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Ecological footprint as a method for evaluation different agriculture production systems

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Abstract

Ecological footprint could be a tool for evaluating impacts of different agricultural production systems (PS). Based on more years field experiments producing vegetables and field crops ecological footprint of conventional (CON), integrated (INT), organic (ORG) and biodynamic (BD) farming systems in Maribor, and CON, INT and ORG in Dolenci was calculated and interpreted using the SPIonExcel tool. Results showed a markedly lower ecological footprint of ORG and BD systems compared to CON and INT which are not significantly different. Identified were possibilities for reducing ecological footprint – for CON and INT by reducing mineral fertilizers and pesticide inputs; for ORG and BD by changing fuels and reducing machinery use.

Introduction

The agro-food sector itself considerably contributes to environmental pressures like emission of climate change gases. It has however the potential to reduce its emissions as well as help society meet its sustainability targets e.g. by providing renewable resources and sequestering carbon in soils or using more sustainable agricultural production systems like integrated and organic farming (Bavec et al. 2009). National and regional policies, the Common Agricultural Policy and Rural Development Reform increasingly include high environmental standards including climate change aspects. Different "green" measures for assuring sustainability of agriculture are planned for CAP in a new EU financial perspective. "Ecological intensification" is a new term in research and professional community which means designing sustainable production systems that save on inputs and are less harmful to the environment. The aims are comparison of different agricultural production systems (PS) on the base of their ecological impact and identification of "ecological hotspots" in the supply chain of agricultural goods and services.

Material and methods

One of the frameworks to apply evaluation methods of sustainability is life cycle assessment (LCA), which assesses the environmental burden caused by a product.

Comparability of the results is a critically scope of the LCA, which may differ from study to study as there are used different tools for calculating (Bavec et al. 2012). One of these tools is the environmental or ecological footprint (Haberl et al. 2001). It aims to estimate the biologically productive area needed to produce materials and energy. The calculations for comparison of different PS were done based on the data from two field experiments.
Experiment 1. The experimental site is located at the University Agricultural Centre near Maribor (46°28N, 15°38E, 282 m a.s.l). The annual mean air temperature of the area is 10.7 °C; where the mean monthly minimum is in January at 0.4 °C and the average monthly maximum is in July at 20.8 °C. Average annual rainfall in the area is around 1000 mm. Sixty 7m×10m experimental field plots were established on a dystric cambisol (deep) (average pH value 5.5 [0.1 KCl solution], soil soluble P at 0.278 g kg^{-1} and soil soluble K at 0.255 g kg^{-1} in ploughing soil layer), and are maintained within two different five-course crop rotation designs. Four PS + control plots were arranged in a randomised complete block split-plot design with four replicates. PS differed mostly in plant protection and fertilization strategies and are defined by the valid legislation and standards – conventional (CON), integrated (INT), organic (ORG), biodynamic (BD) and control plots, where no fertilization/plant protection was used. Also, the same varieties were used in all PS under study of

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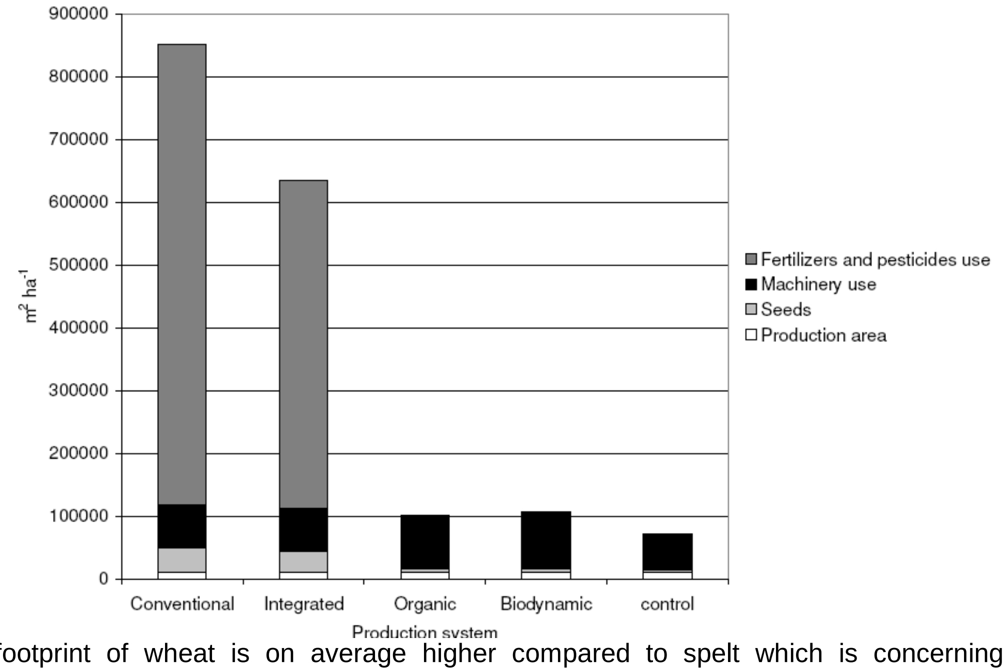
conventional origin for CON and INT systems and of organic origin for ORG, BD and control systems. Presented are results from 2008 to 2010 for spelt and winter wheat.

Experiment 2. The field trial was laid out at the research station in Slovenia, Dolenci near the Hungarian border (46°51'4.43''N 16°17'15.45'' E, 302.1 m a.s.l) over a period of three years (2009-2011). The annual mean air temperature of the area is 9.7 °C and average annual rainfall in the area is 749 mm. The field trial was established on sandy loam (average pH value 6.3 [0.1 KCl solution], soil soluble P at 0.13 g kg^{-1} and soil soluble K at 0.34 to 0.56 g kg^{-1} at the ploughing soil layer (40 cm) was determined using AL-method. The three PS (CON, INT, and ORG) were managed in accordance with EU and national legislation and rules. In the paper are only results for red beat and white cabbage. For calculation of ecological footprint the Sustainable process index was used (SPI©) - it includes the conversion of mass and energy flows into the surface area required by the process (Sandholzer and Narodoslawsky 2007). The software SPIonEXCEL was developed to bring this methodology into an easily applicable form. It calculates the ecological footprint of a process, product, or service with an eco-inventory by summarizing the mass and energy flows to and from the environment over the life cycle in question. We calculated the total ecological footprint (A_{tot}), which is the area necessary to embed the whole life cycle generating a product. Partial footprints were calculated directly from the experimental field trial data with the help of the software SPIonEXCEL, which is available on the internet (http://spionexcel.tugraz.at). The areas are computed on the basis of mass and energy flows, and the infrastructural requirements for the reference period, one year. Within this period, a number of system units were supplied by the process in questions. The specific area was defined as the total area divided by the system units. This specific area is a possible comparative measurement of sustainability and can be related to the area that is statistically available to each person, and this defines the SPI index. Also the efficiency of a PS was calculated using ecological efficiency index (EEI). EEI gives information on how much surface area is needed to produce one unit of a product or what is the ecological footprint of the yield (y) is EEI=Atot/y (m^2/kg).

Results



Ecological footprint of wheat is on average higher compared to spelt which is concerning inputs not demanding field crop (Figure 1). Producing 1 ha CON winter wheat over 85 ha of area is affected and in the case of spelt 65 ha. INT production which is considered as environmentally friendly (Bavec et al. 2009) had slightly lower values (63 and 45 ha, respectively), but real impact on environment had ORG and BD farming practice with 10 to 11 ha use of area for both field crops. In the case of CON and INT the most important impact are using pesticides and mineral fertilizers. Concerning BD and ORG some reductions of ecological footprint could be achieved changing machinery use and using alternative energy sources (plant oil instead of fuel), but due to the spraying of biodynamic materials consumption of machinery is higher in BD production compared to ORG.

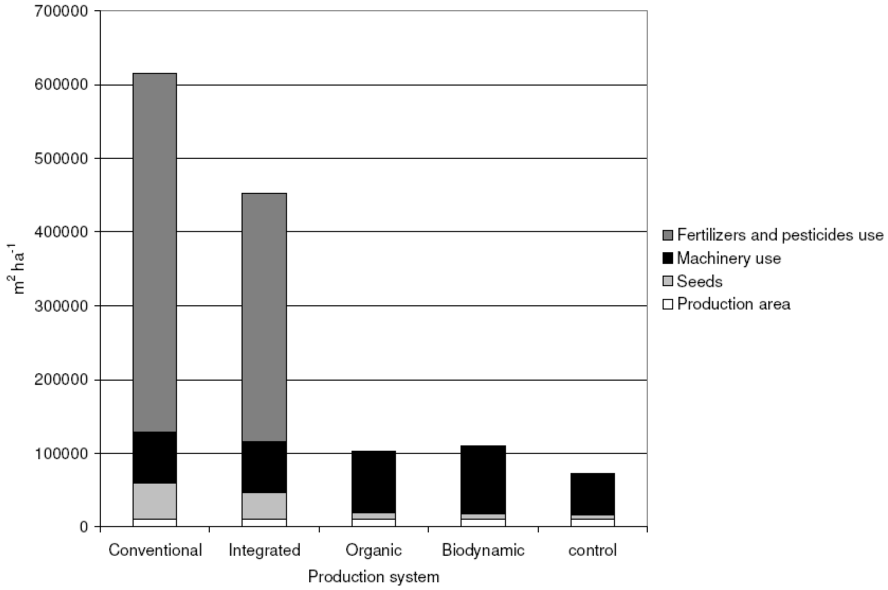
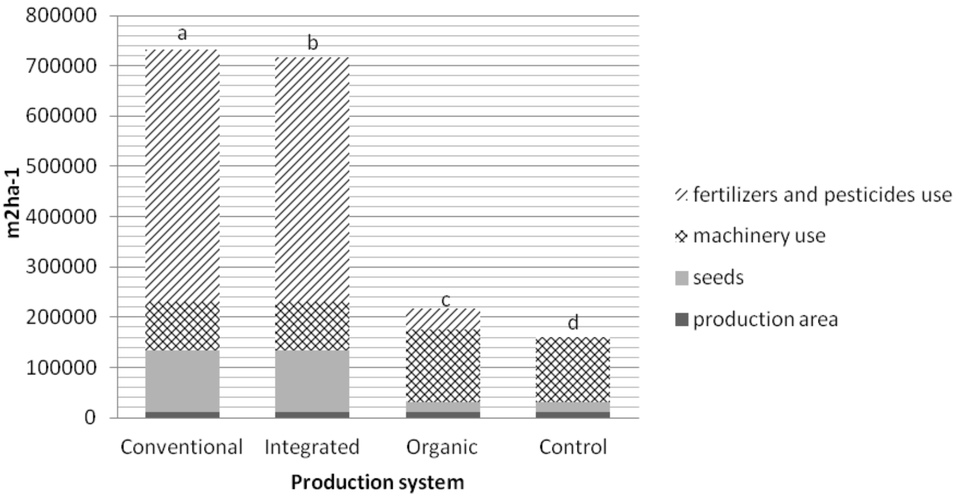


Figure 1: Average yearly ecological footprint (m^2 ha^{-1}) of winter wheat and spelt 2008-2010 in experiment 1.



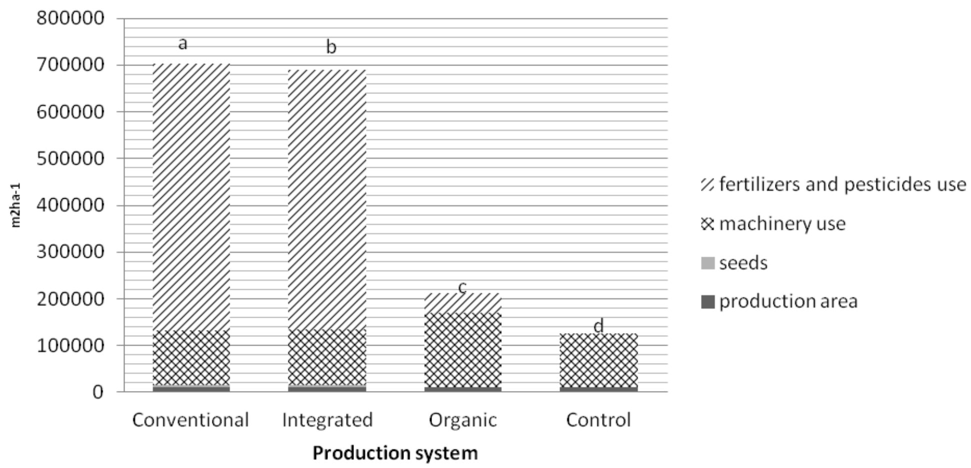


Figure 2: Average yearly Ecological footprint of cabbage and red beet (m2 ha-1) for years 2009-2011 in experiment 2

In the case of field vegetables produced in three PS similar results came out (Figure 2). There is not big difference in ecological footprint between CON and INT – impact of 1 ha production of white cabbage and red beet is on around 70 ha surface area. Statistically significant improvement is ORG production by 3.5-x lower impact.

The highest yields for cabbage and red beet were attained using the CON production system (68,475 kg for cabbage and 27,879 kg for red beet, respectively), while the lowest was in the control plots where the lack of nutrients was evident (Table 1). But the results of the ecological efficiency production give a more insightful picture when yields are taken into the equation. The EEI shows that the highest values for kg of product both cabbage and red beets are for the INT production system but the difference with CON is not significant. The EEI is the lowest in the ORG production system, it is significantly different from CON and INT, but not from control for cabbage. Furthermore, the control plots have shown that production, despite the low ecological footprint and almost no inputs, is not ecologically efficient, because the yield was very low (only 27% of CON for cabbage and 29% of CON for red beets).

Table 1: Average yield (Y) and ecological efficiency index (EEI) depending on production system (PS) in Dolenci for white cabbage and red beet

	White cabbage		Red beet	
PS	Y (kg ha^{-1})	EEI (m^2 kg^{-1})	Y (kg ha^{-1})	EEI (m^2 kg^{-1})
CON	68,475a	10.3±6.1a	27,879a	26.3±12.9a
INT	53,550b	12.9±5.4a	26,547a	27.0±17.4a
ORG	42,150c	5.0±2.1b	17,955b	12.1± 6.2b
Control	18,825d	6.7±3.5b	8,250c	19.3±11.8c

Different letters (a-d) in column mean differences at P<0.01 Duncan's multiple range test

Yields of spelt did not differ between PS, but in the case for the nutrients and other inputs more demanding winter wheat CON system had the highest yield (Table 2). But ecological efficiency index of both cereals showed similar results as thus in vegetables – use of surface area per kg (EEI) of yield is significantly lower in case of ORG and BD compared to CON and INT. INT production system does not perform much better than CON.

Table 2: Average yield (Y) and ecological efficiency index (EEI) depending on production system (PS) in Maribor for spelt and winter wheat

	Spelt		Winter wheat	
PS	Y (kg ha^{-1})	EEI (m^2 kg^{-1})	Y (kg ha^{-1})	EEI (m^2 kg^{-1})
CON	2,260±141ab	280±19a	4,263±469a	230±22a
INT	2,369±247a	207±21b	3,683±451ab	204±19a
ORG	2,039±125ab	52±4c	2,450±263c	47±5b
BD	2,440±180a	49±4c	3,136±305bc	37±3b
Control	1,807±91b	43±3c	2,467±207c	31±3b

Different letters (a-d) in column mean differences at P<0.01 Duncan's multiple range test

Discussion

The results showed significant differences in PS concerning ecological footprints where really positive effect in reducing negative impacts on environment is in ORG and BD system. The experiments demonstrated that INT production which is advertised as environmental friendly and sustainable production system does not perform much better than CON. There are also some possibilities to reduce ecological footprint also in ORG and BD production system.

References

Bavec M, Grobelnik Mlakar S, Rozman Č, Pažek K & Bavec F (2009): Sustainable agriculture based on integrated and organic guidelines: understanding terms. The case of Slovenian development and strategy. Outook on Agr. 38, 89-95.

Bavec M, Narodoslawsky M, Bavec F & Turinek M (2012): Ecological impact of wheat and spelt production under industrial and alternative farming systems. Renewable agriculture and food systems 3, 242-250.

Haberl H, Erb K & Krausmann F (2001): How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926-1995. Ecological Economics 38, 25-45.

Sandholzer D & Narodoslawsky M (2007): SPIonExcel – Fast and easy calculation of the Sustainable Process Index via computer. Resour. Conserv. Recycl., 50, 130-142.