Evaluation of Environmental Impacts of Organic Farming by LCA Method – Greenhouse Gases from Corn Production

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Abstract

Organic farming is perceived as a system with a number of positive impacts on all components of the environment. For more precise assessment of differences in environmental impacts of conventional and organic farming, we need to be able to measure and quantify such impacts. For this the LCA (Life Cycle Assessment) method maybe used as a tool. Among other, the LCA method is also an invaluable tool for assessing GHG emissions related to agricultural production. In this paper, the use of LCA for evaluation of GHG emissions from Zea Mays L. growing is presented. The emission load was calculated by the simplified method LCA, impact category: climate change. The calculation was performed by SIMA Pro software with integrated ReCiPe Midpoint (H) method. The functional unit of the system was represented by 1 kg of corn grain. The model life cycle includes the farm phase (field emissions, seed and planting, fertilizers, plant protection products, agrotechnical operations), calculation of field emissions is also included. The results based e.g. on the yields in Cameroon show clear differences between conventional and organic growing of corn. The GHG emissions expressed in CO_{2e} *are after calculation on production unit 38.57 % lower in organic farming, compared to conventional farming.*

Introduction

Organic farming is perceived as a system with a number of positive impacts. Environmental friendliness is often considered as one of its most significant features (Robertson *et al.* 2000, Pretty *et al.* 2002). This positive impact is usually mentioned in connection with all components of the environment, i.e. soil, which in general has higher organic matter content in organic farming (Mondelaers *et al.* 2009; Fliessbach *et al.* 2007; Mäder *et al.* 2002), biodiversity and agrobiodiversity (Demo *et al.* 2004; Šarapatka *et al.* 2008; Hole *et al.* 2005), water (Lies *et al.* 2001; Haas *et al.* 2002; Niggli *et al.*2011) and, last but not least, climate. For example, American research comparing impacts of organic and conventional farming on a long-term basis, Rodale Institute's Farming Systems Trial, confirms that by introducing organic farming across the USA, the increased carbon sequestration in soil would reduce CO_2 emissions by up to a quarter (LaSalle and Hepperly 2008). Brandt and Svendsen (2011) also point out that organic farming has greater potential to reduce GHG emissions compared to conventional farming systems, with the greatest difference being due to the absence of synthetic fertilizers. Küstermann and Hülsbergen (2008) also came to similar conclusions, saying that organic farming systems generally generate lower amount of N_2O and CO_2 emissions due to lower inputs. This is consistent with the findings previously made by Haas *et al.* (1995).

The impact of the environmental system on mitigation is usually quantified per unit of area, but it is important, from the point of view of objectivity, to recalculate it also to the unit of production. GHG emissions are typically lower in environmental systems, both per unit of area and per unit of production. However, the environmental saving per unit of area is roughly double compared to calculation per unit of production due to lower organic farming yields (Nemecek *et al.* 2005). Thus, the disadvantage of organic farming is lower production per unit of area, increasing the unit load of production by emissions. Average yields in Europe, for example, of organic wheat reach 80 % compared to conventional production (Lackner, 2008). Also Mondelaers *et al.* (2009) report that organic farm yields are on average by 17 % lower than in the conventional farming system. Pimentel *et al.* (2005), on the other hand, state that even with some high-production plants, such as corn, organic farming systems can reach yields comparable to conventional systems. Thus, the yield level plays a key role also in assessing the emission load of organic farming and its comparison with the loads arising from conventional farming systems.

In order to be able to verify the argumentation on lower climate load, or lower GHG emissions by organic farming, it is necessary to evaluate and measure agricultural processes in different conditions and areas. To measure GHG emissions, the Life Cycle Assessment (LCA) method also seems to be one of the suitable methods. It is a tool for evaluating the environmental impacts of the product life cycle based on the assessment of the influence of material and energy flows that the monitored system exchanges with its surroundings (Kočí 2009). Social or economic aspects can be included in its framework, but the main focus is on the environmental component. The LCA method is also an invaluable tool for assessing GHG emissions related to product formation (Finnveden *et al.* 2009). Stern *et al.* (2005) and Brentrup *et al.* (2004) also consider the LCA a suitable tool for evaluating the environmental impacts of agricultural production. This is consistent with the findings of Jensen et al. (2005), who note that over the past decades, the LCA has been supplemented by methods and databases that enable it to be used also in the assessment of impacts within the agricultural sector.

Within the crop production, it is appropriate to assess first the cultivation of crops that are significant in terms of the extent of the areas on which they are grown. These include corn (*Zea Mays L.*), which is one of the world's most widely grown crops, and together with wheat, rice and soya covers about 70 % of caloric consumption of mankind (Šarapatka *et al.* 2008). In many countries of the world, it is one of the most cultivated crops, as one of most important in Cameroon is mentioned by Molua and Lambi (2007) or Matthews *et al.* (2003) and it is the most cultivated one also in many European countries or in the USA. The right choice of the system of its cultivation can thus have a significant impact also in terms of mitigating GHG emissions.

Materials and Methods

A simplified Life Cycle Assessment (LCA) method, defined by international standards ČSN EN ISO 14 040 (CNI 2006a) and ČSN EN ISO 14 044 (CNI 2006b), has been used as a tool for calculating the emission load rate. The results of the study were related to *Climate change* impact category, expressed by carbon dioxide equivalent indicator (CO_{2eq} = 1x CO_2 or 23x CH_4 or 298x N_2O). The calculation was performed by SIMA Pro software with integrated ReCiPe Midpoint (H) method. The functional unit of the system was represented by 1 kg of the final product, i.e. 1 kg of corn grain. Technological procedure of corn cultivation was based on data from specialized literature and the Ecoinvent database. The database was partially adjusted in accordance with the conditions of the evaluated region.

The model life cycle includes the farm phase (field emissions, seed and planting, fertilizers, plant protection products, agrotechnical operations). Infrastructure loads (agricultural buildings, machinery, manufacturing infrastructure, means of transport) were not included in the life cycle and data were not evaluated. In addition to emissions from inputs in the form of fertilizers, the so-called field emissions (N_2O emissions) released after the application of nitrogen fertilizers are produced. The IPCC (*Intergovernmental Panel on Climate Change*) methodology serves for their quantification (De Klein *et al.* 2006).

Results and Discussion

The impacts of corn cultivation in conventional and organic farming systems show different impacts in terms of GHG emissions. In terms of the LCA method, emissions are divided into five subcategories (agrotechnical operations, fertilization, seed, pesticides, and field emissions), with conventional farming showing higher load in the majority of them even after recalculation per unit of production.

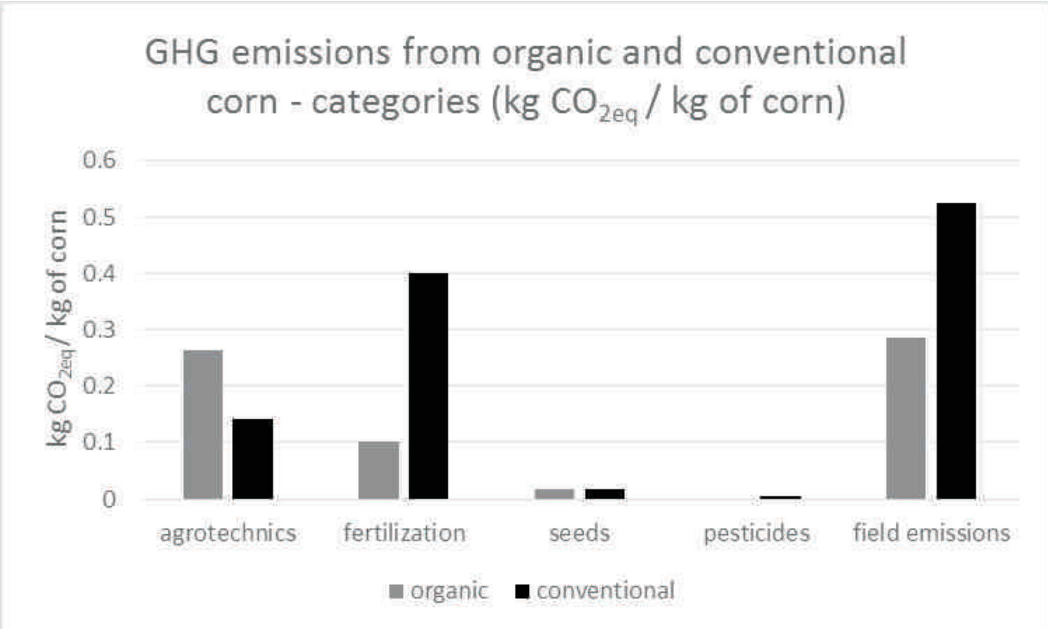

Figure 1. **Greenhouse gases emissions from organic and conventional corn – categories (kg CO_{2eq} / kg of corn)**

As can be seen from the Chart no. 1, only in the agrotechnical operation category, the load of organic farming is higher in relation to conventional farming (0.265 kg of CO_{2eq} / kg of corn in the organic farming system and 0.141 kg of CO_{2eq} / kg of corn in the conventional farming system). This is due to greater need for interventions in the treatment of corn without the use of pesticides and, at the same time, due to lower corn yield in the organic farming system. The category of seed has a relatively negligible impact from the point of view of GHG emissions (0.017 kg of CO_{2eq} / kg of corn in the organic farming system and 0.018 kg of CO_{2eq} / kg of corn in the conventional farming system) and also pesticides that are used only in the conventional farming system (0.005 kg of CO_{2eq} / kg of corn). However, pesticide application has a great environmental impact in other impact categories. From the point of view of GHG emissions, the main difference between conventional and organic farming system originates in particular in the fertilization phase (0.101 kg of CO_{2eq} / kg of corn in the organic farming system and 0.400 kg of CO_{2eq} / kg of corn in the conventional farming system) and in the subsequent phase of field emissions (0.286 kg of CO_{2eq} / kg of corn in the organic farming system and 0.525 kg of CO_{2eq} / kg of corn in the conventional farming system). This difference is caused mainly by the use of synthetic fertilizers in the conventional farming system. This is consistent with the findings of, for example, Tokuda and Hayatsu (2004), Mori *et al.* (2005) and Zou *et al.* (2005), who claim that with the increasing use of chemical fertilizers and manure, the proportion of N_2O released from the soil is usually also increasing.

Higher load. The increase of the emission load due to the use of synthetic fertilizers is then also stated by Fott *et al.* (2003), or Biswas *et al.* (2008).

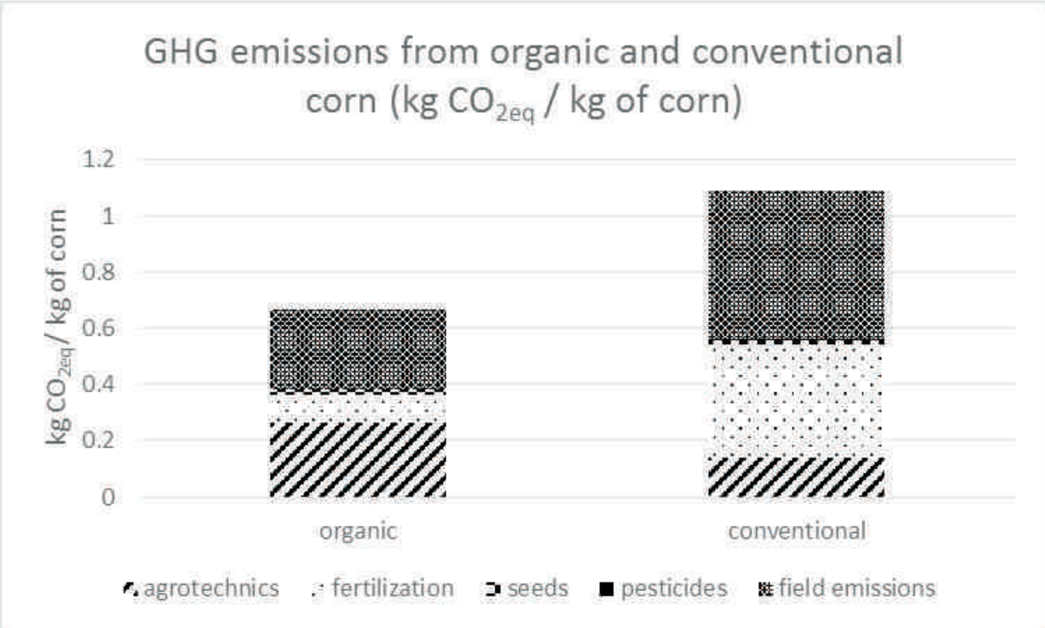

Figure 2. **Greenhouse gases emissions from organic and conventional corn (kg CO_{2eq} / kg of corn)**

The overall emission load in the environmental system, as can be seen from the Chart no. 2, is 0.669 kg of CO_{2eq} / kg of corn in the organic farming system, compared to 1.089 kg of CO_{2eq} / kg of corn in the conventional farming system. An important factor is the conversion of the load from the unit of area to the unit of production, i.e. to the kilograms of CO_{2eq} per one kilogram of corn. For example, Brandt and Svendsen (2011) note that the difference in the emission load of conventional and organic farming is very significant, when we relate this load to the unit of area, but it is partially reduced after conversion to the unit of production.

The emission load quantified per unit of area can be almost two and a half times higher in conventional farming system (3267.8 kg of CO_{2eq} / ha) compared to organic farming system (1338.7 kg of CO_{2eq} / ha).

Conclusion

Organic farming shows lower emission load when cultivating corn, both after conversion to the unit of area and to the unit of production. Since corn is one of the world's most significant cultivated crops also in terms of sown areas, a change in the system may be a tool for reducing GHG emissions. Partial savings can be achieved in particular by changes in fertilization by nitrogen fertilizers and partially also in agrotechnics.

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