SUSTAINABLE SOIL MANAGEMENT

POLICY BRIEF

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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.

THE IMPORTANCE OF SOIL

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 IMPORTANCE OF SOIL

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.

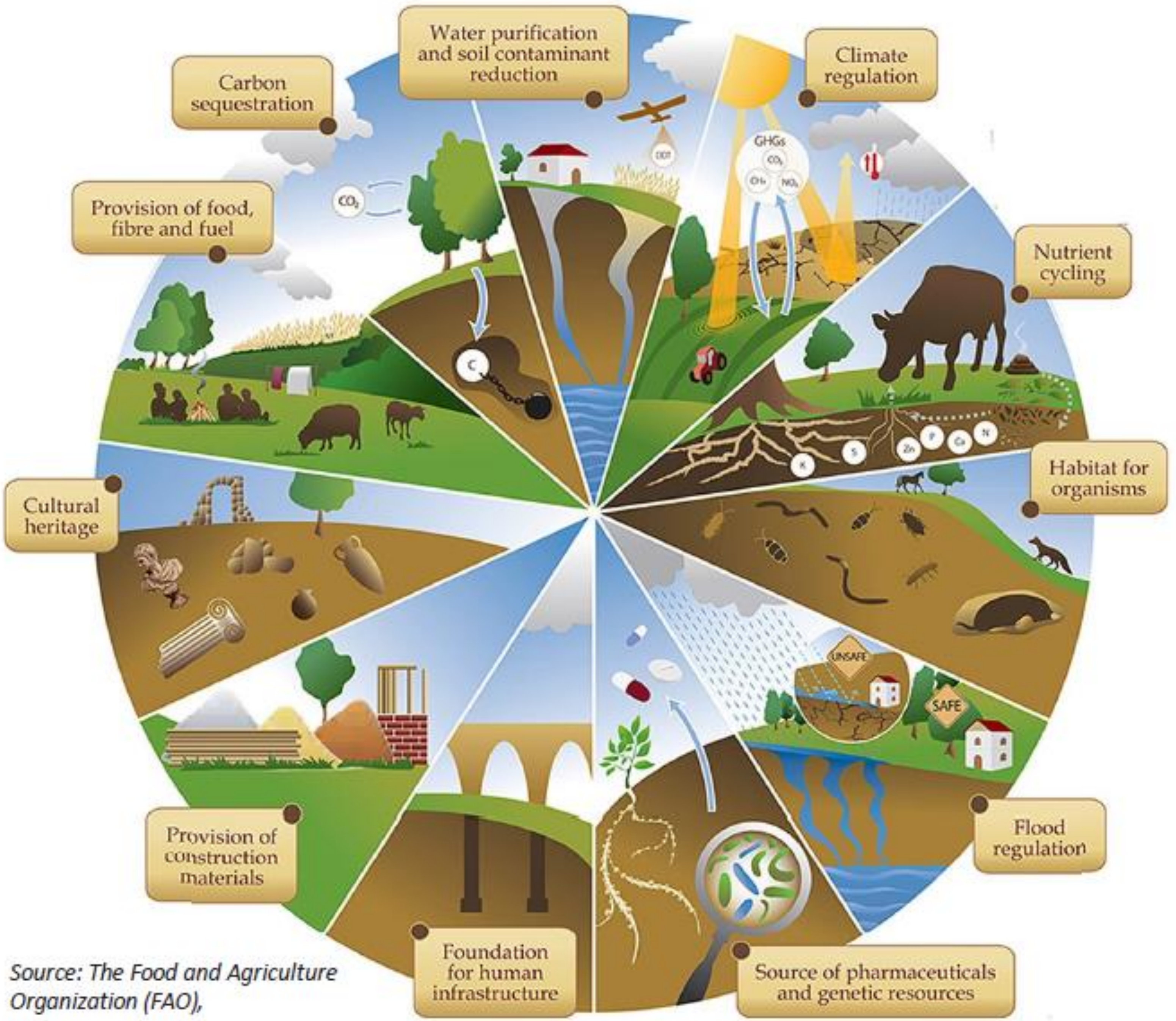
THE IMPORTANCE OF SOIL

Numerous soil ecosystem services have only been recognized 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).

SOIL ECOSYSTEM SERVICES



Source: The Food and Agriculture Organization (FAO),

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".

SOILS ARE INCREASINGLY UNDER PRESSURE

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.

A NEW MOMENTUM FOR SSM 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.

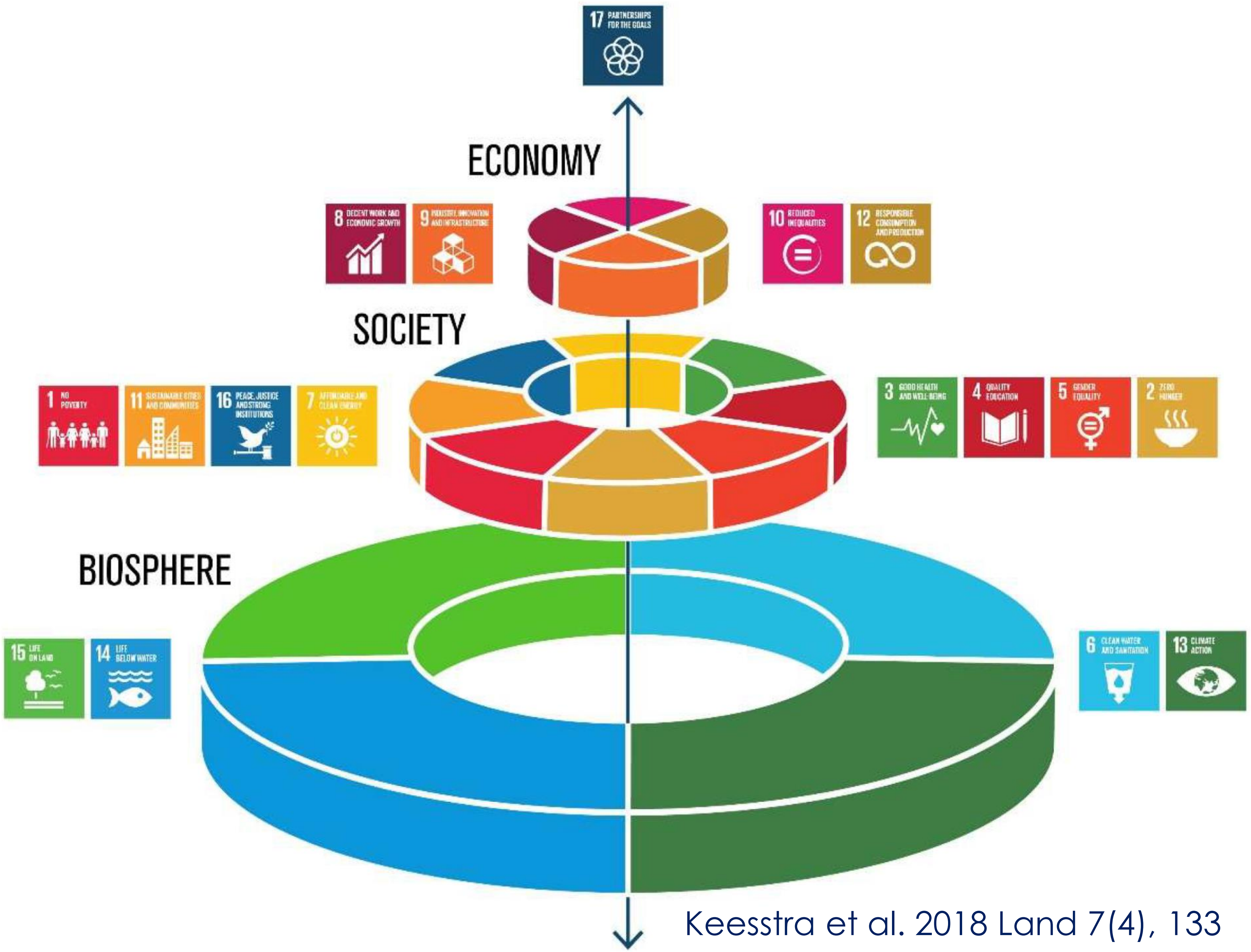
This new momentum is reflected in the global policy agenda: The Sustainable Development Goals (SDG) of the United Nations (UN) have set new global sustainability benchmarks, and achieving a number among them is in fact largely dependent on SSM and appropriate land management.

EU 2030 Soil Management Policy Agenda

The European Green Deal, ratified in 2020, is a set of policy initiatives by the European Commission aimed at making the European Union climate neutral by 2050.

Soil-Related Sustainable Development Goals: Four Concepts to Make Land Degradation Neutrality and Restoration Work

Relation of different domains within the Sustainable Development Goals (SDGs), biosphere, society, and economy.



Keesstra et al. 2018 Land 7(4), 133

A NEW MOMENTUM FOR SSM IN THE POLICY AGENDA

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.

LAND DEGRADATION NEUTRALITY

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".

GLOBAL SOIL PARTNERSHIP

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

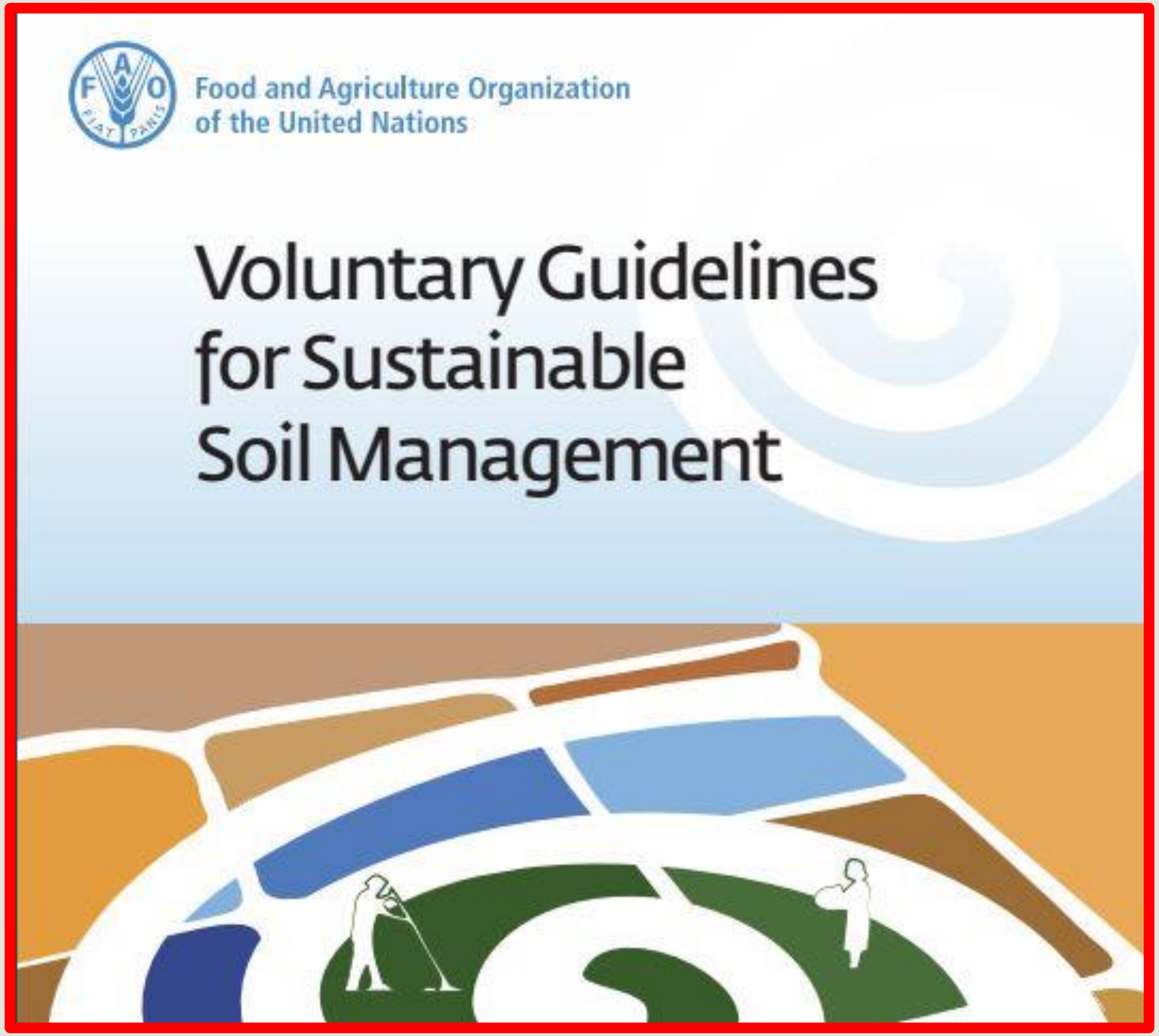
One of the main pillars of action of the GSP is to promote sustainable management of soil resources for their protection, conservation and productivity.

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.

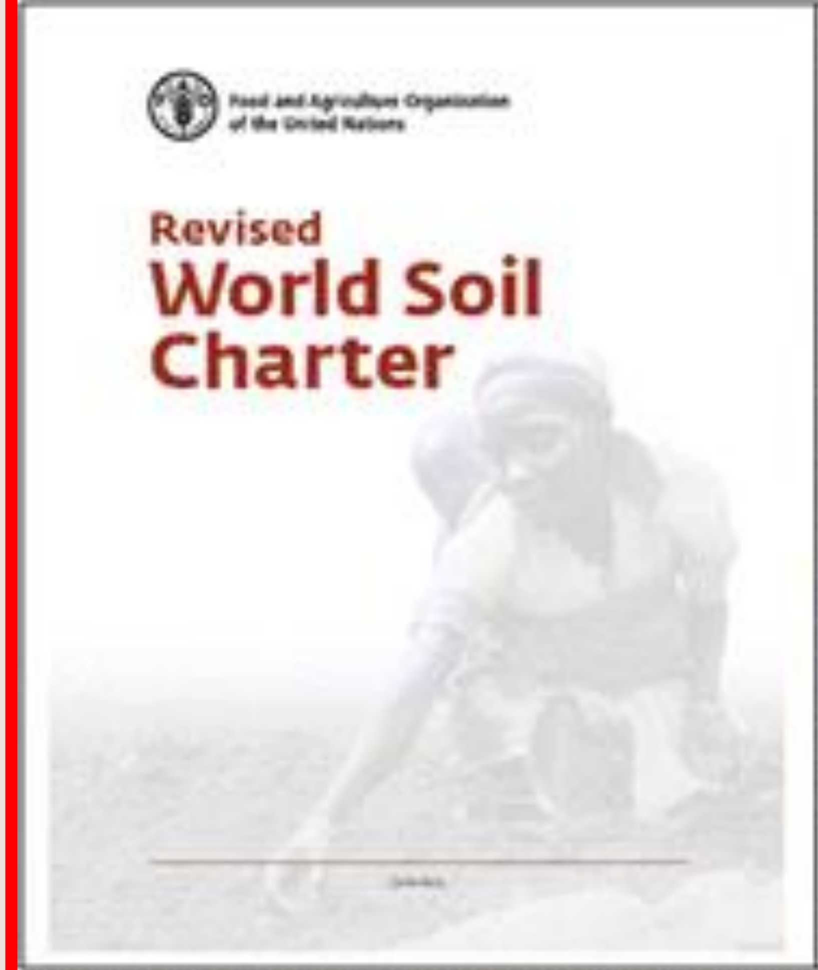
GLOBAL SOIL PARTNERSHIP

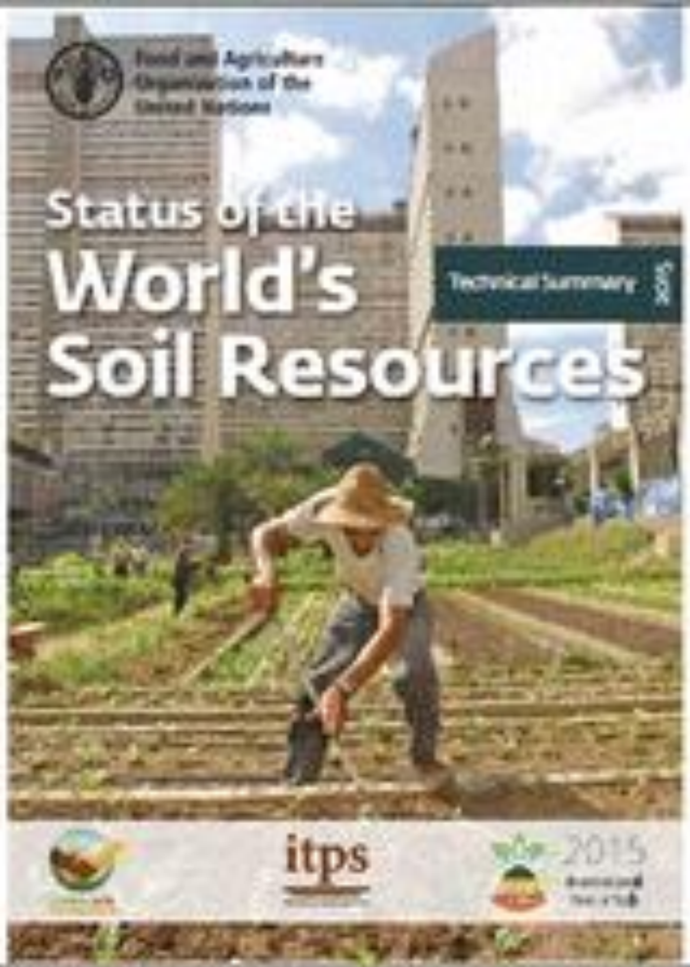
An important achievement was the revision of the World Soil Charter and the publication of the Voluntary Guidelines for Soil Sustainable Management (VGSSM) by the GSP and FAO in December 2016.

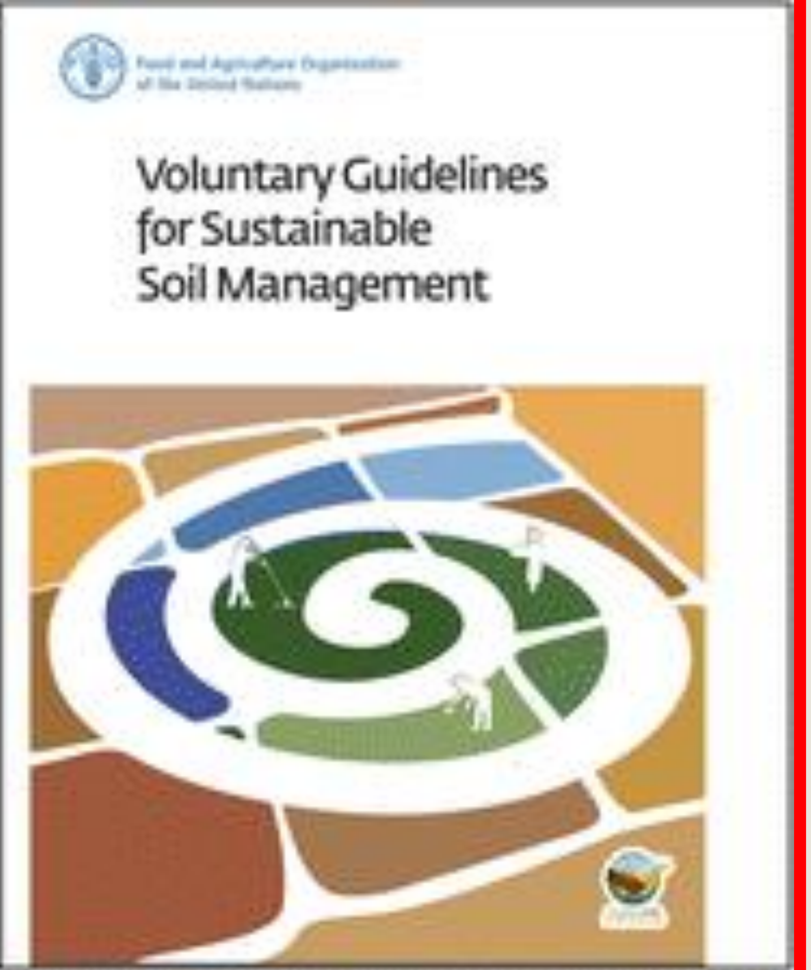
It was the first attempt ever to define sustainable soil management practices at the global level.



GLOBAL SOIL PARTNERSHIP





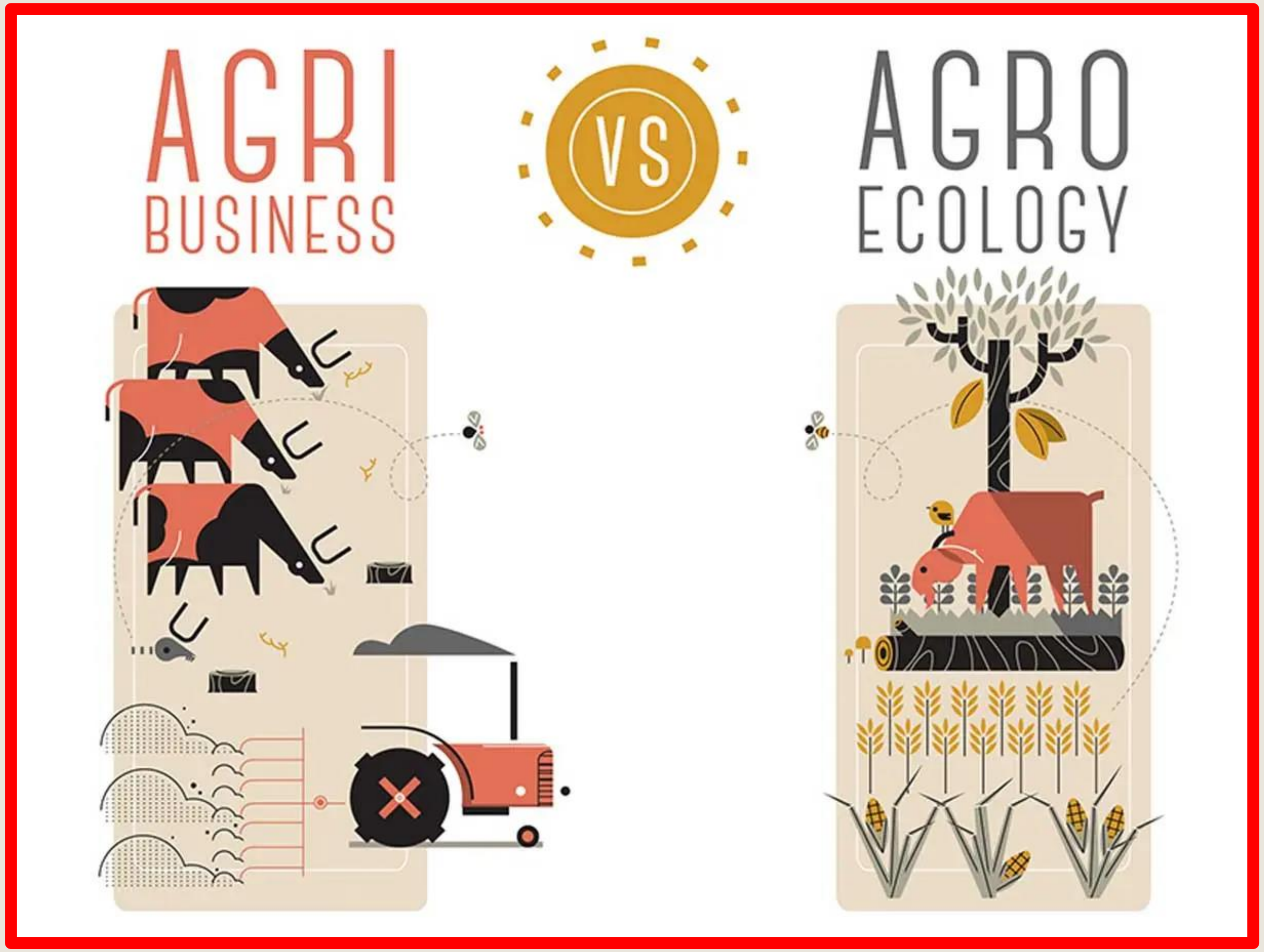


Those guidelines now need to be promoted and implemented at regional, national and local levels.

GLOBAL SOIL PARTNERSHIP

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).



GLOBAL SOIL PARTNERSHIP

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.

ipcc
INTERGOVERNMENTAL PANEL ON
climate change
WMO UNEP

ipbes
Science and Policy
for People and Nature

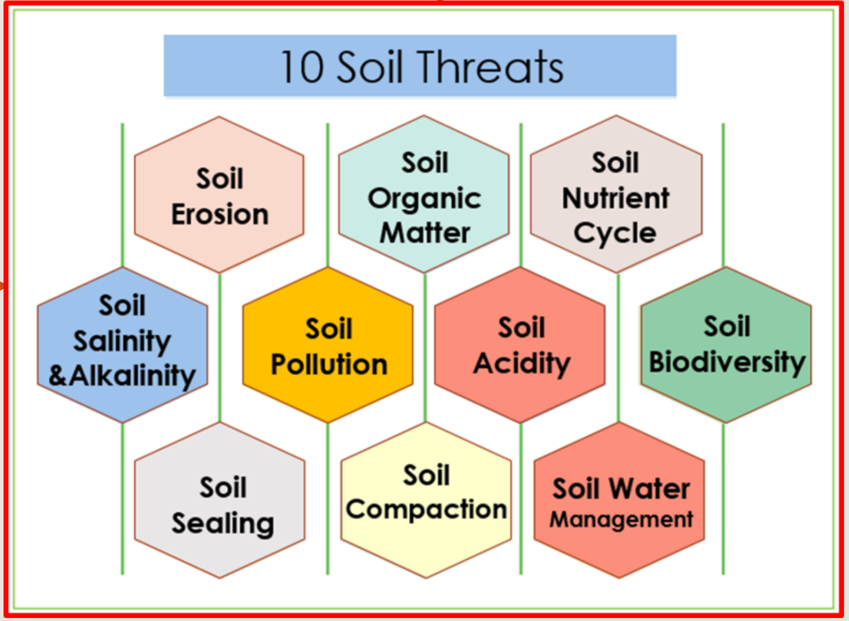
United Nations
Convention to Combat
Desertification

4 POUR 1000
LES SOLS POUR LA SÉCURITÉ ALIMENTAIRE ET LE CLIMAT

GLOBAL SOIL
PARTNERSHIP

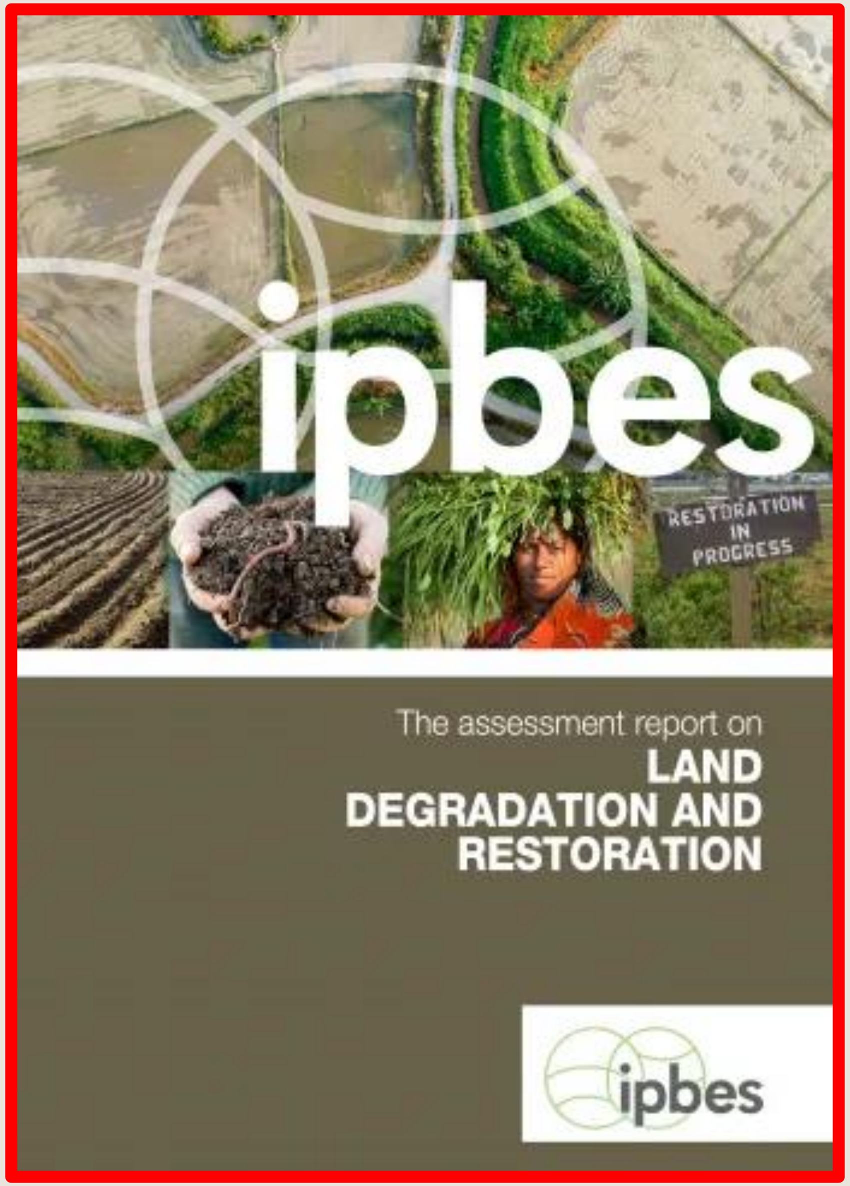
[SSM]
Work Plan

1. Promote Sustainable Soil Management (SSM)
2. Raising awareness about the importance of SSM
3. Supporting SSM research
4. Increasing the availability and quality of soil data and information
5. Harmonizing and standardizing SSM methods, measures and indicators



GLOBAL SOIL PARTNERSHIP

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) published a global assessment of land that has raised awareness on the scale of global land degradation.



The importance of soil has also been recognized in the Climate Agenda, in particular the **4p1000 initiative**, which was launched at the COP21 with the objective to increase soil carbon sequestration by 4‰ per year.

Several events at the COP24 in Katowice focused on agro-ecology and the need to promote sustainable soil management.

DEFINITION OF SSM

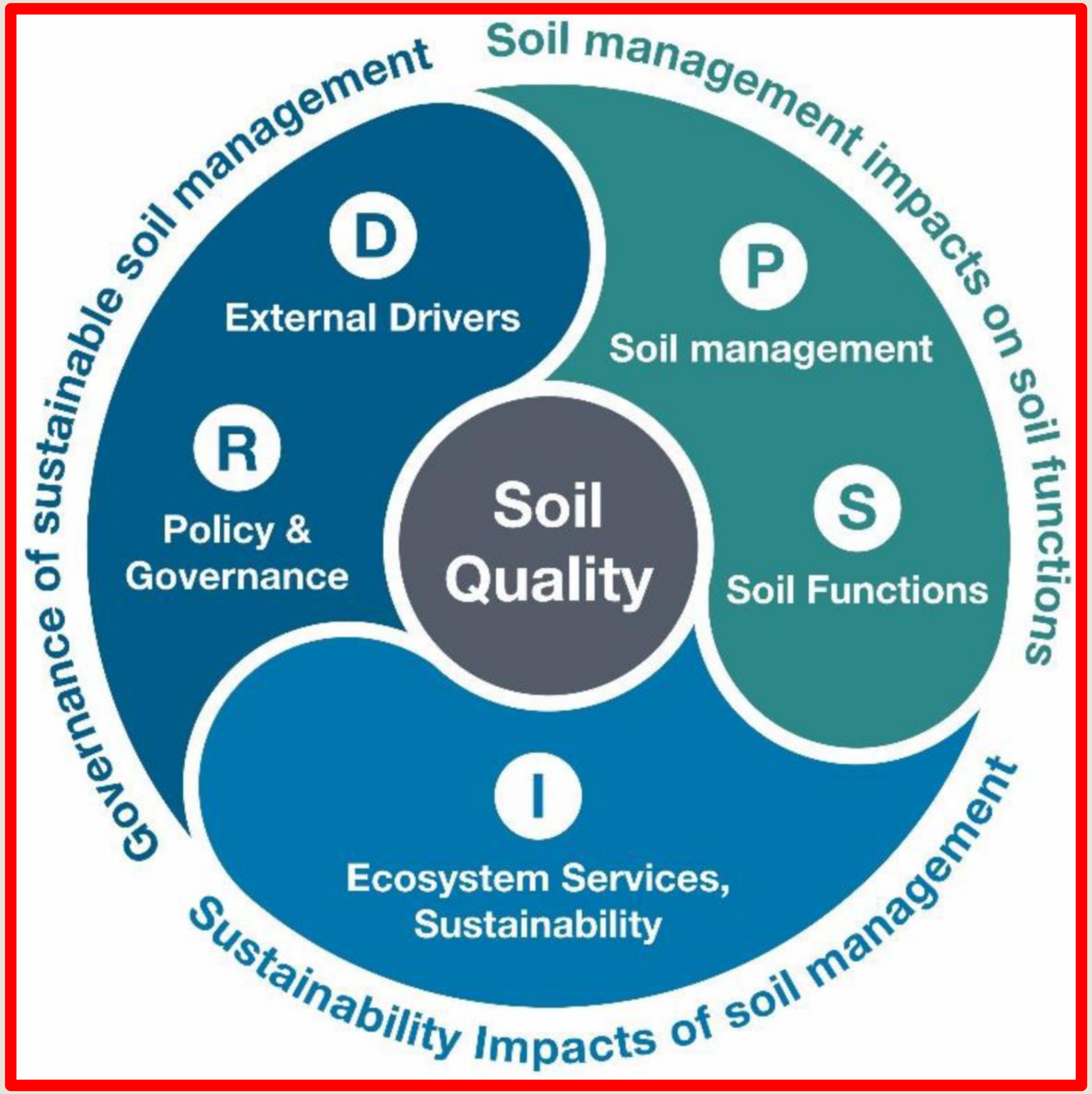
SSM must be coherent with sustainable development principles: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

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:

DEFINITION OF SSM

"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

OVERVIEW OF MOST IMPORTANT SUSTAINABLE SOIL MANAGEMENT MEASURES

PREVENTING SOIL EROSION

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

PREVENTING THE LOSS OF SOM IN ORGANIC SOILS

FOSTERING A BALANCE OF SOIL NUTRIENTS

PREVENTING SOIL COMPACTION

MINIMISING SOIL SEALING

PREVENTING SOIL CONTAMINATION

PREVENTING DECLINE IN SOIL BIODIVERSITY

PREVENTING SOIL EROSION

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.

PREVENTING SOIL EROSION
Good practices

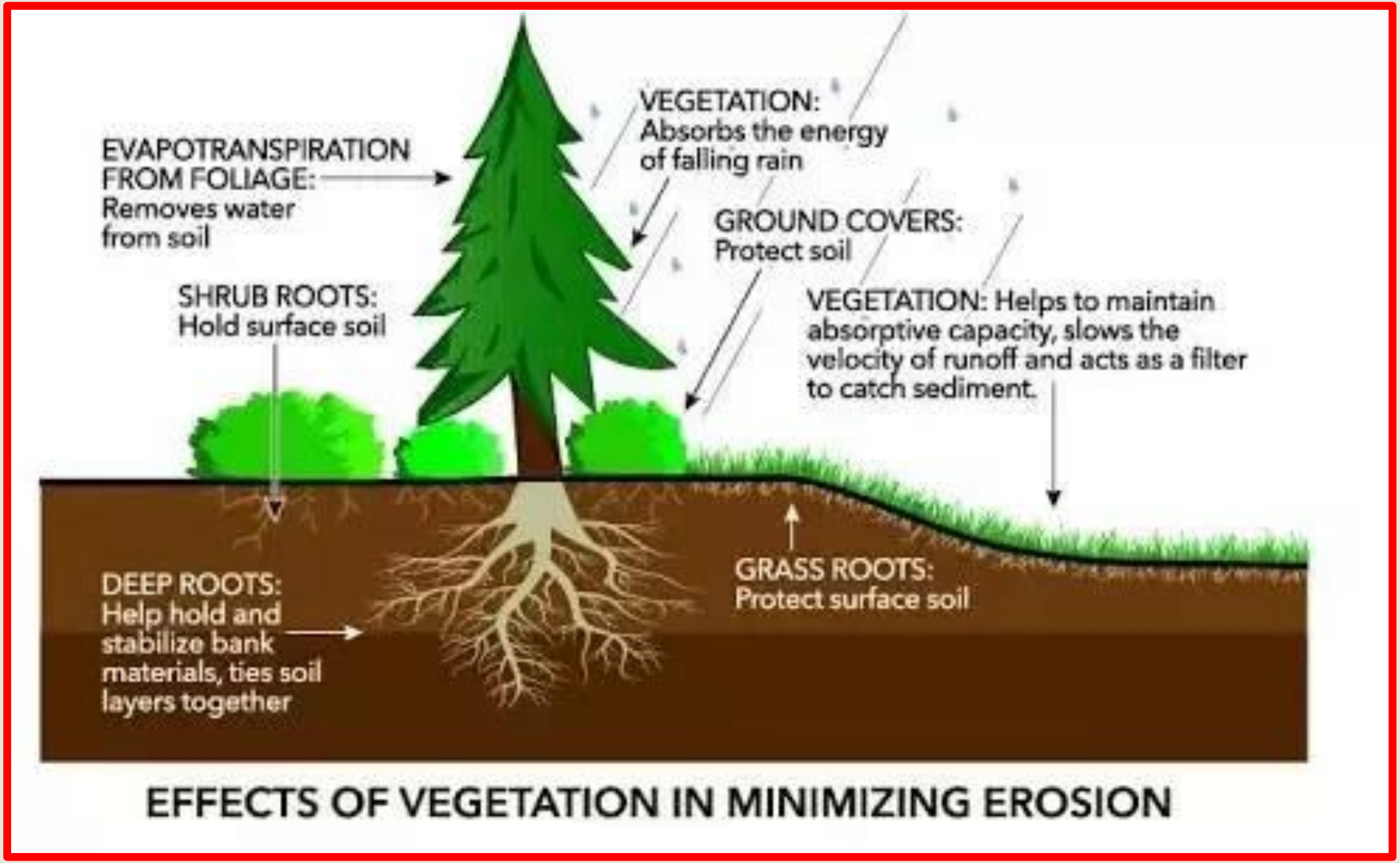
Erosion control is the practice of preventing or controlling wind or water erosion in

- agriculture,
- land development,
- coastal areas,
- river banks and
- construction.

Effective erosion controls handle surface runoff and are important techniques in preventing

- water pollution,
- soil loss,
- wildlife habitat loss and
- human property loss.

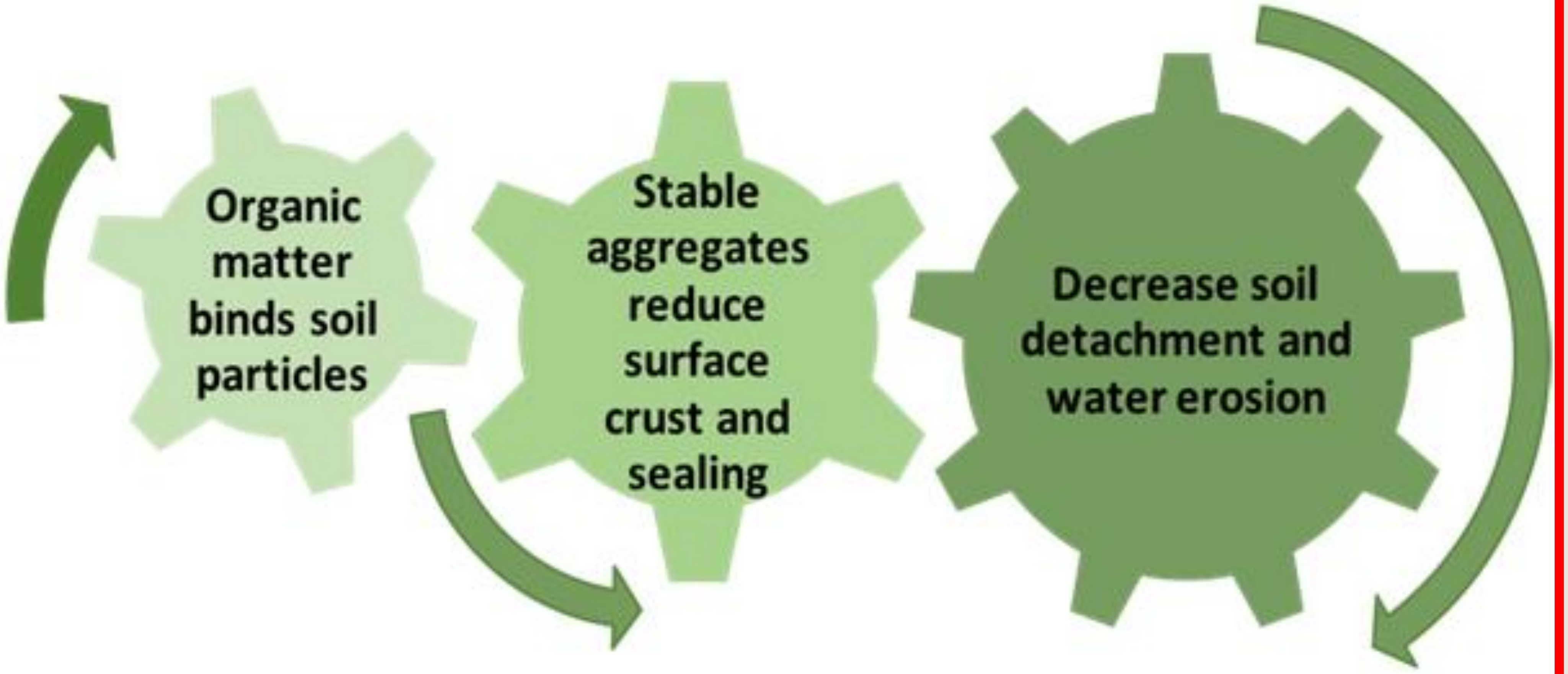
Good practices: A vegetation cover reduces water erosion through reducing surface runoff and increasing infiltration.



Good practices: The roots significantly increase the aggregate stability of the soil. Therefore, planting grass, shrubs and trees helps to manage extremely disturbed areas and stabilize soil.

Soil aggregate stability is a measure of the ability of soil aggregates—soil particles that bind together—to resist breaking apart when exposed to external forces such as water erosion and wind erosion, shrinking and swelling processes, and tillage.

Soil aggregate stability is a measure of soil structure and can be affected by soil management.



Good practices: 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).

Contour bunding or contour farming or Contour ploughing is the farming practice of plowing and/or planting across a slope following its elevation contour lines.

These contour lines create a water break which reduces the formation of rills and gullies during times of heavy precipitation, allowing more time for the water to settle into the soil.

Good practices: 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.

Good practices: 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.

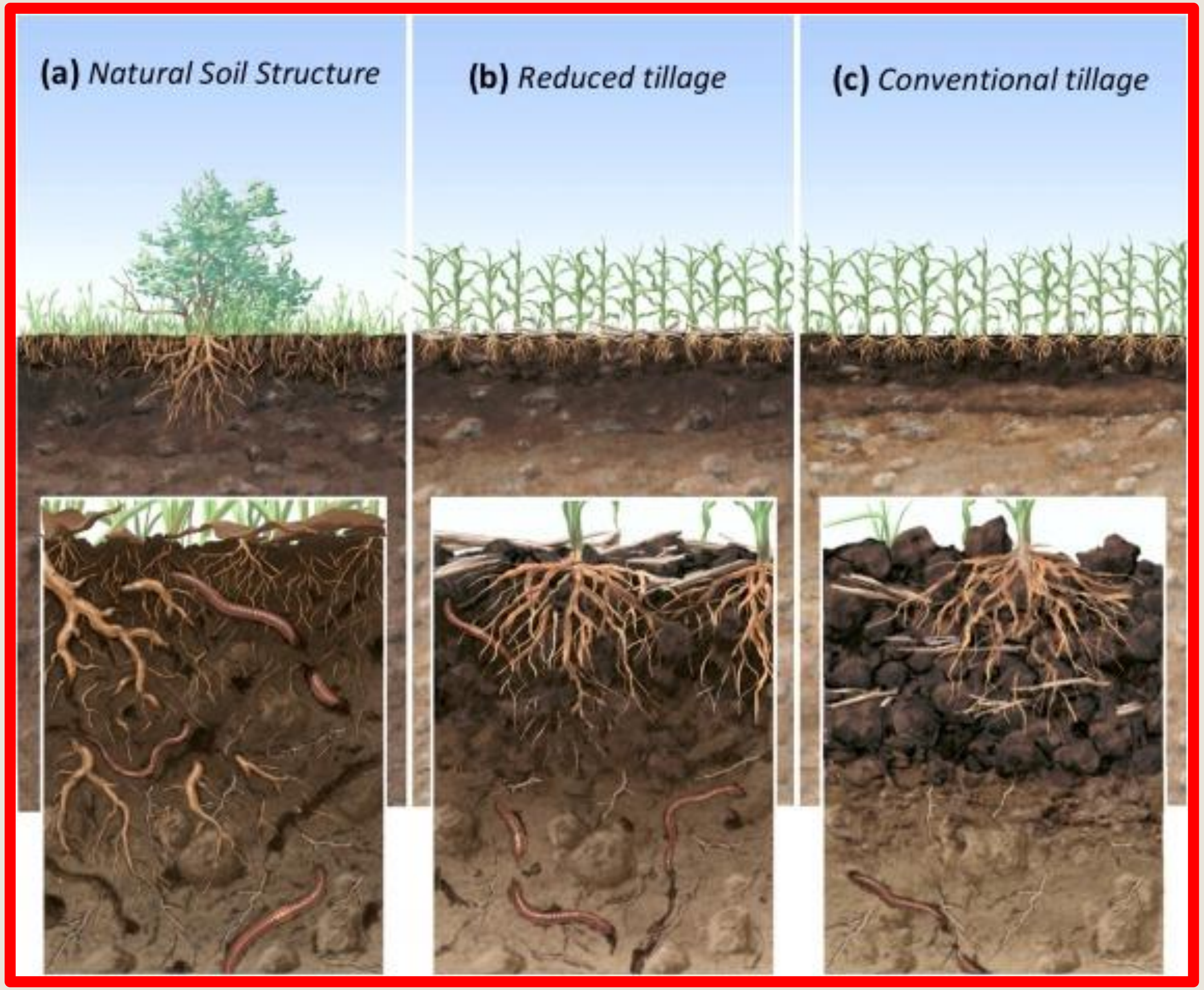
A similar effect is achieved by hedges or grass strips.

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

Soil tillage can affect the stability and formation of soil aggregates by disrupting soil structure.

Frequent tillage deteriorates soil structure and weakens soil aggregates, causing them to be susceptible to decay.

Conservation tillage practices have been shown to reduce soil organic matter decomposition

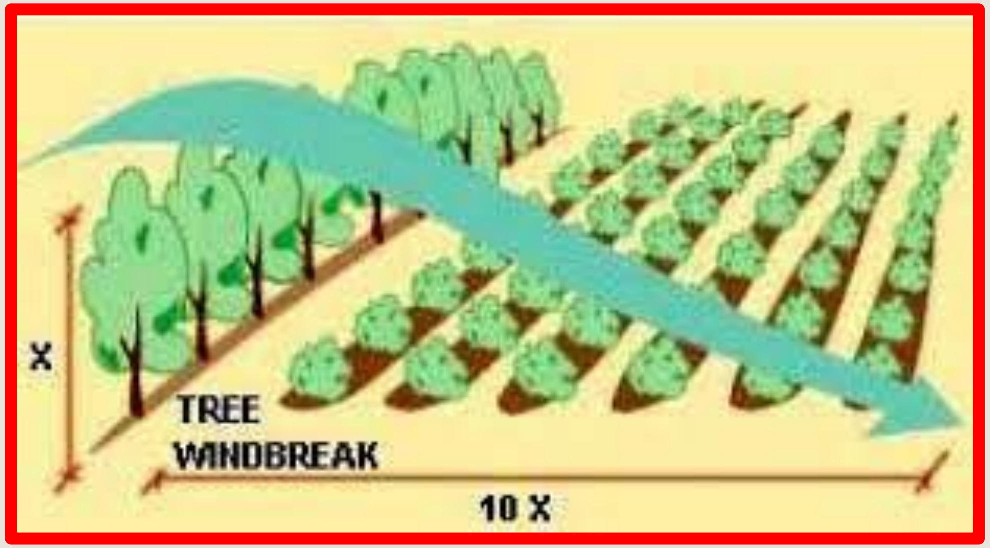


Good practices: Wind erosion can be successfully combated through vegetation practices such as planting shelterbelts or windbreaks perpendicularly to the prevailing wind directions.

A windbreak (shelterbelt) is a planting usually made up of one or more rows of trees or shrubs planted in such a manner as to provide shelter from the wind and to protect soil from erosion.

They are commonly planted in hedgerows around the edges of fields on farms.

Windbreaks and intercropping can be combined in a farming practice referred to as alleycropping, or being deployed along riparian buffer stripes.



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

Deforestation or forest clearance is the removal of a forest or stand of trees from land that is then converted to non-forest use.

Deforestation can involve conversion of forest land to farms, ranches, or urban use.

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

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 stabilizes 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.

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

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).

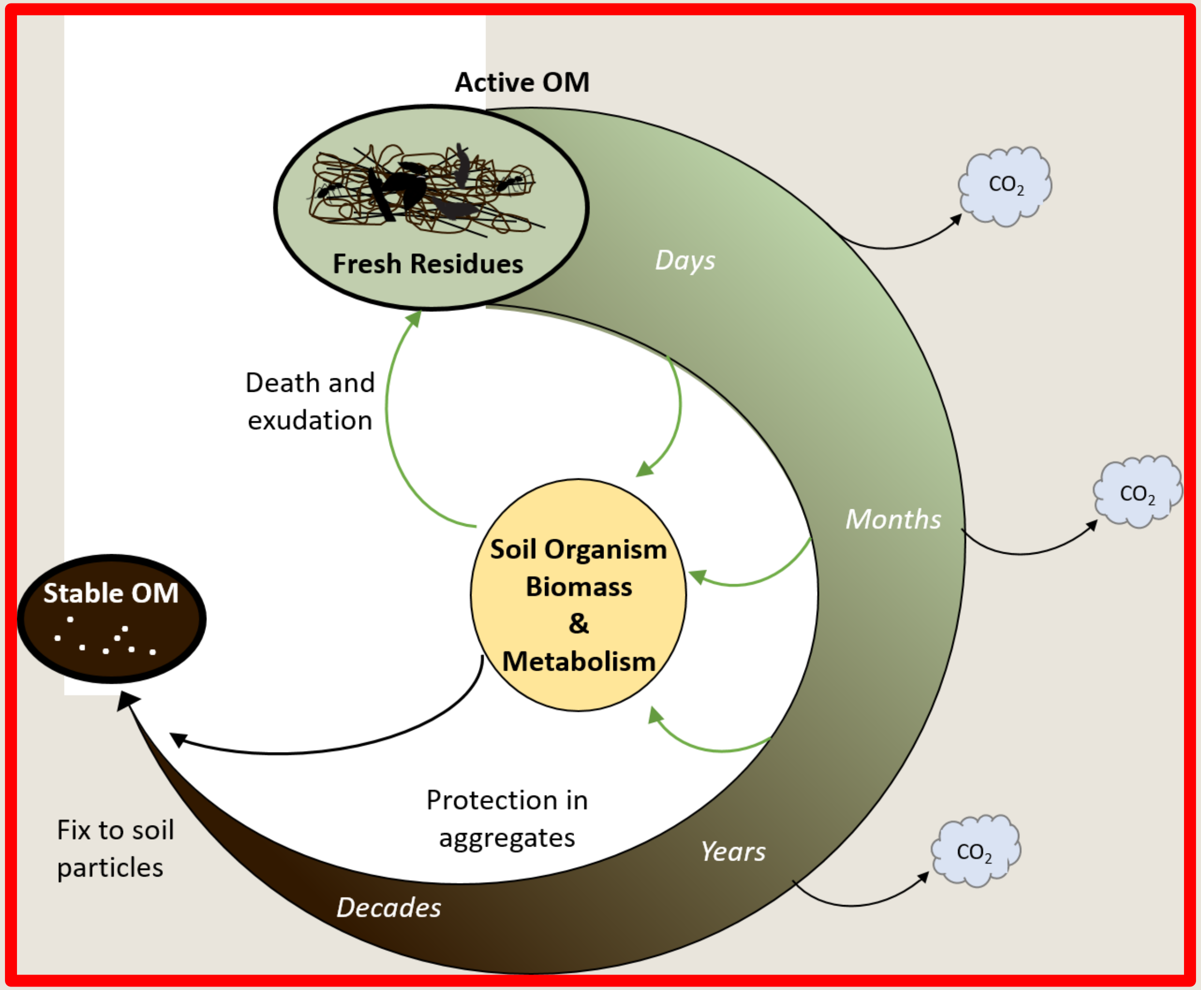
Petagram of carbon (1 PgC = 1 GtC)

1 Gigatonne or metric gigaton (unit of mass) is equal to 1,000,000,000 metric tons.

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

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.



Good practices: 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.

Good practices: Green manure

Green manures are crops grown specifically for building and maintaining soil fertility and structure, though they may also have other functions.

They are normally incorporated back into the soil, either directly, or after removal and composting.

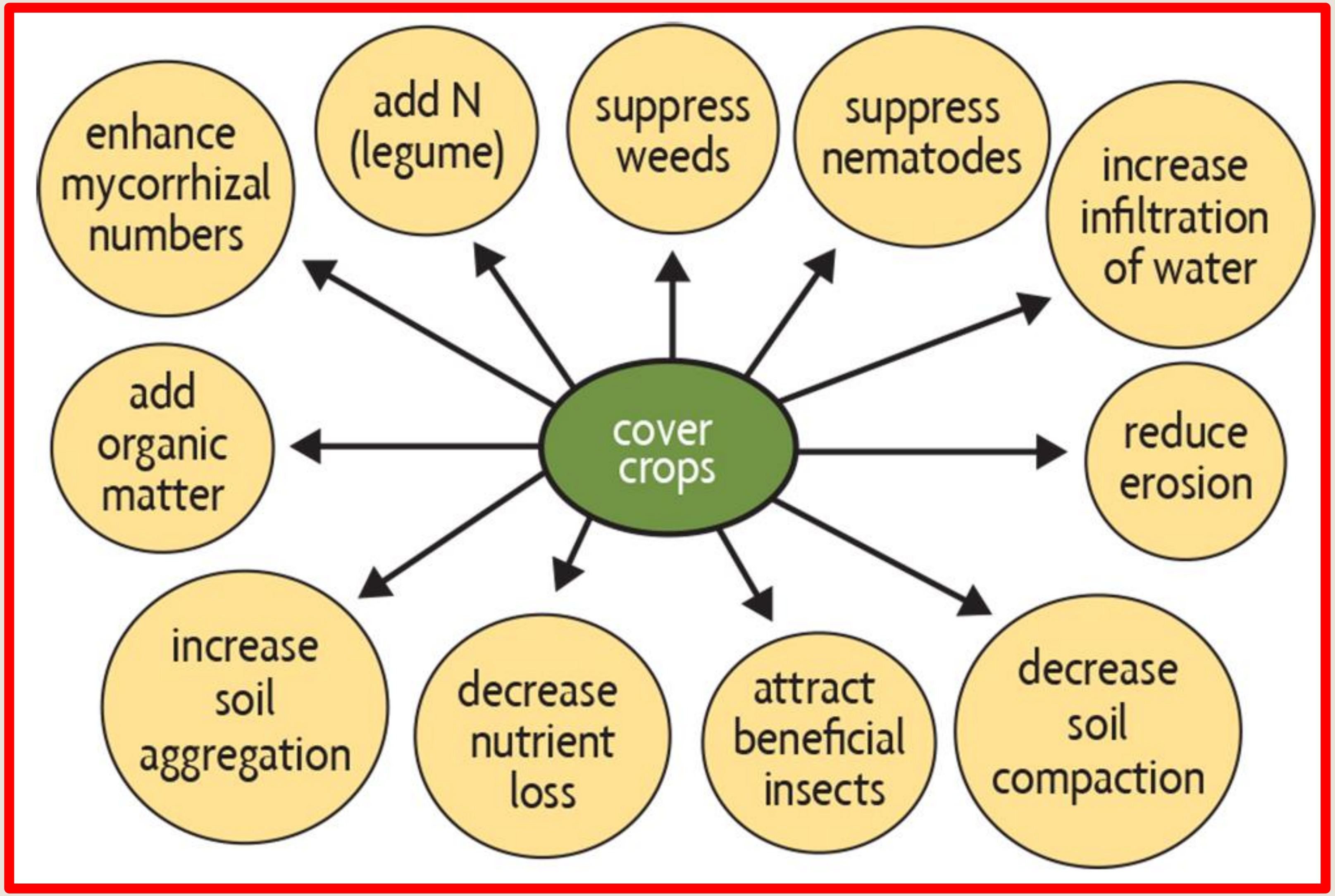
The primary goal is to add organic matter to the soil for its benefits.

Green manuring is often used with legume crops to add nitrogen to the soil for following crops, especially in organic farming, but is also used in conventional farming.

Good practices: **Cover crops** are planted after the catch crops

A cover crop is any crop grown to cover the soil and may be incorporated into the soil later for enrichment.

A catch crop is any crop that is grown with the primary objective of catching excess nitrogen in soils that otherwise may be lost through leaching.



Research has shown that **cover crops** (left) tend to use less water than what is lost to evaporation from bare soil (right) and they provide valuable organic matter as they break down in the soil.

Cover crops can be used for a variety of purposes including protecting the soil, improving soil structure, fixing nitrogen, feeding the soil biological life, and managing soil moisture.

A key soil health concept is that there should be something green and growing during as much of the year as possible.

Good practices: **Organic fertilizers** applied to soil can be a significant source of soil carbon.

It must be emphasized that only safe (uncontaminated) organic materials can be applied to soil.

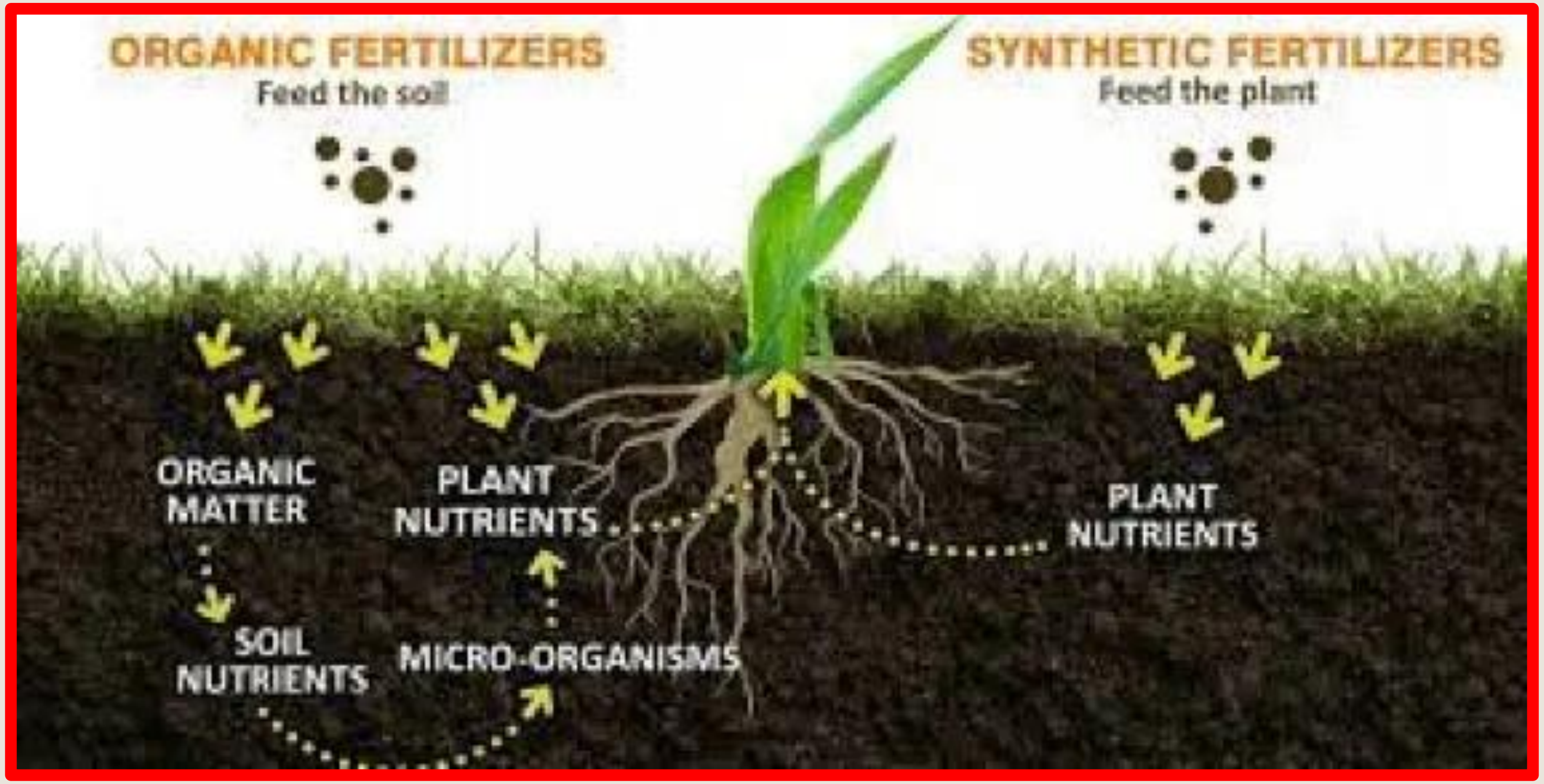
Organic soil amendments might include animal manure or recycled organic matter, e.g. compost, composted sludge, food waste, digestate.

The European Commission proposed a new fertilizer regulation as part of the EU Circular Economy package, aiming at creating an EU market of organic fertilizers with common rules concerning the level of contaminants.

A strong polarization of crop and animal agriculture in recent decades has caused a lack of manure in many regions, leaving space for recycled organics.

Good practices: Organic fertilizers applied to soil can be a significant source of soil carbon.

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.

Good practices: **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.

PREVENTING THE LOSS OF SOM IN ORGANIC SOILS

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.

PREVENTING THE LOSS OF SOM IN ORGANIC SOILS

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).

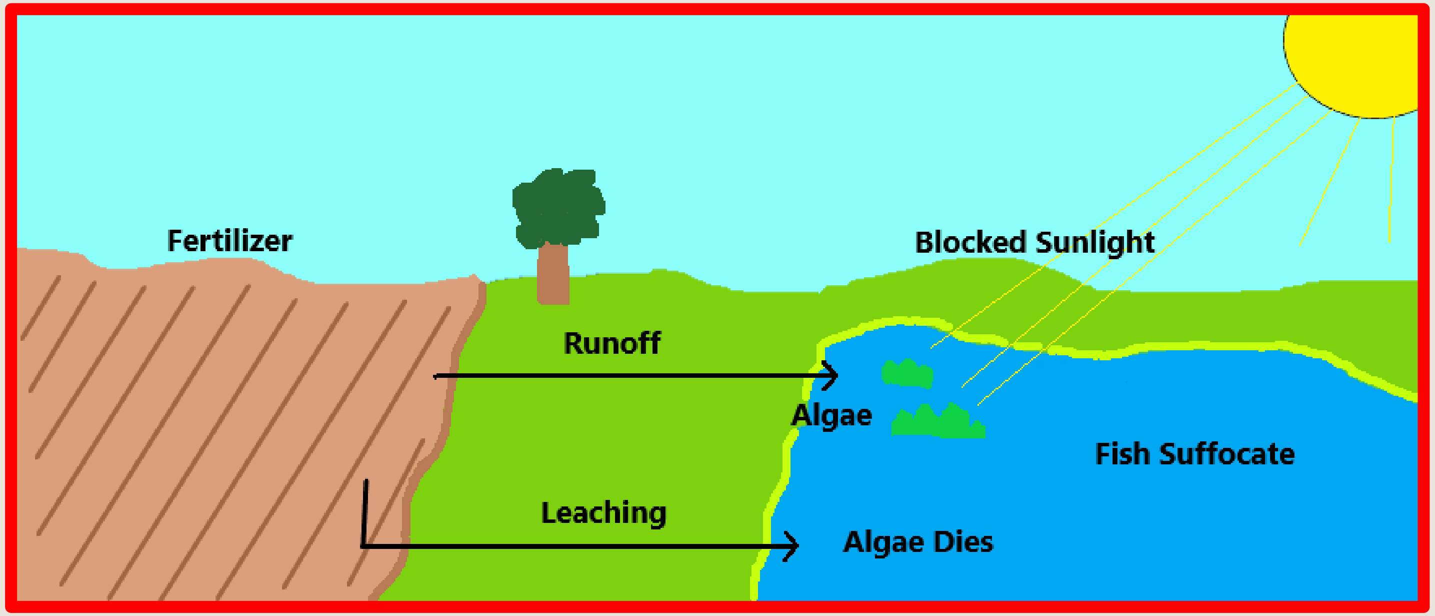
Good practices: Preventing the loss of SOM in peatlands might be achieved by **conserving peatlands** through sustaining a natural water regime, banning agricultural use, **afforestation**, **rewetting** drained peatland, and **banning the ploughing** of grasslands on peat soils.

FOSTERING A BALANCE OF SOIL NUTRIENTS

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)



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).

Fertilizer application, including the types of fertilizers, 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 utilize nutrients and the capacity of soil to retain them.

The use of organic and mineral fertilizers 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).

PREVENTING SOIL COMPACTION

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 easily undone by applying soil loosening or various tillage methods and does not pose a permanent threat to the soil and environment.

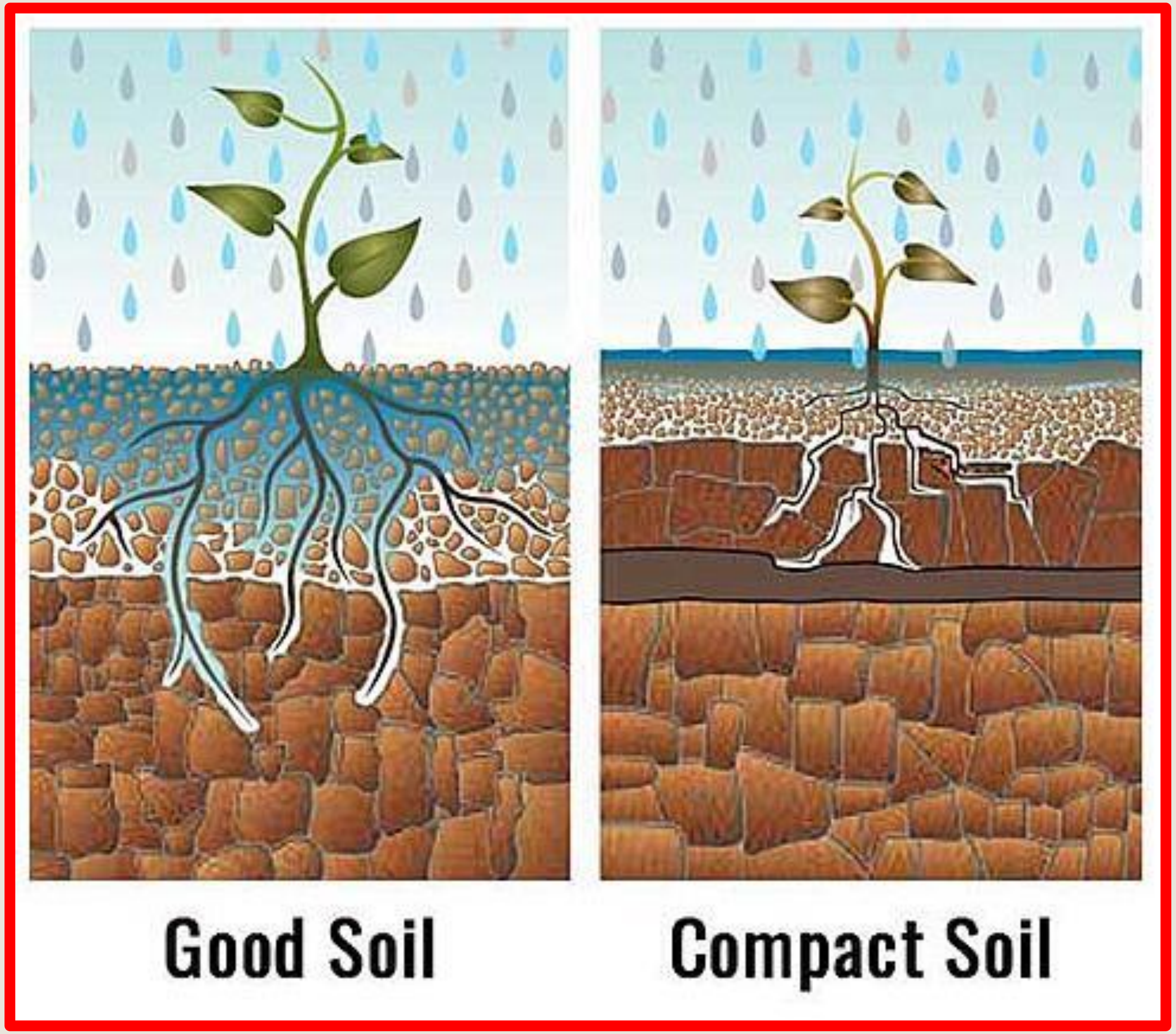
Compaction of the subsoil is considered a process both difficult and expensive to eliminate.

Compaction of the subsoil is especially challenging because it is invisible, cumulative and persistent.

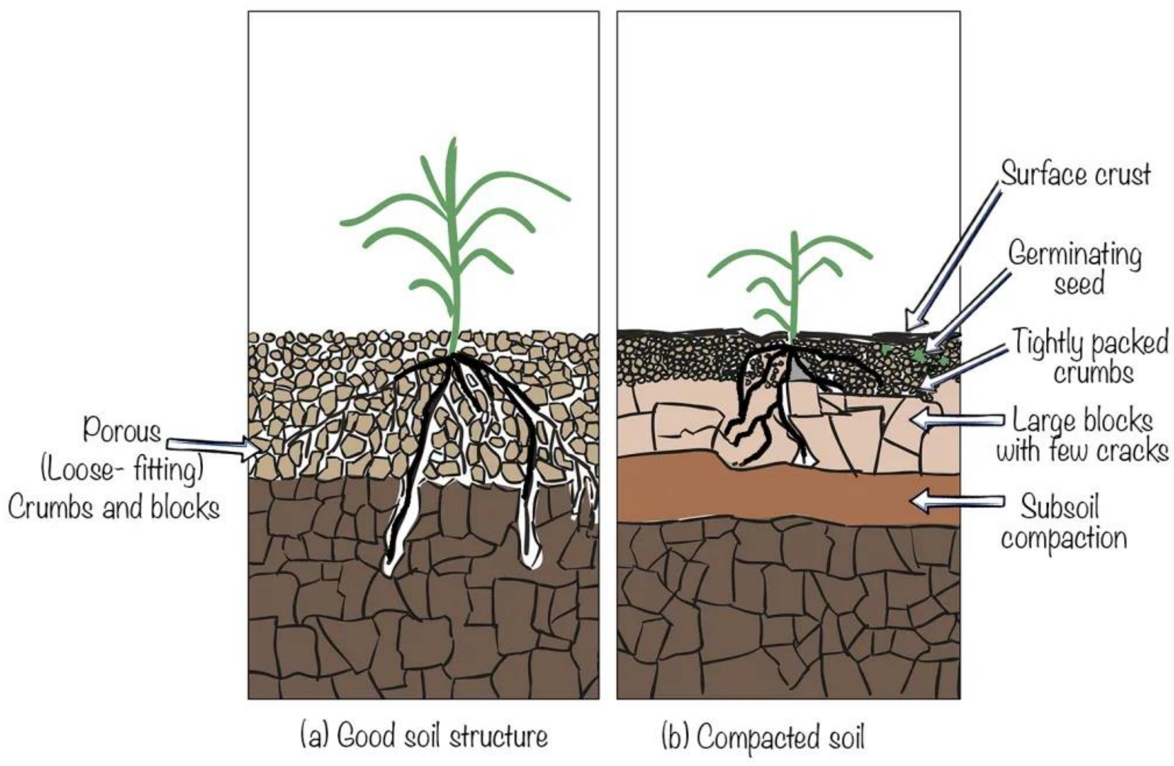
PREVENTING SOIL COMPACTION

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 favored 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.



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.



MINIMISING SOIL SEALING

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 urbanization 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.

MINIMISING SOIL SEALING

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.

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.

Good practices

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.

Good practices

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.

However, the sustainability of soil management in the context of urbanization goes well beyond these measures and involves responsible **spatial planning that would take into consideration soil information and soil functions**, 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.

PREVENTING SOIL CONTAMINATION

1. Preventing diffuse contamination

Agricultural soil can be spoiled with contaminants through so-called diffuse contamination, processes that cannot be linked to a single and definite source.

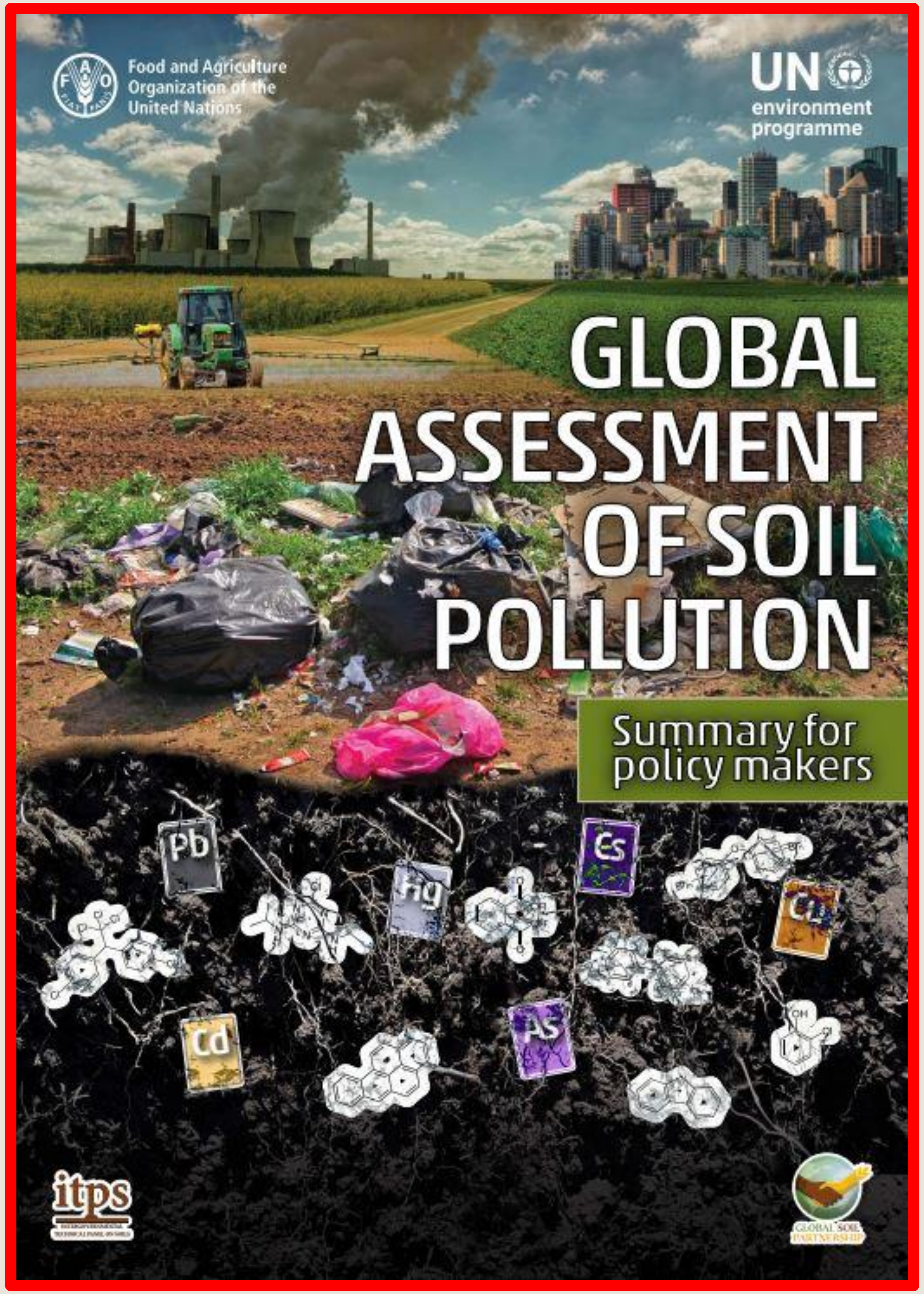
There are various groups of soil contaminants: organic (e.g. polycyclic aromatic hydrocarbons, pesticide residues, antibiotics), inorganic (metals and metalloids) and particulate contaminants, whereas organic pollutants undergo a process of decay, inorganic pollutants do not and therefore stay in the soil (Anaya-Romero et al., 2015).

Agricultural soil can be spoiled with contaminants through so-called diffuse contamination, processes that cannot be linked to a single and definite source.

PREVENTING SOIL CONTAMINATION

1. Preventing diffuse contamination

Sources of diffuse contamination of agricultural soils include the long-distance transport of dusts, long-term use of low quality fertilizers (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.



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.

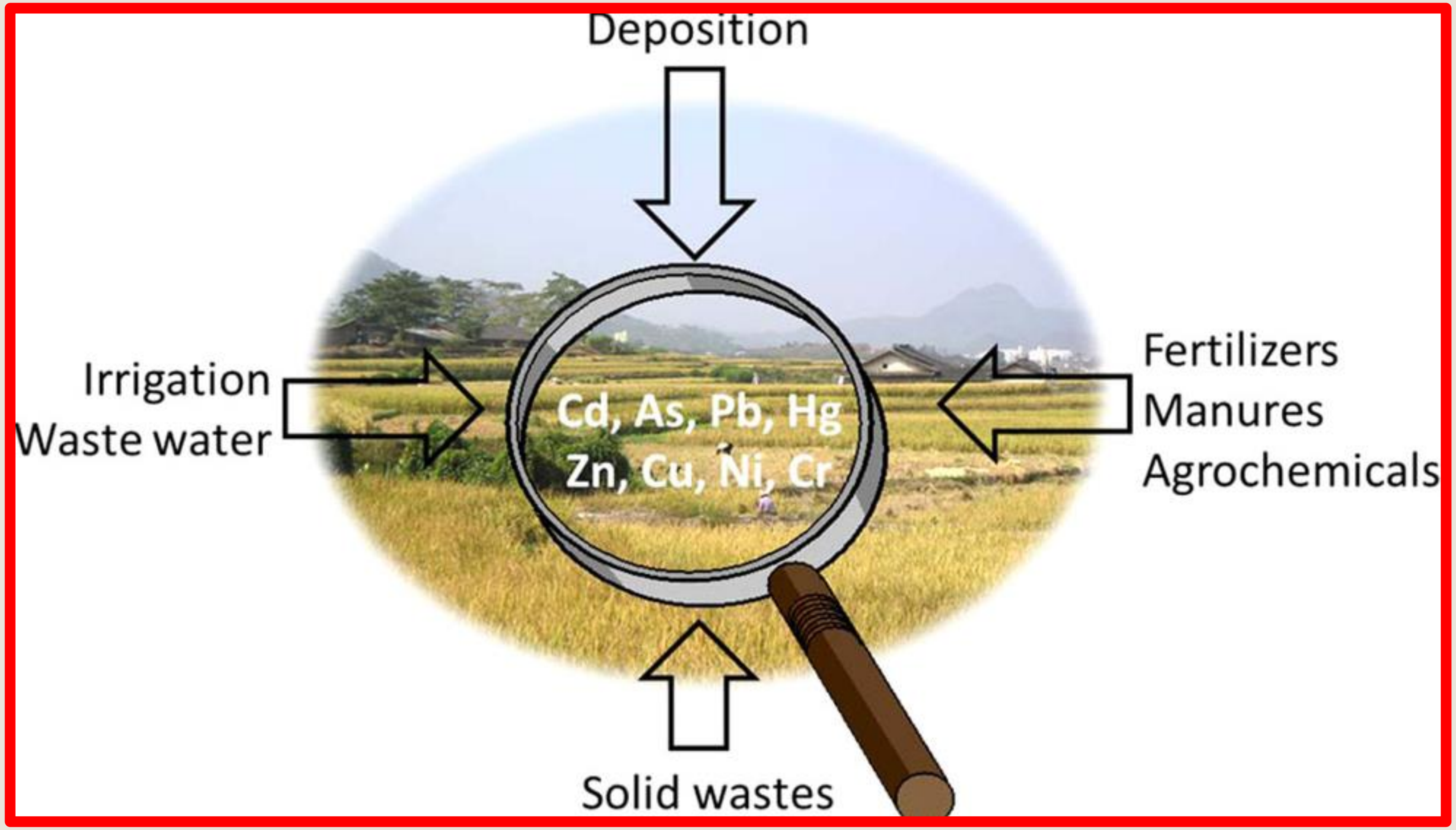
Preventing soil contamination in agriculture can be achieved by **limiting the application and a better control of fertilizers, pesticides and herbicides, as well as controlling the status of manure and exogenous organic matter** applied to soil.

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.

Good practices

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.



PREVENTING SOIL CONTAMINATION

2. Managing point contamination

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.

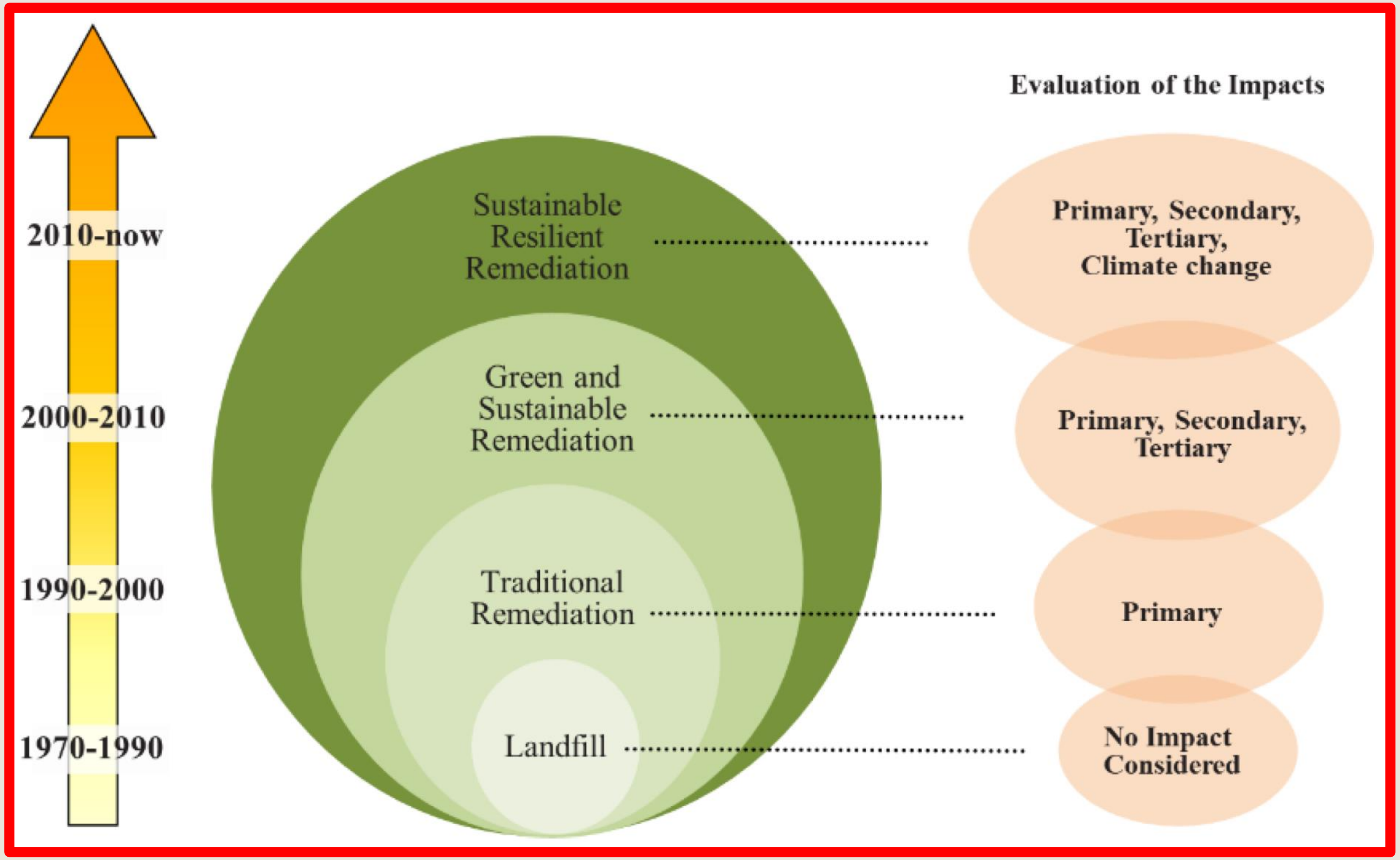
Depending on the contaminant and its concentration in the soil, they may be toxic to plants or pose a hazard to animals and humans or hamper the biological processes in soil.

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.

Good practices

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.

Good practices

The conventional remediation techniques include in-situ vitrification, soil incineration, excavation and landfill, soil washing, soil flushing, solidification and stabilization 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.

Good practices

The proposed and quite advanced methods rely on the processes of chemical stabilization, phytoextraction, degradation or transformation of contaminants.

Gentle remediation includes such methods as in-situ immobilization, phytovolatilisation, phytostabilization, rhizofiltration, rhizodegradation, phytodegradation and phytoextraction (Sarwar et al. 2017).

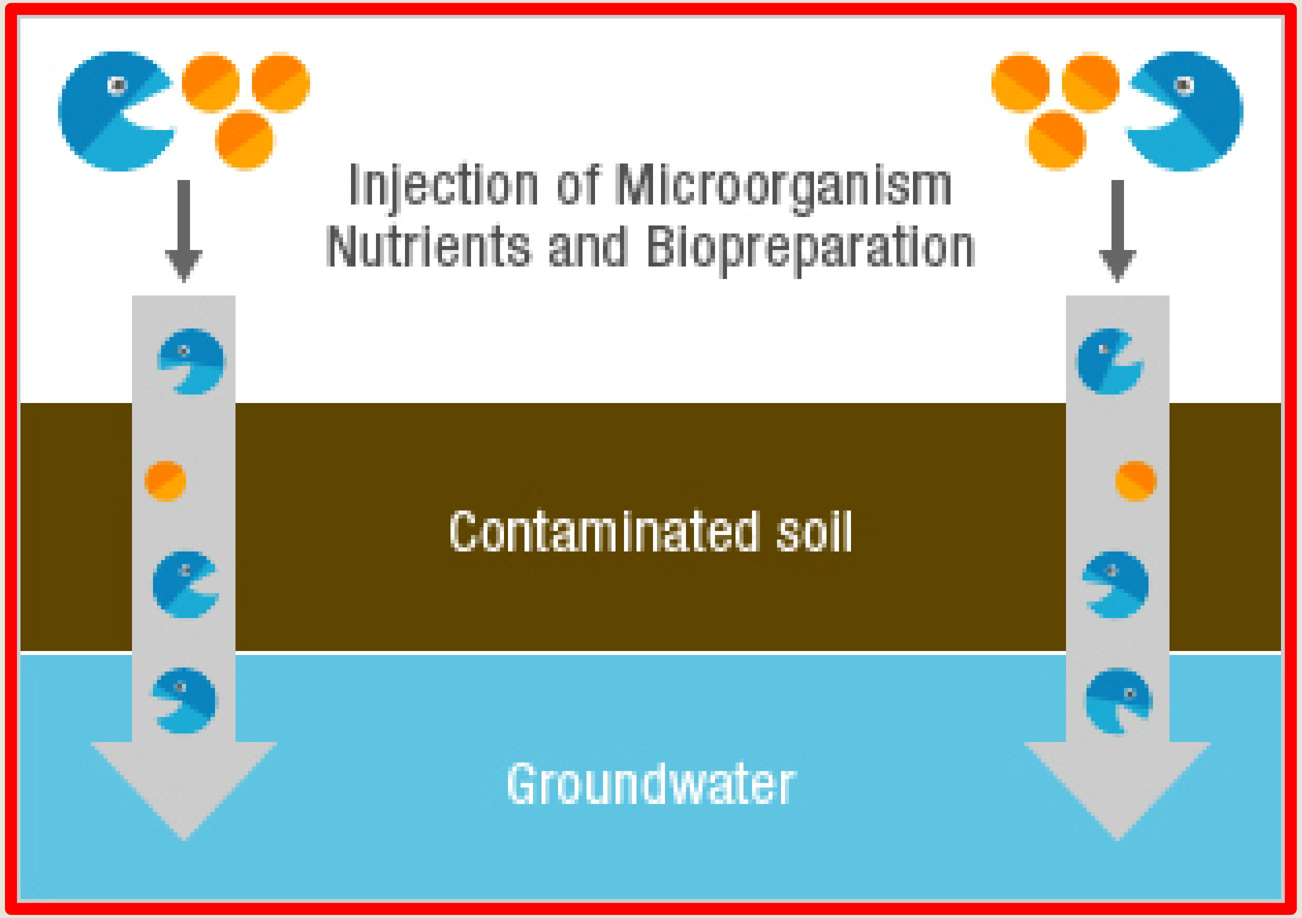
For example, in phytostabilization plants are used to immobilize potentially toxic trace metals in soils through sorption by roots, precipitation, complexation or reduction in the plant rhizosphere, which reduce the mobility and bioavailability of pollutants in the environment.

As a result, it prevents their migration to groundwater or their entry into the food chain.

Good practices

Assisted phytostabilization 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 immobilization.



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).

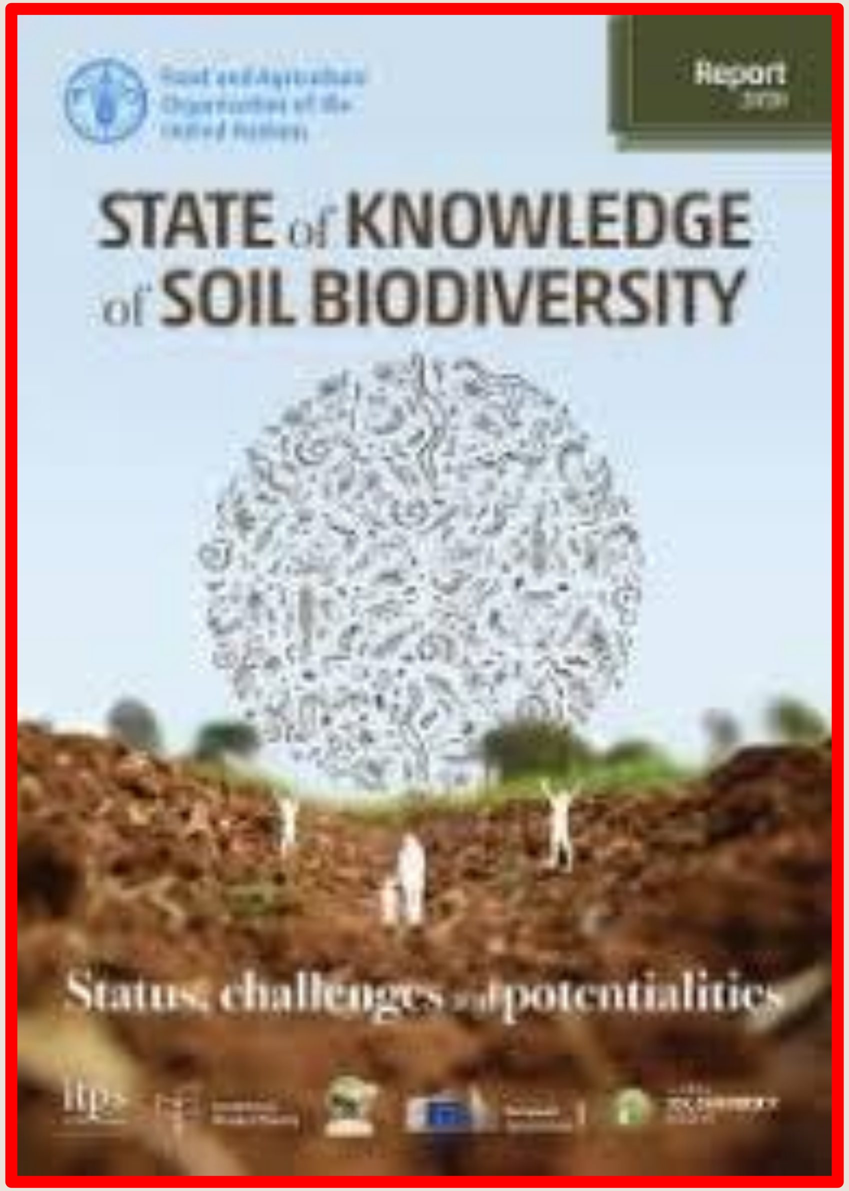
PREVENTING DECLINE IN SOIL BIODIVERSITY

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.

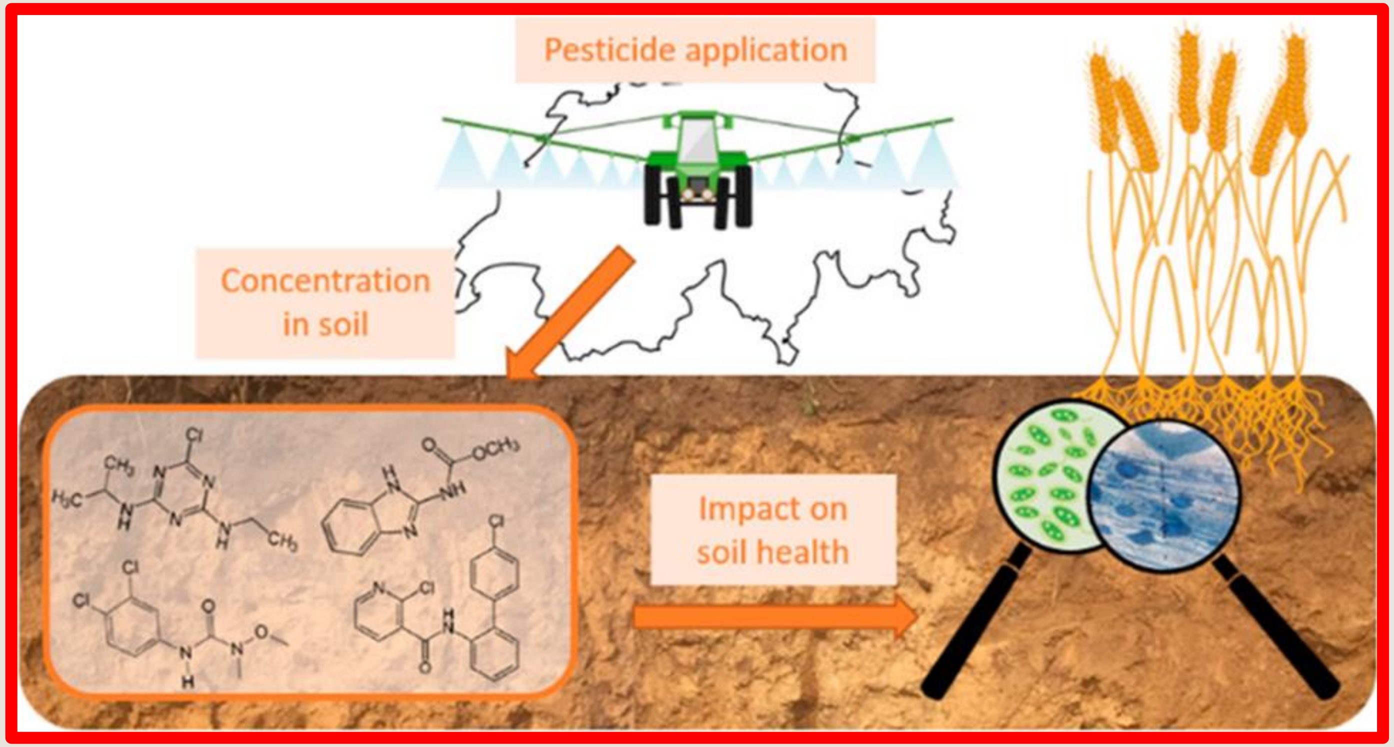
Soil biodiversity ensures a healthy soil system that is necessary for the sustainable functioning of natural and managed lands.



Good practices

Soil biodiversity can be improved by overall sustainable soil management, but also specific measures, such a

- conservation tillage,
- avoiding monoculture,
- intercropping,
- application of safe EOM,
- restricted use of chemicals

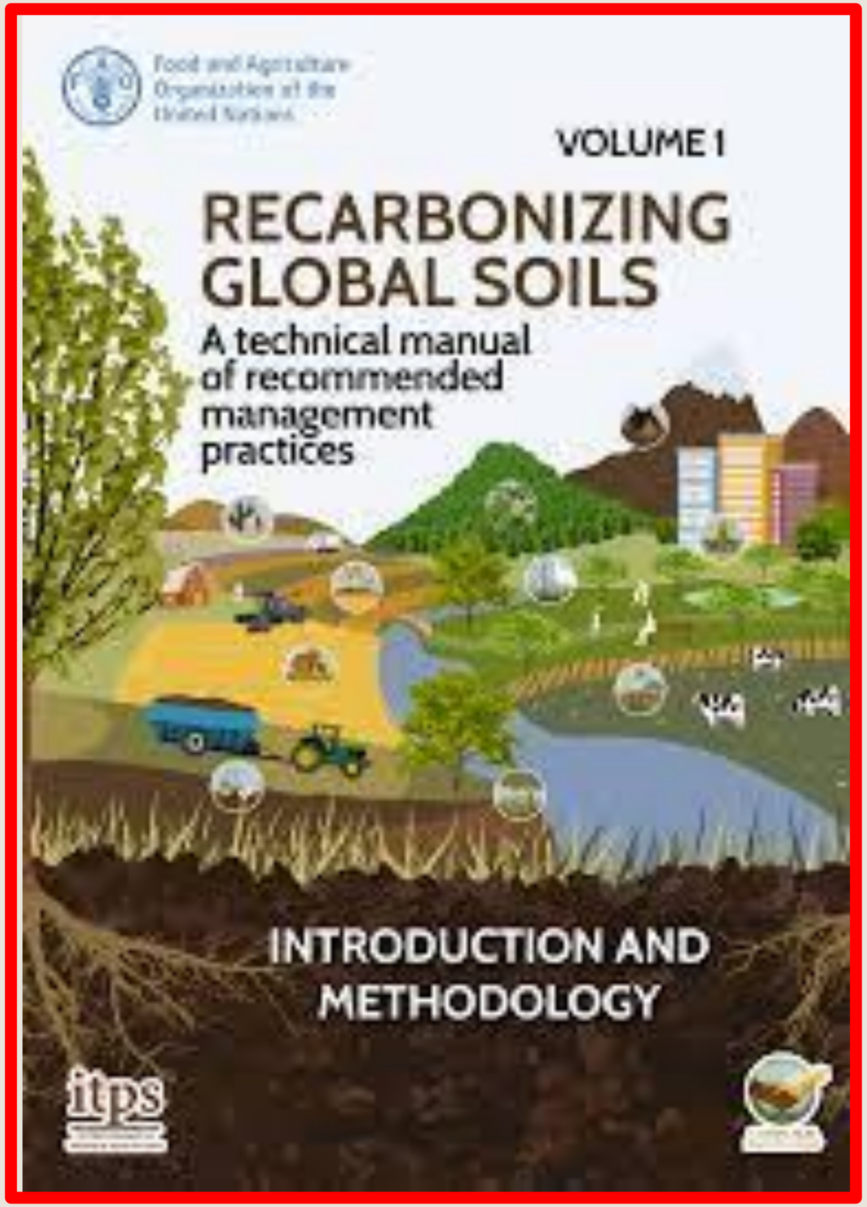


EOM: **E**xogenous **O**rganic **M**atter

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.



SSM AT THE FARM AND LANDSCAPE LEVELS

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.

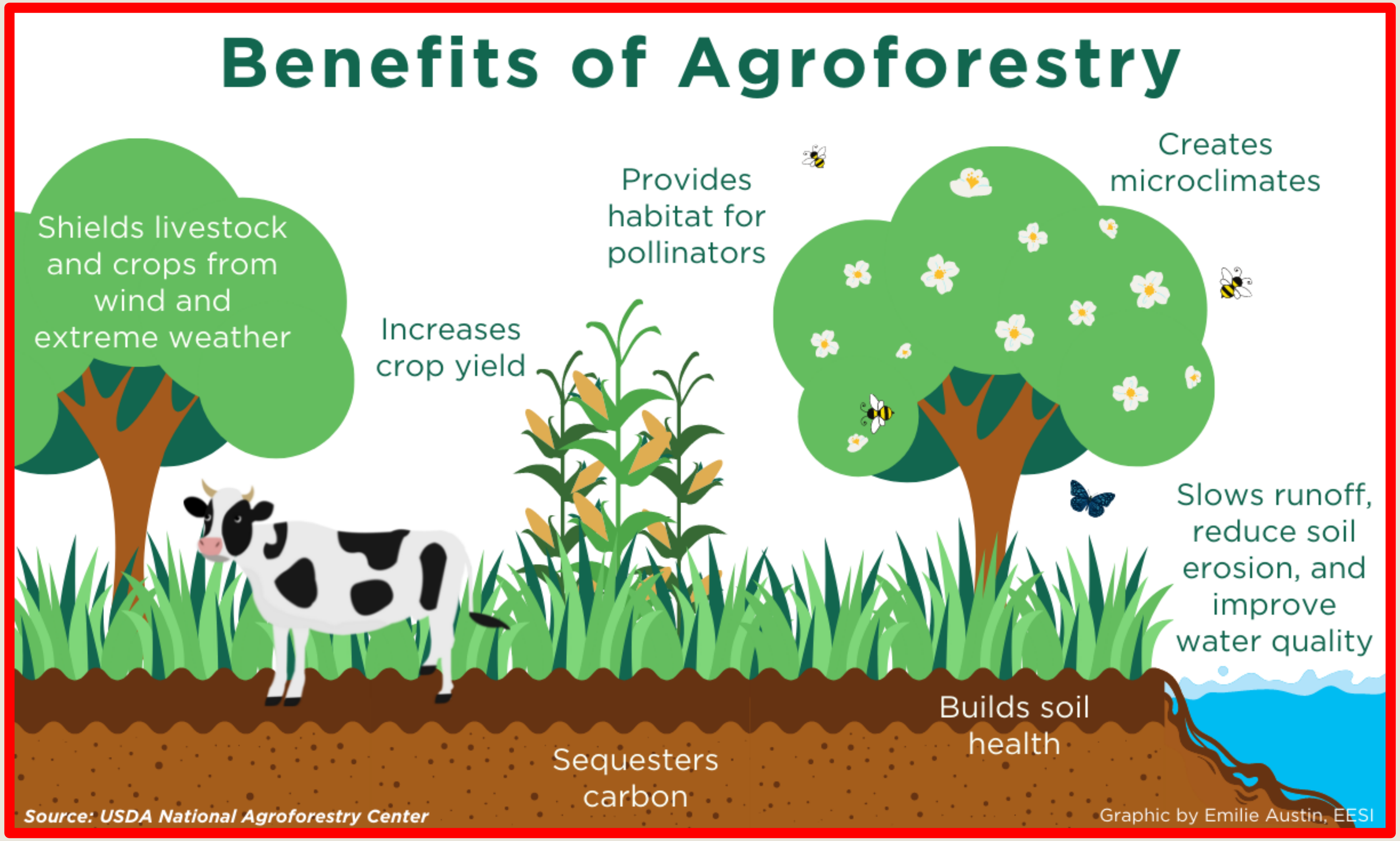
It combines profitable agricultural production with environmental concerns and sustainability and it has been proven to be effective across various pedo-climatic conditions (FAO).

Integrated SSM practices at farm level

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.

Agroforestry is considered a sustainable land management practice since it optimizes 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 harmonized in compliance with the specificity of a site.

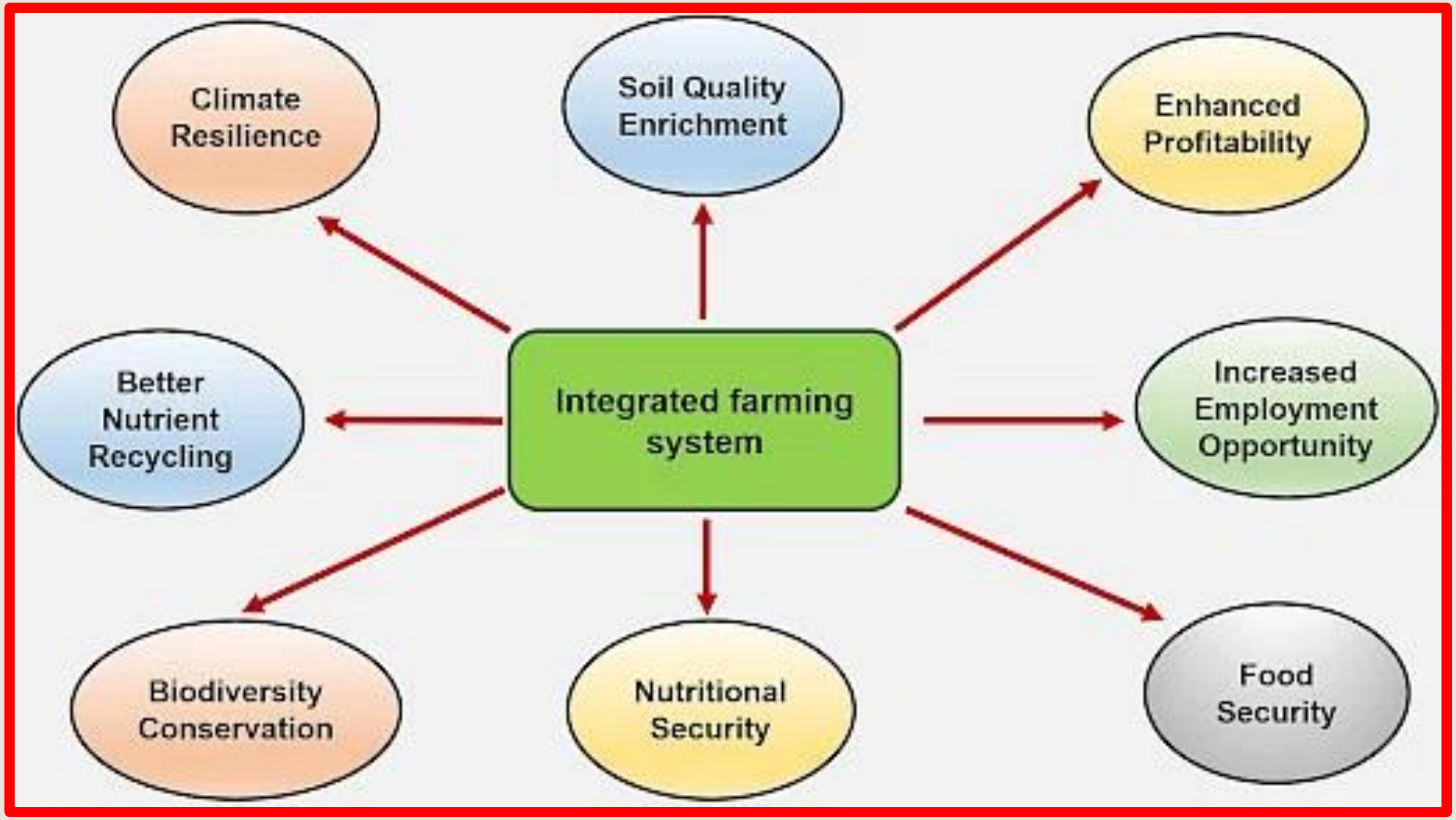
The farmer has to adjust crop selection and rotation, cultivation technology, plant nutrition and plant protection to the natural environment.

This covers optimal soil conservation through environment- friendly management systems and sustainable fertilization 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).

Integrated farming = ecology + economics



Organic farming is based on the idea that the soil is a living system, whereby synthetic fertilizers, 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 fertilizer,
- 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.

SSM AT THE FARM AND LANDSCAPE LEVELS

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.

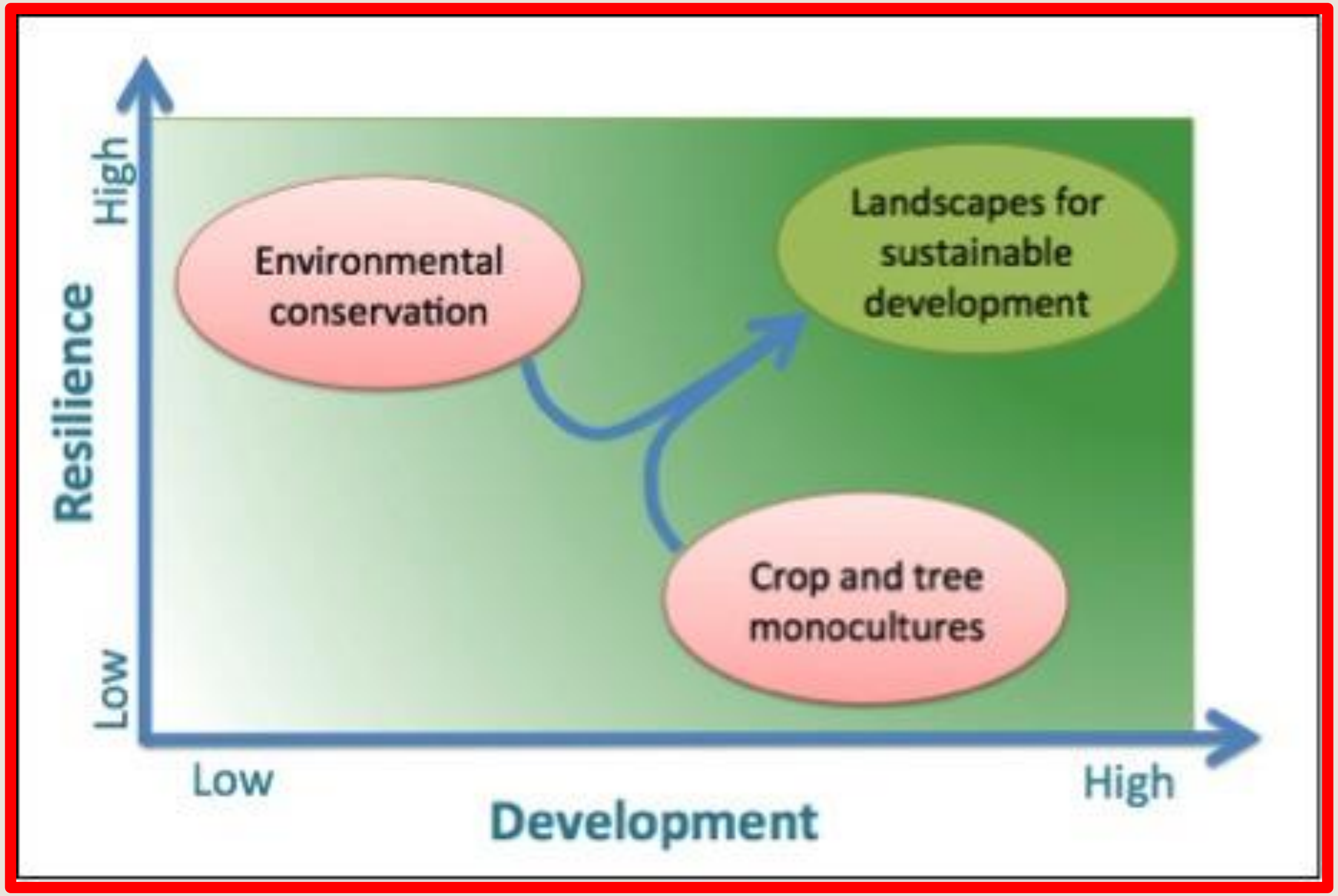
Crop farms apply manure produced in animal farms and provide fodder in return.

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.



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-fertilization, decline of biodiversity, diffuse contamination.

However, data on the scale of implementation of particular SSM measures across Europe is very scarce.

CAP: The **C**ommon **A**gricultural **P**olicy

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.

Thank you

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