Climate impact of producing more grain legumes in Europe

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ABSTRACT

The grain legumes pea and faba beans are among the relevant alternatives to imported soybeans for livestock feed for growing in the European agricultural systems, but what is the climate impact of an increased European production of grain legumes such as pea and faba bean? In order to estimate the overall climate impact of producing more grain legumes in Europe, we applied Life Cycle Assessment (LCA). The results showed that carbon footprints per kg protein of pea and faba bean in Europe did not vary much for different regions in Europe. Based on FAO statistics and an expert survey (Reckling et al., 2014), it was assumed that an increased European production of grain legumes will decrease the import of soybean cake and decrease the export of wheat from Europe. Taken that into account, results showed a small climate benefit of producing more grain legumes in Europe compared to importing soybeans to Europe.

Keywords: grain legumes, LCA, carbon footprint, soybeans, pea, faba bean

1. Introduction

Soybeans are number one on the world import list of agricultural products based on value (FAOSTAT, 2013); indicating that it is one of the most important agricultural products traded globally. Europe has a net import of 22 mill t cake of soybean and 15 mill t soybeans, but it is not the only region with a high demand for soybean protein. The demand for soybeans for the globally increasing livestock production has seen a dramatic increase during the last decade with China being by far the largest importer of soybeans globally (FAOSTAT, 2013). China has seen a three-fold increase in the import of soybeans during the last decade, with Brazil being the major supplier. Brazil's own consumption of soybeans for the increasing livestock production has also increased and due to the increasing demand, the producer prices of soybeans in Brazil have seen a three-fold increase during the last decade. The European livestock production is vulnerable to increasing prices of soy protein and combined with environmental concerns related to the production and import of soybeans, alternative and more sustainable protein sources are potentially attractive for the European livestock sector. The production of livestock feed is a major contributor to global greenhouse gas emissions, making mitigation options to reduce these important.

Pea and faba beans are relevant alternatives to soybeans in the European cropping systems and livestock diets, since they can be grown across Europe in the different agro-climatic zones. The aim of the present study is to assess the impact on GHG emissions of an increased European production of grain legumes.

2. Methods

We applied a life cycle assessment (LCA) approach to assess the overall climate impact of producing more grain legumes in Europe. The analysis focused on the greenhouse gas emissions or potential global warming impact.

2.1. Estimating carbon footprints of single crops

Studied crops

The basis for the analysis was the cultivation of pea and faba beans in five different agro-climatic zones in Europe, including Sweden (SE), Scotland (SC), Germany (DE), Romania (RO) and Italy (IT). All sites were rainfed. The analysis was based on an expert survey (Reckling et al., 2014) for representative crop rotations with and without grain legumes in the different zones.

Functional unit and system boundaries

The functional unit is 1 tonne harvested crop (DM). However, the greenhouse gas emissions per t harvested protein and per hectare are also presented. The main system boundaries in the present cradle to farm gate study include two main processes; 1) production of agricultural inputs and 2) the agricultural production system. The temporal system boundaries are one year of crop production based on current practice in the five different agro-climatic zones

Estimation of emissions

The characterization factors for the global warming potential (GWP) were based on the IPCC 2007 standards for greenhouse gas emissions (IPCC, 2007). Production data from Reckling et al. (2014), such as crop DM yields and amount of fertilizer, were used for the analysis. The same field operations were assumed for all the sites, which included one ploughing, one harrowing, one sowing, 2.5 pesticide applications, fertilizer applications according to the survey and one harvesting. The GHG emissions related to the fertilizer production were based on Williams et al. (2006). The diesel consumption was based on the field operations and the diesel consumption per field operation was estimated as described by Dalgaard et al. (2002). GHG emissions related to diesel and energy consumption was based on data from the Ecoinvent database (Ecoinvent Centre, 2009). The direct and indirect emissions of nitrous oxide (N_2O) were estimated according to the IPCC guidelines 2006 (IPCC, 2006). NH_3 emissions were estimated according to EEA (2013). N leaching was estimated in accordance with Reckling et al. (2014), who estimated N balances and N losses using the ROTOR model (Bachinger and Zander, 2007). Soil carbon changes related to grain legume production were assumed to be insignificant. The grain legume production was modeled as an individual crop in the crop rotation (Knudsen et al. 2013) , but the interactions with the following crops in the crop rotation was taken into account in terms of a reduced fertilizer use in the following crop of 10 kg N (Plantedirektoratet, 2011) . Furthermore, an increased yield in the following crop of 0.3 t cereal DM per hectare was anticipated and included in the analysis, based on information from Reckling et al. (2014).

2.2. Overall analysis

If Europe starts producing more grain legumes such as pea and faba bean for the European livestock production, the import of soybeans and soybean cakes will be reduced. At the same time the crops being replaced in Europe by grain legumes, will have to be produced somewhere else. According to Reckling et al. (2014), the grain legumes will mainly replace wheat in the crop rotations.

The overall analysis assumes that the production of one hectare of either pea or faba bean will replace one hectare of wheat, previously grown on that land and in that crop rotation. Europe has a net import of soybeans and soybean cake of approximately 37 mill tonnes and a net export of approximately 30 mill tonnes of wheat (FAOSTAT, 2013). It is assumed that an increased production of grain legumes in Europe will decrease the import of soybean cake and decrease the export of wheat from Europe.

Europe mainly imports soybean cake and soybeans from Brazil, but also from Argentina, USA and Paraguay according to FAOSTAT (2013). Since Brazil supplies approximately half of the imported soybeans to Europe, the values from Brazil are weighted accordingly (50%) in the average values while the values from the remaining countries are weighted by 17% each of them. Since part of the wheat production in Europe will be replaced by production of peas or faba beans, the wheat needs to be produced elsewhere. According to FAOSTAT (2013), USA, Canada and Russia are the main wheat exporters globally, and they will presumably increase their production accordingly.

To analyze the overall climate impact of those changes, the carbon footprint of the imported soybean and the wheat production outside Europe is also needed. The inputs and yields from soybean and wheat production in the countries concerned are based on FAOSTAT (2013) (average over the last five years) and FertiStat (2007) and the emissions are estimated based of IPCC (2006) and EEA (2013). Protein content of pea, faba bean and soybean are based on Burstin et al (2011). Transport steps for the import and export of the grains are included in the study.

3. Results and discussion

The carbon footprint of the European grain legumes and the imported grain legumes (soybeans) to Europe is presented (Figure 1). The emissions are given in CO_2 equivalents per t protein for comparison across different grain legumes.

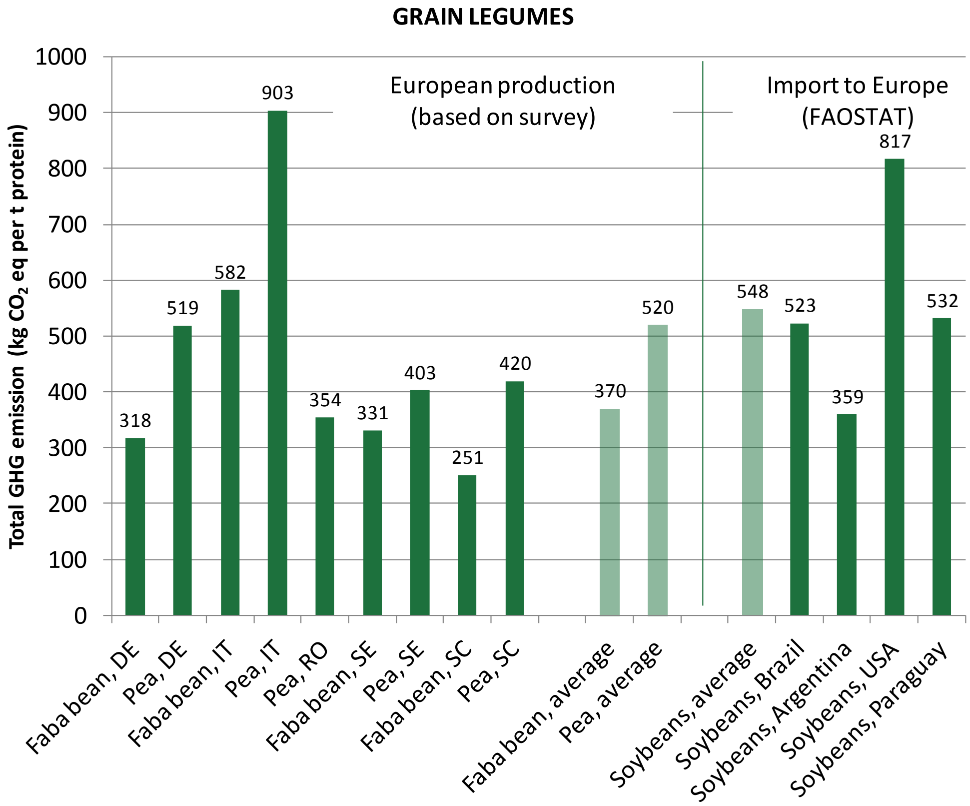

Figure 1. Greenhouse gas emission per t protein for grain legumes produced in five different regions in Europe and soybean imported to Europe. DE, IT, RO, SE and SC refers to the different agro-climatic zones, represented by Germany, Italy, Romania, Sweden and Scotland, respectively.

On average, soybean production outside Europe has a global warming potential of 548 kg CO_2 eq. per t protein. This can be compared to the average for pea and faba bean in our study of 520 and 370 kg CO_2 eq. per t protein, respectively (Figure 1). The higher value for pea is mainly due to lower DM yield and lower protein content in the grains.

The carbon footprint of the wheat produced in Europe (based on Reckling et al., 2014)) can be compared to the carbon footprint of wheat on the world market produced outside Europe (Figure 2). Figure 2 shows that the carbon footprint values are comparable for the wheat production in Europe and outside Europe, despite different yield and input levels. The average values for greenhouse gas emission from wheat production in Europe and outside Europe (Figure 2) are used in the following calculations. Likewise, the values for pea and faba bean production in Europe and for soybean production outside Europe (Figure 2) are used in the overall assessment on the climate impact of producing more grain legumes in Europe.

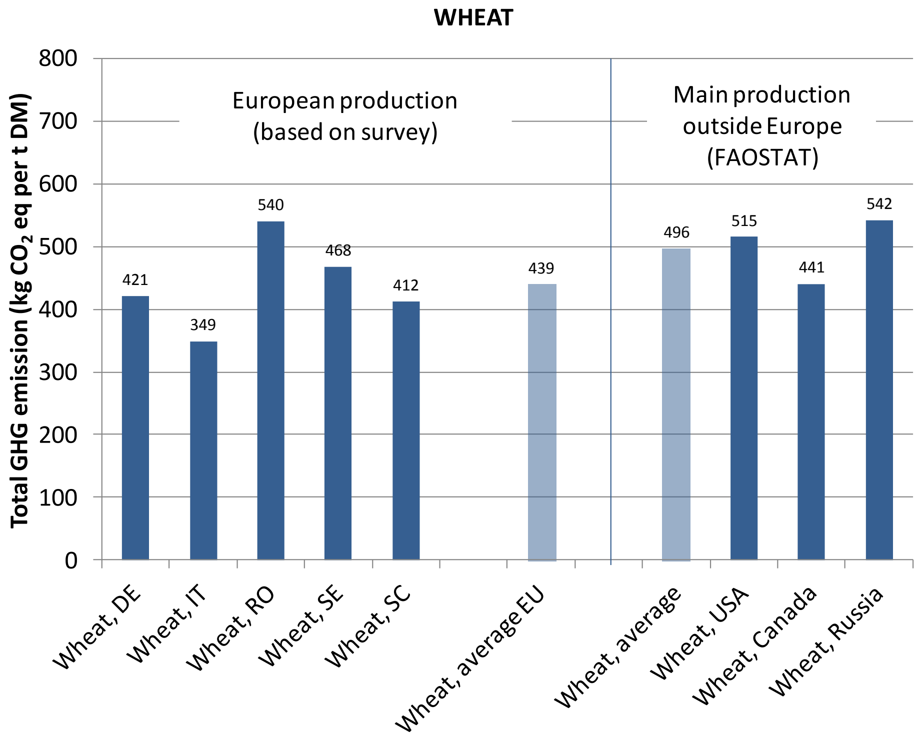

Figure 2. Greenhouse gas emission per t DM for wheat produced in five different locations in Europe and wheat produced by the main wheat exporters outside Europe. DE, IT, RO, SE and SC refers to the different agro-climatic zones, represented by Germany, Italy, Romania, Sweden and Scotland, respectively.

The global flows will be affected when replacing one hectare of wheat in Europe with the production of one hectare of either pea or faba bean in Europe. The wheat formerly produced in Europe will be produced somewhere else. The major global wheat exporters, USA, Canada and Russia are assumed to take over this wheat production. The increased production of grain legumes in Europe, are assumed to replace a corresponding production of protein from soybeans. However, the avoided production soybeans and import of soybean cake to Europe also implies that a certain amount of soybean oil is not produced. The market response to a lower amount of soybean oil on the world market, will, according to Schmidt (2010), be an increase in the production of the marginal vegetable oil, which is palm oil from Malaysia and Indonesia (Schmidt and Weidema, 2008) , and this assumption is used in this work. The division between soybean cake and soybean oil are based on Dalgaard et al. (2008) and the greenhouse gas emissions from palm oil are based on Schmidt (2010).

The overall climate impact of producing more grain legumes in Europe are presented in Table 1 for pea and faba bean.

Table 1. The overall climate impact when replacing one hectare of wheat in Europe with pea or faba bean production, while taking the impact of a reduced soybean import to Europe and an increased wheat production outside Europe into account.

	Kg CO_2 emissions per ha of grain legumes cultivated in Europe	
	PEA	**FABA BEAN**
EMISSIONS		
1 hectare of pea/faba bean production in Europe	296	287
Production of wheat outside Europe	2524	2524
Production of palm oil (to account for less produced soybean oil)	711	1066
TOTAL emissions	3531	3877
AVOIDED EMISSIONS		
1 hectare of wheat production in Europe	-2343	-2343
Soybean production	-329	-493
Soybean, processing to oil and cake[a]	-230	-344
Transport of soybean cake to Europe	-175	-262
Extra carbohydrates in peas/faba beans compared to cake of soybean, avoided cereal production	-733	-610
TOTAL avoided emissions	-3810	-4052
OVERALL climate impact	-279	-175

[a] Dalgaard et al. (2007)

In the assessment it is also taken into account that pea (and faba bean) having the same amount of protein as the cake of soybean that it replaces in the livestock diet, contains more carbohydrates compared to the cake of soybean. This means that it also replaces a certain amount of cereals in the livestock feed – and the production of this cereal can thus be avoided.

The overall impact of producing more grain legumes in Europe showed a small climate benefit compared to importing soybeans to Europe. Approximately 280 kg CO_2 eq. are avoided for each hectare in Europe producing pea instead of wheat. Similarly, 175 CO_2 eq. are avoided for each hectare faba bean produced in Europe instead of wheat.

5. Conclusion

The carbon footprint of pea and faba bean did not vary much over the five different agro-climatic zones in Europe, except from Italy. The carbon footprint of pea cultivated in five different agro-climatic zones in Europe varied from 88-222 kg CO_2 eq. t^{-1} harvested grain DM. On average per kg pea protein, the greenhouse gas emission was 520 kg CO_2 eq. t^{-1} pea protein. For faba bean, the carbon footprint varied from 71 to 165 kg CO_2 eq. t^{-1} harvested grain DM in the different agro-climatic zones in Europe. The greenhouse gas emission per kg protein was on average 370 kg CO_2 eq. t^{-1} faba bean protein.

Based on FAO statistics and Reckling et al. (2014), it was assumed that an increased European production of grain legumes will decrease the import of soybean cake and decrease the export of wheat from Europe. The overall impact of producing more grain legumes in Europe showed a small climate benefit compared to importing soybeans to Europe. Approximately 280 kg CO_2 eq. are avoided for each hectare producing pea instead of wheat in Europe. Similarly, 175 CO_2 eq. are avoided for each hectare faba bean produced instead of wheat in Europe. Thus, the study also illustrates a method for estimating the overall climate effect for a change in production systems.

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