Chapter 11

Environmental Aspects Of Organic Farming

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1. Introduction

In the nature, there is no viable ecosystem that can work without any negative feedback. Any interference with the system does not affect only in one way but it necessarily evokes another often unpredictable reactions. In Europe these days, there are quite natural self-regulating systems with closed energy flows rather exceptionally. This is due to a significant environment disturbance by humans. In terms of area, the main human activity interfering in natural ecosystems was agriculture.

Agroecosystems are tightly connected with more natural, respectively near natural ecosystems. The mutual relationship is bidirectional (nutrient, organism and energy flows, impact on microclimate). In terms of ecological stability, agroecosystems show all disadvantages of juvenile (immature) ecosystems.

Some of the agroecosystem characteristics are:

- additional external energy inputs,
- significantly reduced biodiversity,
- artificial support (selection) of dominant production species,
- juvenile stage of succession (anthropogenic disclimax),
- reduction even paralysing of self-regulatory processes,
- significantly reduced degree of environmental stability
- irreversible degradation processes occurrence

Under the European conditions, there were historically evolved the mixed, commercially oriented, permanent, mechanized systems with high energy-material inputs, i.e. intensive farming systems.

The external manifestation of the intensive agroecosystem is a high degree of landscape urbanization (natural vegetation suppression, sharp land boundaries, the amount of built-up areas, etc.). At the field level, the typical feature is the stand uniformity, inability to self-regulation, often poor ability to environmental adaptation, permanent soil erosion and the need to control other material and energy inputs. Intensive agroecosystems represent a significant spatial landscape heterogeneity reduction and the corresponding species diversity decline.

In real-life working, the intensification is achieved in many ways which are often combined. In particular, the production is narrowly specialised (the number of cultivated plant species is decreasing to monocultures, with livestock, the specialization goes down to level of individual category breeding with no ties to the land and crop production).

Significant intensification factors are concentration (production organisms density increase in time and space), step land use (multistorey stables), high degree of mechanization even technological processes automation, intensive use of additional chemical inputs, energy and information.

Highly intensive mechanized system is becoming completely dependent on external inputs (machinery, fuel, chemicals, seeds). High external energy-material inputs strongly reduce the systems energy efficiency. The ratio of energy input to energy gained from the crop is up to 3:1 while with non-intensive systems, it is 1:20 and more. Within highly intensive mechanized livestock production system, the energy balance is even less effective. However, these systems are very effective in the short term in terms of labour productivity and land utilization.

On the contrary, extensive (low input) farming systems have almost the opposite characteristics. Their main feature is the external input reduction. Extensive agroecosystems are characterized by lower energy and material flows per a unit of area and usually higher diversity, less need for external intervention and greater stability and self-regulatory abilities. They significantly contribute to the conservation of natural resources. Lower inputs can be compensated by a quality management. Reducing inputs usually brings an agroecosystem production capacity reduction. Lower yields can be realized at a lower cost without a significant profit reduction.

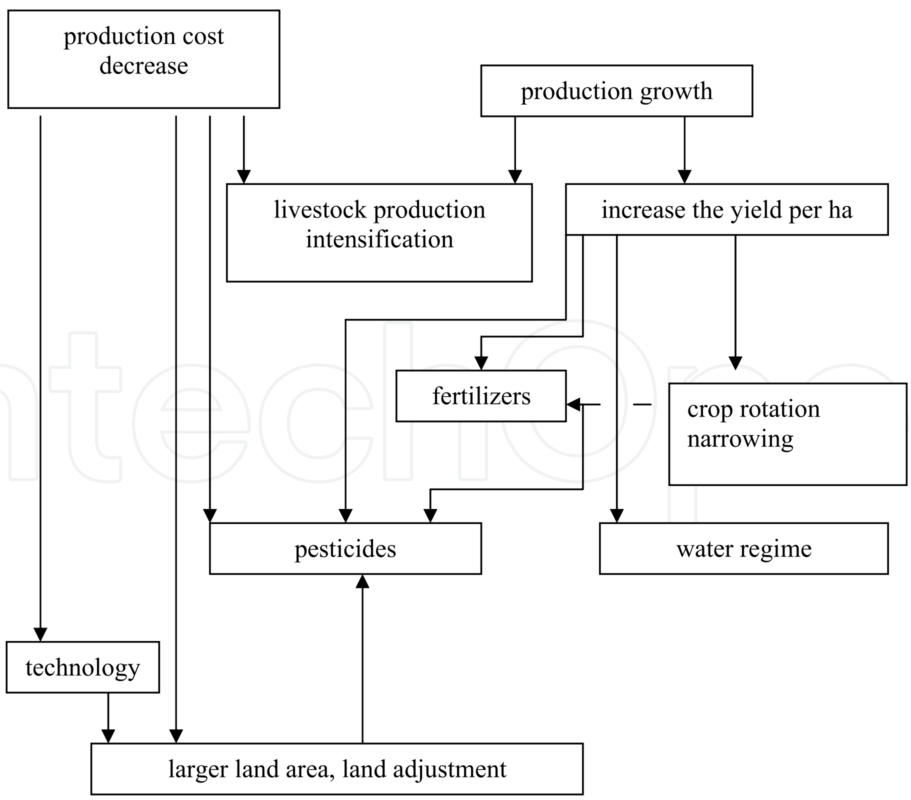
In the world, there are extensive farming systems on 80% of the area and on 20%, there are intensive farming systems. The general trend is the increasing agricultural production intensification in many developing countries (China, Brazil, Russia,...) and chemical inputs reduction, respectively their substitution by biological or rational means in developed countries, especially in the EU. Due to the growing human population and its demands on sufficient of varied and quality food, a certain degree of agroecosystems intensification is necessary. However, it is crucial that agroecosystems have a sustainable character.

According to the simple OECD definition, for sustainable agroecosystems, there can be considered those that meet the needs of these days and do not limit the future generation. The following definition is more precise: *"Sustainable agroecosystems-agricultural and food systems are economically viable, meet society's need for food assurance, while they retain and enhance natural resources and environmental quality for future generations."*

From the definition, it is clear that the sustainable agroecosystem does not carry only the function of food and row material production. The organic farming system is focused on the homogenization of landscape production and non-production functions, where the emphasis is laid on environmental aspects. These include in particular:

1. Maintenance and improvement of soil fertility.
2. Nutrients recirculation and a prevention of the entry of extraneous substance into agroecosystem.
3. Water management in landscape and its protection against contamination.
4. Air quality improvement and greenhouse gas emission reduction.
5. Genetic resources protection and biodiversity maintenance.
6. Preservation of landscape features and their harmonization.
7. Efficient use of energy, focusing on renewable resources.
8. Optimization of life for all organisms, including humans.

Organic farming is based on the principles of sustainable farming and therefore it is a model for the sustainable agroecosystems establishment.



Scheme 1. Impact of market-oriented production on relationships in agroecosystem [54].

1.1. Soil environment

Soil is one of the most important natural resources and plays a key role in agriculture. Healthy soil is essential for growth and evolution of healthy plants. In addition to the production function, the soil has many other functions such as filtering, buffering, transformation and it is the environment for organisms and also its socio-economic function is not negligible.

There are following positive changes within organic farming:

a. soil organic matter (up to 30% higher organic carbon content),

b. increased soil biological activity (by 30-100 %), biomass decomposition indicator,

c. higher total edaphon biomass (by 50-80 %),

d. higher saprophytic fungi abundance, higher root colonization by mycorrhiza,

e. more efficient use of acceptable resources by soil microorganisms,

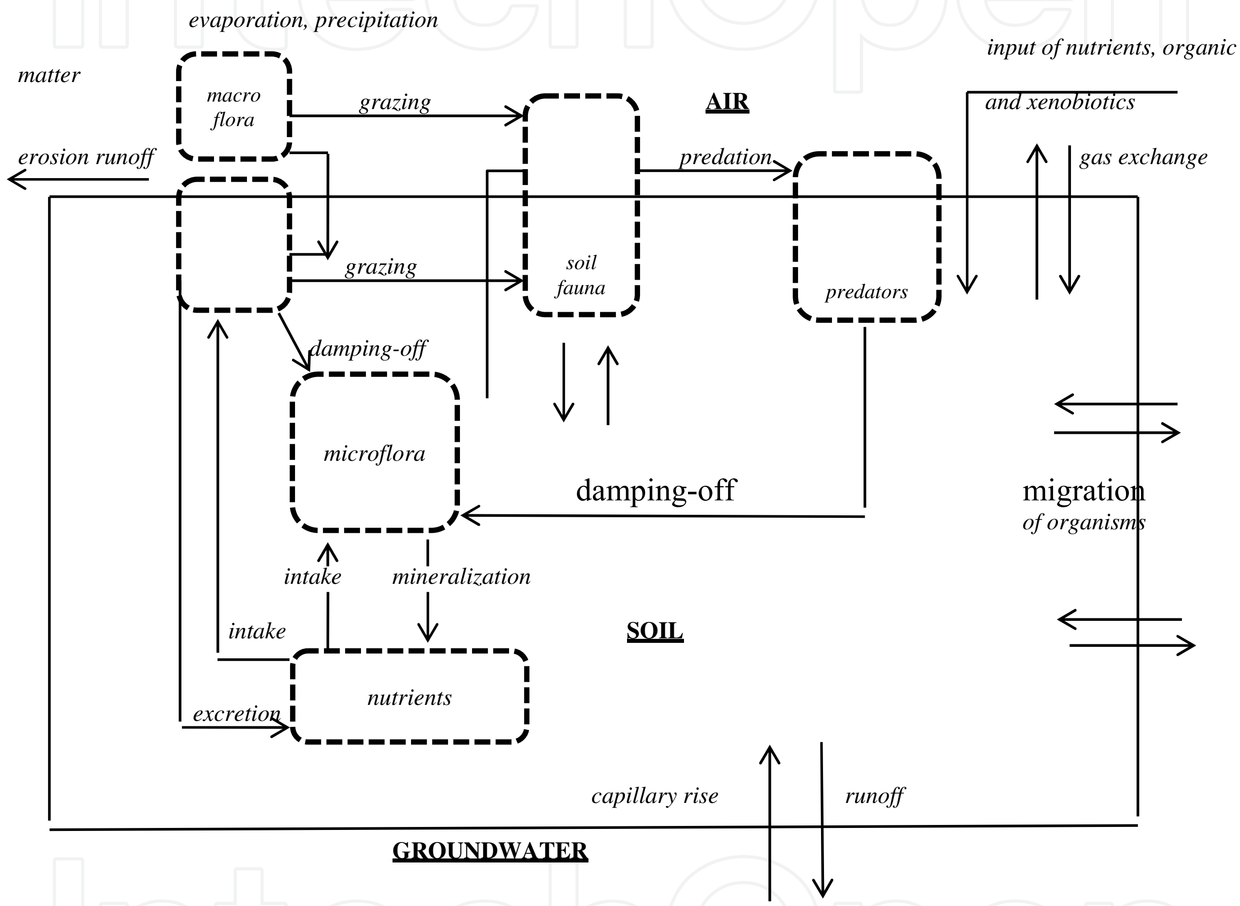
f. improved physical and chemical soil properties, soil structure,

g. improved hydroscopicity and erosion threat reduction

The soil organic matter research is mostly concentrated on the organic carbon content and its changes during conversion to organic farming. Many studies have confirmed that areas under organic cultivation have a higher organic carbon content as compared with areas under conventional cultivation. However, in some researches, there was a higher decomposition of organic matter such as within more intensive soil cultivation associated with mechanical weed control. However, long-term experiments have confirmed the hypothesis that organic farming methods better protected the soil organic matter. The research also points to a larger amount of humic substances. An important factor in the soil organic matter protection is the minimum soil cultivation. A properly designed crop structure, fertilizers, etc. are also important. A higher supply of organic matter in the form of crop residues and organic fertilizers creates favourable living conditions for soil fauna. The soil provides a habitat for a large number of various organisms. The positive role of organisms consists mainly in organic matter decomposition and inorganic substances transformation where nutrients are more accessible for plants and where is also a synthesis of complex organic substances enriching humus reserves in the soil. In organic farming, the key role for nitrogen plant nutrition is played by a symbiotic fixation with papilionaceous plants. In the soil, there is also a nonsymbiotic fixation, e.g. by in-the-soil-free-living heterotrophic aerobic bacteria. Rhizosphere is a zone where the main part of nutrient cycle takes part due to the interaction between soil, roots and microorganisms colonizing the plant root environment. In organically cultivated soils, [35] has observed by 40% more mycorrhiza than in soils within integrated farming.

Natural and active edaphon contributes to the protection of plant roots against parasite and pathogen attack but also to degradation of toxic substances which enter the soil within the chemical plant protection, environmental contamination from industry as well as metabolic products of other organisms. The soil deterioration leads to a biodiversity reduction. Biological degradation of soils is usually associated with their physical and chemical degradation.

The soil liveliness is indicated by a number of indicators: An important role is played by earthworms which are subjects of many studies precisely because of their sensitivity to the soil environment disturbance. Organic farming has up to 50% more biomass and abundance of earthworms as compared to integrated farming, greater biodiversity of earthworm species, changes in the population composition indicated by a larger number of juvenile earthworms. Earthworms are useful-they aerate and mix the soil, help with organic matter decomposition [35].



Scheme 2. Diagram of the soil ecosystem function (adapted according to [54])

An important indicator of the soil organic matter decomposition is the biological activity. However, it is possible to state that changes on biological activity are slow and in many studies comparing organic and conventional farming systems, there were no differences experienced. Some changes (species diversity increase, biomass production decrease resp. yield decrease) occur almost immediately, other (increase of natural soil fertility, soil organic matter content, system stability) show up in the longer term.

On the other hand, the soil deterioration leads to a biodiversity reduction. Biological degradation of soils is usually associated with their physical and chemical degradation. The biodiversity of soil microorganisms is reduced by an intensive cultivation through the use of mineral fertilizers and pesticides. Soils with low humus content and light soils are relatively more sensitive.

A serious problem on large areas, especially of arable land, is a water and wind erosion. Organic farming has a positive impact on its reduction thanks to the more diverse crop rotations with a higher share of clover and grass-legume mixtures, a higher percentage of catch crops and underseeding prolonging the soil cover over the year, a lower representation of wide-row crops (e.g. corn), a more intensive organic fertilization and other factors. Nevertheless, a danger of erosion can occur also in organic farming (and sometimes even more than in conventionally cultivated areas) in particular, because of more frequent mechanical tillage or slower plant development due to a lower mineral nitrogen content in the soil. Structural soils are well more resistant to erosion [50]. When comparing particular factors, we find that positives predominate.

A quality soil ecosystem should meet following criteria:

- water flowing out from the ecosystem should have such a purity that it is suitable for drinking water treatment;
- growth of crops and their composition in terms of consumption should be at an acceptable level;
- microbial processes in the soil should be natural, therefore, relationships between microbial biomass, microbial activity and soil organic matter should be predictable;
- the soil should not contain potentially toxic chemicals (organic and inorganic) in concentration that should affect the previous criteria;
- physical soil properties should enable the normal function of the ecosystem.

1.2. Nutrient recirculation

In agricultural ecosystems, there can be the soil fertility increased by additional inputs such as manure or fertilizer application. Plant nutrition within conventional farming is more dependent on the input of nutrients in the slightly soluble form, predominantly from synthetic fertilizers. A part of nutrients leaves the system as a loss. On the contrary, the natural ecosystem fertility depends almost entirely on natural biological processes, i.e. nitrogen fixation and soil organic matter mineralization. In organic farming, there is the concept of soil as a living system. Therefore, the fertilization system is designed in order to respect natural nutrient cycle and not to adversely affect complex biological processes which nutrient cycles are dependent on. Organic approaches lead to a higher organic matter content in the soil while conventional intensive farming on the arable land can lead to a reduction of this matter content. Assigning of legumes and clover into crop rotations is of a considerable importance because of their agromeliorative effect on the soil. The effect is manifested also on physical properties with an effect on the soil bulk density, water holding capacity, increasing porosity, soil structure stability, etc. The size of invertebrate organism population depends on the physical condition of the soil. They usually require well aerated non-compacted soil with low density.

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A different system of fertilization in conventional and organic farming can have both a direct and indirect effect on soil organisms. The direct effect is related to the composition and the amount of applied fertilizers and the indirect effect is connected with changes of physical and chemical soil properties.

One of the basic principles of organic farming is the most closed nutrient cycle, minimal nutrient loss and limited nutrient supply to the system. In order to maintain the soil production capacity, it is necessary to replace nutrients drawn from soil by harvests and lost nutrients by biologically transformed organic matter in the soil. Regular supply of organic matter into the soil is ensured by crops grown in order to enrich the soil with organic matter (clover, catch crops for green manure), crop residues, residues of cultivated plant roots and manure. Soil organic matter serves as a continuous reservoir of nutrients and energy for the soil environment. It is also a factor of soil environment stabilization. Soil organic matter is a source of nutrients for grown plants, source of energy for soil microorganisms, improves physical and chemical soil properties, water regime, increases decontaminating and buffering soil capacity and decreases nutrient losses washed away from soil, increases antiphytopathogenic soil potential and strengthens the plant immune system.

Growing crops without mineral fertilizers is possible under following assumptions:

- consistent application of all manure
- direct application of recycled biomass and by-products into the soil
- compost production in compliance with the technological process
- use of uncontaminated nutrient resources
- use of peat and humic substances in order to improve habitat and nutritional status of crops
- use of indirect fertilizers containing nitrogen fixating bacteria (free-living in the soil, rhizobia) or bacteria that access e.g. S, P, K and other nutrients form soil reserves.

The function of soil organisms is for transformation of organic matter in the soil irreplaceable. In the initial stage of organic matter transformation, zooedaphon participates in the destruction of crop residues and in the production of organomineral components. The transformation proceeds on depending on organic matter composition, edaphon activity and environmental conditions in terms of mineralization and humification. For the humus formation, there are important root exudates, roots of perennial fodder plants, legumes, manure and compost and dead residues of zooedaphon. A ready potential source of nutrients in the soil is the primary organic matter, root exudates and manure. Crop residues alone cover mineralization losses of about 50%.

Of the total amount of organic matter, less than 10% is humified. The increase of the amount of permanent humus in the soil is a matter of long-term (tens to thousands of years). Water-soluble carbohydrates decay fastest, cellulose, hemicellulose and protein decay average rapidly and lignins and pectins are the slowest. The rate of decomposition of different organic matter sources is greatly different. Sustainable land management system assumes a balanced budget of organic matter in the soil consisting in replacing mineralized organic matter by inputs in the range of mineralization and losses.

Substance	Crop		
	corn	alfalfa	wheat
Water-soluble sugars	6.72	4.36	4.68
Hemicellulose and starch	42.61	14.85	23.30
Cellulose	23.29	32.25	42.12
Proteins	4.75	16.44	4.31
Lignin rest	18.27	29.60	23.00

Table 1. Chemical composition of crop residues (% dry matter).

1.3. Water in landscape

Disposal of pesticides and morforegulators from the organic farming system reduces significantly the contamination of the environment including surface-and groundwater by residues of these substances. In the area of organically cultivated fields, there are surface water and groundwater less contaminated with plant protection products. These substances harm also to aquatic animals, even at low concentrations (below detection limit) [33].

Also the prohibition of use of slightly soluble synthetic nitrogen fertilizers in organic agroecosystems reduces significantly the load of surface-and groundwater by nitrates. Reduced animal surface load of soil (limit for organic farming 1.5 LU/ha, optimum 0.4-1.0 LU/ha in relation to site conditions), optimal manure use (method of treatment and storage, time and rate of its application, higher use of green manure and liquid manure restrictions), appropriate use of leguminous plants and atmospheric nitrogen bounded by them, appropriate crop rotation and an effort to maximize the vegetation cover (catch crops and permanent crops), soil conservation cultivation methods and erosion reduction and other impacts contribute to this. Within organic farming, there are by 35-64% less nitrates washed away as compared to conventional farming agricultural plants [53]. In 40 scientific publication comparing nitrate leaching or a leaching potential analysed by [22], twenty eight stated lower values within the organic farming system, nine issued comparable data and only in three cases, the nitrate leaching respectively its potential were higher within organic farming than in conventional one. Yet, there were two critical areas for potential water pollution recognized and studied within organic farming. These are manure composting and farming with residual nitrogen from leguminous plants. Storage and composting of manure on unpaved surfaces can cause leakage and subsequent contamination of groundwater and surface water. A significant leaching can also occur when the nitrogen source accumulated by leguminous plants is inappropriately used, i.e. by ploughing alfalfa in autumn, followed by sowing crops with low demands on soil nitrogen content [48].

Nutrients from intensively cultivated cropland load water due to overland flow. Within organic farming, this risk is reduced by greater ruggedness of landscape, more extensive integration of landscape features as well as the crop diversity and their optimal distributing. Marginal strips along water courses and reservoirs and protective grass strips on slopes make buffering areas, limit overland flow and prevent erosion and expand biodiversity. Organic farming is supposed to be the preferred farming system especially in the areas of water resources conservation.

Organic farmers fertilize the soil in such way so not to pollute groundwater. Within organic farming in addition to manure and liquid manure, there is green manure also used as fertilizer and legumes are properly incorporated into the crop rotation. This reduces the leaching of nitrogen into groundwater. As a result of leaching through the soil profile and due to erosion and surface runoff, nitrates in water causes contamination of the hydrosphere and along with phosphorus cause eutrophication [30]. Concurrently, there is a leaching of base cations (K+, Ca2+) and thus the upper soil layer are depleted of these nutrients. Indirectly, this leads to acidification. Due to leaching, several tens of kg N. ha-1. year-1 is normally lost [51]. Organically cultivated areas provide better flood protection than conventional surfaces. The high infiltration capacity of the soil with virgin structure may reduce the intensity of floods [49].

1.4. Air quality

Agricultural activities have not a negligible impact also on air quality. Organic farming as a whole contributes to the creation of anthropogenic greenhouse gases with about 14% while the ratio differentiates with particular countries according to the agricultural production intensity. Due to its large area impact, agriculture belongs to the largest producers after industry and mining. [14] state that agriculture contributes to annual increase of GHG emissions with approximately one fifth. Even higher value is stated by [10], whose findings report the proportion of 27%.However, with the increasing consumption of food and agricultural intensification, this percentage is rising. When adding pre-farming and post-farming phases to the agricultural frame itself or quantifying food life cycle, the emission load is even higher. This is mainly due to production of agrochemicals and processing of primary agricultural production. Moreover due to the increasing human population, agriculture will even increase its pressure on the environment. There is constantly running the conversion of natural habitats into agroecosystems and in parallel the intensification of farming on existing agricultural land. This is largely accompanied by other chemicalization of agriculture. The pressure on increasing yields and the food consumption grow aggravate the share of agriculture of emission load production. However in most cases, organic farming produces lower emission load, not only in the field phase but also in the consequential phases.

Agriculture produces emissions in many ways. For example, CO_2 is released during the consumption of fossil fuels or within reduction of organic matter content in the soil. N_20 is released as a result of fertilizer application and within soil processes, CH_4 from the digestive tract of some livestock species. Especially in the crop production, the emission production is influenced by the intensity and thus by the system of farming.

Organic farming has a number of tools which help to reduce emission loads (see tab. 2). [42] in accordance with the IPCC fourth assessment report states as the optimal measures for mitigation (reducing stress) in organic agriculture the following points:

- crop rotation and character of the agricultural system
- management of nutrients and fertilization
- livestock, improving the pasture utilization and fodder supply
- soil fertility management and restoration of degraded soil

Within the environmentally friendly approach, organic farming systems generally seek more precisely to work with energy and to minimize inputs and to close the farm cycle as soon as possible.This leads to a large emission reduction particularly due to the reduction of synthetic nitrogen fertilizers whose production is among the largest producers of GHG emissions. Thanks to the use of organic fertilizers and the inclusion of greater proportion of leguminous plants in crop rotations, the organic farming can contribute significantly to the emission load formation. Thanks to these measures, mainly N_2O emissions are reduced, while the N_2O is identified as a major greenhouse gas and its effect on climate is often referred to as 300 times greater as compared with the effect of CO_2. Another positive aspect of organic farming in terms of greenhouse gas emissions is the reduction of the number of animals per unit of area and limitation of point load caused by high concentrations of animals in one place which is typical for intensive industrial agriculture. Extensiveness of livestock production within organic farming system leads to reduction of methane production and in addition leads to further positive effects on soil and water quality, and in the broader context, also on biodiversity.

Measures	Impact
Fertilization	Using leguminous plants in crop rotations for the fixation of nitrogen and using organic fertilizers replace the use of synthetic fertilizers and the capacity of the soil for carbon sequestration is increased.
Protection against weeds	Thanks to the emphasis on the structure of crop rotations, mechanical, biological and other non-chemical methods of plant protection, the application of herbicides is eliminated.
Protection against pests	Thanks to the selection of resistant varieties, crop rotation edition, use of cover crops, intercrops and undersowing and support of predators and antagonists, the use of insecticides is reduced.
Protection against fungi and mildew	Due to the cultivation of resistant varieties, changes of crop rotation structure, emphasis on seed quality and the use of non-chemical methods of protection, the use of fungicides is reduced or even eliminated.
Closed farm cycle	Ensuring the maximum share of feed on the farm and the correct management of the herd minimize the need to purchase feed.
Continuous soil cover	Minimizing of periods without vegetation cover helps to increase the content of soil organic matter and its decomposition which reduces the need for fertilization.

Table 2. Tools for reducing the emission load resulting from the specifics of organic farming (adapted according to [34])

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In terms of reducing greenhouse gas emissions, the another benefit of organic farming is the fact that organically cultivated arable land stores more carbon into humus. Thus the increase in atmospheric CO_2 is limited and this contributes to the climate stabilization. Binding of carbon dioxide is significantly higher in a longer crop rotation with perennial legume-grass mixture and with fertilization with manure. This is due to the increasing humus content in the soil, longer green land cover with catch crops and more powerful root system of main crops [45]. Rodale Institute's Farming Systems Trial states that the introduction of organic farming nationwide in the USA would manage to reduce CO_2 emissions by up to a quarter due to increased carbon sequestration in soils [32]. Emissions of carbon dioxide from organic farms is up to 50% lower per hectare. The balance of carbon dioxide is positively influenced by non-use of synthetic nitrogen fertilizers and pesticides and also by low doses of phosphorus and potassium, as well as low doses of grain fodder [41].

1.5. Biodiversity

The positive impact of organic farming on biodiversity is based on an effort to extend the range of cultivated crops and livestock and thereby to increase a genetic, species and ecosystem diversity. On this basis and on the basis of environmentally friendly agroecosystem management, the functional agrobiodiversity has increased. Growing biodiversity at all levels (predators, parasites, wild plans, pollinators, soil fauna and flora…) supports the ecosystem functions (population control, competition, allelopathy, organic matter decomposition, nutrient sorption and their cycle…). It contributes to the agroecosystem stability and sustainability. It improves resistance of production organisms against harmful agents gradation and contributes to their effective control, improves the nutrient utilization in agroecosystem and reduces eutrophication. It contributes to the erosion reduction and improves the moisture use, helps to increase diversity and abundance of wild flora and fauna in the landscape.

The high degree of diversity in the landscape, including agricultural land, can be caused by either a variety of abiotic environment (e.g. altitude, height relief zoning, seat rock and soil cover) or by disruption, disturbance caused by both natural interference processes and human activities. In the landscape structure, we can distinguish large areas whose internal environment a limited number of specialized species-"interior species" are bound to and smaller flats, transition zones and various broad interfaces that generate a colourful environment with many species corresponding to a diversity of ecosystems. On the edges of the fields of organic farmers, there are by 25% more birds surveyed than within conventional farming-in autumn and winter even 44% more [11]. They include both species characteristic of the individual habitats-species from forest, field, meadow and species from marginal environments-"edge species"-ecotone species that require more landscape elements for their existence. On the fields in organic farming, there are more accompanying plant species grown, in the ground layer 20-400% more species of wild plants [28]. Among other things, many endangered species of weeds as well [47].

Beneficial organisms prefer natural areas adjacent to the organic fields. Natural areas adjacent to the organically cultivated areas significantly support more beneficial organisms (e.g. ground beetles, spiders, wolf spiders-Lycosidae family and others for nature conservation significant fauna species) than the natural areas adjacent to the integrated areas or areas under the extensive farming [44]. In 41 of 45 studies, the number of earthworms, ground beetles, spiders (especially the Wolf spiders) and birds in the cultural landscape was significantly higher in organically cultivated areas than in the conventional ones. In four cases, there was no difference experienced [43].

The high degree of biodiversity reduces the population of rare species in the inner zones, increases the population of species in the border zones and of animals that require more landscape elements. From this, we can deduce that the right long-term agroecosystem function is directly proportional to the degree of biodiversity and the appropriate degree of stability of the area as a whole.

There are many factors driving agrobiodiversity such as crop range widening (broad crop rotation, specific or varietal mixtures, catch crops, cover crops, intercropping…), supply of organic matter into soil (manure, green manure, perennial crops), optimal fertilization, plant nutrition and protection, soil conservation technologies (direct drilling, mineralization of soil cultivation…) as well as the landscape feature creation (cops, alleys, strip planting, land division…). Areas within organic farming are more diverse (heterogeneous). Organic farmers farm on smaller fields with a greater proportion of green areas and a greater number of plant species. There are also more hedgerows in the organic farm.

In the organically cultivated farms, there are more than 85% greater number of plant species, a third more bats and there live about 17% more spiders and 5% more bird species [20, 23]. On the organic field, there are for example nine times more species of plants and accompanying weeds growing, there live 15% more ground beetles and 25% more earthworms than in the fields within integrated farming [35]. Greater variety of plants, hedges, grassy field margins, smaller areas of land, smaller corn ear density, area gardening, stubble and green soil cover in winter create favourable conditions for e.g. skylark. Already after one year of transitional period, the number of skylark nests has doubled. Nesting swallows and birds of prey also give priority to food from organic areas. In autumn and in winter, there were significantly more seeds and insects for songbirds and also more food for birds of prey found on organically cultivated fields [24].

2. Effect of farming system on greenhouse gas emissions

Among the positive externalities of organic farming belongs its environmental friendliness. This is also evident in the ability to produce less greenhouse gas emissions as compared to conventional intensive farming systems. In order to compare different farming systems more accurately, it is necessary to make a comprehensive analysis of materially energy flows within them and to quantify their impact on the environment. There can be used for example the LCA analysis (Life Cycle Assessment).

LCA analysis is a tool that enable to assess environmental impacts via the product life cycle. Within its framework, we can include also social and economic aspects but the main focus is on the environmental component. It is also an invaluable tool in the assessment of greenhouse gas emissions related to product formation [18].

The LCA study consists of four basic stages: Definition of objectives and the scope, Inventory, Impact assessment and Interpretation [27]. According to [29], in the first step when implementing the LCA methodology (goal setting), the reason for carrying out the method is specified. Life cycle inventory consists in simulating of a product system. Based on the knowledge of the life cycle of the product under consideration and on the basis of previously set system boundaries, there are first all involved processes and their inputs and outputs identified. Connecting processes with adequate energy and material flows into a functional complex, we obtain a product system diagram [26]. In essence, it is a qualitative and quantitative inventory of all inputs and outputs connecting the monitored system with the environment or the collection of the necessary primary data and an assessment of their quality, i.e. authenticity, reproducibility, transparency and confidentiality [29].

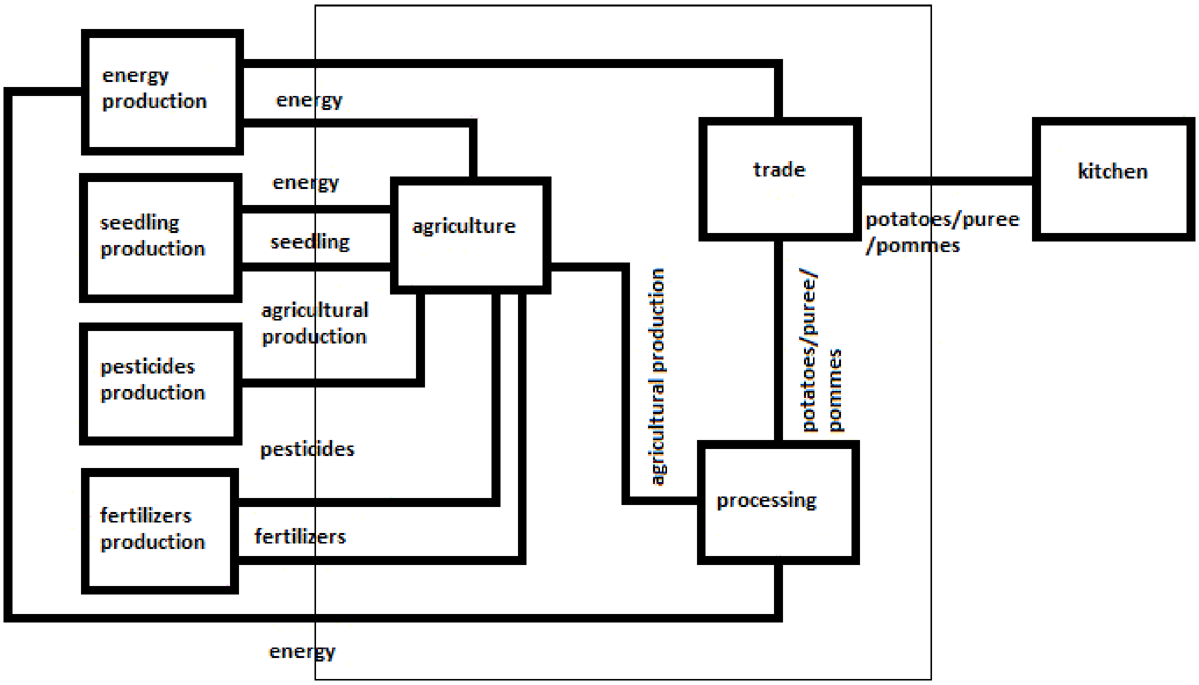
The aim of the life cycle impact assessment is to measurably compare the environmental impacts of product systems and to compare their severity with new quantifiable variables identified as impact category [27]. It is basically a qualitative and quantitative assessment of all negative effects that may be caused in the environment by influences collectively specified in the inventory matrix [46]. In the interpretation phase, outputs of LCA analysis are described. During the inventory phase and the phase of impact assessment, there were made some certain estimates, assumptions and judgements how to continue with the study. There have been some simplifications and approximations adopted. All of these elements must be included in the interpretation phase and must always be set next to the result presentation [27].

For the correct execution of the LCA analysis, it is important to determine the boundaries within which the particular life cycle processes will be monitored. Determination of system boundaries is always a very important step, especially in the area of food production and agriculture, where the clearly identifiable technological processes and systems meet the natural processes and procedures influenced by a number of factors [2, 3].

Each product system consists of a variable number of processes involved in the product life cycle. However, the product under consideration is often related to other processes that may no longer be important for the LCA study. The system boundary serves to the separation of essential and non-essential processes of the product life cycle. Since the choice of system boundaries significantly affects LCA study outcomes and in addition, its intensity and complexity, system boundaries should always be well considered and clearly defined. The choice of system boundaries is carried out with regard to the studied processes, studied environmental impacts and selected complexity of the study.

Not-including any life cycle stages, processes or data must be logically reasoned and clearly explained [26].

When comparing conventional and organic farming systems, we can also omit the calculation of load from buildings and infrastructure because there are only small differences between farming systems while slightly more noticeable difference is apparent within animal production [40]. The reduction of processes under consideration can be made also on the basis of their presumed significance. The assessment can skip those processes, whose overall impact consists totally of only a negligible share, for example of only several percent. These processes can be identified for example based on a comparison of similar studies or expert estimation but in this process it is always necessary to take into account the specifics of the particular situation. If the process significance is set incorrectly, this could have a rough influence on the results of the whole analysis.



Scheme 3. Example of setting the boundaries of the system within LCA analysis [37]

To compare products (systems), it is necessary to define also the functional unit. The functional unit is described as a quantified performance of a product system which serves as a reference unit in a study of life cycle assessment [13]. It is an essential element which all study results are related to. It must be chosen so as to be easily expressible and measurable. The functional unit is the starting point for searching for alternative ways how to fulfil the function with a lower negative impact on the environment [55]. [1] states that the determination of functional units is as a crucial step especially when comparing systems with different levels of production per hectare such as conventional and organic farming system. [15] recommends to involve both functional units into calculations and perform the calculations for both the unit area and the unit of production. The impact of organic system on the mitigation is usually measured per unit area in order to enhance the objectivity. However, it is important to convert it also to the production unit. Greenhouse gas emissions are lower in organic systems per unit area but also per unit of production. However, environmental savings per unit area are due to lower yields within organic farming roughly double as compared with the calculation per unit of production [40]. [25] also states that due to lower yields within organic farming in the calculation of GHG emissions per unit of production, the environmental load increases in relation to conventional farming, so the resulting difference is less than when converted to the unit area. This is consistent with findings of [36] who states that due to lower yields in organic farming, particularly in less developed countries, the environmental effect consisting in the reduction of greenhouse gas emissions is lower when converted to unit of production instead of unit area and in extreme cases, it can even be negative. However, for both methods of calculation for most crops, the greenhouse gas emissions production within organic farming remains lower [38].

Greenhouse gas emissions are expressed in relation to their effect on climate changes by an equivalent of CO_2e (CO_2e=1x CO_2+23x CH_4+298x N_2O). Within various subphases of agricultural production cycle, the emission load of conventional and organic farming differs. For example in the agrotechnical phase with most cultivated crops, the higher emission load per one kilogram of production occurs within the organic farming system. However, it is usually more than satisfactorily compensated by the absence of synthetic fertilizers (especially nitrogen) which are, in terms of emission production, the most loading element. The way of fertilization is directly related to field emissions which are lower in organic farming and there are some savings also due to the absence of pesticide use. To sum up, organic farming produces lower GHG emissions within cultivation of most crops and in some cases, there are very fundamental differences (e.g. Conventional production of rye under condition of central Europe produces almost twice the emissions CO_2e in relation to organic farming).

This can be documented by the study within which the creation of greenhouse gases within the cultivation of crops in conventional and organic farming system under conditions of central Europe was compared. Within the study, the total GHG emissions expressed as CO_2e were observed. This sum was divided into subgroups-agricultural engineering, fertilizers, pesticides, seeds and field emissions. The conventional farming system differs from the organic one in the total CO_2e emissions production as well as in the production within subgroups. Overall results are shown in Figure 1 that summarizes the production of greenhouse gases converted to one kilogram of production and compares the conventional system with the organic farming system.

GHG emissions within cultivation of particular crops vary depending on many factors, while the most CO_2e is released within fertilization and field emissions and also a share of agricultural operation in not negligible. With all surveyed crops except onion, where 0.083 CO_2e/kg of onion in conventional and 0.100 kg CO_2e/kg of onion in organic farming is produced, higher CO_2e emissions were found within the conventional farming system. Within cultivation of wheat, 0.460 kg CO_2e/kg of grains within conventional and 0.423 kg CO_2e/kg of grains within organic farming is released. With rye, it is 0.537 kg CO_2e/kg of grains within conventional and 0.298 kg CO_2e/kg of grains within organic farming, with potatoes 0.145 kg CO_2e/kg of potatoes within conventional and 0.125 kg CO_2e/kg of potatoes within organic farming, with carrot 0.099 kg CO_2e/kg of carrot within conventional and 0.041 kg CO_2e/kg of carrot within organic farming, with tomatoes 0.087 kg CO_2e/kg of tomatoes within conventional and 0.067 kg CO_2e/kg of tomatoes within organic farming and with cabbage 0.078 kg CO_2e/kg of cabbage within conventional and 0.033 kg CO_2e/kg of cabbage within organic farming. It is obvious, that the organic farming system is, in terms of emission, less demanding and therefore more environmentally friendly than conventional farming, where emissions production is increased especially by the use of synthetic fertilizers.

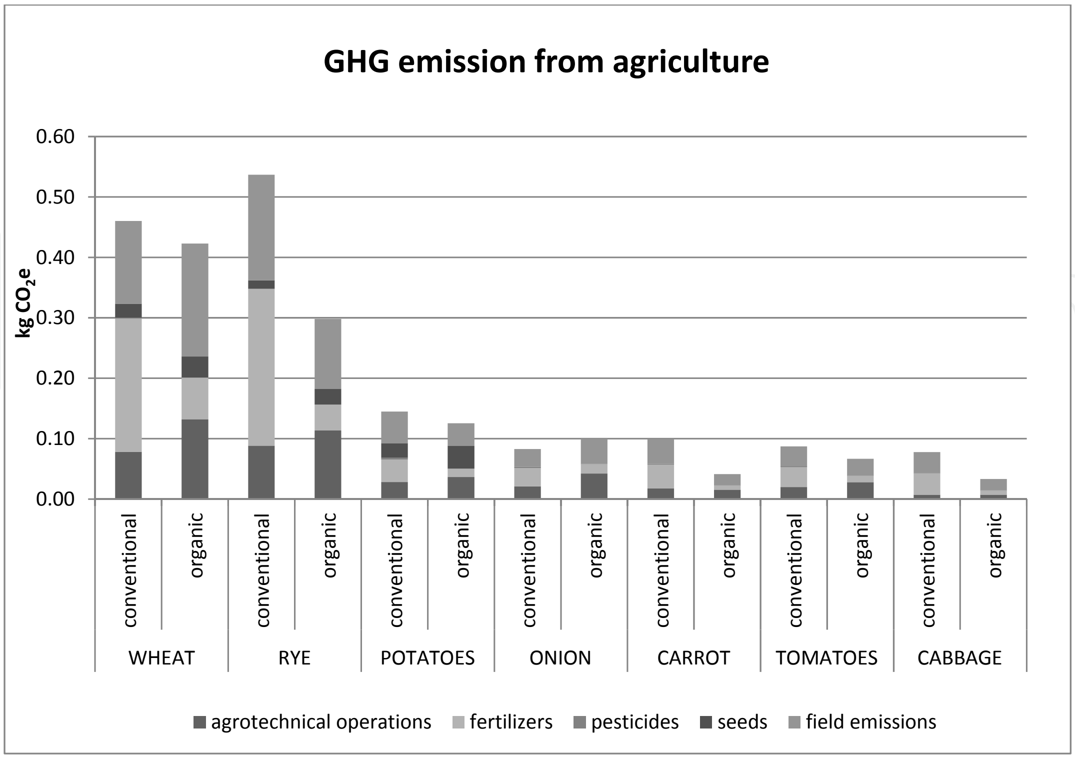


Figure 1. Total production of GHG emissions within growing of selected crops in conventional and organic farming system (in kg CO_2e per 1 kg of production) [38].

Differences between particular subgroups (Farming, Fertilizers, Pesticides, Seeds and Field emission) can be documented as exemplified by the comparison of the cultivation of wheat and rye in conventional and organic farming system. As stated by [31], the system sustainability can be evaluated on the basis of inputs and outputs and their conversion to CO_2e. Due to higher demands for agro-technical procedures and lower yield per hectare, GHG emissions generated in the organic farming system are with rye and wheat higher as compared with the conventional farming system. With wheat, as it is evident from Figure 2, the values within organic farming (0.132 CO_2e/kg of grains) are 69.2% higher than in the conventional system (0.078 CO_2e/kg of grains), with rye then higher by 28.4% (conventional agriculture 0.088 CO_2e/kg of grains, organic farming 0,113 CO_2e/kg of grains). The possibility of reducing GHG emissions by changes in agricultural technology is highlighted also by [16] who identifies the main potential for reduction within tillage. Zero-tillage systems as a tool for reduction of the emission load is also mentioned by [31], who states that the change to zero-tillage systems can lead to reduction of emissions of 30-35 kg C/ha per a vegetation period. Also [4] stated that the technique of reduced (minimum) tillage which is in organic systems used more and more frequently and with greater success supports carbon sequestration significantly.However, unlike conventional zero-tillage systems, the organic systems with limited (minimum) tillage do not require higher inputs of herbicides and synthetic nitrogen [42]. Parallel to the increase of yields, the minimization measures in agricultural technology can contribute to the reduction of emissions and thereby further to increase the environmental emission savings ensured by the organic farming system.

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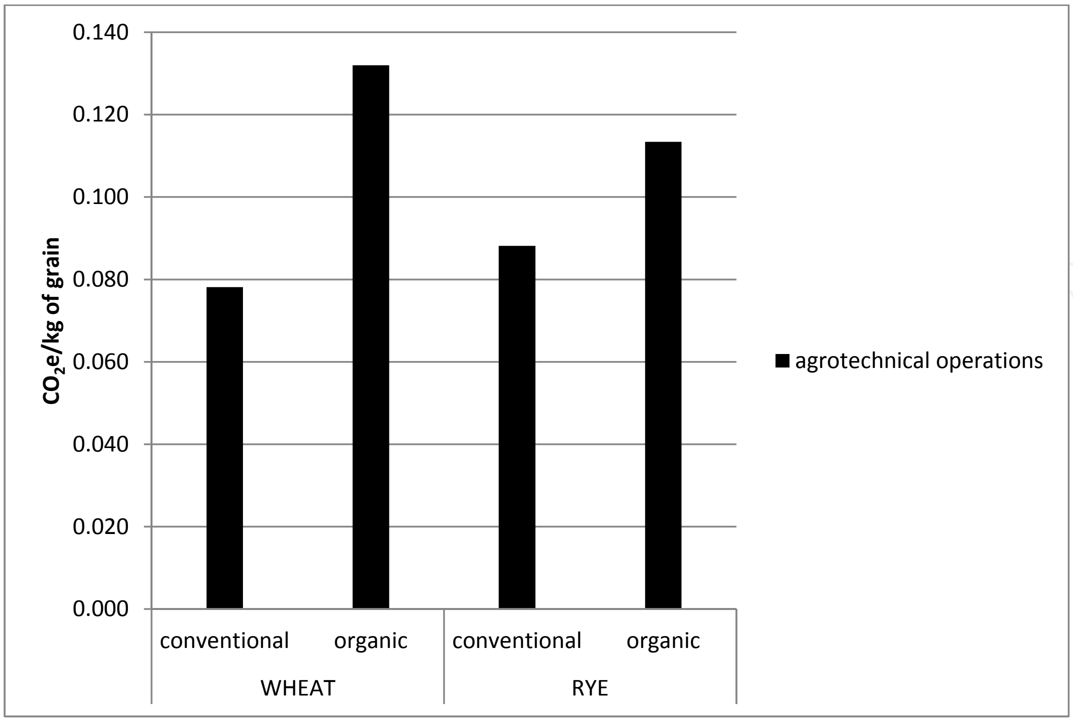

Figure 2. Production of CO_2e/kg of grain from agrotechnical operations during growing of wheat and rye in organic and conventional system of farming

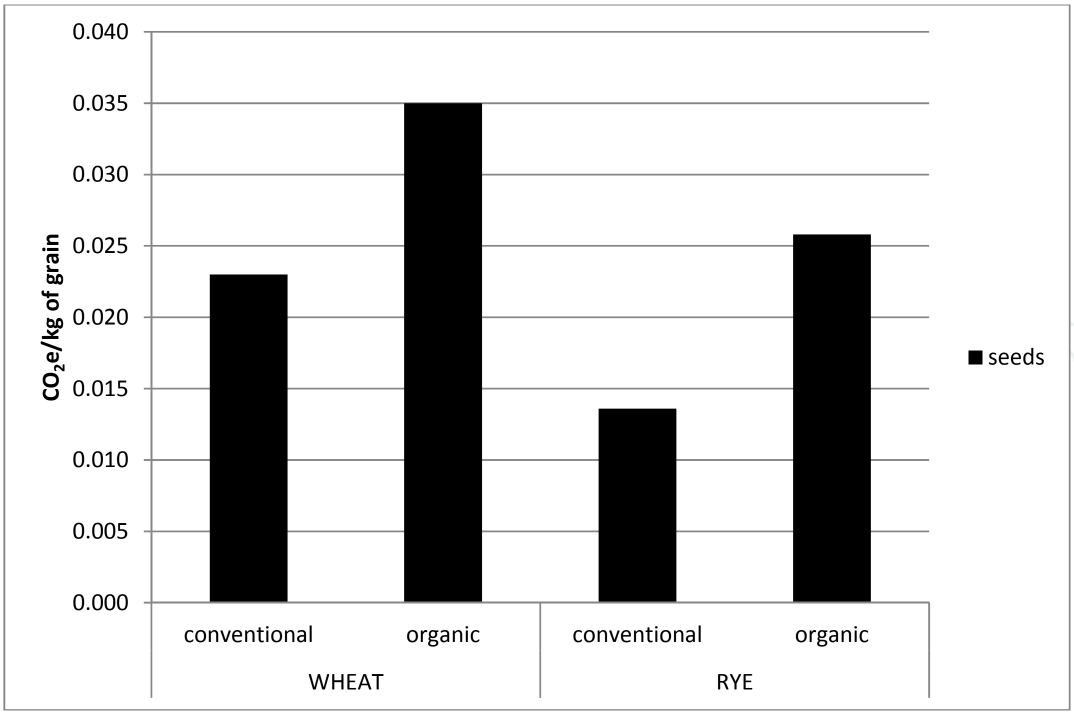

Figure 3. Production of CO_2e/kg of grain from seeds during growing of wheat and rye in organic and conventional system of farming

Higher GHG emissions are within the organic system also with seed (see Figure 3), where the calculated value is 0.023 CO_2e/kg of grains for wheat within the ecological system, respectively 0.035 CO_2e/kg of grains within the conventional one (52.2% more in organic farming) and 0.014 CO_2e/kg of grains for rye within the organic system and 0.026 CO_2e/kg of grains in the conventional system (85.7% more in organic farming). However, of the total amount of emissions, the seed has relatively negligible share.

Field emissions make an important part of the total emission load (see Figure 4), there is not evident an explicit trend. While they are for wheat in the organic farming system by 36.5% higher (0.137 CO_2e/kg of grains in the conventional and 0.187 CO_2e/kg of grains in the organic farming system) however, for rye, there are these values by 33.7% lower in the organic farming system (0.175 CO_2e/kg of grains in the conventional and 0.116 CO_2e/kg of grains in the organic farming system). Differences in the amount of field emissions are caused by a combination of several factors, the main role is played by the difference in the intensity of fertilization (for wheat in the organic farming system, there is applied 20 tons of manure while for rye only 12 tonnes) and by the various ratio of income between conventional and organic farming system (organic wheat yield is 58% of the conventional wheat yield, yield of organic rye makes up 72.5% of the conventional rye yield).

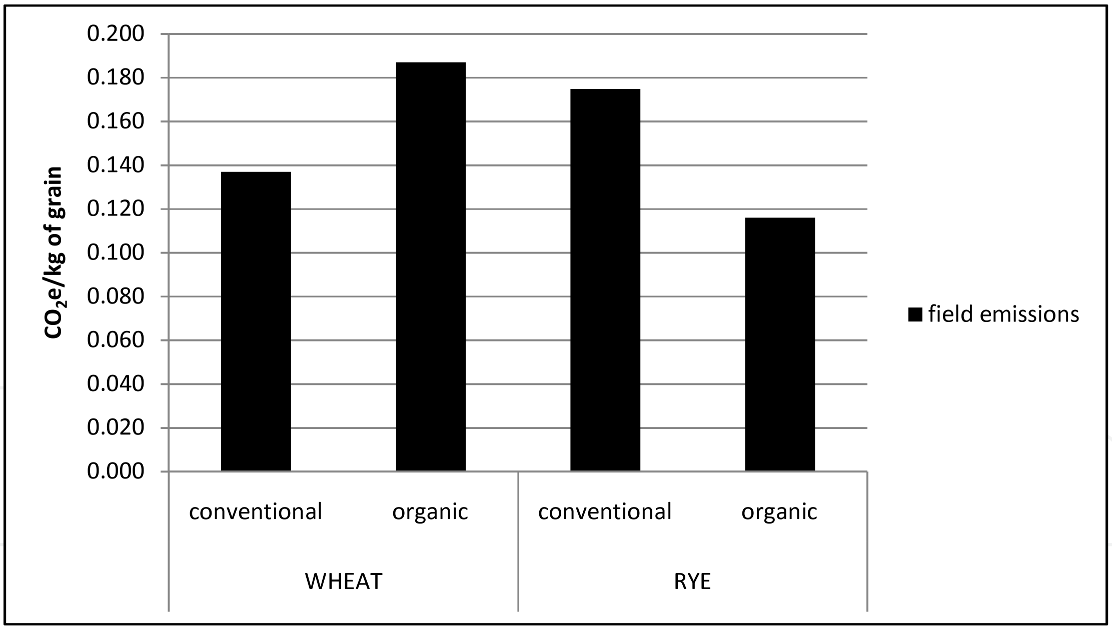

Figure 4. Production of CO_2e/kg of grain from field emissions during growing of wheat and rye in organic and conventional system of farming

The main differences in emission production in conventional and organic farming system arising from the use of agrochemicals in the conventional farming system. While there is a relatively small share of total emissions caused by the use of pesticides (0.22% of total emissions for wheat and 0.19% for rye) and their environmental impact lies mainly in their toxicity, a very high emission load is generated by using synthetic fertilizers (conventional farming system) instead of organic fertilizers (organic farming system). This is consistent with findings of [5, 19] who state that synthetic fertilizers are the main source of greenhouse gas emissions. As it is evident from Figure 5, the conventional farming produces in this stage of the process significantly more GHG emissions. With wheat, these values (0.221 CO_2e/kg of grains in the conventional farming system, 0.069 in the organic farming system) are in organic agriculture by 68.8% lower, for rye then 83.4% lower (0.259 CO_2e/kg of grains in the conventional farming system, 0.043 in the organic farming system).

GHG emissions from fertilization make up a value around 48% (48.04% wheat, 48.27% rye), this is the largest share of total emissions in conventional agriculture, which is consistent with findings of [21] who states this proportion of 40-50% for rape and approaches the data by [6] who states the range of 35-40%. While in organic farming, emissions from fertilization make up in the total amount of GHG emissions only 16.31% with wheat and 14.41% with rye. [17] states that nitrogen management in agriculture loses its effectiveness in terms of the proportion of utilization of applied nitrogen. The total number of inputs is increasing but plants consume actually still smaller share of the applied nitrogen. A large part of the increased amount of fertilizer is not processed by the plant but is released into the water or into the air. To reduce greenhouse gas emissions, it is necessary next to a reduction of synthetic fertilizers also a proper management of their application or the application of fertilizers in general. Both within conventional and organic farming system, there should be able to reduce the environmental load arising from fertilization with nitrogen while maintaining current yield levels.

In terms of emission production, the extensification of conventional farming or its conversion to the organic farming system can be the step leading to a reduction in the overall proportion of anthropogenic GHG emissions. On the contrary, within organic farming, the increased yields are seek. They emphasizes the environmental friendliness also after conversion to the unit of production.

The increase of income, while maintaining the current structure of inputs of organic farming, as a way of deepening its environmental benefit, is referred also by [9]. This is consistent with findings by [12] who states that organic farming systems are significantly more environmentally friendly when they reach a relatively higher yields. [7] states that this can be achieved by e.g. more efficient application of fertilizers and crop rotation balance. Also, the proper selection of varieties could significantly contribute to better yields and their stability within organic farming and in the farming system with low inputs [8]. Productivity in sustainable farming can be increased through many indirect measures based on improving of soil fertility and stimulation of the functions of plants and microorganisms in natural soil processes. The most important role in the soil is yet played by carbon. It is important for soil moisture and at the same time thanks to increasing the carbon content or the soil organic matter in the soil, the production of greenhouse gases released into the atmosphere can be reduced. Strengthening these soil processes in order to increase the productivity is typical for organic farming [40].

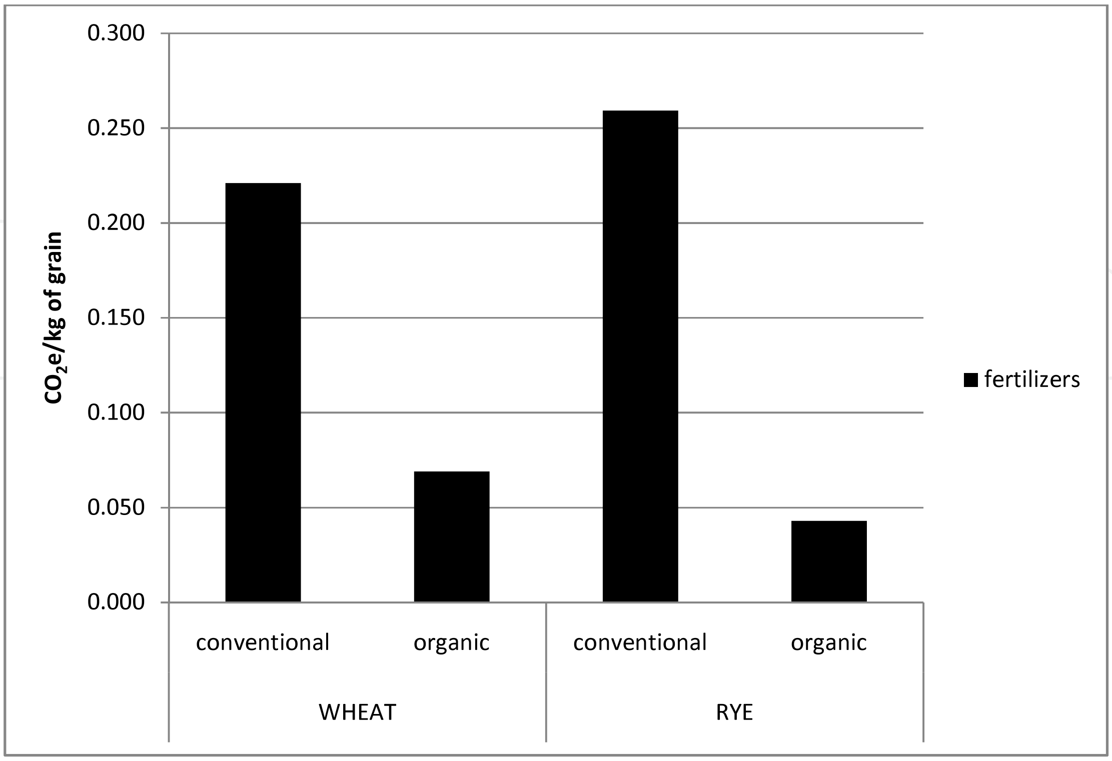

Figure 5. Production of CO_2e/kg of grain from fertilizers during growing of wheat and rye in organic and conventional system of farming

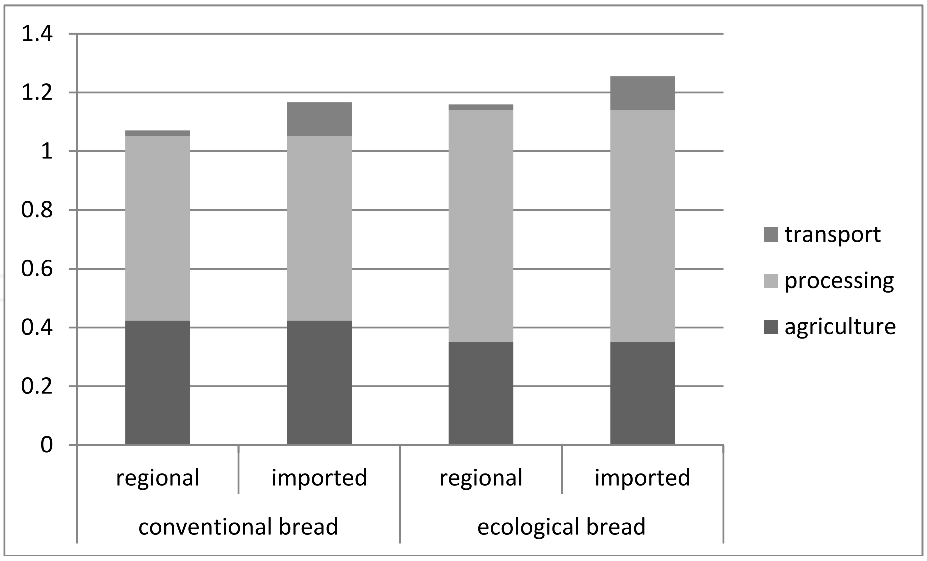

Figure 6. Emission load of bread (in kg CO_2e per 1 kg of bread) [39]

In addition to the agricultural production, also other processes such as processing or transport may be incorporated within the framework of the LCA analysis. While within the livestock production, the post-farm phase is less important in terms of emissions, for crop production, its importance is increasing [52]. As it is evident from figure 6, these processes may in some cases reverse the environmental potential created by the organic farming system within the farm phase. In the case of the production of bread in bio-quality under conditions of the Czech Republic, this leads to a situation where due to different technologies and especially production capacity in organic farming, the final product produces in terms of CO_2e emissions a higher load than conventional products.

Emission load from the transport is in the case of bio-products also often increased due to a lower density of organic producers and processors, thereby the average transport distance between the production chain elements is longer. However, despite the above factors, with a number of products, the greenhouse gas emissions per unit of production remain lower even for the final product. E.g. for the cultivation of potatoes and mashed potatoes production in organic farming, the emission load remains slightly lower even after including post-farm part of the cycle.

3. Conclusion

Predominantly, the farming systems have still been considered as production systems. The typical conventional agroecosystems are characterized as very open, as systems based on technological processes substituting the ecological ones, systems with high labour productivity but with lower biodiversity, flexibility, stability and sustainability on the other hand. On the contrary, the organic farming systems are based on sustainable development principles and the holistic world approach. It is a production system focused on preservation and improvement of natural resources and the environment at the same time. As for the system concept, there is an effort to balance the economic, environmental and social aspects and relations on global and local level. Agricultural activity itself is considered a process of reasonable ecosystem exploitation with respect to its stability and sustainability. Just this divergence between the both approaches, the intensive industrial agriculture on one hand and the sustainable organic farming systems on the other, makes them very different from the environmental point of view.

Intensified conventional farming leads to soil quality decrease. Intensive soil cultivation affects the soil structure negatively and raises the risk of soil erosion. Because of the substitution of mineral fertilizers for organic manures, the content and quality of organic matter decreases and the microbial activity is disturbed. Within the effort to increase the labour productivity, there has been often used larger and heavier agricultural machinery, which leads to intensive soil compaction resulting in unbalanced soil air and water regime, limited root system development, soil biological activity and water absorption reduction and erosion risk increase. The external technical and material inputs markedly increase the energy demands and thus consumption of non-renewable resources together with higher atmospheric pollution. As the specialization develops, number of used species decreases, the preventive function of cropping patterns (pests and diseases reduction) degrades. Crop breeding for high yields brings higher demands for fertilizing and higher plant sensitivity to adverse environment conditions. There is also an increased need of synthetic nitrogen fertilizers. Residual content of nitrogen contributes to underground and surface waters pollution and nitrogen evaporation into the atmosphere. The accumulation of such active substances in the soil results in destruction of useful microorganisms, antagonists and other soil organisms, also leads to development of resistance to pesticides in harmful organisms, decrease of plant and animal species number, pollution of underground and surface waters and the atmosphere with a negative impact to the whole ecosystem. Similarly, the intensifying concentration and specialization of livestock production results in great local amounts of organic wastes, possibilities of their utilisation are not sufficient and the risk of soil and water pollution rises.

Within the organic farming systems the soil quality remains the main interest. Soil erosion control measures include cover crops, mulching, limited soil cultivation, windbreaks planting, use of lighter and smaller machinery, keep an optimal soil structure and looseness. These preservative soil cultivation principles are combined with lower need of pesticides. Thus there is ensured a sufficient nutrient cycle and organic matter content in the soil leading to an optimal soil biological activity and fertility. Generally, the principles of organic farming ensure protection of water sources and soil moisture, prevent the underground and surface waters from pollutants and sediments as well. Water preservation is the priority, there are used terraces, environmental corridors and border zones and other measures. There are also considerable differences in biodiversity, which, within the conventional farming, markedly suffers not only due to crop range reduction leading to monocultures in fact, but also thanks to reduction of associated fauna and flora thought as harmful and thus systematically eliminated or suffering from pesticides or other biocide substances at the same time. By contrast, organic farming purposefully supports biodiversity, takes advantage of more adaptable animal and crop species and varieties to the habitat conditions, uses varied crop rotations, species and variety mixtures, applies technical and organizational measures friendly to the organisms and the environment. Organic farming systems are also more environmentally friendly with regard to the greenhouse gases emissions production. Above all, this emission reduction is achieved thanks to the limited use of synthetic fertilizers and pesticides and lower livestock production intensity.

Although the organic farming systems show much friendlier environmental impact when compared to the conventional ones, there has still been room for further improvements. When compared to the conventional farming systems, one of the most important weakness of contemporary organic farming is a low production capability. In countries with established organic farming yields on arable land reach only 45-100 % in comparison to conventional farming. This difference shows a specific reserve and rising potential of the production capability through appropriate intensification related to natural fertility of a habitat. Among the environmentally acceptable (rational, biological, technological…) means and methods of the ecofunctional intensification within organic farming systems belong e.g.:

- Better management of the soil organic matter
- Use of perennial leguminous plants
- Support of the soil-plant interaction

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- Edaphon environment optimisation
- Intensified recycling and better utilisation of macro and micronutrients, mycorrhiza and nitrogen fixation
- Integration of food production and energy (intercrop biogas production, green manure, stable dung and dung water fermentation prior to their recirculation)
- Landscape management leading to the biodiversity improvement
- Improvement of technology and products used for weeds, pests and diseases elimination (e. g. biological protection, herbal-based pesticides, allelopathy and physical barriers)
- Animal and plant breeding based on the accent on preservation of indigenous markers for resistance and multifunctionality and suitability for organic farming
- Implementation of the precise farming principles into the organic farming systems (automation and robotization, use of sensors in crop and livestock production, GPS and IT)
- Development of new techniques and skills within crop and livestock production that comply with ecological principles and standards (e. g. intercropping, polycultures...)

Sustainable systems should be more focused on preventive measures (crop rotation, precise variety selection), biological regulation methods and balance of all factors of crop production. Similarly, for the conventional farming systems, there can be implemented measures leading to decrease in their environmental impact. Among the main proecological measures belong:

- Land use and a company structure optimisation correspondent to a locality
- Provide maximal species diversity
- Follow crop rotation principles within cropping patterns
- Optimization of the share of leguminous plant related to the soil nutrient content balance and feedstuff need
- Take into account the weeds and pests damage thresholds for pesticides reduction
- Use of mechanical, biological and organizational methods within the plant and animal protection
- Preservation of good soil structure by the means of timely applied field operations
- Reduction and modification of technological operations
- Regular manuring and sweetening
- Reduction of the area under wide-row crops
- Preserve the green soil cover as long as possible
- Use of intercrops, undersowings and green belts
- Preservation of meadows and pastures in flooded areas and slopping grounds

- Preservation of field boundaries reducing soil erosion
- Landscape element planting

The negative impact of intensive conventional farming on the environment and production quality has been gradually reduced by implementation of directives applied by EU members. Public requirements on farming related to all environmental components is predominantly covered by the Crosscompliance system, which emphasises the importance of a responsible control of quality and food safety and animal welfare. The financial support of farming depends on fulfilling conditions stated in GAEC (Good Agricultural and Environmental Conditions), on SMR (Statutory Management Requirements) and on minimal requirements on fertilizer and pesticides use in compliance with the Agroenvironmetal measures (AEO). The mentioned directions generally accepts above stated requirements for improvement of the environmental aspect of the conventional farming.

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