Assessing environmental impacts of cropping systems: comparison of an indicatorbased and a life-cycle analysis-based method

Christian C. Bockstaller, Marine Marion-Wuillemin, Nouraya Akkal-Corfini, Nicolas Munier-Jolain, Michael S. Corson

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Christian Bockstaller ±1, **Marine Marion-Wuillemin** 2,3, **NourayaAkkal-Corfini** 2,3, **Nicolas Munier-Jolain** 4 & **Michael S. Corson** 2,3

1 INRA, UMR LAE Nancy-Colmar, France
2 INRA, UMR SAS Rennes, France
3 Agrocampus Ouest, UMR SAS, Rennes, France
4 INRA, UMR AgroEcologie, Dijon, France

* Speaker

± Corresponding author: christian.bockstaller@colmar.inra.fr

1 Introduction

Design and experimental testing of innovative cropping systems requires assessing their performances. When measurements of impacts are not possible, direct impacts have mainly been assessed at the field level using indicator-based methods (Bockstaller *et al.*, 2008). Systemic assessment frameworks based on life-cycle analysis (LCA) have also been applied to cropping systems (Deytieux *et al.*, 2012). LCA methods address direct and indirect impacts (e.g. linked to production and transport of farm inputs) and therefore are scientifically interesting, but they require more input data and calculation time. This paper aims to compare both approaches and discuss to what extent it is necessary to implement an assessment method based on LCA.

2 Materials and Methods

Fifteen cropping systems were selected for study from the DEPHY database, containing average cropping systems from farms of the French national network "Ecophyto DEPHY"(French action plan to reduce pesticide use (Ecophyto, 2015)). These cropping systems have crop-rotation lengths ranging from 1 (maize monoculture) to 9 (maize/cereals/3-4 years grassland), application rates of mineral nitrogen fertilizers of 0-250 kg $N.ha^{-1}$, and pesticide treatment frequency indices of 0-5.3.

LCA methods implemented in the study were based on pollutant-emission models from the AGRIBALYSE framework, recently developed to support environmental labeling policies of agricultural products in France (Colomb *et al.*, 2015). For the indicator-based method, INDIGO was chosen to estimate direct impacts at the field level (Bockstaller *et al.*, 2008). We focused on the nitrogen-based emissions of nitrate (NO_3), ammonia (NH_3), and nitrous oxide (N_2O). They are estimated in the LCA method by models: the COMIFER approach for NO_3, EMEP/EEA 2009 Tier 2 (for organic fertilization) and EMEP/CORINAIR 2006 Tier 2 (for mineral fertilization) for NH_3 and IPCC 2006 Tier 2for N_2O. For the INDIGO method, these emissions were estimated by the I_N indicator (Bockstaller *et al.*, 2008). In both methods, a mineral nitrogen balance is calculated for the time from harvest to start of the drainage period at the beginning of winter to estimate nitrate leaching.

3 Results – Discussion

Among cropping systems, INDIGO tended to estimate more various nitrate leaching than LCA, and results of the two methods were weakly correlated (r = 0.18) (Fig. 1a). INDIGO tends to estimate slightly lower ammonia emissions than LCA, but results were strongly correlated (r= 0.88) (Fig. 1b). Estimates of nitrous oxide emissions were intermediate, with a weaker correlation than for ammonia but stronger than for nitrate (r = 0.55, data not shown).

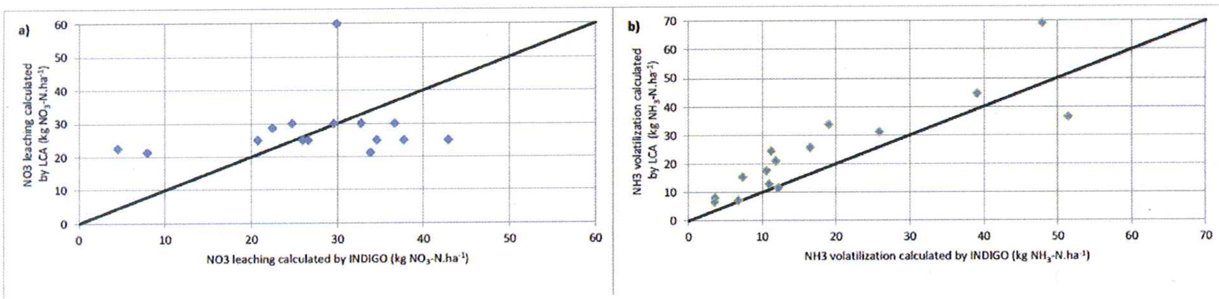

Fig. 1. Comparison of (a) nitrate leaching and (b) ammonia emissions of INDIGO and LCA methods.

According to the LCA method, eutrophication impacts were due almost completely to direct emissions(mainly phosphate and nitrate)from the crop field (Fig. 2a), while climate change impacts came mainly from production of mineral fertilizers, with the contribution of direct field emissions of nitrous oxide less than 30% (Fig. 2b). This highlights the utility of LCA in identifying the sources of impacts. Similar results can be found in the study of Deytieux *et al.* (2012).

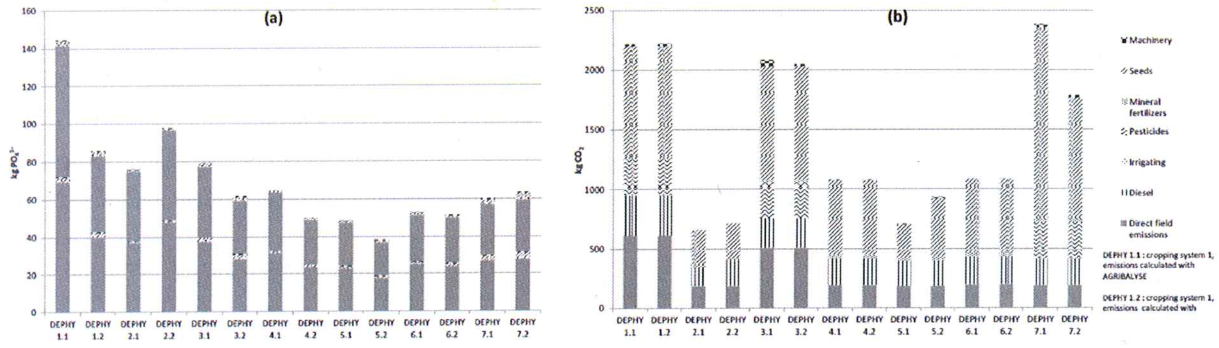

Fig. 2. Contribution of production stages or inputs to (a) eutrophication and (b) climate change impacts estimated by LCA.

4 Conclusions

This study shows that indicator-based and LCA-based methods can estimate similar magnitudes of emissions that contribute to potential impacts, such as eutrophication (or acidification), that are mainly determined by direct emissions from the crop field. Combining an indicator-based method with an LCA-based method could reduce the workload required to estimate direct field emissions in LCA. Such combination of methods will require data transfer between calculation tools to avoid entering the same data twice.

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