Ecological footprint in the organic farming system

Ekologická stopa v systému ekologického zemědělství

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Abstract: This text aims to introduce the results of the ecological footprint (EF) calculations in the system of organic agriculture (OA). The EF is an alternative indicator of the human activity impact on the environment. It is not calculated in monetary units but in hectares as an area needed for resourcing certain production or activity. OA is an agricultural system which respects natural cycles in ecosystems. It is based on old traditions and nowadays, with regard to environmental degradation, comes again forward. The text contains as well the results of some other researches studying mainly energy consumption in agriculture, which is further converted into the EF. The results, however, need to be compared very carefully, since the procedures of calculations as well as the organic farming rules in various countries or particular farms conditions and quality of input data of the mentioned studies may significantly differ. The authors cite them mainly because of illustrative reasons.

Key words: ecological footprint (EF), organic agriculture (OA), ecologically (biologically) productive area, energy consumption

Abstrakt: Tento text má za úkol představit výsledky propočtů ekologické stopy v systému ekologického zemědělství. Ekologická stopa je alternativním indikátorem vlivu lidské činnosti na životní prostředí, který není vyjádřen ekonomicky, ale prostorově. Ekologické zemědělství je systém hospodaření s důrazem na přirozené koloběhy v přírodě, který staví na staletých tradicích a nyní se v souvislosti s poškozováním životního prostředí dostává opět ke slovu. Text obsahuje i výsledky dalších studií zabývajících se převážně zkoumáním spotřeby energie v zemědělství, což je následně přepočteno na ekologickou stopu. Výsledky jednotlivých studií je však potřebné porovnávat mezi sebou velmi opatrně, neboť jak metodiky výpočtů, tak zásady ekologického hospodaření v různých zemích, tak i podmínky konkrétních farem, na kterých byly studie prováděny, se mohou zásadně lišit. Autorky je zde uvádějí z důvodů spíše ilustrativních.

Klíčová slova: ekologická stopa, ekologické zemědělství, ekologicky (biologicky) produktivní plocha, spotřeba energie

Ecological footprint

The Ecological Footprint (EF) is an indicator of sustainable development, which shows the size of the biologically productive area necessary for resourcing the current consumption patterns when using common technologies. Many EF assumptions have been made on the global, national and regional level usually on the basis of international statistical data.

The EF is a tool used to determine an area needed for life necessaries ensuring in the form of certain time unit consumption (usually 1 year). Further, it is compared with an ecologically productive area which is available. Usually a difference appears; when the area used is larger that the area available – then the situation is called the ecological deficit or a gap of sustainable development. It is expressed as an extra amount of resources and services explored from nature which in the long term perspective causes environmental degradation and therefore such way of management is unsustainable.

One of the significant features of the current world is the fact that an individual or a nation influences with its requirements not only its own place but thanks to international trade appropriates as well remote resources. Human activity impact on ecosphere is shattered and the consequences in the form of natural capital destruction are often hidden. The consciousness of human dependency on nature is disappearing. The EF analysis summarizes the people's needs of productive area on the whole planet and gives it into one single number expressed in comprehensible units, mostly hectares. It makes the human – nature relations transparent even for the wide public, who plays an important role in the present protection of nature.

The method of the EF was outlined in 1990s in the British Columbia University in Canada by Mathis Wackernagel and William Rees. Their key book "Our Ecological Footprint" subtitled "Reducing Human Impact on the Earth" was published in 1996 and soon became very popular. The authors were followed by many other scientists, who have tried to improve and develop the method.

In this book, the authors charted a basic way of calculation and listed five consumption categories: food, accommodation, transport, consumption goods, services. To each type of consumption, a category of land use is assigned: energetic land, built-up land, arable land, pastures and forest. While four of these categories need not to be explained, the energetic land is understood as an area of forest able to absorb CO_2 emitted by burning fossil fuels, which are the main source of energy.

When considering the consumption categories, needed sources and their amount for production must be found out (for example the amount of corn for bread production), and the so called "embodied" energy is calculated, which is necessary for production and use. The whole life cycle of a product must be considered: production, transport, usage including final disposal. For example the EF of a household contains the area on which the house stands, but includes among many others as well the energy for bricks production, the energy for heating and maintenance (Wackernagel, Rees 1996).

Calculations made from the national statistics from 1998 say that an average EF of a Czech is 6.7ha/person, while the available ecological capacity in the country is 2.4 ha/person. This means the Czech Republic lives in an ecological deficit and the current consumption patterns are unsustainable. The rate of the agricultural EF and agricultural land (together with production forests) is 114%, however, because of the lack of data not all inputs are included and the total rate is probably even higher (Kušková 2001).

Organic agriculture

The study has calculated the EF in the sector of organic agriculture (OA) which is a special agricultural system using environmentally friendly ways to suppress weeds, pests and diseases. It forbids synthetic pesticides and fertilizers, in animal husbandry it focuses on animal welfare, cares about harmony of the whole agro-ecosystem and its biodiversity and prefers renewable sources of energy and materials recycling. It is a very progressive way of farming which builds on centuries of our ancestors´ experience and respects natural cycles and relations. Therefore, it is able to produce a high quality food. It responds to the sustainable agricultural development principles, which claim the necessity of other than production function, for example the care for landscape or rural development.

OA is considered to be an alternative for solving problems like rural depopulation, decrease of workers in agricultural production and partly as well the problem of unequal regional development. The organic farmers voluntarily refuse the ecologically and health dangerous means of the intensive, chemicalized agriculture in order to produce the quality food and fodder, to maintain a long-lasting soil fertility, environmental friendly landscape management, to create new jobs and to maintain rural population.

OA has been a strategy worldwide supported for the couple of decades. In the Czech Republic, it has been developing since 1990, the largest increase of the ecologically managed area came between 1997–2003, especially because of the reintroduction of the state support system in 1998 (Urban et al. 2003).

METHODOLOGY

Calculations with real data

An agricultural farm close to Roudnice nad Labem was chosen to perform the calculations. The farm lies in the sugar beet production area, in the altitude of 160 m above the see level, in the river-basin of Ohře, in the Dolnooharská plate. The annual average rainfall is 450 mm, the average temperature is 8°C. Plant production is influenced by the rain shadow of the Krušné hory and the České středohoří. Every year the no-rain periods appear in various duration and influence the farm outcome. Drought comes irregularly during spring, summer and autumn. The farm works on 70 ha altogether, which lie on strictly light sandy, naturally fertile loamy as well as on very heavy clayey soil. A quarter of the area is particularly problematic, as soon as an extreme weather comes in the form of drought or too much rain, the outcome is very much influenced. The outcomes on other areas are quite stable.

Regarding the importance of the energetic part of the EF indicator, the place and conditions of farming need to be taken definitely into consideration. They have a large impact on the fuel consumption. This also partly explains the differences in the fuel consumptions which occur in various studies. Some of them are mentioned in this text together with listing of the probable reasons of these differences.

For the EF calculations, it is advisable to choose one single crop-plant and to calculate the EF per one hectare of this plant. Then it can be best used for comparison. For this purpose, it is one hectare of winter wheat. The total area of the farmed winter wheat is 12.98 ha. This is important for splitting the average hectare consumption of common inputs, say the transport of seed. *The question to be answered is the real area needed for the production of winter wheat on one hectare of organically managed land.*

After the discussion with the farmer, 11 operations appear to be undertaken on the field during one year. Fuel consumption according to the technical norms (1997) was assigned to each operation (MZ ČR 1997). The transport of mechanization to and from field is excluded (Table 1).

As regards fuel consumption: for the purpose of the EF, the number 71.37 l/ha needs to be converted to the area counted in hectares. Why? This area will be the energetic part of the EF, which in this case is interpreted as an area of forest needed to absorb CO_2 emitted when burning 71.37 l of fuel. The following conversion formula is taken from Wackernagel:

Table 1. Field operations and their fuel and labor demand

Operation	Fuel consumption (l/ha)	Labour consumption (h/ha)
1. transport of seed 250 km, 2 600 kg of seed, average consumption of van 15 l/100km, return run)	5.77	0.55
2. ploughing	21	1.1
3. harrowing	2.2	0.3
4. sowing	3.8	0.35
5. rolling after sowing	2.6	0.3
6. harrowing	2.2	0.3
7. harrowing of vegetation	1.6	0.2
8. combine harvesting	12	0.55
9. crushing of straw	2.5	0.55
10. transport of harvest	2.2	0.55
11. shallow ploughing	15.5	1
Total	71.37	5.75

Table 2. Conversion factors

1 l of fuel	35 MJ
1 GJ (EF)	0.01 ha
1 work day	6.5 MJ

... if there is 35 MJ in one liter of fuel (diesel), then the fuel consumption for one hectare equals 2497.95 MJ, roughly 2.5 GJ. The conversion coefficient from GJ to hectares is 100 GJ/ha/year, which means that one hectare of forest is necessary to absorb CO_2 emitted when burning fossil fuels that give the energy of 100 GJ. To absorb CO_2 from burning 2.5 GJ, 0.025 ha is needed (250 m^2). This is the main part of the EF energetic part per one hectare of winter wheat grown in a particular case of organic farming.

To convert human labor to hectares is even more debatable. Here the base is in the work of Fluck (1992, cited in Krausmann 2004), where 6.5 MJ is an assumed output for one working day. For our particular case, there are 5.75 hours for a hectare (according to the technical norms from 1997). This number is in the whole calculation neglectable (0.65 m^2), so it is omitted (Table 2).

To follow the procedure of the EF, an area of forest for needed wood should be included, but this is irrelevant in this case. The built-up area, in this case it is negligible as well since there is a farmer's house and some farm buildings but in the context of the whole farmed area it is insignificant. It might have its role in the case of growing herbs where the total growing area is much smaller than when growing crops or grazing cattle.

And to the total summary, we need to count the area where the crop is grown, which is one hectare.

The result is therefore as follows – the EF of growing one hectare of winter wheat in the system of organic farming on the given place is 1.025 ha.

COMPARISONS

To be able to interprete this number and to grasp it in some way, there are couple of other studies listed here. One is concerned with fuel consumption in Czech agriculture, the next one compares inputs into the conventional and organic farming in the conditions of south German mountains and the last one compares inputs into the same types of agriculture, however, there are not given any detailed data about the studied places or soil fertility. The given energetic inputs are converted by the same way as above. Another important notion is that while the above mentioned calculation regards one hectare of a concrete crop, the other studies inform about the average energy consumption on a hectare.

1. Energy demand of agricultural production in the Czech Republic (Pastorek, Syrový 2001)

Fuel and energy consumption is not monitored in Czech agriculture as a whole, though it would not be a problem with the current technical and technological equipment of agricultural firms. It is really surprising that the state does not have an interest in monitoring these costs, from the very reason that the fuel consumption is partly subsidized by the state.

The authors of this study followed among other the consumption of fuel (diesel). Here it is important to realize that fuel consumption of mechanization is not the only energetic input into agriculture, especially in the conventional type of farming, so any possible comparison with the above calculation is rough. The total consumption was 560 400 thousand litres (2000). Divided by 3 062 009 ha of agricultural land in the Czech Republic it equals in average 183 l/ha. This means 0.064 ha of energetic area for one hectare of agricultural land. This consumption includes, however, service firms and non-agricultural activities of the farms. The consumption of agricultural primary production firms goes up to 503 031 thousand litres, in average 164 l/ha. In the EF language it equates 0.0574 ha of the energetic area.

For a rough comparison with the above mentioned case, it is best to calculate the EF energetic part per one average hectare of arable land. There the average consumption is 118 l/ha, which corresponds with 0.0413 ha of the EF energetic part.

The EF of an average hectare of arable land in the Czech Republic is 1.0413 ha. This number is underestimated since the fuel consumption is a part of all energy inputs into agriculture.

2. LCA analysis

The next study comes from a collection of the LCA analyses gathered by the BIO Intelligence Service, which have a general title "External Environmental effects related to the life cycle of products and services" and they are possible to access on the official web pages of the EU. The Life Cycle Assessment (LCA) is a review of the material and energetic flows coming and leaving all phases of a product's or a service's life in the form of input and output. It is a very significant informational tool of ecological policy, which in fact illustrate the impact of a product (service) onto the whole society. Of course the method is not perfect. For example, there might be a problem when setting the borders of gathering the data, otherwise it would be impossible to reach any result. These borders are on the consideration of the researcher and he/she can decide not to include something what another person might consider important. For example, transport is often excluded from calculations.

Let us go back to the particular study. Here the authors compare the intensive (conventional), integrated and organic agriculture. For us, the first and third type is relevant. The unit for comparing is the amount of wheat containing 1 000 kg of protein, which in both types of agriculture means roughly 8 333 kg of wheat (12% of protein). The study includes only the phase of "production" and processing of corn, it does not go any further.

Intensive farming is a system with high inputs in the conditions of Great Britain – the intensive production system on large scales of arable land without animal husbandry, typical for East England, high inputs in form of fertilizers and plant protection agents. The usual yield is 8 t/ha.

Organic farming is a system with low inputs, according to the Swiss experience. Instead of artificial agents, manure is used together with mechanical or manual weed control. To reach 12% protein content, various types of wheat are grown. The usual yield is 4 t/ha.

The main features of these two production systems are listed in Table 3 (data for one hectare and year).

Note a higher amount of labour than there is in our calculation. It might be caused by harder conditions of the mountainous Switzerland or the administration may be included.

What are these results from the EF point of view? Energy consumption comes to 30 900 MJ for the intensively grown hectare of wheat, respectively 13 371 MJ for a hectare of organically grown wheat. These numbers seem to include not just the direct fuel consumption but also other energy, perhaps mainly originating in fertilizers and others chemicals production. After transferring the table number to J/ha, we get 4.4 GJ. The EF from this case is better to compare within these two mentioned types rather than with the above mentioned EF for Czech organic farmer since it is not certain that the content of given energy consumption fully corresponds with the calculation made on the Czech farm.

According to the given conversion coefficient (100 GJ/ha/year), the energetic part of the intensive farming EF results in 0.309 ha and for the organic

Table 3. Comparison of intensive and organic agriculture (data for 1 ha and 1 year)

	Intensive agriculture	Organic agriculture
Fertilizers: N (kg)	240	86
P (kg)	26	24
K (kg)	50	215
Number of active ingredients	115	0
Labour (hours)	15.6	31.5
Mechanization work (hours)	12.6	21.7
Fuel consumption (l)	125.4	125.8
Yield (t)	8	4

farming 0.134 ha. Let us omit again the energy of human labour and the built-up area of the farms (that we do not know anyway) as well as the "forest" part of the EF, which is irrelevant.

The EF of one hectare of wheat growing in the intensive agricultural system described in this study results in 1.309 ha, while in the organic farming system 1.134 ha.

A reader might be as well interested in other results of this study, where the given systems were compared not just from the point of view of energy consumption but as well CO_2 emissions, which means the impact on the greenhouse effect. Intensive agriculture is said to emit 4 400 kg CO_2/ha, organic agriculture 1 060 kg CO_2/ha. This difference confirms that the authors count more sources of CO_2 than the fuel consumption of field mechanization.

The whole study, however, aims at the calculations of total external costs caused by various types of agriculture. Intensive farming then causes total externalities of 100–310 EUR and organic agriculture 68–334 EUR. The results stay neutral, they do not claim explicitly that any of the studied type of agriculture is better or worse.

For a more detailed information please refer the web page cited at the end of this text.

3. South German LCA analysis (Haas et al. 2005)

The LCA analyses intensive, extensive and organic farming on 18 chosen farms. The researches compare energy consumption, the potential of global warming (CO_2 emissions), acidification (SO_2 emissions) and eutrophication (PO_4 emissions). Other analyzed categories, as for example biodiversity or landscape changes seem to be kind of independent on the farming type.

The research was undertaken on South-West of Bavarian region of Allgau. It already belongs to the hilly sub-alpine landscape, which is an important fact for comparing the results. For example the fuel consumption depends very much on the natural conditions of the place. Here it is also a recreational area. There are usually small agricultural firms in average with 20 hectares, 23 cows, who annually give 6 060 kg of milk.

For the EF energetic part calculation, the energy consumption per one hectare is the most important entry. The authors summed the following data: the direct use of fossil fuels (field mechanization fuel), the indirect use of fossil fuels (chemicals and fertilizers production, ...), the electricity or gas (hay drying) and the bought fodder.

Before presentation of the results, please note again some differences from the first case. Once more it is more appropriate to compare the results within this one study rather than with other studies, unless it is certain that the method and input data have the same content. In this case, the farms lie in the mountains which mean other conditions, they are focused on dairy production so the EF transferred from the given energy consumption will not be an EF of one hectare of wheat but the EF of the average hectare on a farm with animal husbandry. In the calculation, the "forest" part, manual labor and built-up area are again omitted. The main part of the EF is again the given hectare – this time dedicated for animal production – and the energy consumption for its maintaining (including the maintenance of the cows grazing on this hectare).

Energy consumption on intensive farms is 19.1 GJ per ha, the highest part of this consumption falls on hay drying and fuel. The energetic part of the EF is therefore 0.191 ha. Alternatively the consumption may be calculated per one tone of produced milk,

Table 4. The comparison of the results of various studies

	Energy land (ha)/ agricultural land (ha)	EF (ha)
Organic winter wheat	0.025	1.025
Pastorek and Syrový Study		
an average Czech agricultural hectare	0.064	1.064
primary production per hectare of Czech agriculture	0.057	1.057
an average hectare of arable land	0.041	1.041
The BIO Inteligence Study		
Intensive agriculture	0.309	1.309
Organic agriculture	0.134	1.134
The Allgau Study		
Intensive pastures	0.191	1.191
Alternative pastures	0.059	1.059

Table 5. Comparison of CO_2 emissions of intensive and organic agriculture

	CO_2 emissions (t CO_2 eq./ha)	
	intensive agriculture	organic agriculture
The BIO Inteligence Study	4.4	1.06
The Allgau Study	9.4	6.3

which gives 2.7 GJ/t on intensive farms. For organic agriculture, the energy consumption results in 5.9 GJ per ha, respectively 1.2 GJ/t.

The EF of the intensively farmed area in the given conditions results in 1.191 ha/ha while the organic farms stump just on 1.059 ha/ha.

Another German study by Haas et al. (1995) states the energy consumption of conventional farms 19.4 GJ per ha and 6.8 GJ/ha of organic farms. A study of Swedish dairy farms shows energy consumption 2.85 GJ/t at the conventional farms and 2.4 GJ/t at the organic farms, which is twice as much as in Allgau. A different calculation may be an explanation.

Just for the interest of the reader, there is a comparison of the emitted greenhouse gases in the Allgau study and the study in point 2. These figures are quite different – the intensive Allgau agriculture emits in average 9.4 tonnes CO_2 eq./ha, organic farming 6.3 tones CO_2 eq./ha, while at the previous study it was 4.4 t CO_2 eq./ha, respectively 1.06 t CO_2 eq./ha. It is not evident how to interprete this difference, let us suppose it was a different procedure of calculation.

See Table 4 and 5 for comparison.

CONCLUSION

As we see from the previous text, organic farming is in most cases a more environmental friendly way of agriculture, though the chosen indicator of ecological footprint is not the best one to confirm fully this hypothesis. There are other aspects in which the organic farming relates more to sustainable development than intensive farming, as for example the care for soil fertility or better conditions for wildlife. Most of the advantages of organic farming cannot in fact to be illustrated by the ecological footprint. Still, even if we are limited to energy consumption, we can see the difference which is mainly caused by the omittance of artificial substances.

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