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Combining agroecology and management science to design field tools under high agrosystem structural or process uncertainty: Lessons from two case studies of grassland management

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ABSTRACT

One way to improve sustainable agriculture is to use existing resources and technologies better by finding synergies between plants, soil, climate and management practices. However, for many agricultural situations there is a lack of understanding about the structure of biological and ecological relationships that drive resource dynamics. Therefore, it remains a challenge to build tools for farmers and advisors that fit with these uncertainties and that are generic. In this paper, we define an "agroecological engineering" approach from a combination of several methods of knowledge production: analytical methods that are de-contextualised (e.g. experimentation, on-farm observations) and holistic and contextualised methods based on workshops and training sessions with stakeholders. The key feature of the approach is the construction of a "boundary object", i.e. a support facilitating the communication between researchers and stakeholders, which evolves from a premise into a support tool during the course of a research project and then helps organise knowledge flows between methods. Two long-term studies involving grassland management were used to illustrate the approach. Based on these examples and on the literature, we show that the approach needs to address four issues for defining generic operational tools to find site-specific solutions: aims and principles of the approach, development of tool support throughout a research project, knowledge flow among knowledge-production methods, and the function of agroecosystem models. A remaining scientific challenge is the extrapolation of tool prototypes outside the case studies on which they were based.

1. Introduction

Research for enhancing agricultural sustainability requires incorporating knowledge into means of support for public, collective (e.g. advisors) and individual (e.g. farmers) actions, decisions, and teaching. To cope with new challenges (e.g. climate change), many studies consider biological interactions between components of agricultural systems. Underlying principles are grouped together under the term "agroecology", which can be considered a scientific discipline, a movement and a practice (Wezel et al., 2009). Such diversity in meaning corresponds to the multiple scales and dimensions at which the studies are performed, the scientific disciplines involved, the research purpose and the method of knowledge production. Wezel et al. (2009) recommend that those who use "agroecology" define their scope and aim explicitly.

Accordingly, some researches involved in the design of action-oriented tools based on ecological principles (e.g. diversity, capacity, cycling, stability) have defined a research field called "agroecological engineering" (Dalsgaard et al., 1995). In fact, agroecological engineering covers two main approaches that differ in terms of methodological issues and the knowledge produced. One approach, related to integrated resource management, is occasionally referred to as agroecological engineering (Hengsdijk and van Ittersum, 2003). It addresses agricultural sustainability at a larger scale to support public policies (Hengsdijk and van Ittersum, 2003) and at a smaller scale to accompany farmers in their management (Jakku and Thorburn, 2010). Agroecosystem models used in these studies are based on available and up-to-date agroecological knowledge. Main scientific challenges are related to: (i) up-scaling (i.e. linking micro- and macro-analysis, multi-criteria assessment) and linking models at the core of the research (Van Ittersum et al., 2008); (ii) model calibration; (iii) definition of input/output variables that fit well with stakeholder expectations; and (iv) the degree of detail at which biophysical processes and decisions should be incorporated within models (Martin et al., 2012).

Our approach involves the management of agroecosystems for which there is a lack of understanding about the structure of biological and ecological relationships that drive resource dynamics.

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This is particularly the case for agricultural systems with high biological interactions between components. Current models do not enable a sound response to management practices and environmental factors, or even indicate what to observe at the field level to manage such systems, due to a low ability to control processes and observe relevant agroecosystem features. The main scientific challenge is then to produce new knowledge about agroecosystem functioning that is scientifically sound and conforms to end-user expectations. In these situations, the approach cannot consist of improving agronomic models, because one does not know what processes to include. Nor is it suitable for an actor-oriented approach that considers innovation as the outcome of a mutual learning process between actors with complementary contributions (Probst and Hagmann, 2003), because studying plant systems only in their natural and human contexts may ignore key features of plant ecology. The appropriate approach remains an open question.

On this basis, in agreement with Xu and Li (2012), I believe that such goals require multidisciplinary studies that include ecology and agronomy to produce knowledge about biological systems and include management science to develop support tools. Thus, to build credible, relevant and appropriate supports for end-users, I assume that agroecological engineering should be rooted in agroecology and management science. While agroecological research can help define innovative practices based upon sound science, management science can help work for and with end-users, knowing that in agriculture, management requires adaptation to local conditions (Hansen et al., 2009). In other words, it requires combining "soft" and "hard" methodologies.

This raises several issues that are common to both approaches, for example producing knowledge and establishing methods to ensure that research outputs (scientific knowledge related to the agroecosystem) and outcomes (usable knowledge) (Matthews et al., 2010) are scientifically credible, relevant and appropriate (producing unbiased information which respects stakeholder values) to decision makers (Cash et al., 2003). Participatory modelling has emerged as a powerful tool to cope with these issues, identifying the impacts of solutions to a given problem, and enhancing stakeholder learning (Jakku and Thorburn, 2010; Voinov and Bousquet, 2010). However, some issues are specific to the approach I proposed. They related mainly to which knowledge-production methods to use, e.g. controlled experiments, modelling, surveys, or on-farm analysis, and how to combine them to develop learning tools.

Based on a brief literature review of engineering research in agronomy and management science, I propose in the first section a framework for steering agroecological engineering research. The main idea is that during the course of an action-oriented research project one should alternate phases of agroecological knowledge formalisation (i.e. formal definition), with its contextualisation (i.e. adaptation for a group using it, placing it in its socio-technical context). Contextualisation will improve output credibility and outcome relevance and appropriateness. I assumed that passing from knowledge contextualisation to knowledge formalisation, and vice versa, may be facilitated by building "boundary objects" (BOs), i.e. supports to help people from different communities build a common understanding. Two case studies of stakeholder collaboration to develop management tools for grassland management were used to explore the relevance of the framework. They consisted of two ten-year grassland projects that followed the request by regional advisory services to promote more sustainable grassland-based livestock systems (Section 2). From a scientific viewpoint, I aimed to develop a toolkit based on grassland ecology principles. After summarising the current tool content, I examined ways knowledge production, e.g. via experimentation, was developed in response to its contextualisation to enhance tool users' capabilities during the course of the research project. Output characteristics and outcome strengths of the approach were compared to those of less contextualised approaches. In the final section, I draw generic lessons from this analysis, showing that explicitly stating the methodological research choices promotes organisation of other research that poses similar questions.

2. Framing the approach

2.1. Engineering in different domains

2.1.1. Agronomy

Most literature about action-oriented agronomy describes decision-support systems (DSSs). Agroecological engineering approaches for supporting public policies consist of (i) "goal-driven design of cropping or farming systems, (ii) quantification of production targets, and (iii) definition of the optimal mix of inputs required to realise production targets" (Hengsdijk and van Ittersum, 2003). Usually such research is at least at a regional scale and involves the use of computer models to predict consequences of management options on performance or to design cropping systems for a given context.

A newer agroecological engineering approach to support actions at a smaller spatial scale is to consider the farm as a "managed, harvested ecosystem" rather than a "factory" (Weiner, 2004). This paradigm change makes it harder to define which variables to optimise and forces researchers to address not only "means-based" indicators but "effect-based" indicators (Van der Werf and Petit, 2002). To do so, most related literature describes the use of computer models of biophysical processes in farming systems; however, adoption of such DSSs is usually low (e.g. McCown, 2002). These DSS often become BOs that facilitate social learning instead of decision tools (Jakku and Thorburn, 2010). An approach that combines different types of knowledge and methods has not been clearly established yet. For example, it is not clear whether computer models should be at the core of DSSs or whether they should be used to build them (Duru and Martin-clouaire, 2011). Finally, the question arises of how to build such tools.

2.1.2. Management science

Research engineering provides managers with clearer representations of complex processes, which enable them to act more effectively. Iterative exchanges between field observations and scientific theory are necessary due to issue complexity, uncertainty, or the lack of knowledge at the appropriate level (Chanal et al., 1997). BOs are "material or abstract objects that simultaneously inhabit independent but intersecting social worlds, are flexible to the needs of multiple communities, yet durable enough to maintain an identity" (Star and Griesemer, 1989). When placed in a management context, support-tool prototypes act as BOs by creating connections between stakeholders involved in tool development (Jakku and Thorburn, 2010). This encourages manager feedback and strongly influences outputs and outcomes by generating hypotheses. Many collaborative practices between managers and researchers have been identified (Mesny and Chaillot, 2008). From the engineering viewpoint, collaboration between "researcher-engineers" and managers aims to provide models, frameworks and tools to the latter in response to a perceived problem (e.g. Van Aken, 2005). Some have established methods for developing scientific knowledge both from and for practice. For example, Avenier and Bartunek (2010) suggest a three-step process for researchers and managers to design a research question: jointly identifying a practical concern of potential research interest, reviewing the literature, and deciding whether existing knowledge permits them to deal with the problem. If not, this theoretical gap becomes the research question. This approach is relevant for agriculture, which is