O.53 - Life Cycle Assessment of Wheat and Apple Production Systems within the ENDURE Project

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Abstract

Within the ENDURE activity RA3, a goal of sub-activity RA3.4 is to calculate the environmental impacts of apple and wheat production strategies by life cycle assessment with a focus on pesticide applications. The analysis of production systems includes the actual production from cultivation, specifically from the preparation of orchards up to harvesting and finally the uprooting of the orchards, as well as the environmental impacts linked with the production of input factors. For each case study and region two systems with different intensities (integrated and organic production) were analysed. Data was collected by local project partners. The Swiss Agricultural Life Cycle Assessment tool (SALCA) was used for the impact assessment. The impact categories were linked with resource management (non-renewable energy demand, global warming potential), nutrient management (eutrophication and acidification potential) and human and ecological toxicity. These were calculated for the functional units ha/year and kg/dry matter yield or kg/apple. For the analysed systems this study shows some overall advantages of organic wheat production over integrated, with the exception of nutrient management, where impacts in organic production are not substantially lower. For the analysed apple production strategies, organic production is only advantageous for resource management and eco- and human toxicity per ha. For all other categories the impacts generated by integrated production strategies are lower.

Introduction

Within the ENDURE activity RA3 (sustainability assessment of crop production systems) a goal of sub-activity RA3.4 is to calculate the environmental impacts of apple and wheat production strategies by life cycle assessment with a focus on pesticide applications.

The analysis of production systems includes the actual production from cultivation, specifically from the preparation of orchards up to harvesting and finally the uprooting of the orchards, as well as the environmental impacts linked with the production of input factors (fertilisers, pesticides, machinery and seed). Data were collected by local project partners for the regions north eastern part of Emilia-Romagna (Italy (IT), apple and wheat), Wielkopolskie (Poland (PL), wheat), Saxony-Anhalt (Germany (DE), wheat), Denmark (Denmark (DK), wheat), Swiss and German parts of Lake Constance (apple), Lleida (Spain (ES), apple) and the Rhone valley (France (FR), apple). For each case study and region two systems with different intensities (for example fertilisation and pesticide use) were analysed. A comparison between systems in different regions appeared unreliable because differences in data sources were too large. Also it should be noted that a generalisation of the results is not feasible, because only a single crop and not a crop rotation is analysed and especially for the organic systems official statistics are rare and the results are strongly characterised by single assumptions (for example, grass clover as previous crop).

The Swiss Agricultural Life Cycle Assessment tool (SALCA) was used for the impact assessment. It includes the environmental inventories of agricultural inputs, taken from Nemecek & Erzinger (2005) and

Frischknecht et al. (2004), methods developed by the Agroscope Reckenholz-Tänikon Research Station (ART) for the estimation of direct field emissions (ART, 2008) and impact assessment methods listed in Nemecek et al. (2005). Additionally, the toxicity method IMPACT2002+ (Jolliet et al., 2003) is taken into consideration. Since agriculture has to fulfil multiple functions, which cannot be covered with a single functional unit, the following functional units were considered: 1.) Area occupation (ha/year), representing the function of land cultivation (sustaining land use, landscape protection, limited use of basic life resources) and showing the level of production intensity. 2.) Dry matter (wheat grains) or fresh weight (apple fruit) yield, representing the function of production.

In both case studies the impact categories energy use, global warming potential and ozone formation are strongly characterised by the field operations and the amount of mineral fertilisers used. In addition for apple production systems hail protection and irrigation (Emilia-Romagna and Lleida) generate high impacts (Figure 1). In general:

The non-renewable energy demand per ha in apple production is 2 to 10 times higher than in wheat production.

In both case studies the impacts per ha of the organic systems are lower compared to the integrated systems.

The integrated systems reach lower impacts concerning the function of production with the exception of non-renewable energy used to produce one kg of wheat grain dry matter.

The eutrophication and acidification potentials are dominated by direct field emissions of NO_3, NH_3 and N_2O from fertiliser applications. Therefore the results mainly depend on type and amount of fertiliser, time of application and the application technique. From the systems under consideration it emerges (Table 1) that:

- The fertiliser input and therefore the eutrophication and acidification potentials in apple orchards are in most cases much lower than in wheat production.
- The organic apple production systems cause higher eutrophication and acidification potentials per ha except the Italian system and per kg/apple (data not shown).
- The low-input wheat production systems show in general higher impacts for both functional units. They are mainly caused by the previous crop grass clover or the high amount of organic manure applied and the associated NO_3, N_2O (grass clover, organic manure) and NH_3 (organic manure) emissions.
- Finally, the eco- and human toxicity figures strongly depend on the active ingredients used and on the toxicity impact assessment methods considered.

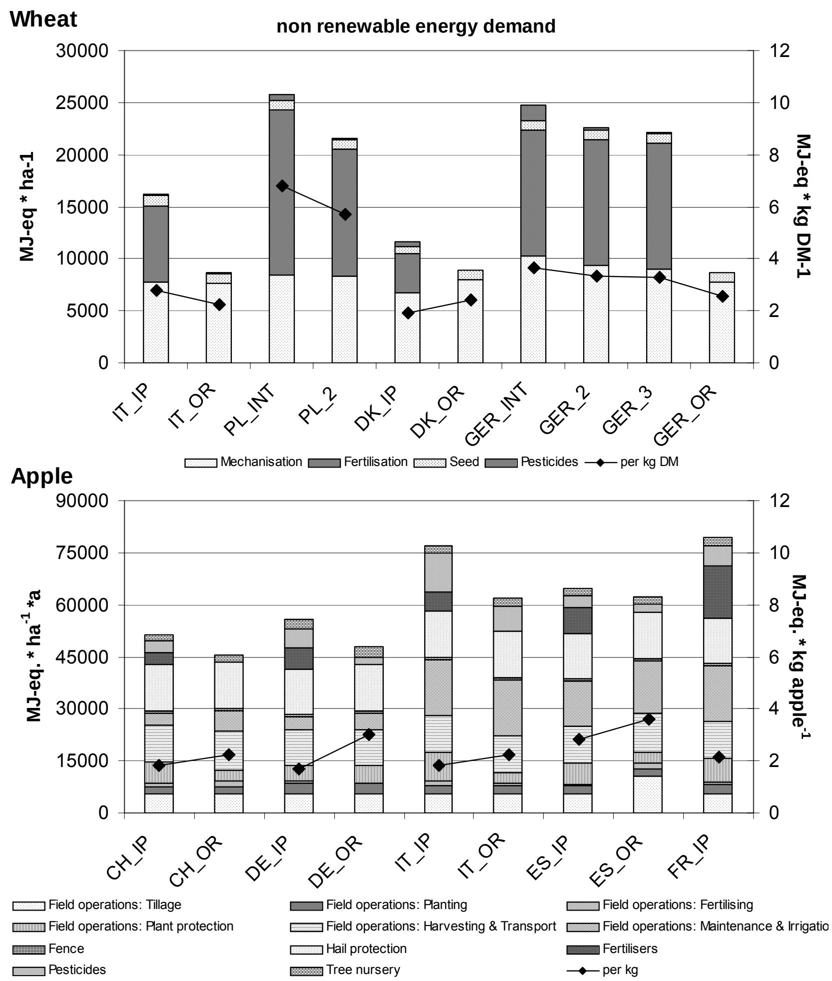

Figure 1: Non-renewable energy demand (per ha and kg/dry matter or kg/apple respectively) and contribution of the single input factors to the total energy demand of wheat and apple production systems. IT = Italy, PL = Poland, DK = Denmark, DE = Germany; IP = integrated production, Org = organic, Int = intensive, 2 = less intensive than Int, 3 = less intensive than 2, CH = Switzerland, LC = Lake Constance, ES = Spain, FR = France

In the wheat case study two different pictures arise. For those methods with higher impacts for pesticides than for heavy metals, the low input systems perform better because no pesticides or only a few with lower toxicity were applied. However, their results are worse for the methods with higher impacts for heavy metals, because of the organic manure applied and its high content of some heavy metals compared to the mineral fertilisers. The results of the apple case study are more homogenous. The organic systems reach in general lower impacts per hectare (Tab. 1), but because of the low yields the impacts per kg/apple are in most cases higher than in the integrated production (data not shown).

Bearing the above mentioned limitations in mind the analysed low-input or organic production systems in both case studies show drawbacks in resource management per kg wheat grain dry matter (kg apple fruit) produced and in nutrient management compared with the intense systems. Regarding toxicity the results for the wheat case study are strongly determined by the impact assessment methods. The analysed organic apple production systems show in general lower toxicity per ha but higher values per kg/apple produced.

Tab. 1: Overview of the analysed environmental impacts of the different wheat and apple production systems (per ha/year). The results are related to the most intense production for each region for better readability. IT = Italy, PL = Poland, DK = Denmark, DE = Germany; IP = integrated production, Org = organic, Int = intensive, 2 = less intensive than Int, 3 = less intensive than 2, CH = Switzerland, LC = Lake Constance, ES = Spain, FR = France

Wheat	**IT**		**PL**		**DK**		**GER**			
	IP	**Org**	**Int**	**2**	**Ip**	**Org**	**Int**	**2**	**3**	**Org**
energy use (MJ)	1.62E+04	53%	2.57E+04	84%	1.17E+04	77%	2.47E+04	91%	90%	35%
GWP (kg CO2)	2.77E+03	86%	4.86E+03	80%	2.75E+03	92%	4.49E+03	97%	97%	59%
ozone form.(kg C2H2)	1.02E+00	77%	1.31E+00	91%	7.82E-01	101%	1.37E+00	91%	88%	57%
eutrophication (kg N)	8.02E+01	180%	1.39E+02	82%	1.13E+02	114%	1.01E+02	98%	97%	163%
acidification (kg SO2)	2.87E+01	330%	2.26E+01	81%	9.44E+01	75%	2.17E+01	97%	96%	566%
aqTox EDIP (m3 water)	6.67E+05	85%	1.29E+06	88%	6.37E+05	90%	1.06E+06	92%	90%	51%
aqTox CML (kg DCB)	5.89E+02	31%	6.65E+02	73%	3.71E+02	41%	7.11E+02	62%	36%	21%
aqTox IMPACT (kg TEG)	1.14E+02	9%	5.27E+01	49%	1.01E+02	0%	5.71E+01	45%	70%	1%
teTox EDIP (m3 soil)	5.81E+03	54%	4.67E+05	99%	1.20E+05	2%	2.30E+06	24%	19%	0%
teTox CML (kg DCB)	4.82E+00	174%	6.21E+01	10%	1.45E+01	25%	1.12E+02	5%	5%	3%
teTox IMPACT (kg TEG)	1.44E-02	40636%	1.60E-01	70%	3.23E+00	58%	1.15E-01	78%	75%	1654%
hTox EDIP (m3 total)	2.70E+09	147%	4.96E+09	82%	2.73E+09	135%	3.66E+09	97%	96%	114%
hTox CML (kg DCB)	5.96E+05	79%	7.59E+05	92%	4.62E+05	102%	7.96E+05	91%	88%	58%
hTox IMPACT (kg TEG)	7.57E-02	1460%	1.40E-01	83%	1.01E+00	60%	1.16E-01	82%	78%	525%

Apple orchards	**CH_LC**		**GER_LC**		**IT**		**ES**		**FR**
	IP	**ORG**	**IP**	**ORG**	**IP**	**ORG**	**IP**	**ORG**	**IP**
energy use (MJ)	5.14E+04	89%	5.57E+04	86%	7.71E+04	81%	6.47E+04	96%	7.94E+04
GWP (kg CO2)	3.16E+03	91%	3.49E+03	85%	4.16E+03	74%	3.93E+03	89%	5.49E+03

ozone form.(kg C2H2)	2.55E+00	105%	2.54E+00	98%	2.98E+00	84%	2.72E+00	111%	3.16E+00
eutrophication (kg N)	1.87E+01	142%	2.16E+01	120%	2.49E+01	82%	1.91E+01	155%	3.75E+01
acidification (kg SO2)	2.93E+01	155%	3.54E+01	119%	4.35E+01	75%	3.53E+01	166%	6.90E+01
aqTox EDIP (m3 water)	5.48E+05	103%	5.59E+05	88%	6.33E+05	77%	6.09E+05	89%	7.38E+05
aqTox CML (kg DCB)	3.73E+03	23%	6.36E+02	41%	1.17E+04	2%	3.09E+04	1%	3.90E+04
aqTox IMPACT (kg TEG)	4.72E+03	1%	1.32E+03	3%	7.87E+04	0%	1.38E+03	3%	3.91E+02
teTox EDIP (m3 soil)	7.26E+04	87%	8.80E+04	71%	1.20E+05	77%	9.92E+04	82%	1.89E+05
teTox CML (kg DCB)	9.78E+01	3%	2.86E+02	3%	1.22E+02	7%	8.73E+01	8%	1.10E+03
teTox IMPACT (kg TEG)	5.80E-01	84%	7.33E-01	72%	7.01E-01	70%	7.30E-01	71%	1.03E+00
hTox EDIP (m3 total)	8.69E+08	183%	9.07E+08	101%	1.16E+09	76%	1.00E+09	193%	1.23E+09
hTox CML (kg DCB)	1.38E+03	79%	1.44E+03	79%	2.10E+03	80%	1.43E+03	104%	1.10E+04
hTox IMPACT (kg TEG)	5.22E-01	82%	4.50E-01	98%	6.69E-01	86%	5.29E-01	87%	7.90E-01

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