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First draft catalogue of soil health improvement practices

Version n° 1

Soilcrates Task 5.1 team

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10	Compost	☐	☑	☑	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐
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12	Biochar	☐	☑	☐	☐	☑	☐	☐	☑	☐	☐	☑	☐	☐
13	Seaweed products	☐	☑	☐	☐	☐	☑	☐	☐	☑	☐	☑	☐	☐
14	Digestate	☐	☑	☐	☐	☑	☐	☐	☐	☐	☑	☑	☐	☐

Practice	Potential Soil Health Benefit												
	Addressing soil compaction	Increasing soil organic matter	Addressing soil nutrient distortions	Addressing erosion and run-off	Improving water management	Enhancing soil resilience handling heat, drought, excessive water	Addressing soil salinisation	Addressing soil pollution	Suppressing harmful organisms	Closing farm nutrients cycles	Improving functional soil biodiversity	Improving aboveground biodiversity	Increasing soil cover
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32 Water catchments infrastructure	☐	☑	☐	☑	☑	☑	☐	☐	☐	☐	☐	☑	☑
33 Anthropic rills	☐	☐	☐	☑	☑	☑	☐	☐	☐	☐	☑	☑	☑
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1 Introduction

1.1 Purpose

This is the draft version of a catalogue of agricultural practices that have the potential of improving soil health. This is phrased more elaborately than the title of this catalogue, because application of the described practices will not automatically improve soil health. Whether or not they will do so, depends on a variety of factors which are addressed in the practice sheets.

The main purpose of this catalogue is providing inspiration for the living labs which are part of the HORIZON EU Soilcrates project activities. These living labs will be implementing experiments with innovative soil improvement practices and this catalogue can help decide on what experiments would be particularly useful to implement as living lab participants.

The information is not complete, but it is meant to provide some overview, and for selected practices more information can be obtained through links to further reading that are provided as well.

Descriptions are relatively short, and for this reason suggestions for further reading are included as well (chapter four). To further inspire decision-making processes in the living labs, a few 'out-of-the-box' practices are included in a more concise description as well (chapter three).

This version of the catalogue will be further upgraded based on already planned improvements, elaborations and feedback that readers provide. This work will be continuing over the next few years as part of the mission of Soilcrates. Related deliverables will be made available through the Soilcrates website (https://soilcrates.eu/).

1.2 Setup

The core of this catalogue is chapter two, which contains two-pager descriptions of 36 agricultural practices. The legend at the beginning of the chapter (2.1) describes how the practice sheets are meant to be interpreted.

In chapter three, a few **innovative practices** are described in less detail. These are often practices which have not been researched sufficiently, but may nevertheless inspire living labs.

Chapter four provides an **overview of further reading material** with sources from Italy, Spain, France, Ireland, and the Netherlands. A simple overview enables a quick check regarding which sources provide further information on which practices.

Chapter five presents the **longlist of agricultural practices that were considered** and from which a shortlist of 36 practices was selected. Practice number six can be applied with such variety that we decided to split it up into four sub-practice descriptions. Practice 16 was later dropped as a suitable practice, and to not confuse the work by different people on the different practices, we left the number on the list for now. In the final version it will be deleted and the numbers above 15 will be adapted.

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2 The practice sheets

2.1 The legend

The following explains the indications provides in the practice sheets. Please note that the indications under 5., 6., and 11. are approximate only because of the variety of conditions that need to be considered for many of the practices.

LEGEND:

1. Name/descriptor of practice
2. Basic description of practice
3. Practical advice on application
4. Crops (for which this practice is particularly relevant)
5. Potential impact

Indication	*Meaning*
––	Seriously negative impact
–	Some negative impact
0	Neutral
+	Some positive impact
++	Seriously positive impact

<u>Options for ecosystem services</u>

Provisioning	***Regulating***	***Supporting***	***Cultural (non-material)***
• Food, fuel and fiber provision	*• Climate regulation*	*• Nutrient cycling*	*• Cultural and non-material elements*
• Income provision	*• Water regulation*	*• Provision of habitat*	
	• Erosion control	*• Biodiversity*	
	• Pollution control		
	• Pest and disease regulation		

6. Application considerations

a. Suitable soil (marked which one(s) apply)
b. Suitable climate (marked which one(s) apply)
c. Application costs - labour (indicated what applies)

Indication	*Means*
🟢	Less work → Saves time
🔵	Same as standard practice
🟡	More work → Requires extra effort
🔴	Much more work → Requires significant effort

d. Application costs - materials (indicated what applies)

Indication	*Means*
🟢	Lower costs → Saves money
🔵	Same as standard practice
🟡	More costs → Requires extra investment
🔴	Much more costs → Requires significant investment

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e. **Difficulty/knowledge needed to apply** (indicated what applies)

Indicator	*Meaning*
0	Nothing different than general farm practice
1	Involves limited new application knowledge and experience
2	Takes some effort to (learn how to) apply
3	Takes a significant effort to (learn how to) apply

f. **Suitable scale of application as indicated**

8. **Extent to which well-researched**

Indicator	*Meaning*
1	Limited: with some effort a few sources can be found
2	Average: general descriptions can be found
3	More than average: one of the focus areas of soil-related research
4	Significant: a lot of research has been done – many sources available

9. **Further considerations**
10. **Research**
11. **Potential soil health benefit (marked are the ones that apply)**

In red the primary potential soil health benefit (s) , and if applicable, in dark yellow the secondary one(s).

12. **Key references and further reading**

Scan the QR-code which leads to an overview of sources in relation to practices, for international sources as well as sources from France, Ireland, Italy, Spain, and the Netherlands.

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2.2 The 36 draft practice sheets

In the following, 36 practices are described in summary two-pagers. They are often compound practices in the sense that they often involve a variety of ways in which certain core principles can be applied. In relation to cover crops (practice number six) this was so much the case, that we decided to create four variants of the practice sheets.

The descriptions are not meant as the one and only way to understand what these practices are about and how they may be applied. Foremost, they are meant to be a starting point of investigation and decision-making, hopefully in many cases wetting the appetite for consulting other, more detailed and authoritative sources as well.

We are trying to make descriptions such that they will be useful for a broad readership from at least the five countries from which representatives are involved in writing this catalogue. We do realise, however, that some practices will be more relevant for one country than another. And, it will not always be possible to touch on all relevant specifics and nuances.

This preliminary draft will be updated soon to address at least some of its current limitations.

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1. Reduced or non-inversion tillage

Basic description of the practice

Reduced tillage is a soil management practice that minimizes mechanical soil disturbance. The most common approach is non-inversion tillage (no ploughing) or reduced depth of primary tillage, which preserves the soil's natural layering. This enhances soil structure, reduces erosion and runoff by maintaining a stable soil matrix, and creates a rough surface that improves water infiltration. Reduced tillage may also contribute to carbon sequestration by slowing organic matter decomposition. While carbon tends to accumulate in the upper soil layers, it may decline in deeper ones. Furthermore, reduced tillage creates a favorable environment for biodiversity and soil life. Successful implementation requires effective weed control, proper crop residue management, crop rotation, and measures to prevent soil compaction from heavy machinery. However, challenges include an increased risk of plant-pathogenic fungi and limited suitability for certain soil types and small-seeded crops.

Implementation

1. Choose the right reduced tillage approach based on your crops, soil and available machinery. Plan for a cover crop to improve weed suppression.
2. Assess equipment needs - determine whether new machinery, such as a subsoiler or equipment for cover crop incorporation and seedbed preparation, is required.
3. Adjust your primary tillage timing to match mechanisation and suitable soil conditions. This may differ from traditional ploughing schedules.
4. Monitor and refine your approach to (cover) crop residue incorporaton, seedbed preparation and weed management. It may take several years for the soil to reach a new balance and reach the same yields, so be prepared to adapt and learn.

Crops for which relevant

Reduced tillage can be used for various crops but is less suitable for those that require intensive soil disturbance, such as root and tuber crops. It is also challenging for crops that need fine seedbeds and have low weed competitiveness, such as carrots and onions.

Potential impact

On soil physics

+

On soil biology

+

On soil chemistry

+

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

4

Potential impact on ecosystems services

Provisioning/regulating:

- Climate regulation
- Water regulation
- Erosion control

Supporting/cultural:

- Provision of habitat
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

- Yield reductions may occur initially but generally recover as the soil adapts.
- Weed pressure may increase since ploughing no longer buries weed see
- Implement a smart crop rotation to help manage weed pressure effectively.
- Heavy clay soils and fields with high weed pressure may be unsuitable for reduced tillage. In organic systems the lack of herbicides may cause increased costs for (hand) weeding.
- Direct seeding may be a viable option in fields with adequate soil moisture.
- Soil density may slightly rise, but this is often offset by improved soil stability and aggregation.
- Prevent soil compaction by limiting heavy machinery use, as subsoiling and ploughing will not be available fo remediation.

Potential soil health benefit

✓	Addressing soil compaction
✓	Increasing soil organic matter
✓	Addressing soil nutrient distortions
✓	Addressing erosion and run-off
✓	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
✓	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
☐	Increasing soil cover

Research

Due to the wide variation in reduced tillage practices, there is a lack of knowledge about its effects in different contexts. Additionally, non-inversion tillage is thought to support carbon sequestration by reducing organic matter decomposition, though its overall impact remains debated. Variations in study results may be due to differences in crop types, organic matter inputs, and climatic conditions across research settings.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Ciska Nienhuis, Isabella Selin-Norén

Contact: https://soilcrates.eu/

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2. Buffer zone strips

Basic description of the practice

Buffer zone strips are permanently designated areas along the edges of agricultural fields.The plant composition of these strips—often a mixture of grasses, herbs, and flowering species—can vary widely. By intercepting runoff, these uncultivated edges fill the main purpose to improve water quality, particularly by preventing nutrient and sediment flow into nearby ditches. Furthermore they can enhance biodiversity by providing habitat for pollinators, beneficial insects, birds, and small mammals. In addition to supporting wildlife, buffer strips can contribute to natural pest control and potentially reduce the need for pesticides.

Implementation

1. Remove perennial weeds before seeding.
2. Choose a strip width and a flower or grass mix based on desired benefits and potential pathogen hosts.
3. Select the optimal seeding period for your climate and calculate the necessary seed quantity.
4. Plan mowing times to avoid the breeding season of birds.

Crops for which relevant

Not any crop in particular.

Potential impact

On soil physics	On soil biology	On soil chemistry
0	0	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Erosion control ◍ Pollution control ◍ Pest and disease regulation	◍ Provision of habitat ◍ Biodiversity ◍ Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Buffer strips occupy valuable agricultural land. To offset this, consider valorizing the harvested biomass. For instance, using the biomass as fertilizer can recycle nutrients back into the soil, enhancing sustainability.

Additionally, buffer strips planted with attractive flowers can engage the public, promoting awareness of biodiversity and sustainable farming practices.Regular mowing is used as a management strategy to limit the spread of unwanted species.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ✓ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on buffer strips has predominantly focused on their effectiveness in nutrient retention, particularly nitrogen (N) and phosphorus (P), in surface runoff. Studies have also explored sediment control and the influence of various vegetation types on this process. Additionally, the impact of buffer strips on biodiversity has been investigated.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Ciska Nienhuis

Contact: https://soilcrates.eu/

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3. Agroforestry

Basic description of the practice

Agroforestry is the purposeful integration of trees or shrubs into farming systems with livestock or arable farming to benefit from their interactions. This practice can involve planting trees within arable fields or grassland, or establishing hedges along field boundaries. The systems' design depends on its intended purpose, such as enhancing natural pest control, generating additional income, fodder production, providing wind protection, or producing biomass for woodchips. The design, in turn, determines the necessary management activities, including tree protection, fertilization, harvesting, and pruning.

Implementation

1. Be aware of national and local laws and regulations regarding tree planting before starting agroforestry.
2. Implementing agroforestry requires careful planning, including tree selection, spacing, and species compatibility with crops or livestock.
3. Manage tree-crop competition, e.g., for soil moisture by selecting deep-rooted species, for light e.g., on the base of tree canopy etc.
4. Depending on the species of the trees, organise the harvest.

Crops for which relevant

Depending on the design, implementing agroforestry is relevant to all types of crops.

Potential impact

On soil physics

\+

On soil biology

\+

On soil chemistry

\+

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

1- 10 ha. 10 - 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:

◍ Food, fuel and fiber provision ◍ Climate regulation ◍ Water regulation ◍ Erosion control ◍ Income provision
◍ Pest and disease regulation

Supporting/cultural:

◍ Nutrient cycling
◍ Provision of habitat
◍ Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Implementing agroforestry can greatly alter how a farm operates and appears. Many aspects of the agroforestry system are still under-researched, so be aware of possible side effects on the main crop.

Learning from a range of peers is valuable, helping to adapt the system to fit the farm style and natural surroundings. Planting trees for harvestable products requires gaining new knowledge and market contacts.

Think about possible extra labour requirements. While agroforestry offers sustainable, long-term ecosystem benefits, successful implementation requires adaptation to local conditions.

Potential soil health benefit

✓	Addressing soil compaction
✓	Increasing soil organic matter
☐	Addressing soil nutrient distortions
✓	Addressing erosion and run-off
✓	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
✓	Improving functional soil biodiversity
✓	Improving aboveground biodiversity
☐	Increasing soil cover

Research

A lot of research has focused on its environmental benefits, such as improved soil health, biodiversity, water management, and carbon sequestration in specific systems.

Less attention has been given to local adaptation of systems, farmer adoption, and economic viability. There is a need for more research on their long-term economic viability, the specific impacts of different tree species on soil health, and the resilience of these systems under climate change.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Isabella Selin-Norén

Contact: https://soilcrates.eu/

Funded by the European Union

4. Apply diversified crop rotation

Basic description of the practice

This factsheet is about a wider, more diverse, crop rotation which benefits soil health. A rotation focussing on cash crops could reduce soil quality, which could be improved by diversifying crop rotations. A more varied cropping system could lower pest and disease pressure, thereby reducing the need for pesticides and enhancing soil health. In addition for example grain crops and/or winter cover crops may improve soil health by maintaining soil organic matter, and it has a positive impact on biodiversity in general.

Implementation

1. Select what kind of crop rotation you want.
2. Check the available machinery for tillage and harvesting.
3. Make a fertilisation plan for your crop rotation .
4. Start with tillage and planting/seeding.
5. After harvesting evaluate and adjust.

Crops for which relevant

Suitable for intensive cropping systemens.

Potential impact

On soil physics	On soil biology	On soil chemistry
+	+	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Climate regulation ◍ Water regulation ◍ Pollution control ◍ Pest and disease control	◍ Nutrient cycling ◍ Provision of habitat ◍ Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Challenges include financial viability. A wider crop rotations helps suppressing harmful organisms, but a wrong choice may be disastrous (e.g., pathogen nematodes). Policy incentives and knowledge-sharing can help farmers overcome barriers like planning complexity and reduced short-term profitability.

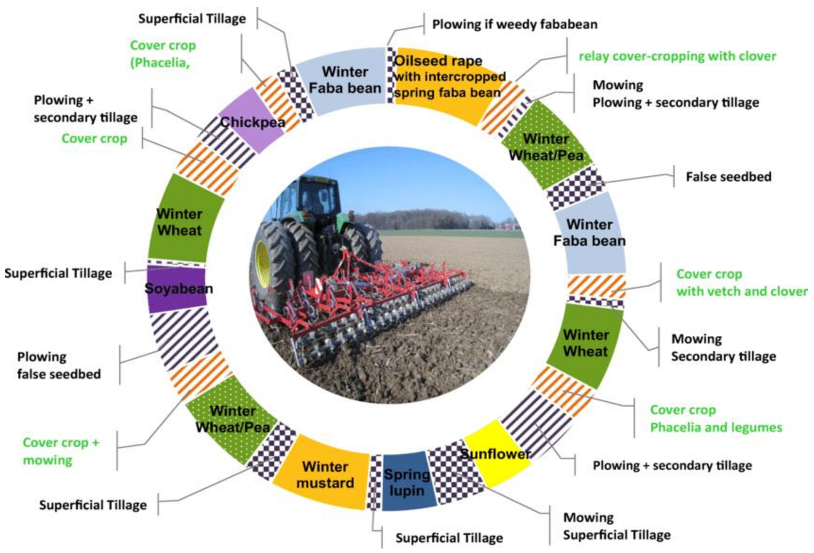
Potential soil health benefit

- ✓ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

A lot of research has been done on wider crop rotations and the impact on yields, organic matter, nitrogen and phosphate. In addition, research has also been done on crop rotations in a partnership between livestock and arable crops. There is research need for specific soil characteristics, such as drought sensitivity, compaction and soil life.

For further reading material on this and other practices, visit:



Source:
Brice Mosa and Violaine Deytieux © 2018

Date: April 2025

Authors: Marjan Toren and Ciska Nienhuis

Contact: https://soilcrates.eu/

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5. Strip cropping

Basic description of the practice

Strip cropping involves growing crops in alternating, narrow strips across a field. It is essentially a form of in-place crop rotation and is well-suited to existing mechanization. Strip widths typically range from 1.5 to 27 meters, with common widths of 3, 6, 9, or 12 meters, depending on machinery size and intended purpose. This system is expected to enhance yields and reduce pest and disease pressure. Neighboring crops can positively influence each other—through improved light distribution, wind buffering, attraction of natural enemies, and limiting the spread of diseases by reducing direct contamination. In addition, strip cropping supports greater habitat availability for biodiversity due to a more diverse cropping pattern.

Implementation

1. Choose which crops you want to work with and determine the strip width based on the available mechanization. Take into account harvest operations, where you may need to drive into neighboring strips.
2. Create a spatial strip cropping plan that shows which crops will be planted in each strip—ideally over multiple years. Also consider the space needed for headlands and make sure to have a gap year in space so that pests and diseases cannot follow their host crop into the subsequent season.
3. Sow your strips with the selected crops, preferably using GPS for accuracy.
4. Continue managing your crops as usual, and monitor your field to observe any effects.

Crops for which relevant

Strip cropping suits a variety of crops, such as cereals, legumes, root crops, and brassicas. Careful planning helps ensure beneficial crop neighbors while avoiding negative interactions like shading or pest issues.

Potential impact

On soil physics

0

On soil biology

0

On soil chemistry

0

Application considerations

Application material cost

●

Application labour cost

● ●

Effort/knowledge needed

3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:

- Pest and disease regulation

Supporting/cultural:

- Provision of habitat
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

In many countries, annual crop registration is required and can be complex for strip cropping systems. Other challenges include difficulty in strip-specific management for fertilisation, pesticide application and irrigation. Strip cropping contributes to a more diverse and visually appealing landscape. The use of autonomous machinery could significantly ease labor demands, making the system more practical. However, addressing technical challenges may require investments in specialized equipment and exploration of alternative market opportunities, such as decentralized sales channels and niche markets for diverse crops. Research shows that narrower strips tend to enhance biodiversity, though wider strips are generally more labor-efficient to manage.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Ongoing research aims to resolve technical challenges, including the application of irrigation and chemical plant production products. European (Dutch) research so far has focused on yield effects, natural enemies, disease suppression and biodiversity but as each system and context is unique it is difficult to extrapolate the effects to other systems. Internationally and historically, there has been research on systems with only two crops in the US and in less mehcanized systems in China.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Ciska Nienhuis

Contact: https://soilcrates.eu/

Funded by the European Union

6a. Cultivation of cover crops for carbon sequestration

Basic description of the practice

Cover crops (including green manure, catch crops) may have several agro-ecological benefits one of which is carbon sequestration. By definition, carbon sequestration refers to actual reduction of atmospheric CO_2. Cover crops contribute to this by the production of biomass from photosynthesis. The idea of this practice is to select cover crops that are better than others in adding organic matter to the soil. In temperate climates, cover crops may be sown after the main crop harvest in the end of the summer or early autumn. During the winter period growth is restricted. In spring, regrowth usually occurs. For the purpose of carbon sequestration, the biomass (roots and aboveground) is ploughed under and not harvested. During summer, the biomass will be decomposed, partly ending in stable forms of soil organic matter.

Implementation

1. Choose the right cover crop and or mixture based on carbon sequestration e.g., grasses, winter cereals. Take into account soil type, sowing time and possible nematode status.
2. Start with seeding and optionally fertilize.
3. Select the right method of cover crop termination and incorporation e.g., chemical or mechanical. Be aware that onderploughing reduces carbon sequestration.
4. Evaluate and adjust.

Crops for which relevant

Cover crops: (winter-) cereals, grass.
In principle, this practice is applicable in all arable rotations , and in the arable phase of grass-maize rotation.

Potential impact

On soil physics

+

On soil biology

0

On soil chemistry

+

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha. | 1- 10 ha. | 10 - 50 ha. | > 50 ha.

Extent to which well-researched

3

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Climate regulation	◍ Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

Cover crops can reduce certain nematodes, but may actually multiply nematodes. For The Netherlands, a scheme is available to take this into account in the selection (Best4Soil project). In addition, cover crops with resistances against certain plant-parasitic nematodes are available in some countries and can contribute to the control of nematodes.

Cover crops may be grown in individual stand and also in mixtures. In The Netherlands it is important that the cover crop is able to establish itself well before winter. For optimal biomass production, the length of the cultivation period should be considered, e.g., time of sowing and of incorporation. Incorporation should not be done in wet conditions as this may lead to rotting processes.

Harvesting the cover crop (removal) obviously limits the amount of organic matter returned to the soil and should be avoided. It is best to have a few weeks between incorporation and sowing of the main crop. Also, some nitrogen may be required to avoid N immobilization which might restrict main crop growth.

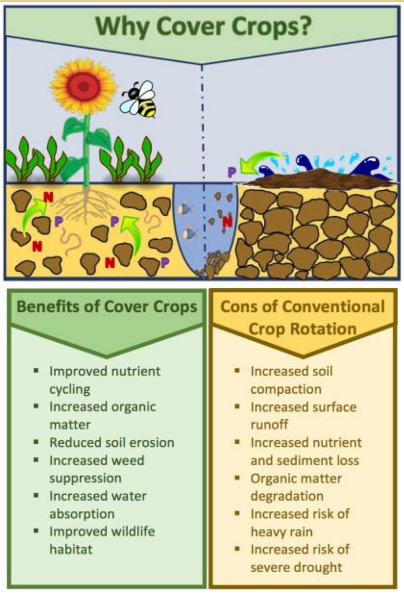
Potential soil health benefit

✓	Addressing soil compaction
✓	Increasing soil organic matter
☐	Addressing soil nutrient distortions
☐	Addressing erosion and run-off
☐	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
✓	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
✓	Increasing soil cover

Research

Ample research within the frame work of climate change has been done, but often using data from decades past. New data on how much dry matter is actually produced per cover crop, and its nitrogen content, are pending.

For further reading material on this and other practices, visit:



Source: https://fyi.extension.wisc.edu/foxdemofarms/files/2017/01/Why-Cover-Crops_v4.jpg

Date: April 2025

Authors: Marjoleine Hanegraaf

Contact: https://soilcrates.eu/

Funded by the European Union

6b. Cover crops for biological nitrogen fixation

Basic description of the practice

Cover crops may have several agro-ecological benefits one of which is biological nitrogen fixation. carbon sequestration. By definition, biological nitrogen fixation is the process whereby soil atmospheric N2 gas is taken up by Rhizobium bacteria in the root nodules of leguminous plants and transformed and transported into organic nitrogenN in plant tissues. The idea concept of this practice is to select leguminous cover crops instead of non-leguminous cover crops. In temperate climates, cover crops may be sown after the main crop harvest end of summer / early autumn. During the winter period growth is restricted. In spring, regrowth usually occurs. For enriching the soil with this nitrogenIn order for the stored nitrogen to become available again, the biomass (roots and aboveground) is ploughed underincorporated into the soil and not harvested, or, they are harvested and transported to another field and worked inincorporated there. Either case, the biomass will be decomposed during summer, partly ending in stable forms of soil organic matter.

Implementation

1. Choose the right cover crop and or mixture based on biological nitrogen fixation e.g., clover, vetch and other leguminous crops. Take into account soil type, pH, sowing time and possible nematode status.
2. Start with seeding and optionally fertilize, but not with nitrogen.
3. Select the right method of destruction e.g., chemical or mechanical.
4. Evaluate and adjust.

Crops for which relevant

Leguminous cover crops, e.g., vetch, red and/or white clover .

Potential impact

On soil physics

0

On soil biology

0

On soil chemistry

+

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

3

Potential impact on ecosystems services

Provisioning/regulating:

◍ Nutrient cycling

Supporting/cultural:

For information on relevant legislation and regulations, visit:

Further considerations

Too much mineral nitrogen present in the soil will reduce/impede biological nitrogen fixation. This process takes place when roots are nodulised with active rhizobium bacteria. In the Netherlands, it is assumed that rhizobia are always present in agricultural soils. To stimulate the bacteria and obtain optimal nitrogen delivery, ensure optimal pH. In The Netherlands this may be c. 0.5 – 1 unit higher than otherwise advised.

You have to be aware of that the nitrogen from leguminous crops comes available during the season. Whereas mineral nitrogen is available directly after application. Leguminous crops in general are more sensitive to certain diseases, such as Aphanomyces and Pythium root rot.

In addition, they are often moderate to good hosts of plant-parasitic nematodes such as root-knot, root-lesion and stem nematodes.

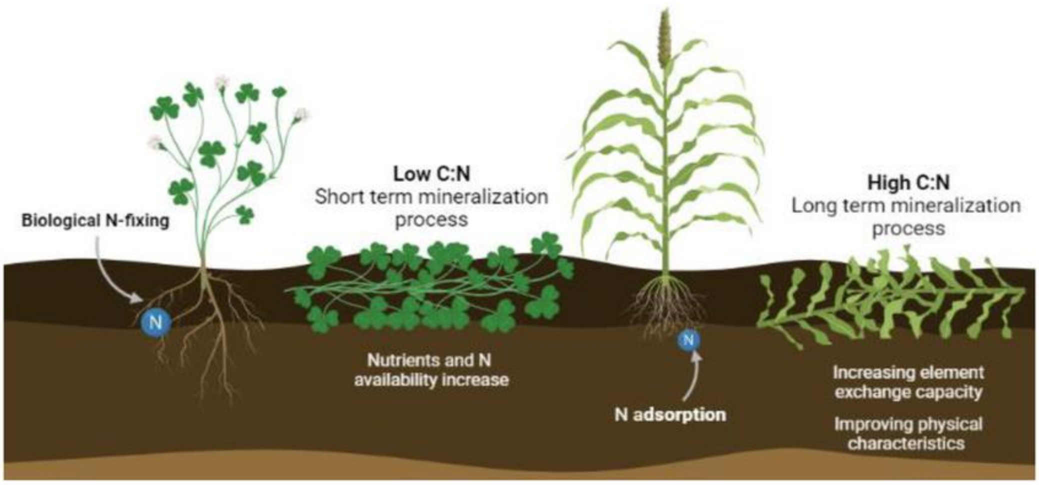
Potential soil health benefit

✓	Addressing soil compaction
✓	Increasing soil organic matter
✓	Addressing soil nutrient distortions
☐	Addressing erosion and run-off
☐	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
✓	Closing farm nutrients cycles
✓	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
✓	Increasing soil cover

Research

Well researched practice, with data available for N-input per cover crop and status of cover crop development. Research is needed on the effect of frequency of leguminous crop cultivation on disease pressure.

For further reading material on this and other practices, visit:



Source:
Quintarelli et al. 2022.
Cover crops for sustainable cropping systems: a review.
Agriculture 12(12).

Date: April 2025

Authors: Marjoleine Hanegraaf

Contact: https://soilcrates.eu/

Funded by the European Union

6c. Cultivation of catch crops to reduce nitrogen leaching

Basic description of the practice

Cover crops may have several agro-ecological benefits one of which is to catch nitrogen that otherwise would be lost to deeper soil layers and/or ground waters. The idea of this practice is to catch mineral nitrogen before it leaches out in winter. In spring, the biomass (roots and aboveground) is ploughed under and not harvested. The biomass will be decomposed during summer, partly ending in stable forms of soil organic carbon. A catch crop is a special type of cover crop that remain unfertilized.

Implementation

Step 1: Assess Site Conditions and Objectives
•Evaluate soil type, drainage, fertility, and existing nutrient levels.
•Identify leaching risks (e.g. sandy soils, heavy rainfall areas).
•Set clear objectives (e.g. nitrate retention, erosion control, biomass production).
Step 2: Select Suitable Catch Crop Species
•Choose species based on:
*Nitrogen uptake capacity (e.g. mustard, radish, ryegrass).
*Climate suitability (winter hardiness, drought tolerance).
*Root architecture for nutrient scavenging.
*Compatibility with main crops (avoid pest/disease carry-over).
Step 3: Determine Sowing Time and Method
•Sow immediately after harvest of main crop to maximize N uptake.
•Use direct drilling or broadcast seeding with light incorporation.
•In regions with short post-harvest windows, consider undersowing.
Step 4: Manage Growth and Termination
•Monitor biomass accumulation and ground cover.
•Terminate catch crops at appropriate times (4–6 weeks before main crop sowing).
oMethods: mowing, incorporation, or rolling (non-chemical if organic).
•Avoid regrowth or nutrient immobilization before next crop.
Step 5: Integrate into Crop Rotation and Nutrient Planning
•Adjust nitrogen fertilization in subsequent crops based on N retained and mineralized from catch crop residues.
•Monitor soil nitrogen levels regularly.
•Use catch crops to diversify rotations and improve soil resilience.
Step 6: Comply with Policy and Monitor Outcomes
•Align with EU agri-environmental schemes (e.g. CAP greening, nitrate directive).
•Document practices and outcomes (e.g. nitrate testing, biomass yields).
•Use decision support tools and models for ongoing improvement.

Crops for which relevant

Many different types of cover crops are available, see longlist for The Netherlands
https://www.rvo.nl/onderwerpen/mest/vanggewas-op-zand-en-lossgrond

Potential impact

On soil physics	On soil biology	On soil chemistry
0	0	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 3

Potential impact on ecosystems services

Provisioning/regulating:

◍ Nutrient cycling

Supporting/cultural:

For information on relevant legislation and regulations, visit: GLB

Further considerations

In spring time the catch crop may deplete the soil for moisture causing problems for the main crop. Cover crops can reduce certain nematodes, but may actually multiply nematodes. For The Netherlands, a scheme is available to take this into account in the selection (Best4Soil project).

Key considerations include selecting regionally adapted catch crop species, ensuring timely sowing and termination, managing soil moisture and fertility, aligning with main crop rotations, and complying with European agri-environmental policies to effectively reduce nitrogen leaching.

Potential soil health benefit

- ✓ Addressing soil compaction
- ✓ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ✓ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Much research has been done for both clay and sandy soils. More research is needed for the nitrogen contents of the rooting systems.

Frontiers of research focus on identifying optimal catch crop species, planting schedules, and management practices that maximize nitrogen uptake, minimize leaching, and improve soil health, while integrating catch crops into diverse cropping systems under varying climate conditions.

For further reading material on this and other practices, visit:

Source: Liu, 2013. Phosphorus Leaching as Influenced by Animal Manure and Catch Crops

Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

6d. Selection of cover crops in relation to nematode control

Basic description of the practice

Cover crops may serve various purposes (see other factsheets). However, in the selection of cover crops care should be taken not to increase the risk and/or incidence of a nematode -outbreak. a well-chosen green manure crop is one way to control plant parasitic nematodes.

A nematode outbreak can occur if inappropriate cover crop species are chosen—particularly those that are hosts to plant-parasitic nematodes (e.g., certain brassicas or legumes). If these host plants are used repeatedly or in poorly rotated systems, they can allow nematode populations to build up in the soil. Additionally:

- Poor termination timing may allow nematodes to reproduce further.
- Lack of species diversity can favor specific nematode species.
- Reusing susceptible cover crops across seasons can increase the nematode pressure on the subsequent main crop.

Implementation

The above highlights the importance of selecting cover crops based on nematode-host status and compatibility with the entire rotation system.

1. Choose the right cover crop and or mixture based on carbon sequestration e.g., grasses, winter cereals. Take into account soil type, sowing time and possible nematode status.
2. Start with seeding and optionally fertilize.
3. Select the right method of destruction e.g., chemical or mechanical. Be aware that onderploughing reduces carbon sequestration.
4. Evaluate and adjust.

Crops for which relevant

All major arable crops.

Potential impact

Potential impact	
On soil physics	0
On soil biology	++
On soil chemistry	0

Application considerations

Application material cost	● (blue)
Application labour cost	● (orange)
Effort/knowledge needed	3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 4

Potential impact on ecosystems services

Provisioning/regulating:

- Pest and disease control

Supporting/cultural:

For information on relevant legislation and regulations, visit:

Further considerations

Key considerations for nematode control with cover crops in Europe include selecting non-host or biofumigant species, understanding local nematode populations, timing cover crop termination properly, and rotating with main crops to prevent nematode buildup or resistance.

A scheme has been developed in The Netherlands. See picture below.

Good practice:
-Rotate suppressive and non-host species.
-Avoid using known host cover crops where nematode pressure is high.
-Test soils for nematode populations before choosing species.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

It is not known for other countries how a similar scheme would look like. Nematode-resistant or suppressive cover crop species commonly used in European agriculture:
-Brassicaceae (Mustard family) contain glucosinolates that release isothiocyanates, which suppress nematodes.
-Grasses (grains) are typically non-hosts and can reduce nematode populations by denying them food sources.
-Some legumes can host nematodes but specific species may be chosen carefully.

For further reading material on this and other practices, visit:

Nematode scheme 2025
Best4Soil Nematode scheme

Date : Wednesday, March 26, 2025
Country : United Kingdom
Description :
Soil Type : sandy soil

Ctrl+Click on a cell for background information about the crop / nematode combination

	Root-knot nematodes							
	Meloidogyne arenaria Peanut root-knot nematode	*Meloidogyne chitwoodi* Columbia root-knot nematode	*Meloidogyne fallax* False columbia root-knot nematode	*Meloidogyne hapla* Northern root-knot nematode	*Meloidogyne incognita* Cotton root-knot nematode	*Meloidogyne javanica* Sugarcane root-knot nematode	*Meloidogyne minor* Root-knot nematode	*Meloidogyne naasi* Barley root-knot nematode
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Fodder rape / Leafy turnip	?	?	? i	? i	?	?		?
Black oat	?	●●● i	●●●	? i	?	?		●
Phacelia	?	●	●	●●	?	?		-
Marigold	?	-	-	-	●● R	●● R		-

Root lesion nematodes								
Pratylenchus brachyurus	*Pratylenchus convallaria* Convallaria root lesion nematode	*Pratylenchus crenatus* Cereal root lesion nematode	*Pratylenchus fallax* Grass root lesion nematode	*Pratylenchus neglectus* Sugarbeet lesion nematode	*Pratylenchus penetrans* Northern root lesion nematode	*Pratylenchus thornei* Thorne's root lesion nematode	*Pratylenchus vulnus* Walnut root lesion nematode	
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	
?		?		?	●●● i			Fodder rape / Leafy turnip
?		?		?	- i			Black oat
?		?		?	●●●			Phacelia
●● R		? i		?	--			Marigold

Legend damage	
	unknown
(green)	none
(yellow)	little (0-15%)
(orange)	medium (16-35%)
(magenta)	serious (36-100%)

Legend propagation	
--	active population decline
?	host plant susceptibility unknown
-	non host
●	poor
●●	moderate
●●●	strong
R	variety dependent
S	serotype dependent
i	some information

Legend soil type	
1	sandy soil
2	(reclamed) peat soil
3	sandy clay loam
4	clay soil
5	silty soil (loess)

Best4Soil received funding from the European Union's Horizon 2020 Programme for Coordination and Support Action, under GA n° 817696.

Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

7. Intercropping

Basic description of the practice

Intercropping is an agricultural practice where two or more crops are grown simultaneously on the same land. The main goal is optimizing resource use (sunlight, water, nutrients) and enhancing productivity per unit area. Strategic species combinations, such as deep- and shallow-rooted plants, maximize complementary interactions and efficient soil resource use. Legumes fix nitrogen, reducing synthetic fertilizer needs, supporting soil fertility, and improving yield and protein content—particularly in organic systems. Seed rates often exceed 100% combined, tailored to specific goals, like legumes boosting cereal protein levels. Intercropping typically results in a higher Land Equivalent Ratio (LER), indicating more efficient land use compared to monocultures. It supports biodiversity by creating habitats for beneficial insects, reducing weed, pest, and disease pressures, lowering input costs, and increasing resilience to environmental stresses. Yield benefits are most pronounced in low-production regions, while in high-production areas, such as The Netherlands, lower yields have been reported.

Implementation

1. Determine the goal: Clearly define the purpose of the mixed cropping system, such as improving soil health, pest control, protein content or maximizing yield.
2. Check for suitable mechanization: Ensure that appropriate machinery is available. Sowing may need to be done in two stages or with adjusted equipment. After harvest, consider mechanization for dividing the harvest efficiently.
3. Select crops with complementary growth cycles: Choose crops that have different growth patterns to maximize the use of available space and resources throughout the growing season.
4. Ensure broad sowing for weed suppression: Use dense sowing techniques to effectively suppress weeds and reduce competition for nutrients, water, and light.

Crops for which relevant

In principle, it can be applied to all crops but is most commonly used in the following combinations: maize & catch crops, cereals & legumes (wheat, barley, or oats with clover, field beans, or peas), rapeseed & beans or clover, and undersowing of grasses in cereals.

Potential impact

On soil physics: 0

On soil biology: 0

On soil chemistry: 0

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed: 2

Suitable soil	Suitable climate
✓ Clay	✓ Maritime
✓ Sandy	✓ Mediterranean
✓ Loamy	✓ Continental

Suitable scale of application

< 1ha. | 1- 10 ha. | 10 - 50 ha. | > 50 ha.

Extent to which well-researched: 3

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Pest and disease regulation	◍ Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

Herbicide and pesiticide selection in intercropping is limited. Other constraints include mechanization issues, uneven ripening, separating mixed harvests and market uncertainties. Mixed cropping makes managing soil diseases through crop rotation more challenging. There is a higher risk of increasing populations of nematodes or fungi.

A variant for intercropping is mixing cultivars of the same species. Then the purpose is yield security, resiliance and risk spreading in general.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Widely researched but many questions unanswered. Effects of specific combinations often only limited quantified, lessons from research of commonly used combinations are often not included in new research, relevance to common cultivation often not considered. Evidence is limited, and effects are often neutral or slightly positive. The impact on soil-borne pathogens and nematodes has been little to no studied. Development of crop varieties that ripen uniformly can be studied.

For further reading material on this and other practices, visit:

Source: https://www.wur.nl/en/project/optimization-of-soybean-productivity-quality-and-profit-through-soybean-maize-mung-bean-intercropping-in-east-java-indonesia-.htm

Date: April 2025

Authors: Ciska Nienhuis

Contact: https://soilcrates.eu/

Funded by the European Union

8. Tagetes patula for nematode control

Basic description of the practice

Cover crops may have several agro-ecological benefits (see factsheets 6a-d) one of which is nematode control. Cultivation of Marigolds (Tagetes patula) in particular helps to control free-living endoparasitic nematodes, e.g., Pratylenchus penetrans. It is important that Tagetes remains on the field for at least 3-4 months, without any weeds. Otherwise the nematodes might still multiply.

Implementation

1. Choose Tagetes only for crop rotations with economically important crops and infestation of P. penetrans . Also take into account other nematode infestations.
2. This cover crop is to be treated as other crops in terms of fertilisation and chemical weed control.
3. Select the right sowing time for allowing 3-4 months growth at the field taking into account frost sensitivity.
4. Evaluate the effect on nematode suppression.

Crops for which relevant

In cropping plans with relatively high financial yielding crops such as onions, flower bulbs, strawberry and potatoes and rose and tree nurseries. Cropping plans with crops that are sensitive for P. penetrans.

Potential impact

Potential impact	
On soil physics	0 +
On soil biology	+
On soil chemistry	0 +

Application considerations

Application material cost	● (orange)
Application labour cost	● (blue)
Effort/knowledge needed	2

Suitable soil		Suitable climate	
☐	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
☐	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 3

Potential impact on ecosystems services

Provisioning/regulating:

- Pest and disease regulation

Supporting/cultural:

For information on relevant legislation and regulations, visit:

Further considerations

Several key considerations are essential to ensure effectiveness:

Species Selection: Not all Tagetes species are equally effective. Tagetes patula and Tagetes erecta have demonstrated strong suppressive effects on root-knot nematodes (Meloidogyne spp.) and lesion nematodes (Pratylenchus spp.), primarily through the production of thiophenes, natural nematicidal compounds in their roots.

Sufficient Biomass and Root Contact: The nematicidal effect depends on high root density and biomass production, as the active compounds are released from root exudates. Thus, achieving good stand establishment and allowing adequate growing time (typically 2–3 months) is critical.

Climate and Seasonality: Tagetes is sensitive to frost and low temperatures, limiting its use to warmer months or milder climates. It is not suitable as an overwintering cover crop in mo

Timing in Crop Rotation: Tagetes should be planted between main crops in periods where nematode populations are active. It is most effective when grown prior to a susceptible crop, breaking the nematode lifecycle before planting. Consider application in combination with another crop with a short cultivation period.

Field History and Monitoring: Use soil testing to confirm presence of nematode species that are controlled by Tagetes. Avoid repeated monoculture use, which may lead to resistance buildup or reduce soil biodiversity.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research In The Netherlands has shown that the effect of this measure may last at least three years after application.

Research frontiers on Tagetes for nematode control focus on optimizing species selection, understanding allelopathic mechanisms, improving biomass production in temperate climates, and integrating Tagetes effectively into crop rotations without compromising soil health or biodiversity.

For further reading material on this and other practices, visit:

Pictur

Date: April 2025

Authors: Ciska Nienhuis,Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

9. Species diversification in grassland

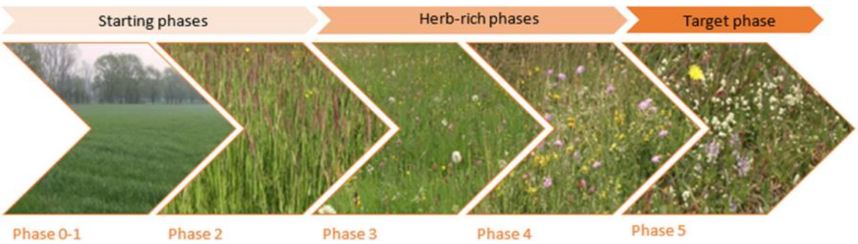
Basic description of the practice

The cultivation of herb-rich grassland is thought to have various benefits, e.g., improved cow health and higher milk production of improved protein contents. Different rooting depths of species may improve water uptake by plants as well as water infiltration in the soil. Also, leguminous crops, e.g., clover, can fix nitrogen. Overall, herb-rich grasslands may have positive effects on animals themselves, as well as on biodiversity, climate and environment.

In short, the key reason for choosing diversification of grassland would be to enhance forage resilience and quality while reducing input dependence (e.g. fertilizers) and improving soil and animal health under changing climate and market conditions.

Implementation

1. Select whether to overseed or reseed taking into account presence of weeds, e.g., cough grass, and soil quality. When reseeding, choose the appropriate methods for grass destruction and soil tillage.
2. Choose the herb species mixture to use.
3. Follow sellers' instructions for fertiliser use and sowing.
4. Apply a light mowing regime to allow the herbs to establish.



Source: DeCock et al. 2022. **Ecosystem multifunctionality lowers as grasslands under restoration approach their target habitat type**

Crops for which relevant

Mono-cultures of grass, e.g., English ryegrass.

Potential impact

On soil physics	On soil biology	On soil chemistry
+	+	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 3

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Climate regulation ◍ Pest and disease control	◍ Nutrient cycling ◍ Provision of habitat ◍ Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

The range of possible mixtures is high and may include a diversity in grass species, nitrogen fixing leguminous crops, and other herbs. Consequently, the effects as outlined above may differ. Take into account the expected feed value (protein, energy) and palatability of the selected mixture in the feeding regime for the cows. Be aware that the proportion of herbs decreases over time and options for chemical weed control are restricted.

Key considerations include selecting complementary species (e.g. legumes, herbs, grasses) suited to local soils and climate, managing grazing intensity to maintain species balance, ensuring seasonal forage availability, and monitoring nutrient cycling to optimize productivity, persistence, and environmental benefits in herb-rich European dairy grasslands.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

The transfer of nitrogen from clover to grass is well researched. The composition of mixtures may be extended, e.g. with species adapted to drought.

Research on species diversification in European dairy grasslands explores how including legumes and deep-rooted herbs (e.g. chicory, plantain) improves forage yield, drought resilience, nitrogen use efficiency, pollinator support, and reduces reliance on synthetic fertilizers.

For further reading material on this and other practices, visit:

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Date: March 2025

Authors: ???

Contact: https://soilcrates.eu/

Funded by the European Union

10. Compost

Basic description of the practice

Compost is a simple way to increase soil health, e.g., organic matter, soil microbial diversity, soil fertility. Organic matter is essential for most soil functions such as soil structure, water purification and release, carbon sequestration and regulation (release), biodiversity and nutrient cycling. It is generally considered a best practice of fertilizing at the level of crop rotation at the same time improving soil health.

Implementation

Stepwise plan:
1. Choose the time to apply compost, i.e., in spring or in autumn, taking into account the rotation, e.g., not before a N-demanding crop such as potato.
2. Select an appropriate compost quality, preferably with label and analysis.
3. Assess the amount to apply on the organic matter content of the compost and in the soil.
4. Adapt mineral fertilisation to the nutrients applied with compost and their mineralisation.
5. Use a manure-spreader for topsoil application.

Types of compost:

1. Green Waste Compost
• Source: Plant material (e.g., grass clippings, leaves, hedge trimmings). • Use: Soil amendment to improve structure and organic matter; generally low in nutrients.
2. Manure-Based Compost
• Source: Animal manures (e.g., cow, horse, poultry) often mixed with straw or bedding.
• Use: Rich in nutrients, especially nitrogen and phosphorus; excellent for fertility building.
3. Municipal Solid Waste (MSW) Compost
• Source: Organic portion of household waste (post-sorting). • Use: Used in non-food cropping or with strict quality control; risk of contamination with plastics or heavy metals.
4. Food Waste Compost
• Source: Pre- or post-consumer food waste. • Use: Nutrient-rich; increasingly used in circular agriculture; may require hygienization.
5. Vermicompost (Worm Compost)
• Source: Organic matter processed by earthworms. • Use: High in microbial activity and plant-available nutrients; often used in horticulture or as a biofertilizer.
6. Bio-compost (e.g., Compost with Biochar or Additives)
• Source: Organic waste mixed with biochar, rock dust, or microbial inoculants.
• Use: Enhances soil microbial life, carbon sequestration, and nutrient retention.

Crops for which relevant

Suitable for all crops.

Potential impact

Impact	
On soil physics	+
On soil biology	+
On soil chemistry	+

Application considerations

Consideration	
Application material cost	●
Application labour cost	●
Effort/knowledge needed	1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha. 1- 10 ha. 10 - 50 ha. > 50 ha.

Extent to which well-researched: 4

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
Climate regulation	Nutrient cycling
Water regulationl	Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Be aware that the effect of composts vary with the type and ripening status. Nitrogen immobilisation may occur especially with unripe composts, and/or liginin rich. Be selective in your choice of compost, e.g., avoid pollution (glass, microplastics, PFAS, heavy metals, etc.) considering availability and costs. Also compare with alternatives, e.g., farm-yard manure, digestate, straw.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ✓ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Most research is focused on either the short or the long term effects of composts. Field experiments are needed to develop an advisory system that combines both.

Research focuses on exploring how different compost types (e.g. manure-based, green waste, vermicompost) affect soil microbial activity, nutrient availability, carbon storage, and crop yield, while evaluating contamination risks (e.g. plastics, heavy metals) and their role in sustainable nutrient recycling systems.

For further reading material on this and other practices, visit:

res

Date: April 2025

Authors: Ciska Nienhuis, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

11. Bokashi

Basic description of the practice

Bokashi is a fermentation method for organic residues. Under the anaerobic conditions, the temperature rises to a maximum of 40 degrees, which may kill some weed seeds and pathogens. Bokashi may be considered a source of nutrients and/or soil improver and a way to upgrade local organic (biomass) residues.

Implementation

To produce Bokashi:
1. Collect the raw materials. Anything can be used, from ditch and roadside clippings to leaves and crop residues.
2. Mix the source material with lime, then moisten with a solution of effective micro-organisms, then solidify and cover with plastic.
3. After about eight to ten weeks of fermentation, the product is 'ripe' and the silage can be reopened. The end-product would have a carbon to nitrogen ratio (15:1 to 25:1) and humidity (40 to 50 per cent).

To apply Bokashi:

4. Have the bokashi analysed for nutrients and organic matter.
5. Choose the right time to apply, i.e., in spring or in autumn, taking into account the rotation.
6. Choose the amount to apply using the nutrient and/or organic matter contents.
7. Adapt mineral fertilisation to the nutrients applied with bokashi and their mineralisation.
8. Use a manure-spreader for topsoil application.

Crops for which relevant

Bokashi is soil improver suited for all crops in the rotation.

Potential impact

On soil physics

0 +

On soil biology

0 +

On soil chemistry

0 +

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

2 3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha. 1- 10 ha. 10 - 50 ha. > 50 ha.

Extent to which well-researched

1 2

Potential impact on ecosystems services

Provisioning/regulating:
- Climate regulation
- Water regulation

Supporting/cultural:
- Nutrient cycling
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Compare with alternatives, e.g., farm-yard manure, digestate, straw. Also pay attention to the national laws and regulations for the production and/or use of Bokashi.

Effective bokashi use in European agriculture requires selecting balanced organic materials (e.g. food waste, manure), fermenting under airtight, anaerobic conditions with microbial inoculants (EM or lactobacillus), allowing proper post-fermentation maturation, and timing field application to avoid nitrogen immobilization, optimize microbial benefits, and comply with organic or environmental regulations.

Additional considerations:
- Cooler climate? Extend fermentation period (typically 2–4 weeks); insulate bokashi bins or store in a frost-free area.
- Manure management regulations? Bokashi may help reduce ammonia and methane losses—align with nitrate directive and CAP eco-scheme rules.
- Organic farming systems? Bokashi is permitted under EU organic standards if materials are certified organic or untreated.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ✓ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

It is not known whether diseases and weeds are killed sufficiently during fermentation. Observations are reported that bokashi incorporated in clay soils may lead to oxygen depletion, and this would need more research, also as to how to prevent this.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: ???

Contact: https://soilcrates.eu/

Funded by the European Union

12. Biochar

Basic description of the practice

Biochar is produced by pyrolysis of organic biomass at high temperatures with little oxygen. It is considered a soil amendment of which the decay is retarded due to the pyrolysis process. Biochar can be made of different organic materials such as straw, wood and several other organic materials. Applying biochar will contribute to carbon sequestration since its decay is retarded for decades and it may stay in soils for centuries.

Implementation

1. Define Objectives and Assess Site Conditions
•Clarify goals: carbon sequestration, soil improvement, nutrient retention, GHG mitigation, etc. • Assess soil needs: pH, texture, organic matter, nutrient status. • Consider crop type: Some crops (e.g. maize, vegetables) respond more positively to biochar than others.
2. Choose the Right Biochar Type
•Select feedstock: Wood-based for structure; manure-based for nutrients. • Ensure quality compliance with EBC (European Biochar Certificate) standards (e.g. low PAHs, metals).
3. Determine Application Rate and Method
•Application rate: Commonly 2–20 tons/ha depending on soil and crop. • Blending: Pre-mix biochar with compost, manure, or digestate to improve nutrient availability and microbial colonization. • Application method: Incorporate into soil (e.g. shallow tilling) or band-place for row crops.
4. Monitor Soil and Crop Response
•Track changes in:
oSoil pH and nutrient levels; o Water retention; o Crop yield and quality
•Adjust application rate or blend based on observed outcomes and lab results.
5. Integrate with Farm Management and Policy Tools
•Align with CAP eco-schemes or carbon farming credits. • Combine with organic or regenerative practices (e.g. reduced tillage, compost use). • Keep records for certification or subsidy schemes.
6. Evaluate Long-Term Effects
•Monitor carbon persistence in soil (biochar stability = centuries). • Evaluate cumulative impacts on soil biology, structure, and emissions.
•Adapt based on new research and multi-year results.

Crops for which relevant

Application of biochar should be considered as a soil adement that reamain present on the long term.

Potential impact

On soil physics	On soil biology	On soil chemistry
0	0	0

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:
- Climate regulation
- Water regulation
- Erosion control

Supporting/cultural:
- Nutrient cycling
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

A large meta-analysis showed that biochar application leads to improved water use efficiency, microbial activity, soil organic carbon and greenhouse gas emissions. However, the effects of biochar can vary greatly depending on the quality of the organic material used for production and if the pyrolysis was incomplete, this may lead to biochar with contaminants or high salinity etc.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ✓ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ✓ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Biochar has a lot of attention because of its potence for carbon sequestration due to its retarded decay.

Research in Europe investigates how biochar from various feedstocks (e.g. wood, manure) affects soil pH, nutrient retention, microbial activity, and greenhouse gas emissions. Current frontiers include tailoring biochar properties to specific soils and crops, co-applying it with composts or digestates, and integrating it into carbon farming schemes.

For further reading material on this and other practices, visit:

Date: March 2025

Authors: Lena Madden, Hina Imtiaz, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

13. Seaweed products

Basic description of the practice

Seaweed (fresh and/or dried) can be used directly as mulch, composted, or processed into liquid fertilizer or/and biostiumulant. There are different products from different species and types seaweed which leads to different effects. Depending on the type, there are positive effects such as moisture retention, pest suppression, and boosting plants' resistance to disease. In coastal areas of Ireland, Spain, Italy, and the Netherlands, farmers have historically collected and applied seaweed to enhance sandy or degraded soils, making its use a long-standing agricultural practice.

Implementation

1. Define Agronomic Objectives
Identify specific goals such as enhancing crop resilience to abiotic stress (e.g., drought, salinity), improving nutrient uptake efficiency, or boosting yield and quality.
Assess the suitability of seaweed biostimulants for the target crops and farming systems.
2. Select Appropriate Seaweed Species and Products
Choose seaweed species known for beneficial properties, such as Ascophyllum nodosum or Laminaria digitata, which are rich in bioactive compounds like alginates and phytohormones.
Opt for products that comply with the EU Fertilising Products Regulation (EU) 2019/1009, ensuring they meet safety and quality standards.
3. Determine Application Method and Timing
Application Methods:
  - Foliar Spray: Apply diluted seaweed extract directly to plant leaves for rapid absorption.
  - Soil Drench: Incorporate into irrigation systems to enhance root uptake.
  - Seed Treatment: Soak seeds in seaweed extract to promote germination and early growth.

 Timing:
  - Apply during key growth stages or periods of stress (e.g., transplanting, flowering) to maximize benefits.

4. Integrate with Existing Nutrient Management Plans
5. Monitor and Evaluate Outcomes
6. Ensure Regulatory Compliance and Sustainability

Crops for which relevant

Application of seaweed is suitable for various crops.

Potential impact

On soil physics

0 +

On soil biology

0 +

On soil chemistry

0

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Climate regulation	◍ Nutrient cycling
◍ Water regulation	◍ Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

In the nearby future the use of nitrogen and agro pesticides will decrease. The use of seaweed products may be an additive to keep plants healthy. Unprocesed seaweed directly from the see may not be a usable fertilizer due to high salt concentration.
When applying seaweed in European agriculture, success depends on selecting the right species—typically brown seaweeds like Ascophyllum nodosum or Laminaria digitata, which are rich in bioactive compounds such as alginates, cytokinins, and betaines. These compounds can improve plant stress tolerance, root development, and nutrient uptake.
Key considerations include:
- Source and Sustainability: Use sustainably harvested or farmed seaweed to avoid ecological harm, especially in coastal areas subject to EU marine protection regulations.
- Processing Form: Seaweed is applied as extracts, powders, or mulches; liquid extracts are common for foliar sprays or fertigation.
- Application Timing: Often used at early growth stages or during stress periods (e.g. drought, cold shock) for best results.
- Salt Management: Raw or minimally processed seaweed may contain high sodium or chloride levels—important to manage, especially on salt-sensitive soils.
- Regulatory and Organic Compliance: Seaweed products are generally allowed in EU organic farming, but must be certified and traceable.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

There is a lot of reseach about applying seaweed (-based products). However, significant gaps remain regarding long-term effects, economic feasibility, optimal application rates, species-specific benefits, and broader ecological impacts. It is also not known what the mode of action of seaweed on plants.

For further reading material on this and other practices, visit:

icture

Date: April 2025

Authors: Lena Madden, Hina Imtiaz, Ciska Nienhuis

Contact: https://soilcrates.eu/

Funded by the European Union

14. Digestate

Basic description of the practice

Digestate is a by-product of anaerobic digestion—a natural process in which microorganisms break down organic materials such as manure, crop residues, or grass to produce biogas. This process produces a liquid and a solid fraction of digestate which the liquid fraction is the most available. It serves as a nutrient-rich fertilizer, containing nitrogen (N), phosphorus (P), and potassium (K), with a higher proportion of mineral nutrients compared to the original organic material. Digestate also has significantly reduced levels of pathogens and weed seeds relative to the original material. Like other organic fertilizers, it can contribute to enhanced soil structure, improve moisture retention, and support microbial activity. Studies have shown that digestate can improve soil structure and fertility, leading to increased crop yields. Additionally, combining digestate with other organic amendments, such as compost, can enhance soil microbial diversity and activity, contributing to long-term soil health .

Implementation

1. Define Agronomic Objectives and Assess Site Conditions: Identify goals, do a soil analysis, determine crop requirements.
2. Select Appropriate Digestate Type and Quality
   Digestate Forms:
      Liquid Digestate: High in readily available nutrients; suitable for immediate nutrient supply.
      Solid Digestate: Rich in organic matter; beneficial for improving soil structure and long-term fertility.
   Quality Assurance: Ensure digestate meets quality standards
3. Develop a Nutrient Management Plan
4. Ensure Regulatory Compliance
5. Implement Application Best Practices
   Application Methods:
      Injection: Reduces ammonia emissions and odor; places nutrients closer to plant roots.
      Surface Spreading: Simpler but may lead to higher nutrient losses; incorporation into soil is recommended.
   Equipment Calibration: Ensure spreading equipment is properly calibrated for uniform application.
   Weather Considerations: Avoid application during heavy rainfall or on frozen ground to minimize runoff risks.
6. Monitor and Evaluate Outcomes

Crops for which relevant

Application of digestate is suitable for various crops.

Potential impact

On soil physics

0 +

On soil biology

0 +

On soil chemistry

0 +

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha. 1- 10 ha. 10 - 50 ha. > 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:
- Climate regulation
- Water regulation

Supporting/cultural:
- Nutrient cycling
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Digestate is a by-product of biogas production which is an alternative to fossil fuels. Futhermore, it is a useful alternative for mineral fertilizers which does not contribute to soil organic matter and cost a lot of energy to produce.

However, the soil benefits of digestate may not be more than those of organic fertilizers in general as the organic matter concentration may be lower. n comparison with mineral fertilizer there are soil health benefits, just as for other organic fertilizers. For soil health the initial product before producing biogas with a higher fraction of organic matter would be preferable.

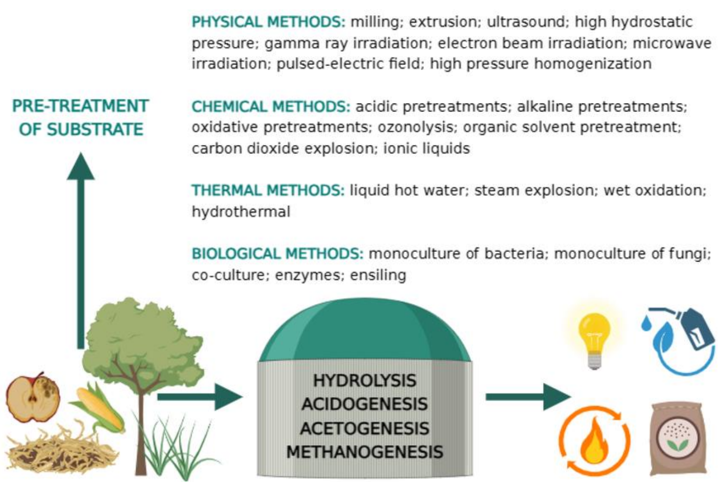
Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ✓ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ✓ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on digestate application in European agriculture focuses on optimizing its use as a renewable fertilizer to enhance soil health, crop productivity, and environmental sustainability. Key areas include understanding its impact on soil microbial communities, nutrient cycling, and carbon sequestration, as well as developing best practices for its integration into farming systems.
Research also highlights potential risks associated with digestate use, such as nutrient leaching and greenhouse gas emissions, emphasizing the need for proper management practices. Ongoing studies aim to refine application methods and rates to maximize benefits while minimizing environmental impacts.

For further reading material on this and other practices, visit:



Date: April 2025

Authors: Barra Caracciolo A, Grenni P, Narciso A, De Carolis C, Ancona V, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

15. Applying clay minerals

Basic description of the practice

This about applying vermiculite, lava split, bentonite, clinoptilolite, and other clay minerals/rocky material.
Materials like vermiculite, lava split, bentonite, and clinoptilolite (a type of zeolite) are applied to improve soil structure, water retention, and nutrient availability. Vermiculite and bentonite enhance water-holding capacity, especially in sandy soils. Clinoptilolite helps with ammonium and potassium exchange, reducing nutrient leaching. Lava split improves aeration and drainage in heavy soils. These materials are often used in horticulture, organic farming, or degraded soils and are either mixed into topsoil or applied in planting zones. Their use supports sustainable, low-input systems, particularly in dry regions or where soil health restoration is a priority.

By following a structured approach, farmers can utilize clay minerals and rock-based amendments to enhance soil health and crop productivity:

Implementation

1. Assess Soil and Crop Needs
   Soil Testing: Evaluate soil texture, pH, nutrient levels, and water-holding capacity.
   Identify Objectives: Determine goals such as improving drainage, increasing water retention, or enhancing nutrient exchange.
2. Select Appropriate Amendment
   Vermiculite: Ideal for increasing water retention in sandy soils.
   Lava Split: Enhances aeration and drainage in heavy clay soils.
   Bentonite: Improves water-holding capacity and cation exchange in sandy soils.
   Clinoptilolite (Zeolite): Aids in nutrient retention and slow-release fertilization.
   Other Clay Minerals: Choose based on specific soil deficiencies and crop requirements.
3. Determine Application Rates and Methods
   Dosage: Follow manufacturer recommendations, typically ranging from 1 to 5 tons per hectare, depending on soil conditions.
   Application Method: Incorporate amendments into the topsoil using tillage equipment to ensure even distribution.
4. Integrate with Existing Soil Management Practices
5. Monitor and Evaluate Outcomes: soil testing; observe crop performance, adjust practices
6. Ensure Compliance with Regulations

Crops for which relevant

Grasslands, arable crops, horticulture.

Potential impact

On soil physics: +

On soil biology: 0

On soil chemistry: +

Application considerations

Application material cost: ● (red)

Application labour cost: ● (orange)

Effort/knowledge needed: 1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application: < 1ha. 1- 10 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:
- Climate regulation
- Water regulation

Supporting/cultural:
- Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

Applying these materials in European agriculture may help improve soil functionality, but their success depends on careful planning and site-specific application.

Material-Specific Functions

Vermiculite improves water retention and cation exchange capacity, making it ideal for light, sandy soils and horticultural systems.

Lava split enhances soil aeration and drainage, particularly helpful in compacted or heavy clay soils.

Bentonite, a swelling clay, improves water-holding and is especially useful in dry or drought-prone regions.

Clinoptilolite (a zeolite) is known for its high cation-exchange capacity and ability to buffer and slowly release nutrients like ammonium and potassium, reducing leaching losses.

Key Considerations

Soil Testing: Essential before application to determine deficiencies (e.g. poor structure, low nutrient retention, drought-prone).

Application Rates and Methods

Integration with Organic Matter

Avoid over-application to prevent mineral imbalances or soil compaction (especially with fine clays like bentonite).

Potential soil health benefit

✓	Addressing soil compaction
☐	Increasing soil organic matter
✓	Addressing soil nutrient distortions
☐	Addressing erosion and run-off
☐	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
☐	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
☐	Increasing soil cover

Research

Some research has been done on mineral soils, and effects on yield measured. Results are inconclusive at best.

European research on vermiculite, bentonite, clinoptilolite, and similar amendments explores their effects on drought resilience, nutrient retention, and soil microbiota. Key research gaps include long-term field performance, optimal application rates across soil types, interactions with organic amendments, and scalability in regenerative and carbon-farming frameworks under diverse European conditions.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

17. Wood ash

Basic description of the practice

Wood ash, which is rich in potassium, calcium, and trace minerals, serves as a valuable soil amendment. It aids in increasing the soil pH, which makes it advantageous for acidic soils. Ash enhances soil structure, boosts microbial activity, and supplies vital nutrients for plant growth. Farmers in Ireland, Spain, and various other European nations have traditionally utilized wood ash to enhance soil quality, especially in areas with acidic soil. It can be used directly on the soil, composted, or combined with organic matter. However, its use should be regulated to avoid excessive alkalinity and nutrient imbalances. Stay clear of ash from treated or painted wood, as it could contain harmful substances.
It is most suitable for crops that require potassium and alkaline conditions.

Implementation

Ash must be in moderate quantity, as overapplication can increase soil pH excessively. Traditionally in Ireland, farmers combined ash with compost or manure to balance nutrient availability. Ways of application include:

1. Direct Soil Application (Surface Spreading)
   How: Wood ash is spread using lime spreaders or manually across fields.
   When: Typically applied in autumn or early spring before sowing.
   Note: Must be incorporated shortly after application to reduce wind drift and nutrient loss.
2. Soil Incorporation (Ploughing or Tillage)
   How: Ash is mixed into the topsoil using ploughs, harrows, or rotary tillers.
   Why: Improves pH balance more effectively and minimizes surface loss of nutrients.
3. Blended with Compost or Manure
   How: Ash is mixed with organic amendments before application.
   Benefits: Balances pH, buffers acidity in compost, and reduces nutrient leaching.
4. Pelletized or Granulated Form
5. Liming Substitute
   How: Replaces or supplements traditional liming materials (e.g., calcium carbonate).

Crops for which relevant

Root vegetables (such as carrots and potatoes), brassicas (like cabbage and kale), fruit trees, berry plants, legumes, and vegetables that tolerate alkaline conditions, such as asparagus and spinach.

Potential impact

On soil physics	On soil biology	On soil chemistry
o	+	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
● (green)	● (blue)	2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
☐	Sandy	✓	Mediterranean
☐	Loamy	☐	Continental

Suitable scale of application: 1- 10 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Water regulation	◍ Nutrient cycling ◍ Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Wood ash is most appropriate for acidic soils and should be used sparingly in alkaline conditions. Irish farmers used to apply ash to peat-rich soils in order to enhance fertility and lower acidity. To avoid nutrient imbalances, mix ash with compost or organic materials. It offers beneficial minerals such as magnesium and calcium; however, it does not contain nitrogen. Therefore, the use of extra organic fertilizers might be necessary. To avoid nutrient leaching prior to application, ash should be kept dry. Ash application can be advantageous, but it should adhere to local environmental guidelines to prevent contamination risks.

To avert the possible buildup of heavy metals in soils, several European nations (Ireland included) impose regulations on the overuse of wood ash. Ensuring effective and sustainable agricultural use of soil pH involves proper testing before application.

For ≥ 50 ha. the collecting, transporting of wood ash become more difficult and expensive.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Despite its potential, several critical research gaps remain:

Standardization of Application Rates
– Effects vary widely depending on ash composition, soil type, and crop. There's a lack of unified agronomic guidelines across Europe.

Long-Term Impacts on Soil Health
– Limited studies on cumulative effects, such as nutrient imbalances, salt buildup, or shifts in soil microbial communities.

Heavy Metal Accumulation and Risk Assessment
– Some ashes may contain trace elements (e.g., Cd, Pb, Zn); more data is needed on leaching risks and thresholds for safe use.

Interaction with Organic Amendments and Microbiota
– Synergistic or antagonistic effects when used with composts, manures, or biochar are not fully understood.

For further reading material on this and other practices, visit:

Pic

Date: April 2025

Authors: Lena Madden, Hina Imtiaz, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

18. Gypsum

Basic description of the practice

Too low calcium occupation on the clay humus complex and/ or too high sodium occupation can be the cause of structural problems, especially on clay soils. These types of problems can occur on plots with, for example, saline seepage. A consequence of this is that the crumb ability of the soil and its soil structure is insufficient. It may result in more clods ending up on the harvester, resulting in extra tare. Adding gypsum can increase calcium availability and contribute to a better structure and, harvestability. When the calcium replaces the sodium, soil structure may improve.

Another reason to apply gypsum on (acidic) sandy soil types is to increase the calcium availability in soil.

Implementation

On clay soils with problems with soil structure, an application (500 – 5000 kg of product / ha) can result in an improvement of soil structure. With potatoes, it is common to apply the gypsum after planting, before the furrow has been build up. In this way, the gypsum is applied to the top layer of the soil, which is expected to result in better harvestability (Bussink 2009) .
On sandy soils where is applied to improve the availability of calcium, usual a few hundred kilograms per hectare are given.
The is a granule of gypsum on the market. This product is easy to apply with the equipment for mineral fertilizers. There is a wet powder available that has to be applied with special equipment (a spreader and excavator). The last option is in particular interesting when lager amounts have to be applied because the price per ton gypsum is cheaper.

Crops for which relevant

It is interesting for fields where structural problems occur caused by too low a calcium occupation on the CEC or when there is too much sodium on the CEC. Gypsum is especially interesting for potatoes on soils with structure problems because it increases the harvestability of potatoes and may result in less tare.

Potential impact

On soil physics	On soil biology	On soil chemistry
+	0	0

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	0

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
☐	Loamy	✓	Continental

Suitable scale of application

< 1ha. 1- 10 ha. 10 - 50 ha. > 50 ha.

Extent to which well-researched

3

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Pollution control	◍ Nutrient recycling

For information on relevant legislation and regulations, visit:

Further considerations

The use of gypsum can contribute to a better soil structure and crumbability. But on fields with larger problems (e.g. heavy clay soils with bad structure or structure problems caused by saline seepage), the expected effect will be disappointing.

Key considerations for applying gypsum in European agriculture include ensuring soil suitability (e.g. sodic or compacted soils), using appropriate rates based on soil tests, and avoiding over-application in low-pH soils. Gypsum improves calcium levels, reduces compaction, and enhances soil structure, but must be managed carefully to prevent nutrient imbalances or runoff risks.

Potential soil health benefit

- ✓ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ✓ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

In European agriculture, research on gypsum focuses on its role in improving soil structure, reducing sodicity, enhancing calcium availability, and mitigating phosphorus runoff into waterways. Key frontiers include optimizing application for loamy and compacted soils, assessing the long-term effects on microbial activity and nutrient dynamics, and evaluating safe, sustainable use of industrial by-products like phosphogypsum.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Johan Specken, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

19. Microbial biostimulants

Basic description of the practice

Microbial biostimulants may enhance soil health by introducing beneficial microorganisms that may improve nutrient availability, root growth, and soil structure, depending on what kind of biostimulant is used. These biostimulants can include compost tea, extracelular polymers, fungi (e.g., Mycorrhizae), and other microbial consortia. Application requires selecting the right product based on soil type and crop needs. It is commonly applied as seed coatings, root drenches, or foliar sprays, often alongside organic matter or fertilizers to enhance effectiveness. Proper soil moisture and aeration are crucial. Microbial biostimulants improve soil health by increasing nutrient cycling, enhancing plant-microbe interactions, and suppressing pathogens. They are expected to stimulate root exudates, fostering microbial diversity and improving soil aggregation. Key factors for success include product viability, correct dosage, and environmental conditions.

Implementation

1. Chose the biostimulant you want te use based on the specific challenges on your farm.
2. Use proper application methods depending on the type which may vary (such as coating seed, dipping roots, mixing irrigation water).
3. Avoid compacted, saline, or waterlogged soils.

Crops for which relevant

Microbial product can be used in all kind of crops but are specifically interesting for organic system and cropping systems with low input.

Potential impact

On soil physics

0 +

On soil biology

0 +

On soil chemistry

0 +

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

1

Potential impact on ecosystems services

Provisioning/regulating:

- Biomass provision
- Pest and disease regulation

Supporting/cultural:

- Nutrient cycling
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Many suppliers offer microbial biostimulants, but their effectiveness is not always scientifically proven. It is important to critically assess whether a product delivers the desired results on your farm. Concerns involve variable field efficacy, interactions with existing soil microbiota, regulatory uncertainty under EU law, and the need for integration with broader nutrient and soil health strategies for consistent, beneficial outcomes.

Effective use of microbial biostimulants in European agriculture requires selecting well-adapted strains (e.g. Rhizobium, Azospirillum, Trichoderma) tailored to specific crops and soil conditions. Application must ensure microbial viability, often requiring protection from UV and desiccation. Farmers should consider soil microbial competition, timing with crop phenology, and compatibility with fertilizers or pesticides.

Potential soil health benefit

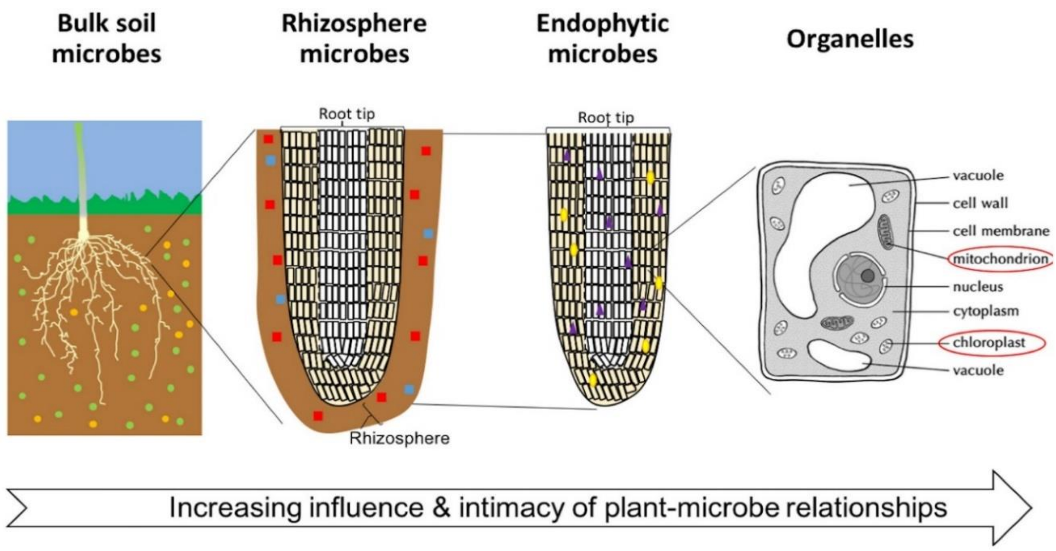
- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ✓ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on biostimulants has focused on their impact on nutrient uptake, stress tolerance, and crop health and yields.

However, more research is needed explaining modes of action,and regarding long-term effects, specific microbial biostimulants and optimal application methods for diverse crops and soil types. Knowledge gaps remain in understanding the costs, and the consistency of results across varying environmental conditions.

For further reading material on this and other practices, visit:



Date: April 2025

Authors: Jesús Rodrigo-Comino and Lucía Moreno-Cuenca, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

20. Humic products

Basic description of the practice

Humic acid and humate products are formed during the decomposition of organic matter. It are molecules that are negatively charged that are extracted from organic deposits or organic matter. Humic acid and humate products are thought to improve soil health and crop growth by improving nutrient availability through nutrient chelating, improving root growth, water retention and microbial activity. Application methods can vary, including soil spraying, foliar spraying and seed treatment.

Implementation

Stepwise Plan for Applying Humic Acid and Humate Products in European Agriculture:

1. Assess Soil and Crop Needs
2. Select Appropriate Product
   Source: Choose products derived from leonardite or other approved sources.
   Formulation: Decide between liquid, granular, or soluble powder forms based on application method and crop type.
   Certification: Ensure compliance with EU regulations, especially for organic farming.
3. Determine Application Method and Timing
   Soil Application: Incorporate into the soil during pre-planting or early growth stages to improve soil structure and nutrient availability.
   Foliar Application: Apply during active growth phases to enhance nutrient uptake and stress resistance.
   Seed Treatment: Coat seeds to promote germination and early root development.
4. Integrate with Fertilization Practices
5. Monitor and Evaluate

Crops for which relevant

Application is suitable for various crops.

Potential impact

On soil physics

0

On soil biology

+

On soil chemistry

+

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Biomass provision ◍ Climate regulation ◍ Pollution control	◍ Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

The evidence of effectness under field conditions is poor. Many suppliers offer humic substances, but their effectiveness is not always scientifically proven. It's important to critically assess whether a product delivers the desired results on your farm.

Key considerations for applying humic acids and humate products in European agriculture include matching product type (e.g. potassium humate) to soil and crop needs, ensuring product quality and concentration, and applying at the right growth stage. Effects depend on soil pH, texture, and organic matter. Concerns include inconsistent field results, lack of standardized efficacy data, and unclear mechanisms of action under varying European soil-climate conditions.

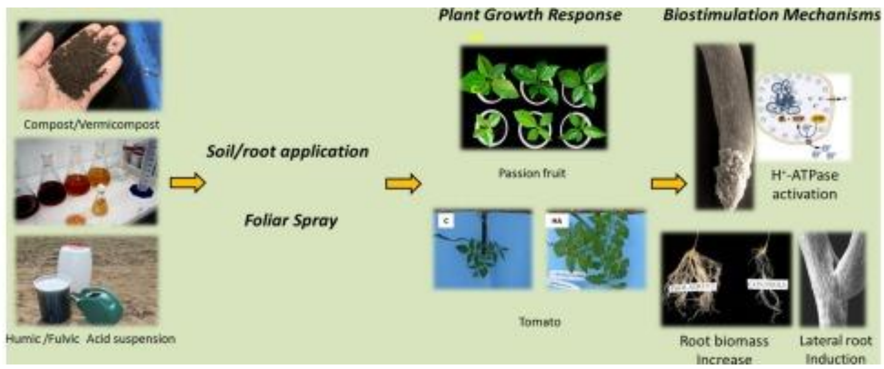
Potential soil health benefit

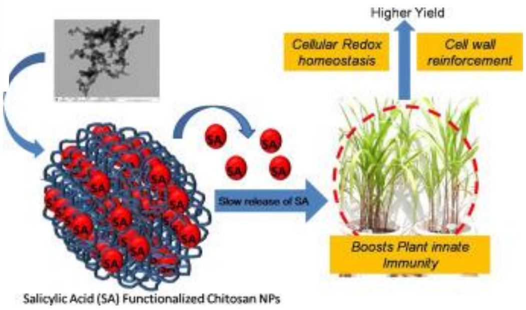
- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

There exist a few reviewing studies in which the effect of humic substances for their effectness has been examined.
Four research gaps have been identified.
1. More field research is needed to confirm the plant growth benefits of humic products under varied conditions.
2. Scientific acceptance is limited by unclear mechanisms, especially in real-world settings.
3. The reliability of the products needs to be improved by standard quality controls.
4. Claims about improved soil health lack long-term field evidence.

For further reading material on this and other practices, visit:





Date: April 2025
Authors: Jesús Rodrigo Comino and Lucía Moreno Cuenca, Seerp Wigboldus
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Funded by the European Union

21. Calcium limestone and other minerals

Basic description of the practice

Applying calcium limestone (calcitic lime), gypsum, and other minerals provides essential nutrients (Ca, Mg, K, Na) and amends soil, optimizing pH and nutrient availability. Previous soil analyses are crucial to determine the correct mineral and application rate. Application involves even spreading, often followed by incorporation. Calcium limestone raises pH, improving nutrient accessibility and soil structure. Gypsum improves drainage and reduces sodium. Other minerals, like potassium feldspar, provide K, though slowly. The goal is healthier, balanced soil for improved growth and yields. Successful implementation relies on soil testing for amendment type and amount. Finer materials should react faster. Moisture content matters. Incorporation into topsoil is generally recommended. While research supports benefits, practical experience varies. Improved yields may not be immediate. Long-term effects include improved soil health and sustained yields, but repeated applications may be needed. Combining with fertilizers can influence effectiveness. Farmers may observe significant yield improvements after liming acidic fields.

Implementation

Previous soil tests for accurate application rates. Finer materials should react faster. Incorporate organic amendments for best results. Suitable for acidic or sodic soils. Constraints include cost and availability. Challenges include lack of knowledge by applicants; address with education and demonstrations.

Key advice for applying calcium limestone and other mineral amendments (Ca, Mg, K, Na) includes basing applications on detailed soil testing to address specific pH and nutrient imbalances. Lime should be finely ground for better reactivity and applied uniformly, ideally in autumn. Balance is crucial—excessive calcium can reduce magnesium or potassium uptake. Avoid sodium-based amendments unless correcting sodicity. Integrate mineral applications with crop rotations and organic matter inputs to enhance nutrient availability and soil structure over time.

Crops for which relevant

Especially those sensitive to pH imbalances or nutrient deficiencies, including legumes, vegetables, and fruit trees.

Potential impact

On soil physics	On soil biology	On soil chemistry
+	+	++

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
● (red)	● (orange)	3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application: 1- 10 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Biomass provision	◍ Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

Concerns exist regarding optimal application rates for different soil types and crops, and the long-term impacts on soil biology. A trade-off might be improved soil structure but increased labor for application. Constraints include the cost of materials and necessity of previous accurate soil testing, availability in certain regions, and the time required for amendments to take effect. Barriers to farmer adoption include lack of awareness about the benefits, perceived high costs (especially upfront), and uncertainty about return on investment. Cost-benefit analyses are crucial, considering both short-term application expenses and long-term yield improvements and reduced fertilizer needs.

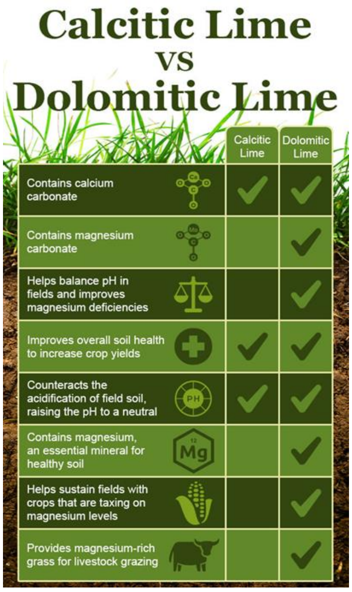
Potential soil health benefit

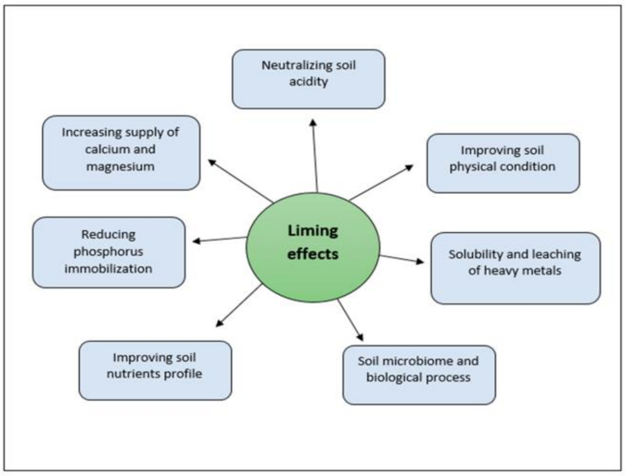
- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on mineral amendments like clays, lime and gypsum is extensive, focusing on their effects on soil chemistry, nutrient availability, and crop yields. However, long-term impacts on soil microbial communities and optimal application strategies for diverse cropping systems remain under-researched. Knowledge gaps exist regarding the precise mechanisms of nutrient release and the interaction of these amendments with other soil management practices.

For further reading material on this and other practices, visit:





Date: March 2025

Authors: Jesús Rodrigo Comino and Lucía Moreno Cuenca

Contact: https://soilcrates.eu/

Funded by the European Union

22. Water erosion control measures

Basic description of the practice

Soil erosion control measures, such as vegetation cover, mulches, or terraces, aim to minimize soil loss from wind and water. Establishing vegetation involves planting appropriate species and maintaining healthy growth. Mulching involves applying organic or inorganic materials to the soil surface. Terraces or stone walls are constructed earth embankments or manual barriers that break up hillslope length and stop runoff. Implementation involves land preparation, material application (mulch), or earthmoving (terraces or stone walls). These methods reduce erosion by intercepting raindrops, reducing surface flow velocity. Vegetation roots bind the soil, while mulches protect the surface and retain moisture. Terraces and stone walls can slow water flow and trap sediment. The expected outcome is reduced soil loss, improved water infiltration, and enhanced soil fertility.

Implementation

Achieve hillslope stability and rainfall storage. Maintain healthy vegetation. Constraints include cost of materials/labor. Challenges include lack of knowledge and perceived short-term yield reductions. Promote demonstrations, highlight long-term benefits, and offer technical/financial assistance to encourage adoption.

Crops for which relevant

No specific crops.

Potential impact

On soil physics: ++

On soil biology: +

On soil chemistry: +

Application considerations

Application material cost: ●

Application labour cost: ●

Effort/knowledge needed: 1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application: 10 - 50 ha.

Extent to which well-researched: 4

Potential impact on ecosystems services

Provisioning/regulating:

- Climate regulation
- Water regulation
- Erosion control
- Pollution control

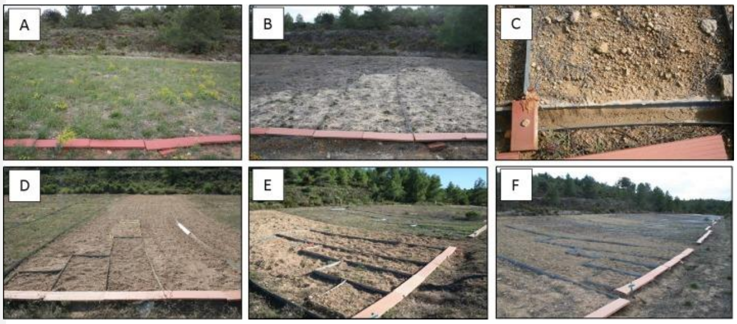
Supporting/cultural:

- Provision of habitat
- Biodiversity
- Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Concerns exist regarding the effectiveness of different erosion control measures for specific soil types, soil management and rainfall patterns. Outstanding questions include the optimal combination of techniques and their long-term impact on soil health. A trade-off might be increased labor for terrace and stone wall construction versus reduced land availability. Constraints include the cost of materials (mulch, seed), labor, and specialized equipment. Barriers to adoption include lack of awareness of effective techniques, perceived high costs, and potential short-term yield reductions. Cost-benefit analyses should consider long-term productivity gains from reduced soil loss and improved water management, offsetting initial expenses.



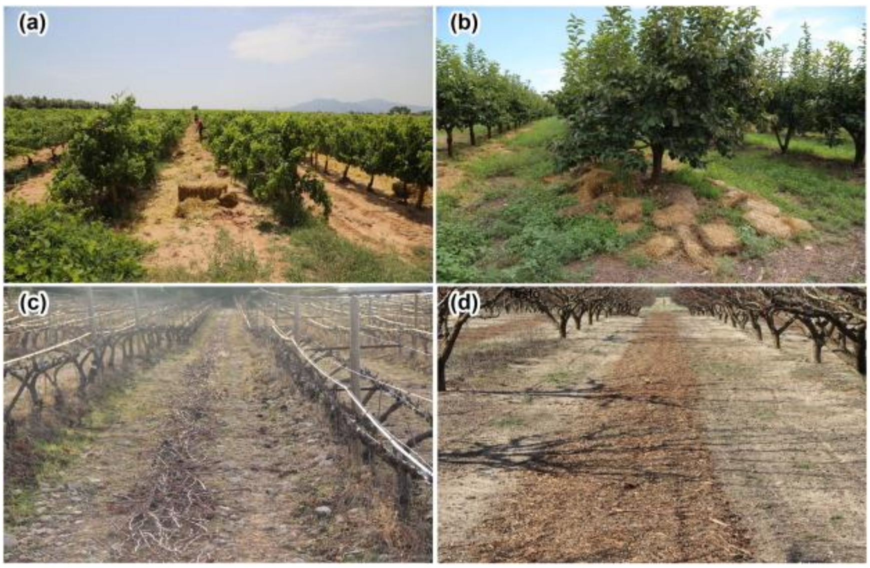
Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ✓ Addressing erosion and run-off
- ✓ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Research on soil erosion control is extensive, focusing on the effectiveness of various techniques (vegetation, mulches, terraces, stone walls) in reducing soil loss. However, research gaps remain regarding long-term impacts on soil properties and the optimal integration of different soil biota status. More research is needed on the economic viability of various approaches and their adaptability to diverse farming systems.

For further reading material on this and other practices, visit:



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Authors: Jesús Rodrigo Comino and Lucía Moreno Cuenca

Contact: https://soilcrates.eu/

Funded by the European Union

23. Wind erosion control by windbreaks

Basic description of the practice

Wind erosion control, primarily through windbreaks or shelterbelts (rows of trees or shrubs), aims to reduce wind speed and protect topsoil and reduce crop damage. The process involves establishing a barrier that intercepts wind, reducing its velocity and turbulence. Windbreaks work by creating a wind shadow, reducing wind speed downwind. This can minimize soil particle detachment and transport which means reduced soil loss. Windbreaks creates a beneficial microclimate.

Implementation

1. Select appropriate tree/shrub species for your climate and soil.
2. Proper spacing and orientation are crucial. Place the windbreak perpendicular to the most common wind direction.
3. Plant the windbreak in the cold season but not during frost.
4. Maintain the windbreak by pruning and weeding if needed.

Crops for which relevant

Windbreaks are particularly relevant for crops vulnerable to wind damage.

Potential impact

On soil physics	On soil biology	On soil chemistry
++	0	0

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	2

	Suitable soil		Suitable climate
✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Income provision ◍ Climate regulation ◍ Erosion control	◍ Provision of habitat ◍ Biodiversity ◍ Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Planting trees may increase yield but reduce crop area, with limits due to setup costs and the space trees take up. Choose your species carefully, they are maybe hosts for diseases. If the windbreak borders a field, take into account competition for water and nutrients with the crop field.

Key considerations for effective windbreaks in European agriculture include selecting species suited to local climates and soils, ensuring proper spacing and orientation to maximize wind reduction without shading crops, and maintaining accessibility for machinery. Concerns include competition for water and nutrients, potential pest habitats, and long-term maintenance. Integration must balance biodiversity benefits with productivity goals and fit within agri-environmental and landscape planning regulations.

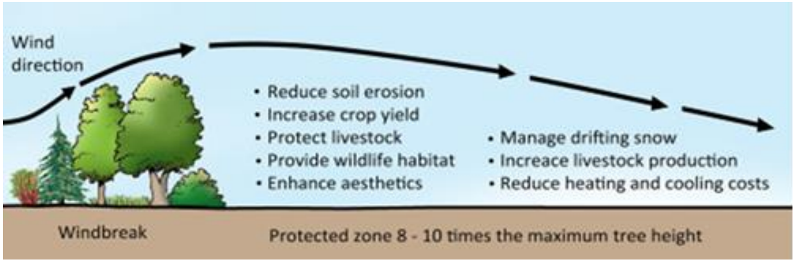
Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ✓ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on windbreaks is substantial, focusing on their effectiveness in reducing wind speed, soil erosion, and improving microclimate. More research is needed on integrating windbreaks into different farming systems and assessing their economic viability. Research on windbreaks in European agriculture highlights benefits such as reduced wind erosion, enhanced microclimates, and increased yields under drought and heat stress. Key research gaps include quantifying long-term impacts on soil health, biodiversity, and carbon sequestration, optimizing design for various landscapes, and integrating windbreaks into mechanized and intensive farming without compromising operational efficiency.

For further reading material on this and other practices, visit:



Date: April 2025

Authors: Jesús Rodrigo Comino, Lucía Moreno Cuenca, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

24. Low pressure tyres

Basic description of the practice

The rational behind this practice is to reduce the pressure on the soil, in the prevention of soil compaction. The application of low-pressure tyres is an agricultural practice aimed at reducing soil compaction by distributing the weight of farm machinery over a larger area. The principle behind this practice is to use tyres with a larger surface area and lower air pressure to decrease the pressure exerted on the soil, thus helping maintain its structure and prevent compaction, which can impair root growth and water infiltration. Enhanced traction from low-pressure tyres leads to reduced slippage, which in turn lowers fuel consumption during field operations. These benefits are particularly relevant for heavy machinery operating on sensitive soils.

Implementation

The available machinery should be appropriate. Implementing low-pressure tyres involves equipping farm machinery, such as tractors and harvesters, with tyres designed to distribute weight more evenly. The practice is especially useful for fields that experience frequent traffic from heavy machinery. Low-pressure tyres should be used on all vehicles that traverse the field, particularly during wetter conditions, when soil is more susceptible to compaction. Timing is crucial, as using low-pressure tyres during or after rainfall can minimize the risk of soil damage. It may require farmers to adjust their equipment setup, which can involve some additional investment in tyres or machinery adaptations. Key advice includes:

1. Adjust tyre pressure to load and field Conditions, always matching tyre pressure to axle load, implement weight, and soil moisture conditions, using a central tyre inflation system (CTIS) if available, to adjust pressure between road and field in real time, and preventing under-inflation on the road as it can cause tyre damage;
2. Train Operators and Monitor Usage (regularly monitor for uneven wear, sidewall stress, or improper ballast, which can undermine the benefits of low-pressure use);
3. Integrate Tyres into Whole-System Planning: Factor tyre choices into broader soil compaction management strategies (e.g. controlled traffic farming, reduced passes), and combine low-pressure tyres with correct axle configurations and weight distribution to maintain soil structure and machinery efficiency.

Crops for which relevant

It is more an issue of relevance for soil type than for crops.

Potential impact

On soil physics

++

On soil biology

0

On soil chemistry

0

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

10 - 50 ha. > 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:

◍ Water regulation

Supporting/cultural:

◍ Provision of habitat
◍ Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Low-pressure tyres are used in European agriculture to reduce soil compaction, especially on heavier or wetter soils common in Northern and Central Europe. Key considerations include adjusting pressure to match field load and soil moisture, using central tyre inflation systems (CTIS) for on-the-go pressure changes, and maintaining correct ballast. Concerns involve higher upfront costs, increased road wear at low pressures, and ensuring operators are trained to optimize traction without sacrificing fuel efficiency or tyre lifespan.

Potential soil health benefit

✓	Addressing soil compaction
☐	Increasing soil organic matter
☐	Addressing soil nutrient distortions
☐	Addressing erosion and run-off
✓	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
☐	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
☐	Increasing soil cover

Research

Research Gaps:

Long-Term Soil Health: While short-term benefits are evident, studies on the long-term impacts of low-pressure tyres on soil structure and health are limited.

Economic Analysis: Comprehensive cost-benefit analyses considering factors like tyre lifespan, maintenance costs, and fuel savings are needed to guide adoption decisions.

Integration with Farming Systems: Research is needed on how to best integrate low-pressure tyre technology with existing farming practices and machinery, especially in diverse European agricultural systems.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

25. Growing deep rooting crops

Basic description of the practice

The practice makes use of the fact that root systems of some crops may improve soils, in top- and subsoil. In the topsoil, improvements may be in terms of both soil structure and nutrient cycling. In the subsoil, improvements may result from adding organic matter at deeper soil layers and improving water and air circulation. Plant roots can help to penetrate compacted soil layers (not rocky material) and in this way improve soil structure with biopores but there is also a side effect of rhizodeposits and the input of organic carbon from decomposing roots. This can increase the abundance and activity of earthworms and micro-organisms, and consequently the number of biopores and stable soil aggregates. Dicotyledonous plants have in general a better ability to penetrate compacted soil than monocotyledonous crops.

Impementation

1. Diagnose soil compaction. Identify fields with compacted or poorly structured subsoil using a spade, penetrometer, or field indicators.
2. Choose suitable deep-rooting crops. Select crops like **lucerne, lupins, chicory, sunflower, sugar beet, or fodder beet and fodder radish** that are known to penetrate compacted layers.
3. Adapt tillage and rotation. Minimize tillage to avoid disturbing root development, and fit the crop into the rotation as a cover or break crop.
4. Give time to grow and monitor effects. Allow roots time to reach deeper layers, and monitor soil structure and biology over multiple seasons.

Important Considerations:
Soil moisture at sowing influences root penetration ability.
These crops work best when combined with reduced traffic, low-compaction tyres, and minimal tillage.

Crops for which relevant

Crops such as carrot, alfalfa, chicory etc., can be used as bio-subsoilers. Other examples of deep rooting crops are grass and some cereals, some cover crops, and also some tree species.

Potential impact

On soil physics	+
On soil biology	0
On soil chemistry	+

Application considerations

Application material cost	●
Application labour cost	●
Effort/knowledge needed	1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

< 1ha. | 1- 10 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Biomass provision ◍ Water regulation ◍ Erosion control	◍ Nutrient cycling

For information on relevant legislation and regulations, visit:

Further considerations

Implementation of biosubsoiling can be challenging. It may not suit all farming systems, especially where changes in tillage or crop rotation significantly affect economic returns. Effects take time—deep roots need a full season or more to reach compacted or dry subsoil layers, and in shallow or rocky soils (e.g. Mediterranean regions), the practice may not be feasible.

Possible risks include re-compaction after mechanical loosening, short- and long-term pH decline, reduced nutrient levels, and potential yield drops. Some cover crops may also increase the risk of soil-borne diseases. However, well-chosen species can offer multiple benefits, so careful selection is essential.

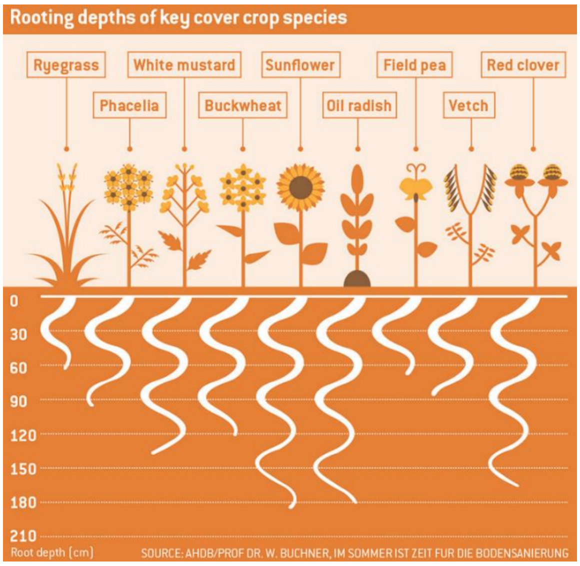
Potential soil health benefit

✓	Addressing soil compaction
✓	Increasing soil organic matter
☐	Addressing soil nutrient distortions
☐	Addressing erosion and run-off
☐	Improving water management
✓	Enhancing soil resilience handling heat, drought, excessive water
☐	Addressing soil salinisation
☐	Addressing soil pollution
☐	Suppressing harmful organisms
☐	Closing farm nutrients cycles
✓	Improving functional soil biodiversity
☐	Improving aboveground biodiversity
☐	Increasing soil cover

Research

In many studies, the effectiveness of the methods for biosubsoiling including deep rooting crops, were limited to crop growth, penetration resistance and dry bulk density. Few experiments could conclusively suggest that deep rooting crops work for biosubsoiling and are profitable for farmers. Nonetheless, there is acceptance among farmers. Knowledge gaps exist for air and water balance.

For further reading material on this and other practices, visit:



Sources:
Top: Cornell College of Agriculture and Life Sciences
Left:
https://stmaaprodfwsite.blob.core.windows.net/assets/sites/1/Cover-crop-rooting-depths-wp-crop.jpg

Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

26. Perennial crops

Basic description of the practice

The purpose of applying perennial crops in the farming system, includes supporting soil protection and nutrient cycling. Perennial crops are often used in crop rotations by organic and livestock farmers.
It is useful to distinguish between field crops and shrubs and trees. Cattle feed crops, e.g. clover, lucerne (alfalfa) and clover-grass mixes are examples of crops that add soil organic matter, and, for the leguminous crops, add nitrogen to the soil. Shrubs and trees may be cultivated in a variety of cropping designs for agro-forestry, e.g. surrounding a grassland, or in strips in arable fields.
Roots of perennial legume, grass and woody crops improve the soil – especially soil structure and density. Large taproots will penetrate deeply into the soil profile and break up near plow pans and subsurface compaction. The fibrous root systems of legumes and grasses will aggregate soil particles and form granular structures in the seedbed.

Implementation

1. Assess Farm Suitability and Objectives: Soil and Climate Compatibility, evaluating your farm's soil type, pH, drainage, and climate conditions to determine suitable perennial crops; Land Use Planning, identifying areas where perennials can be integrated without disrupting existing operations, such as field margins, buffer zones, or less productive lands; Define Goals, whether for erosion control, fodder production, carbon sequestration, or diversification—to guide crop selection and management practices.
2. Select Appropriate Perennial Species
   Crop Selection: Choose species that align with your farm's goals and environmental conditions. Examples include:
   - -Agroforestry Systems: Incorporate trees like chestnuts or hazelnuts with understory crops.
   - -Perennial Grains: Explore options like intermediate wheatgrass (Kernza) for grain production.
   - -Forage Crops: Consider species like alfalfa or perennial ryegrass for livestock feed.

   Biodiversity Considerations: Integrate a mix of species to enhance ecosystem services and reduce pest and disease pressures.
3. Adapt Management Practices
   - -Establishment: Prepare the land appropriately, considering reduced tillage methods to preserve soil structure.
   - -Maintenance: Implement practices such as mulching, pruning, or controlled grazing to manage growth and productivity.
   - -Harvesting: Adjust equipment and schedules to accommodate perennial crop cycles, which may differ from annuals.
4. Monitor and Evaluate Performance
5. Engage with Support Networks

Crops for which relevant

Trees, Shrubs, Grassland, fibre crops such as Miscanthus, Bamboo,

Potential impact

On soil physics	On soil biology	On soil chemistry
+	+	+

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
●	●	3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

< 1ha. 1- 10 ha. 10 - 50 ha.

Extent to which well-researched

2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Food, fuel and fiber provision ◍ Income provision ◍ Climate regulation	◍ Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Integrating perennial crops in European farming systems requires careful species selection—e.g. Kernza, alfalfa, willow, or silvoarable trees—matched to local soil type, rainfall, and farming goals (e.g. fodder, biomass, grain, biodiversity). Key considerations include managing root competition with annuals, adapting equipment for non-annual harvest cycles, and allowing for delayed economic returns. Soil preparation and weed control are critical during establishment. Concerns include policy gaps, limited market access for perennial outputs, and the need for farmer training. Long-term success depends on integrating perennials into rotations, agroforestry, or buffer zones, supported by CAP eco-schemes and advisory networks.

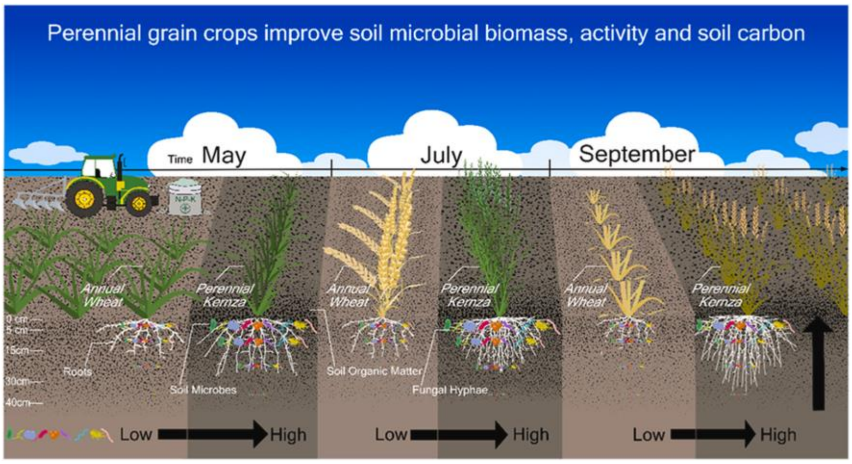
Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Research on perennial crops in European farming systems focuses on their potential to enhance soil health, carbon sequestration, and resilience to climate extremes. Promising areas include perennial grains (e.g. Kernza), silvoarable systems, and deep-rooted forage crops. Key research gaps involve long-term yield stability, ecosystem service quantification, economic viability across diverse regions, and effective integration into mechanized, conventional cropping systems under varying CAP and policy frameworks.

For further reading material on this and other practices, visit:



Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

27. Soil (phyto) remediation

Basic description of the practice

Soil remediation is the broad process of removing, reducing, or neutralizing contaminants in soil to restore its health and functionality. It can be biological, chemical, or physical in nature. Common practices include:

-Bioremediation – Using microbes to break down organic contaminants (e.g. oil spills, pesticides).

-Phytoremediation – A biological method of cleaning up polluted soils, water, or air using plants. Certain plant species are capable of absorbing, breaking down, or stabilizing contaminants such as heavy metals, organic pollutants, or excess nutrients through their roots, stems, or leaves.

- Soil washing – Physically removing contaminants by flushing soil with water or chemical solutions.
- Thermal desorption – Heating soil to vaporize volatile contaminants.
- Soil capping or containment – Covering polluted soil with clean material to prevent exposure or leaching.
- Soil replacement or excavation – Removing contaminated soil and replacing it with clean fill.

Implementation

We focus here on phytoremediation. Depending on what is needed, one of the following practices can be applied:

Phytoextraction – Plants take up contaminants (e.g. lead, cadmium, arsenic) and store them in their biomass, which is later harvested.

Phytostabilization – Plants immobilize contaminants in the soil, preventing their movement into water or air (e.g. with grasses in mine tailings).

Phytodegradation – Plants metabolize and break down organic pollutants (e.g. hydrocarbons, pesticides) in their tissues.

Rhizofiltration – Plant roots absorb pollutants from water, often used in constructed wetlands.

Phytovolatilization – Plants take up pollutants and release them into the air in a less harmful form (used for some heavy metals or selenium).

This may in particular be relevant in the case of:
- Agricultural soils with heavy metal accumulation
- Buffer strips to absorb nutrient runoff

Crops for which relevant

Soil (phyto) remediation focuses on issues in the soil and uses plants to address this.

Potential impact

Potential impact	
On soil physics	++
On soil biology	++
On soil chemistry	++

Application considerations

Application considerations	
Application material cost	●
Application labour cost	●
Effort/knowledge needed	3

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

< 1ha.

Extent to which well-researched

1

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Pollution control	

For information on relevant legislation and regulations, visit:

Further considerations

Applying phytoremediation in European farming systems requires selecting appropriate plant species based on the type and concentration of soil contaminants (e.g. heavy metals, hydrocarbons).

Key considerations include site-specific factors like pH, drainage, and climate, as well as ensuring safe disposal or processing of contaminated biomass. Concerns involve slow remediation rates, potential food chain contamination if edible crops are used, and limited effectiveness on mixed or deeply buried pollutants.

Effective phytoremediation in European farming systems requires selecting hyperaccumulator plants (e.g. Brassica juncea for heavy metals, Populus spp. for organic pollutants) suited to local climate and soil conditions. It's crucial to assess contaminant type (e.g. cadmium, lead, PAHs), depth, and concentration through soil testing. Non-food crops should be prioritized to avoid entering the food chain. Farmers must manage biomass disposal—e.g. incineration for metal-loaded plants—and monitor progress over multiple growing seasons. Concerns include slow remediation rates, seasonal growth limitations, and regulatory gaps in integrating phytoremediation with EU agri-environmental schemes or CAP funding.

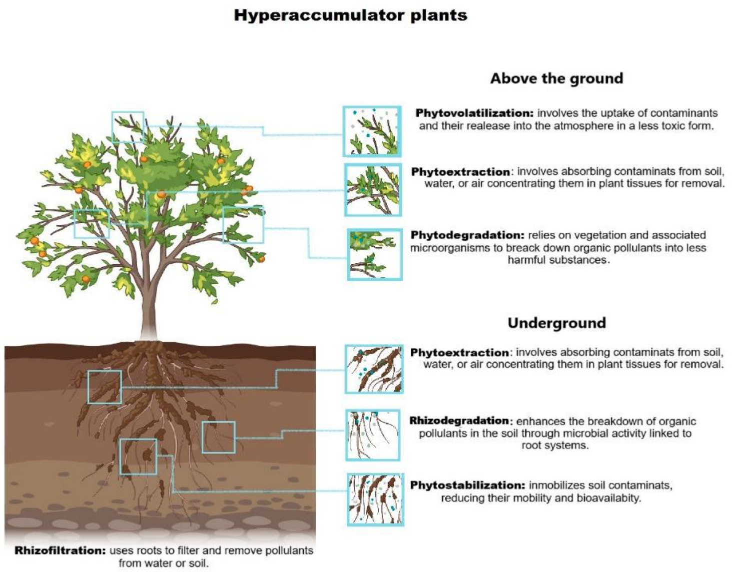
Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ✓ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ✓ Addressing soil salinisation
- ✓ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Phytoremediation from saline soils (sodicity) has been researched extensively after inpoldering of sea clay soils. For river clay soils, the perspectives of phytoremediation to reduce the load of heavy metals has been investigated to some extent but has not been taken up much. Recently, research has been done for inundation as a practice to reduce adverse conditions of soil biology, i.e. nematodes, and weed control.

For further reading material on this and other practices, visit:



Date: April 2025

Authors: Marjoleine Hanegraaf, Seerp Wigboldus

Contact: https://soilcrates.eu/

Funded by the European Union

28. Field inundation

Basic description of the practice

Inundation involves submerging an arable field under water for several months to reduce soil pathogens, pests, and weeds, leading to healthier crops and higher yields This practice is an effective alternative to the chemical ways of soil disinfestation. It is executed in a number of steps: flattering the field and loosening the soil, constructing barriers around the field to keep the water in, closing the drainage pipes and submerging the field to a depth of around 10 cm. The anaerobic conditions causes fermentation of organic matter which produces toxic compounds to soil organisms. This effectively reduces pathogens but may also have temporary negative effects, such as a decline in beneficial soil biota. Depending on the parcel's condition, soil type, and application method, it can impact soil structure and nutrients both positively and negatively.

Implementation

1. Identify soil pathogens present and assess whether inundation is an effective and economically feasible control measure.
2. If possible, grow an early-harvested crop before inundating the field.
3. Enhance inundation effectiveness by incorporating organic matter beforehand.
4. Inundation should be carried out at soil temperatures of at least 16 degrees Celcius and for a period of at least 12 weeks.
5. Fill and drain the field slowly to maximize the effectiveness and to preserve the field.
6. Test soil nutrient levels after inundation.
7. Choose a salt-tolerant crop for the next planting, as inundation may increase soil salinity.
8. After inundation: add organic material (e.g. compost, organic manure) to restore soil life.

Crops for which relevant

Crop rotations with arable crops that provide a high revenue per hectare.

Potential impact

On soil physics

– 0 +

On soil biology

–

On soil chemistry

– 0 +

Application considerations

Application material cost

●

Application labour cost

●

Effort/knowledge needed

2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

1- 10 ha.

Extent to which well-researched

3

Potential impact on ecosystems services

Provisioning/regulating:

◍ Pest and disease regulation

Supporting/cultural:

For information on relevant legislation and regulations, visit:

Further considerations

Inundation is a costly and labor-intensive practice, making it essential to cultivate profitable crops to offset expenses. It is only suitable for flat fields or those that can be easily leveled and requires a reliable water supply. For effective treatment, full inundation must be maintained throughout the entire period. Furthermore, the effectiveness on heavy clay soil may be lower but this is not entirely clear.

Inundation is also applied in countries like the Netherlands to counteract land subsidence.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Considerable research has explored inundation's effectiveness against various pathogens, pests, and diseases, as well as its impact on soil physics, chemistry, and biology. More research on how to restore soil life after inundation is desired. Additionally, information is still lacking on how inundation influences certain pathogens.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Isabella Selin-Norén

Contact: https://soilcrates.eu/

Funded by the European Union

29. Permanent grassland on fields of poor soil quality

Basic description of the practice

This measure may be chosen for fields of poor soil quality that need protection, and for which other agricultural uses are not suitable. Establishing permanent grassland involves maintaining grass cover without ploughing and reseeding. Instead, renovation is done through overseeding into existing vegetation. In animal husbandry, this measure involves that the grasslands are not renewed by ploughing and reseeding, but by seeding in the standing sward. Nor is grass grown in rotation with other crops. The measure enhances soil carbon sequestration significantly, improves soil organic matter, and stabilizes soil structure, which reduces erosion risks and nutrient runoff. Biodiverse grasslands (including herbs) further increase ecosystem resilience and soil biological activity. Permanent grassland preserves soil physical conditions and biological health, reducing the need for fertilizers and minimizing soil disturbances, contributing to long-term soil sustainability and ecosystem services like climate regulation, water retention, and biodiversity enhancement

Implementation

1. Select plot: Choose low-quality soils unsuitable for cropping (e.g., poor fertility, erosion risk).
2. Establish grassland: Sow a permanent grass mix, ideally with herbs, using minimal soil disturbance. This is best done in autumn, so that the young grass may establish itself before winter. Alternatively, reseeding may be done in spring.
3. No ploughing: Maintain cover by overseeding if needed; avoid tillage and heavy traffic.
4. Monitor & manage: Check grass cover yearly, control weeds, and apply organic amendments to support soil health.

Crops for which relevant

Grass.

Potential impact

On soil physics	On soil biology	On soil chemistry
+	0	0

Application considerations

Application material cost	Application labour cost	Effort/knowledge needed
● (green)	● (green)	1

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
✓	Sandy	☐	Mediterranean
✓	Loamy	☐	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched: 2

Potential impact on ecosystems services

Provisioning/regulating:	Supporting/cultural:
◍ Water regulation ◍ Erosion control	◍ Provision of habitat

For information on relevant legislation and regulations, visit:

Further considerations

At loamy and loss soils, known for slight inclination, perennial grassland may help in protection the soil from compaction, giving rise to low water infiltration, and subsequently runoff. Grass yields may decline over time, which may lead to extra costs for buying feed. Also, composition in the grass sward may change unfavourably over time, leading to a lesser value of the grass mixture for feeding. Therefore, this measure is not likely to be applied on a large area per farm the economic benefit is too low.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

This practice is well-researched, especially regarding its effects on carbon sequestration, erosion control, and biodiversity. Long-term studies confirm benefits for soil structure and organic matter. However, knowledge gaps remain on optimal species mixtures for different soil types and climates, and on economic returns in low-input systems. More research is also needed on integration with livestock management and resilience under extreme weather conditions.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Marjoleine Hanegraaf, Ciska Nienhuis

Contact: https://soilcrates.eu/

Funded by the European Union

30. Integrated Crop Management

Basic description of the practice

Integrated Crop Management (ICM) is a systematic approach to applying a diverse set of measures aimed at enhancing the resilience of cropping systems against diseases, pests, and weeds in order to reduce the dependency on pesticides. ICM includes both preventive and direct control strategies, tailored to the crops, soil type, and the farmer's preferences. ICM measures include designing an effective cropping system, such as crop rotation and using field margins, strip cropping, or agroforestry. Selecting resistant and healthy plant varieties is key. A good soil quality and cultivation practices, like planting time, seed rate, and fertilization, also contribute to crop resilience. Monitoring and evaluation help in targeted control, optimizing the choice, timing, and method of control. For direct control, the use of chemical, mechanical, and ecological methods together ensure an efficient approach. Possible benefits for soil quality of ICM depends on the measures implemented and the extent to which pesticide use can be decreased.

Implementation

1. Determine which key pests, diseases, and weeds that are the most problematic on your farm or field.
2. Take time to explore which measures are best suited to your challenges and your farm and crop, as this may require significant knowledge and consideration. In addition, it is possible that there are trade-offs between measures. For example, a measure fitting for weed management might have negative effects on pest management. Choosing (cover) crop varieties with appropriate resistances and/or tolerance is an easy and effective measure to implement.
3. Implement the different measures that you have selected.
4. Monitor the pests, diseases and weeds that are present as prevention should be prioritized over direct control measures. This is especcially true for soil-borne pests and diseases, since they require management for a period of (potentially) many years.

Crops for which relevant

ICM is relevant to all crops affected by pests, diseases and weeds but more is known about it for common (cash) crops.

Potential impact

On soil physics

–

On soil biology

+

On soil chemistry

0

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

2 3

Suitable soil / Suitable climate

✓	Clay	✓	Maritime
✓	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

1- 10 ha. 10 - 50 ha. > 50 ha.

Extent to which well-researched

4

Potential impact on ecosystems services

Provisioning/regulating:

- Pest and disease regulation

Supporting/cultural:

- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

It's important to take the time to assess which practices are most suitable for a specific farm. While the additional labor requirements of integrated crop management (ICM) may be balanced out by reduced pesticide use, the impact may vary significantly depending on the specific measure implemented. To manage expectations; not all pests, diseases, and weeds can effectively be controlled using an ICM strategy, as the necessary knowledge is still evolving. Furthermore, some effects of ICM take time to become apparent, so it's essential to consider both the costs and labor involved.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ✓ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

A significant amount of research on integrated crop management (ICM) exists, but it tends to focus on specific crops and contexts, leading to a variety of practices with differing effectiveness. While the evidence base is strong in certain areas, gaps remain, especially regarding the broader applicability of these practices across diverse farming systems. Long-term studies and research on environmental variability are also lacking. More work is needed to develop universally applicable guidelines and address these knowledge gaps.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Isabella Selin-Norén

Contact: https://soilcrates.eu/

Funded by the European Union

32. Water catchments infrastructure

Basic description of the practice

Water catchment infrastructure includes physical structures like small dams, stone or earthen walls, and terraces, designed to retain, redirect, or slow down water flow, particularly in sloped or erosion-prone landscapes. These systems capture rainwater or runoff, reducing erosion, enhancing infiltration, and improving soil moisture availability. Terracing transforms steep slopes into level steps, reducing hydrological connectivity and runoff velocity. Proper design and regular maintenance are crucial to avoid terrace collapse, wall failures, or waterlogging. When well implemented, such infrastructures support soil conservation, reduce sediment loss, and stabilize terrain. Abandonment or poor construction may lead to landslides, piping, and long-term degradation. This practice is particularly effective in Mediterranean and mountainous regions where water scarcity and slope instability are common, contributing to long-term productivity and ecosystem resilience.

Implementation

1. Select sloped or erosion-prone fields where runoff is high and water retention would benefit crops and soil stability.
2. Tailor terraces, small dams, or stone/earthen walls to the slope, soil type, and rainfall intensity. Consider flow direction and outlet safety.
3. Use appropriate materials and techniques to ensure stability. Involve trained personnel or community support where possible.
4. Prevent waterlogging and structural damage by integrating safe spillways and drainage paths.

Crops for which relevant

This practice is particularly relevant for tree crops (e.g. olives, almonds), vineyards, cereals, and vegetables grown on sloped or erosion-prone terrain.

Potential impact

On soil physics

++

On soil biology

+

On soil chemistry

+

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

2

Suitable soil		Suitable climate	
✓	Clay	☐	Maritime
☐	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application

1- 10 ha. 10 - 50 ha.

Extent to which well-researched

3

Potential impact on ecosystems services

Provisioning/regulating:

- Biomass provision
- Water regulation
- Erosion control

Supporting/cultural:

- Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Water catchment infrastructure, while effective in controlling erosion and managing water flow, requires careful design and regular maintenance to avoid failures like wall collapse or waterlogging. In regions with steep terrain, the infrastructure can be costly to build and maintain. The labor-intensive nature and high initial investment are significant barriers, especially for smallholder farmers. Furthermore, improper construction or abandonment may lead to long-term degradation, including landslides and further erosion. On the positive side, well-maintained systems contribute to long-term soil health and productivity by enhancing water retention and reducing erosion. However, trade-offs include significant upfront costs and the need for continuous upkeep to ensure success.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ✓ Addressing erosion and run-off
- ✓ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Research on water catchment infrastructure, particularly terraces, dams, and walls, is substantial, focusing on their effectiveness in reducing erosion and enhancing water retention. However, gaps remain in understanding the long-term environmental impacts, the optimal design for diverse landscapes, and the economic viability for smallholder farmers. More research is needed on integrating these systems with other agricultural practices and assessing their sustainability under changing climate conditions.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Jesús Rodrigo Comino and Lucía Moreno Cuenca

Contact: https://soilcrates.eu/

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33. Anthropic rills

Basic description of the practice

Anthropic rills are man-made shallow channels designed to manage sufce water flow. This involves the formation of erosion channels caused by human activities, such as wheel tracks and footsteps in cultivated areas, especially in steep slopes. This phenomenon occurs in areas where the soil is poor and has been altered by cultivation practices, intensive training systems, and other human interventions. The anthropic rills or agri-spill ways modify the land morphology, which can reduce surface runoff and improve soil moisture retention if managed correctly. This practice helps control water flow and enhances infiltration in areas prone to erosion. Proper soil tillage and monitoring the formation of rills are crucial to prevent excessive erosion. Soil type, slope, and vegetation cover are key factors to ensure the practice's effectiveness in improving soil health.

Implementation

1. Identify sloped, erosion-prone areas with compacted tracks or embankments where rill formation can help manage runoff.
2. Design shallow, spaced rills along contour lines or natural flow paths, adapted to slope gradient, soil type, and rainfall intensity.
3. Use light equipment or manual tools to create stable, shallow channels without exposing subsoil or increasing erosion risk.
4. Inspect rills regularly after rainfall; adjust spacing, depth, or orientation if excessive erosion or waterlogging occurs.
5. Prevent clogging or erosion by maintaining ground cover with vegetation or mulch.

Crops for which relevant

This practice is particularly relevant for vineyards, orchards, and other crops grown on sloped terrains prone to erosion, where water management is crucial for soil health.

Potential impact

On soil physics: +

On soil biology: +

On soil chemistry: 0

Application considerations

Application material cost: ●

Application labour cost: ●

Effort/knowledge needed: 1

Suitable soil		Suitable climate	
✓	Clay	☐	Maritime
☐	Sandy	✓	Mediterranean
✓	Loamy	✓	Continental

Suitable scale of application: 1- 10 ha. 10 - 50 ha.

Extent to which well-researched: 3

Potential impact on ecosystems services

Provisioning/regulating:

- Biomass provision
- Water regulation
- Erosion control

Supporting/cultural:

- Provision of habitat
- Biodiversity
- Cultural and non-material elements

For information on relevant legislation and regulations, visit:

Further considerations

Creating anthropic rills can significantly reduce soil erosion and improve water retention, especially on steep slopes. However, there are challenges such as high labor requirements and potential for localized waterlogging if not properly managed. Barriers to implementation include a lack of awareness and the initial cost of creation. While the practice may require more work upfront, the long-term benefits include reduced erosion, improved water infiltration, and potential savings in irrigation costs. The trade-off involves balancing the labor-intensive nature of the practice with its soil conservation benefits, which can contribute to better soil health and sustainable farming over time.

Potential soil health benefit

- ☐ Addressing soil compaction
- ☐ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ✓ Addressing erosion and run-off
- ✓ Improving water management
- ✓ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ✓ Improving functional soil biodiversity
- ✓ Improving aboveground biodiversity
- ✓ Increasing soil cover

Research

Research on the application of anthropic rills in European agriculture is limited. While natural rills are typically associated with soil erosion, the concept of deliberately constructed rills for beneficial purposes is not well-documented in European farming systems. Consequently, there is a lack of empirical studies evaluating the effectiveness, design parameters, and long-term impacts of such structures. Further research is needed to explore their potential role in sustainable water management and soil conservation practices.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Jesús Rodrigo Comino and Lucía Moreno Cuenca

Contact: https://soilcrates.eu/

Funded by the European Union

34. Soil decompaction measures (additional)

Basic description of the practice

Several agricultural practices can alter soil compaction (e.g. agricultural vehicle traffic). To address this issue, on the one hand, typical mechanical processes such as ploughing can be applied to recover the initial compaction; on the other hand, less harmful practices for biodiversity can be applied, mainly natural recovery - freeze and thaw - and biomechanical recovery - deep-rooting crops.

As you can see in the indications provided at the bottom of this page, it depends what type of soil decompaction practice is applied in terms of what will be the implications. For allowing natural processes to take place there will be a quite different situation than when (deep) ploughing is applied.

Implementation

Ploughing is mainly applied in early autumn. It consists in turning over the soil when it is damp, to loosen it and prepare sowing. This allows to de-compact the soil, aerate it and dynamize the micro-organisms. At this step, it is also possible to remove the remains of previous crops. This practice can however have a negative long-term impact on soil health as it modifies the properties of the different soil layers and disturbs the soil biota equilibrium.

Swelling and shrinking and/or freezing and thawing are undergone by the soil and cannot be precisely “programmed”. If the climate and the soil composition (clay) are suitable, these mechanisms allow a natural decompaction of soil. Swelling occurs during the wet seasons and shrinking during the dry ones. Equivalent phenomena occur with freezing and thawing due to the density change of water depending on its physical state. These natural decompaction processes can’t take place in sandy soils; their efficiency also depend of the water content of soil when thawing or drying start..

Crops for which relevant

Any crop that is grown in soil that happens to be compacted.

Potential impact

On soil physics

+

On soil biology

-- +

On soil chemistry

- +

Application considerations

Application material cost

Application labour cost

Effort/knowledge needed

0 2

Suitable soil		Suitable climate	
✓	Clay	✓	Maritime
☐	Sandy	✓	Mediterranean
☐	Loamy	✓	Continental

Suitable scale of application

< 1ha.	1- 10 ha.	10 - 50 ha.	> 50 ha.

Extent to which well-researched

1 4

Potential impact on ecosystems services

Provisioning/regulating:
- Water regulation
- Erosion control

Supporting/cultural:
- Nutrient cycling
- Biodiversity

For information on relevant legislation and regulations, visit:

Further considerations

Deep ploughing (typically >30–40 cm) is occasionally used in Europe to disrupt compacted subsoil layers and improve root penetration in crops like maize or sugar beet. However, it should be applied only when compaction is clearly diagnosed (e.g. using a penetrometer).

Key concerns include loss of deep-soil organic carbon, disruption of soil microbial and fungal networks, and increased risk of erosion, especially on sloped or light-textured soils. Deep ploughing must be followed by soil-improving practices, such as cover cropping, reduced tillage, organic amendments, and traffic minimization, to prevent long-term damage and rebuild soil structure and biology.

Potential soil health benefit

- ☐ Addressing soil compaction
- ✓ Increasing soil organic matter
- ☐ Addressing soil nutrient distortions
- ☐ Addressing erosion and run-off
- ☐ Improving water management
- ☐ Enhancing soil resilience handling heat, drought, excessive water
- ☐ Addressing soil salinisation
- ☐ Addressing soil pollution
- ☐ Suppressing harmful organisms
- ☐ Closing farm nutrients cycles
- ☐ Improving functional soil biodiversity
- ☐ Improving aboveground biodiversity
- ☐ Increasing soil cover

Research

Research on deep ploughing in European agriculture explores its potential to alleviate subsoil compaction and enhance crop yields, particularly in sandy soils during drought conditions. Studies indicate that deep ploughing can improve root development and nutrient uptake, leading to increased yields in certain contexts . However, key research gaps persist, including the long-term effects on soil organic carbon sequestration, microbial communities, and overall soil health. Additionally, the economic viability and environmental implications of deep ploughing across diverse European farming systems require further investigation to inform sustainable soil management practices.

For further reading material on this and other practices, visit:

Date: April 2025

Authors: Wafa Guiga

Contact: https://soilcrates.eu/

Funded by the European Union

3. Out-of-the-box inspiration on innovative practices

Please note that the following practices are shared as inspiration only, and have not yet been well-researched or documented.

Name/ key indication of practice :	**Vertical mulching : deepening of the topsoil, adding material to the subsoil**
Brief **description** of what it is about and how it is implemented:	Vertical mulching involves drilling narrow holes into the soil and filling them with compost or other organic materials. This technique mimics natural soil processes, such as those created by earthworms, and is typically applied using hand tools or specialized equipment in compacted or poorly structured soils.
Target/goal – what is it meant to be good for:	The goal is to break up compacted or restrictive layers, restore root growth and water infiltration, and stimulate biological activity in deeper soil zones. By targeting the subsoil directly, this practice supports long-term improvements in soil structure, health, and plant resilience.
Any additional important/useful **considerations**:	Choose compatible crop species to avoid competition. Ensure sufficient light and moisture for germination. Use precise sowing equipment for good seed-soil contact. Terminate the cover crop at the right moment to avoid yield loss.
Weblink (if available):	
Country where this is practiced already (even if just one/two persons):	Netherlands
Author:	Ciska Nienhuis

Name/ key indication of practice :	**Undersowing or direct seeding (i.e. sowing a crop into, for example, a green manure crop)**
Brief **description** of what it is about and how it is implemented:	This practice involves sowing a main crop into a living cover crop (direct seeding) or establishing a second crop beneath an existing one (undersowing), typically without tillage. It requires careful timing and adapted sowing equipment to ensure good seed placement while limiting competition between plant species.
Target/goal – what is it meant to be good for:	The goal is to maintain continuous soil cover to protect and regenerate soil health. This includes reducing erosion, suppressing weeds, stimulating biological activity, and improving resilience to drought and extreme weather, while promoting efficient nutrient cycling.
Any additional important/useful **considerations**:	Timing and crop choice are critical to avoid competition for light, water, and nutrients between the cover crop and the main crop. In some systems, terminating the cover crop mechanically or through frost is necessary to avoid interference with the cash crop.

Weblink (if available):	https://www.kairos-agrifood.com/loonwerk-directzaai#:~:text=Directzaai%20door%20Kairos%20in%20de,besparen%20op%20mechanisatiekosten%20en%20arbeid.&text=Het%20merendeel%20van%20het%20gangbare,andere%20gewassen%20kan%20interessant%20zijn.
Country where this is practiced already (even if just one/two persons):	Netherlands and Canada
Author:	Ciska Nienhuis

Name/ key indication of practice :	**Aerating slurry**
Brief **description** of what it is about and how it is implemented:	Slurry aeration involves adding oxygen to manure before application, either during storage or shortly before spreading. This process shifts decomposition from anaerobic to aerobic, making the slurry more stable and biologically compatible with soil ecosystems. The technique is used in both livestock and mixed farming systems and can be done intermittently or continuously, depending on equipment and management
Target/goal – what is it meant to be good for:	The main goal is to reduce the presence of harmful anaerobic compounds, improve the nutrient profile of the slurry, and enhance its effect on soil life. Aerated slurry can contribute to reduced methane and odour emissions and support soil health—provided it is applied under the right conditions to avoid increased ammonia or nitrous oxide losses.
Any additional important/useful **considerations**:	Avoid over-aeration, as it can raise pH and increase ammonia losses. Apply aerated slurry quickly after treatment, ideally via injection or incorporation. Monitor temperature and foaming, and consider combining with acidification or cover systems to minimize emissions.
Weblink (if available):	
Country where this is practiced already (even if just one/two persons):	Netherlands
Author:	Ciska Nienhuis

4. Further reading - overview of sources in relation to the practices

4.1 Overview table

Information Sources:	Practices																																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
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4.2 Overview of **sources**

Identification number	Source
EU level and international sources	
1	Practice sheets which probably will not be ready in time to draw on: https://inbestsoil.eu/resources/
2	Best4Soil project outputs: https://www.best4soil.eu/factsheets; https://www.best4soil.eu/videos
3	**Techniques for the recovery of compacted soils in Europe:** https://edepot.wur.nl/629799
4	Building soils for better crops: https://www.nrcs.usda.gov/sites/default/files/2022-10/BSBC%20Excerpt%2001.%20Start%2C%20End%2C%20Core%20Messages%20%2831%20pages%29_0.pdf
5	Ontario best practices soil health: https://bmpbooks.com/resource/soils/
6	Farming with soil life: https://www.sare.org/wp-content/uploads/Farming-with-Soil-Life.pdf
7	Soil management on organic farms: https://www.organic-crop-production.com/organic_crop_production/soil_management_organic_farms/management_practices_soil_health.htm
8	Innovative soil management practices across Europe: https://shinyapp.cra.wallonie.be/isompe-inventory/
9	Sustainable agricultural practices and methods - European Commission
10	U.S. department of Agriculture: 4 main principles to improve soil health: https://www.farmers.gov/conservation/soil-health
11	https://www.diverimpacts.net/de/service/practice-abstracts.html
Source from the Netherlands	
1	Sustainable soil management: https://publications.deltares.nl/1230934c.pdf
2	Practices for soil carbon sequestration: https://slimlandgebruik.nl/sites/default/files/2023-07/Brochure_maatregelen-voor-het-vastleggen-van-koolstof-minerale-bodems.pdf; CO2Bodem Klei | Slim Landgebruik; CO2Bodem Zand | Slim Landgebruik
3	Practices for sustainable soil management: https://research.wur.nl/en/publications/overzicht-maatregelen-duurzaam-bodembeheer
4	Practice factsheets PPS Better Soil Management: https://www.beterbodembeheer.nl/nieuws/prestaties-van-bodemmaatregelen-overzichtelijk-voor-de-praktijk/
5	Agricultural water management and practices: https://agrarischwaterbeheer.nl/thema/bodembeheer/ ; Maatregelen - Deltaplan Agrarisch Waterbeheer
6	Good soil management: https://www.goedbodembeheer.nl/Maatregelen
7	Key performance indicators for sustainable agriculture: https://wiki.groenkennisnet.nl/space/kpikll
8	https://www.waterschaplimburg.nl/publish/pages/5037/water_vasthouden_op_landbouwpercelen_in_zuid-limburg_15_maatregelen_def.pdf
9	https://www.best4soil.eu/assets/factsheets/nl/23.pdf
10	daw_overzicht_maatregelen_bootlijst_september_2022.pdf of https://agrarischwaterbeheer.nl/maatregelen/
11	Factsheets Louis Bolk Instituut – example: https://www.louisbolk.nl/sites/default/files/publication/pdf/factsheet-toepassing-van-vaste-organische-mest.pdf
12	https://edepot.wur.nl/161084
13	https://www.louisbolk.nl/thema/duurzaam-bodembeheer
14	https://www.aaltjesschema.nl/Maatregelen/Biologischegrondontsmetting/Inundatie.aspx
15	https://www.louisbolk.nl/sites/default/files/publication/pdf/agroforestry-op-het-landbouwbedrijf.pdf
16	https://groenkennisnet.nl
17	https://www.handboekbodemenbemesting.nl/nl/handboekbodemenbemesting/ingangen/bodem.htm
Sources from France	
1	Multiscale assessment of soil ecosystem services in agroecosystems: https://hal.inrae.fr/hal-03299072/document
2	Good practices in Agroforestry: https://www.agroforesterie.fr/documentation/
3	Agronomic practices favorable to functional biodiversity implemented by farmers in DEPHY and GIEEs collectives in Nouvelle-Aquitaine: https://agroecologie.org/retour-experience https://collectifs-agroecologie.fr/fileadmin/user_upload/National/187_eve-CollectifsAgroecologie/Documents/Nouvelle-Aquitaine/2021_Synthese_pratiques_agronomiques_biodiv_fonctionnelle.pdf
4	Agroforestery in an organic farming system: https://www.produire-bio.fr/wp-content/uploads/2017/03/Recueil-agroforesterie-VF.pdf
5	Impact of cover crops: https://www.adaf26.org/wp-content/uploads/2023/10/Presentation-Couverts-GRAB-17-10-2023-1.pdf
6	https://rd-agri.fr/detail/DOCUMENT/chambres_d'agriculture_306068
7	https://agriculture-de-conservation.com/Le-biochar-enjeu-climatique-potentiel-agronomique-et-leviers-pour-une.html
8	https://www.ecovi.fr/blogs/infos/actualite-scientifique-l-utilisation-du-bokashi-dans-l-agriculture-biologique?srsltid=AfmBOooCxVfkSLY_TSmUVuoZie3jZse7MTBQiAJpIJggfPY1u6OrPNe4
9	https://ecophytopic.fr/sites/default/files/Agronomie_Fiche3_Cultiver%20sans%20labour_MD.pdf

Identification number	Source
Sources from Ireland	
1	https://www.farmingfornature.ie/wp-content/uploads/2023/01/Climate-Actions-Tillage.pdf
2	https://www.teagasc.ie/media/website/publications/2024/Farming-for-a-Better-Future---Johnstown-Castle-July-2024.pdf
3	
4	https://www.teagasc.ie/media/website/publications/2024/Branching-Out.pdf
5	https://intercropvalues.eu/wp-content/uploads/2023/07/7-Principles-of-design-of-intercropping.pdf
6	
7	https://www.teagasc.ie/media/website/publications/2024/Branching-Out.pdf
8	https://www.farmersjournal.ie/more/climate-and-environment/biochar-a-growing-sector-in-ireland-760936
9	https://www.teagasc.ie/media/website/publications/2022/Hemp4Soil---Community-Soil-Biodiversity-Project.pdf
10	https://bim.ie/wp-content/uploads/2023/05/BIM-Technical-Report.pdf
11	https://www.seai.ie/sites/default/files/renewable-energy/bioenergy/biogas-boilers/Anaerobic-Digestion-Implementation-Guide.pd
12	https://www.tipperarycoco.ie/sites/default/files/2022-07/Code%20of%20Good%20Practice%20Biosolids%20in%20Agriculture-Guidelines%20for%20Farmers.pdf
13	https://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/cofordconnectsnotes/00675CCNPP43Revised091216.pdf
14	https://www.teagasc.ie/media/website/publications/2020/Biostimulant-biofertiliers-and-biopesticides.pdf
15	https://www.fertilizer-assoc.ie/wp-content/uploads/2022/11/Fert-Assoc-Tech-Bulletin-No.-2-Lime.pdf
16	https://irishconcrete.ie/wp-content/uploads/2019/09/Soil-pH-and-Liming_Lecture_DWall_2019-Lime-Industry.pdf
17	https://www.farmingfornature.ie/wp-content/uploads/2020/11/Watercourse-Management-1.pdf
18	https://centerforagroforestry.org/wp-content/uploads/2024/04/06_Windbreaks_TrainingManual_2024Master_0410_Digital-7.pdf
19	https://agroforestrynet.eu/wp-content/uploads/2019/10/20190529_factsheet_06_en_web.pdf
20	https://www.teagasc.ie/media/website/rural-economy/farm-management/chapter6.pdf
21	https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/guidance_on_the_safe_use_of_tractors_and_machinery_on_farms.pdf
Sources from Italy	
1	Voluntary guidelines for sustainable soil management: https://openknowledge.fao.org/handle/20.500.14283/i6874it
2	Strategic Plan CAP Italy, 2023: https://www.reterurale.it/downloads/Piano_Strategico_della_PAC_23-27_v.2.1.pdf
3	Ministerial Decree 46/2019 – Annex 4 – 2.1 and 2.3; Regulation relating to reclamation, environmental restoration and emergency, operational and permanent safety interventions of areas intended for agricultural production and livestock farming, pursuant to Article 241 of Legislative Decree 3 April 2006, no. 152. (19G00052); https://www.normattiva.it/uri-res/N2Ls?urn:nir:ministero.ambiente.e.tutela.territorio.e.mare:decreto:2019-03-01;46!vig=
4	Guidelines for the preparation of plans monitoring or management of the impact on soil quality and carbon in soil. ISPRA. 2022; https://www.mase.gov.it/sites/default/files/archivio/normativa/linee_guida_ISPRA_implementazione_RED_II.pdf
5	Legislative Decree 75/2010; Amendment and revision of the fertiliser framework, pursuant to article 13 of the law of 7 July 2009, no. 88. (10G0096); https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2010-04-29;75
6	LIFE HELPSOIL. Soils and adaptation to climate change through sustainable farming techniques; https://www.reterurale.it/buonepraticheLIFE/helpsoil
7	Joint Research Centre; Project SoCo information sheets, 2009; https://esdac.jrc.ec.europa.eu/projects/soco-fact-sheets
8	Consorzio Italiano Biogas; The agricultural digestate for organic fertilization, 2024; https://www.consorziobiogas.it/wp-content/uploads/2024/06/Digestato-Manuale-B5-2024-WEB.pdf
9	Legislative Decree 99/1992 on the implementation of Directive No. 86/278/EEC concerning the protection of the environment, in particular soil, in the use of sewage sludge in agriculture; https://www.gazzettaufficiale.it/eli/id/1992/02/15/092G0139/sg
Sources from Spain (Spanish language sources)	
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4.3 The selected **practices**

Identification number of the practice	Practice short description	Brief explanation if it is not obvious
(Soil) cultivation (system) related		
1	Apply minimum tillage or no-tillage	(significantly) Reduced soil disturbance
2	Apply buffer strips (also see riparian buffer zones)	A buffer strip is an area of land maintained in permanent vegetation that helps to control air quality, soil quality, and water quality, etc.
3	Apply agroforestry system	
	Food forest	can be in combination with land retirement
	Silvopastoral	
	Sylvicultural	
	Agrisilvopastoral	
	Riparian buffer zones	
Choice of crops/ cropping system /crop diversification related		
4	Apply diversified crop rotation	
5	Apply strip cropping	
6	Apply cover crops (variety of options)	spit up in four types to describe them in relation to the specific purpose
7	Inter-cropping	
8	Apply Tagetes (Marigold)	
9	Species diversification in grassland	
Organic amendments		
10	Apply green compost, vermicompost, termophilic compost, compost tea	
11	Apply bokashi	
12	Apply biochar	
13	Apply seaweed	
14	Apply digestate	
Inorganic amendments		
15	Apply vermiculite, lava split, bentonite, clinoptilolite, and other clay minerals/rocky material	Rock powders and other natural mineral products with multiple trace elements.
~~16~~	**Deleted**	
17	Apply ashes	
18	Apply gypsum	
Soil stimulants		
19	Apply microbial biostimulants	Compost teas, Effective Micro-organisms, Extracellular Polymeric Substances (EPS), Biodynamic preparations, and other microbial inoculants or biostimulants applied to soil, manure, seeds, root balls, or foliage.
20	Apply humic acids and humate products (e.g. perlhumus), sea weed	Non-microbial biostimulants
21	Apply system of high calcium limestone, gypsum, and other minerals applied to achieve specific ratios of cations (Ca, Mg, K, Na) or other nutrient claimed to improve soil and crop health.	Albrechts method? So this is about a particular system of application, not just the products by themselves.
Counteract physical conditions		
22	Apply water erosion/runoff control, e.g. through contouring	
23	Apply wind erosion control field windbreaks and shelterbelts (also see agroforestry)	
24	Apply low pressure tyres on tractor	Prevent/undo compaction
25	Apply deep rooting crops	Prevent/undo compaction
26	Apply perennial crops	
Soil repair		
27	Apply soil remediation; phytoremediation	Clean soil from contaminants

Identification number of the practice	Practice short description	Brief explanation if it is not obvious
28	Apply inundation	
Preventative measures		
29	Apply permanent ground cover	
30	Apply system of minimal use of pesticides; e.g. through mechanical weed control, biological control of pests, etc.	
Water management		
31	Irrigation	Reel irrigation, drip irrigation, subirrigation, and controlled drainage optimize water management
32	Water catchments infrastructure	Deposits and dams, walls to direct water, terracing
33	Anthropic rills	
Soilcompaction (additional)		
34	Deep ploughing	

5. The **longlist** from which practices were selected

Practice short description	Brief explanation if it is not obvious
(Soil) cultivation (system) related	
Apply minimum tillage or no-tillage	(significantly) Reduced soil disturbance
Apply buffer strips (also see riparian buffer zones)	A buffer strip is an area of land maintained in permanent vegetation that helps to control air quality, soil quality, and water quality, etc.
Apply residue management	handling of stems, leaves, chaff and husks that remain in the fields after crops are harvested for grain, seed or fiber.
Apply agroforestry system	
Food forest	can be in combination with land retirement
Silvopastoral	
Sylvicultural	
Agrisilvopastoral	
Riparian buffer zones	
Terrace cultivation	on steep slopes
Contour tillage	
Animal tillage	Using pigs/chickens etc to open up the soil
Apply mulch tillage	
Mob-grazing / planned grazing	(for pasture farmers)
Introduce more animal species into system	Different species have different foraging habits; fertilize soils; increase plant and soil microbe diversity. Can make for more resilient systems
Use traditional breeds of animals	More suited to local environment; less likely to require inputs/medicines which have an impact on soil
Choice of crops/ cropping system /crop diversification related	
Apply diversified crop rotation	
Apply strip cropping	
Apply sod crop in rotation	
Apply cover crops (variety of options)	spit it up in describing them per purpose
Inter-cropping	
Mixed cropping	Differs from intercropping. Two or more crops planted and harvested together
Apply Tagetes (Marigold)	
Apply break crop	
Species diversification in grassland	
Use of legumes (either in rotation, inter-cropped or mixed cropped)	To fix atmospheric nitrogen
Use seeds saved from locally adapted crops	Improved yield. They will be more suited to the local conditions (soil/climate/etc). We also need more genetic variability within the crops we grow especially as a buffer to climate change. The plant goes hand-in-hand with the soil...
Organic amendments	
Apply ramial wood chip (RWC)	Increase biological activity (esp fungal), SOC, P availability, water holding capacity, etc
Fatty acid amendments e.g. fish hydrolysate, neem oil	Feeds mycorrhizal and saprophytic fungi
Apply clippings (e.g. from side of the road), and all kinds of raw fibres such as coconut, alfalfa, etc.	
Apply green compost, vermicompost, termophilic compost, compost tea	

Practice short description	Brief explanation if it is not obvious
...+ other composts: black soldier fly larvae (bsfl) compost; Johnson-Su 'BEAM' compost; woody compost	
Apply fermented plant extracts, e.g. comfrey, nettle, etc	
Apply liquid biofertiliser	Made from water, cow manure, raw milk, molasses, wood ash; optional additions of yeast, worm castings, kelp extract, rock dust. Anaerobes extract and chelate nutrients. Used as a foliar spray
Apply mushroom compost	
Aplly bokashi	
Apply biochar	
Apply straw	
Apply bloodmeal, bone meal, fishmeal, etc.	Dead animal products
Apply pure manure	
Apply seaweed	
Apply thick fraction manure; fibre fraction manure	
Apply manure mixed with fibres	
Apply digestate	
Apply mulch (organic)	
Chop and drop'	Cut plant material and drop on ground. Serves as a compost and a mulch. Often used in mixed-cropping systems, e.g. agroforestry.
Apply effective microorganisms (EMs)	Facultative microbes (can live in both aerobic and anaerobic conditions) can be cultivated in a passive brewing process: e.g. lactic acid bacteria (LAB)
Apply Indigenous Microorganisms (IMOs) and associated preparations	Used to increase soil biology. Collect IMOs from local area using rice/wheat bran, etc.
Mycorrhizal inoculants	
Inorganic amendments	
Apply vermiculite, lava split, bentonite, clinoptilolite, and other clay minerals/rocky material	Rock powders and other natural mineral products with multiple trace elements.
Apply sludge	Struvite?
Apply lime, shells	Raising the pH
Apply gravel, sand	
Apply ashes	
Apply pH lowering chemical additives	
Apply gypsum	
Soil stimulants	
Apply trace elements	Manganese, molybdeen, etc.
Apply microbial biostimulants	Compost teas, Effective Micro-organisms, Extracellular Polymeric Substances (EPS), Biodynamic preparations, and other microbial inoculants or biostimulants applied to soil, manure, seeds, root balls, or foliage.
Apply humic acids and humate products (e.g. perlhumus), sea weed	Non-microbial biostimulants
Apply product for improving nutrient availability	Hormons, etc.
Apply system of high calcium limestone, gypsum, and other minerals applied to achieve specific ratios of cations (Ca, Mg, K, Na) or other nutrient claimed to improve soil and crop health.	Albrechts method? So this is about a particular system of application, not just the products by themselves.

Practice short description	Brief explanation if it is not obvious
Counteract physical conditions	
Apply water erosion/run-off control, e.g. through contouring	
Apply wind erosion control field windbreaks and shelterbelts (also see agroforestry)	
Apply drainage system	
Apply (deep) ploughing, spading	Prevent/undo compaction
Apply low pressure tyres on tractor	Prevent/undo compaction
Use wider tyres on machinery	
Use lighter machinery (e.g. two-wheeled tractor for smaller farming operations)	reduce compaction
Apply practice/habit of only entering field when dry enough	Prevent/undo compaction
Apply deep rooting crops	Prevent/undo compaction
Apply perennial crops	
(Land retirement)	
Apply fallow	
Path management (for small farms/market gardens)	e.g. woodchip; stropharia inoculated woodchip; living pathways, etc
Soil repair	
Apply soil remediation; phytoremediation	Clean soil from contaminants
Apply inundation	
Apply subsurface drainage	Apply and optimize existing drainage infrastructure and Maintain functional drainage system
Preventative measures	
Apply permanent ground cover	
Apply system of minimal use of pesticides; e.g. through mechanical weed control, biological control of pests, etc.	
Anaerobic soil desinfectation	
Biosolarization	
Shelterbelts	reduce wind stress (and thus reduce evapotranspiration) and damage / increases pest control (e.g. by providing habitat for beetles, etc), ++
No-till	Minimise damage to soil biology and soil structure
Watermanagement	
Irrigation	Reel irrigation, drip irrigation, subirrigation, and controlled drainage optimize water management
Water strorage	Underground and basins
Water catchments infrastructure	deposits and dams
Use of soil moisture sensors	
measurement crop water needs	
deficit irrigation	
use of acceptable water quality	