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CHARACTERIZATION OF CROP ROTATIONS VARIABILITY BY COMBINING MODELLING AND LOCAL FARM INTERVIEWS

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1 Introduction

The characterization of actual crop rotations on a large territory is a major challenge for local stakeholders in order to understand agricultural impacts on natural resources, e.g., nitrate leaching (Beaudouin *et al.*, 2005). Although various mathematical descriptions and simulations of crop rotations have been proposed (e.g., Castellazi *et al.*, 2010), few models propose to reconstruct actual crop sequences and to simplify their diversity in a reasonable number of crop rotations. The aim of this work was thus to combine modelling and farm interviews to characterize crop rotations which were representative of different soil characteristics and farming systems over a whole agricultural area of 70,000 ha.

2 Materials and Methods

Our study area was the Niort Plain in western France (about 71,000 ha) over the 2007-2012 period. 699 farms with at least one parcel in the study area were identified. This area is characterized by a diversity of farming systems, i.e., specialized farms in cereals or livestock and mixed crop-livestock farms, and a diversity of soils (deep alluvial soils, shallow calcareous soils, etc.).

We developed the RPG Explorer software to facilitate the analysis of the spatially-explicit data from the French Land Parcel Identification System (LPIS), called RPG. The main tasks performed by the software are: (i) classifying farms in two groups according to the proportions of temporary and permanent grasslands in their cropping plans (ii) intersecting yearly LPIS GIS data in order to reconstruct crop sequences over the period 2007-2012, and (iii) modelling the main crop rotations representative of the observed crop sequences, depending on the farming systems and/or soil units. The crop rotation model implemented in RPG Explorer is derived from the linear optimization model CropRota (Schönhart *et al.*, 2011). It uses as input data the agronomic value of all pre-crop – following crop sequences (2-year sequences), the maximal frequencies of each crop in crop rotations, and the observed proportion of each crop, 2-year sequence and 3-year sequence reconstructed by RPG Explorer. The model derives the proportion of each potential rotation so that the agronomic value over all rotations is maximized. The proportions of each rotation are further constrained so that the modelled proportions of each crop, 2-year sequence and 3-year sequence match their observed proportions. In comparison to CropRota, RPG Explorer considers the proportions of observed 2 and 3-year sequences in optimization, which allows to model rotations that better match observed crop sequences, whatever their agronomic value.

To discuss the model outputs, 85 farm interviews were conducted on the study area: 40 cereal farms and 45 mixed crop-livestock farms. The main rotations were requested for each farm, as well as the reasons of their choice and their location (only for 31 interviews).

3 Results – Discussion

RPG Explorer identified 292 cereals farms and 407 mixed crop livestock farms. 5890 6-year sequences were reconstructed for cereals farms and 12381 for mixed crop-livestock farms, including 2112 and 4231 different 6-year sequences over the period 2007-2012. On the basis of the yearly cropping plan and of the 2 and 3-year sequences included in these 6-year sequences, RPG explorer modelled 160 rotations for cereals farms and 230 rotations for mixed crop-livestock farms. The 15 most frequent rotations represented 58 % and 60 % of the area for the cereals farms and the mixed crop livestock farms respectively (Table 1). Rapeseed-winter wheat-sunflower-winter wheat, sunflower-winter wheat and maize monoculture were the three main crop rotations modelled (excluding grasslands and set-aside), and were the main rotations according to the interviews too (28/85). Except rotation 12, all modelled rotations were identified in the surveys. Nevertheless, some farmers declared rotations that were not modelled by RPG Explorer, especially rotations of more than 6 years which were not modelled due to computation limit. For example, the 8-year rotation tG-tG-tG-C-RS-W-S-W was surveyed and partially corresponded to the modelled rotation 12.

Some differences were observed between cereal farms and mixed crop-livestock farms (Table 1). Because of the role of grasslands in cattle feeding, the proportions of rotations with temporary grassland was higher for mixed crop-livestock farms (e.g., rotation 12). Conversely, cereals farms integrated more oil-seed crops and protein crops in their rotations (rotations 11, 14 and 15), which highlighted a higher diversification of cash crops in their cropping plans.

Table 1. Proportions of modelled crop rotations and their occurrence in interviews

Rotation number	Rotation description *	All systems		Cereals farms		Mixed crop-livestock and livestock farms	
		Area (%)	Interviews	Area (%)	Interviews	Area (%)	Interviews
1	RS-W-S-W	17,89%	28 / 85	17,33%	13 / 40	15,76%	15 / 45
2	pG	10,71%	Undefined**	0,64%	Undefined**	15,44%	Undefined**
3	M	7,11%	23 / 85	7,04%	15 / 40	6,17%	8 / 45
4	S-W	6,73%	10 / 85	9,41%	8 / 40	4,15%	2 / 45
5	RS-W	3,98%	1 / 85	6,60%	1 / 40	1,81%	0 / 45
6	tG	3,75%	Undefined**	0,25%	Undefined**	5,38%	Undefined**
7	RS-W-B	2,96%	3 / 85	3,51%	3 / 40	2,21%	0 / 45
8	S-W-B	2,52%	6 / 85	3,14%	4 / 40	1,79%	2 / 45
9	SA	2,10%	Undefined**	3,25%	Undefined**	1,10%	Undefined**
10	M-W	2,07%	3 / 85	1,74%	0 / 40	2,00%	3 / 45
11	RS-W-P-W	1,20%	6 / 85	2,23%	3 / 40	0,40%	3 / 45
12	tG-tG-tG-C-RS-W	1,15%	3 / 85	0,00%	0 / 40	1,70%	3 / 45
13	RS-W-M-W	1,09%	7 / 85	0,00%	2 / 40	1,62%	5 / 45
14	RS-W-B-P-W-B	0,82%	3 / 85	1,24%	3 / 40	0,45%	0 / 45
15	RS-W-O-W	0,76%	1 / 85	1,27%	0 / 40	0,35%	1 / 45

*B: spring or winter barley, C: other cereals, pG/tG: permanent/temporary grassland, M: maize, O: other oil seeds, P: protein crops, RS: rape seed, S: sunflower, SA: set-aside, W: winter wheat ** Not systematically asked in the interviews

There was a spatial structuration of modelled rotations according to soil units (Fig. 1). For example, maize monoculture (rotation 3) was dominant in the valleys while the rotation 1 was dominant on the plateaus. This location of maize monoculture in the valleys was confirmed by 9 out of 15 interviews in which its location was specified.



Fig. 1. Maps of the modelled proportions of two rotations

Soil types were not the only drivers of crop rotations. Farm interviews highlighted that availability of irrigation was a major driver of some atypical rotations, e.g., rotations with field vegetables or maize monoculture on the shallow soils of the plateaus. Agro-environmental schemes also explained some rotations: integration in rotations of temporary grasslands (alfalfa) for biodiversity preservation or of protein crops in order to reduce nitrogen inputs.

Farm interviews allowed us to specify the exact crops included in rotations, e.g., durum wheat, triticale, sorghum or oat, silage maize or grain maize, alfalfa or ray-grass, whereas LPIS data only specified respectively “other cereals”, “maize” and “temporary grasslands”. This additional knowledge is required to assess the environmental impacts of crop rotations, which can be very different according to the considered crops, e.g., nitrate leaching for alfalfa and ray-grass. In the future, a more quantitative process should be proposed to validate the modelled rotations but raises the issue of the availability of exhaustive and spatialized data at field scale about crop rotations. Other approaches for simplifying the diversity of crop sequences could also be of interest, e.g. the classification proposed by Leenhardt *et al.*, 2012.

4 Conclusions

Our results showed that combining modelling and local interviews can help to define and spatialize the main rotations over an agricultural area. While modelling is needed to define the proportions of rotations that match the observed crop sequences, farms interviews are still mandatory to understand the drivers of rotations and refine their description.

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