RESILIENCE OF SOCIAL-ECOLOGICAL SYSTEMS IN EUROPEAN RURAL AREAS: THEORY AND PROSPECTS

MARLEEN SCHOUTEN
Wageningen University and Research Centre,
Economics of Consumers and Households,
Wageningen, Netherlands.
E-mail: Marleen.Schouten@wur.nl

MARTIJN VAN DER HEIDE
Agricultural Economics Research Institute (LEI),
Public Issues Division,
The Hague, Netherlands.

WIM HEIJMAN
Wageningen University,
Economics of Consumers and Households,
Wageningen, Netherlands.
E-mail: Wim.Heijman@wur.nl

Paper prepared for presentation at the 113th EAAE Seminar "THE ROLE OF KNOWLEDGE, INNOVATION AND HUMAN CAPITAL IN MULTIFUNCTIONAL AGRICULTURE AND TERRITORIAL RURAL DEVELOPMENT", Belgrade, Republic of Serbia December 9-11, 2009

RESILIENCE OF SOCIAL-ECOLOGICAL SYSTEMS IN EUROPEAN RURAL AREAS: THEORY AND PROSPECTS

Abstract

In today's world, rural areas are confronted with a spectrum of changes. These changes have multiple characters, varying from changes in ecosystem conditions to socio-economic impacts, such as food- and financial crises. They present serious problems to rural management and largely affect future perspectives of rural areas. Rural resilience refers to the capacity of a rural region to adapt to changing external circumstances in such a way that a satisfactory standard of living is maintained, while coping with its inherent ecological, economic and social vulnerability. Rural resilience describes how rural areas are affected by external shocks and how it influences system dynamics.

This paper further eradicates on this concept, by exploring in detail what the importance is of resilience theory within rural areas. An answer is tried to be given to the question how to detect resilience in rural areas, by reviewing the existing literature and to the question how to enhance resilient rural development. Finally questions are formulated for further research within the field of rural resilience.

Key words: Resilience; social-ecological systems; rural development; complex adaptive systems; system dynamics.

1. Introduction

Rural areas in the European Union occupy 90% of the territory and approximately 50% of its population. Agriculture and forestry are the main land types and play a key role in the management of natural resources in rural areas and in determining the rural landscape (EC, 2009). Rural areas have undergone and are undergoing major changes. These changes are partly the result of agricultural policies, but there are other driving forces, both ecological, spatial and sectoral, which affect rural areas. Different policies and trends have large environmental impact in terms of land use, landscape changes, environmental pollution and biodiversity loss, and large economic impact in terms of changing demographics, reduction in agricultural employment and diversification of the rural economy.

No agreement exists on how to define the European rural area. Different categorizations and classifications are used, mainly based on socio-economic criteria (EEA, 1999). The OECD defines rural areas in terms of population density. In this paper, rural areas are defined as predominantly rural (>50% of the population living in rural communities) and significantly rural (15%-50% of the population living in rural communities). This classification can be spatially referenced with a reasonable degree of accuracy throughout the EU (OECD, 2007).

The way EU's rural areas develop is plural. While some rural areas still struggle with agricultural restructuring and population decline, others have been more successful in re-organizing agricultural production, and further developed their agri-business. Some have also benefited from the re-location of enterprises and mostly retired people from the urban to the less congested rural areas (Sallard, 1998). EU's rural areas are also more and more confronted with the increased importance of non-agricultural sectors, e.g. industry and services. While agriculture is losing importance, at least every second job in predominantly rural areas is in the service sector. Urbanization pressure and abandonment of land has led to a decrease in the area of agricultural productive land by 5% over the past 20 years (EEA, 1999). Intensification, marginalization, specialization and concentration have resulted in an increasing spatial differentiation of rural areas in terms of economic, social and environmental outcomes. In the future, also climate change could further distort the impact of agricultural practices on rural areas. The growing seasons will be extended, the variability of the climate will increase, which will lead to severe changes in productivity and will all have their effects on the nature and shape of rural areas. The main characteristic of the changes mentioned above is their unpredictability. While being unpredictable, these changes present serious problems to rural management and largely affect future perspectives of rural areas. To cope with these versatile changes, rural areas have to develop a certain amount of resilience, which refers to the capacity of a system to absorb disturbances and re-organize while undergoing change so as to still remain essentially the same function, structure, identity and feedbacks (Walker et al., 2004). Being more resilient, a rural area can better cope with changes without immediately ending up in a negative cycle after a disturbance.

Heijman et al. (2007) introduced the concept of rural resilience. Rural resilience refers to the capacity of a rural region to adapt to changing external circumstances in such a way that a satisfactory standard of living is maintained, while coping with its inherent ecological, economic and social vulnerability. In analogy to urban resilience (Colding, 2007; CSIRO, 2007) the concept of rural resilience determines the degree to which a specific rural area is able to tolerate alteration before reorganizing around a new set of structures and processes. It describes how well a rural area can balance ecosystem, economic and social functions (Heijman et al., 2007). This paper further eradicates on this concept, by exploring in detail what the importance is of resilience theory within rural areas. An answer is tried to be given to the question how to detect resilience in rural areas, by reviewing the existing literature and to the question how to enhance resilient rural development. Finally questions will be formulated for further research within the field of rural resilience.

The structure of the paper is as follows. After the introduction, first an overview will be given of resilience theory, applied to rural areas in the European Union. The main disturbances which rural areas are faced with are discussed, as well as the adaptation strategies. In section 3 the rural system and its components will be discussed in dept. In

section 4, a literature review is given of attempts to assess resilience and the importance of modeling for analyzing rural dynamics is discussed. In section 5 some policy recommendations are given for the enhancement of rural resilience. This paper is concluded by the formulation of questions for further research.

2. Resilience in rural social-ecological systems

2.1 Resilience theory

Since the introduction of the concept of resilience in 1973 by the ecologist Holling, the concept also emerged in literature on psychology, economics and sociology (Gardner et al., 2007). The application of resilience to the uncertainties and rapid changes of rural areas has been minimal. Heijman et al. (2007) introduced the concept of rural resilience. This concept is based on the idea that ecological, economic and social systems become increasingly entangled, and interactions between these systems are increasing in intensity and scale. A rural area may be considered as a social system interacting with and depending on an ecological substrate and whose survival depends, among others, on its interrelations with the system of natural resources. The environment and its natural resources are conditioned by the actions of the population. The rural area can therefore be termed as a social-ecological system (SES) (Ambrosio-Albala et al., 2008). They should be seen as overlapping components, together forming a holistic complex adaptive system. The adaptive capacity of a rural system is a central feature of resilience and refers to the ability of a system to adjust to changing internal demands and external circumstances (Carpenter et al., 2008). Highly adaptive systems not always enhance resilience. Highly adaptive systems can lead to a loss of resilience through an increase in adaptability in one place, that may lead to a loss of adaptability and thereby resilience in another place. Moreover, increasing adaptability to known shocks, may optimize the system for this regime of shocks, but makes the system less resilient to unknown shocks (Walker et al., 2006). Therefore the interactions between and within systems should always be taken into account.

Within the context of rural resilience, the importance of spatial scales is paramount, and arises from a reciprocal relationship. Processes on a local scale can have global impacts on a longer run, while global trends can have direct or indirect effects on a local level or the levels in between (Van Den Bergh et al., 1991). Loss of ecosystem resilience, for example by a decrease in biodiversity, can have large global climate effects. And environmental and socio-economic processes might have important different consequences on a regional scale. An area's specific environmental, economic and social structures determine the resilience of the area, or the adaptability to external environmental and socio-economic forces (Van Den Bergh et al., 1991).

2.2 Adaptation strategies

The rural area is subject to a spectrum of disturbances. (White et al., 1985) define a disturbance as 'any relatively discrete event in time that disrupts ecosystem,

community, or population structure and changes resources, substrate availability or the physical environment'. A disturbance regime is defined in terms of scale, frequency, predictability and severity (White et al., 1985; Turner et al., 1998). Ecologists tend to focus on natural disturbances, like fire, floods, hurricanes, insect outbreaks etc. Within social-ecological systems, other types of disturbances need to be included such as abrupt changes in regulations and world market shifts (Janssen et al., 2005).

Disturbances in one system of resilience can affect the resilience in other systems. If a rural area would not be economically resilient, meaning that the area is vulnerable to economic shocks, such as a reduction in wealth, sudden rise in interest rates or increased unemployment, the population would gradually move away and vulnerability increases. Progressively smaller shocks are needed to cause crisis in the rural system. Vulnerability is a core concept of resilience and it includes the attributes of persons or groups that enable them to cope with the impact of disturbances, like natural hazards or socio-economic crises (Janssen et al., 2006). If the ecological sources of a rural area would not be resilient, conditions for ecosystem services, landscape services and agriculture would deteriorate, and – again - the vulnerability of the rural area would increase. For example, the natural biodiversity in landscapes can exert a bio-control function in crops, and prevent pest outbreaks in crops. A rich variety of species, each with variable population densities, constitute a more reliable control system compared to a situation with one or two main predator species. In other words, functional diversity of the agents providing the landscape service natural pest control increases the resilience of the SES. Also social sources of resilience such as social capital (trust and networks, experiences for dealing with change) are essential for the capacity of social-ecological systems in rural areas to adapt to and shape change (Folke, 2006). These social sources of resilience will be further discussed in section 3.2.

3. The rural system and its components

3.1 Rural system components

Before going into dept into the assessment of resilience in rural areas, it is helpful to first get a grasp of the different components that together form the rural social-ecological system. According to Cumming (2005) system components can be thought of as the pieces of the system that interact in a dynamic way. These components include e.g. human actors of various kinds, particular ecosystem types or habitat types, resources, goods and materials, and abiotic variables. System components interact or fit together. Examples of relationships are nutrient cycles, food webs, economic and ecological competition, land tenure, and interactions between human actors.

To be able to analyze the rural area as a complex social-ecological system, the system should be divided into simple units. Figure 1 shows the different components and their main relationships in a schematic way.

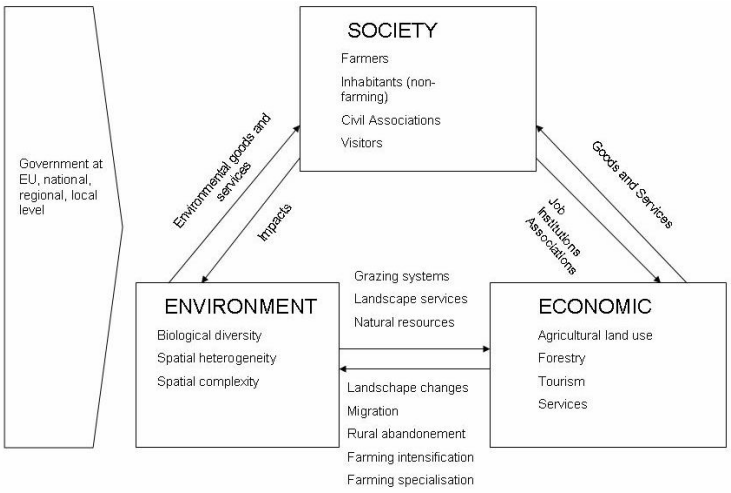

Figure 1 - Components of the rural social-ecological system and the involved stakeholders. The boxes represent the components, the arrows the interactions between these. From Rescia et al. (2008) (modified).

Four rural subsystems can be identified as key to understand the functioning of the system, namely:

1. Economic
2. Society
3. Environment
4. Government

The boxes represent the different system components, and the arrows represent the interactions between them. In this schematic overview of the rural SES, the government is treated as being externally influencing the system components and the interactions between these components. The governmental component will be discussed in more detail in section 3.3.

3.2 Rural actors, social networks and rural identity

A basic distinction is made between rural stakeholders that are farmers, non-farming inhabitants and visitors. These stakeholders all weigh economic, social and environmental outcomes in a different way. For the inhabitants, the economic dependency on the area can differ from weak to strong, based on their dependency on e.g. the agricultural or tourist sector. Changes in the landscape, for example, can have different economic and social outcomes for inhabitants. Traditions, rural identity and the community sense can play a large role in this development. In this way, disturbances that would jeopardize the landscape can affect farmers, but can also have large impacts on the local non-farming community. That is, exploring economic activities in an area, can lead to important social changes. Social outcomes are less important to visitors. They are basically interested in what the environment has to offer them. They demand a certain natural environment, and this can sometimes be conflicting with other activities.

'Hard' factors, like natural and human resources, investments, infrastructure and business development are traditionally seen as the main determinants for rural development policies. However, there is an increased recognition that also less tangible or 'soft' factors are important. These include for example social capital, social cohesion and local knowledge, which all contribute to rural development and increased rural cohesion. Social capital also determines to a certain extend the adaptability of a rural SES, and thereby enhances its resilience. There are three main determinants of social capital: leadership, social networks and trust. Leadership must be part of the dynamic process, and should include responsiveness to changing socio-economic and natural conditions. Co-operation and motivation within a social network depends strongly on the structure of the network, and thereby determines the adaptive capacity of the network. A lack of trust within the social network leads to inefficient information flows and deteriorates the social structure and thereby the system's resilience (Callaghan et al., 2008).

Figure 1 shows that the governmental system component is treated as being an external component influencing the SES, because of its multi-level character. Policies can have a far-reaching effect on rural areas and rural municipalities. There is a great variety of areas and instruments for rural area policies of which two broad categories can be distinguished: Policies directed to the agricultural sector, and rural development policies, which take into account a multi-sectoral approach from a regional development perspective. Structural changes in sector-based agricultural policies directed towards markets have been analyzed in many studies. Though, the

impact of rural development policies is more difficult to grasp, and evaluation studies are rare. The impact of policy measures on rural areas depends strongly on the dynamics generated by other factors, such as interest rates, job opportunities etc. (Happe et al., 2008). More on rural development policies in section 5.

4. Assessing resilience in rural social-ecological systems

4.1 Pitfalls for operationalisation

Having gained insight in the different components that together form the rural dynamic system, it is interesting to assess the resilience of such systems, eventually ending up with desirable characteristics of rural areas and their communities. However, assessing the resilience of social-ecological systems in general is challenging. Lots of pitfalls appear when operationalizing resilience in social-ecological systems. Should the operationalisation approach be theory or data driven? What kind of measures should be used to be of relevance for policy decision making? How many variables should be used to describe a rural social-ecological system? Walker et al. (2006) state that although social-ecological systems are self-organized through a large number of abiotic and biotic variables, the most important changes can be understood by using a small amount of variables. These key variables operate at different scales, with slower and faster rates in time and space. Because these variables influence the overall dynamics of the system, they are of direct interest to system managers. System managers tend to focus on fast variables. However, in ecosystems, the variables that control shifts and adaptability to changes, such as soil, sediment and long-lived organisms, tend to change slowly. From the propositions stated in Walker et al. (2006) can be concluded that ecological system components have slowly changing variables, whereas socio-economic components mainly have fast changing characteristics.

4.2 Review of resilience assessments in social-ecological systems

Given the various pitfalls, different attempts have been done in literature to assess or measure resilience in SES's in various analytical contexts. Most methodologies are applied to limited geographical and time scales and quantitative approaches have been largely based on valuation (UNESCAP, 2008). In ecological literature, especially the insect outbreak systems of spruce budworm (Ludwig et al., 1978) and fishing in lake-rich landscapes (Carpenter et al., 2004) are famous for their well defined systems and focus on system dynamics. These case studies use simple mathematical models that allow for an analysis of the long-run behavior of these systems, while looking at the possible attractors and the states in which the system can be. Also case studies with a social background exist in which social processes are included in the system dynamics, and in which multiple resources are involved (Gunderson et al., 2006; Berkes et al., 1992). The variety of frameworks that exist for the study of SES's often lack a clear description of the structural changes and a comprehensive analysis of the system

dynamics, which are key aspects for resilience theory. As Folke et al. (2002) argue, resilience measures for SES's should focus on the variables that underlie the capacity of environmental systems to provide ecological services to socio-economic systems.

All resilience assessments in SESs are constrained by complexity and the availability of data. There are two main approaches for assessing resilience that are used the most in literature. That are 1) the development of a resilience index to compare resilience at a macro level, between countries or regions 2) case study or series of case studies to assess resilience. In Table 1, a review of approaches to assess resilience is summarized.

Table 1 - Approaches to assess resilience in social-ecological system

Author	Discipline	Assessment objective	Methodology	Result
Case study approach				
Rose, A (2005) Modeling regional economic resilience to disasters: a computable general equilibrium analysis of water service disruptions	Economics	To advance a CGE analysis for application to estimating the regional economic impacts of earthquakes and other disasters	Develop methodology for recalibrating CGE model parameters with empirical estimates of production losses due to a lifeline supply disruption.	Application of the model showed how indirect economic losses vary according to the overall level and sectoral mix of water shortages, the extent of pre-event mitigation and post event inherent and adaptive resilience
Bruneau, M., S. E. Chang, R.T. Eguchi, G.C. Lee, T.D. O'Rourke, A.M. Reinhorn, M. Shinozuka, K. Tierney, W.A. Wallace, D. Von Winterfeldt (2003) A Framework to quantitatively assess and enhance the seismic resilience of communities	Ecology	To define seismic resilience of communities and quantitative measures of resilience that can be useful for a coordinated research effort focusing on enhancing this resilience	Framework relying upon complementary measures of resilience and includes quantitative measures for robustness and rapidity, resourcefulness and redundancy, together integrated into four dimensions of community resilience.	The framework can be used for comprehensive characterization of the earthquake problem to establish needs and priorities. The contribution of various activities to seismic resilience can be evaluated.
Ives, A. (1995). Measuring Resilience in Stochastic Systems", in Ecological Monographs 65 (2) 1995, pp. 217-233. Ecological Society of America	Ecology	To measure resilience in a stochastic ecological system	Deterministic resilience= return time to equilibrium. Stochastic resilience= ratio of variability in population densities to variability in population growth rates, calculated from community matrix describing the average interaction strengths within and among species	Simple methodology that can be applied to a wider range of ecological communities
Tierney, K., Bruneau, M (2007) Conceptualizing and Measuring Resilience: a key to disaster loss reduction, TR News, June 2007	Ecology and Sociology	To define disaster resilience, and to develop measures appropriate for assessing resilience and demonstrate the utility of the concept through empirical research	Development of the R4 framework of resilience including four components robustness, redundancy, resourcefulness, and rapidity.	The framework suggests a range of approaches to enhance resilience, and to develop a robust organizational and community capacity to respond to disasters.
Elbourne, A., D. Lanser, B. Smid and M. Vromans, 2008, Macroeconomic resilience in a DSGE model, CPB Discussion Paper.	Economics	To use the dynamic stochastic general equilibrium (DSGE) model to analyze the resilience of an economy in the face of external shocks	Relevant measure for resilience is the level of expected discounted utility. Combining micro founded structural approach with empirical models, taking into account the effects of labour market, goods market and capital market inflexibilities in response to supply and demand shocks	Effect of market rigidities (price stickiness, wages) on the expected level of utility is minimal. Especially when comparing to the effect of market competition, while having a direct effect on output.

Author	Discipline	Assessment objective	Methodology	Result
Case study approach				
Cumming, G.S., G. Barnes, S. Perz, M. Schmink, K.E. Sieving, J. Southworth, M. Binford, R.D. Holt, C. Stickler, T. Van Holt (2005) An Explanatory framework for the empirical measurement of resilience	Ecology	To present an exploratory framework for the operationalization of resilience for empirical studies	A surrogate measure for resilience is developed with the use of the surrogate system identity. Key components for system identity like innovation and memory are used to obtain a set of specific focal variables	The concept system identity provides a level of generality that can be used to compare measure of resilience across cases.
Bennet, E.M., G.S. Cumming, G.D. Peterson (2005) A Systems model approach to determining resilience surrogates for case studies	Ecology	To define a method in which simple systems models are used as a framework to identify resilience surrogates for case studies	Development of a four-step process of identifying resilience surrogates through development of systems models	The construction and analysis of simple systems models provides a useful basis for guiding and directing the selection of surrogate variables that will offer appropriate empirical measures of resilience
Loucks, Daniel and John Gladwell (eds.) Sustainability Criteria for Water Resource Systems. Cambridge University Press (1999)	Ecology	To measure resilience and assess comparative resilience of multiple scenarios	Resilience is accessed by dividing the number of times a satisfactory performance value follows an unsatisfactory performance value by the total number of unsatisfactory values	Resilience along with reliability and vulnerability help in selecting the most sustainable alternative. Simple methodology that can be applied to multiple alternatives
Macro level comparative analysis				
Brenkert, A.L., E.L. Malone (2005) Modeling Vulnerability and resilience to climate change: a case study of India and Indian States	Economics and Ecology	To apply an indicator-based modeling approach using a Vulnerability-Resilience Indicator Prototype to assess the vulnerability of Indian states to climate change	Six criteria used to design a methodology for vulnerability assessment, based on these criteria, 17 coping, adaptive capacity and sensitivity indicators are calculated and an overall indicator of vulnerability is aggregated.	Robust modeling framework allows analysts and stakeholders to systematically evaluate vulnerability and resilience at sub-national level
L. Briguglio, G., S. Concordina, S. Bugeja, N. Farrugia (undated) Conceptualizing and Measuring Economic Resilience, Economics Department, University of Malta	Economics	To develop a conceptual framework for the analysis and measurement of economic resilience between countries	Resilience index is based on an average of four components, value varying from 0-1	Positive relation of economic resilience with GDP per capita, and negative relation with economic vulnerability. Per capita GDP is found to be more sensitive to resilience than to vulnerability.

When looking at the macro level comparative analysis, two studies, namely Brenkert et al. (2005) and Briguglio et al. (2005), attempt to provide an indication of the relative subsystem resilience, be it social, ecological or economic. The construction of a unified resilience index for integrated social-ecological systems is challenging. Developing such a system would fill an important gap left by the available indicators. So far, shocks are considered in each subsystem, while in fact shocks are transmitted across the subsystems, thereby affecting each subsystem. Maybe a conceptual basis should be developed for the selection and weighting of indicators that measure the resilience of each subsystem and to combine them in order to capture the adaptive capacity of the integrative system. One should wonder what the value-added of such an index could be, for example for policy analysis.

When looking at the articles under the case study approach also mainly attempt to provide an indication of a relative subsystem of resilience have been explored. Two articles, namely Rose (2005) and Elbourne et al. (2008), focus on economic resilience, by using general equilibrium models. Two articles, namely Cumming et al. (2005) and Bennet et al. (2005), focus on surrogate variables, mainly in ecological case studies, that could be appropriate empirical measures for resilience. From the table can be concluded that there is a surge of scholars studying and managing ecosystems and social systems as one, social-ecological system. First, there should be an understanding of the processes within social-ecological systems, before there could be focused on the management for social-ecological resilience and ultimately on the assessment of resilience within these systems. By applying resilience theory to empirical case studies, the current state of a social-ecological system can be assessed, and predictions can be made about whether or not the properties of interest are resilient. This assessment can be used by policy makers to 1) identify their actions as being (non) resilient, and (2) to identify strategies that focus on enhancing or reducing particular priorities, such as human health or invasive species, as system disturbances occur (Cumming et al., 2005).

4.3 Modeling rural dynamics

As stated in the previous section, it is of vital importance to first get a full understanding of the processes within SES's, before one could focus on the assessment of resilience of these systems. Especially in rural areas, where these processes have a highly interactive and dynamic character, these understandings are essential. The use of simulation models have been proven an adequate method to represent a real life system including the complex interactions that it exhibits. To model a social-ecological system, all three social, economic and ecological components must be taken together to fully understand the system dynamics (Berkes, 2003). In this current paper, rural areas are seen as open systems operating far from equilibrium, with material, energy and information flowing both into and out of them. It is the way in which their internal socio-economic and ecological components are organized, that determines how the flows are used and traded.

In this system, humans should be seen as an integral part of the rural area. In many models, humans are seen as external drivers on ecosystems or as users of the environment, but not influencing it.

There are several ways to construct these simulation models. One is systematic experimentation, which would be less effective in this case. The reason for this is that studying human behavior in complex environmental settings is difficult to realize because the effects of interventions may depend strongly on the context in which they are implemented. Rather, a methodology is needed that allows for experimenting with behavioral processes within different actors, with social processes between actors and with interactions between actors and the environment. Agent-based simulation offers a perspective on simulating human behavior in complex environments, and thus may provide a suitable tool to experiment with the management of complex environmental resources. Agent-based modeling is a rapidly emerging modeling technique to incorporate more realism into models, while not focusing purely on economic rational behavior. It originates from the field of artificial intelligence, and consists of a number of 'agents' representing decision-making entities, which interact both with each other and with their environment. These agents can make decisions and change their actions as a result of this interaction (Grimm et al., 2005). Within the model, agents have their own interpretation of their environment, build up from experiences with the interactions with their environment. The behavior of the whole system depends on the aggregated behaviors of the individual agents. Social interactions, adaptation and multiple scales of decision making are taken into account. These models offer a way of exploring the impact of links between agents within the system.

Woolridge et al. (1995) identify three basic properties in an agent-based model (ABM). These are reactivity, which is the ability to respond to events in the environment; pro-activity, the ability to demonstrate some behavior determined by its particular objectives, taking the initiative to satisfy its necessities; and sociability; the ability to interact with other agents or humans to fulfill its objectives. These properties give agent-based systems a great versatility in comparison with other approaches by providing a new type of representation of the problem domains. ABMs are therefore also very suitable for analyzing resilience within rural areas because the dynamic, non-linear behavior of agents within the rural area can be simulated as well as their reaction to unknown shocks.

5. Towards resilient rural policy development

A stated in section 3.3, the role of governmental policies is of paramount importance to the adaptability and thereby to the resilience of rural SES's. Understanding how these policies drive change, and the channels and actors through which they get effective in rural areas is fundamental to the design of effective policies in rural areas (Happe et al., 2008). Policies can have various characteristics, from having an

accelerating nature, to a way to slow down certain developments. This will be illustrated with the following example. In the past, agricultural support policies have led to an increase in production while encouraging the maintenance of marginal farms. Market price support systems lead to higher returns on products, which was transferred to higher input prices for production factors. High prices encouraged the expansion of production, beyond market demand while using capital-intensive production methods (OECD, 1994). Guaranteed prices reduced uncertainties and therefore reduced the incentive for farms to diversify and spread production risk. A decrease in agricultural sector resilience was the result.

Since the variation among rural areas is great, policies need to be addressed and tailored to the situation in a specific rural context involving all actors shaping rural areas. What specific policy measurements could enhance resilience in rural areas? In 2005, Janssen and Osnas defined characteristics that make SES's resilient. These characteristics can be used by policy makers while designing rural development policies. The three characteristics that make a system more resilient are redundancy, modularity and diversity in agents and interactions (Janssen et al., 2005). Redundancy enables a system to maintain its function when a component is lost, and the redundant component takes over the function. An example of redundancy in institutions is informal and formal rules of resource management. Low et al. (2003) gives a good example with Lobster fisheries in Maine. They have developed a comprehensive set of rules to govern their use of resources, next to the existence of formal state and federal regulations on lobster fisheries. Modularity is a second key factor for system resilience (Low et al., 2003). With modularity a system is meant that has different functional parts or modules that can evolve somewhat independently. The modules are loosely linked to each other, but not depending on each other. Within social sciences, this is known as polycentricism. A third general factor for resilience is diversity in agents or interactions. In complex adaptive systems, such as rural areas, different components can become specialized in different tasks. In systems with low diversity, there is less chance of creating new ideas, components or connections (Janssen et al., 2005).

From these three system characteristics that enhance resilience policy recommendations can be extracted. When designing policies, there is a trade-off between specialized adaptation, meaning policies that are specialized in stimulating or preventing a certain development of one component, but this also decreases the resilience of the system, because it is more vulnerable to new types of disturbances. A high diversity of policies that cover a large part of the system is needed to create more resilient rural SES. A good example is taken from Hackl et al. (2007). In this article local compensation payments made to farmers are analyzed for providing landscape amenities in Austrian Alpine tourist communities. The payments the farmers receive are the result of a bargaining process at the municipal council level. The benefits gained by these services are

important for all three components of the rural SES discussed in section 3 and thereby increasing the resilience of the whole rural SES.

6. Conclusions

In this paper, the idea is put forward that rural areas are dynamic socio-ecological systems, made up of social, economic and ecological components interacting together. These systems are exposed to sudden shifts in rural dynamics, and these changes present serious problems to rural management. After the introduction by Heijman et al. (2007) this paper further eradicates on the principle of rural resilience, and thereby proposing adaptation strategies and policy recommendations to build and enhance resilience in rural systems. The question is challenged how to measure resilience and thereby including its system dynamism through focusing on the interactions between the three main system components. Through the use of a literature review, attempts are analyzed to assess resilience in SES. Based on the results discussed in this paper, the following research questions can be raised. How can the resilience of dynamic rural social-ecological systems be assessed and what measures can reinforce the interactions between the three components underlying a social-ecological system in a rural area, in order to maintain a certain desirable system state? How can rural development policies be analyzed, based on their contribution to a resilient SES? What is needed in terms of policy measures, to enhance the resilience of rural SES? To address these questions, further research is needed on the processes occurring in rural system to learn to understand how they interact together to contribute to overall system dynamics. Given the literature overview in Table 1, scholars did not succeed yet in simulating dynamics in a SES in a practical way. Modeling plays a central role in this process. Especially agent-based modeling is a promising technique that asks for further research.

Acknowledgments

This research is part of the strategic research program “Sustainable spatial development of ecosystems, landscapes, seas and regions" which is funded by the Dutch Ministry of Agriculture, Nature Conservation and Food Quality, and carried out by Wageningen University Research centre. We are indebted to many of our colleagues for discussions and ideas that are reflected throughout this paper.

Literature

1. Ambrosio-Albala, M. and Delgado, M., 2008. Understanding rural areas dynamics from a complex perspective. An application of Prospective Structural Analysis.
2. Bennett, E.M., Cumming, G.S. and Peterson, G.D., 2005. A systems model approach to determining resilience surrogates for case studies. Ecosystems, 8: 945-957.
3. Berkes, F. and Folke, C., 1992. A systems perspective on the interrelations between natural, human-made and cultural capital. Ecological Economics, 5: 1-8.

4. Berkes, F., J. Colding and C. Folke, 2003. Navigating social-ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge, UK.
5. Brenkert, A.L. and Malone, E.L., 2005. Modeling vulnerability and resilience to climate change: A case study of India and Indian states. Climatic Change, 72: 57-102.
6. Briguglio, L., Cordina, G., Bugeja, S., Farrugia, N., Conceptualizing and measuring economic resilience.
7. Bruneau, M., Chang, S., Eguchi, R.T., Lee, G.C., O'Rourke, T.D., Reinhorn, A.M., Shinozuka, M., Tierney, K., Wallace, W.A. and von Winterfeldt, D., 2002. A Framework to Quantitatively Assess and Enhance Seismic Resilience of Communities.
8. Callaghan, E.G. and Colton, J., 2008. Building sustainable & resilient communities: A balancing of community capital. Environment, Development and Sustainability, 10: 931-942.
9. Carpenter, S.R. and Brock, W.A., 2004. Spatial complexity, resilience, and policy diversity: Fishing on lake-rich landscapes. Ecology and Society, 9.
10. Carpenter, S.R. and Brock, W.A., 2008. Adaptive capacity and traps. Ecology and Society, 13.
11. Colding, J., 2007. 'Ecological land-use complementation' for building resilience in urban ecosystems. Landscape and Urban Planning, 81: 46-55.
12. CSIRO, 2007. Urban Resilience: Research prospectus: A resilience alliance initiative for transitioning urban systems towards sustainable futures, CSIRO.
13. Cumming, G.S., Barnes, G., Perz, S., Schmink, M., Sieving, K.E., Southworth, J., Binford, M., Holt, R.D., Stickler, C. and Van Holt, T., 2005. An exploratory framework for the empirical measurement of resilience. Ecosystems, 8: 975-987.
14. E.C., 2009. The Common Agricultural Policy and the Lisbon Strategy, European Commission Agriculture and Rural Development
15. online: http://ec.europa.eu/agriculture/lisbon/index_en.htm.
16. E.E.A., (European Environmental Agency) 1999. 3.13. Rural areas - our link to the land. In: Environment in the European Union at the turn of the century, Environmental assessment report No. 2.
17. Elbourne, A., Lanser, D., Smid, B. and Vromans, M., 2008. Macroeconomic resilience in a DSGE model, CPB Netherlans Bureau for Economic Policy Analysis, The Hague.
18. Folke, C., 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16: 253-267.
19. Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S. and Walker, B., 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations. Ambio, 31: 437-440.
20. Gardner, J.S. and Dekens, J., 2007. Mountain hazards and the resilience of social-ecological systems: Lessons learned in India and Canada. Natural Hazards, 41: 317-336.
21. Goodwin, B.K., Mishra, A.K. and Ortalo-Magnè, F.N., 2003. What's wrong with our models of agricultural land values? American Journal of Agricultural Economics, 85: 744-752.

22. Grimm, V. and Railsback, S.F., 2005. Individual-based modeling and ecology. Princeton series in theoretical and computational biology. Princeton University Press, Princeton [etc.].
23. Gunderson, L.H., Carpenter, S.R., Folke, C., Olsson, P. and Peterson, G., 2006. Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. Ecology and Society, 11.
24. Hackl, F., Halla, M. and Pruckner, G.J., 2007. Local compensation payments for agri-environmental externalities: A panel data analysis of bargaining outcomes. European Review of Agricultural Economics, 34: 295-320.
25. Happe, K., Balmann, A., Kellermann, K. and Sahrbacher, C., 2008. Does structure matter? The impact of switching the agricultural policy regime on farm structures. Journal of Economic Behavior and Organization, 67: 431-444.
26. Heijman, W., Hagelaar, G. and Heide, M.v.d., 2007. Rural resilience as a new development concept, EAAE seminar Serbian Association of Agricultural Economists, Novi Sad, Serbia.
27. Janssen, M.A. and Osnas, E.E., 2005. Adaptive capacity of social-ecological systems: Lessons from immune systems. EcoHealth, 2: 93-101.
28. Janssen, M.A. and Ostrom, E., 2006. Resilience, vulnerability, and adaptation: A cross-cutting theme of the International Human Dimensions Programme on Global Environmental Change. Global Environmental Change, 16: 237-239.
29. Loucks, D.P. and Gladwell, J.S., 1999. Sustainability criteria for water resource systems. Sustainability Criteria for Water Resource Systems.
30. Low, B., Ostrom, E., Simon, C. and Wilson, J., 2003. Redundancy and diversity: Do they influence optimal management? Navigating Social-ecological Systems: Building Resilience for Complexity and Change: 83-114.
31. Ludwig, D., Jones, D.D. and Holling, C.S., 1978. Qualitative analysis of insect outbreak systems: The spruce budworm and forest. J. Anim. Ecol., 47: 315-332.
32. OECD, 1994. Agricultural policy reform: new approaches - the role of direct income payments, OECD, Paris.
33. OECD, 2006. Trends in Agricultural and Rural Development Policies in OECD Countries. In: Coherence between Agricultural and Rural Development Policies. Diakosavvas, D. (ed.), Development Division, OECD, Paris.
34. OECD, 2007. OECD Regions at a Glance 2007, Paris.
35. Rescia, A.J., Pons, A., Lomba, I., Esteban, C. and Dover, J.W., 2008. Reformulating the social-ecological system in a cultural rural mountain landscape in the Picos de Europa region (northern Spain). Landscape and Urban Planning, 88: 23-33.
36. Roberts, M.J., Kirwan, B. and Hopkins, J., 2003. The incidence of government program payments on agricultural land rents: the challenges of identification. American Journal of Agricultural Economics, 85: 762-769.
37. Rose, A., 2007. Economic resilience to natural and man-made disasters: Multidisciplinary origins and contextual dimensions. Environmental Hazards, 7: 383-398.

38. Rose, A. and Liao, S.Y., 2005. Modeling regional economic resilience to disasters: A computable general equilibrium analysis of water service disruptions. Journal of Regional Science, 45: 75-112.
39. Tierney, K. and Bruneau, M., 2007. Conceptualizing and measuring resilience: A key to disaster loss reduction. TR News: 14-17.
40. Turner, M.G., Baker, W.L., Peterson, C.J. and Peet, R.K., 1998. Factors influencing succession: Lessons from large, infrequent natural disturbances. Ecosystems, 1: 511-523.
41. Van Den Bergh, J.C.J.M. and Nijkamp, P., 1991. Aggregate dynamic economic-ecological models for sustainable development. Environment & Planning A, 23: 1409-1428.
42. UNESCAP, 2008. Sustainability, resilience and resource efficiency: Considerations for developing an analytical framework and questions for further development , Environment and Development Division, UNESCAP Expert Group Meeting: Sustainability of economic growth, resource efficiency and resilience, UN Conference Centre, Bangkok, 22-24 October 2008.
43. Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A., 2004. Resilience, adaptability and transformability in social-ecological systems. Ecology and Society, 9.
44. Walker, B.H., Anderies, J.M., Kinzig, A.P. and Ryan, P., 2006. Exploring resilience in social-ecological systems through comparative studies and theory development: Introduction to the special issue. Ecology and Society, 11.
45. Weersink, A., Clark, S., Turvey, C.G. and Sarker, R., 1999. The effect of agricultural policy on farmland values. Land Economics, 75: 425-439.
46. White, P.S. and Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. The ecology of natural disturbance and patch dynamics: 3-13.
47. Woolridge, M. and Jennings, N., 1995. Intelligent Agents-Theory and Practice. Knowledge Engineering Journal.