Building farm resilience through farmers´ experimentation

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Abstract: *This paper discusses how farmers' experimentation can be a building block for resilience at their farms. A core challenge in natural resource management is to enhance resource users' learning and capabilities so that they can make informed decisions and adaptively manage the land. In other words, resource users, such as farmers, need to develop their capacity to manage for resilience of agro-ecosystems so that the ecosystem services from agriculture (like food, fibres, cultural values, etc) can be sustained and enhanced. One way to develop this capacity may be through experimentation on the farm. Experimentation is one way for farmers to learn about and manage their environment. Farmers' experiments can be described as the activity of introducing something totally or partially new at the farm and to evaluate the feasibility of this introduction. We use literature about farmers' experiments and resilience theory to build the arguments of this paper. The outcome of experiments can be management changes, new insights, or technology. These can be passed on to others in the farmers' social network and potentially be built into institutional memory at higher scales. We contend that farmers' experiments have a strong relation to learning and resilience building in farming systems.*

Keywords: *farmers' experiments, farming, social-ecological resilience, local knowledge, sustainable agriculture*

Introduction

Humanity depends on vital ecosystem services, one of them being outputs from agriculture (Millennium Ecosystem Assessment, 2005). Changes that impact agriculture, such as energy prices, market fluctuations, climate change, and the increasing pace of which farms are closed down in Europe, raises the question how to sustain ecosystem services from agriculture. Agricultural management systems are needed that secure the capacity of agro-ecosystems to sustain societal development and progress with essential ecosystem services (Folke et al., 2003).

Seen from the local level, farmers face dynamics and disturbances at the farm, induced by local, regional, national or global trends, seasonality or shocks. Thus, farmers need the ability to cope with, adapt to and shape change without losing options for future adaptability (cf. Folke et al., 2003). In other words, farmers need to build farm resilience (cf. Milestad and Darnhofer, 2003).

A resilient system has the capacity to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks (e.g. Carpenter et al., 2001; Walker et al., 2004). Thus, resilience is the capacity of a system to cope with change. There is no such thing as an ever-stable system. In the context of agriculture, farmers have always lived in changing environments – socially, ecologically, economically, and politically – where surprise and disturbances are inevitable. Each major environmental or social change alters the human-environment relationship, and a new balance develops (cf. Gunderson and Holling, 2002; Berkes and Turner, 2006). The ability of individuals to adapt to changing circumstances and to alter their behaviour is important for building social-ecological resilience (Fazey et al., 2007). Indeed, resilience thinking offers a framework for understanding the dynamics of complex systems (Bennet et al., 2005). Resilience places the emphasis on the ability of the linked social-ecological system to deal with change and provides insights on what makes a system less vulnerable (Berkes, 2007). Because of the dynamic and complex nature of farming systems, and because we are dealing here with an interdependence between humans and ecosystems, i.e. agro-ecosystems, resilience theory can be a useful framework when analyzing farms.

Resilience has proven difficult to measure and operationalise (Bennet et al., 2005, Cumming et al., 2005). Carpenter et al. (2001) suggest that social-ecological resilience has three defining characteristics: buffer capacity (the amount of change a system can undergo while maintaining its functions and structures), self-organisation (as opposed to lack of organisation or organisation imposed by external factors), and the ability to build the capacity for learning and adaptation.

In order to apply these characteristics at the farm level, Milestad and Darnhofer (2003) created criteria for assessing farm resilience based on farming systems literature (e.g. Röling and Jiggins, 1998; Pretty, 1998, 2002; Ellis, 2000). While these criteria were developed explicitly for the farm level, they have not been tested on any empirical material.

An attempt to operationalise social-ecological resilience was made by Folke et al. (2003). Based on a number of case studies they suggest four clusters of factors that build resilience in social-ecological systems:

The first, *learning to live with change and uncertainty*, focuses on the need to learn from crises and to acknowledge the existence of uncertainty and surprise in development. Management actions on the farm may include spreading risks by e.g. diversification.

The second, *nurturing diversity for reorganisation and renewal*, emphasises the need to use ecological and social memory when coping with change. Ecological memory consists of the diversity of species within and between functional groups (Nyström and Folke, 2001). Basically, farmers that use and enhance biodiversity in their experiments nurture ecological memory. Social memory consists of a diversity of individuals, institutions, organisations, and other actors with different and overlapping roles within and between groups of people that are crucial for the management for resilience. In order to build resilience, social memory needs to be in tune with ecosystem dynamics and encompass ecological knowledge.

The third, *combining different types of knowledge for learning*, acknowledges that both scientific and practical, local knowledge are important in order to develop the ecological knowledge needed to build resilience. Thus, the knowledge of different actors and groups are relevant. Further, Folke et al. (2003) emphasise the knowledge of ecosystem processes and functions as most pertinent.

Finally, Folke et al. (2003) suggest *creating opportunity for self-organisation toward social-ecological sustainability* as the fourth factor to build resilience. This can be done by recognising the dynamic interplay between diversity and change, as well as cross-scale issues such as the impacts of external political and economic drivers (e.g. market fluctuations or policy changes). Thus, ecosystems and their governance need to match and be on similar scales in order to build social-ecological resilience.

Farming systems have been described from a variety of angles and with differing purposes. One research tradition concerns the knowledge and technology development of farmers, their interaction with formal research and farmers' strategies to cope with and adapt to change (cf. Scoones and Thompson, 1994; Sumberg and Okali, 1997; Ellis, 2000; Hoffmann et al., 2007). In this research field, farmers' experiments are considered a management method to deal with dynamics and changes that occur. Experimentation is one of the fundamental strategies involved in farmers' attempt to learn about and control their environment (Rhoades and Bebbington, 1991). While some authors describe farmers' experiments as the 'background noise' of farming, i.e. something that cannot be properly separated from the daily activity of farming (e.g. Saad, 2002; Bentley, 2006), we are interested in farmers' experiments as the activity of introducing something totally or partially new at the farm (or combining things that are already there in new ways) and to evaluate the success or failure of this introduction (Quiroz, 1999). These explicit experiments are those that are actively performed by farmers with the clear intention of *trying something new* (Hasenhündl, 2008). Such experiments can be provoked by external change and emerging problems, they can be stimulated by personal interest and curiosity, or they can be deliberate trials to effect desired future changes (Rhoades and Bebbington, 1991; Sumberg and Okali, 1997). Most literature on farmers' experiments emerged from Asia, Africa and Latin America and little has been written about the European context (Kummer and Vogl, 2009). We hypothesise that farmers' experiments are conducive in understanding how

resilience can be built at the farm. Thus, we need to shed more light on farmers' experiments in all parts of the world.

Many authors agree that all farmers have experimental capacity (Johnson, 1972; Rhoades and Bebbington, 1991; Stolzenbach, 1999; Quiroz, 1999; Critchley and Mutunga, 2003). However, this does not mean that all farmers are innovative and are able to cope with changing conditions (cf. Quiroz, 1999). Some farmers may not be interested in experimenting. In addition, policies, regulations and subsidy systems may inhibit or support farmers' experiments. Experimenting farmers are not a homogenous group. They have been found to be both resource rich and resource poor (Amanor, 1993 in Saad, 2002), both male and female, both outsiders and well-integrated, and both well-educated and less educated (Reij and Waters-Bayer, 2001). However, some similarities can be found among experimenting farmers. For example, many farmer experimenters have travelled to, and experienced other areas (Critchley and Mutunga, 2003), and many are devoted to full time farming and are flexible enough to be able to experiment (Reij and Waters-Bayer, 2001).

The process of learning and testing knowledge is vital for building social-ecological resilience towards sustainability (Berkes and Turner, 2006). An important aspect is whether or not local knowledge helps monitor, interpret, and respond to dynamic changes in the context in which farmers live (Berkes et al., 2000). In this context, learning is a key component, which is enhanced by careful experimentation (cf. Walker et al., 2006).

In this paper we explore whether farmers' experiments can contribute to building social-ecological resilience on farms and in the regional food system. We do this by relating to the literature on farmers' experiments. We analyse farmers' experiments by taking the four clusters of factors that build social-ecological resilience from Folke et al. (2003) as a point of departure.

How experimenting farmers can build resilience

Learning to live with change and uncertainty

Farmers live in dynamic environments which they have to master to be able to build social-ecological resilience. To build farm resilience, there has to be knowledge, practices and social mechanisms that recognise that dynamics like disturbance, change and crisis are part of development (Folke et al., 2003). These dynamics can emerge from events on the farm, or can be influences from outside the farm. The necessity to deal with change and uncertainty can be a reason why farmers experiment (Hoffman et al., 2007). Changes in farmers' economic realities or a need to save on labour or capital, or both, can also be reasons for farmers to experiment (Critchley, 2000; Bentley, 2006). Other motives for experimentation range from survival, response to disaster, social responsibility, peer pressure, problem solving and curiosity (Rhoades and Bebbington, 1991; Millar, 1994; van Veldhuizen et al., 1997; Gupta, 2000 in Saad, 2002). Influences from outside the farm can motivate farmers to try new things, and change management practices as a result (Bentley, 2006).

Experiments can act as tools to help farmers to deal with emerging crises (Quiroz, 1999). Confronted with crises, farmers often need to draw on their previous experiences. Results and insights from earlier experiments provide useful knowledge and practical solutions that farmers can use in case of an emerging crisis. Further, experiments may help farmers to shape their farming system so that a crisis does not have harmful impacts. It is also possible that a crisis can be used as an opportunity for development. Turning crisis into opportunity is characteristic for resilient systems (Folke et al., 2003).

Examples for risk-spreading and insurance building strategies can also be found in the context of transforming the overall management of the farm, such as in the conversion to organic farming. Many farmers experiment with organic production methods before they decide to convert. Experiments and the knowledge they generate help farmers to decide whether organic farming is suitable for themselves and their farms, thus reducing the risk of making the wrong decision (Padel, 2001; Leitgeb, 2006).

Experiments that are set up on a small scale are examples of risk-spreading strategies (Sturdy et al., 2008). For example, the farmer experiments with a new crop or management technique in a small field or in the homegarden (Saad, 2002) before the crop or management technique is used at larger fields. Starting on the small scale allows the farmer to collect experiences of the new crop or management technique in a safe manner.

Spreading risks is also connected to management of diversity, of both agro-ecosystems and institutions (Folke et al., 2003). Experiments that diversify the farm income or that enhance biodiversity on the farm can be risk-spreading strategies.

Nurturing diversity for reorganisation and renewal

Diversity is an important aspect of farmers' capacity to build social-ecological resilience (e.g. Cumming et al., 2005; Berkes, 2007). Diversity gives complex systems the ability to cope with change at the same time as it offers the potential for reorganising after change (Carpenter et al., 2001). Thus, diversity is not only a risk-spreading strategy, but also the source of the ability to reorganise and renew a farming system after major change. Compared to the simplified ecosystems created by agro-industrial monocultures, many traditional or alternative management systems use and maintain a diversity of resources that provide broader livelihood portfolios and/or increase biodiversity on the farm (Berkes and Folke, 1998; Berkes, 2007; Björklund et al., 2009). Farmers' experiments that use and support biodiversity at the farm and/or at a regional level can build resilience (Folke et al., 2003). A common type of experiments carried out by farmers is the testing of new crops and varieties. Farmers use biodiversity in order to find suitable crops and varieties of crops for their farms (e.g. Bentley, 2006).

Diversity is important in the social realm as well. Farmers can develop a collective memory of experiences with resources and agro-ecosystem management. This memory provides a context for social responses to change; it increases the likelihood of flexible responses, and seems to be particularly important in times of crisis, reorganisation and renewal (Folke et al., 2003). Increasing the diversity of actors has the potential of bringing new thinking and expanding the role of information, education and dialogue (Berkes, 2007). Folke et al. (2003) describe social memory as consisting of the diversity of individuals, groups, institutions and organisations with different but overlapping roles. Such roles may be that of innovators, entrepreneurs, networkers and knowledge carriers: all of roles that experimenting farmers can have (cf. Reij and Waters-Bayer, 2001). Farmers who experiment and develop new management practices and new knowledge enhance social memory in the region where the farm is situated through stimulating discussion, change and learning (Kroma, 2006).

Combining different types of knowledge for learning

Using and developing new knowledge is intrinsically linked with farmers' experiments. When farmers adopt, adapt and formulate new ideas, try them out in different settings, evaluate the results and make decisions of their value for improving the farm, they are involved in knowledge development (van Veldhuizen et al., 1997; Rajasekaran, 1999). When doing this, farmers can use different types of knowledge; 'old' local knowledge as well as 'new' knowledge that can come from a multitude of sources such as other farmers, media, science or extension service (e.g. Bentley, 2006). Driven by intuition or an explicit desire to learn, information and ideas needed to start an experiment can very well come from the formal research sector and/or extension services (Stolzenbach, 1999; Sturdy et al., 2008). In this way, farmers can combine different knowledge systems and thus use knowledge from their own farm in combination with knowledge developed by research institutions or knowledge from other sources. This is important since no knowledge system alone is sufficient for maintaining sustainable resource use (Alcorn et al., 2003). Formal and informal research is complementary and may create synergies (Hoffmann et al., 2007).

Farmers build knowledge on agro-ecological functions and processes when performing their experiments and they also use this knowledge when planning experiments (Quiroz, 1999; Rajasekaran, 1999). This knowledge is vital when building resilience (Folke et al., 2003). Farmers´ experiments build resilience when the processes and outcomes of the experiments result in new knowledge and innovative management systems suitable to agro-ecological, socio-cultural and economic conditions (cf, Rajasekaran, 1999).

In order to build social-ecological resilience, the process knowledge developed in experiments requires social networks and institutional frameworks to be sustained effectively (Folke et al., 2003). Farmers who communicate, discuss and exchange results from experiments expand this knowledge into networks and institutions (Wu and Pretty, 2004). The partners in this process can be other farmers, farmer organisations or groups, researchers, advisors, consumers or any other actors.

Creating opportunity for self-organisation toward social-ecological sustainability

Systems that do not allow change will generate surprise and crisis. Systems that allow too much change and novelty will suffer loss of memory. Folke et al. (2003) suggest that the interplay between change and the capacity to respond to, and shape change is key in self-organisation, and that self-organisation is vital in building social-ecological resilience. Self-organisation in this context could be finding windows of opportunities or the ability to keep control of the farm in turbulent times.

Self-organisation can emerge when farmers experiment to make their farm less dependent on external influences and/or when farmers use dynamics and diversity to find creative solutions (cf. Milestad and Darnhofer, 2003; Folke et al., 2003).

Farmers' performance occurs embedded in a particular agro-ecological and socio-cultural context that exists beyond the farm gate and that is usually beyond the farmers' control (Quiroz, 1999). Thus, there is a variety of changing conditions to which farmers have to adjust, such as changing policies, market fluctuations and erratic weather events. Experimenting farmers are likely to be more prevalent in areas undergoing environmental change and areas with high biodiversity (Saad, 2002). Experimenting represents one of the major on-going activities farmers use for adapting to these changing conditions (cf. Quiroz, 1999). Confronted with dynamic processes, farmers need experiments that help them to be flexible and open for new opportunities that are created by change (Stolzenbach, 1999) while using diversity and local knowledge. Experiments may also aim at reducing dependence on external influences from higher scales (Quiroz, 1999; Bentley, 2006). External influences are cross-scale dynamics and external drivers that impact the farm, e.g. policies and subsidies, or powerful market actors.

Conclusion

Conventional research has long overlooked the active and creative role of farmers in innovation processes (Chambers et al., 1989; Röling and Wagemakers, 1998; Chikozho, 2005). We propose that the knowledge development that farmers carry out through experimentation should not only be acknowledged in research, but that farmers' experimentation could be vital when building resilience on the farm.

The outcome of experiments can be management changes, new knowledge, or technology. These can be passed on to others in the farmers' social network and potentially be built into institutional memory at higher scales. Institutions such as regulations or advisory services can benefit from the outcomes of farmers' experiments. For example, an outcome of a farmer's experiment can be a new cultivation technique, which in turn spreads to other farmers and is later incorporated into the programme of an advisory service. Local knowledge is a living resource that is constantly reinvented (Röling and Brouwers, 1999). Farmer expertise is an indispensable element in sustainable agriculture, i.e. sustainable agriculture requires farmers to be experts in managing complex systems (Röling and Brouwers, 1999).

However, a number of open questions remain. For example, does a farmer experiment because s/he has a farm that is robust enough to experiment with, or because the farmer aims to build resilience? Both alternatives seem plausible. While young, resource poor farmers in unstable environments have been found to experiment (Saad, 2002), older and resource rich farmers also do (Saad, 2002). It is a mixture of personal interests, need and incentive that makes farmers experiment (Leitgeb et al., 2008).

There is not a universal set of farmers' experimentation characteristics. What matters is the fact that farmers conduct experiments. Thus, government policies need to be supportive of – at least not inhibit – farmers' experiments (Chikozho, 2005). Therefore it is important to develop policy tools that support farmers in this role (Johnson, 1972; Quiroz, 1999). For example, subsidy systems could be developed that give farmers a range of possibilities to fulfil a policy measure rather than only one option. Another possibility would be to engage farmers more actively in the advisory system rather than making them passive receivers of information.

Farmers' experimentation is the core methodology in enhancing farmers' understanding of their resource system (Rhoades and Bebbington, 1991). At the same time, farmers' knowledge of the agro-ecosystem forms the foundation for their experiments (Rajasekaran, 1999). Thus, farmers' experiments draw on experience and previous knowledge, but allow for novelty within the framework of accumulated experience (cf. Folke et al., 2003). Through experimentation farmers demonstrate capacities to cope with and adapt to change, to confront contemporary and future situations, to assess existing strategies to deal with environmental and socio-economic forces (Dei, 1988 in Rajasekaran, 1999; Bentley, 2006). In short, through creativity and innovations farmers can decrease their vulnerability (Reij and Waters-Bayer, 2001) and build social-ecological resilience.

In order for farmers' experiments to be an effective strategy for building social-ecological resilience the social memory held by individual experimenting farmers needs to be connected to, and supported by, individuals or groups outside the farm. In the same vein, institutions such as regulations, subsidies and support payments influence the possibility of farmers to carry out experiments. Thus, it is important to take account of the experiments that take place at the farm level and also give farmers room for creativity within the regulatory frameworks and conditions for farming.

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References

Alcorn, J. B., Bamba, J., Masiun, S., Natalia, I. and A.G. Royo (2003) Keeping ecological resilience afloat in cross-scale turbulence: an indigenous social movement navigates change in Indonesia. In: Berkes, F., Colding, J. and C. Folke (eds.) Navigating social-ecological systems: Building resilience for complexity and change. Cambridge University Press, Cambridge, UK, pp. 299-327.

Bennet, E.M., G.S. Cumming and G. D. Peterson (2005) A systems model approach to determining resilience surrogates for case studies. *Ecosystems* 8: 945-957.

Bentley, J.W. (2006) Folk experiments. *Agriculture and Human Values* 23: 451-462.

Berkes, F. and C. Folke (eds.) (1998) Linking social and ecological systems. Management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK.

Berkes, F. (2007) Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards* 41: 283-295.

Berkes, F. and N.J. Turner (2006) Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. *Human Ecology* 34 (4): 479-494.

Berkes, F., J. Colding and C. Folke (2000) Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10 (5): 1251-1262.

Björklund, J., Westberg, L., Geber, U., Milestad, R. and J. Ahnström (2009) Local selling as a driving force for increased on-farm biodiversity. *Journal of Sustainable Agriculture* 33: 885-902.

Carpenter, S., Walker, B., Anderies, J.M. and M. Abel (2001) From metaphor to measurement: Resilience of what to what? *Ecosystems* 4, 765-781.

Chambers, R., Pacey, A. and L.A. Thrupp (eds.) (1989) Farmer first: farmer innovation and agricultural research. Intermediate Technology Publications, London, UK.

Chikozho, C. (2005) Policy and institutional dimensions of small-holder farmer innovations in the Thukela River Basin of South Africa and the Pangani River Basin of Tanzania: a comparative perspective. *Physics and Chemistry of the Earth* 30: 913-924.

Critchley, W. R.S. and K. Mutunga (2003) Local innovation in a global context: documenting farmer initiatives in land husbandry through WOCAT. *Land Degradation & Development* 14: 143-162.

Cumming, G.S., G. Barnes, S. Perz, M. Schmink, K. E. Sieving, J. Southworth, M. Binford, R. D. Holt, C. Stickler and T. Van Holt (2005) An exploratory framework for the empirical measurement of resilience. *Ecosystems* 8: 975-987.

Ellis, F. (2000) Rural Livelihoods and Diversity in Developing Countries. Oxford University Press. Oxford, UK.

Fazey, I., Fazey, J.A., Fischer, J., Sherren, K., Warren, J., Noss, R.F. and S.R. Dovers (2007) Adaptive capacity and learning to learn as leverage for social-ecological resilience. *Frontiers in Ecology and the Environment* 5(7): 375-380.

Folke, C., J. Colding and F. Berkes (2003) Synthesis: Building resilience and adaptive capacity in social-ecological systems. In: F. Berkes, J. Colding and C. Folke (eds). Navitaging social-ecological systems. Building resilience for complexity and change. Cambridge University Press, Cambridge, UK, pp. 352-387.

Gunderson, L.H. and C.S. Holling (eds.) (2002) Panarchy. Understanding Transformations in Human and Natural Systems. Island Press. Washington DC.

Hasenhündl, K. (2008) Farmers' experiments – the farmers' view. Farmers' perceptions of implicit and explicit experimentation, exemplified on two research areas in rural Cuba. Diploma Thesis, University of Natural Resources and Applied Life Sciences, Vienna.

Hoffmann, V., Probst, K. and A. Christinck (2007) Farmers and researchers: how can collaborative advantages be created in participatory research and technology development? *Agriculture and Human Values* 24(3): 355-368.

Johnson, A. W. (1972) Individuality and experimentation in traditional agriculture. *Human Ecology* 1: 149-159.

Kroma, M. M. (2006) Organic farmer networks: facilitating learning and innovation for sustainable agriculture. *Journal of Sustainable Agriculure* 28(4): 5-28.

Kummer, S. and C.R. Vogl (2009) Bäuerliche Experimente. Forschung ohne Wissenschaftler. *Ökologie & Landbau* 152 (4): 54-56.

Leitgeb, F. (2006) Hemmende und fördernde Faktoren für die Umstellung auf ökologische Landwirtschaft in periurbanem Gebiet. Die Sichtweise von Experten und Landwirten in Valencia, Spanien. Diploma Thesis, University of Natural Resources and Applied Life Sciences, Vienna.

Leitgeb, F., E. Sanz, S. Kummer, R. Ninio and C.R. Vogl (2008) Academic discussion about farmers' experiments – a synthesis. *Pastos y Forrajes* 31 (1): 3-24.

Milestad, R. and I. Darnhofer (2003) Building farm resilience: The prospects and challenges of organic farming. *Journal of Sustainable Agriculture* 22 (3): 81-97.

Millar, D. (1994) Experimenting farmers in Northern Ghana. In: Scoones, I. and Thompson, J. (eds.). Beyond farmer first: rural people's knowledge, agricultural research and extension practice. Intermediate Technology Publications, London, UK, pp. 160-165.

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC.

Nyström, M. and C. Folke (2001) Spatial resilience of coral reefs. *Ecosystems* 4: 406-17.

Padel, S. (2001) Conversion to organic farming: A typical example of the diffusion of an innovation? *Sociologia Ruralis* 41, 40-61.

Pretty, J. (1998) The living land: agriculture, food and community regeneration in rural Europe. Earthscan, London, UK.

Pretty, J. (2002) Agri-culture. Reconnecting People, Land and Nature. Earthscan Publications. London, UK.

Quiroz, C. (1999) Farmer experimentation in a Venezuelan Andean group. In: Prain, G., Fujisaka, S. and Warren, M. D. (eds.). Biological and cultural diversity. The role of indigenous agricultural experimentation in development. Intermediate Technology Publications, London, UK, pp. 113-124.

Rajasekaran, B. (1999) Indigenous agricultural experimentation in home gardens of South India: conserving biological diversity and achieving nutritional security. In: Prain, G., Fujisaka, S. and Warren, M. D. (eds.). Biological and cultural diversity. The role of indigenous agricultural experimentation in development. Intermediate Technology Publications, London, UK, pp. 134-146.

Reij, C. and A. Waters-Bayer (2001) An initial analysis of farmer innovators and their innovations. In: Reij, C. and Waters-Bayer, A. (Eds.). Farmer innovation in Africa. A source of inspiration for agricultural development. Earthscan, London, UK, pp. 77-91.

Rhoades, R. and A. Bebbington (1991) Farmers as experimenters. In: Haverkort, B., van der Kamp, J. and Waters-Bayer, A. (eds.). Joining farmers' experiments. Experiences in participatory technology development. Intermediate Technology Publications, London, UK, pp. 251-253.

Röling, N. and J. Brouwers (1999) Living local knowledge for sustainable development. In: Prain, G., Fujisaka, S. and Warren, M. D. (eds.). Biological and cultural diversity. The role of indigenous agricultural experimentation in development. Intermediate Technology Publications, London, UK, pp. 147-157.

Röling, N. and J. Jiggins (1998) The ecological knowledge system. In: Röling, N. and Wagemakers, W.A.E. (eds.) Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, Cambridge, UK, pp. 283-307.

Röling, N. and W.A.E. Wagemakers (eds.) (1998) Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, Cambridge, UK.

Saad, N. (2002) Farmer processes of experimentation and innovation. A review of the literature. Working document No. 21, CGIAR systemwide program on participatory research and gender analysis. Available online: http://www.prgaprogram.org/download/working_documents/wd21.pdf.

Scoones, I. and J. Thompson (eds.) (1994) Beyond Farmer First. Rural people's knowledge, agricultural research and extension practice. Intermediate Technology Publications. London, UK.

Stolzenbach, A. (1999) The indigenous concept of experimentation among Malian farmers. In: Prain, G., Fujisaka, S. and Warren, M. D. (eds.). Biological and cultural diversity. The role of indigenous agricultural experimentation in development. Intermediate Technology Publications, London, UK, pp. 163-171.

Sturdy, J. D., Jewitt, G. P. W and S.A. Lorentz (2008) Building an understanding of water use innovation adoption processes through farmer-driven experimentation. *Physics and Chemistry of the Earth* 33: 859-873.

Sumberg, J. and C. Okali (1997) Farmers' experiments. Creating local knowledge. Lynne Rienner Publishers, London, UK.

van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson, D. A. and J. Thompson (eds.) (1997) Farmers' research in practice. Lessons from the field. ILEIA readings in sustainable agriculture. Intermediate Technology Publications, London, UK.

Walker, B., C.S. Holling, S. Carpenter and A. Kinzig (2004) Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9(2):5. [online] http://www.ecologyandsociety.org/vol9/iss2/art5/

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S. and L. Schultz (2006) A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* 11(1):13 [online] http://www.ecologyandsociety.org/vol11/iss1/art13/

Wu, B. and J. Pretty (2004) Social connectedness in marginal rural China: the cases of farmer innovation circles in Zhidan, north Shaanxi. *Agriculture and Human Values* 21: 81-92.