Design and ex ante assement of cropping systems with legumes in four European countries

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1 Introduction

Cropping systems (CSs) with grain legumes (GLs) provide many agronomical and environmental benefits. However, the area dedicated to these crops has largely decreased in Europe since the 90ies and currently represents no more than 1.8% of the arable land (FAOSTAT, 2014). Moreover, GL-based CSs contribution to sustainable development depends on their local adaptation and on their fit with most stakeholders' requirements. The aim of this study was to design, together with local experts adapted GL-based CSs in 4 countries, and to assess their sustainability, accounting for the diversity of stakeholders' points of view. This work was performed in Sweden, Spain, Czech Republic and France.

2 Materials and Methods

In order to assess the CS sustainability, we used MASC© (Multi attribute Assessment of the Sustainability of CSs, a tool to assess sustainable development at the CS scale; Sadok *et al.*, 2009) and CRITER (a tool calculating most indicators used as inputs in MASC©). These tools were adapted to take into account GL crops, and the context (socio-economic and pedo-climatic) of each country.

Table 1. Presentation of different regions studied

Country	Region	Soil type	Climate	Reference CS
Spain	Andalucia	Vertisol	Mediterranean	Faba beans/Wheat or Sunflower/Wheat (2 year rotations)
Sweden	Skania	Light clay	Temperate to cold	Wheat, barley, oilseed rape, sugar beet (6 year rotation)
France	Parisian basin	Loamy clay	Temperate	Oilseed rape/Winter wheat/Spring barley (3 year rotation)
Czech Republic	Olomuc region	Silty sand	Continental	Oilseed rape/Winter wheat/Silage maize/Spring barley (4 year rotation)

In a first step, a reference CS, typical for each region, was described and assessed. The four studied countries represent various types of soil and agro-ecosystems (Table 1). In a second step, innovative CSs (nature of the crops in the rotation, and their management plans) were collectively designed with researchers, farmers and technical advisers from each country, according to a defined set of objectives and constraints: introduce GLs in the CSs, improve yield stability, decrease fertilizer and pesticide uses. All innovative CSs were assessed and then compared to the reference. Data for the description of CSs (soil, climate, crop management plans) were collected for the 4 countries from local farm managers and researchers or from previous experiments.

3 Results and Discussion

In all countries, designed innovative CSs involved at least two GL species, as sole crop or intercropped with cereals, as for the example of Sweden (Fig. 1). Their crop rotations were at least 3 years longer than reference ones, in order to (i) diversify the crop sequence and (ii) respect delay between GL crops regarding diseases. Faba bean and pea were introduced as main crops in each country, as well as lupin in Sweden, chickpea in Spain and alfalfa in Czech Republic. Management of all crops was designed to decrease fertilizer and pesticide uses. Cover crops, mostly based on forage legumes, were added to provide green manure. Other techniques were also applied to decrease chemical inputs, such as large rows to allow mechanical weeding, relay and companion crops or variety mixture.
In France, the assessment results showed that introducing GLs may improve the overall sustainability. It mainly improve the environmental component by decreasing negative impacts of fertilizers and pesticides. It did not systematically decrease the economic sustainability, mostly depending on the selling price of the grain legume introduced, differing between the CS Innov1 (Pea) and the CS Innov2 (Lentil) (Table 2).

In Sweden, the reference CS was quite diversified (6 year rotation and 3 different crop families) and already had a good sustainability rate. However, introducing GLs in the crop rotation allowed improving air and soil quality as well as preservation of non-renewable resources.
In the chosen region in Spain, the most important problem is soil erosion. The tool was modified to be adapted to those specific local conditions. The innovative CSs did not seem to improve the environmental dimension. This lack of changes may be explained by a low use of fertilizers on the reference CS and a choice to apply low tillage in the reference and innovative CSs, which did not allow decreasing the herbicide use.
In all countries, introducing GLs was usually linked with a lower input management (especially N fertilizer) and allowed diversifying the crop sequence. The use of less chemical inputs may therefore explain some of the better results of the environmental dimension. The social dimension is defined mainly as a balance between health risks for the farmer linked to pesticides and the CS complexity (number of crops and management). This explains that the social sustainability did not highly differ between innovative and reference CSs. The economic dimension also includes the long term production capacity which can explain why reference CS and innovative CSs may have the same sustainability, even if GLs are usually less profitable in the current economic context.
It is important to keep in mind that the tools CRITER and MASC were not designed first to deal with GLs and the calculation of some criteria still needs improvement based on additional scientific knowledge (e.g. biodiversity conservation). The results of their assessments could evolve with improvement of the calculation of those criteria.

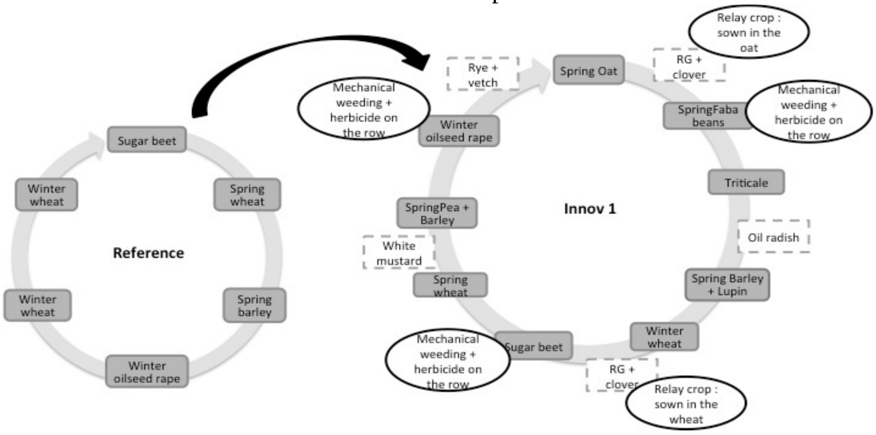

Fig 1. Reference and designed cropping systems for Sweden

Table 2. Assessment of cropping systems for 3 countries

	Spain			Sweden			France		
The higher mark the better	Ref 1	Ref 2	Innov 1	Ref	Innov 1	Innov 2	Ref	Innov 1	Innov 2
Economic (between 5 and 1)	5	5	5	5	5	5	4	2	5
Social (between 5 and 1)	5	5	2	5	4	5	3	4	3
Enviro (between 5 and 1)	4	3	3	5	5	5	3	5	5
Overall sustainability (between 7 and 1)	4	7	4	6	7	7	4	5	6

As the characterization of sustainability can highly differ according to different stakeholders, the sustainability assessment of these CSs has to account for this diversity. Thus, in a third step, meetings with stakeholders will be organized in each country to catch their points of view on sustainability and use them to assess the sustainability of the designed CSs. Current and innovative performances will then be compared within each country. This meeting with stakeholders will also allow us to discuss the feasibility of innovative CSs and to identify the innovative ones accepted by most (or even all) stakeholders (Ravier *et al.*, 2015).

4 Conclusions

This design assessment work on CSs allowed us to compare different innovative CSs with GLs in different contexts. Even if results differ between situations and innovative CSs, the introduction of GLs brings some changes in the CS sustainability. It usually improves the environmental dimension while keeping a good economic sustainability. These assessments give to each country a more concrete frame to start working with farmers in order to improve CSs sustainability.

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