGANIC CARBON SEQUESTRATION

What is it?

Soil organic matter (SOM) is a basic indicator of soil quality decisive for physicochemical properties, such as sorption and buffering capacity, as well as many biological processes and water retention. High content of organic matter stabilises soil structure, reducing susceptibility to compaction, as well as water and wind erosion (Fenton et al., 1999). The preservation of SOM resources is important, not only for the maintenance of soil production functions, but also for the sequestration of carbon from the atmosphere.

Soil is the world's largest terrestrial pool of carbon (Scharlemann et al., 2014) and plays a crucial role in the global carbon balance (Lal, 2013). At global level the Soil Organic Carbon (SOC) pool stores an estimated 2.300 PgC – of which 1.500 PgC in the first meter of soil – which is more carbon than is contained in the atmosphere (roughly 800 PgC) and terrestrial vegetation (500 PgC) combined (FAO and ITPS, 2015). This phenomenal organic carbon reservoir in soil is not static but is constantly cycling between the different global carbon pools in various molecular forms (Kane, 2015).

The situation at the European level

SOM content varies across Europe depending on climate, soil genesis, land use (De Brogniez et al., 2015). In general, croplands contain much less SOM than wetlands and forests, while also being the most sensitive to SOM loss. A loss of SOM is forecasted for around 30% of the European area under current land management practices, especially in the Southern part of Europe. At EU level, soil carbon stocks are estimated between 73 and 78 billion tonnes[6] of which around 50% is found in peatlands. Soil can be a source or a sink of carbon depending on the way it is managed. Soils under grassland and forests are a carbon sink (estimated up to 80 million tonnes of carbon per year) whereas the majority of EU arable soils are suffering net carbon loss each year (estimated from 10–40 million tonnes of carbon per year), contributing to climate change. The conversion of grassland and forest into cropland is the main factor of carbon emission from agricultural land. The largest emissions of CO_2 from soils are due to conversion (drainage) of organic soils, and amount to 20–40 T of CO_2 per hectare per year.

Around **45% of the mineral soils in Europe have low or very low organic carbon content (0–2%)** and 45% have a medium content (2–6%)[7].

There is a large variability across the EU: in the Southern part of the EU, SOM is very low while organic soils in Northern countries are very rich in SOM. According to the LUCAS topsoil survey in 2015, croplands in the EU on average contain 17.63 g/kg against 39.78 g/kg for grasslands.

[6]The State of Soil in Europe. JRC, 2015, page 10, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC68418/lbna25186enn.pdf

[7]The State of Soil in Europe. JRC, 2015, page 12, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC68418/lbna25186enn.pdf

Scientific studies indicate that land use changes like the transformation of grassland, peatland or forest into cropland is associated with important and fast emission of carbon in the atmosphere, while the improvement of soil organic content by appropriate management practices takes more time

Good practices:

In order to sustain soil functions and soil fertility, soil organic matter must be kept at a stable level. This can be achieved through a positive balance of organic matter in the soil, reducing soil disturbance by tillage, improving soil structure and enhancing soil biodiversity.

Bringing sufficient amounts of plant residues to the soil is a common measure for sustaining SOM. These practices include growing green manure crops, catch crops, perennial forage and cover crops, and leaving crop residues in the field. The plant residues are ploughed in and slowly decomposed by the soil biota to constitute a source of soil humus. Green manure may sustain SOM at the current level or even increase its content and sequester carbon in soil. Legumes are especially valuable as green manure plants since they also increase nitrogen levels in soil. Cover crops are planted after the catch crops. They provide a carbon source, stimulate soil aggregation and protect against the leaching of nutrients and erosion of soil particles. Soil erosion can obstruct the accumulation of organic matter (OM) in soil.

Organic fertilisers applied to soil can be a significant source of soil carbon. It must be emphasised that only safe (uncontaminated) organic materials can be applied to soil. Organic soil amendments might include animal manure or recycled organic matter, e.g. compost, composted sludge, food waste, digestate. The European Commission proposed a new fertiliser regulation[8] as part of the EU Circular Economy package[9], aiming at creating an EU market of organic fertilizers with common rules concerning the level of contaminants. A strong polarisation of crop and animal agriculture in recent decades has caused a lack of manure in many regions, leaving space for recycled organics. These usually serve as a better source of soil carbon than manure and crop residues since they contain more stable carbon. However, the application of exogenous organic matter (EOM) must be controlled and follow good practice recommendations, as the excess of easily degradable OM may contribute to environmental damage.

Application of reduced tillage as a measure limiting SOM mineralisation (*Photo: J. Smagacz*)

[8]http://europa.eu/rapid/press-release_IP-18-6161_en.htm

[9]http://ec.europa.eu/environment/circular-economy/index_en.htm

Conservation tillage reduces the disturbance of the soil profile, protecting soil structure and enhancing SOM accumulation. Reducing tillage involves limiting the aeration of soil and related SOM mineralization. However, reduced or no-till practices result in carbon accumulation only when applied in long-term. Permanent grasslands are effective for carbon accumulation in mineral soils, especially when grass and legume species are combined.

Level of implementation: farmer.

PREVENTING THE LOSS OF SOM IN ORGANIC SOILS

What is it?

Peat soils are formed through the accumulation of plant residues under conditions of nearly permanent water saturation and the absence of oxygen. Peatland soils, containing high amounts of carbon, fulfil a range of functions, including production, and even more importantly, regulating services for water, biodiversity and climate. They also provide aesthetic, information and recreation functions for humans (Schuman and Joosten, 2008). Peat soils cover only around 3% of the Earth's land but they contain 20-30% of global soil organic carbon. There is no better terrestrial carbon reservoir. However, drainage aimed at reclaiming peat lands, especially intensive in 20th century, has resulted in the intensive degradation of peat soils. Drainage of peat lands converts OM accumulation processes into an accelerated decomposition of SOM due to oxidation processes, loss of structure and water retention potential. This results in the degradation of these soils and their ecological and environmental functions (e.g. habitat and water retention). The drainage of peat soils may result in the reduction of their SOC content from around 50% of the total soil mass to under 10% in a relatively short period of time (i.e. several decades).

The situation at the European level

Joosten (2009) estimated that the global total C stock in peat soils is around 445 700 Mton. This makes peat soils one of the major stocks of C in the world, containing even more than the atmosphere (Van Akker et al., 2015). Byrne et al. reported in 2004 that the total area of peat soils in the EU Member States and Candidate Countries was around 34 million ha. Based on Schils et al. (2008) 5.8 million ha is drained, including the 3.6 million ha used in agriculture as cropland or grassland.

Drained agricultural peat soils intensively mineralise, which causes large emissions of CO_2, amounting to 20-40 tonnes of CO_2 per hectare per year (Van den Akker et al., 2015).

Good practices:

Preventing the loss of SOM in peatlands might be achieved by **conserving peatlands** through sustaining a natural water regime, banning agricultural use, **afforestation**, **rewetting** drained peatland, **and banning the ploughing** of grasslands on peat soils.

Level of implementation: farmer/land owner/water manager.

Peatland degradation stimulated by drainage and peat extraction (*Photo: J. Niedźwiecki*)

Peatland with ongoing OM accumulation process (*Photo: J. Niedźwiecki*)

FOSTERING A BALANCE OF SOIL NUTRIENTS

What is it?

The sustainability of agricultural production is highly dependent on an appropriate balance of nutrients in soil. Nutrient surplus in soils, especially for nitrogen and phosphorus, might result in the eutrophication and deterioration of water quality and of aquatic ecosystems, as well as increased emissions of nitrous oxide to the atmosphere, leaching of bioavailable nitrogen to the water used for human consumption, thus creating hazards to human health (VGSSM). In some countries over 70% of nitrate in river waters comes from agricultural sources (Kay et al., 2012)

The situation at the European level

Nutrient balance is defined as the difference between the nutrient inputs to the farming system (mineral and organic fertilisers) and the nutrient outputs, such as the uptake of nutrients by crops. The average nitrogen surplus in EU agriculture is 51 kg/ha, posing a risk of water eutrophication, especially in some countries where the excess of nitrogen is greater than 100 kg/ha.[10]

Good practices:

First of all, it is recommended to achieve a nutrient balance in soil through **enhancing and sustaining natural fertility** (enhancement of soil organic matter, soil conservation, rotations, cover crops). Fertiliser application, including the types of fertilisers, rates and timing should be **appropriate to the natural soil productivity** and the buffering capacity of soil. Reintroduction of **crop-livestock systems** or crop-livestock-forest systems contributes to a better balance of nutrients in soil through the improved cycling of nutrients. **Liming acidic soil** increases the efficiency of plants to utilise nutrients and the capacity of soil to retain them. The use of organic and mineral fertilisers should be **precisely tailored to the needs** of a given crop. **Soil and plant-tissue testing** should be adopted and widely implemented. Such testing helps to precisely assess nutrient needs (VGSSM).

Level of implementation: farmer.

Fertiliser application (*Source: wikipedia.org*)

PREVENTING SOIL COMPACTION

What is it?

Soil compaction occurs when soil is exposed to densification by heavy equipment or during the grazing of animals, especially in conditions of excessive moisture. Compaction of cultivated topsoil can be relatively

[10]https://data.oecd.org/agrland/nutrient-balance.htm

easily undone by applying soil loosening or various tillage methods and does not pose a permanent threat to the soil and environment. Compaction of the subsoil is considered a process both difficult and expensive to eliminate. Compaction of the subsoil is especially challenging because it is invisible, cumulative and persistent. It is defined as the densification of soil and the loss of air-filled porosity, which results in an inferior soil structure, the deterioration of soil biological processes, and accelerated water run-off. Soil compaction is favoured by natural conditions (soil texture and weather) and has a rather local character, but it may constitute a serious problem to soil functions and may also accelerate other degradation processes.

The situation at the European level

Some studies indicate that the compaction of soils is a significant problem across Europe. It has been estimated that around 11% of soil in Central and Eastern Europe has been affected by compaction (Batjes, 2001). The estimates of European subsoils being highly susceptible to compaction lie between 23 and 36%, while 18% is already moderately affected (Jones at al., 2011).

Good practices:

Sustainable practices preventing soil compaction include: **avoidance, controlling traffic, reducing pressure** on soil by decreasing axle load, measures **increasing SOM** in soil, as well as more advanced drainage and aeration systems.

Level of implementation: farmer.

Soil compaction due to using heavy machinery (*Photo: L. Maring*)

MINIMISING SOIL SEALING

What is it?

Soil sealing is defined as the covering of soils by buildings, constructions and fully or partly impermeable artificial material (asphalt, concrete, etc.) (Prokop et al, 2011). Sealing is a part of land take processes. Land take is known as urbanisation or increase in artificial surfaces, usually at the expense of agricultural

or natural areas. Soil sealing and land take are driven by the need for new housing, as well as business and transport infrastructure related to the socioeconomic development of cities. Most social and economic activities depend on sealed areas and developed land. The related soil loss has considerable consequences for the capacity of land and soil to fulfil environmental functions. The overall quality of life in cities greatly depends on the density, spatial diversity and richness of green areas, which contribute to the mitigation of smog and the diminishing of heat waves. Soil sealing also reduces the capacity of soil to retain water, increasing the hazard of flooding.

Sealing of soil with impermeable materials limits water retention in cities (*Photo: K. Mikulska*)

The situation at the European level

There is an intensive and often uncontrolled increase in artificial surfaces, most of which becomes sealed. According to the CORINE land cover spatial databases, artificial areas covered 4.1%, 4.3% and 4.4% of EU territory in 1990, 2000 and 2006, respectively. This corresponds to an 8.8% increase of artificial surface in the EU between 1990 and 2006. In the same period, population increased by only 5% (Prokop et al., 2011). Between 2006 and 2012, the annual land take in the European countries (EEA-39) assessed using CORINE land cover (CLC) data was approximately 107 000 ha/year. In this period over 46% of all land converted to artificial surfaces in the EEA-39 countries was taken from arable land or permanent crops. Between 2009 and 2012, soil sealing increased in most EEA-39 countries by a total of 2 051 km^2. This corresponds to 0.0356 % of the total EEA-39 area or an annual average increase of 683 km^2 (EEA). The conversion of land into artificial areas in the EU has been accelerating over the years, with growth from 2012 to 2015 being about 6 % higher than from 2009 to 2012.

Good practices:

Sustainable management of soil in urban areas, understood as preventing excessive soil sealing, can be grouped into limitation, compensation and mitigation categories, as presented in the EC guidelines on best practice to limit, mitigate or compensate soil sealing (EC, 2012).

Limiting soil sealing has priority over mitigation or compensation measures, since soil sealing is a practically irreversible process. This is vital for protecting food production potential and soil related ecosystem functions for the future. Limiting might assume the form of **reduced overall land take** rate (transformation of agricultural land into urban functions) or **reduced conversion of the most valuable soils**. It is very important to set soil

quality as a key consideration in urban planning. Soils differ in their capacity to fulfil particular functions and this consideration should be made part of the planning process through involving soil databases and soil maps. Limiting soil sealing can also be achieved through **incentives for recycling land** (e.g. brownfield regeneration) instead of developing new sites.

Mitigating soil sealing may involve the **use of permeable materials** in construction work, in order to protect soil functions to a certain extent. Permeable materials enable water evaporation, which is important for avoiding the heat island effect, while also decreasing the cost of water treatment and reducing risk of flooding. **Green infrastructure** systems, such as dense green areas, grasses, shrubs and tree plantings, absorb water and air pollutants and lower the temperature.

Effective compensating measures can involve the **re-use of topsoil**, as weak as the development of **compensation systems,** whereby the soil loss resulting from construction work is compensated through measures carried out somewhere else. **Fees collected for the conversion** of agricultural into urban land can be used to reclaim land at another site.

Green infrastructures in city centres have cooling effects and absorb dusts and pollutants (*Photo: K. Mikulska*)

However, the sustainability of soil management in the context of urbanisation goes well beyond these measures and involves responsible **spatial planning that would take into consideration soil information and soil functions**[11]**,** including the role of soil with regard to air quality, temperature extremes, combating flooding risk, etc. – all the aspects conductive to the quality and safety of life in urban areas.

Level of implementation: spatial planners, city administration.

[11]http://publications.deltares.nl/1230934a.pdf

PREVENTING SOIL CONTAMINATION

1. Preventing diffuse contamination

What is it?

Agricultural soil can be spoiled with contaminants through so-called diffuse contamination, processes that cannot be linked to a single and definite source. There are various groups of soil contaminants: organic (e.g. polycyclic aromatic hydrocarbons, pesticide residues, antibiotics), inorganic (metals and metalloids) and particulate contaminants, whereas organic pollutants undergo a process of decay, inorganic pollutants do not and therefore stay in the soil (Anaya-Romero et al., 2015). Sources of diffuse contamination of agricultural soils include the long-distance transport of dusts, long-term use of low quality fertilisers (e.g. phosphates containing excessive lead and cadmium), the application of manure containing veterinary drug residuals, intensive pesticide and herbicide application, uncontrolled sewage sludge application, as well as irrigation with contaminated water.

The situation at the European level

The magnitude of current diffuse contamination processes at the EU level is difficult to evaluate due to the complexity of diffuse sources and the uncertainty of the data on contaminant input. For example, there is data on the herbicide applications per country, but no data is available on the actual pesticide concentration in European soils (Anaya-Romero et al., 2015). Diffuse soil contamination does not usually lead to environmental degradation but may result in serious problems regarding the quality of crops. There is a knowledge gap on the magnitude of soil diffuse pollution at EU level. The EU LUCAS survey and national soil inventory have data on heavy metals, however there are few data on pesticides residues and even less on emerging contaminants which are recognized as important issues. The analysis of pesticides residues was part of LUCAS 2018 soil analysis for the first time.

Good practices:

Sustainable management of agricultural soils involves limiting the input of persistent contaminants (e.g. trace elements, polycyclic aromatic hydrocarbons, pesticide residues) to soil. Preventing soil contamination in agriculture can be achieved by **limiting the application and a better control of fertilisers, pesticides and herbicides, as well as controlling the status of manure and exogenous organic matter** applied to soil. Especially in agricultural areas affected by diffuse contamination processes, **mitigation measures** are of major importance. An elevated content of contaminants in soil affects the quality of crops, transferring contaminants to the food chain with potential impact on human health and lowering the potential for agriculture. Measures such as the selection of crops and cultivars that differ in their capacity to avoid the accumulation of contaminants, introducing alternative crops (e.g. cropping industrial plants or energy biomass), as well as alternative land uses (e.g. afforestation), are all recommended.

Level of implementation: farmer/industry.

2. Managing point contamination

What is it?

Soils in the vicinity of smelters and mining sites accumulate metals and emit large amounts of metal-rich dust. Since metals are not subject to decomposition, this contamination legacy will remain for a prolonged period of time, even if dust emission is substantially reduced. Special attention must be given to hazardous sites, such as abandoned smelters or mines and tailings (Adriano, 2001). Point contamination with organic compounds is related to the petrochemical industry for example, as well as pesticide waste management facilities, former military bases, etc. Depending on the contaminant and its concentration in the soil, they may be toxic to plants or pose a hazard to animals and humans or hamper the biological processes in soil.

The situation at the European level

According to the data collected through the European Environment Information and the Observation Network for Soil (EIONET-SOIL), the total number of identified contaminated sites caused by point pollution is 2.5 million, while the estimated number of potentially contaminated sites is 11.7 million (Panagos et al., 2013). It is estimated that the annual management cost of contaminated sites in Europe is around 6 billion Euro (Panagos et al., 2013).

Good practices

- the ”polluter pays” principle, the avoidance of new spills
- risk assessment, determining the seriousness of the problem
- risk management, mitigating significant problems revealed by the risk assessment.

Barren wastelands as a secondary source of pollutants (*Photo: G. Siebielec*)

Reclaimed wasteland covered with grasses and shrubs limiting pollutant dispersion (*Photo: G. Siebielec*)

In cases of serious soil contamination, remediation is in principle necessary, while the urgency of remediation and the method to be applied has to be determined on the basis of site-specific **risk assessment** (Swartjes et al. 2012, Cachada et al., 2016). **Risk management** involves a range of measures aimed at limiting the risk related to contamination.

The **conventional remediation techniques** include in-situ vitrification, soil incineration, excavation and landfill, soil washing, soil flushing, solidification and stabilisation of electro-kinetic systems. Generally speaking, the physical and chemical methods suffer from limitations such as high cost, intensive labor, irreversible changes in soil properties and the disturbance of native soil microflora. Chemical methods can also create secondary pollution problems. On the other hand, they ensure a relatively quick effect.

Therefore, the cost effective, efficient and environmentally-friendly **gentle remediation techniques** are recommended. Gentle remediation encompasses a number of technologies which include the use of plants and associated soil microbes for reducing the exposure of local receptors to contaminants. The proposed and quite advanced methods rely on the processes of chemical stabilisation, phytoextraction, degradation or transformation of contaminants. Gentle remediation includes such methods as in-situ immobilisation, phytovolatilisation, phytostabilization, rhizofiltration, rhizodegradation, phytodegradation and phytoextraction (Sarwar et al. 2017). For example, in **phytostabilisation** plants are used to immobilise potentially toxic trace metals in soils through sorption by roots, precipitation, complexation or reduction in the plant rhizosphere, which reduce the mobility and bioavailability of pollutants in the environment. As a result, it prevents their migration to groundwater or their entry into the food chain. **Assisted phytostabilisation** involves a combined effect of plant growth and soil amendments. **Natural attenuation** is an approach involving natural processes of soil decontamination – the contaminants are left on the site and are subjected to biological processes of decomposition or chemical immobilisation.

Sustainable remediation is a term that describes actions that eliminate unacceptable risks in a safe and timely manner, and which maximise the overall environmental, social and economic benefits of the remediation (SuRF-UK).

Level of implementation: land owners/industry.

PREVENTING DECLINE IN SOIL BIODIVERSITY

What is it?

Soil biodiversity is defined as the mix of living organisms in the soil. They interact with each other and with plants and small animals, creating a network of biological activity (Orgiazzi et al., 2016). Soil functions and processes affected by soil biodiversity include: soil productivity, carbon and nutrient cycling, erosion control, stability of soil structure, GHG emissions. Soil biodiversity ensures a healthy soil system that is necessary for the sustainable functioning of natural and managed lands.

The situation at the European level

The driving forces behind the decline of soil biodiversity include land use change, overuse and exploitation at the ecosystem level, as well as change in the natural environmental conditions and ecotoxins at the species level. Soil biodiversity usually declines in connection to other soil degradation processes, such as the loss of SOM, the application of pesticides and chemical fertilisers, soil contamination, soil compaction and insufficient crop residues (Tibbett et al., 2015). Although the knowledge on current trends in soil biodiversity is limited, it is commonly agreed upon that it is reduced by intensive agricultural production. Soil biodiversity does not decline independently from other soil degradation processes.

Good practices:

Soil biodiversity can be improved by overall sustainable soil management, but also specific measures, such as **conservation tillage, avoiding monoculture, intercropping, application of safe EOM, restricted use of chemicals**.

Level of implementation: farmer.

SSM AT THE FARM AND LANDSCAPE LEVELS

In the following sections, a number of general sustainable soil management strategies are formulated, with regard to the farm and landscape levels. They are not focused on a specific SSM target, but can address multiple targets in a positive way.

Integrated SSM practices at farm level

Conservation agriculture (CA) aims at achieving sustainable and profitable agriculture based on the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. It combines profitable agricultural production with environmental concerns and sustainability and it has been proven to be effective across various pedo-climatic conditions (FAO).

Agroecology is based on the sustainable use of local renewable resources, local farmers' knowledge and priorities, sensible use of biodiversity to provide ecosystem services and resilience, as well as solutions that provide multiple benefits (environmental, economic, social) from a local to a global level.[12,13]

Agroforestry is considered a sustainable land management practice since it optimises the use of natural resources. It is based on the integration of woody vegetation with agricultural production and provides a higher biomass production per unit of land, while also providing more ecosystem services than agricultural land without forest. It reduces soil erosion and nitrogen leaching, and increases carbon sequestration and landscape biodiversity (Santiago--Freijanes et al., 2018).

Integrated farming is an agricultural production system that fulfils both ecological and economic demands. Agronomic methods of crop production are harmonised in compliance with the specificity of a site. The farmer has to adjust crop selection and rotation, cultivation technology, plant nutrition and plant protection to the natural environment. This covers optimal soil conservation through environment-friendly management systems and sustainable

Vegetable production in organic system helping to keep soil uncontaminated and sustain SOM (*Photo: M. Kowalik*)

[12]http://www.fao.org/about/meetings/second-international-agroecology-symposium/en/

[13]http://agroecology-europe.org/

fertilisation and pest control. Chemicals are used in reasonable amounts, only to support overall agronomic strategy. Groundwater, surface waters and adjacent biotopes do not get polluted (Rents et al, 2008).

Organic farming is based on the idea that the soil is a living system, whereby synthetic fertilisers, fungicides and pesticides are excluded from organic farms. They rely instead on crop rotation and residues, animal and green manures, and the biological control of pests and diseases to maintain soil health and productivity (Litterick and Watson, 2018). Organic farming practices usually include: wide crop rotation for an efficient use of soil capacity, restrictions on the application of chemicals, livestock antibiotics, food additives, etc., prohibition of the use of genetically modified organisms, using livestock manure as fertiliser, producing fodder on the farm, selecting resistant and adapted plant and animal species, raising livestock in free-range systems and organic feeding. Due to their character, organic farms keep soil uncontaminated and take care of soil carbon, which results from substantial plant residues incorporated into the soil.

Sustainable management at landscape level

Besides exercising good agricultural practice at farm level, some measures at landscape level can also contribute to sustainable soil management. For example, **promoting organic farming at landscape level** can diminish the pressure on soil in an entire region, the **cooperation between farms for the exchange of manure or land sharing** enables an environmentally sound use of resources and reduces pressures on soil and water. Crop farms apply manure produced in animal farms and provide fodder in return. Such an exchange helps to protect groundwater against excessive nutrients and to sustain SOM in the entire region.

Integrated management of small watersheds is an effective way to combat soil erosion at landscape level. Such erosion control programs should involve the plantation of catch trees, planning of roads, conservation of woods and bushes, land use changes, etc. The reduced erosion helps to maintain the quality of surface water and sustain SOM at an appropriate level.

6. SUSTAINABLE SOIL MANAGEMENT PRACTICES IN CURRENT EU POLICIES

Since there is no EU legislation on soil, soil protection is scattered over many EU policy instruments. SSM are not mentioned in existing EU legislation, but some measures in the existing policy comply with the sustainable management of soil to a certain extent. The major policy addressing soil protection is CAP, which implements some measures combating erosion, soil organic matter decline, over-fertilisation, decline of biodiversity, diffuse contamination. However, data on the scale of implementation of particular SSM measures across Europe is very scarce.

7. POLICY RECOMMENDATIONS FOR A WIDER IMPLEMENTATION OF SUSTAINABLE SOIL MANAGEMENT

- Supporting the integration of SSM practices for achieving desirable results and increased benefits – e.g. combining crop rotation with cover crops and conservation tillage in EU (CAP) and at national level.
- Some SSM measures are applied by farmers as an element of common good practice and some of them are part of the CAP measures, however the implementation of SSM measures should be further supported. Different options of support include: (a) making subsidies conditional on SSM practice – subsidies should not support unsustainable management practices; (b) providing extra support during a 5–7 year transition

phase towards sustainable soil management (compensation during the conversion phase – training and additional effort required, production/revenue can be affected), (c) providing incentives/additional support to integrated SSM practices.

- National policies taking specific climate and soil conditions into account play a major role, especially when addressing the soil-related weaknesses in EU regulations.
- SSM will be effective in urban areas only if it involves a combination of various approaches, such as responsible planning based on spatial databases, regulations for limiting the loss of best soils, support for land rehabilitation, etc.
- Awareness raising plays a vital role in promoting and implementing SSM, regardless of the type of land (agricultural, urban, post-industrial, etc.). There is still a need to increase awareness of the importance of soils in general and of the positive effects of SSM for food security, environmental safety, quality of life and human health. Societies should be made aware of the significance of SSM by demonstrating what they yield in terms of economic and societal benefits (and avoided costs), whereby they might be more inclined to adopt SSM.
- SSM training for farmers and advisors is needed. Effective advisory networks should provide a platform for promoting SSM practices.
- Collecting and disseminating good practices and success stories.
- Promoting the exchange of SSM practices through appropriate platforms (e.g. farmer networks and associations).
- In regions with soil contamination problems, SSM is site-specific and may involve the mitigation of risk, gentle remediation or clean-up actions, depending on the risk level.
- The development of soil databases is required for documenting SSM implementation needs and monitoring the status of soil.
- Cooperation between countries and regions for addressing transnational and trans-regional challenges, exchanging knowledge and good practice examples.

REFERENCES

Adriano D.C. 2001. Trace elements in the terrestrial environments: Biogeochemistry, bioavailability, and risks of heavy metals. 2nd ed. Springer-Verlag, New York.

Anaya-Romero M., Marañón T., Cabrera F., Madejón E., Madejón P., Murillo J.M., Vrinceanu N.O., Siebielec G., Geissen V. 2015. Soil contamination. In: Stolte J. et al. Soil threats in Europe. Status, methods, drivers and effects on ecosystem services. JRC Technical Reports. European Union, ISBN 978-92-79-54018-9, p. 92-103

Batjes N.H. 2001. Soil data for land suitability assessment and environmental protection in central and eastern Europe – the 1:2.500.000 scale SOVEUR project. The Land 5.1, 51-68.

Brundtland G. 1987. Report of the World Commission on Environment and Development: Our Common Future. United Nations General Assembly document A/42/427

Cachada A., da Silva E.F., Duarte A.C., Pereira R. 2016. Risk assessment of urban soils contamination: The particular case of polycyclic aromatic hydrocarbons. Sci Total Environ, 551-552, 271-284.

De Brogniez D., Ballabio C., Stevens A., Jones R.J.A., Montanarella L., 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 66, 121-134.

FAO and ITPS. 2015. Status of the World's Soil Resources (SWSR) – Technical Summary. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

Fenton T.E., Brown J.R., Mausbach M.J. 1999. Effects of long-term cropping and organic matter content of soils: implications for soil quality, In R. Lal (ed.), Soil Quality and Erosion. Boca Raton FL: CRC Press, 95-124.

Jones A., Panagos P., Barcelo S., Bouraoui F., Bosco C., Dewitte O., Gardi C., Erhard M., Hervás J., Hiederer R., Jeffery S., Lükewille A., Marmo 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. & Yigini Y. 2011. The State of Soil in Europe. Luxembourg, Publications Office of the European Union.

Joosten H. 2009. The Global Peat land CO2 Picture. Peatland status and emissions in all countries of the World. Ede, Wetlands International. 10 pp.

Kane D. 2015. Carbon Sequestration Potential on Agricultural Lands: AReview of Current Science and AvailablePracti tt sustainableagriculture.net/wp-content/uploads/2015/12/Soil_C_review_Kane_ Dec_4-final-v4.pdf

Kay P., Grayson R., Phillips M., Stanley K., Dodsworth A., Hanson A., Walker A., Foulger M., McDonnell I., Taylor S. 2012. The effectiveness of agricultural stewardship for improving water quality at the catchment scale: Experiences from an NVZ and ECSFDI watershed. Journal of Hydrology 422-423: 10-16.

Lal R. 2013. Soil carbon management and climate change, Carbon Management, 4:4, 439-462, DOI: 10.4155/cmt.13.31

Orgiazzi A., Bardgett R.D., Barrios E., Behan-Pelletier V., Briones M.J.I., Chotte J.L., De Deyn G.B., Eggleton P., Fierer N., Fraser T., Hedlund K., Jeffery S., Johnson N.C., Jones A., Kandeler E., Kaneko N., Lavelle P., Lemanceau P., Miko L., Montanarella L., Moreira F.M.S., Ramirez K.S., Scheu S., Singh B.K., Six, J., van der Putten W.H., Wall D.H. (Eds.). 2016. Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg. 176 pp.

Panagos P., Borrelli P., Poesen J., Ballabio C., Lugato L., Meusburger K., Montanarella L., Alewell C. 2015. The new assessment of soil loss by water erosion in Europe. Environmental Science & Policy, 54, 438-447.

Paya Pérez A., Rodriguez Eugenio N. 2018. Status of local soil contamination in Europe: Revision of the indicator "Progress in the management Contaminated Sites in Europe, EUR 29124EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-80072-6, DOI: 10.2760/093804, JRC107508

Prokop G., Jobstmann H., Schonbauer A. 2011. Report on best practices for limiting soil sealing and mitigating its effects. Publisher: European Commission, Brussels, Technical Report – 2011 – 050, ISBN: 978-92-79-20669-6

Santiago-Freijanes J.J., Rigueiro-Rodrı´guez A., Aldrey J.A., Moreno G., den Herder M., Burgess P.J., Mosquera--Losada M.R. 2018. Understanding agroforestry practices in Europe through landscape features policy promotion. Agroforestry Systems, https://doi.org/10.1007/s10457-018-0212-z

Sarwar N., Imran M., Shaheen M.R., Ishaque W., Kamran M.A., Matloob A., Rehim A., Hussain S. 2017. Phytoremediation strategies for soil contaminated with heavy metals: modificastions and future perspective. Chemosphere, 171, 710-721.

Sarwar N., Imran M., Shaheen M.R., Ishaque W., Kamran M.A., Matloob A., Rehim A., Hussain S. 2017. Phytoremediation strategies for soil contaminated with heavy metals: modificastions and future perspective. Chemosphere, 171, 710-721.

Scharlemann J.P.W, Tanner E.V.J., Hiederer R., Kapos V. 2014. Global soil carbon: understanding and managing the largest terrestrial carbon pool, CarbonManagement, 5:1, 81-91, DOI: 10.4155/cmt.13.77

Schils R., Kuikman P., Liski J., van Oijen M., Smith P., Webb J., Alm J., Somogyi Z., van den Akker J., Billett M., Emmett B., Evans C., Lindner M., Palosuo T., Bellamy P., Alm J., Jandl R., Hiederer R. 2008. Review of existing information on the interrelations between soil and climate change (CLIMSOIL), pp. 208, http://ec.europa.eu/environment/soil/pdf/climsoil_report_dec_2008.pdf

Swartjes F.A, Rutgers M., Lijzen J.P.A., Janssen P.J.M., OtteP.F., Wintersen A., Brand E., Posthuma L. 2012. State of the art of contaminated site management in The Netherlands: Policy framework and risk assessment tools. Sci Total Environ, 427-428, 1-10.

Schumann M. & Joosten H. 2008. Global Peatland Restoration Manual. Institute of Botany and Landscape Ecology, Greifswald University, Germany.

Reents H.J., Küstermann B., Kainz M. 2008. Sustainable Land Use by Organic and Integrated Farming Systems. In P. Schröder, J. Pfadenhauer and J.C. Munch (Ed.): Perspectives for Agroecosystem Management. Balancing Environmental and Socio-Economic Demands, ISBN: 978-0-444-51905-4, 17-39.

Litterick A.M., Watson C.A. 2018. Organic Farming. In: Encyclopedia of Applied Plant Sciences (Second Edition), 311-317.

Stolte J. et al. 2015. Soil threats in Europe. Status, methods, drivers and effects on ecosystem services. JRC Technical Reports. European Union, ISBN 978-92-79-54018-9

Tibbett M. 2015. Decline in soil biodiversity. In: Stolte J. et al. Soil threats in Europe. Status, methods, drivers and effects on ecosystem services. JRC Technical Reports. European Union, ISBN 978-92-79-54018-9, p. 146-154.

Van den Akker J., Berglund K., Berglund O. 2015. Decline in soil organic matter in peatsoils. In: Stolte J. et al. Soil threats in Europe. Status, methods, drivers and effects on ecosystem services. JRC Technical Reports. European Union, ISBN 978-92-79-54018-9, p. 146-154.

COLOPHON

Funded by the European Commission, DG Environment (SOILS4EU, Service contract No 07.0201/2016/742739/ SER/ENV.D.I)

April 2019

This policy brief was written by Grzegorz Siebielec (IUNG) with contributions of Nina Hagemann (UFZ) and Agnieszka Klimkowicz-Pawlas (IUNG).

It was graphically set up by Katarzyna Mikulska (IUNG).

Photo on the first page: High density of so called ecologically beneficial elements helps to combat soil erosion and protects water and biodiversity (*S. Bartke*)

Date	Version	Prepared by	Review by	Approved by
11-4-2019	1	Grzegorz Siebielec IUNG	Linda Maring Deltares	Henriette Otter Deltares