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Organic farming

Basic principles and good practices

FiBL

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Organic agriculture has grown intensely worldwide in recent years. The demand for naturally produced food is continuously increasing. Likewise, the interest of governments in environmentally friendly agriculture and healthy food is also increasing. Therefore, it is expected that the area under organic production will continue to grow.

This dossier explains the basics of organic agriculture and shows how these are applied in practice. It serves as a valuable source of information for farmers considering conversion to organic farming. The dossier is also a guide for the private sector, government representatives, NGOs and other interested parties in their efforts to make food production in Europe (and elsewhere) more sustainable.

Why organic farming?

Organic farming offers many advantages, both for producers and consumers, as well as for nature and the climate. Therefore, it is not surprising that this form of agriculture is gaining increasing attention from the society and politics worldwide.

Improvement of income

Organic farming requires more effort, especially for weed control, and achieves on average 20 % lower yields than conventional farming. Nevertheless, most organic farms generate a higher income than conventional farms. The reasons for this are, on the one hand, lower expenses for inputs and higher producer prices. On the other hand, organic farmers in many countries benefit from government subsidies.

Because the organic market also has interesting niche markets, many organic producers strive to diversify their production, which guarantees them greater financial security. Organic farms can add more value by processing agricultural raw materials on-farm and through utilising direct marketing channels. As a rule, organic farmers or their organisations negotiate prices with buyers in advance, thus securing stable prices and guaranteed sales. Direct communication between producers and buyers helps to establish reliable and cost-efficient value chains.

Reduced external dependence

Efficient nutrient circulation within the farm reduces dependence on external fertilisers. Higher natural soil fertility, increased biodiversity and lower production intensity overall contribute to healthier crops and a reduced need for pesticides. Greater independence increases job satisfaction and makes production economically more secure.

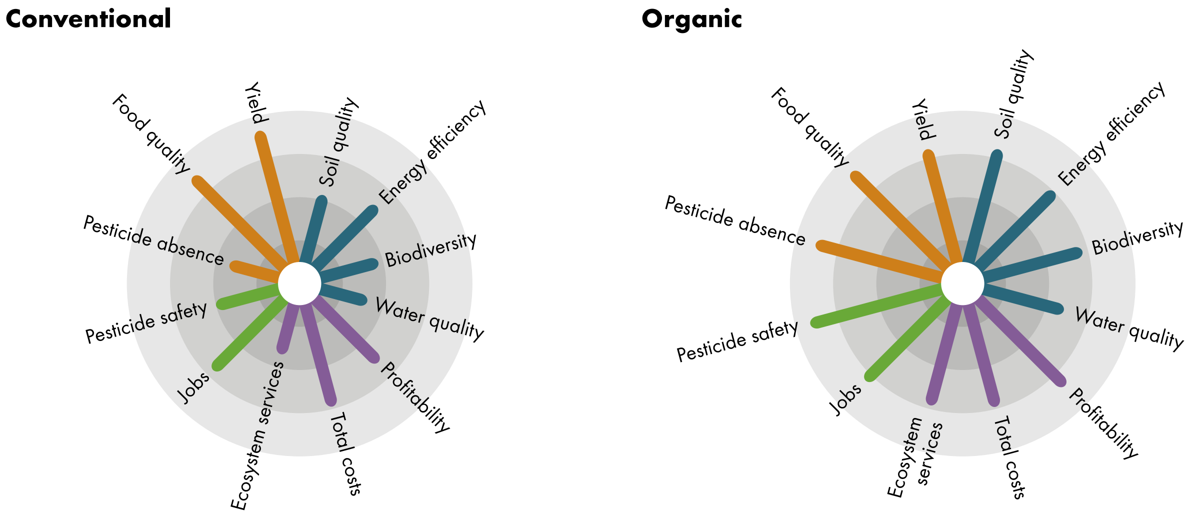
Protection and promotion of natural resources

Organically managed soils contain more humus and have a better structure than mineral-fertilised soils. As a result, they silt up and erode less as well as absorb and store rainwater better. This improved water supply of organic crops contributes to a better drought tolerance than in conventional crops.

The higher supply of biomass in the soil and organic fertilisation promotes soil organisms' activity in organically managed soils. High biological activity is important for healthy crops, nutrient supply, and stable yields.

Organic farming has also been shown to directly and indirectly promote biodiversity, which is the basis for natural pest regulation.

Figure 1: Comparison of organic and conventional agriculture



Organic farming performs better than conventional farming in almost all areas. Only yields are often lower in organic farming.
Source: Reganold J. P., Wachter J. M. 2016. Organic agriculture in the twenty-first century. Nature plants 2(2): 15221.

In addition, organic farming safeguards healthy groundwater and water bodies with low contributions of nitrate and pesticide contamination; it is gentle on the climate, and is energy efficient.

Healthier food

Exposure to organic pesticides is minimal for farmers and nature. By not using synthetic chemical pesticides, organic fruits and vegetables have an average of 180 times less pesticide residue than conventional produce.

Sustainable cultivation with a promising future

Organic agriculture is continuously adopting new research findings to improve production with gentlier and more efficient practices. Scientific research and the development of technical innovations in daily practice complement each other perfectly. Organic farming is eager to use high-tech solutions, such as the detecting and regulating weeds using modern equipment with image recognition software, or the use of drones to spread beneficial insects in arable crops.

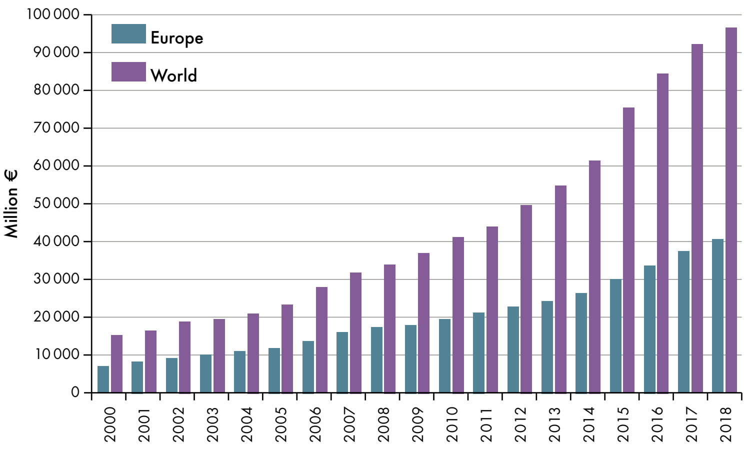
Development of organic agriculture worldwide and in Europe

Continuous growth of organic markets

In the last 20 years, the organic market in Europe and worldwide has grown annually with single- to double-digit rates (Figure 2). In 2018, growth in Europe was 7.8 percent and retail sales rose to over 40 billion euros. In the same period, the global organic market reached a volume of almost 97 billion euros.

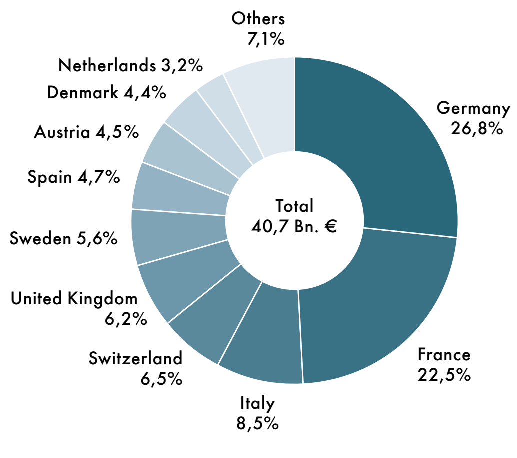
The European Union is the second largest single market for organic products after the United States (40.5 billion euros). Within Europe, Germany is the most important market with nearly 11 billion euros, followed by France with 9.1 billion euros (Figure 3). In 2018, important national markets recorded double-digit growth; for example, the French organic market grew by 15 percent.

Figure 2: Development of organic retail in Europe and worldwide from 2000 to 2018



Source: FiBL-AMI surveys 2000-2020

Figure 3: Shares of selected countries in the European organic market in 2018



Source: FiBL-AMI survey 2020

Steady expansion of production areas

The growing demand for organic products has been accompanied by a steady increase in the area of agricultural land farmed organically: in 2018, the increase in Europe was more than 1 million hectares (Figure 4), representing an 11 percent increase in area. In 2018, nearly 419,000 producers in Europe managed 3.1 percent of agricultural land organically. Globally, organic farmland reached an all-time high of 71.5 million hectares.

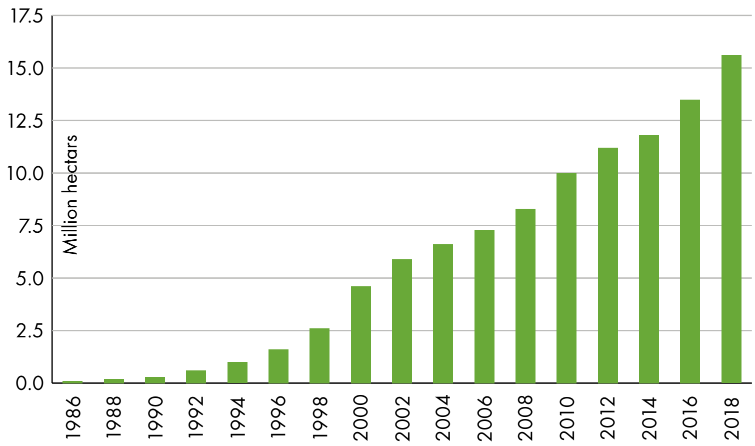
Strong increase in processing and international trade

In 2018, there were over 96,000 certified processors of organic products and over 6,600 importers in Europe. The driving force behind the strong growth of international trade in many European countries are consumers and supermarket chains. Both are seeking a wider range of organic products, increasingly also industrially processed foods. The demand for food of animal origin, especially milk and eggs, is growing particularly strongly. Organic meat consumption is also growing steadily. The strong demand for organic animal feed leads to a strong increase in feed imports in Western Europe, which is accompanied by a strong expansion of organic farmland, especially in Eastern Europe, where excellent conditions prevail for growing organic cereals and root crops such as sunflowers and soybeans.

Increasing demand for organic food

Across Europe, more and more organic food is being bought. In 2018, Europeans spent around 50 euros per person, which is double the amount spent since 2008. In the same reference year, Swiss and Danish people spent the most on organic food, with over 300 euros per person. Denmark has the highest organic market share in the world with over 11.5 percent. Individual products and product groups reach market shares of over 20 percent. Organic eggs are top sellers in many countries. In several countries they already account for around 30 per cent of the value of all egg sales (see Table 1).

Figure 4: Development of the organic cultivation area in Europe from 1986 to 2018



Sources: Lampkin, Nic, FiBL-AMI surveys 2006–2020, and OrganicDataNetwork surveys 2013–2015, based on national data sources and Eurostat

Table 1: Shares of organic product groups in the total market of product groups in countries in Europe in 2018

	Austria	Denmark*	France*	Germany	Sweden*	Switzerland
Baby food			12.7 %			
Beverages			5 %		5.6 %	3.7 %
Bread and bakery products			3.4 %	8.6 %	3.5 %	
Fresh vegetables	16.0 %	20.4 %	6.3 %	9.7 %	12.2 %	25.4 %
Fruit	10.7 %	18.8 %	7.7 %	7.8 %	18.4 %	16.2 %
Eggs	22.3 %	32.6 %	29.6 %	21.0 %		27.6 %
Fish and Fish productes			2.5 %		12.9 %	
Meat and meat productes	4.4%		2.4 %	2.5 %	2.9 %	6.1 %
Milk and Milk productes	16.5 %		4.4 %		10.4 %	

Source: FiBL-AMI survey 2020; *Data from 2018

Organic farming in Europe: opportunity and challenge

Organic farming as an interesting development opportunity

Organic agriculture offers itself as a solution for many European countries to revitalise farmland with sustainable practices and to achieve better yields and prices. Various governments have recognised this potential and provide financial support to organic farming.

Thanks to government support and a broad network of organic inspection organisations, the certified organic acreage has grown steadily in recent years.

The interest in healthy and sustainably produced food is steadily increasing. Urban centers are particularly important drivers of this development.

Export as a driving force

The driving force for the expansion of organically certified areas in Europe has so far been the strong growth in demand for organic products in some Western European countries. Thanks to good producer prices and market prospects for organic products in Europe, not only farms but also many processors have converted partly or fully to organic production in recent years. In terms of value, the most important products to date, depending on the country, are organically produced cereals, vegetables, fruits, dairy products and eggs.

Bread grain is one of the most demanded organic raw materials.

Targeted quantitative and qualitative growth

The European organic sector has significant potential for further growth. Where farmers use only small amounts of synthetic chemical fertilisers and pesticides, the conversion to organic production is an obvious step forward.

For governments and international donors, promoting organic agriculture is a valuable way to foster income in rural areas while protecting resources and the environment. Diversifying organic production for export, as well as for the domestic market, opens up opportunities to attract more young people to agricultural production. This is of utmost importance given the strong migration of youth from rural regions to the cities. Organic farming is particularly interesting for young people, as it not only opens up new long-term employment opportunities, but also promotes innovative thinking and action. Both lead to a higher personal satisfaction in daily work.

Addressing challenges systematically

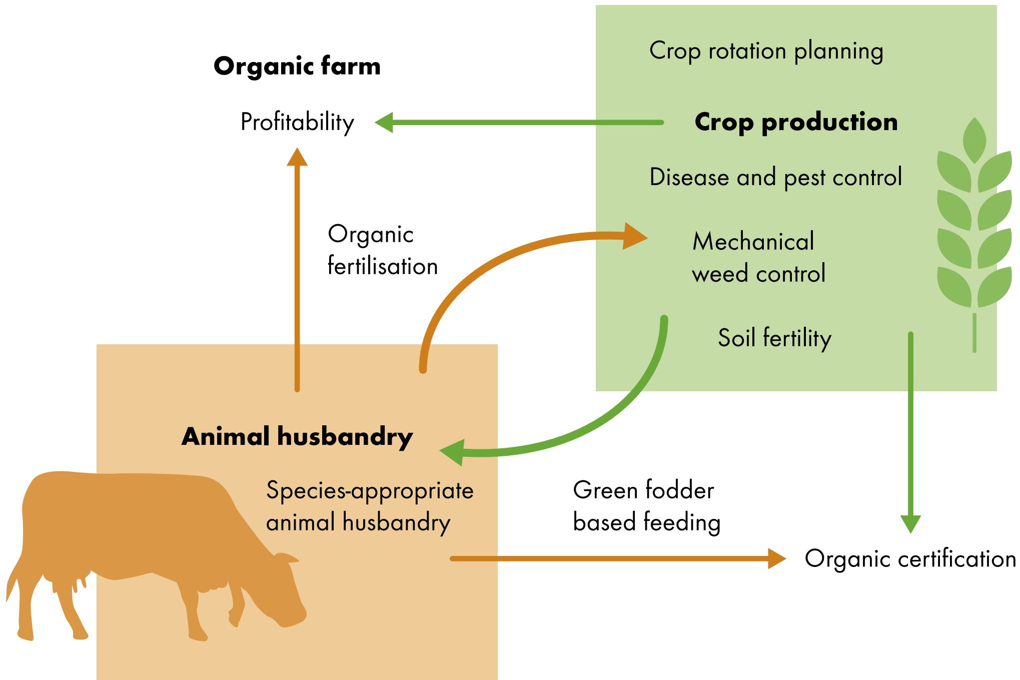
All in all, organic agriculture is demanding and requires sound governmental frameworks such as a favourable legislation and support measures. Equally important is a good implementation of organic agriculture by farmers themselves.

The challenges on the farm are manifold. They start with optimal farm and crop rotation planning during conversion and extend to daily decisions for optimising the production of individual crops in terms of costs and labour. The latter is important for increasing yields and profit margins across the crop rotation. Livestock challenges are similarly high.

Organic farms strive for closing nutrient cycles, prioritising the use of on-farm or locally available resources. Fertile soil is the most important production capital of organic farmers. It must be built up through balanced crop rotation and organic fertilisation to ensure good yields and farm profitability. Figure 5 visualises the production system and the main challenges for organic farmers.

Conversion to organic agriculture also often encourages adjustments in crop rotation to promote soil fertility and regulate weeds.

Figure 5: Most important challenges on organic farms



Crop production and animal husbandry are closely linked on organic farms. Coordination and efficient use of farm resources are important prerequisites for farm success.

Principles of organic farming

Organic farming strives for a resource-saving, environment- and animal-friendly and social production of healthy food. Thereby, the term ‚organic' refers to the use of organic fertilisers and other natural inputs and the avoidance of synthetic chemical pesticides and mineral nitrogen fertilisers.

‚Organic' also refers to an ecological approach which follows the natural laws of a living organism in which all elements are interconnected. Accordingly, organic farming relies on meaningful synergies between soil, plants, farm animals, insects, environmental factors such as water or climate, and humans. The organic farmer seeks to use ecological principles and processes to achieve optimal yields while protecting the environment. In this sense, organic farming is a holistic way of farming: in addition to the production of high quality food, preserving natural resources such as fertile soil, clean water and rich biodiversity is an important goal.

The four IFOAM-principles

The four principles of IFOAM, the International Federation of Organic Agriculture Movements, form the basis for organic agriculture (see Box 1). The principles express the contribution that organic agriculture and the people involved should make to a better agriculture worldwide. They form the guideline for the further development of organic agriculture.

Box 1: The four principles of organic agriculture	
Health	Organic agriculture aims to preserve and strengthen the health of the soil, plants, animals, people and the planet as a whole and indivisible.
Ecology	Organic agriculture should build on, work with, emulate and strengthen living ecosystems and cycles.
Fairness	Organic agriculture should be based on relationships that guarantee justice with regard to the common environment and equal opportunities in life.
Care	Organic agriculture should be practiced in a precautionary and responsible manner to preserve the health and well-being of present and future generations and to protect the environment.

Organic agriculture strives for the production of healthy foods with a careful use of resources.

Economy in harmony with nature, animals and humans

Organic agriculture differs from conventional production in essential aspects. In crop production, organic farming aims at preserving the natural resources on a long-term. In animal husbandry, high animal welfare and lifetime performance are key targets.

Organic processing strives for a gentle transformation of the raw materials to preserve their nutritional value. In order to achieve the best possible quality for organic foods, processors depend on high quality raw materials.

The consistent separation of organic and conventional raw materials and the complete documentation of all operations from the field to the point of sale prevent commingling and contamination of organic with conventional produce.

Table 2: The main principles of organic farming	
Organic agriculture strives for: • Reverence for life • Careful use of resources • Closed farm cycles as much as possible • Preservation and promotion of soil fertility • Great diversity of habitats • Preventive instead of direct plant protection • Species-appropriate husbandry and feeding of livestock • Healthy and robust animals • High-quality food • High acceptance by the non-agricultural population **Organic production and trade pay attention to:** • Spatial separation of conventional and organic seeds and crops at harvest, transport, storage and trade • Trade only through certified companies • Traceability of products along the entire value chain	**Organic producers refrain from:** • Genetically modified seeds or seeds treated with synthetic chemical pesticides • Herbicides • Mineral nitrogen fertilisers • Easily soluble P-, K-, Mg- and trace element fertilisers • Chemical-synthetic plant protection products • Routine use of veterinary medicines • Antimicrobial growth promoters • High performance in crop production and animal husbandry **Organic processors refrain from:** • Additives (wherever possible) • Artificial sweeteners, stabilisers, preservatives, glutamate as flavour enhancer • Colours and artificial flavours • Hardened fats

Legal requirements for organic production

Organic production is legally regulated. Certification guarantees that the requirements defined in the organic regulations are met, from agricultural production to processing and marketing.

State and private organic regulations

The requirements for organic production are defined in international (e. g. EU regulations), state (e. g. Swiss organic regulations) and private regulations (e. g. Bio Suisse, Bioland, Demeter). The respective requirements must be met for organic certification.

The international and state organic regulations are strongly influenced by the IFOAM basic standards as well as the recommendatory guidelines of the Codex Alimentarius (collection of standards of the United Nations). The legal basis for organic agriculture in Europe is the EC Organic Regulation, which came into force in 1993 and has been amended and revised several times since then. The current Regulation (EU) 2018/848 is dated May 30, 2018, and comes into force in January 2022. The regulation applies in all EU countries and acts as the central reference regulation for other European countries, especially in Eastern Europe.

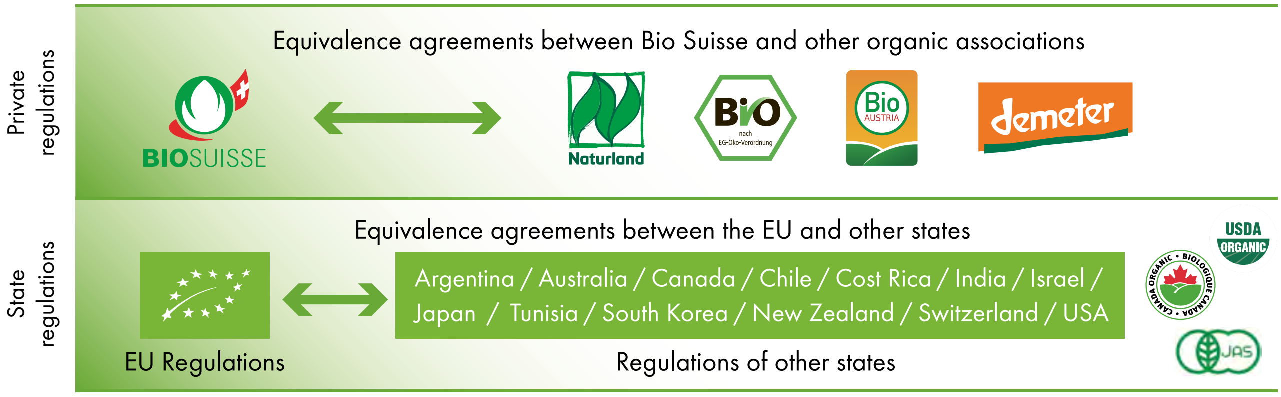
The requirements under private law are set by the various organic farming associations, which also act as private label organisations. To facilitate mutual market access of organic products, there are agreements among organic farming associations that garantee that these standards are equivalent (see Figure 6 and Box 2 on page 10).

Protection of the terms ‘organic’ and ‘ecological’

All organic regulations and codes protect the terms ‘organic’ and ‘ecological’ – including their abbreviations ‘Bio’ and ‘Eco’ – in a range of variants and languages. Accordingly, these may only be used for products for which the organic standards have been met in production, processing and trade.

Compliance with the standards is controlled by accredited certification organisations with announced and spontaneous inspections.

Figure 6: State and private regulations and equivalent standards on organic farming



The governmental regulations define the legal minimum requirements for the certification of organic food. The private law standards distinguish themselves through higher requirements. Some labels have agreed that their products are considered equivalent..

Policy differences and equivalence

The private organic standards that were developed in different countries are generally stricter than the state requirements. They position themselves on the market promising higher sustainability, higher animal welfare and higher food quality standards for consumers. The members of these label organisations rely on this promise to better market their products.

The stricter requirements of the private labels are based on the following differences to the EU organic regulation (for details, see pages 46 and 47):

- **Overall farm management:** organic management of all farm branches and units.
- **Stricter animal husbandry regulations:** compulsory grazing for ruminants, limited proportion of concentrated feed in the total feed ration, restrictions on permissible conventional feed components.
- **Biodiversity:** designation of a certain percentage of the farm area for the promotion of biodiversity, production measures which promote biodiversity.
- **Social responsibility:** compliance with minimum social requirements in the working conditions of employees.

Producers who want to sell their products in different markets with different labels must be certified for several organic standards. Many certification organisations are therefore accredited for several standards. Producers can thus gain access to different target markets with affordablee additional costs.

Box 2: Simplified label certification thanks to equivalence agreement

Within Europe, some label organisations have similar technical requirements for the cultivation of food. Therefore, they have concluded so-called equivalence agreements among themselves. This means that products that have been certified for a particular label are also certified for other ‚equivalent' labels. However, this procedure only applies to products that have been sourced in the country in which the label organisation is based. For example, Naturland-certified goods from Germany are considered equivalent in Switzerland under the equivalence agreement with Bio Suisse. In contrast, Naturland-certified products from countries other than Germany must be additionally inspected and certified by a certification organisation accredited by Bio Suisse in order to be marketed with the Bio Suisse label. Such a post-certification causes additional costs for the producers in the country of origin and for the importers.

Soil fertility as the basis of organic production

The soil as a living system

Weakened and degraded soils cannot produce good yields in organic farming. Organic farmers therefore depend on good natural soil fertility.

Many soil processes depend on the activity of soil organisms and can vary greatly due to the composition of the organism populations and the conditions in the soil. Soil organisms promote the decomposition and transformation of crop residues into organic fertilisers, mix the soil, and contribute to the formation of a good soil structure. . By doing so, they regulate pathogens in and on the soil. These processes release minerals and nutrients that plants need for growth. At the same time, stable humus compounds are built. They are important nutrient and water stores, and contribute to a stable soil structure.

Through the lens of organic agriculture, soil fertility is primarily the result of biological processes – in contrast to conventional agriculture, where ‚soil fertility' depends heavily on the external supply of plant nutrients in mineral form. In organic farming, the focus is not primarily on the soil's nitrogen, phosphorus and potassium contents, but on an elevated humus content and a high biological activity in the soil that makes nutrients available to the plants through natural decomposition of soil organic matter.

The natural biological processes in the soil contribute to balanced plant growth and resistant plants. A humus-rich and biologically active soil is easy to work, absorbs rainwater well thanks to its porous structure, and is robust against silting and erosion. A fertile soil is also an efficient reservoir of excess nutrients and CO_2. Healthy soils thus prevent the euthriphication of water bodies and contribute to the reduction of greenhouse gases and thus global warming.

An active, humus-rich soil is of central importance for organic production.

A fertile soil …

- produces high quality yields appropriate to the location,
- efficiently converts nutrients into yields,
- maintains an active and diverse soil flora and fauna,
- closes the nutrient cycles through undisturbed decomposition and transformation of plant and animal residues,
- restores a healthy balance after ‚disturbances' such as disease, heavy rainfall or inappropriate tillage,
- can efficiently retain or break down pollutants,
- stores nutrients, water and CO_2 well,
- minimises erosion by water and wind.

Table 3: Processes in the soil promoted by soil organisms

Biological decomposition	Dissolution processes at the source rock by metabolic products.
Microstructure / crumb formation	Mixing of organic substances with mineral soil particles to form stable clay-humus complexes.
Aggregate formation	Consolidation of soil particles and increase of crumb stability.
Mineralisation	Decomposition and degradation of organic substances to inorganic compounds, which become available again as nutrients for plants.
Humification	Conversion of dead organic matter into stable humus complexes that improve soil structure and fertility.
Nitrification / Denitrification	Binding and conversion of nitrogen.

Box 3: Earthworms as builders of fertile soils
With a lifespan of 5–8 years, earthworms are the longest-lived soil animals. They play a central role in building soil fertility in different ways:

- They feed on dying plant debris and excrete the so-called worm castings, a nutrient-rich clay-humus mixture. Worm castings contain on average 5 times more nitrogen, 7 times more phosphorus and 11 times more potassium than normal soil.
- Earthworms produce 40 to 100 tons of valuable worm castings per hectare per year in Central European soils. This corresponds to an annual soil growth of 0.5 cm in fields and up to 1.5 cm in meadows.
- Worm castings form stable crumb structures that help soil become less silted, are easier to work, and better at retaining nutrients and water. For example, earthworms make heavy soils looser and sandy soils more cohesive.
- Earthworms work up to 6 tons of dead organic material into the soil per hectare per year in the field. At the same time, they transport soil material from the subsoil to the topsoil, keeping it young.
- Earthworm channels improve the absorption and storage of water and ensure good aeration of the soil. Earthworm-rich soils absorb 4 to 10 times as much water during heavy rains as soils with smaller earthworm populations.
- Earthworms promote the colonisation and reproduction of beneficial soil bacteria and fungi in the channels and castings. After infested foliage is moved into the soil, leaf-dwelling harmful organisms are biodegraded.
- Over 90 percent of earthworm channels are colonised by plant roots, which not only promotes root growth but also dramatically improves plant access to nutrients and water.

The skim plough is the simplest form of gentle soil cultivation.

The clay-humus components and mucilaginous substances in earthworm castings improve the soil's structure and cohesion.

Active promotion of the soil organisms

The revitalisation of the soil is a core concern of organic farming. Accordingly, management practices that promote a greater diversity of soil organism populations are essential. This includes the supply of suitable ‚food' from crop residues, perennial clover-grass meadows, green manures, and catch crops. Soil organisms are also enhanced by the use of rotted manure or compost.

Shallow cultivation of the soil without turning, rotating or compacting promotes soil structure and is especially gentle on the larger soil organisms such as earthworms.

Gentle and effective tillage

Intensive tillage has increased rates of erosion and led to the loss of around 30 percent of arable soils worldwide over the past 40 years. Organic farmers instead try to avoid intensive tilling practices, aiming to work the soil as gently as possible. Intensive and deep mixing of the soil with reversible ploughs and tillers, combined with heavy machinery and tractors is avoided.

Ideally, organic tillage aims to maintain the natural stratification of the soil as much as possible, turning only the topsoil, to promote soil fertility. In case of soil compaction, the subsoil is deeply loosened (see Box 4).

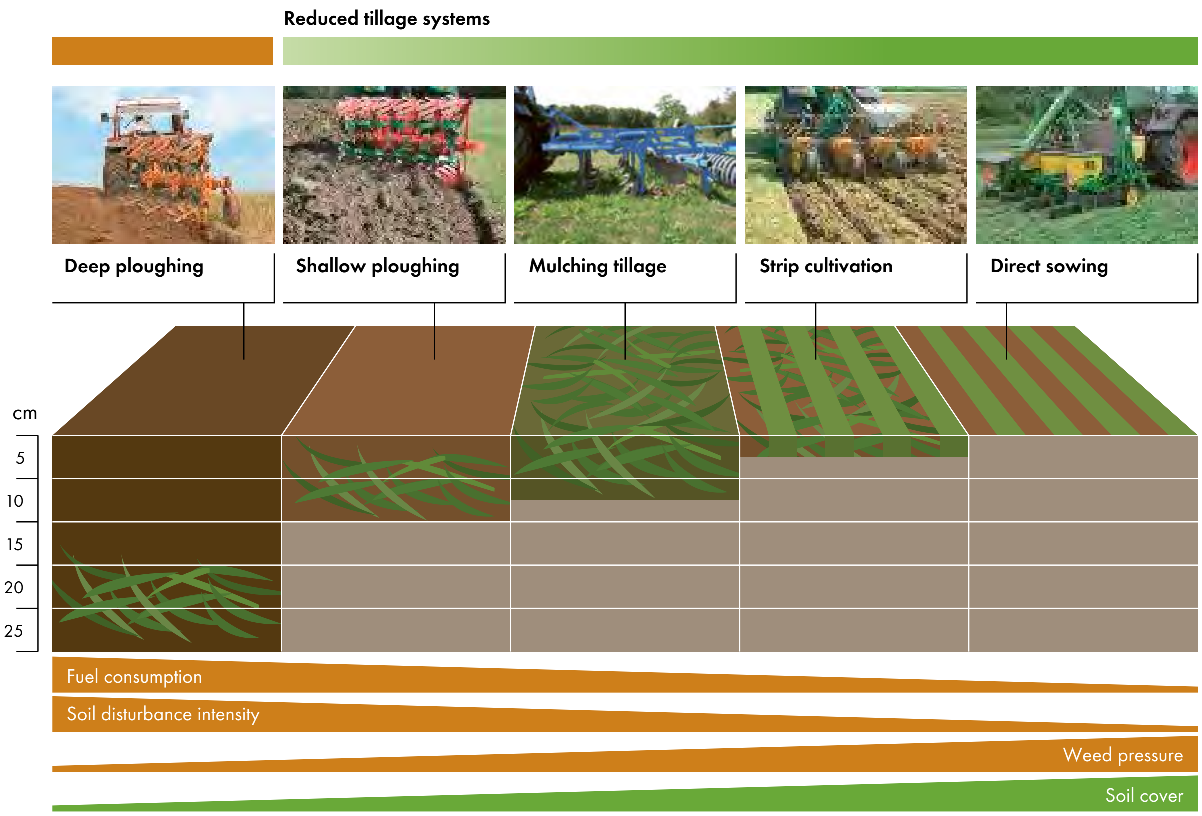
Depending on the soil and crop rotation, different implements are available which can be used. So far, the following devices and techniques have proven successful:

- **Incorporation of crop residues with the disc harrow or a skim plough:** stubble cultivation with a high area performance.
- **Mulch sowing after cereals, silage maize or oilseed rape:** under dry conditions, one or two surface stubble cultivations with the cultivator, disc harrow or skim plough (‚Stoppelhobel') and sowing of cereals, oilseed rape and mixed grain-legume crops.
- **Ley termination with a shallow cultivator with goosefoot blades in two passes:** suitable in heavy soils and dry conditions; very shallow, full-surface peeling of the sward; 1st pass 3–4 cm deep, 2nd pass 6–7 cm deep.

Box 4: Soil tillage – what to look out for?

- To avoid soil compaction, tillage should only be carried out on well-dried, load-bearing soil, and the use of heavy machinery should be avoided. If heavy machinery must be used, it needs to have double tires or be equipped with balloon tires or tracks.
- Ploughing and high speed rotating equipment should be used with reservations, since they kill many earthworms, especially in spring and autumn (ploughing kills about 25 %, rotating equipment up to 70 %!) and destroy the soil structure. Working the soil in dry and cold conditions damages the earthworms much less, as they stay in deeper soil layers under such conditions.
- If possible, the soil should be tilled only superficially so as not to bury fresh organic matter in deep soil layers. Depending on the soil type, the soil condition and the crops grown, different implements should be used. Skim ploughs such as the ‚Stoppelhobel' undercut the crop cover over the entire surface, but do not turn or mix the topsoil. Stubble ploughs undercut and mix the top layer of the soil, but do not invert it. The rotary plough turns the soil and thus works in crop residues and weeds well.

Figure 7: Reduced tillage systems in comparison to conventional tillage



Source: American Society of Agricultural Engineers, Cooper; adjusted by FiBL.

This flat cultivator undercuts the crop with overlapping goosefoot shares over the entire surface and only minimally mixes the soil. This soil-friendly implement combination is particularly suitable for basic soil cultivation on fields with few weeds after crops with little crop residue (e. g. between two cereal crops).

Soil structure and humus building

A high soil humus content is of central importance for soil fertility. A decrease in humus content leads to poor soil structure that is prone to compaction, has a lower water absorption capacity and nitrogen supply potential.

An increase in humus content, on the other hand, results in a more biologically active and crumbly soil with a pH in the neutral range, generally better nutrient availability, and higher nitrogen supply.

The effects of humus depletion due to unsustainable management are usually only noticeable after several years. Accordingly, building humus in soils takes years. The fastest way to increase humus content is by adding green manure or manure compost. Perennial leys, implemented as part of a humus-enhancing crop rotation, are of great importance in a medium and long term (see Table 4).

Table 4: How to increase humus content in the long term and increase the nutrient supply in the short term?

Green waste and manure compost: Provide stable humus compounds that mostly resist decomposition.	Humus buildup: ●●●● Nutrient supply: ●
Woody crop residues: Promote lignin-degrading, slow-growing soil fungi that add diversity to soil flora.	Humus buildup: ●●●● Nutrient supply: ●
Perennial clover grass: Provides considerable amounts of easily degradable root mass for earthworms and microorganisms and for humus buildup.	Humus buildup: ●●● Nutrient supply: ●●●●
Green manures: Form large amounts of more or less easily degradable biomass, can store nutrients, fix atmospheric nitrogen (legumes) and make it plant-available. Perennial green manures significantly foster humus buildup.	Humus buildup: ●● Nutrient supply: ●●●
Reduced tillage: Increases humus content in topsoil, promotes biological activity and good soil structure, thereby essentially increasing the soil's water retention capacity.	Humus buildup: ●● Nutrient supply: ●

● low impact ●●●● high impact

Crop rotations: optimising short- and long-term goals

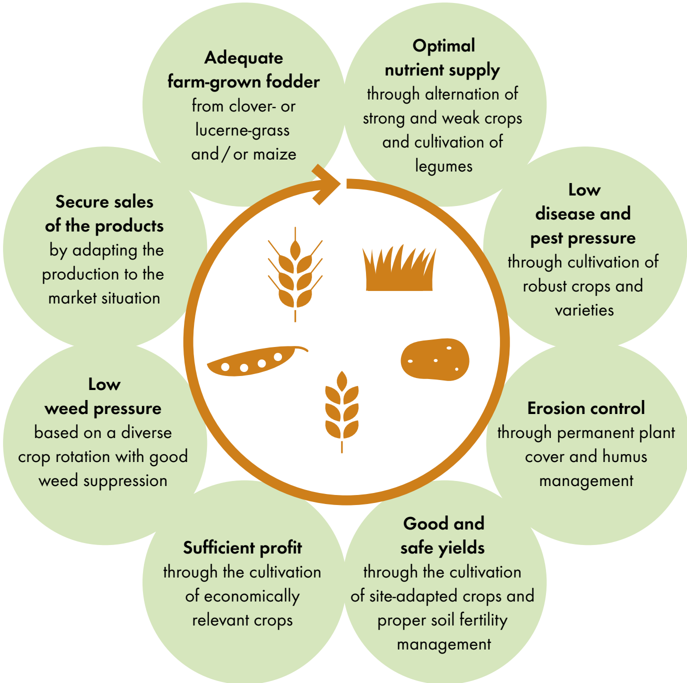
Crop rotations play an improtant role in organic farming. They must pursue short-term goals and ensure healthy and productive soil in the long term.

The functions of crop rotations are (see Figure 8):

- **Maintain soil fertility:** A balanced crop rotation is the key to healthy soil development. It must include humus-building crops such as clover grass, lucerne, green manures and / or grain legumes.
- **Provide nutrients for subsequent crops:** Pure legume seeds or mixtures in main or catch crops and undersown crops can provide large amounts of nitrogen for subsequent crops.
- **Containing weeds:** Dense and tall-growing crops – especially perennial crops such as clover-grass – can effectively suppress weeds. In the rotation, they ideally preceed weed-susceptible crops. The farther a crop is positioned from clover-grass, the better its competitiveness against weeds must be. Alternating between summer and winter crops prevents one-sided weeding with spring or fall germinators.

- **Regulation of diseases and pests:** To avoid soil-borne diseases and pests, classic crop rotation rules must be followed. Although legumes are the most important nitrogen suppliers in organic arable farming, their share should not be too high, otherwise the risk of legume fatigue increases (see page 18 for more details).
- **Protection against erosion:** Especially on slopes or in silty or sandy soils that are prone to erosion, the soil should be planted as continuously as possible.
- **Generating long-term profit:** Cultivation of site-appropriate crops with good yields and attractive producer prices at low production costs is important for generation of income. An unbalanced orientation of the crop rotation based on short-term economic criteria can have a negative impact on the yield capacity of the soil on the long run.
- **On-farm fodder production:** Livestock farms should produce as much own and high-quality fodder as possible. Field forage production should make up at least one-sixth of the crop rotation. Clover- or lucerne-grass mixtures are ideal. Grain-legume-cereal mixtures are suitable for the production of concentrated feed.

Figure 8: Goals of crop rotations design on organic farms

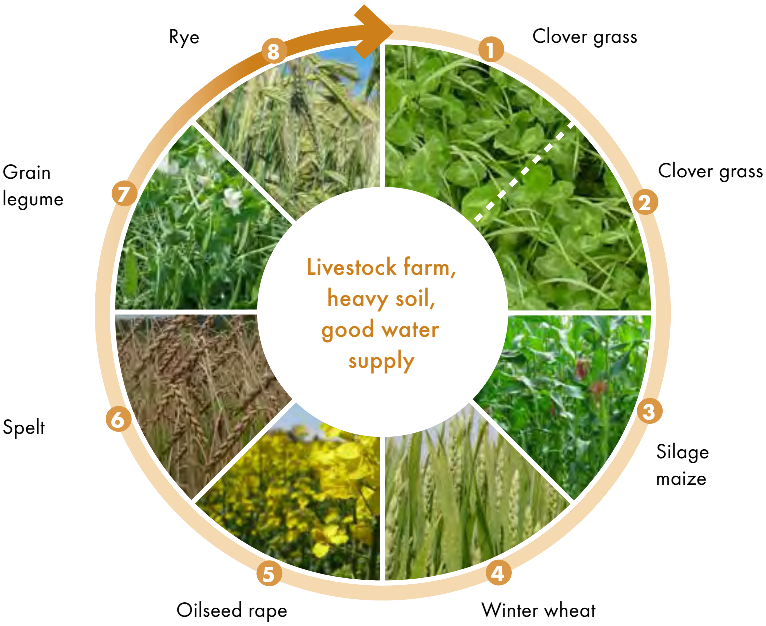


Nitrogen-fixing legumes, for example in clover-grass mixtures as shown, are essential in organic crop rotations to maintain reasonably high yield levels.

Box 5: Basic rules for crop rotations on organic farms

- At least 20 % permanent legume-grass mixtures to promote soil fertility and suppress weeds. For effective suppression of root weeds, clover- or lucerne-grass mixtures are generally necessary for 2 or 3 primary crop seasons.
- Not more than 50 % cereal crops to prevent soil-borne cereal diseases.
- At least 1 year break before replanting the same crop. At least 1 year between wheat, spelt and barley; 2 years between rye, and 3 years between oats (oat cyst nematodes), 2 years between maize, more than 4 years between potato, and oilseed rape; 6 years between sunflower. Between legumes the intervals range from 2 years between soybeans to 6 years between protein peas. In vegetable production, the recommended interval between 2 main crops of the same family with more than 14 weeks standing time is at least 24 months.
- Alternation between root crops and grain legumes on the one hand and root crops and cereals on the other hand.
- Combination of humus-producing and humus-depleting crops to permanently maintain soil fertility.
- Alternating between winter and summer crops and early and late sowings to keep soil-borne diseases and problem weeds under control.
- Soil cover in winter to prevent nutrient loss and erosion.
- Growing catch crops to build up nutrients in the soil, protect against soil erosion, and improve the farm's own forage base.

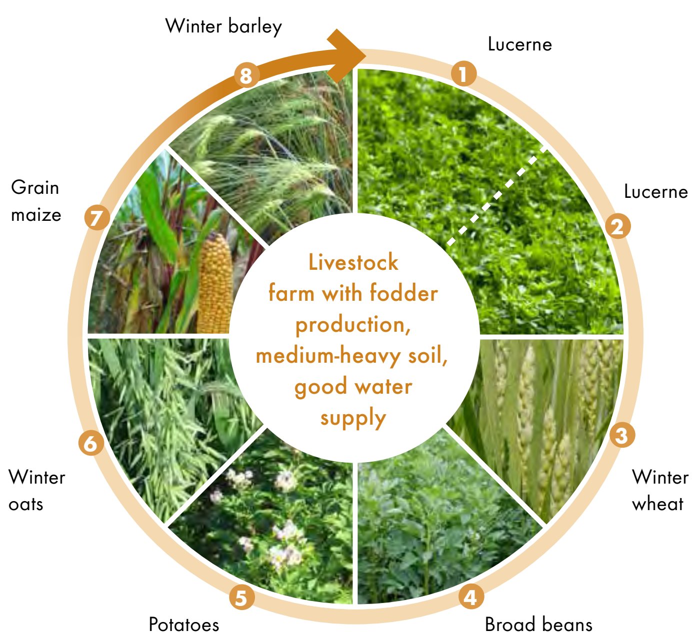
Crop rotations examples for Central Europe



Comments

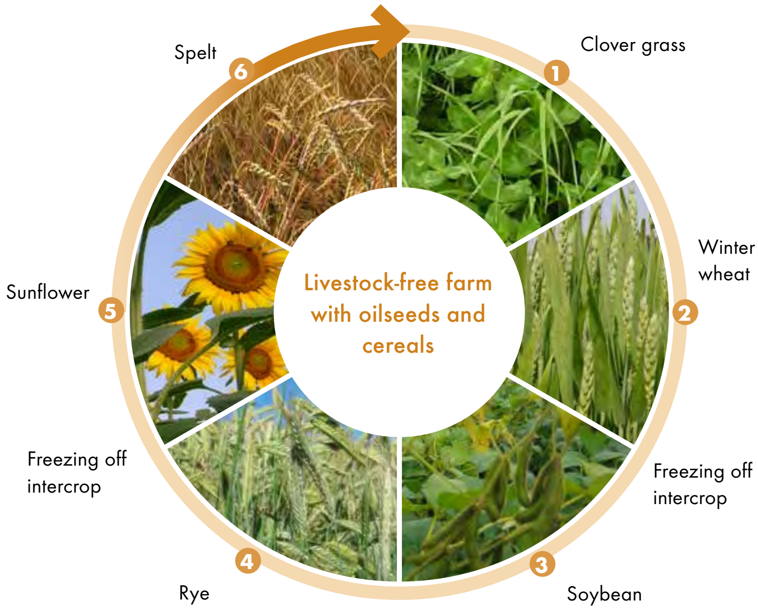
- Good weed suppression thanks to 2 years of clover grass.
- Alternating summer and winter crops prevents unilateral weeding.
- The nutrient-demanding crops winter wheat and silage maize / grain maize come after clover grass, while the less nutrient-demanding crops spelt, sunflower and rye tend to be grown at the end of the crop rotation.
- The cultivation of catch crops contributes to a continuous soil cover.
- The mixed crop grain white pea-barley is ideally grown as a winter crop.

Alternative crop rotation
Clover grass – Clover grass – Winter wheat – Green manure or intercrop – Grain maize – Spelt – Green manure – Sunflower – Rye



Comments

- Alternating summer and winter crops prevents unilateral weeding.
- If there is no demand for animal feed, lucerne can be replaced by green manure or exchanged with a livestock farm for farmyard manure.



Comments

- Crop rotations on livestock-free farms are usually shorter than on livestock farms because of the smaller choice of crops.
- Crops with a high nitrogen requirement and low value added, such as oilseed rape, are rarely grown on livestock-free farms because they rely on relatively expensive organic commercial fertilisers.
- Soybean, unlike protein peas or field beans, leaves virtually no nitrogen in the soil for the following crop.

Central role of legumes in crop rotations

Promoting soil fertility

- Legume-grass mixtures, especially perennial clover and lucerne-grass mixtures, are essential for building humus. With these crops, the soil comes to rest. Legume-containing green manures also promote soil structure.
- The longer the legume-grass mixtures' growing season is, the higher their preceding crop value for the following crop.
- Grain legumes have a lower humus-building effect and supply less nitrogen than legume-grass mixtures.
- Dense legume-grass mixture stands are very effective at suppressing seed and root weeds. Three-year-old, intensive legume-grass mixtures also suppress thistles effectively.
- Short-stand duration green manures suppress seed weeds in particular.

Binding atmospheric nitrogen

- Legume crops can add more than 100 kg of atmospheric nitrogen to the soil per hectare per year. However, the legumes provide different amounts of nitrogen to the following crop. While grain legumes such as soybean use the fixed atmospheric nitrogen mainly for their own growth and grain formation, clover-grass meadows accumulate large amounts of nitrogen in the soil, being available in the short and medium term. How much nitrogen is available to the following crop, depends on the composition and the age of the mixture, the time of incorporation, the biological activity of the soil, the soil properties and climate. At soil temperatures below 10 °C, the mineralisation of nitrogen is very slow; at 22 °C mineralisation is highest.

Dissolving nutrients in the soil

- Green manure plants and deep-rooted legumes can use their extensive root systems to dissolve nutrients such as potassium, magnesium, and phosphorus in deeper soil layers and bring them to the crop's root region.

Loosening the soil

- Lucerne is effective at rooting through the soil to a depth of up to 3 meters. With its taproot, it can break through compacted soil horizons, thereby increasing the soil's rootability and improve water infiltration.

As soon as the legumes sprout from the soil, nodule bacteria form on the roots, fixing atmospheric nitrogen. With the onset of the reproductive phase, their development ends.

Lucerne is both an excellent forage crop and a valuable preceding crop, providing up to 250 kilos of nitrogen per hectare for the following crop. Its deep roots help to access nutrients in deeper soil layers while improving soil structure.

To avoid legume fatigue, recommended cultivation breaks between legumes must be maintained.

Legume fatigue as a challenge

Effects of legume fatigue

In arable farms, the cultivation of legumes is very important. However, frequent cultivation of grain and forage legumes can cause legume fatigue, a special type of soil fatigue. Legume fatigue is noticeable in legumes through growth depression and yield reduction. This has detrimental effects on the entire crop rotation:

- **Reduced nitrogen fixation capacity:** Reduced nitrogen supply leads to yield and quality losses.
- **Spread of weeds:** Weakly developed legume stands are infested more with weeds. This has a negative impact on the entire crop rotation.
- **Reduced forage production:** Lower legume growth and nitrogen fixation result in lower roughage yields. These can lead to feed shortages on livestock farms.

Causes and measures

Legume fatigue is a complex disease with various causes. It is usually a combination of soil-borne pathogens, poor soil structure and nutrient deficiencies. Because direct control of legume fatigue is not possible, it is important to prevent its development. The complexity of the causes of legume fatigue often requires expert advice to correct the problem. The most important measures to prevent legume fatigue are:

- **Cultivation breaks:** Recommended cultivation breaks to the crop itself and to other grain legumes must be observed. Cultivation breaks can be 3–6 years.
- **Variety selection:** If possible, use hardy varieties recommended for the region. For example, certain field bean and pea varieties have greater tolerance to foot diseases.
- **Use healthy seed:** Use certified seed whenever possible to eliminate the import of seed-borne diseases.
- **Promote rapid youth development:** Wait for favourable soil conditions for sowing, i. e. dried soil and sufficient warm temperatures, no heavy precipitation causing silting and crusting of the soil surface. Select a sowing depth adapted to the crop type and location for rapid emergence. Promptly break up encrusted and silted soil surface with a harrow.
- **Organic fertilisation:** Organic fertilisers stimulate soil microbial activity, which promotes rapid decomposition of crop residues and pests attached to them.
- **Favourable pH and nutrient supply:** A pH of 6 to 7 is optimal for microbial nitrogen fixation. At pH levels below 6, nitrogen fixation by nodule bacteria is inhibited. In addition to a good supply of phosphorus, iron and sulphur, a good availability of micronutrients such as molybdenum, copper, boron and nickel is essential. Yet, balanced soils normally supply these nutrients in sufficient amount.

Humus build-up through good crop rotation planning

Humus is the actual nitrogen store of the soil. Targeted humus management to maintain and increase the soil's humus content is of central importance for proper nutrient supply of organic crops.

The greatest contribution to humus build-up is made by perennial legume-grass mixtures as part of the crop rotation. Catch crops, green manures and most grain legumes, such as soybeans and peas, contribute to a lesser extent to humus build-up.

Balanced nutrient supply from organic sources

Organic nutrient sources instead of synthetic mineral fertilisers

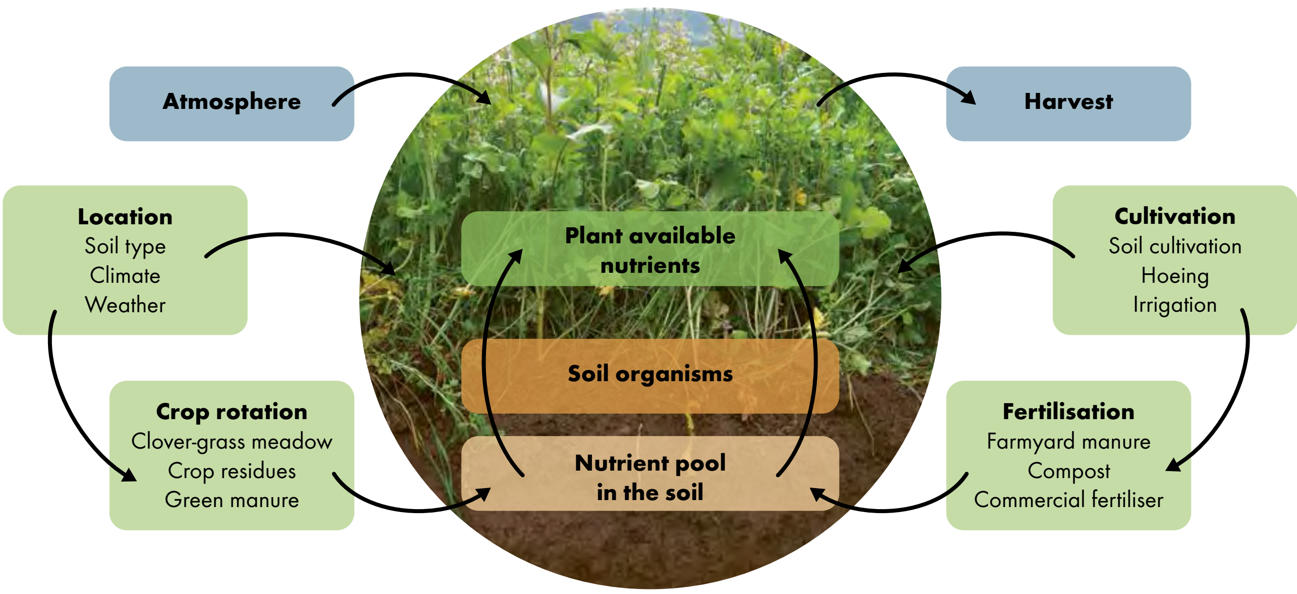
A good nutrient supply to crops is just as important in organic farming as in conventional farming. However, the supply of nutrients in organic farming differs fundamentally from that in conventional farming. Whereas in conventional agriculture, plant-available nutrients are mainly supplied in a mineral form, organic farming supplies nutrients mainly in a natural, organically bound form, as it is found in crop residues, farmyard manures, composts and green manures. Thus, organic farming supplies the nutrients through the soil, which promotes a more balanced supply of the nutrients based on the needs of the plants (see Figure 9). Small nutrient balance deficits, common on organic farms, are normally supplemented from soil nutrient stores and do not require additional fertiliser applications.

Soil microorganisms as fertilisation drivers

Organically bound nutrients must be mineralised so that the plants can absorb them. Soil microorganisms are primarily responsible for the mineralisation process. However, they not only mineralise organically bound nutrients, but also dissolve nutrients from the parent rock and, in some cases, bind nitrogen from the air (see page 17). For their part, plants promote microbiological activity in the root sphere by actively excreting energy-rich substances.

In contrast, when crops are fertilised with mineral fertilisers, the soil organisms are bypassed. As a result, their number and diversity in the soil decrease, which has negative effects on soil structure and the regulation of harmful organisms in the soil.

Figure 9: Plant nutrition via the soil



In the logic of organic agriculture, soil fertility is mainly the result of biological processes, not added mineral nutrients. Soil organisms play a central role in the biological system. They convert crop residues, root excretions, organic fertilisers and other organic substances from the 'nutrient pool in the soil' into humus and into mineral nutrients available to plants.

Making optimal use of on-farm nutrient sources

Farm manure, compost and other organic fertilisers contribute nitrogen and other nutrients to crop rotation in the short, medium and long term – depending on their C / N ratio (see Box 7).

In organic farming, legumes are at least as important as farm and commercial fertilisers as net suppliers of nitrogen. Tillage and mechanical weed control stimulate nutrient mineralisation in the soil and thus also supply nitrogen to crops.

However, due to the different nutrient sources and the complex biological conversion processes, estimating the nutrients available to crops is more difficult in organic farming than in conventional agriculture.

Avoiding nutrient losses

Nutrients stored in the soil are the fuel for plant growth and good yields. On many organic farms, the amounts of nutrients available to feed crops are low. In particular, the availability of nitrogen limits the yields on many farms.

Good nutrient management starts with avoiding nutrient losses through erosion, leaching, and gaseous losses. Nutrient losses are particularly relevant for nitrogen, which is essential not only for plant growth, but also for soil organisms – and thus for overall soil biological activity.

Important measures to prevent nutrient losses are:

- Maintaining a permanent soil cover in winter.
- Undersowing crops with cover crops.
- Low-loss storage, preparation and application of farmyard manures and waste fertilisers.
- Appropriately timed tillage and fertilisation.

Crop residues incorporated into the topsoil provide essential nutrients to soil microorganisms. An increased activity of the soil organisms promotes soil fertility.

Table 5: Important nitrogen sources of different farm types

	Grassland farm	Mixed farm	Arable farm without livestock	Vegetable farm
Manure from the farm	●	●		
Supply of farm manure / compost			○	○
On-farm compost production		○	○	○
Commercial organic fertilisers			○	●
Permanent meadows	●	○		
Leys		●	○	○
Green manures		○	●	○
Grain legumes		○	●	

● Main source of nitrogen ○ Supplementary nitrogen source

The use of foreign manures is treated differently in different organic regulations.

Good nitrogen management

Nitrogen is the most critical plant nutrient driving growth. The amount of nitrogen available to crops from humus depends largely on soil content, soil temperature, soil moisture, soil aeration, and especially on the C / N ratio of organic nutrient sources (see Box 7).

Warm, well-aerated soils with sufficient moisture are needed for optimal mineralisation of nitrogen by soil microorganisms. In contrast, low temperatures, drought, compaction, or waterlogging of the soil impede mineralisation of organically fixed nitrogen.

In dry conditions, irrigation can stimulate mineralisation. If the subsoil is compacted, mechanical deep loosening under dry conditions can improve soil aeration. However, loosening should ideally be complemented by seeding perennial deep-rooting plant species such as lucerne.

Under favourable conditions, loosening the topsoil with a harrow or hoe stimulates the soil's mineralisation process. Mineralisation of 15–25 kg N per hectare can be expected per hoeing pass. Hoeing can thus achieve a comparable effect to a single application of fertiliser.

Supplement nutrient supply

Supply of farm fertilisers

Farms with nutrient-poor soils, or arable and vegetable farms with high nutrient exports, often rely on added nutrients to ensure long-term yields. Arable farms traditionally use farm manures. Livestock-free arable and vegetable farms use commercial fertilisers, when animal manures are not available. Where the basic requirements for phosphorus and potassium can be met with farm manures and compost, commercial fertilisers play a role mainly for nitrogen supply.

Manure and compost are primarily basic fertilisers for phosphorus and potassium and suppliers of organic matter. Unlike manure, some of the nitrogen in slurry is rapidly available to plants. Slurry is thus well suited for short-term nitrogen fertilisation or as a top dressing in crops with a long growing season.

While the current EU organic regulation allows the supply of manure, slurry and dung from conventional livestock farming if these do not originate from industrial livestock farming (max. 2.5 LU per hectare, pig farming not predominantly on slats, no poultry farming in cages), the new EU organic regulation 2018/848, which comes into force on 1.1.2022, stipulates that farmyard manure must originate from organic production and should preferably be composted.

Use of commercial fertilisers

Commercial fertilisers are used to supplement or replace farm fertilisers from locally available sources. All commercial fertilisers used in organic production must meet the requirements of organic agriculture regulations, and be listed in applicable input lists (see page 24).

Box 6: Restricted nutrient use

To avoid environmental problems, the EU regulation (Directive 91/676/EEC) limits the total amount of applied farm manure of animal origin to a maximum of 170 kg of nitrogen per year and hectare of agricultural land. This limit applies to manure, dried manure and poultry manure, compost from animal excrements, and liquid animal excrements. Organic fertilisers from other sources than animal-manures can be used to cover the nitrogen need of crops that require more than 170 kg N per hectare (e. g. high yielding green-house crops).

Most important organic fertilisers

Manure and slurry from livestock farming as well as composts and green manure chippings from crop production are the most important organic fertilisers in organic farming. In certain countries, fermentation substrates from biogas plants are also increasingly used.

The organic fertilisers affect the soil with different qualities:

- **Slurry** contains very different levels of nitrogen depending on its origin (animal species), housing system (e. g. for cows: tie stall or loose housing) and dilution. The availability of the nitrogen contained can also vary greatly. Urea manure contains the most available nitrogen (slightly more than full manure), but should be diluted with water at a ratio of 1 : 3. Slurry is particularly well suited for targeted nitrogen applications in arable and forage crops. But slurry contributes little to humus buildup.
- **Manure** can vary greatly in quality, depending on the animal species and storage. For soil structure and yield formation, rotted and composted manure are clearly better than fresh or piled manure. To improve plant tolerance of manures through (partial) decomposition, they are stored temporarily at the edge of a field or on the manure slab, and turned a few times.
- **Compost** contributes the most to soil structure of all organic fertilisers. However, young composts containing much lignin can lead to nitrogen blockage in the soil due to a high C/N ratio (see Box 7). Supplemental fertilisation with manure or another readily available organic nitrogen source can reduce this risk.

Manure and green waste can be turned into valuable compost in a controlled rotting process at the edge of fields along pathways.

Table 6: Properties of the main organic fertilisers

Features	Manure	Slurry	Compost	Digestate
Nutrient composition	Balanced (cattle) P-rich (poultry)	K-rich (cattle) P-rich (pig)	P-rich	Liquid: very N-rich Solid: N-rich
N-availability / N-efficacy	Slow / long	Fast short	Manure compost: good / medium Green waste compost: low / long	Liquid: short / short Solid: short; long, if composted
Suitability for top dressing	Poor	Good	No	Good
Soil improvement	Yes	No	Yes	Liquid: no Solid: yes, if composted
Most important fields of application	Root crops, vegetables, grassland	Grassland, cereals, spring crops with high N demand	Vegetables, cabbage, potatoes, maize, cereals, oilseed raps, sugar beets, legumes, grassland	
Distribution accuracy	Good (with fine spreader)	Good (with drag hose)	Good (with fine spreader)	Liquid: good (with drag hose) solid: good (with fine spreader)
Transportability	Good (more difficult on slopes)	Short distances good	Good (more difficult on slopes)	Short distances good

The humus-like compost is an excellent soil conditioner.

- **Digestate or liquid manure** contains a lot of ammonium (NH_4), which readily escapes as ammonia (NH_3) when it dries. Therefore, liquid manure should only be applied to absorbent soil in cool and damp weather with little or no wind, and incorporated superficially into the soil quickly. Solid digestate can be post-rotted to turn it into high-quality compost. However, fertilisation with digestate is only permitted under restrictions in organic farming (see also Annex 1 EU Reg 889-2008).

Organic commercial fertilisers

The use of commercial fertilisers is common, especially in organic vegetable production, to meet the nutrient needs of very demanding crops. In organic arable crops, the use of commercial fertilisers was originally justified only for crops with a high yield. Yet, price reductions for commercial biofertilisers in industrialised countries have made their use interesting also for traditional market crops such as maize, potatoes, cereals and field vegetables as a supplement to farm fertilisers and green manures.

In potato cultivation, additional yields of 10 to 30 percent can easily be achieved with commercial fertilisers. In addition, the use of commercial fertilisers results in a reduction of scab and dry core on potatoes – and thus to a higher product quality – compared to fertilisation with manure and slurry. Furthermore, commercial fertilisers are of versatile use and can be applied cost-effectively. Due to frequent nitrogen deficiencies, organic nitrogen fertilisers are used the most. However, the use of commercial fertilisers neglects the principle of a closed nutrient cycle in organic farming.

Box 7: Correctly assessing nitrogen in organic fertilisers
The nitrogen effect of a fertiliser depends not only on its nitrogen content, but also on the ratio of carbon to nitrogen (C/N ratio). Manure has a C/N ratio of about 7, compost of 10 to 20, straw of 50 to 100.
Up to a C/N ratio of about 10, mineralisation of nitrogen is fast. As the C/N ratio increases, mineralisation slows down and the contribution to humus buildup increases. At a C/N ratio above 25, organic fertilisers remove nitrogen from the soil for their own decomposition, thus competing for nitrogen with the crops. Therefore, very straw-rich manure and other organic materials with a high C/N ratio should be composted before use.
The rate of nitrogen uptake by crops also depends strongly on the general availability of nitrogen in the soil. This depends, among other things, on the temperature and moisture of the soil, the diversity and vitality of soil life, and the supply of nitrogen from root exudates of legumes.

Organic commercial fertilisers are versatile and can be used in a targeted manner, making them particularly interesting for crops with special nitrogen supply requirements.

Nitrogen-rich commercial fertilisers in organic farming can be divided into three groups:

- **Organic commercial fertilisers of animal origin:** hair meal pellets, horn products, feather meal, meat bone meal.
- **Organic commercial fertilisers of plant origin:** vinasse, potato fruit water and concentrates, residues from maize processing, mashes, malt culms (Maltaflor).
- **Other organic fertilisers:** legume fertilisers, biosol, hydrolysates.

Fertilisers and soil conditioners allowed in organic farming in Europe are listed in Annex I of the EU Organic Regulation. Yet, private organic standards have additional restrictions on the use of fertilisers. The use of fertilisers is also subject to national legislation.

FiBL's European Input List at www.inputs.eu features information on all products that comply with the rules for organic production.

Box 8: Problem of phosphorus deficiency

On farms without nutrient inputs, phosphorus can become limiting in crops with high P requirements, such as cereals and maize. Feeding manure or compost can replace the use of rock phosphate when phosphorus is deficient. Growing legumes and promoting the activity of soil microorganisms can also mobilise larger amounts of phosphorus bound in the soil.
Farms that suffer from phosphorus deficiency despite a balanced phosphorus balance in plants or animals often have a high soil pH. When the pH is high or very low, phosphorus uptake by plants is impeded. If the pH is too high, technical production measures such as not using lime-based fertilisers and applying cattle or digestate manure can help to lower the pH.

Box 9: Regulations and lists of allowed inputs

Which inputs are permitted in organic production depends on various sets of regulations:

- **National legislation in the country of origin:** In the country of production, only inputs that are permitted or not prohibited under national legislation may be used. In countries with legislation on organic agriculture, the use of inputs is regulated in separate ordinances.
- **National legislation in the importing country:** If organic products are exported, they must also comply with the regulations in force in the importing country. This applies to the use of critical inputs that are subject to national bans, but also to conformity with government organic regulations (e. g. EU organic or NOP).
- **Private organic regulations:** If certification for a private organic label (e. g. Bioland, Naturland, Bio Suisse) is sought, their regulations must also be complied with.

All regulations and private codes have their own lists of inputs, which list the excipients that are allowed. The farm input lists generally cover the following inputs:

- Fertilisers and soil conditioners
- Plant protection products
- Substrates
- Feed materials and feed additives
- Cleaning agents and disinfectants
- Food processing aids

Operationally, inputs are mostly listed in annexes of organic regulations (e. g. in the EU Organic Regulation No. 889/2008 in Annexes I-II as well as VII-IX, and in the NOP regulation in force in the USA in Subpart G). Most of the input lists are available online and are made available through local or international certification organisations.
For certification according to the EU Organic Standard outside the EU, the EU Organic Regulation's list of inputs applies. An online reference is the EU input list compiled by FiBL at www.inputs.eu.

Valuable intercrops

Green manures, intercrops and perennial legume-grass mixtures help to conserve and provide nutrients for the next main crop. In addition, they help to protect the soil from erosion, fix atmospheric nitrogen and stabilise the soil structure when sown shortly after the harvest of main crops. Depending on the intended use, pure seeds or different mixtures are used. Mixtures cover and stabilise the soil better, make better use of available legume nitrogen, and have a lower risk of failure.

Despite being time consuming, labour intensive and costly, the cultivation of green manures is economically worthwhile over the crop rotation, as the cash crops provide more stable yields.

Important to know about intercrops:
- Legume-grass mixtures with at least 2 main crop years are best for soil fertility.
- Legume-grass mixtures should be cut regularly and the cuttings removed. This stimulates plant growth and promotes soil building.
- Also stockless farms should grow enough green manures and clover- or lucerne-grasses.
- Grasses promote humus build-up more than legumes because of their strong soil rooting and rather slow decomposition.
- Winter-hardy clover-grass mixtures or ryegrass after cereals or forage rye (including vetch) or winter turnip (Chinese turnip) after potatoes or maize provide good erosion control.
- Fast-growing species such as forage oats, forage rye, mustard, and turnip can conserve nitrogen for the following crop particularly well.
- Summer vetch and Alexandrian clover are good for short-term revegetation of about 3 months during the season.
- Sudan grass, bristle oats or ramtil (*Guizotia*), which emerge quickly, suppress weeds well and are in some cases very drought resistant, are particularly suitable on sites with low rainfall.

Table 7: Green manures and their effects

Green manure/ batch	Humus build up	Nitrogen for succeeding crop	Deep loosening	Erosion control in winter	Plant protection [1]	Weed suppression	Comments
Clover grass <2 years	●●●	●●●	●●	●●●●	●	●●●	Suppresses thistles and bindweed. Lucerne-grass mixture with good deep rooting. Wireworm risk in the following crop.
Intermediate feed	●●●	●●●●	●●●	●●●	●	●	Good green manure between cereals and maize.
Lupines, grain beans (until flowering)	●	●●●●	●●●	●	●	●	Susceptible to many nematode species. Low wireworm risk in the following crop.
Peas, vetches (until flowering)	●	●●●●	●	●	●	●●	Peas are also suitable for winter cropping, vetches depending on the type.
Phacelia (until flowering)	●	●	●	●	●	●●●	Not related to crop species. Prevents N leaching.
Oil radish	●	●	●●●	●	●●●	●●●	Prevents N leaching. Recovery effect on nematodes depending on the variety.

Legend: ● little effect; ●●●● strong effect; (1) Diseases with a wide host range and nematodes

- For deep loosening where soil is compacted, oil radish, perennial lucerne, lupines, and grain beans are well suited. However, the soil must first be deeply loosened with a cultivator.
- Overwintering green manures such as winter peas and vetches can help relieve some stress on crop rotations by interrupting the reproduction of root gall nematodes if turned early enough in the spring.

Box 10: Note for green manures!
- Green manures must not be closely related to the main crops in the rotation. Grain legume green manures do not belong in rotations with grain legumes as a main crop.
- Some diseases and pests such as Sclerotinia, Rhizoctonia, and some nematode species have many different hosts. Therefore, highly susceptible green manures should be avoided when growing susceptible main crops such as oilseed rape, vegetables, or sunflowers.

Weed control: prevent and regulate mechanically

Avoidance of herbicides

Heavy weed infestation greatly reduces crop yield and hampers harvest. For weed regulation, organic farming does not use herbicides. Instead, organic farmers rely on preventive cultural measures and the use of sometimes sophisticated mechanical equipment such as harrows, hoes and brushes. Flaming equipment may also be used.

Because direct regulation of weeds – especially regulation of problem weeds such as ragweed, thistles, couch grass, and dock – has its limitations, organic farmers strongly rely on preventive measures for weed control. With consistent application of preventive cultural measures, weed pressure and thus crop risk are kept low. For reasons of profitability, the aim is to dispense entirely with manual labour in arable farming, with the exception of sugar beet and soybeans and for the removal of individual root weeds.

Efficient regulation of seed and root weeds is essential in both arable and vegetable production. Mechanical weed regulation may imply sound investments in adjustable machinery to effectively control weeds in different crops, along the whole crop rotation.

Box 11: Ragweed – problem plant no. 1 in warm and dry regions

Ragweed (*Ambrosia artemisiifolia*) must be controlled by law in many European countries due to the strong allergenic effect of its pollen. Since ragweed develops easily in open soil in warm locations and is tolerant of drought, its spread must be prevented while still young. The most important measure for this is a permanent ground cover.

Combination of different measures

To keep weed pressure and thus the effort for mechanical weed control as low as possible, seed and root weeds are preventively regulated with a weed-suppressive crop rotation and tillage adapted to the situation. The use of weed-free seed is another important preventive measure. Moreover, weed control is also about preventing weeds' spread through seeding or carryover with machinery, farm fertilisers and seed. The propagation of root weeds by fragmentation of rhizomes must also be avoided.

In general, organic agriculture does not strive for complete control of weeds, but rather for avoiding weed competition during critical stages of crop development. In contrast to 'simple' weeds, practically zero tolerance applies to problem weeds to prevent their propagation from the beginning.

Table 8: Impact of preventive measures on seed and root weeds

Domains	Measures	Seed weeds	Root weeds
Crop rotation	High proportion of clover-grass in the rotation	●●●	●●●
	Fast or high growing crops and varieties	●●●	●●
	Alternation of winter and summer crops	●●	●
	Catch crops and green manures	●●●	●●
Ground cover	Close row spacing	●●	●●
	Plus 10 % seed rate	●	●
	Rather late sowing date	●●	●
	Undersowing	●●	●
	Mixed cropping	●●	●
Seed stock	Use of certified seed	●●●	●
	Avoiding seeding	●●●	●●
	Weed-free straw	●●	●
Seedbed preparation	Periodic use of the plough	●●	●●●
	Applying the false seedbed technique	●●●	●
	Shelling during stubble cultivation	●	●●●
Fertilisation	Use of well rotted (manure) compost	●●	●
	Adequate nitrogen application	●●	●●

Legend: ● little effect; ●●● strong effect

Weed-controlling crop rotation

A versatile, well-thought-out crop rotation is the most effective preventive measure against weeds. Therefore, planning of crop rotation must consider the weed situation in the fields besides reflecting the crop and market related aspects.

What to look out for when designing the crop rotation?

- **Weed pressure on a plot:** Weed pressure can vary significantly between crop fields. Soil compaction, weed seed stock in the soil, or problem weeds may necessitate avoidance of a weakly competitive crop, or require a 'crop break' by introducing perennial clover- or lucerne-grass.
- **Crop competitiveness:** The competitiveness of an arable crop against weeds depends largely on its early development, growth height, and growth period. Crops with quick early development, rapid canopy closure, tall growth and broad leaves are the most competitive. The duration of maturation is also important because just before maturity, many crops allow light to reach the soil. This stimulates seed weeds to germinate and may allow them to seed. In this regard, cereals – especially rye, spelt, triticale, and tall-growing wheat varieties – are considered competitive crops. Because of their slow early growth, maize, oilseed rape, and field beans are less competitive until canopy closure is reached. Crops with low competitiveness are sugar beets and field vegetables such as carrots and onions, which never fully cover the ground.
- **Special role of legume-grass mixtures:** Legume-grass mixtures have a special function in crop rotation because of their good weed suppression. While high and dense 2- to 3-year legume-grass mixtures suppress all types of weeds effectively, annual seedings mainly suppress seed weeds. For annual seeding, fast-growing legume mixtures (e. g., with Persian clover and Alexandrian clover) have proven most effective. For preventive regulation of root weeds, legume-grass mixtures should make up at least 20 % of the crop rotation.
- **Alternation of summer and winter crops:** Frequent alternation of summer and winter crops (e. g. winter wheat before potatoes or maize) prevents weeds from multiplying undisturbed over several years and building up a large seed stock.
- **Undersowing:** Undersowing is possible not only in arable crops but also in permanent crops. Undersowing covers the soil and suppresses germinating weeds in less-competitive crops (e. g. ground clover undersown in oilseed rape). As a rule, undersowing is only worthwhile if the cover crop persists for a longer time, up to winter time, or even better into the following spring. Timing must be right for successful undersowing: seeds are sown just before the crop's canopy closes. Sowing too early leads to competition with the main crop, and sowing too late can cause the undersown crop to develop insufficiently. Clover species such as white, red, crimson, Alexandrian, subterranean and yellow clover are best suited for undersowing.
- **Sowing catch crops:** Fast-growing summer intercrops cover the soil quickly after a main crop and suppress seed and root weeds. Cruciferous crops such as mustard, oilseed rape or oil radish are suitable for suppressing couch grass. Since


Good germination and rapid youth development of the crops are of great importance to leave as little room as possible for emerging weeds to develop.

grasses and clovers have a slower early growth, their cultivation is not recommended in catch crop mixtures.
- **Cultivation of mixed crops:** Grain legumes can be grown in mixed crops with cereals. Cereals cover the soil quickly, unlike grain legumes, and serve as a supporting crop for grain legumes during the ripening phase. The combination of such crops hampers weed development and makes harvesting easier. Overall, mixed crops tend to produce a higher yield per unit area than a single crop.
- **Reduction of seed stock with weed cures:** Weed cures are designed to stimulate the germination of weed seeds in the soil and then spill the seedlings with a harrow. Weed cures are very effective at reducing the seed stock of annual weeds in the soil, and thus help reduce overall weed pressure on a field. Moreover, weed cures are especially valuable before low-competition crops such as soybeans or sugar beets.

Whereas in arable crops mainly the harrow is used, sophisticated hoeing equipment is employed in vegetable production.

Efficient direct weed control with suitable equipment

Despite preventive measures, weeds in most arable crops still need to be regulated mechanically throughout the cultivation period. The most important tool for mechanical weed control in organic farming is the harrow. It can be used in practically all crops with a high impact thanks to its large working width and high working speed.

In contrast to the harrow, hoes have a smaller working width and rely on wide row spacing. They also require precise steering by a second person or camera-controlled steering. Hoeing equipment is also significantly more expensive to purchase, maintain and use, than the harrow. Therefore, whenever possible, the harrow should be used. Hoeing equipment must be used in a very crop-specific manner and must be correctly adjusted in order to have an optimal effect when using it.

Box 12: Precision tined weeder

A few years ago, a new and interesting weeding implement, the Treffler precision tine, came on the market. Although this tined weeder has a rigid frame like conventional harrows, the tine pressure can be adjusted centrally, hydraulically and via an intelligent spring system from 200 g to 5’000 g. This has several advantages:

- Smooth adjustable tine pressure.
- Only slight lateral deflection of the tines.
- Optimum adaptation to soil properties.
- Constant tine pressure, enabling its use also in ridged crops (in contrast to a conventional harrow).

Table 9: Most important devices for weed control		
Features	**Row-independent**	
Type of device	Tine(d) weeder / Harrow 	Rotary hoe 
Row spacing in crops	–	Cereals: 24 cm; soybeans, sunflower: 50 cm; maize: 75 cm
Use mainly in	Cereals and row crops	Maize, cereals, soybeans
Mode of operation	Tears out, buries	Tears out, buries and mixes the soil
Effect in the row	Yes; the tines work the same everywhere	Yes; the rolling coulters also run in the row
Adjustment of the unit pressure	Via angle of tines or hydraulics or support wheel	Via the inclination of the vertically running coulters
Mineralisation	Low, loosens the soil 2–3 cm deep	Large, loosens the soil to 5 cm depth
Range of action	Germinating weeds to weeds in the 2-leaf stage	Germinating weeds to weeds in the 2-leaf stage; loosens crusted soil
Handling, assessment	Easy handling, versatile, lowest cost of all implements; high surface area efficiency	Heavy device; effect similar to harrow, limited use, can damage crops
Usual working width	6, 9, 12 m	3 m
Brands	Hatzenbichler, Treffler, Einböck	Yetter, Moro

The most important cultivation practices

Managing the weed seed stock

The stock of weed seeds in the soil can be very high as seed weeds can produce several hundred seeds per plant and can have a germination capacity for as long as 60 years. With an average annual germination rate of 2–3 % and a seed production of 15,000 seeds per m², 300–450 seedlings develop per m² per year. Unrestrained propagation of annual weeds or the introduction of weed seeds with crop seeds or straw can quickly cause the seed stock in the soil to increase massively. To minimise the propagation of seed weeds, their seeding must be prevented with all means.

In some weeds, the seeds are capable of germinating even when immature. Therefore, weeds should be uprooted or the flower stalks removed before seed stalks form. To prevent cut-off seed stalks from ripening, as in the case of cereals, they must be disposed of in the waste and should not be thrown on the compost heap.

Row-dependent		
Hoe	Star cultivator	Finger weeder
		
Cereals: 16 cm; oilseed rape, beets, sunflowers, soybeans: 50 cm; maize: 75 cm	Maize, potatoes: 75 cm	Soybeans, beets, maize, beans: 50 or 75 cm
Root crops (excluding perennial crops)	Dam crops	Field vegetables, soybeans
Cuts and buries	Tears out and buries, mixes the soil	Tears out and buries
Yes; for coulters with ridging body (otherwise: no); protective discs possible for small crops	No, when mounding up; yes, when mounding with slanted discs	Yes; fingers dig into the rows
Via the spring pressure on the parallelograms or the support wheel on spring tines (depending on model)	Inclination of the vertically running stars	Inclination of the wheels (30°: aggressive, 15°: gentle cultivation)
Moderate; loosens 2–3 cm deep	Large; loosens soils 5 cm deep	Low; loosens 2–3 cm deep
Weeds and grasses up to the 4-leaf stage	Germinating weeds to weeds in the 2-leaf stage; loosens crusted soil	Germinating weeds to weeds in the 2-leaf stage
Easy handling, light weight, many variation possibilities, rear or front mounting, with or without camera control	Heavy device, conversion from tilling on to tilling off required, not recommended for stony soils	Lightweight, can be combined well with a star cultivator, a hoe or used alone
3 m (6 m in combination with harrow)	3 m	3 m
Schmotzer, Hatzenbichler, Einböck, Fobro, Kress	Hatzenbichler, Fobro, Kress, Schmotzer	Hatzenbichler, Kress, Schmotzer

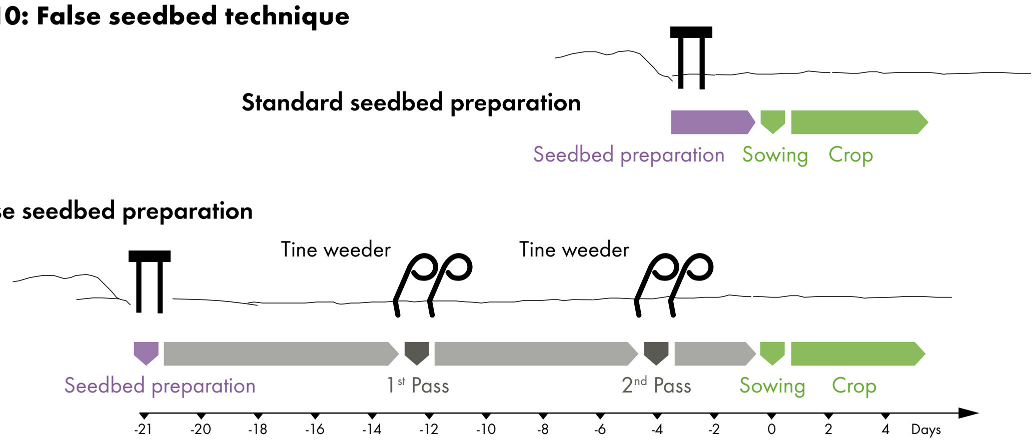
Removing weeds before they set seed is an important measure to control them.

Regulation of root weeds

Root weeds such as blackthorn, thistles, bindweed and couch grass can become a major problem in arable farming if the soil is not properly tilled. These weeds use their roots to store nutrients and can survive for extended periods.

Mechanical tillage poses the risk of cutting the roots into small pieces. The individual root or rhizome pieces can sprout individually and multiply the weed population explosively.

Figure 10: False seedbed technique



In the false seedbed technique, the seedbed is prepared 2 to 4 weeks before sowing. The weeds are then allowed to germinate and are repeatedly worked shallowly (2 cm deep) with a tined weeder or a harrow at intervals of 7 to 10 days. The shallow tillage stimulates new seeds to germinate.

Regulation of root weeds requires repeated undercutting of the soil over the entire surface at a depth of 10–12 cm with a stubble plough, cultivator and harrow during the intercropping period. The rhizomes must be transported to the soil surface to dry them out or freeze them in winter. Between tillage passes, at least one week should be waited. After stubble cultivation, a green manure or perennial clover grass should be sown to suppress new sprouts.

Disc harrows and rotary tillage equipment should not be used to rehabilitate fields infested with root weeds. Deep inversion ploughing, for its part, carries rhizome fragments into deeper soil layers where they are difficult to control.

Regulation of annual weed seeds

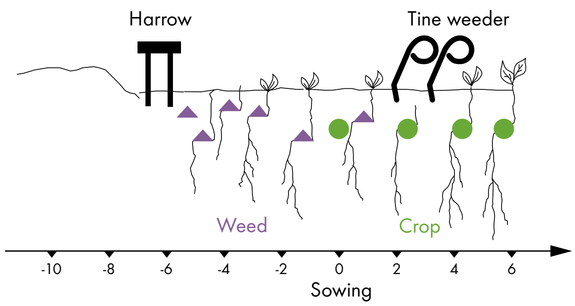
Annual weeds such as millet, goosefoot and amaranth can be regulated by roughly preparing the seedbed early with the disc harrow or, on heavy soils, with the rotary harrow or rototiller. After the weeds have germinated, they are buried with the harrow and new seeds are encouraged to germinate (see Figure 10). The process can be repeated several times at intervals of 7–10 days. To prevent weed seeds from being brought to the surface, the tillage depth is reduced with each pass. To stimulate germination, a brief sprinkling may be applied under dry conditions.

Blind harrowing

Blind harrowing is particularly useful for slow-emerging crops up to 3 days after sowing (see Figure 11). While the crop is still protected in the soil, many seed weeds have already germinated and can be buried or exposed with the harrow. At this stage, weeds are very sensitive and can be easily regulated. Blind harrowing can achieve an efficiency of 80–90 % when executed correctly.

For a good result, the working depth must be respected and the harrow must not injure the seedlings of the crop in the soil. Too late or too deep blind harrowing can lead to major crop losses by damaging the vulnerable crop sprouts.

Figure 11: Blind harrowing



Between sowing and emergence of the crop, a pass with the harrow is made with harrow tines set flat for a working depth of 2–3 cm only. To increase the efficiency, the crop can be sown into the germinating weeds (after a weed cure with the false seedbed technique approximately 1–2 weeks after the last pass).

Organic plant protection: prevention and protection

The use of synthetic chemical pesticides is prohibited in organic farming. Avoiding diseases and pests with preventive measures is key in organic agriculture, even more so as the effectiveness of most natural plant protection products is limited. The optimal use of preventive measures such as selecting suitable locations, resistant varieties, appropriate cultivation systems and cultural measures should result in the growth of healthy and resistant plants and natural regulation of pests by natural enemies. Biological plant protection products are only used if preventive (or indirect) plant protection measures are not sufficient (see Figure 12).

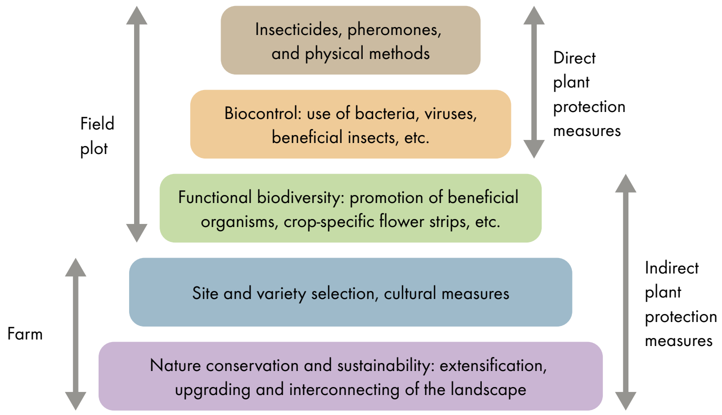
Healthy soil – healthy plants

Preventive plant protection begins with a healthy soil. A biologically active soil has a fundamental disease-inhibiting effect (see page 11) and is the basis for healthy crop development in a near-natural, biologically diverse system that promotes beneficial insects.

A richly structured environment with interconnected semi-natural habitats, such as flowering strips of native wild herbs, hedgerows and flowering borders, has been shown to promote natural plant pest enemies. Among these beneficial insects are hoverflies, ladybugs, and chalcid and braconid wasps.

The targeted promotion of beneficial insects in the field with nectar-giving flowering plants sown as flower strips and companion plants in the crop promotes the survival of the natural enemies and their regulatory potential against pests.

Figure 12: Biological crop protection pyramid as a strategy model



The crop protection strategy in organic farming can be seen as a stepped pyramid. The bottom-up approach requires good knowledge of the biology of diseases and pests, the effectiveness of measures, as well as intensive observation of the crops.

Suitable choice of species and varieties

In addition to species selection and adherence to recommended growing intervals, the choice of resistant and robust varieties to prevent diseases (and to some extent pests) is of major importance in organic farming. This applies to all crops, but especially to permanent crops such as orchards and vineyards.

Targeted direct crop protection

In most arable crops, consistent preventive measures are usually sufficient to keep disease and pest infestation below the damage threshold. In contrast, the cultiviation of potatoes, vegetables, fruits and grapes usually depends on the use of biological plant protection products to minimise yield losses and quality defects in the harvested crop due to pests and diseases.

The use of direct plant protection measures always depends on current or impending infestation pressure. Where available, forecasting models and weather forecasts are consulted to apply crop protection products timely. Regular observations are indispensable for effective pest and disease management in organic farming.

Table 10: Key preventive measures to control diseases and pests	
Fertile soil	• Sustainable humus management • Gentle tillage • Avoiding compaction • Soil cover
Balanced plant nutrition	• Fertilisation according to crop needs • Choice of suitable fertilisers
Crops adapted to the location	• Suitable crops for soil, climate, farm and location
Resistant and tolerant varieties	• Healthy seeds or planting material • Varieties with crucial resistances • Variety mixtures
Suitable cultivation methods	• Versatile crop rotation • Favourable sowing or planting time • Suitable sowing or planting distances • Mixed cropping • Undersowing • Hygienic measures
Promotion of beneficial insects	• Flowering strips • Hedges • Accompanying flora • Fallows strips

Dispensor with female sexual scents to confuse male codling moth and summer fruit tortrix. The confusion technique is approved in organic farming against various moth species in orchards and vineyards.

Gentle biological plant protection

Biological plant protection involves the use of living beneficial organisms and biotechnical measures for infestation monitoring, prevention and direct control of pests.

Natural antagonists of pests, including predators, parasites, parasitoids and pathogens (entomopathogens), can be promoted by sowing pollen- and nectar-giving flowering plants in flower strips. Certain natural enemies, including beneficial insects, mites, nematodes, bacteria, viruses, and fungi, are also commercially available. Common uses include applying bacterial preparations such as *Bacillus thuringiensis* against pest caterpillars or the selective release of parasitoids against certain insect pests in greenhouse crops.

Biotechnical crop protection measures include fine-mesh nets against insects in vegetable and fruit production or glue rings on fruit trunks to trap female frost moths, blood lice and other pests migrating up the trunk.

Insect traps with frass attractants such as juice or vinegar and colours that are attractive for the respective pest (yellow panels, white panels) are primarily used to monitor infestations. The regular recording of insect catches enables the assessment of the need for plant protection measures and suitable treatment times.

Dispensers with female sex pheromones are also used in organic fruit, grapevine and vegetable production to confuse males of moth species. This can be used to disrupt their mating and reduce their egg-laying on the crop.

However, pheromone traps have a limited extent for controlling infestations, because a large number of traps are required and the influx of mated females from elsewhere must be low. Therefore, the use of pheromone traps is primarily suitable for flight control of moths.

Trichogramma ichneumon flies can be applied as eggs in balls of decomposable maize starch. The ichneumon wasps lay their eggs in the eggs of the European maize borer and destroy them.

Targeted use of biopesticides

The plant protection products approved in organic farming are based on natural plant or mineral substances. These protect the environment and leave hardly any residues on the harvested products. Nevertheless, the use of plant protection products can be problematic from an ecological point of view and from the consumer's perspective. Even selectively acting natural pesticides can harm the beneficial fauna. Moreover, applying the agents with a tractor requires energy and can lead to soil compaction.

Plant protection products against insect pests use various plant extracts as well as oils and soaps. Against fungal diseases, sulfur, copper as well as alumina preparations and special plant extracts are used.

The use of copper is viewed critically in organic farming, as the heavy metal accumulates in the soil and damages soil organisms at higher inputs. Alternative natural substances to replace copper are under development and about to be approved. As long as copper is still used, it is vital to keep the amount applied as low as possible (see Figure 13).

All approved plant protection products for organic farming are listed in recognised input lists (see Box 9).

Figure 13: Optimisation of copper use in potatoes

Infestation situation	No infestation in the region (50 km radius)	Infestation in the region	Infestation in neighbouring fields or in own fields
Risk for blight	low	medium	high
dosage of copper (g pure copper per ha)	no	low 200–300 g	high 500–800 g

For optimum use of copper, the dosage is adapted to the infestation situation.

Table 11: Direct measures and active substances for disease and pest control

Agents and measures	Application examples
Barriers and traps	• Barrier against snails (snail fence) • Glue traps against cherry flies • Glue traps against whiteflies in greenhouses
Nets	• Fine-mesh nets against carrot flies, cabbage flies, etc.
Spreading of beneficial organisms	• Beneficial insects bred by specialised companies, such as ichneumon wasps, predatory mites and predatory bugs are used mainly in greenhouses. • Specific bacteria and viruses (e.g. *Bacillus thuringiensis*) are used against various pest butterflies in the field.
Agents against fungal diseases	• In fruits, grapevines and potato, preventive agents such as sulfur, alumina, plant extracts or copper are used. These agents prevent harmful fungi from entering the plants.
Agents against insect pests	• Plant extracts (e.g. from flowers of a chrysanthemum species or seeds of the neem tree), oils, rock powders or soaps are available to combat insect pests.

Table 12: Direct measures and active substances for disease and pest control			
Group of harmful organisms	**Active agent**	**Agent / measure**	**Application examples**
Fungi	Vegetable	Fennel oil	Mildew
	Mineral	Copper	Downy mildew (grapevine), late blight (potato), scab (pome fruits)
	Mineral	Sulfur	Powdery mildew (pome fruits & grapevine)
	Mineral	Alumina	Scab (pome fruit), powdery and downy mildew (grapevine)
	Mineral	Potassium bicarbonate	Powdery mildew (grapevine)
	Microorganisms	*Coniothyrium minitans*	Sclerotinia rot (arable crops)
Bacteria	Microorganisms		Fire blight (pome fruits)
Insects	Vegetable	Azadirachtin (Neem)	Aphids (fruits), thrips, whiteflies (vegetables)
	Vegetable, animal	Potash soap	Aphids, spider mites (fruits & vegetables)
	Vegetable	Pyrethrin	Aphids, frost moths (fruits), aphids, spider mites, thrips & whiteflies (vegetables), Grapevine cicada (grapevine)
	Vegetable	Rapeseed oil	Aphids & cup scale insects (fruits)
	Vegetable	Kerosene oil	Scale insects (fruits & nuts), spider mites (grapevine)
	Mineral	Sulfur	Mites (grapevine)
	Mineral	Alumina	Walnut fruit fly (walnut), cherry vinegar fly (grapevine), rape beetle (oilseed rape)
	Microorganisms	Spinosad	Fruit moth (fruits), moth and pea moth (grapevine)
	Microorganisms	*Bacillus thuringiensis*	Grape berry moth (vines), frost moth (fruits), coal owl, cabbage cockroach & whitefly (cabbages), Colorado potato beetle (potatoes)
	Microorganisms	*Beauveria*	May beetle (fruits & arable crops)
	Physical	Trap	Cherry fly, cherry vinegar fly (fruits & berries)
	Physical	Net	Carrot fly, cabbage fly, etc. (vegetables)
		Confusion technique	Codling moth (fruits & walnut), grape berry moth (grapevine)
	Beneficial insects	Nematodes	European pine weevil (fruit & berries)
		Predatory mites	Spider mites (berries & vegetables)
		Gall midges	Aphids (berries & vegetables)
		Ladybugs	Aphids (fruits, vegetables & nuts)
		Lacewings	Aphids (vegetables)
		Parasitic wasps	Aphids (vegetables), maize borers (corn)
		Predatory bugs	Whiteflies, aphids, spider mites & thrips (vegetables), spider mites (berries)
Snails	Mineral	Iron phosphate	Snails (arable crops & vegetables)
	Physical	Snail fence	

Box 13: Limiting the amount of copper
To limit possible negative effects of copper, its use in organic fruit, grapevine, vegetable, potato and hop production is restricted. According to the EU organic regulation, a maximum of 6 kg of pure copper per hectare and year is permitted. The standards of organic associations such as Bio Suisse have set lower amounts.

Animal husbandry: adapted to species and location

Linking of crop production and animal husbandry

Animal husbandry plays an important role in organic farming, as the livestock helps to close the nutrient cycle on the farm:

- Excrements of livestock provide highly valuable organic fertilisers to revitalise the soil and nourish crops.
- Ruminants and other grazers efficiently transform forage from grassland into value added products. At the same time, the grassland is essential for preserving humus and regulating weeds in crop rotations.
- Straw produced on the farm can be used as bedding in animal husbandry. The straw binds nutrients from animal faeces and excreted urine. The resulting manure is a good soil conditioner and long-term fertiliser.

Ruminants convert cellulose that is unusable for humans into valuable food. Milk achieves an efficiency of 45 % in the conversion of plant energy and protein into food. Meat, with an efficiency of around 15 %, is considered more of a byproduct of milk.

Animal-friendly husbandry

Keeping farm animals in a manner appropriate to their species is a central concern of organic farming. The animals should be healthy, feel well, and be able to live out their natural behaviour as fully as possible. Compared to conventional animal production, organic animal husbandry aimes less at achieving maximum performance with high stocking densities, high daily gains, high milk and laying yields, but is rather aiming at a cost-efficient production and a high lifetime performance of the animals. This minimises the stress on the animals and negative impacts on the environment.

This approach requires that organic farmers are familiar with the species-specific needs of their farm animals and consider these needs in the best possible way. Therefore, the stables are conceived based on the natural behaviour of the farm animals. This includes sufficient space for movement, activity opportunities, social contact, shelter and feeding opportunities. When building stables, the aim is to find a compromise between optimum conditions for the animal and practical solutions for the animal keeper.

Outdoor climate stimuli through regular runout and pasture are important for the health of the animals. Therefore, the EU organic regulation and the organic associations require runout and/or pasture for all animal species.

Species- and performance-appropriate feeding

The feeds must be adapted to the digestive system of the respective animal species. Ruminants obtain their performance primarily from high-quality forage. Therefore, some organic standards have set an upper limit on the percentage of concentrates in ruminant rations.

Calves receive a bottle ration of whole milk for 3 months. Piglets must be suckled for at least 40 days. This ensures the supply of antibodies and guarantees natural development of the young animals. However, this also means that it takes significantly longer to raise young animals on organic farms than on conventional farms.

Organic animal husbandry requires more time for daily observation and care of the animals. Yet, the close monitoring and the consistent consideration of the animals' needs results in much lower veterinary and pharmaceutical costs. Nevertheless, competent advice is key for successful organic animal production.

Preventive animal health

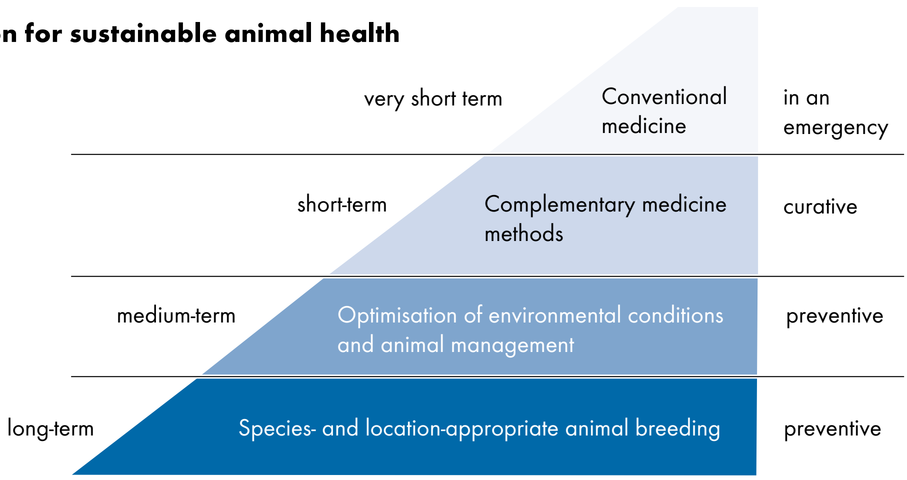
Organic regulations prohibit the prophylactic administration of chemotherapeutic drugs and antibiotics to livestock. Hormones and genetically modified feeds are prohibited in organic agriculture. Instead, organic farming relies on breeding robust animals adapted to their location, species-appropriate husbandry conditions and feeding tailored to their needs, to mitigate diseases.

Animals on organic farms are given sufficient space for resting and feeding. A pleasant stable climate with draft-free, fresh air, dry, littered lying areas, daylight, and regular access to an outdoor run and pasture, as well as contact to conspecifics contributes to the animals' well-being and fosters health.

In the case of illness, natural remedies such as homeopathy and phytotherapy are preferred. Natural remedies also help to prevent the development of resistance in bacteria. In an emergency, synthetic chemical medications are also allowed to restore an animal's health and avoid suffering.

Important
If chemical-synthetic medicines were applied, the involved animal products are subject to special requirements, e. g. doubling the legal withdrawal period before marketing.

Figure 14: The pyramid of prevention for sustainable animal health



The animal health strategy in organic farming is based on long and medium-term prevention of diseases. For healing, complementary medicine methods are to be used preferentially.

Table 13: Animal species-specific measures according to the EU organic regulation

Cattle	Small ruminants	Pigs	Laying hens
			
• Tethering permitted • Bedded or dry, well-insulated lying areas • Unhindered access to feeders and waterers • Sufficient fresh air and daylight in the barn, low dust and noxious gas concentrations, age-appropriate temperatures, adapted humidity • Sufficient space for natural standing, comfortable lying down, turning around, grooming and assuming all natural positions • Rearing and fattening calves in groups on litter • Minimum drinking time of 3 months with unchanged milk • No systematic dehorning • No systematic attachment of rubber rings and docking of tails	• Minimum suckling or drinking period of 35 days with unchanged milk • No tethering of goats as of 2023	• Group, family housing • Structured pens • Sufficient space • Individual weaning with nesting material (long straw) • Late weaning • Rich environment • Burrowing material • Spatial arrangement, sure-footed underground • Cooling facilities, wallows • Scouring opportunities • Strict separation of lying and defecation areas • Natural jumping, boars in the barn to stimulate oestrus • Consideration of individual temperature requirements • Minimum sowing period of 40 days • Conventional dairy waste max. 35 % of annual ration (dry matter), all other conventional feed components max. 5 %. • No systematic docking of tails and clipping of teeth • Roughage in the daily ration	• Keeping with traditional run, no cage keeping • $^1/_3$ of the floor area solid and littered • Adequately large manure pit • At least 4 m of entry and exit flaps per 100 m² of housing area • At least 8 hours night rest without artificial light • Cleaning and disinfection of the barns between occupancies • No beaks trimming • Perches • Greened run with at least 2 paddocks • Sufficient number of water and feeding troughs • Roughage in the daily ration

Important
The private organic standards build on the requirements of the EC Organic Regulation, but contain additional and higher requirements. To ensure label-compliant application, producers must consult the requirements in the corresponding original regulations!

Conversion to organic production

The demand for organic products is increasing steadily, the technology for organic production is continually developing, and the political framework increasingly favours organic agriculture. These are exciting conditions to consider conversion to organic production. When reflecting possible conversion, following key questions arise:

- To whom will I sell my organic products?
- On what terms will my organic products be purchased?
- Is organic production more profitable than conventional production?
- What changes does the conversion to organic production entail in terms of personnel, production technology and economics?
- Are important investments needed when converting to organic?

Before switching to organic production, sales opportunities must be clarified.

Market access as a basic condition for conversion

Although overall demand for products is increasing in many markets, demand can vary widely between different commodities and over time. Particularly in countries where domestic consumption of organic products is still low, there is often a lack of sales opportunities in the domestic market. In such contexts, production must primarily target the export market. Yet, foreign importers are usually only interested in organic products of good quality and from farms that have completed conversion. This makes conversion more difficult, because organically produced conversion goods have to be sold at conventional prices, unless a special 'conversion price' was negociated.

Building local marketing structures for organic products can be rewarding, but requires perseverance.

Transparent and fair purchase contracts for conversion and organic products are a vital pre- re- quisite for a financially secure conversion to orga- nic production. Good contracts regulate which products are accepted at which conditions (quantity, quality, price) with which certification. Sometimes such contracts are rather declarations of intent. These can serve the purpose to clarify the new production and marketing situation, which is key for careful conversion planning.

Establishing own sales structures to market directly to local consumers may be attractive for farms close to cities. However, such an approach may require a lot of time, work, and perseverance. In addition, providing a wide range of fresh produce (i. e. vegetables, fruits, meat, eggs, and possibly dairy products) can be a high production and logistical challenge for the farm. Often, farmers who engage in such a business model cooperate with other farmers involving the production of other organic produce to be in the position to offer a wider assortment of products to clients.

Good planning of the conversion from a production and economic perspective

Successful conversion requires good planning and must take various interlinked aspects into account:

Crop production

- The suitability of land for organic production must be carefully evaluated for different crops, based on site conditions such as soil fertility, weed pressure and climate.
- Based on crop suitability and market demand, it is crucial to plan an appropriate crop rotation.
- Required equipment for weed control in arable and vegetable crops must be identified and well reflected.
- Strategies and measures for the management of pests and diseases in crops must be defined.
- For orchards and vineyards, the suitability of varieties and cropping systems must be clarified.

Animal husbandry

- Livestock farms must check whether the existing stables and run-out facilities comply with the considered organic standards.
- The quantity and quality of the animal feed produced on the farm must be analysed according to the feeding needs.
- The processing of the animal manure and its use in crop production should be examined.
- For stockless farms, it may be interesting to explore cooperation with nearby livestock-keeping farms (e. g. taking over farm manure in exchange for the supply of roughage). Otherwise, options for integrating livestock into the farm can be explored (e. g. mobile layer management).

Input of labour

- The additional work for crop maintenance measures, the care of livestock and marketing must be well estimated to ensure that sufficient personnel are available.

Changes in the scale and structure of production are particularly costly in livestock farming. Restructuring in crop production, except for fruit and grapewine growing, usually has a lower financial impact.

Need of investment

- Adjustments may be needed in barns to meet welfare requirements and for animals to have access to an outdoor run and/or pasture.
- In some instances, new barn construction may also be required for livestock to meet organic requirements.
- For tillage and mechanical weed control, it may be necessary to purchase appropriate equipment, if it cannot be rented.

Exchanges with experienced advisors and organic producers provides valuable insight on how to grow crops organically.

Profitability calculations at the heart of the conversion planning

A good economic analysis is essential for sound conversion planning. All aspects that can have an impact on the farm's profit should be considered:

Expected yields

- In the first few years after conversion, yields can be expected to decline. However, by systematically building up soil fertility, yield stability and yield levels can increase again in the medium to long term.
- Organic crops generally achieve yield levels 20 % lower than conventionally grown crops due to lower nutrient levels and less effective crop protection. The differences vary from crop to crop, depending on the intensity of production in conventional farming.
- The lack of experience with organic farming may increase the yield risk, especially in challenging crops in the first years.

The conversion to organic production must be well thought out and calculated.

Cost variations

- With the conversion to organic agriculture, there is usually a shift from variable costs (i. e. fertiliser, feed, pesticides) to fixed costs (i. e. including machinery, employee costs). The changes must be estimated as accurately as possible for the various production areas in order to obtain a realistic overall picture of the cost changes.
- Organic seeds and seedlings can be significantly more expensive than conventional ones.
- For certain arable and vegetable crops, the cost of mechanical weed control must be estimated very high, especially if it must be done by hand.
- With the start of conversion, organic certification costs are incurred, unless these are covered by the authorities or the buyer.

Selling prices

- In general, higher prices can be achieved for organic produce than for conventional produce. And it is likely that prices for conventional produce will decrease in the long term compared to organically certified produce.
- Higher selling prices are essential to compensate for lower yields and the additional costs incurred by organic production.
- Conversion farms without direct sales opportunities are often 'price takers', i. e. they have to follow the prices defined by the buyers. For economic security, the level of selling prices must be predictable – or even better – contractually fixed.
- If possible, a surplus price for organically produced in-conversion produce should be negociated to have a more favourable economic situation during the conversion period (whereby the conversion period for annual crops is 2 years and for permanent crops 3 years).

Access to government support services

- In many countries, organic production is supported and promoted by the government. The most important support measures relate to direct payments, which compensate for the positive effects of organic farming on the environment and society. In Western countries, these subsidies are most important as a source of income for organic farmers.
- In countries where organic agriculture is actively promoted, subsidies may also be offered to bridge the conversion phase. In this case, the certification costs are often covered by a government subsidy programme.
- Subsidised advisory services and investment loans are also common as an incentive for conversion to organic production.

To assess the financial impact of organic conversion, realistic local reference figures for expected yields are very important. If such figures are missing, it may be even more important to involve an expert to support the development of a business plan. Based on sound assumptions for revenues, prices, and costs, the expert will calculate annual profit margins for various scenarios and liquidity for a 10-year period. It is not uncommon for such calculations to show that 3 to 5 years are needed to stabilise respectively improve the profit situation after the start of the conversion.

Good reflection of motivation factors and risks

The improvement in profitability due to higher sales prices and the growing demand for organic pro- ducts are the main incentives for many producers to switch to organic production. However, successful organic farming also requires a personal interest of farmers in agricultural production and committment from the side of the farmer to shift towards agricultural practices that are more natural. Such committment is key as it involves perseverance and willingness to continuously improve one‘s farming practices with a 'hunger to learn' – especially from nature. Fast learning facilitates to mitigate or even prevent yield and income losses due to lack of experience.

Important
To ensure that the entire family is on board with the conversion to organic production, it is important to have an open conversation among all parties regarding motivation and conversion fears.

The conversion to organic production requires that all those involved have the necessary motivation to embark on this new path together.

Motivation is also essential to take on the increased workload of biological disease and pest control, mechanical weed control, and farm inspection. For sure, a convincing, heartfelt commitment makes it easier to adopt new approaches to production and marketing and to seek exchanges with other producers. Such an attitude is the basis for being able to respond to new opportunities that organic farming offers. Ideally, a positive attitude is shared among all family members involved.

Control and certification: part of the business model

In organic farming, the credibility of organic products is a top priority. Anyone who produces, processes or trades organic products is inspected annually by a recognised, independent inspection body for compliance with the corresponding organic standards. If the result is positive, the inspected farm receives a certificate as confirmation that the implemented production practices match with the guidelines of a specific organic standard.

In general, private standards such as Bioland, Naturland, Bio Suisse and Demeter are stricter than public regulations such as the EU organic regulation or NOP that applies in the USA (see Figure 6). Private standards generally require a whole-farm conversion to organic production. In contrast, the EU organic regulation allows organic certification of individual farm branches (e. g. organic certification of arable crops, while animal production or viticulture are managed conventionally).

Verification of compliance with organic standards by independent inspection authorities is part of the core business of organic farming.

Control along the complete value chain

Organic certification includes all actors of an organic value chain such as farmers, processors, traders and retailers. Controls include scheduled annual visits to verify documentation and management practices. Inspection bodies may also consider carrying out additional, unannounced checks.

In addition to compliance with organic standards, inspections along the value chain also focus on ensuring that organic products are transported and stored separately from conventional goods at all times so that the quantities produced, traded and consumed are consistent. Moreover, volume flow controls along the value chain are essential for avoiding fraud through the reclassification of conventional goods as organic goods.

Control of the organic farm

The legal basis for the control of organic farms is the conclusion of a control contract between the producer and an organic control body. The date of conclusion of the contract marks the beginning of the conversion of land and animals to organic production. The conversion period until approval for the sale of certified organic goods is 2 years for annual crops and 3 years for permanent crops. Only in exceptional cases the conversion period can be shortened depending on the applied standard, (e. g. in the case of previously unused or non-conventionally farmed land).

The first inspection visit always serves to take stock of the farm and to verify the most important information. Among other things, this includes an assessment of the production areas, buildings and livestock, and a review of other measures relevant to compliance with the organic standards, such as seed purchase, fertilisation, stable facilities and feeding.

The annual inspections consist, on the one hand, of checking the records and documentations. This reveals, for example, whether the inputs used comply with the applied standards. On the other hand, the inspector tours the farm with the farm manager to inspect the production areas, stables and storage facilities. This gives a real impression of the farm, the crops and the animal husbandry.

Based on the farm visit, an inspection report is drawn up showing the extent to which the farm complies with the specific guidelines and whether it can be certified after the conversion period. Simultaneously, the inspection process serves to define any measures that need to be implemented until the next inspection, when deficiencies are observed. In case of serious incompliances, such as the use of prohibited inputs, the organic certificate of a farm can also be withdrawn immediately.

Advisors and inspection bodies offer pre-audits as a preliminary clarification before the conversion. These provide valuable information about the most important challenges during the conversion period.

Label and market access

With the organic certificate issuance, a successfully inspected farm can use the organic label that is linked to the specific certified standard (see Figure 7). According to the EU organic regulation, products that have been certified may be marked with the EU organic logo for sale. For the use of the logos of private label organisations such as Naturland, Bioland, Bio Suisse or Demeter a farm must meet additional conditions and be certified according to the standards of these labels.

Box 14: Online management of certificates
Organic certificates are increasingly being managed online. This has the advantage that the time-consuming and costly administration of paper copies of certificates is no longer necessary – and that the certificates can also be viewed by clients. In the case of www.bioc.info, for example, trading companies are automatically informed by e-mail of changes in the certification status of their suppliers.

Important
To access different target markets, it may be useful to conclude an inspection contract for several standards. In this case, the inspection body must be accredited to inspect all desired standards. A pre-audit prior to the conclusion of such contract may be useful to show which standards can be met with relatively little effort.

Organic food is marketed with different labels, depending on the certification. In addition to the organic standard labels, organic labels of supermarkets gain importance. The latter refer to compliance with specific organic standards that the supermarket chains relate to.

Requirements of the EU organic regulations and private organic labels

Summary of the requirements for the production and certification of organic products in Europe according to EU organic regulation and private organic standards		
Scope	**EU Regulation 2018/848**	**Private guidelines [2] (Bio Suisse [3])**
Binding rules and regulations	Regulation (EU) 2018/848 on organic production and labelling of organic products	Bio Suisse guidelines for the production, processing and trade of ‚Bud' products
Basics	Organic management of individual parts of the farm is possible under certain conditions.	The entire farm must be managed organically.
Control and certification	Control and certification by an inspection body recognised and accredited for the EU organic regulation.	Inspection and certification by an inspection body recognised for the Swiss Organic Regulation and based in Switzerland, or inspection by an EU-accredited inspection body and subsequent certification by ICB (International Certification Bio Suisse) [4].
	For the marketing of organic products or organic produce in conversion, an EU organic certificate must be available.	As a requirement for Bio Suisse certification, a valid EU organic certificate must be available. For marketing with the Bio Suisse trademark ‚Knospe', a valid Bio Suisse certificate must be available.
	Certification of produce in conversion from non-EU countries is not possible.	Certification of produce in conversion from non-EU countries is only possible with a valid EU organic certificate.
Duration of conversion	2 years for annual crops, 3 years for permanent crops. Shortening of the conversion period is possible under certain conditions.	2 calendar years. A shortening of the conversion period is not possible.
Marketing during the conversion	Without a shortened conversion period, organic marketing of the product is not possible in the first conversion year.	The produce can be marketed as produce in conversion in the 1st year of conversion.
Promotion of biodiversity	No special regulations.	At least 7 % of the agricultural area must be designated as areas for the promotion of biodiversity.
Nutrient supply	Only products according to Annex I EC 889-2008 allowed (from 2022, the annexes of EU Regulation 2018/848 apply).	Only products according to Annex I EC 889-2008 allowed, with the exception of synthetic chelates and high-percentage chlorine-containing potash fertilisers.
	• The supply of nitrogen from farmyard manure is limited to 170 kg per ha and year (no limits are prescribed for e.g. meat meal). • The supply of phosphorus and potassium is not limited in quantity.	• A detailed nutrient balance must be available. • The supply of nutrients is limited to 225 kg N and 80 kg P_2O_5 per ha and year. • An input of mineral potassium fertilisers exceeding 150 kg per ha and year is only allowed with proof of need.
Plant protection	• Only products according to Annex II EC 889-2008 are allowed. • Copper: maximum 6 kg pure copper per ha and year.	Only products according to Annex II EC 889-2008 are allowed with the following exceptions: • Special rules for horticultural crops, potatoes, grapewine, stone and pome fruits. • No bioherbicides, synthetic pyrethroids in traps and growth regulators.

Summary of the requirements for the production and certification of organic products in Europe according to EU organic regulation and private organic standards		
Scope	**EU Regulation 2018/848**	**Private guidelines [2]: example Bio Suisse [3]**
Seeds	• Organic seed is mandatory. • Conventional, untreated seed only, if it can be proven that organic seed is not available. • GM seed is prohibited.	As EU organic regulation but additionally: • Cereal cultivation: only organic seed, no hybrid seed (except for maize). • For crops that are also grown in genetically modified (GM) quality in the country of organic soy production in the country of production of organic soy, certified propagation material must be used.
Crop rotation and soil protection	• Crop rotation must include legumes / green manure crops. • Use of farm manure / compost to maintain / improve soil fertility.	• At least 20 % soil-building crops. • At least 50 % of the arable land planted in winter. • Cultivation break of at least 12 months between crops of the same species. • Cultivation of erosion-prone areas only, if protective measures have been taken.
Water management	• Water pollution from nutrient inputs must be prevented.	Water quality must not be affected. In areas with risks related to water withdrawal the following applies: • Water withdrawal must not lead to a lowering of the groundwater table. • Only water-saving irrigation techniques may be used. • The legality of the water withdrawal must be proven. • A water management plan must be maintained.
Land grabbing	• No regulations	• Land acquired by land grabbing cannot be certified.
Clearing and burning	• No regulations	• Clearing of ‚High Conservation Value Areas' is prohibited. • Pre- and post-harvest burning of areas is prohibited.
Social responsibility	• No regulations	The following minimum requirements must be met: • Written work contracts. • No health and safety hazards. • Equality regardless of gender, religion, etc. • Right to freedom of association and collective bargaining.
Trade and processing	• Regulations according to EC 834/2007 and 889/2008	Storage and processing of products as well as trading activities must comply with Bio Suisse guidelines.

1 http://ec.europa.eu/agriculture/organic/eu-policy/eu-legislation/brief-overview/index_de.htm
2 Other organic label organizations in Europe have similar requirements
3 www.bio-suisse.ch/media/VundH/Regelwerk/rl_2015_gesamt_d.pdf
4 www.icbag.ch/index.php/de/dokumente-und-downloads/richtlinien-und-weisungen

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