Challenges of Organic Arable Farming

1st module: Strategies to enhance soil fertility and assessment of soil fertility and quality





Module objectives

- In organic farming systems, soil fertility means more than just providing plants with macro- and micronutrients. An effective fertility management interests plants, the soil organic matter and the soil biology. Additionally, it is one of the central roles of organic agriculture to either enhance or sustain the overall quality and health of the soil ecosystem.

- This module aims at introducing the major problems in soil fertility of organic arable farming, explaining soil fertility and soil quality concepts, and at providing information about strategies that help enhance the fertility and assess the quality of organically-managed soils. Eventually, such module is meant to encourage the participants' discussion on this important topic.

Module outlines

1- Soil fertility concept	Definition
2- Challenges in fertility management	2.1. Manage rotations 2.2. Nutrient supply 2.3. Cultivation technique
3- Strategies to enhance soil fertility	3.1. Soil organic matter enhancement 3.2. Legumes 3.3. Crop rotations 3.4. Intercropping 3.5. Bio-effectors
4- Soil quality concept	4.1. Definition 4.2. Importance 4.2. Assessment
5- Conclusion	

1. Soil fertility concept

- Soil fertility is defined in terms of the ability of a soil to supply nutrients to crops (Patzel et al., 2000; Gisi et al., 1997), while a broader definition integrating a number of diverse soil functions to promote plant production is more useful (nutrient supply, soil structure, water holding capacity, etc.).

- The enhancement of soil fertility was a crucial value already to the pioneers of organic farming, but the conservation of fertile soils is not always given enough attention, and yet organic farming depends on good natural soil fertility. Exhausted and damaged soils cannot offer the desired performance. Hence, the management of soil fertility requires a lot of care.

- Soil fertility management is specific to the farming system and to the climatic conditions that may dictate specific management strategies.

1. Soil fertility concept

There are many perspectives and definitions of soil fertility in agriculture. The perspective we mainly rely on depends on what we assess: if we want to assess the soil itself, we go for the Biocentric definition. If we require something particular from the soil, we focus on the Functional definition. If we measure the soil fertility on the basis of the yield, we choose the Yield definition; if we consider other properties of the soil itself, we take into account the Factor perspective.

Perspectives and definitions of soil fertility

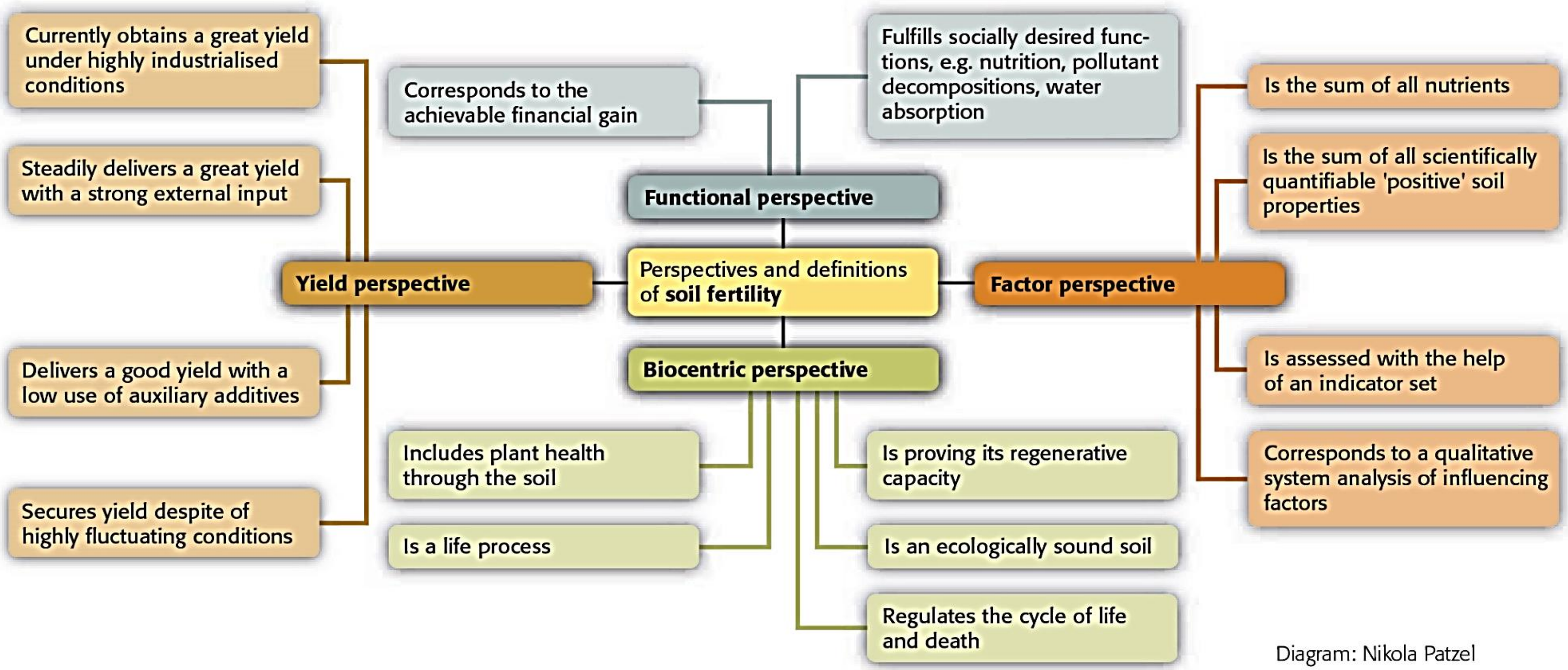


Diagram by Nikola Patzel. Source: The Basics of Soil Fertility Shaping our relationship to the soil - FiBL

2. Challenges

The major difficulties observed and challenges related to soil fertility can be summarized as follows:

- How to effectively design and manage rotations for maximum fertility;
- Providing nutrient supply: which off-farm inputs to include, when to apply them and where to find them;
- How to cultivate the soil to maintain fertility;
- Knowledge gaps on how to manage the system for maximum fertility and how to measure soil fertility using soil and plant tissue analysis.

Furthermore, farmers may face one or more of the following problems:

- Nutrient leaching (specially N);
- Building soil fertility in stockless systems (lack of livestock);
- Organic matter loss due to oxidation caused by tillage.

2. Other challenges

Stockless systems (lack of livestock) often rely on off-farm inputs to build fertility. Farmers with stockless systems have to be more creative and exchange forage or manure with neighbouring livestock farmers, or to supply biogas plants with green waste in exchange for digestate.

In some cases, “cut and carry” might be needed as a method of transporting fertility around the farm. (Cut and carry or "zero grazing" is a famous feeding system practiced by the small-scale dairy farmers in which cutting, collecting and transporting natural forages are done to feed the indoor-kept livestock).

In some other cases it is fundamental to use catch crops in order to limit the amount of nitrogen leaching, e.g. using intercropping of a grain legume and cereal for a “catch and release” system where the legume provides nitrogen to the cereal crop.

3. Potential solutions

In the following slides a summary of the major techniques used to face the above mentioned challenges.

Solutions start when different fertility components are addressed:

- Soil physical conditions (air, water, aggregates) that are strongly associated to the soil organic matter content and roots penetration by different crops within the rotation plan.
- Soil nutritional status especially N that can be provided by legumes.
- Living organisms and biological status of the soil that can be enhanced through suitable bio-effectors.

3. 1. Soil Organic Matter enhancement

Organic farming has the capacity to increase soil organic matter in the top-soil (Gattinger et al., 2012). Building soil organic matter (SOM) enhances the chemical, biological, and physical properties of the soil, in order to optimize crop production (Watson et al., 2002). Hence, it is critical that organic farmers take a long-term view of SOM as key point in the soil fertility management.

Why SOM?

- It plays a major role in soil structure, water management, prevention of erosion and nutrient supply;
- It provides both a habitat and an energy source for soil micro and macro fauna;
- It builds the capacities of soil fertility under reduced tillage system (Cooper et al., 2016). Watch this video;

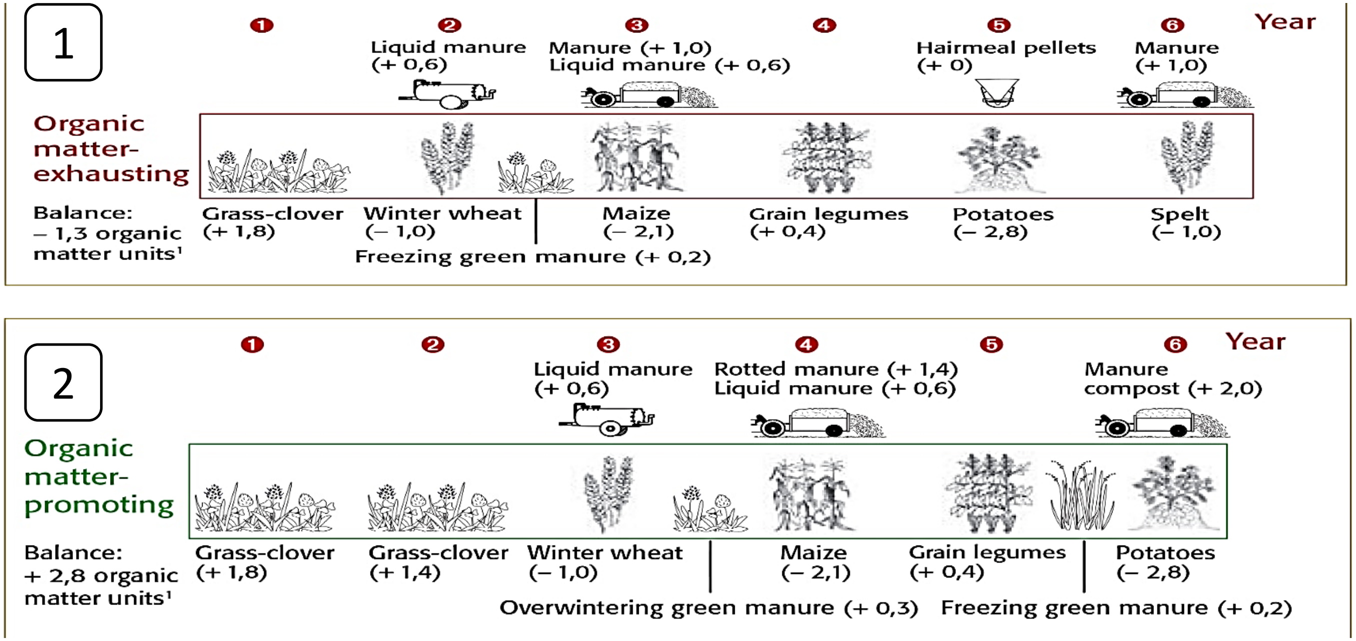
Adding manure is believed to increase the supply of SOM, therefore the proper storage and timing of applications are of paramount importance.

3. 1. Soil Organic Matter enhancement

Schematic examples of a organic matter-promoting and of an organic matter-exhausting crop rotation.

In root-crop-dominated crop rotations a negative humus balance is usually observed. Even crop rotations with strongly exhaustive root crops and an average of 0.5 to 0.8 livestock units can achieve a positive humus balance.

In (1) rotation only makes use of stacked manure and has only single-year grass-clover. In combination with a single frost-kill green manure (e. g. mustard), OM is depleted because of the root crops.



In (2) rotation comprises two years of grass-clover that significantly contributes to the formation of OM. Adding rotted manure and manure compost brings much steadier OM into the soil. Farms lacking animal manure may improve their OM balance with generous additions of plant-based compost.

Source: The Basics of Soil Fertility Shaping our relationship to the soil - FiBL

3. 2. Legumes

- Legumes are essential to supply nitrogen but only a few species are used.
- The availability of suitable varieties and the understanding of management and the benefits at each level of the farming system of these species are lacking.
- Synchronizing supply and demand of both nitrogen and phosphorus is challenging and there are few reliable models available to help with decision making.
- It is vital to use legume mixtures due to the following reasons:
    1. Stability: they provide greater resilience to variable weather, climate and management conditions;
    2. They combine early and late weed suppression characteristics;
    3. They show a slower decomposition during incorporation and hence there is a potentially better N utilization by the following crops;
    4. They extend forage availability for key insect pollinators.

3. 2. Legumes

Legume solutions recommended by ORC (The Organic Research Centre in the United Kingdom):

1. Red clover: high forage yield, high yield of subsequent crop;
2. White clover: high yield, high yield of subsequent crop;
3. Black medick: moderately high yield in second year, resistance to decomposition (lignin content and C:N ratio), high yield of subsequent crop;
4. Birdsfoot trefoil: good yield, high yield of subsequent crop;
5. Lucerne: high yield, resistance to decomposition, high yield of subsequent crop. It prefers high pH;
6. Sainfoin: moderate yield, resistance to decomposition (high polyphenols);
7. Crimson clover: an annual with high yield, high value for pollinators.

3. 3. Crop rotations

- Increasing diversity through the use of alternative crops provides an integration of different spatial and temporal approaches within rotations including cover cropping and undersowing. Their interaction is needed;

- Selecting the pre-crop is fundamental in determining yield and N supply to the following crops (Preissel et al., 2015);

- Crop choice and rotation are well known to influence P availability and green manures could be specifically chosen to increase P availability in the following crops (Cavigelli and Thien, 2003). Check the benefit of using hairy vetch as excellent green manure here.

3. 3. Crop rotations

- Rotations including clover grass leys and legumes such as broad beans as fertility-building cash crops are widely adopted.

- Rotation design utilizing intercropping and undersowing with legumes as well as a better understanding of cover crops and green manures should also help arable farmers improve soil fertility. Here you can find a useful guide to manage green manure.

- Recommendations to design your rotation are available for Maize and different other arable crops.

- The appropriate combination of crops and green manures prevents spread of perennial weeds and increases the crop yield and quality. Weed-suppressing crop rotations are absolutely essential for sustainable organic arable farming.

3. 4. Intercropping

- Intercropping is very promising for both nutrient supply and soil structure management.
- Different crop and forage species have varying abilities to extract macro and micro nutrients from soil (Lindström et al., 2013) as a result of both root morphology and their interactions with the mineral and biological soil matrix (Richardson et al., 2009).
- Deep rooting species also improve soil structure and drainage because different morphological and eco-physiological traits benefit from different niches.
- Another interesting idea which requires further research is the principle of "ecological precision farming" which very much relies on intercropping to overcome the limitations of soil variation and to reduce adverse environmental impacts (Jensen et al., 2015).

3. 4. Intercropping

- Example for successful intercropping system::

The cultivation of half-leafless grain peas and barley as a mixed crop. The barley serves as a supporting crop, significantly increasing the pea yield. After several years of trials in Switzerland, the mixed crop of grain peas and barley has achieved the yield-stablest combination for protein production. Check further details here.

3. 5. Bio-effectors

- Bio-effectors are able to promote crop growth and nutrient acquisition basically through improving the bioavailability of nutrients.
- They comprise microorganisms (plant growth promoting rhizobacteria/PGPR, mycorrhizal fungi and endophytes) and bio-active compounds such as plants and seaweed extract and compost extract.
- Bio-effectors improve soil biology and help promote crop growth and nutrient acquisition. However, this increased focus on soil biology will require the development of suitable indicators and assessment methods for the biological activity.
- Research is done in the EU Biofector project, the CORE organic Improve-P project and in the international Biofi project (ISCB).

3. 5. Bio-effectors

Under stress conditions, bio-effectors could offer alternatives to the conventional use of chemical fertilizers by transforming plant-unavailable forms of nutrients into plant-available forms and by extending the volume of soil explored for nutrients uptake (root growth promotion and/or mycorrhizal associations).

Positive results obtained with bio-effectors on different crops when combined with alternative fertilizers or reduced levels of mineral fertilizers.

Crop	Bio-effector	Alternative fertilizers	Effect	Experimental set-up
Maize	*Pseudomonas* strain	Composted manure	Early growth promoted	Field
Maize	Humic acids from artichoke compost	Composted manure, fresh digestate, rock phosphate	up to + 40 % crop biomass (in alkaline soils)	Pot
Tomato	*Pseudomonas* and *Bacillus* strains	Composted manure	+ 80% crop biomass	Field
Pigeon pea intercropped with finger millet	mycorrhiza and *Pseudomonas* strains	50% recommended mineral fertilizer	+ 48% crop biomass (in low fertility soils)	Field

Source: Thonar C., internal report of FiBL

4. Soil quality concept

4.1. Definition

- The American Soil Science Society has also defined the SQ as “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain biological productivity, maintain or enhance water and air quality, and promote human health and habitation” (Karlen et al., 1997).

- Recently, an interesting definition was formulated by Garbisu et al. (2011); “Soil quality is the capacity of a soil to perform ecosystem processes and services, while maintaining ecosystem attributes of ecological relevance”.
- Soil quality indicators must include a panel of physical, chemical, biochemical and biological soil properties.

4. 1. Importnce

Why is soil quality essential in organic farming?

1. The organic farming system entails much more than simply substituting one set of management practices and inputs for another. Organic farming is a methodology that strives to mimic natural ecosystems in its focus on building soil health. In fact, to fulfil the many requirements to certify a farm as organic, a farmer must establish a plan to improve soil quality.
2. The goal of organic agriculture is to maintain a non-negative trend in productivity while maintaining soil quality, thus monitoring soil quality is to be kept in mind.
3. Agricultural sustainability of organic farming depends on productive high-quality soil, e.g. soil biological properties and processes are of great importance, since the majority of nutrients are derived from microbial decomposition of various fractions of organic matter and not from fertilizers bought off the farm, as most conventional farms do.
4. Organic agricultural systems offer opportunities to substantially improve the soil quality.

4. 3. Assessment

SQ assessment should be goal-oriented and the importance of recognizing soil indicators need to be soil and site-specific (Powers et al., 1998). Because different soils function differently, it is also important that soil indicators and critical thresholds are tailored to different soil types and different soil functions (Craigg, 2006).

Farmer-friendly tools that help in the visual assessment of soil structure are becoming widely available:

- Soil Quality Test Kit (USDA 2001)
- Visual Soil Assessment Field Guide for Annual Crops by the FAO (Shepherd et al., 2008)
- Visual Soil Assessment Field Guide or cropping and pastoral grazing (Shepherd, 2000)
- Soil Assessment Manual by Spade Diagnosis (Hasinger, 1993).
- The Muencheberg Soil Quality Rating (SQR)

5. Conclusion

- Best soil fertility management is the backbone of productive organic farming and changes the soil carbon content, the crop yield and economics (explore this tool.
- Organic farmers may partly ignore elements of best practice because of economic reasons (e.g. high proportion of few cash crops in the rotation, soils compaction because of untimely tillage).
- Rotation design and increased diversity through techniques such as intercropping show great promise for soil structure management.
- Organic reduced tillage has a positive effect on soil microorganisms and earthworms in terms of abundance and diversity. See how it works here.
- Intercropping offers many benefits as different crop and forage species have varying abilities to extract macro and micro nutrients from soil.
- In livestock-based arable systems the use of nitrogen-fixing perennial legumes provides N while in stockless systems perennial leys are generally not economically good.
- Bio-effectors improve plant biomass production and can be fungal strains, mycorrhiza and humic acids.

Further tools

Here are some further tools in the context of this module available in other languages than English

- Green manure and cover crops in organic agriculture: general introduction (leaflet) / French
- Intercropping grain peas with barley (video) / German

Linkography:

1- Key reports from "Baltic manure" project

2- State of art of composting and anaerobic digestion in Italy

3- Recommendations on bio-waste

4- Soils and cropping systems in organic

5- Latest projects by FIBL regarding soil quality

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