

Research Article

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Environmental and economic aspects of *Triticum aestivum* L. and *Avena sativa* growing

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Abstract: This paper deals with the assessment of cultivation of bread wheat (*Triticum aestivum* L.) and oat (*Avena sativa*) grown in Central Europe within the conventional and organic farming systems in terms of greenhouse gas emissions and economic profitability. Organic farming may be one of the tools for mitigation of greenhouse gas emissions from agricultural production. In the context of crop production, cereals rank among the most commonly grown crops and therefore bread wheat and oat were chosen. The Climate change impact category was assessed within the simplified LCA method and the production of greenhouse gas emissions expressed in CO₂e per the production unit was calculated. Economic balance of the cultivation of monitored cereals was compiled based on the yields, farm gate prices and costs. On its basis, the cultivation of wheat within the organic farming system appears to be the most profitable. From an environmental point of view, the emission load of the organic farming system is reduced by 8.04 % within the wheat production and by 15.46 % within the oat cultivation. Therefore, the organic farming system in the Czech Republic appears to be more environmentally friendly and economically efficient within the cereals production.

Keywords: Greenhouse gases emissions, LCA, wheat, oat, yields, economic profitability

1 Introduction

The production of greenhouse gas emissions is still a frequently discussed issue. Berner & Berner [1] assumes that human activities also contribute to climate change. Svendsen [2] states that, within the European Union, the largest polluters are energetics, which release 27.8% of anthropogenic greenhouse gas emissions, transportation with 19.5% and industry with 12.7%. Agriculture is in fourth place with 9.2%. This share varies depending on the country, e.g. 9.5 % in Austria [3], 7.7 % in Germany [4], 15.8 % in Denmark [5] and 6.4 % in the Czech Republic [6]. One of the tools for reducing greenhouse gas (hereinafter referred to as GHG) emissions may be the change of a farming system. Organic farming usually produces lower GHG emissions due to its extensivity. The Farming Systems Trial at Rodale Institute, an American long-term research project comparing organic and conventional agriculture, states that the introduction of nationwide organic farming in the USA would reduce CO₂ emissions by up to one quarter due to increased carbon sequestration in soils [7].

It is necessary to understand the impacts of agriculture and be able to quantify them in order to efficiently implement measures to reduce GHG emissions. As stated by Lal [8], the system sustainability can be evaluated on the basis of inputs and outputs and their conversion to CO₂e. One of the most appropriate tools for this assessment is the LCA method (Life Cycle Assessment) [9-11]. According to Kočí [12], the LCA method assesses the environmental impact of a product based on the assessment of the material and energy flow, which the monitored system shares with its surrounding environment.

However, when applying an environmentally friendly farming practice, it is still necessary to maintain the ability to ensure food sovereignty and economic profitability of farming. The question of profitability is considered the major decision criterion by farmers. Lower yields are offset by higher farm gate prices within the organic farming system. This also applies to cereal production. The cultivation of which, in organic management, may be considered profitable and environmental savings are another added value.

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2 Methods

Environmental impacts of wheat and oat cultivation were evaluated in terms of GHG production. GHG emissions were expressed in CO_{2e} when CO_{2e} = 1x CO₂ + 23x CH₄ + 298x N₂O. The SIMA Pro software and the Ecoinvent database were used to calculate CO_{2e} emissions. The life cycle of chosen crops were modelled in accordance with the standards ČSN EN ISO 14040 and ČSN EN ISO 14044. The impact category “Climate change” was assessed within the simplified LCA method. The method focused on the agricultural phase of oat and wheat cultivation in the conventional and organic farming systems. The inputs and outputs were referenced to the unit of one hectare and the resulting value was converted to a functional unit of 1 kg of oats. The outcome was the yield per hectare and the input included technology operations, amount of seeds, fertilizers and plant protection products. The calculation also takes field emissions into account. The input data coming from the Ecoinvent database were adjusted in accordance with the principles of farming in Central Europe. The most common agrotechnical practices were used for conventional and organic farming, and the chains of operations included in the calculation of GHG emissions in the agricultural phase of growing oats were determined according to the data obtained from a sample of 60 conventional and organic farms from the Czech Republic. Furthermore, yields and farm gate prices of wheat and oat during the period from 2007 to 2014 were found within the conventional and organic farming systems. The data acquired from the farms were adjusted in accordance with Standards of agricultural production technologies by Kavka [13,14]. The standards from 2006 were used when analyzing the period of 2007 - 2010, and standards from 2012 were used for the period of 2011 – 2014, to calculate the cost of oat and wheat cultivation. The “Standard” standard was used for the calculations. Additionally, all technological and variable costs, fixed costs and insurance against natural disasters were included into the calculations.

3 Results

The impact of the selection of a management system on the environment has not been sufficiently quantified so far for the conditions of the Czech Republic. In respect to air and climate changes, quantification of the load arisen in connection with various farming activities has been missing. Although the primary motivating factor for farmers has remained the economic efficiency, many organic farmers have also been giving increasing weight to the environmental impacts, so the quantification of the differences between a conventional and ecological system in the conditions of the Czech Republic is becoming more important for them.

In terms of the GHG emissions, there are significant differences between oat and wheat production within the conventional and organic farming systems. 0.078 kg CO_{2e} / kg of wheat using conventional farming practices and 0.132 kg CO_{2e} / kg of wheat using organic farming methods, and 0.045 kg CO_{2e} / kg of oats using the conventional system and 0.116 kg CO_{2e} / kg using the organic system is produced in the agrotechnical operation phase (table 1, figure 1, 2, 3). Higher GHG emissions produced in the agrotechnical phase of the organic farming system mainly arise from lower yields and greater need for agrotechnical inputs related with non-chemical plant protection. Fertilization is the major source of GHG emissions. When organic farming, 0.069 kg CO_{2e} / kg of wheat and 0.036 kg CO_{2e} / kg of oat was produced. Conversely, the values produced by conventional farming tend to be higher, h.e. 0.221 kg CO_{2e} / kg of wheat and 0.167 kg CO_{2e} / kg of oat. The difference is mainly caused by the application of synthetic fertilizers, especially nitrogen fertilizers used in conventional farming. Also, a modest increase in GHG emissions occurs after the application of pesticides when 0.002 kg CO_{2e} / kg of oat grains and 0.001 kg CO_{2e} / kg of wheat grains are produced. Pesticides are not used within the organic farming system. Therefore, the emission load of this phase is negligible but, from the environmental point of view, the problems rather result from pesticide

Table 1. Greenhouse gas emissions of wheat and oat production.

	Wheat		Oat	
	Conventional	Organic	Conventional	Organic
Agrotechnical operation	0.078	0.132	0.045	0.116
Fertilizers	0.221	0.069	0.167	0.036
Pesticides	0.001	0.000	0.002	0.000
Seeds	0.023	0.035	0.018	0.027
Field emissions	0.137	0.187	0.127	0.123

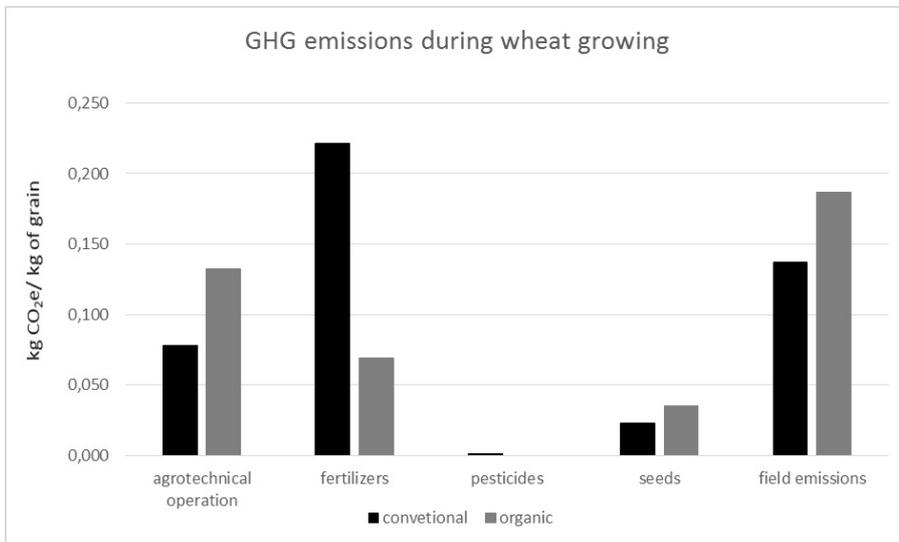


Figure 1. Greenhouse gas emissions during wheat production.

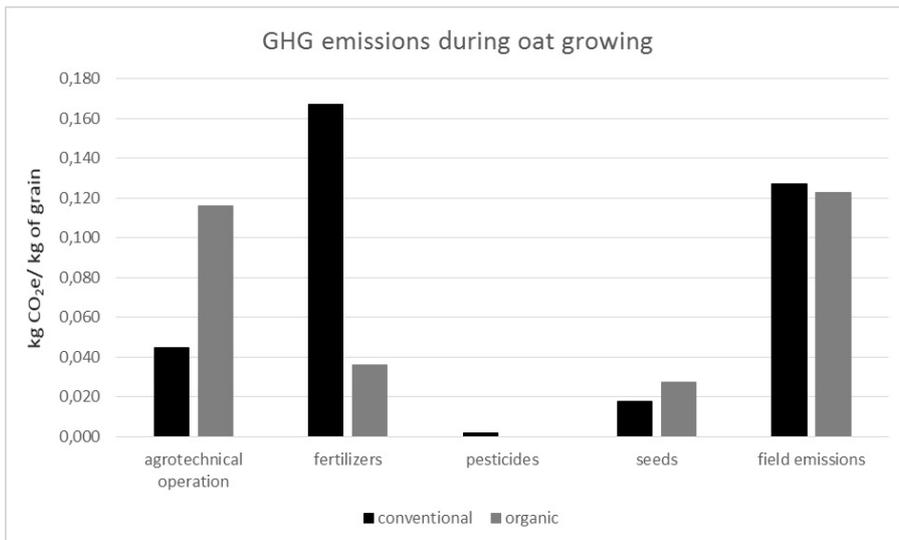


Figure 2. Greenhouse gas emissions during oat production.

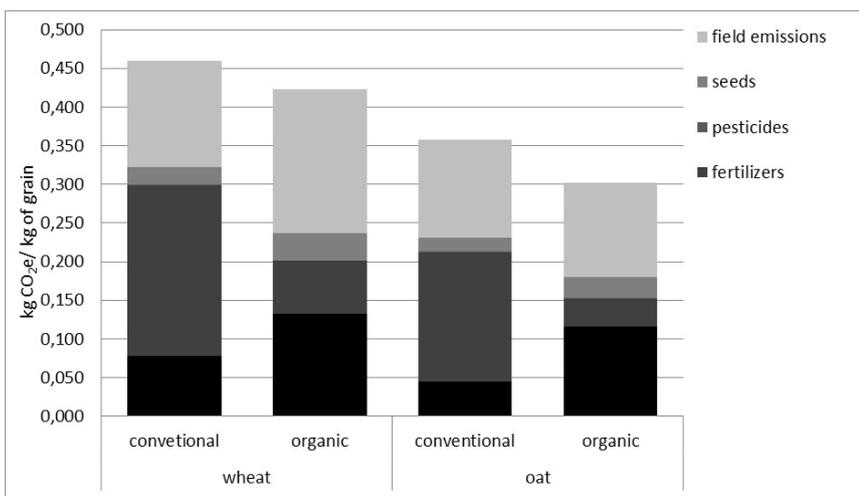


Figure 3. Greenhouse gas emissions during wheat and oat production.

residues, their impacts on biodiversity, etc. A relatively low emission load is produced in the seed phase when 0.023 kg CO_{2e} / kg of wheat grains and 0.018 kg CO_{2e} / kg of oat grains are produced using the conventional system whereas 0.035 kg CO_{2e} / kg of wheat grains and 0.027 kg CO_{2e} / kg of oat grains is produced using the organic system. A significant amount of GHG emissions are produced in the field phase. Some of the main factors are the difference in the yields and the amount and type of the fertilizers used in the conventional and organic farming systems. During cultivation of wheat, 0.137 kg CO_{2e} / kg of grains is stored using conventional methods compared to 0.187 kg CO_{2e} / kg of grains using organic methods. With oat, it was 0.127 kg CO_{2e} / kg of grains using conventional methods and 0.123 kg CO_{2e} / kg of grains using organic farming methods. Total emissions resulting from the conventional farming are higher in the production of wheat (0.460 kg CO_{2e} / kg of grains vs. 0.423 kg CO_{2e} / kg of grains released within the organic system), as well as oat production (0.358 kg CO_{2e} / kg of grains vs. 0.303 kg CO_{2e} / kg of grains produced within the organic system). Therefore, the emission load of the organic farming system is lower by 8.04 % within the wheat production and 15.46 % within the oat cultivation.

Many significant differences occur when comparing the economic aspects of cultivation of oat and wheat across farming systems. The resulting economic balance is heavily dependent on the hectare yield of grains. In the period of 2007 - 2014, the hectare yield of oat grains was 2638 kg / ha using organic farming methods and 3638 kg / ha using conventional farming methods. The hectare yield of wheat grains was 3325 kg / ha using organic farming methods and 6050 kg / ha using conventional farming methods. In the conventional system, the achieved hectare

yield was higher by 28% for oats and 45% for wheat as compared with the organic system. As it is evident from Figures 4, 5, 6 and 7, the highest oat yield per hectare was 3800 kg / ha for conventional farming and 3200 kg / ha for organic farming. The highest wheat yield per hectare was 6800 kg / ha for conventional farming and 3700 kg / ha for organic farming. However, the lowest oat yield per hectare was 3100 kg / ha when using conventional farming methods and 2000 kg / ha when using the organic system, and the lowest wheat yield per hectare was 5000 kg / ha when using the conventional system and 2500 kg / ha when using the organic system.

Also, the farm gate prices of the raw materials (grain) are a significant parameter and highly variable. During the period considered, the average farm gate prices were: 5448 CZK (ca. 198 EUR) / t of grain for organic wheat, 4274 CZK (ca. 155 EUR) / t of grain for conventionally grown wheat, 4116 CZK (ca. 150 EUR) / t of grain for organic oat and 3231 CZK (ca. 118 EUR) / t of grain for conventionally grown oat. Farm gate prices for each year of the period is shown in Figure 4, 5, 6 and 7. The average farm gate prices of conventionally grown wheat and oat were both lower by 21.5% compared to the organic farming system.

The third important factor in the economic evaluation of growing crops is the total cost of production of 1 t of grain (CZK / t of production). When comparing the organic and conventional systems, the costs are generally higher within the organic farming system. The average cost was 7173 CZK (ca. 261 EUR) / t of grain with organic oat, 5920 CZK (ca. 215 EUR) / t with conventionally grown oat, 5661 CZK (ca. 206 EUR) / t with organic wheat and 4389 CZK (ca. 160 EUR) / t with conventionally grown wheat. Within the organic system, the total costs were higher by 17.5%

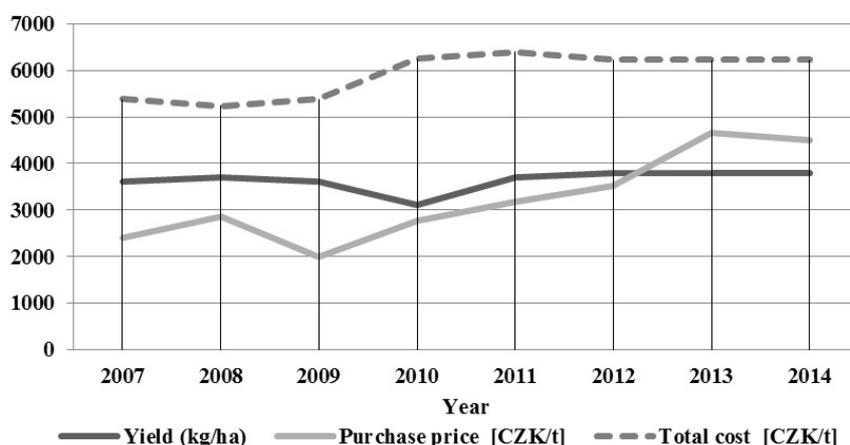


Figure 4. Yields, purchase prices and costs of oat production using conventional farming practices.

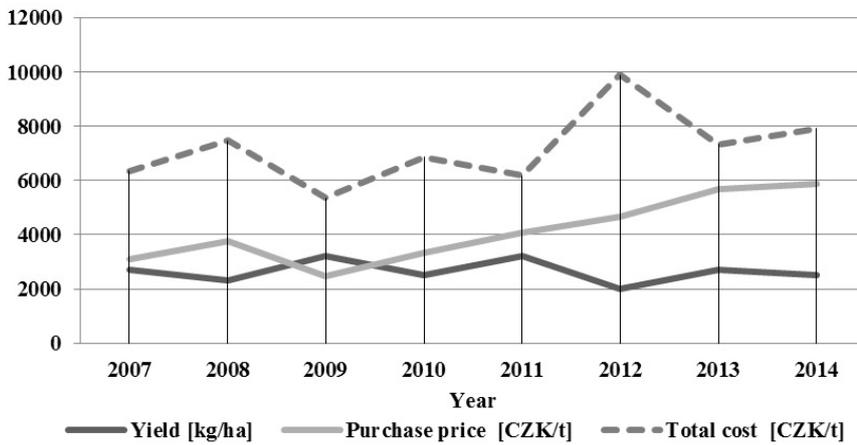


Figure 5. Yields, purchase prices and costs of oat production using organic farming methods.

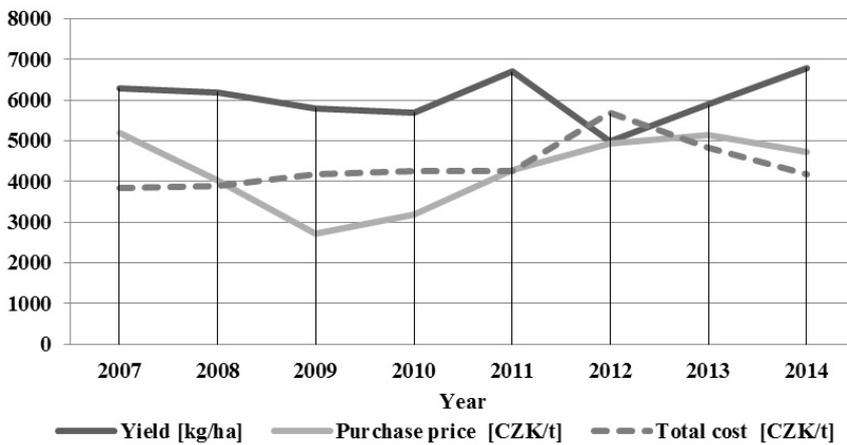


Figure 6. Yields, purchase prices and costs of oat production using conventional farming practices.

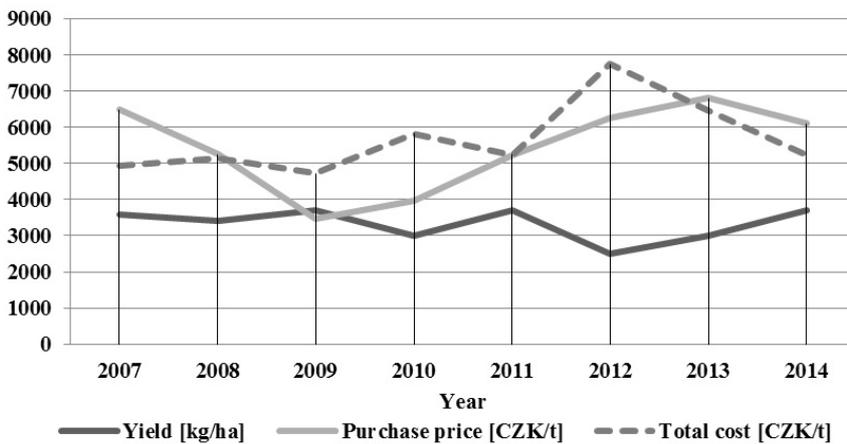


Figure 7. Yields, purchase prices and costs of wheat production using organic farming practices.

with oat and by 22.5% with wheat in comparison with the conventional system.

As Figures 4, 5, 6, and 7 show, the total cost of production of 1 t of oats and wheat exceed the farm gate price and hence the profitability is achieved after counting subsidies within both farming systems. Basic subsidies, i.e. the SAPS (Single Area Payments) for the conventional and organic farming, as well as the subsidies for organic farming (arable land) granted through the Rural Development Programme are included in Table no. 2. Adding the subsidies, growing wheat seems to be the most profitable in the organic farming system (profit 7,894.4 CZK (ca. 287 EUR) / ha), as well as in the conventional farming system (3832.5 CZK (ca. 139 EUR) / ha). Conversely, growing oats appears to be economically inefficient because the positive result is achieved only within the organic farming system (538.26 CZK (ca. 20 EUR) / ha) whereas it is unprofitable within the conventional farming system (-5254.33 CZK (ca. -191 EUR) / ha). In practice, the results may be affected by other factors, e.g. gaining additional subsidies (e.g. the LFA - Subsidies for areas with natural or other specific constraints - which might be useful for growing at higher altitudes).

4 Discussion

Wheat, one of the most important food crops, and oats, a less demanding cereal typical for the organic farming, were chosen to assess the possibility of reducing GHG emissions in crop production. Gajdošová & Šturdík [15] also describe the importance of wheat and the worldwide increase in its cultivation. Zimolka [16] states that, in terms of sown area, wheat is the dominant crop in the Czech Republic. Oats, a 'low input' cereal typical for organic farming is also described by Šarapatka & Urban [17].

A choice of the farming system as a factor influencing GHG emissions is referred to by Barton et al. [18] who state that production of GHG emissions is influenced, in addition to other factors, by the production system and its regional specifics. Also, Küstermann and Hülsbergen

[19] state that organic farming systems produce less N_2O and CO_2 emissions generally due to lower inputs. A similar conclusion had been previously reached by Haas et al. [20], as well as Bos et al. [21]. Daxbeck et al. [22] claim that the conventional farming system produces a higher emission load than the organic one. A lower emission load (by about 8.04 % for wheat and 15.46 % for oat) was calculated based on a production unit. Brandt & Svendsen [23] also describe a positive impact of organic farming and state that the difference between the organic and conventional farming is very significant if emission reductions are related to the area unit. The difference is partially reduced when calculated per a production unit. Nemecek et al. [24] comes to the same conclusion and states that environmental savings per unit area are roughly double when compared with the calculation per unit of production. The total emission load resulting from the cultivation of wheat (0.460 kg CO_2e / kg of grain in the conventional system and 0.423 kg CO_2e / kg of grain in the organic system) is lower than stated by e.g. Carlsson-Kanyama and Gonzalez [25] who reported 0.63 kg CO_2e / kg of grain using the conventional system. On the contrary, Dorninger and Freyer [26] describe lower values, 0.361 CO_2e / kg of wheat grain produced using the conventional system and 0.132 CO_2e / kg of grain produced using the organic system. Differences between results are mainly due to differences in yields.

In the cultivation of oat and wheat, the largest emission savings occur in the phase of fertilization in the organic system. Smith et al. [27] states that changes in fertilization, i.e. a certain degree of extensification and a proper use of organic fertilizers, may lead to CO_2e emission reductions, which is consistent with the statement of Johnson et al. [28] who also affirm that the proper N management can reduce N_2O emissions, while similar conclusions were reported by Dalal et al. [29], Robertson and Grace [30] and Monteny et al. [31]. In addition, Tokuda and Hayatsu [32], Mori et al. [33] and Zou et al. [34] state that with the increasing use of chemical fertilizers and manure, a share of N_2O emitted from soil also usually increases (i.e. field

Table 2. Profitability of wheat and oat production in organic and conventional farming.

Crop	Costs CZK/t	Yields (t/ha)	Purchase price (CZK/t)	Subsidies (CZK/ha)	Profitability (CZK/ha)
Wheat OF*	5661	3,325	5448	8602.6	7894.4
Wheat CF*	4389	6,050	4274	4528.3	3832.5
Oat OF	7173	2,638	4116	8602.6	538.3
Oat CF	5920	3,638	3231	4528.3	-5254.3

* OF = organic farming *CF = conventional farming

emissions). The phase of field emission is, along with the phase of fertilization, one of the most significant sources of GHG emissions and therefore changes in fertilization and a proper use of organic fertilizers may be effective measures towards the mitigation of GHG emissions in crop production, while the transition from conventional to organic farming system is also beneficial.

In agricultural practice, farmers often place emphasis primarily on the economic efficiency of operations. It results from a combination of factors: income, costs and farm gate price. Seufert et al. [35] state that cereal yields from the organic farming system are typically lower than in the conventional one. This is in accordance with the lower yields, by 28% for oats and 45% for wheat, detected within the organic farming system in contrast to the conventional farming system. Šarapatka & Urban [17] state that the organic cereal yields reach about 1/2 values compared to the conventional farming in the Czech Republic. In Europe, the organic yields are on average 80% of conventional yields [36]. A difference in yields between the conventional and organic production is also described by De Backer et al. [37] and is evident from the example of leek production from conventional farming systems that reach 27% higher yields as contrasted to the organic farming system. Also Mondelaers et al. [38] report that yields of organic farms are on average 17% lower than in the conventional farming system. In contrast, Pimentel et al. [39] state that the organic production of some highly productive plants, such as maize, may achieve yields comparable with the conventional systems.

Neuerburg and Padel [40] argue that direct sale is important to organic farming because it may provide sales for a higher price. However, in practice, farmers are sometimes forced to cut the farm gate prices due to the general overproduction and high overall yields. High wheat production in the Czech Republic and neighbouring countries also leads to a high offer on the market, which has a negative impact on the general decline in farm gate prices [41]. Low farm gate prices and price fluctuation throughout the year consequently affect the overall economic efficiency of crops [42]. Generally, higher farm gate prices are more typical for organic production compared to the conventional production [43]. This is consistent with the findings when the farm gate prices of oat and wheat were by 21.5% higher for organically grown crops during the monitored period.

Costs per the production unit were higher, as well, 17.5% for oats and 22.5% for wheat compared to the conventional farming system. Higher production costs associated with the organic system are mainly due to low yields compared to the conventional system, and

this may reach up to 40% depending on the season [44]. Also, Konvalina et al. [45] point out that the cost per the production unit for organic farming are higher by 10 – 30 %, which is consistent with the results.

Organic farming system in the Czech Republic appears to be more economically efficient in the production of both wheat and oats, however, the factors influencing profitability are highly variable and change annually. From an environmental point of view, the positive impact of the organic farming system was supported due to lower GHG emissions when growing both crops. Most organic farming in the Czech Republic has a form of cattle breeding without market production of milk on permanent grasslands, and in a number of cases this activity is economically unsustainable and fully dependent on subsidies. It follows from the results that the development of farming on arable land, where the site conditions allow, and growing certain cereals, in particular, may strengthen the economic self-sufficiency of organic farmers in the conditions of the Czech Republic and contribute to a reduction of GHG emissions. They may also be reduced by the farmers using conventional farming procedures, particularly through a reduced application of synthetic nitrogen fertilizers and their partial replacement by alternatives, e.g. in the form of organic fertilizers or precise dosing.

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Conflict of interest: Authors declare nothing to disclose.

References

- [1] Berner K., Berner R.A., *Global Environment - Water, Air, and Geochemical Cycles*, Princeton University Press, New Jersey, USA, 2012
- [2] Svendsen G.T., *How to Include Farmers in the Emission Trading System*, ICROFS News, 2011, 1, 10-11
- [3] Anderl M., Freudenschuss A., Friedrich A., Haider S., Jobstman H., Köther T., et al., *Austria's National Inventory Report 2011: Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol*, Umweltbundesamt GmbH, Vienna, Austria, 2011
- [4] Strogies M., Gniffke P., *National Inventory Report for the German Greenhouse Gas Inventory*, Federal Environmental Agency, Dessau, Germany, 2013
- [5] Nielsen O.K., Mikkelsen M.H., Hoffmann L., Gyldenkaerne S., Winther M., Nielsen M., et al., *Denmark's National Inventory Report 2011 - Emission Inventories 1990-2009 - Submitted under the United Nations Framework Convention on Climate*

- Change and the Kyoto Protocol, National Environmental Research Institute, Aarhus University, Aarhus, Denmark, 2011
- [6] Miňovský O., Krtková E., Fott P., National Greenhouse Gas Inventory of the Czech Republic, ČHMÚ, Praha, 2013
- [7] La Salle T., Hepperly P., Regenerative Organic Farming: a Solution to Global Warming, Rodale Institute, Kutztown Pennsylvania, USA, 2008
- [8] Lal R., Carbon Emission from Farm Operations, *Environ. Int.*, 2004, 30, 981 990
- [9] Halberg N., Van Der Werf H.M.G., Basset-Mens C., Dalgaard R., De Boer I.J.M., Environmental Assessment Tools for the Evaluation and Improvement of European Livestock Production Systems, *Livest. Prod. Sci.*, 2005, 96, 33 50
- [10] Stern S., Sonesson U., Gunnarsson S., Oborn I., Kumm K.I., Nybrant T., Sustainable Development of Food Production: A Case Study on Scenarios for Pig Production, *Ambio*, 2005, 34, 402 407
- [11] Brentrup F., Küsters J., Kuhlmann H., Lammel J., Environmental Impact Assessment of Agricultural Production Systems Using the Life Cycle Assessment Methodology – I. Theoretical concept of a LCA method tailored to crop production, *Eur. J. Agron.*, 2004, 20, 247 264
- [12] Kočí V., Life cycle assessment LCA, Ekomonitor s.r.o., Chrudim, 2009
- [13] Kavka M., Norms of agricultural production technologies: cultivation and breeding technology and normative calculation, 1st Ed., IAEI, Prague, Czech Republic, 2006 (in Czech)
- [14] Kavka M., Norms of agricultural production technologies: cultivation and breeding technology and normative calculation, 2st Ed., IAEI, Prague, Czech Republic, 2012 (in Czech)
- [15] Gajdo ová A., turdík E., Biological, Chemical and Nutritive-Health Characteristics of Baker Cereals, *Nova biotechnologica*, Bratislava, 2004 (in Slovak)
- [16] Zimolka J., Wheat: cultivation, evaluation and use of grains, Profi Press, Prague, 2005 (in Czech)
- [17] Šarapatka B., Urban J., Organic farming in practice, PRO BIO, Šumperk, 2006 (in Czech)
- [18] Barton L., Kiese R., Gatter D., Butterbach-Bahl K., Buck R., Hinz C., et al., Nitrous Oxide Emissions from a Cropped Soil in a Semi-Arid Climate, *Glob. Chang. Biol.*, 2008, 14, 177 192
- [19] Küstermann B., Hülsbergen K.J., Emission of Climate-Relevant Gases in Organic and Conventional Cropping Systems, In: D. Neuhoﬀ (Ed.), Proceedings of the 2nd Scientific Conference of the International Society of Organic Agriculture Research (18 20 June 2008, Modena, Italy), ISOAR, 2008, 570 573
- [20] Haas G., Geier U., Schulz D., Köpke U., A Comparison of Conventional and Organic Agriculture - Part 1: Climate-Relevant Carbon Dioxide Emission from the Use of Fossil Energy, *Berichteüber Landwirtschaft*, 1995, 73, 401 415
- [21] Bos J.F.F.P., De Haan J. J., Sukkel W., Schils R.L.M., Comparing Energy Use and Greenhouse Gas Emissions in Organic and Conventional Farming Systems in the Netherlands, In: U. Niggli (Ed.), Proceedings of the 3rd International Congress of the European Integrated Project Quality Low Input Food – Improving Sustainability in Organic and Low Input Food Production Systems (20-23 March 2007, Hohenheim, Germany), QLI, 2007, 439 442
- [22] Daxbeck H., Pavlack M., Pinterits M., Raisenberger M., Sobl U., Spitaler R., et al., Four dimensions of healthy food (health, economy, ecology, society), University of South Bohemia in České Budějovice, České Budějovice, 2008 (in Czech)
- [23] Brandt U.S., Svendsen G.T., A Project-Based System for Including Farmers in the EU ETS, *J Environ Manage*, 2011, 92, 1121 1127
- [24] Nemecek T., Huguenin-Elie O., Dubois D., Gaillard G., Life cycle assessment of farming systems in the Swiss arable farming and fodder production, *Agroscope FAL Reckenholz, Zürich, Switzerland*, 2005 (in German)
- [25] Carlsson-Kanyama A., Gonzalez A.D., Potential contributions of food consumption patterns to climate change, *Am. J. Clin. Nutr.*, 2009, 89, 1704 1709
- [26] Dorninger M., Freyer B., Current achievements and future potential of organic agriculture to climate protection in Austria, IFOL, BOKU Wien, 2008 (in German)
- [27] Smith P., Martino D., Cai Z., Gwari D., Janzen H., Kumar P., Greenhouse gas mitigation in agriculture, *Phil. Trans. R Soc. Lond. B Biol. Sci.*, 2008, 363, 789 813
- [28] Johnson J., Franzluebbbers A. J., Weyers S.L., Reicosky D.C., Agricultural opportunities to mitigate greenhouse gas emissions, *Environ. Pollut.*, 2007, 150, 107 124
- [29] Dalal R.C., Wang W., Robertson G.P., Parton W.J., Nitrous oxide emission from Australian agricultural lands and mitigation options: a review, *Aust. J. Soil Res.*, 2003, 41, 165 195
- [30] Robertson G.P., Grace P.R., Greenhouse gas fluxes in tropical and temperate agriculture: the need for a full-cost accounting of global warming potentials, *Environ. Dev. Sustain.*, 2004, 6, 51 63
- [31] Monteny G.J., Bannink A., Chadwick D., Greenhouse gas abatement strategies for animal husbandry, *Agr. Ecosyst. Environ.*, 2006, 112, 163 170
- [32] Tokuda S., Hayatsu M., Nitrous Oxide Flux from a Tea Field Amended with a Large Amount of Nitrogen Fertilizer and Soil Environmental Factors Controlling the Flux, *Soil Sci. Plant Nutr.*, 2004, 50, 365 374
- [33] Mori A., Hojito M., Kondo H., Matsunami H., Scholefield D., Effects of Plant Species on CH₄ and N₂O Fluxes from a Volcanic Grassland Soil in Nasu, Japan, *Soil Sci. Plant Nutr.*, 2005, 51, 19 27
- [34] Zou J., Huang Y., Lu Y., Zheng X., Wang Y., Direct Emission Factor for N₂O from Rice-Winter Wheat Rotation Systems in Southeast China, *Atmos. Environ.*, 2005, 39, 4755 4765
- [35] Seufert V., Ramankutty N., Foley J.A., Comparing the yields of organic and conventional agriculture, *Nature*, 2012, 485, 229 232
- [36] Lackner M., Socio-environmental dimension to the Austrian nutrition: scenario analysis, Institute of Social Ecology, Klagenfurt University, Vienna, Austria, 2008 (in German)
- [37] De Backer E., Aertsens J., Vergucht S., Steurbaut W., Assessing the Ecological Soundness of Organic and Conventional Agriculture by Means of Life Cycle Assessment (LCA): A Case Study of Leek Production., *Br. Food J. Hyg. Rev.*, 2009, 111, 1028 1061
- [38] Mondelaers K., Aertsens J., Van Huylbroeck G., A Meta-Analysis of the Differences in Environmental Impacts between Organic and Conventional Farming, *Br. Food J. Hyg. Rev.*, 2009, 111, 1098 1119
- [39] Pimentel D., Hepperly P., Hanson J., Douds D., Seidel R., Environmental, Energetic, and Economic Comparisons of

- Organic and Conventional Farming Systems, *Bio Science*, 2005, 55, 573-582
- [40] Neuerburg W., Padel S., *Organic farming in practice: the transition to organic farming, horticulture and animal husbandry, economics and marketing*, FOA, Prague, 1994 (in Czech)
- [41] Novák J., Janotová B., *Economy of winter wheat cultivation*, *Úroda*, 2009, 11, 14-16 (in Czech)
- [42] Abrham Z., Kovářová M., *Economy of growing and harvesting of cereals*, Research Institute of Agricultural Engineering, Prague, 2006 (in Czech)
- [43] Janotová B., Boudný J., *Economy of growing wheat and the assumption for 2013*, *Úroda*, 2014, 8, 26-28 (in Czech)
- [44] Moudrý J., Moudrý J. jr., Konvalina P., Kopta D., Šrámek J., *The economic efficiency of the plant bioproduction: applied methodology*, 1st ed., Faculty of Agriculture, University of South Bohemia in České Budějovice, 2008 (in Czech)
- [45] Konvalina P., Moudrý J., Moudrý J. jr., Kalinová J., *Crop production in organic farming*, 1st ed., Faculty of Agriculture, University of South Bohemia in České Budějovice, 2008 (in Czech)