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A participatory method for the design and integrated assessment of crop-livestock systems in farmers' groups

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ABSTRACT

Crop-livestock integration promises more sustainable farming systems, but is constrained by organizational and technical issues at the farm level. Developing locally-adapted crop-livestock systems between specialized farms remains theoretical due to a lack of methods for their design and of analysis of benefits and limits for their monitoring. This article presents a method for participatory design and assessment of territorial crop-livestock systems and its application to a group of organic farmers specialized in crop or livestock production in southwestern France. We developed an adapted assessment framework for territorial crop-livestock systems. We used it firstly to produce a diagnosis of strengths and weaknesses of farming systems then to identify the potential for new crop-livestock interactions between farms and finally we designed and assessed crop-livestock integration scenarios with farmers. The technical and organizational options for change were selected to satisfy objectives of partners, illustrated by specific performance criteria (biological regulation, work management economic viability, social learning and capacity building, embeddedness of agriculture in the territory, integration in public policies). This study shows the crucial role of an adaptive methodology that includes ad hoc indicators to support the design of sustainable farming systems that considers specific agroecosystem, constraints and objectives of farmers.

1. Introduction

Integrated crop-livestock systems are often seen as models of sustainable agriculture based on complementarities between activities and a subsequently higher level of nutrient cycling and ecosystem services (Havet et al., 2014; Lemaire et al., 2014; Russelle et al., 2007). However, historical dynamics and economic rationality in developed countries led to farm overspecialization (Peyraud et al., 2014; Poux et al., 2009), far too intensive to be sustainable (Rockström et al., 2009). At the farm level, specialization of equipment and farmers' skills, as well as constraints of rearing animals, make difficult to return animals to crop-specialized farms (Meynard et al., 2013; Peyraud et al., 2014). Specialization and the associated intensive use of industrial inputs lead to environmental issues like water scarcity, biodiversity decline, and diffuse pollution by nitrates and pesticides. Recent studies (e.g. Lemaire et al., 2014; Moraine et al., 2014, 2016) claim that developing more sustainable farming systems require innovative approaches that allow overcoming farm-level constraints by developing crop-livestock interactions at the local level. Indeed, a "Territorial Crop-Livestock System" (TCLS), which contains coordinated and structured exchanges (e.g. grain, forage, manure, animals) between different farming systems, is a way to address production and organization issues at the farm level (e.g. self-sufficiency, work management) and environmental issues at the local level (Asai and Langer, 2014).

Several methods have been developed to design agricultural systems to address environmental issues at the landscape level, regarding water quantity (Castelletti and Soncini-Sessa, 2007; Murgue et al., 2015), water quality (Moreau et al., 2012; Pahl-Wostl and Hare, 2004; Ravier et al., 2015), pollination, ecosystem services and biodiversity (Berthet et al., 2012). Such studies require to deal with the ill-defined nature of the problem to be tackled and incomplete scientific knowledge about key causal relationships. Researchers have to support local stakeholders to specify the problem through participatory methodology based on hybridization of scientific and actors' knowledge and perceptions (Cash et al., 2003; Etienne, 2010; Murgue et al., 2015). Designing a TCLS typ-

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ically raises issues about coordination between stakeholders as demonstrated by Asai and Langer (2014). It requires also dealing with individual farmer and collective expectations and identifying trade-offs between objectives at different levels: biophysical levels (e.g. field, farm and landscape, Ravera et al., 2014) and social levels (individual vs. collective level). Analyzing and explaining these trade-offs is necessary for successful development of a TCLS and requires an adequate framework, especially "locally adapted" indicators for assessment (Lefèvre et al., 2014). Moraine et al. (2016) developed a conceptual framework of crop-livestock integration that presents key processes and expected benefits to promote the systemic design of TCLS. Its use in several European case studies (Moraine et al., 2014) shows that it facilitates identification of the current issues in farming systems and support identification of practices for integrated crop-livestock systems. However, it is limited by its theoretical and qualitative character. Structured design process and quantitative assessment method remain to be developed to fully design and assess the technical and organizational dimensions of TCLS in a systemic way and consider the specific characteristics and constraints of farming systems.

In this article, we present a methodology to design the technical and organizational functioning of a TCLS. To do so, we studied the ecological components (e.g. natural resources, ecosystems) and social components (e.g. farmers' decisions, supply chains, commercialization) of current farming systems and of potential TCLS. Our methodology was applied within a group of organic farmers (southwestern France) that we led through iterative sequences of diagnosis/design/assessment of a TCLS. Particularly, an original quantitative and qualitative assessment approach dealing with system metabolism, ecosystem services, socio-economic performances and local issues has been developed and applied. Our methodology enabled us to investigate the potential complementarities between crop and livestock farms, identify the issues and ideas for organization of crop-livestock exchanges and assess the sustainability and interest for farmers of developing a TCLS. After presenting these results, we discuss the potential for developing a generic method and tools to structure the design and assessment of sustainable TCLS in farmers' groups.

2. Materials and methods

2.1. Case study: a group of organic farmers in a highly diverse agricultural area

The study was conducted in Tarn-et-Garonne, a region in southwestern France with highly diversified agricultural landscapes. The region is divided into four agricultural sub-regions (Fig. 1):

- North: "Bas-Quercy", clay-limestone hills, diversified farms (cereals, livestock, fruit trees) due to heterogeneous soil fertility.
- East: "Causses of Quercy", karstic relief (200–500 m in elevation) with a dry climate and poor soils, mainly containing very extensive livestock production.
- Center: "Terraces of Garonne", alluvial terraces close to river beds, with fertile soils and much irrigation infrastructure for maize, fruit trees, vegetables. Wheat and sunflower strongly dominate rainfed fields.
- Southwest: "Plain of Lomagne", hilly plain with shallow soils, dominated by rainfed cereals.

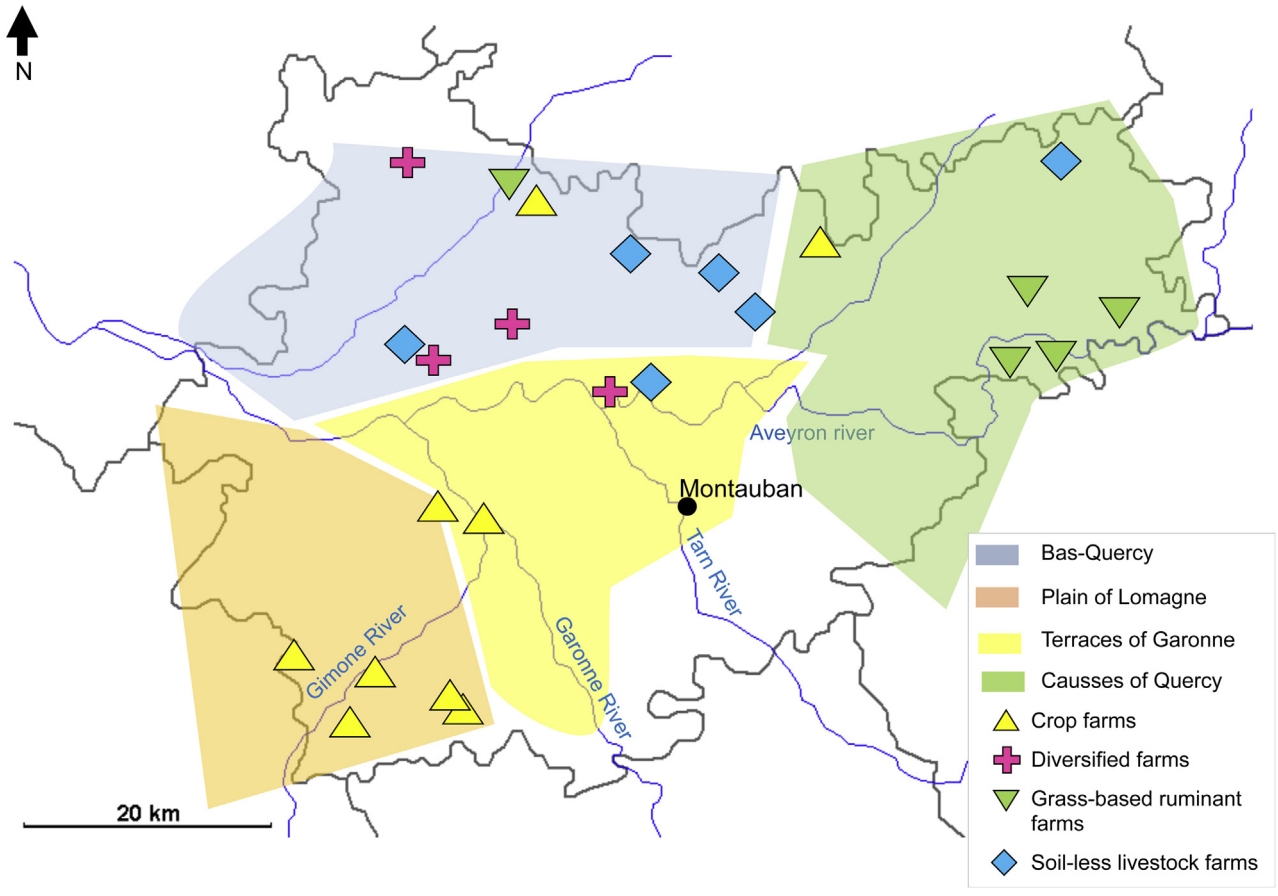

Fig. 1. Locations of farms in Tarn-et-Garonne's main agricultural areas. Gray lines outline the administrative district of Tarn-et-Garonne.