Europ. J. Agronomy 65 (2015) 40–51

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Designing eco-efficient crop rotations using life cycle assessment of crop combinations

Thomas Nemecek[a,*], Frank Hayer[a,b], Emmanuel Bonnin[c], Benoît Carrouée[d], Anne Schneider[d], Christophe Vivier[e]

[a] Agroscope, Institute for Sustainability Sciences, CH-8046 Zurich, Switzerland
[b] Swiss Federal Office for the Environment, CH-3003 Bern, Switzerland
[c] Chambre d'Agriculture de la Nièvre, F-58028 Nevers, France
[d] Union Nationale des Plantes Riches en Protéines UNIP, F-75008 Paris, France
[e] Chambre d'Agriculture de l'Yonne, F-89015 Auxerre, France

ARTICLE INFO

Article history:
Received 1 April 2014
Received in revised form 2 December 2014
Accepted 18 January 2015
Available online 6 February 2015

Keywords:
Life cycle assessment
Crop rotation
Crop combination
Nitrogen fertilisation

ABSTRACT

Intensive arable crop production has major impacts on the environment and solutions for their reduction are needed. Diversification of crop rotations together with improved nitrogen management is an option for more eco-efficient cropping systems. The potentials for reducing the environmental impacts cropping systems were investigated by means of life cycle assessment (LCA) in three regions in France (Beauce, Burgundy and Moselle).

The crop management data were compiled by the Chambers of Agriculture in the three regions based on field survey data (2002–2009 in Burgundy and Moselle and 2004–2008 in Beauce) and completed by experts. The LCA calculations were carried out by the SALCA-crop tool, using the ecoinvent and SALCA inventory databases and SALCA emission models. The LCAs were calculated for crop combinations, which were an efficient way to analyse a large number of crop rotations. A crop combination is defined as the inventory of a given crop, with a defined preceding crop and eventually including a catch crop.

Nitrogen management revealed to be a key driver for the environmental impacts. It dominated the non-renewable energy demand, the global warming potential, the ozone formation potential, the acidification potential, and the eutrophication potential. Strong correlations between N fertilisation and these environmental impacts were found. The introduction of pea allowed to reduce the total eutrophication over the whole crop rotation. The mitigation of environmental impacts was not only possible per hectare, but also per € gross margin II. The eco-efficiency can thus be improved by reducing the level of N fertilisation. A reduction of N fertilisation could be achieved also by a reduction of the fertiliser doses to the non-legume crops, in addition to the introduction of legumes. Both ways proved to be effective and the combination of both was the most promising. However, trade-off between environmental and economic goals was identified.

Diversification of cereal intensive crop rotations proved to be generally favourable from an environmental point of view. Catch crops had favourable effects on nutrient leaching a slightly favourable effects on biodiversity and soil quality. The ecotoxicity potentials were dominated by a few active ingredients only; the diversification did not lead to generally reduced ecotoxicity potentials.

Diverse crop rotations with reduced N input are a promising way to reduce the environmental impacts of intensive arable crop rotations.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

France has the largest area of arable crops in the EU (18.3 millions ha in 2012, FAO, 2014). The total consumption of nitrogen (N) fertilisers and pesticides is also the highest of all EU countries. Intensive use of inputs is related to several adverse impacts on the environment such as water pollution, reduction of biodiversity or

* Corresponding author. Tel.: +41 58 468 72 54; fax.: +41 58 468 72 01.
E-mail address: thomas.nemecek@agroscope.admin.ch (T. Nemecek).

http://dx.doi.org/10.1016/j.eja.2015.01.005
1161-0301/© 2015 Elsevier B.V. All rights reserved.

emission of greenhouse gases (Stoate et al., 2001). Well designed crop rotations are key elements of good agricultural practice, but this know-how has partly been lost in the course of the specialization and intensification of agricultural production. The role of crop rotations in reducing environmental impacts has also been recognised in the current CAP reform of the European Commission (2011).

In particular, the introduction of legumes has the potential to reduce environmental impacts, through the ability to fix nitrogen from the air in symbiosis with *Rhizobium* bacteria, and consequently reduce the use of mineral N fertilisers on the one hand, and by diversifying the crop rotation on the other hand (Köpke and Nemecek, 2010; Nemecek et al., 2008). The legumes, thus, provide nitrogen to the crop rotation and act as break-crops in crop rotations with a high share of cereals, both with potentials to reduce environmental impacts. These potential benefit, however, strongly depend on the design of the crop rotation. The main objective of the CASDAR-PCB project (improvement of the economic and environmental performance of crop rotations with oilseed rape, wheat and peas) was to assess the environmental and economic performance of crop rotations including oilseed rape and wheat, with and without grain legumes (Carrouée et al., 2012a,b; Schneider et al., 2010).

The design of efficient crop rotations from an environmental point of view requires a comprehensive tool, allowing to assess various environmental impacts directly caused by the cropping systems as well as those arising as a consequence of the inputs used. Eco-efficiency is defined as the ratio between environmental impact and economic value (called "environmental intensity" by Huppes and Ishikawa, 2005) and can quantify the environmental performance. Life cycle assessment (LCA) is a tool allowing to quantify numerous environmental impacts over a life cycle. It has been successfully applied in a number of studies on crops and cropping systems (Brentrup et al., 2004a; Kim and Dale, 2005). By taking into account a variety of environmental impacts, possible reductions of environmental impacts at the expense of creating new environmental problems can be detected, and thus avoided. Moreover, by accounting for different life cycle phases, shifts of environmental burdens to other life cycle stages can be avoided. The cropping system can thus be assessed as a whole.

The specific objective of this study was to quantify the environmental impacts of introducing peas into standard rotations in selected French regions by means of LCA and to evaluate the potentials of reducing environmental impacts by diversified crop rotations and improved N management.

LCA is a data intensive method and determining an optimal composition of a crop rotation requires calculations for numerous crop rotations. Therefore, a more efficient approach than analysing each crop rotation separately was needed in this study. We used crop combinations to assess a large number of crop rotations with a limited number of LCA calculations. A crop combination is defined as the inventory of a given crop, with a defined preceding crop and—if present—also including the catch crop.

2. Material and methods

2.1. Choice of regions, crop rotations and agronomic data

Three regions have been chosen for this study in France, namely Burgundy, Beauce and Moselle. The following criteria were used to select the regions:

- Arable regions with a high proportion of cereals.
- Potential to increase the grain legume area.
- Representation of the variability of soils and climates of major arable crop production regions in France.
- Data availability.
- Regional partners participating in the CASDAR-PCB project.

The soil and climate parameters taken into account for the calculation of the direct emissions are given in Table A1 in the Supplementary material.

2.2. Yields and crop management data

The crop management data were compiled by the Chambers of Agriculture in the regions concerned (Chambre d'Agriculture de la Nièvre, Chambre d'Agriculture de l'Yonne, Chambre d'Agriculture de Moselle) and INRA. In order to define representative data for an average crop management in the region, averages of at least five years were used for the yields, pesticide use, quantity and time of application of fertilisers and soil tillage (2002–2009 in Burgundy and Moselle and 2004–2008 in Beauce). For this, data from field surveys from three centres of the CERFRANCE network have been evaluated (CERFRANCE Aube, CERFRANCE 277, CERFRANCE Alliance Centre). Missing data were completed by the experts from the Chamber of Agriculture of the respective region. For the machinery work processes, the number of passes was determined from the crop management databases from each region, where available and completed by the experts. The averages prices from the years 2005 to 2009 were used for the economic calculations. The datasets were checked for internal consistency by the experts.

To take into account, the effect of the crop rotation on the yields, the following adaptations have been made for wheat yields relative to the average yields: −510 kg/ha for wheat after cereals in Burgundy and Moselle, respectively, −500 kg/ha in Beauce conventional system and −300 kg/ha in Beauce integrated system, +240 kg/ha for wheat after rape seed or pea in Burgundy and Moselle, respectively, +300 kg/ha in Beauce conventional and +200 kg/ha in Beauce integrated system, and +170 kg/ha for rapeseed following pea (all regions and systems). These values were based on a statistical analysis for wheat and on the experimental results from the project for rapeseed following pea, since this combination is seldom found in practice. The fertilisation for these crop combination was adjusted for the effect of the preceding crops.

2.3. Crop rotations

A total of 64 crop rotations were defined for the three regions. They were chosen by the experts from the region according to following criteria:

- Agronomic criteria, such as compatibility of harvest and sowing dates,
- incidence of diseases, and
- potential to use the nutrients left after harvest in the soil.

The set of crop rotations included those typically practiced in the region, but also new crop rotations that are rarely or not practiced but that have the potential to make better use of the residual nutrients in the soil. For Beauce, two cropping systems were distinguished: a conventional system and an integrated system. The latter is characterised by reduced fertiliser and pesticide inputs as well as lower yields. In Burgundy, additional crop rotations with reduced N fertiliser input were modelled.

For the purpose of comparability between the regions, two standard (S1 and S2) crop rotations without pea and three alternative crop rotations with pea (P1, P2 and P3) were defined as presented in Table 1. The standard rotation S1 was composed of rapeseed, wheat and barley. In Burgundy, only summer malting

Download English Version:

https://daneshyari.com/en/article/4508883

Download Persian Version:

https://daneshyari.com/article/4508883

Daneshyari.com