Participatory design of livestock systems adapted to new climatic conditions

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Abstract

Climate change progressively makes obsolete the current agricultural production strategies built with respect to previous landmarks of average and extreme climatic situations. In order to remain viable in the expected climatic context farming systems will need to evolve both in their structure and management. Because farmers and extension services are the primary actors in agricultural production they have to be involved in the process of designing adequate renewed systems. However, the complexity of most design approaches produced by research (e.g. based on computer models) prevents them from deep involvement in such design projects. This paper presents a game-based design approach developed to foster the involvement of farmers and extension services in the design and evaluation of livestock systems. The game, called "forage rummy", relies on a number of "boundary objects" that put relevant pieces of scientific knowledge in a more understandable and tractable form for the design task. These are a player-friendly game board in which sticks representing year-round forage production and animal feeding requirements have to be assembled. Playing the game consists in iterating tentative configurations of a livestock herd (production goal, size), the grassland resources (types of grass and associated area and usage), and feeding diet along a 12 month cycle in a given economic and climatic scenarios. The generation and evaluation of each configuration are done collectively in a participatory workshop and exploit a simple balance model. A diversity of use is permitted by this game depending on the matter being discussed. The paper describes its use in the design of dairy systems adapted to climate variability and change expected by 2050. From our experience with the forage rummy, we synthesise lessons about key factors enhancing participation, focus and depth of discussion, and learning about the relevance of potential farming systems adaptations.

1. Introduction

Livestock systems are currently threatened by a number of bio-climatic and socio-economical changes or issues (Steinfeld et al. 2006), such as climate change, water scarcity, biodiversity conservation or the uncertain price of cereals and concentrates. These changes are interrelated, and their pace, scale and even their direction are unpredictable (Thompson and Scoones, 2009), generating increasing sources of uncertainty for livestock farming. Uncertainty and change also makes the task of the extension services arduous as the farming systems and management practices promoted one day may become irrelevant to a farmer's situation very quickly. The need for continuous adaptation calls for the design of alternative options (Rammel and van den Bergh, 2003) to better cope with, take advantage of or adjust to changing conditions (Smit and Wandel, 2006). These options for adapting farming systems may involve changes in the management and even in the structure of the farming system. This corresponds to changes in the process whereby resources and situations are manipulated over time by the farmer in trying to achieve his goals (Dillon, 1979), and in the pool of production resources available respectively.

Adaptation science has been defined by Meinke et al. (2009) as "... the process of identifying and assessing threats, risks, uncertainties and opportunities that generates the information, knowledge and insight required to effect changes in systems to increase their adaptive capacity and performance”. The complexity of the issues dealt with and the need for salience, feasibility and acceptability of the alternative options (Cash et al., 2003) require the integration of scientific as well as empirical knowledge (Thompson and Scoones, 2009) to support a collective design and evaluation process. As explorers, implementers and testers of different options and systems, farmers are the final decision-makers of whether or not farming options and systems are adapted, that is salient, feasible and acceptable in their respective contexts. The field of adaptation science therefore calls upon researchers to develop participatory approaches (Meinke et al., 2009) capable of supporting the design and evaluation of adapted farming systems.

Agronomic researchers incorporating participation in their modelling approach generally do it on the consultative mode instead of the collegiate mode (according to the classification proposed by Barreteau et al., 2010) required to design farming systems adapted to the variety of farming contexts. To support the collegiate design and evaluation of adapted livestock systems, we have developed a game called “forage rummy” (as in the card game, players seek for combinations of forage and animal sticks further described here) aimed at involve farmers and extension services as major players in the design and evaluation process (Martin et al. 2011a). It relies on a participatory systems approach that integrates multidisciplinary scientific knowledge as well as empirical knowledge of farmers and extension services. It consists in iteratively designing livestock systems and evaluating their biophysical and organizational feasibility. As far as the authors know, this work is the first example of a game aimed at designing farming systems. In this article, the game is presented with particular emphasis on how to convert scientific concepts into usable forms of support for farmers and extension services (Cash et al., 2003). The supports of the game have been designed to constitute “boundary objects”, i.e. material or abstract objects that simultaneously inhabit independent but intersecting social worlds; supports that are flexible to the needs of multiple communities and durable enough to maintain an identity (Star & Griesemer, 1989), After presenting the game in section 2, we illustrate it for designing and evaluating livestock systems adapted to climate variability and change around 2050 in section 3. The last section discusses the strengths and weaknesses of this game-based approach to support adaptation to climate change.

2. Forage rummy

2.1. Framework

As participatory approaches are generally case-specific, they are relevant to stakeholders’ concerns and contexts. They also provide fair and unbiased information that respects stakeholders’ values (Nassauer and Opdam 2008). However, participatory approaches alone can neglect relevant knowledge or technical innovation from agricultural science (Spinuzzi 2005). On the other hand, modelling biophysical processes guarantees credibility of scientific knowledge production - and therefore scientific adequacy - but may be inappropriate for a local context, especially if models are only science-driven (Sturtevant et al. 2007; Raymond et al. 2010). Combining modelling and stakeholders’ participation appears relevant to our objectives as it avoids the weaknesses of both approaches. Consequently, we use models to build supports representing the farm environment (e.g. climate) and situations (i.e. system states and outputs) that stakeholders can compare to their tacit representations. These supports convey action-oriented expertise (Eckert and Bell 2005), and their application relies on careful workshop design and preparation (McCrum et al. 2009). The experience-based knowledge of farmers and advisors include farm management, which enables to allocate resources over space and time consistently with specific objectives (e.g. production, environment or labour) that have local and practical value. Scientific knowledge about farm management involve general principles that structure the functioning of grassland-based livestock systems. These principles shape the supports used in workshops.

Forage rummy is organised in three steps (Fig. 1) and based on several boundary object described in section 2.2. Step 1, developed in section 2.3, aims at specifying the scope (e.g. climate variability or change) of the participatory research and at developing the boundary objects needed. Steps 2 and 3, described in section 2.4., consist in the presentation and use of these supports to encourage information exchange and dialogue among stakeholders and to provide relevant feedback for researchers (Holman and Harman 2008).

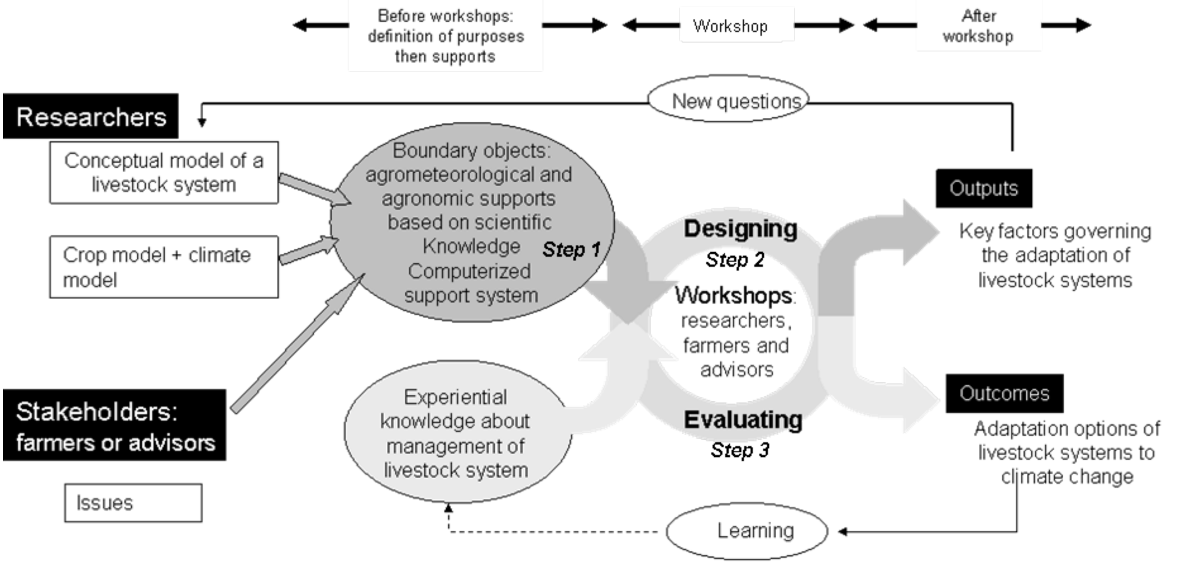

Figure 1: Framework of the forage rummy (dotted line: feedbacks not considered in this study)

2.2. Boundary object patterns

A key challenge for livestock farmers is to manage the feeding of the herd in compliance with desired, attainable and accessible forage production given a climatic context (Fig. 2a). This management problem is represented on a game board (Fig. 2b). To deal with the dynamics of the system over time, the time horizon of one year was considered and partitioned into 13 four-week periods. Along the x-axis, the board is divided into the 13 four-week periods. Along the ordinate, the upper part is an area axis expressed in hectares of forage production (Fig. 2c) and the lower part is an animal feeding requirements axis expressed in kilograms per day per representative animal of the herd batch regarding morphological, reproductive and physiological descriptors, and diet (Fig. 2d).

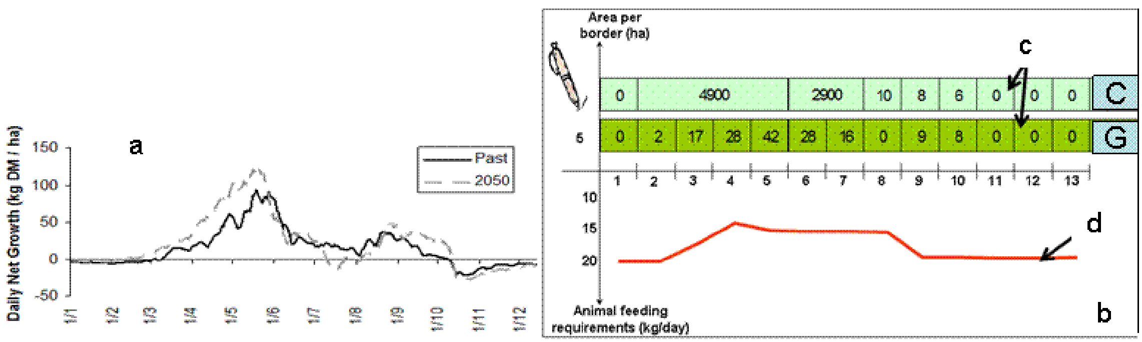

Figure 2: Schematic representation of an informative support for comparing daily herbage growth for past and future climate (a) and the game board (b) together with the forage (c) that is grazed (G) or cut (C) and animal feed requirement (d). The abscissa of the game board is divided into 13 four-week periods representing one year. Along the ordinate, the upper part of the axis is used to fix the area assigned to each forage stick, and the lower part is an animal feeding requirements axis expressed in kilograms per day per representative animal.

The upper part of the board is thus used to represent the farmland area on which forage is produced throughout the year, while the lower part deals with the feeding requirements of the herd. The board is the core element of forage rummy as it embeds the underlying conceptual model of a livestock system (a set of fields allocated to the different forage crops into several assemblages, each single assemblage being attributed to feed a particular herd batch), making it explicit to the participants and enforcing a common understanding among researchers, farmers and extension services.

2.3. Specifying the scope and the boundary objects

Specifying the scope of the participatory research allows for researchers to determine which boundary objects are needed (e.g. types of grasslands and crops, series of climatic years), then to develop them into informative and interactive supports. Informative supports describe the farm environment (e.g. local climate), the constraints (e.g. restriction on maize silage use) and the objectives (e.g. ensure forage self-sufficiency). Interactive supports represent components of the farm (e.g. grasslands, animals). These boundary objects are actually tailored to enable players make projections of potential farming system adaptations to climate change.

Although forage crops are all intended for feeding animals, they display consistent differences as regards their productivity, seasonality and feed quality and hence their use. For instance, maize is grown for several months, harvested once and can then be fed as silage throughout the year, whereas permanent grasslands are grown for several years, and are either grazed or harvest possibly several times per year. There are also different types of grasslands (e.g. permanent and sown), each exhibiting wide diversity. All these facts have far-reaching consequences for the way farmers assemble areas of diverse forage crops and for the overall organization of the livestock system. Thus they are represented on forage sticks that display forage production across the year of a combination of a forage crop and its year-round management at a four-week timescale. Sticks can be generated using simulation models, databases or expert knowledge.

As for forage crops, animals display differences and seasonal variations in their morphological, feeding, reproductive and physiological descriptors, in particular due to their management by the farmer (INRA, 2007). These facts affect the way farmers divide herd into batches, decide to manage reproduction and feeding (fig. 2d), and allocate sets of forage crops to each herd batch. Again, we considered it very important to make these differences and seasonal variations explicit and visible in our boundary objects. For an animal representative of a herd batch and its year-round management (e.g. a highly productive dairy cow calving in autumn), the game contains sticks that display the feeding requirements in kilograms per day for each four-week period. Sticks can be generated using the INRA fill unit system (INRA, 2007), a feed evaluation and rationing system.

2.4 Participatory design by using the boundary objects

Boundary objects are used in the course of participatory workshops in which a livestock system is designed through an iterative trial-and-error approach. The idea is to generate a livestock system configuration in view of satisfying some general objective (here, meeting forage self-sufficiency in new conditions induced by climate change), evaluate its biophysical and organizational feasibility and then reiterate until satisfaction is attained (steps 2 and 3 in Figure 1). The players are first introduced to the game board, the set of forage and animal sticks and the rules to use them. This could be done by representing an existing or stylized farming system on the game board. This awareness phase is expected to enable players focusing entirely on reflexions and discussions about designing a system consistent with a new situation. Playing the game starts with selecting the desired animal sticks according to farmers' objectives regarding mainly animal productivity and reproductive period. Then diet cards are selected that specify a type of diet e.g. grazed herbage with silage maize and concentrates assigned to the herd batch over a four-week period. Diet cards make the connection between animal and forage sticks. The latter then have to be selected and combined with corresponding areas. The selection of the sticks aims at matching animal feeding requirements with accessible forage production over each four-week period with respect to the diet cards selected. This involves paying particular attention to the seasonal variations of forage production and animal feeding requirements.

The calculations required by the game to accurately match animal feeding requirements with accessible forage production over each four-week period can be complicated. For this reason, we have developed a spreadsheet to automate the calculations of indicators used for evaluation and thereby hasten the process whereby players decide whether to continue with a new iteration of the design and evaluation steps. The interface available to players summarizes the following input information: (i) the choices made for herd management (calving date, year-round diet regime); (ii) the choices made regarding the selection and area allocation to combinations of forage crops and their year-round management; (iii) the resulting distribution of the farmland between forage crops. The interface then provides output indicators: (i) animal feeding requirements over each four-week period; (ii) forage production over each four-week period; (iii) animal intake for each type of food over each four-week period; (iv) the resulting satisfaction of animal needs over each four-week period and its extent, and the forage stocks needed over the period; (v) the resulting graphical representation of year-round distribution between grazed herbage, forage stocks and concentrates in the animals' diet. The input information and output indicators provided by the spreadsheet are available to the players at any time during the game.

3. Application to designing livestock systems adapted to climate change

We have developed a three-stage approach to support the participatory design of livestock systems adapted to the particular issue of climate variability and change. This approach is relevant to foster adaptation to both internal and external changes of the farm (e.g. internal change; new objectives -self sufficiency- or new means -silage not allowed-, external changes: climate change).

We assume that the design of a farming system has to be done gradually from strategic choices (system dimension and main objectives) towards more tactical issues (how to manage the system to reach those main objectives). According to the "model for action" (Sebillotte and Soler, 1990), those two aspects of farm management (strategy vs tactic) rely on different background knowledge. Strategic choices of a farmer rely on his perception of the average context in which the system is whereas his tactical plan (decision-making rules) deals with the variability of this context. The design approach therefore has to include two kinds of workshops: one dealing with the average climate change and one dealing with climate variability. In this example, 3 workshops lasting about two hours and involving 2 to 4 farmers and/or advisers and 2 researchers were set up.

In the first workshop, players represent on the game board an existing or stylized farming system and evaluate it with the spreadsheet. At this stage, they do not need to think about what they should change in the system to cope with a new production context, e.g. climate change by 2050. At the same time they handle interactive support (e.g. forage stick) and see which associated variable in the evaluation spreadsheet (e.g. area allocated to the forage stick) could be modified and which evaluation indicator it gives.

The core objective of the first workshop is the determination of a strategy for the farming system faced with climate change (e.g. by 2050). During the first round, players design a farming system using the following boundary objects (graphs of daily temperature, daily soil water availability, weekly rainfall and daily grass growth as informative supports, and forage sticks as interactive supports) representing an average climatic year of the past. These boundary objects are constructed by averaging the considered variables (e.g. dry matter of forage production) over several climatic years. During the second round, the players follow the same exercise using supports representing an average climatic year of the future. They can change any part of the livestock system to better cope with the new production context.

In the second workshop, players refine the system designed in the first workshop. Starting with this initial system, they confront it with two consecutives climatic years representing part of future climatic variability. In the meantime, they refine this initial farming system and, if necessary, reconsider its main objectives (e.g. forage stock at the end of the year, milk production). However, they may comply with constraints over space related to the structure of the farm (e.g. utilised agricultural land area, permanent grassland area and irrigated area).

The third workshop aims to reveal tactical management that enables dynamic response to the conditions of a peculiar climatic year disclosed progressively. The climatic year considered exhibits the typical variability of future climate. In this way players react to the weather and related forage production they have to manage at each four-week period. They also have to think about what they should do to make the system viable whatever might happen in the next period. Here, only tactical adaptations may be performed.

Each phase of the approach is essential and cannot be skipped. Indeed, players have first to understand how to play (trail round and round for past average climate) and then pre-design the system for adapting it to major change (round for future average climate). This pattern is necessary to frame the specification of the system for fitting with more specific years (second workshop). At last, decision making rules could rightly been expressed only if objectives and general operations of the system are yet determined (third workshop).

4. Discussion and conclusion

Research programs are increasingly evaluated in terms of "outcomes (changes in values, attitudes and behaviour in the world beyond the walls of the research institute) rather than outputs (in the form of knowledge embodied in peer-reviewed articles, software or datasets)" (Matthews et al., 2011). Following such incentives, in addition to the outputs generally produced by such projects, we have developed forage rummy in order to generate outcomes by stimulating discussions between farmers and/or extension services, reflective and interactive analysis and learning around the design and evaluation of farming systems.

4.1. Outcomes for players and outputs for researchers

Still, from the application presented and the other experiences that we have had with forage rummy, we observed that the game helped to stimulate enthusiastic discussion about farming, its underlying logic and the most promising technical and business trends. By using the forage rummy, farmers confront their farming logics, share and formalise their knowledge and can progressively arrive at a consensus about the advantages and disadvantages of their technical choices. Playing the game under a climate change scenario leads them to discuss the scope for adapting their current systems, in particular to cope with the increasing frequency of unfavourable seasons with dry summers. In this way, it proves successful in stimulating enthusiastic reflective and interactive analysis by players. The player's enthusiasm is a key feature (Bots and van Daalen, 2007) that, we believe, is attributed to the speed of the evaluation process using the spreadsheet model as it enables them to quickly assess the consequences of their choices before investing into a new design and evaluation loop. Analysis by the players is supported by the considerable knowledge and dataset made available through easily understandable visual representation on the forage sticks. Farmers learn about the various degrees to which forage crops resist drought according to their management or the extent to which the seasonality of their production differs. They then built arguments upon it in the course of the game. This process is known as adaptation by design (Meinke et al., 2009).

Science often tackles practical issues based on knowledge resulting from partial or discipline-related views, whereas the broad biological, economic and social aspects of this information should be assessed (Meinke et al., 2009). By observing the players, researchers gain understanding about farmers' reasoning in organizing or adapting their systems. This is of particular interest as the management component of farming systems is generally neglected by the farming systems research community (McCown et al., 2009). Observation of farmers playing the game therefore offers an opportunity to look inside farmer's mental model (Duru and Martin-Clouaire, 2011). Repetition with different players might lead to generic insights about how to integrate into farm models the way farmers cope with unpredictable and uncontrollable factors and come up with different options depending on the conditions encountered. This is a precondition to achieve “relevance to real world decision-making and management practice” in farming system models (Keating and McCown, 2001). The use of such models might then help to reinforce the production of outcomes to support the development of farming systems adapted to a range of conditions.

4.2. Strength of the method for designing livestock systems adapted to new climatic conditions

Forage rummy belongs to the family of model-based farming system design approaches (see Martin et al. (2012) for a review). In most cases, description of these approaches in the literature is limited to the model that is used to evaluate farming systems designed while the methodology of the design process remains obscure. With forage rummy, both the design and evaluation processes are clearly formalized. Forage rummy is tailored to design innovative livestock system adapted to local conditions, i.e. taking into account the agro-ecological peculiarities of regions (e.g. climate, spatial heterogeneity of soil type), and farmers' goals and assets (Hansen et al. 2009). Most farm models rely on very detailed mechanistic submodels, especially of the biophysical processes, and require data from on-farm measurements that are very difficult to collect (Martin et al., 2011b). In contrast, thanks to the clarity and simplicity of its conceptual model and for the sake of its usability, the forage rummy uses simple submodels and empirical data from experts. Such modelling choices were supported by the authors' experience with the development of more complex models (Cros et al., 2004; Martin et al., 2011c) and by the literature on participatory modelling. Indeed, the latter states that a simple model is easier to communicate and explain than more complex models which generally have narrow applicability, are data-demanding and hence difficult to calibrate for a new application context (Voinov and Bousquet, 2010). This actually corresponds to a change in the function of computer models in the design process, from a core complex and integrative whole to a set of simple models used independently for prior preparation or in support of the design process.

The modelling choices concerning the boundary objects also facilitate involvement of the players. For them, the game constitutes a material and social platform to experiment with and to support learning about farming systems and consequently to develop their adaptive capacity (Darnhofer et al., 2010). The use of informative supports allows to reproduce in a simplified manner, one or more aspects of the players environment, both known (e.g. past climate) or expected (e.g. future climate). The boundary objects create artificial situations close to the real ones. In the application, players easily get into the game because they feel they have already experienced the effects of climate change. Interactive supports allow them to reproduce realistically and rapidly some aspects of their activity (e.g. feeding animals), which leads them to engage decision thinking in the virtual context presented, and thus to express arguments, preferences and critics of the choices envisioned. The interactive and iterative nature of the design and evaluation process help to ensure the quality of the information produced (Voinov and Bousquet, 2010). For instance, the forage sticks converting relevant and objective scientific knowledge into easily understandable information confer higher credibility, legitimacy, and saliency to the design process and its outputs. It helps to make the process transparent, in addition to specifying the assumptions being made.

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References

Barreteau, O., Bots, P.W.G., Daniell, K.A. (2010). A framework for clarifying “participation” in participatory research to prevent its rejection for the wrong reasons. Ecol. Soc. 15(2): 1.

Bots, P.W.G., van Daalen, C.E. (2007). Functional design of games to support NRM policy development. Simulat. Gaming 38: 512-532.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B. (2003). Knowledge Systems for Sustainable Development. Proc. Nat. Acad. Sci. USA 100: 8086-8091.

Cros, M.J., Duru, M., Garcia, F., Martin-Clouaire, R. (2004). Simulating management strategies: the rotational grazing example. Agr. Syst. 80 : 23-42.

Darnhofer, I., Bellon, S., Dedieu, B., Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems. A review. Agron. Sustain. Dev. 30: 545-555.

Dillon, J.L.(1979). The Definition of Farm Management. J. Agr. Econ. 31: 257-258.

Duru, M., Felten, B., Theau, J.P., Martin, G. (2012). A modelling and participatory approach for enhancing learning about adaptation of grassland-based livestock systems to climate change. Regional environmental change (in press).

Duru, M., Martin-Clouaire, R. (2011). Cognitive tools to support learning about farming system management. Crop and Pasture Science: 790-802.

Hansen, S., Lyytinen, K., Avital, M. (2009). Project Innovation Through Exploration and Exploitation : Requirements Practice in Large-Scale IS Development Environments presented at *Information Systems. Thirtieth International Conference on Information Systems*, Phoenix, Arizona.

Holman, I.P., Harman, J. (2008). Preliminary evaluation of the benefits of a participatory regional integrated assessment software. Climatic Change 90: 169-187.

INRA (2007). Alimentation des bovins, ovins et caprins. Besoins des animaux – Valeur des aliments. Tables INRA 2007. Paris, France. Quae Editions.

Keating, B.A. and McCown, R.L. (2001). Advances in farming systems analysis and intervention. Agricultural Systems 70: 555-579.

Martin, G., Felten, B., Duru, M. (2011a). Forage rummy: A game to support the participatory design of adapted livestock systems. Environ Modell Softw 26: 1442-1453.

Martin, G., Martin-Clouaire, R., Duru, M. (2012) Farming system design to feed the changing world: a review. Agronomy for Sustainable Development 32.

Martin, G., Martin-Clouaire, R., Rellier, J.P., Duru, M. (2011c). A simulation framework for the design of grassland-based beef-cattle farms. Environ Modell Softw 26: 371-385.

Martin, G., Theau, J.P., Therond, O., Magne, M.A., Martin-Clouaire, R., Duru, M. (2011b). Diagnosis and Simulation: a suitable combination to support farming systems design. Crop Pasture Sci. 62: 328-336.

Matthews, K.B., Rivington, M., Blackstock, K., McCrum, G., Buchan, K., Miller, D.G. (2011). Raising the bar? – The challenges of evaluating the outcomes of environmental modelling and software. Environ. Modell. Softw. 26: 247-257.

McCown, R.L., Carberry, P.S., Hochman, Z., Dalgliesh, N.P., Foale, M.A. (2009). Re-inventing model-based decision support with Australian dryland farmers. 1. Changing intervention concepts during 17 years of action research. Crop Pasture Sci. 60: 1017-1030.

McCrum, G., Blackstock, K., Matthews, K., Rivington, M., Miller, D., Buchan, K. (2009) Adapting to Climate Change in Land Management: the Role of Deliberative Workshops in Enhancing Learning. Environ Policy Gov 19: 413-426.

Meinke, H., Howden, S.M., Struik, P.C., Nelson, R., Rodriguez, D., Chapman, S.C. (2009). Adaptation science for agricultural and natural resource management – Urgency and theoretical basis. Curr. Opin. Environ. Sustain. 1: 69-76.

Rammel, C. and van den Bergh, J. (2003). Evolutionary policies for sustainable development: adaptive flexibility and risk minimising. Ecol. Econ. 47: 121-133.

Raymond, C., Fazey, I., Reed, M.S., Stringer, L.C., Robinson, G.M., Evely, A.C. (2010) Integrating local and scientific knowledge for environmental management. J Environ Manage 91: 1766-77.

Sebillotte, M., Soler, L.G. (1990). Les processus de décision des agriculteurs – I. Acquis et questions vives. In: Brossier, J. (Ed.), Modélisation systémique et systèmes agraires. INRA, Paris.

Smit, B. and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. Global Environ. Chang. 16 : 282-292.

Spinuzzi, C. (2005). The methodology of participatory design. Tech Commun 52: 163-174.

Star, S.L. & Griesemer, J.R. (1989). Institutional Ecology, 'Translations' and Boundary Objects : Amateurs and Professionals in Berkeley's Museum . Social Studies of Science 19. 387-420.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C. (2006). Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, Rome, Italy, 390 p.

Sturtevant, B.R., Fall, A., Kneeshaw, D.D., Simon, N.P.P., Papaik, M.J., Berninger, K., Doyon, F., Morgan, D.G., Messier, C. (2007). A toolkit modelling approach for sustainable forest management planning: achieving balance between science and local needs. Ecology & Society 12.

Thompson, J. and Scoones, I. (2009). Addressing the Dynamics of Agri-Food Systems: An Emerging Agenda for Social Science Research. Environ. Sci. Policy 12: 386-397.

Voinov, A., and Bousquet, F. (2010). Modelling with stakeholders. Environ. Modell. Softw. 25: 1268-1281.