An attempt to clarify the resilience concept for renewed strategies of agricultural and farm modernization

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Abstract: The elastic concepts of vulnerability, resilience and sustainability became core concepts in social-ecological analyses of natural resource use and management. Relationships between resilience and sustainability have been critically discussed, whether they imply contradictory or complementary requirements. We discuss in detail one of the terms, resilience, for its application in agricultural development and modernization strategies and show that vulnerability, resilience and sustainability require successive clarification of their internal differentiations before they can be connected and the relationships between them specified. For this purpose a typology for social and ecosystem aspects of resilience, applicable for agricultural social-ecological systems, is formulated. This typology requires to specify for resilience analysis the nature of the agricultural system under consideration, the forms of coupling between ecological and social system components (e.g., lose or dense, functional or dysfunctional coupling), the properties of social and ecological resilience (e.g., diversity, redundancy, robustness), the organizational capacities required in resource management and modernization strategies (e.g., that of learning and adaptive systems), and the key actors in management strategies. We conclude that the internal differentiations and the differences between the concepts of resilience and sustainability need to be specified to prevent the reduction of sustainability to resilience. Our results are illustrated with examples of analyses of agricultural development from different European research projects.

Keywords: resilience, vulnerability, sustainability, agricultural modernization, peri-urban agriculture, Sweden

Research on environmental vulnerability, resilience and sustainability

The concepts of vulnerability, resilience and sustainability are interpreted and applied differently in interdisciplinary and ecological research. One way to dissolve the multiplicity of competing concepts is, to transform these in typologies of vulnerability, resilience and sustainability for specific types of systems, actors, institutions and knowledge forms. The typology of forms of resilience described below is an example, specifying the nature of the social-ecological system (SES), the forms of coupling between ecological and social system components (e.g., lose or dense, functional or dysfunctional coupling), the properties of social and ecological resilience (e.g., diversity, redundancy, robustness), the organizational capacities required in resource management and modernization strategies (e.g., that of learning and adaptive systems), and the key actors in management strategies.

The following discussion of resilience research and its application in agricultural development and modernization strategies is based on literature reviews and material from several European research projects. The aims are (1) to specify the multidimensional concept of resilience through socio-ecological classifications and (2) to illustrate the application of the concept in the study of

agricultural SES. For the application it is, furthermore, required to clarify the connections between vulnerability, resilience and sustainability.

Resilience in relation to vulnerability and sustainability

Analyses of vulnerability, resilience and sustainability are often part of developing integrated frameworks for research and resource management. For vulnerability analysis this is done by (Pethick and Crooks, 2000, Turner et al, 2003, Adger, 2006, Fussel and Klein, 2006, Romieu et al, 2010). For resilience analysis (Adger, 2000, Folke, 2006, Sapountzaki, 2007, Derissen et al, 2011) give examples. For sustainability analysis (Manderson, 2006, Tabara and Pahl-Wostl, 2007, Bruckmeier, 2009, Clifton, 2010, and Raskin et al, 2010) show some ways to deal with the complexity of the term in different contexts. However, attempts to integrate vulnerability, resilience and sustainability analyses are rare.

Vulnerability analysis originates from research on natural disaster and poverty where the aim is to identify and strengthen the ability of individuals, groups or social communities to cope with natural or social disturbance. The term needs to be broadened for natural resource management under conditions of climate change. What has become vulnerable through climate change is the global society or the economic world system. To protect this system requires multi-scale and transnational coordination of natural resource management in strategies of global governance.

Resilience is, according to its ecological origins, a functional concept to measure the ability of ecosystems to maintain stability after disturbance (engineering resilience), or to absorb disturbance through shifts to other equilibrium states without collapsing (ecological resilience). Resilience of ecosystems may counteract resilience of social and economic systems and vice versa. In agricultural SES the differentiation between social and ecological forms and subtypes of resilience requires an analysis of the interrelations of vulnerability reduction, resilience and sustainability – how does each form (social, ecological, socio-ecological) of vulnerability, resilience and sustainability affect the other forms (positive, negative, neutral effects)?

Sustainability implies the maintenance of long-term development capacity of SES, which implies beyond resilience coping with the limited availability of natural resources and redistribution of resources between users. Vulnerability and resilience analysis appear, in this sequence, as steps of sustainability analysis. Vulnerability to environmental disturbance can be reduced through measures that create as well resilience as sustainability of SES; but the kinds if measures chosen to reduce vulnerability can also undermine ecological resilience and sustainability. Similar difficulties of the concepts of vulnerability and ecological resilience are discussed by (Mumby et al, 2014). (Loyd et al, 2013) specify social components of resilience in the notion of social-ecological resilience: that of capacity development, social and transformative learning to restructure a SES in response to disturbances.

Resilience of agricultural SES

Agro-ecosystems can be seen as examples of interacting social and ecological systems. Most ecological strategies for resilient and sustainable agriculture are for non-European countries in the Global South, discussed in the international dialogue of development cooperation (e.g., Auerbach et al, 2013), with three salient concepts.

(1) Ecosystem resilience: Analysis of resilience of agro-ecosystems has advanced from studies of ecological resilience (summarized by Cabell and Oelofse, 2012) to more elaborate forms of resilience analysis connected with the concept of ecosystem services or benefits provided by ecosystems to humans (Paavola and Hubacek, 2013). Another form of ecosystem-related resilience of

agriculture is achieved with the alternative forms of agriculture, organic farming or community based agriculture, where the connection between ecosystems and people or resource users is emphasized (King, 2008). In all these approaches the linkage between resilience and agriculture is created through the maintenance of biodiversity and ecosystem functions (Fischer et al, 2006). A broad notion of "rural resilience" is emerging from these studies, described by (Heijman et al, 2007) as *"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"* (Schouten et al, 2009: 4).

(2) Livelihood resilience: In difference to resilience of agreo-ecosystems, livelihood resilience starts from the other side of the dichotomy "ecosystems and people". Rural livelihood studies have been carried out in great number and manifold perspectives, also regarding the connections between vulnerability, resilience and sustainability. Local livelihood studies *"may miss out on long-term shifts which will, in time, undermine livelihoods in more fundamental ways. Long-term temperature rises may make agriculture impossible, shifts in terms of trade may undermine the competitiveness of local production or migration of labour to urban areas may eliminate certain livelihood options in the long-term. ... Sustainability and resilience thus cannot always emerge through local adaptation in conditions of extreme vulnerability."* (Scoones, 2009: 19).

(3) Climate resilience: Global climate change is mainly discussed for countries in the Global South where the majority of agricultural producers are still smallholders. For these the international policies to react to climate change, with the core elements of biofuel production on agricultural land, soil carbon markets and strategies of climate-smart agriculture, are doubtful solutions, supported by the FAO and recommended by the World Bank as a "triple-win solution" to "*increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing GHG emissions and increasing carbon storage on farmland"* (Chung and Billingsley, 2012: 12). The distorting effect of these approaches is seen as benefitting the agriculture in OECD-countries through shifting of environmental burdens to poor countries, whereas in OECD-countries such strategies of climate adaptation are less important, less practiced and less conflict-loaded.

Developing a framework for resilience in the context of sustainable resource management

Conceptual models and methods of knowledge integration for combined analyses of vulnerability, resilience and sustainability develop with heuristic frameworks and typologies. The search of knowledge for resource management is guided through experiments and participatory research, as paradigmatically formulated in sustainability science, resilience research, and adaptive management.

Approaches of adaptive management develop through experimenting and learning, using heuristic frameworks to search and combine the knowledge required for the management of an SES, for a policy or project (Gallopin, 2006, Janssen and Ostrom, 2006). Adaptive management can be understood as a framing strategy to combine vulnerability reduction and resilience to achieve sustainable resource management. Some requirements of such integrated approaches have been formulated by (Manderson, 2006) as

- importance of (phased) temporal perspectives in sustainability,
- specifying inter-systemic relations and dynamics (of social and ecological systems),
- necessity to take into account changing interpretations of the sustainability concept,
- becoming aware of continuously changing situations in multi-contextual processes of sustainable development (where local, national, international and global strategies of management interact and overlap).

Institutions of resource management are confronted with increasing complexity of inter-systemic relations and problems, requiring capacities for anticipation, use of interdisciplinary knowledge and various perspectives, reflection of guiding concepts, dealing with incomplete and complex information, cooperation and participation. Further capacities for sustainable development include networked thinking, critical thinking, ability to identify problems, responsible action, and cooperation in groups (Rieckmann, 2011: 49ff).

A framework accounting for the vulnerability of coupled human-environment systems was developed by (Turner et al, 2003: 8074) as a multi-scale framework to identify local, regional and global components of the vulnerability to hazards in SES. This framework requires more systematic integration of vulnerability, resilience and sustainability analyses.

Resilience and robustness of SES

A step towards interdisciplinary analysis of resilience in SES is made with the differentiation between ecological resilience of natural systems and robustness as the equivalent of resilience in coupled social and ecological systems with man-made control and feedback systems (Janssen and Anderies, 2007: 46). The authors connect the concepts of resilience and robustness with the ecological model of the adaptive cycle, generating management and policy recommendations contrary to that in conventional resource management literature, taking into account the uncertainty of managerial decisions. To accept failures in local and regional SES appears as a way "*to learn how to improve the robustness of social-ecological systems at larger scales. To maintain robustness of social-ecological systems in the longer term, we may need to avoid the temptation of specializing our responses to increase robustness to specific perturbations"*, thus becoming more flexible and being able to adapt to changes (Janssen and Anderies, 2007: 61).

The discussion of terminological variation, inconsistence and contradiction (Peterson, 2000: 325) resulted first in trials to connect resilience with other concepts such as adaptive capacity, (ir-)reversibility of state changes, temporal and spatial scales of resilience (Gunderson et al, 2002: 256f). Later publications on resilience discuss the coupling of social and ecosystems that can vary from mal-adaptive to functional coupling and co-evolution. Ecosystems influenced by humans

show different stability domains that do not depend on ecological dynamics only, require a differentiation between ecological and social forms of resilience. Ecological and social resilience may require contradicting behavior of human individuals, groups, and resource management institutions (Sapountzaki, 2007). Although differences between social and ecological systems are obvious, trials to differentiate and specify the resilience concept for the different systems types have not gone far, differentiating between resilience of ecosystems and robustness of human designed systems (Anderies et al, 2004, Perrings, 2006, Gallopin, 2006, Janssen and Anderies, 2007, Gotts, 2007).

Resilience and sustainability

The main ecological model to describe resilience is that of the adaptive cycle or connected adaptive cycles. Critical reflection of the model in interdisciplinary perspectives - where social and ecological components of system development need to be clearly differentiated - shows: for long-term strategies and integrated development of SES it is an (over-)simplified functional model. For transition to sustainability more refined models are required, including social-systemic components. Without further analysis of the inter-systemic complexity of interacting social and ecosystems strategies for resilient and sustainable agriculture remain doubtful in their effects.

Developing a framework and applying it for the study of agricultural SES

The framework

Classifications and criteria for the management of SES with different system components can be connected in multi-scale approaches. These show the plurality and diversity of management strategies derived from heuristics for resilient SES (e.g., Walker et al, 2006) and typologies of SES (e.g., for urban systems: Alessa et al, 2009). The typology of Alessa et al does not include the full range of types of interaction social and ecological systems. It is a typology constructed for identifying resilient, vulnerable and mixed SES. Also the heuristics and propositions by Walker et al are limited to two key variables for resilience management, adaptation and learning (Berkes and Turner, 2006: 490). (Binder et al, 2013) compare ten conceptual frameworks for SES-analysis, taking into account the context, the social and the ecosystem structures, the interaction and dynamics between social and ecological systems. They show more the difficulties of a coherent SES-analysis than advances in practice: only three frameworks (human-environment system, management and transition framework, and SES) conceptualize the reciprocal interaction between social and ecosystems in both directions; these three are also the ones that can be used for analyzing the dynamics of SES (Binder et al, 2013: table 9ff).

Starting from these preliminary analyses of SES we identify a number of conceptual key elements for combined analyses of vulnerability, resilience and sustainability. They are summarized in Box 1.

Box 1: Criteria for developing an integrated framework of vulnerability, resilience and sustainability analysis and its application in resource management

1. Forms of coupling of eco- and social system components in SES: lose/extensive or dense/intensive, partial or systematic (one or several/many resources), functional or dysfunctional (mal-adaptive), material or symbolic, short-term or long-term, actor-specific (for specific groups) or inclusive (everyone), technology based or labour-based, mediated through scientific or other knowledge

2. Connecting analyses of V(ulnerability), R(esilience) and S(ustainability): disciplinary perspectives (V,R,S as ecological concepts, e.g., for ecosystem analysis); interdisciplinary perspectives (V,R,S differentiated for social and ecosystems, with different implications for each concept/system, e.g. SES-analysis); "cross-over analysis": identifying for each form (social, ecological, socio-ecological) of V, R, S the positive and negative consequences for the other forms of V, R, S, to create integrated approaches and transdisciplinary perspectives (integration of scientific and managerial perspectives/research and application); multi-scale management of SES; strategies for reduction of external inputs for production and resource processing

3. Knowledge integration and institutional arrangements for integrated natural resource management: important types of knowledge include scientific, managerial, and various forms of local and traditional ecological knowledge (Gomez-Baggethun et al, 2013, Ruiz and Corbera, 2013), for which different integration strategies include knowledge transfer (conventional strategies), cooperation (e.g., participatory research and management), collective learning arrangements (e.g., of social movements), experiments (e.g., adaptive management), bi-directional knowledge sharing

4. Heuristics to design resource management rules for resilience and sustainability: e.g., management of nested and overlapping systems (redundancy mechanisms), strategies to maintain biodiversity; general resilience heuristics (panarchical relations with top-down and bottom-up interaction; adaptability, transformability: Walker et al, 2006); general sustainability heuristics (with principles of sufficiency, efficiency, collective learning)

5. Application of the framework and translation in resource management rules: rules for system-, sector-, resource-, site-specific management approaches (e.g. in management of specialized agricultural systems); rules for connected resource management systems (upward linking: multi-scale approaches; horizontal linking: neighboring systems/areas); indicator systems for resilience (Cabell and Oelofse, 2012) and sustainability (sustainable development indicators/SDI, environmental sustainability index/ESI, ecological footprints, material and energy flow analyses/MEFA, human appropriation of net primary production/HANPP)

6. Key actors in different phases of resource management: identified for specific SES through methods of stakeholder (power) analysis, or varying forms of interest negotiation, power sharing, participation and cooperation

Sources: own compilation; literature reviewed

A framework based on criteria described in Box 1 is not standardized but differentiated for specific SES; it requires further elaboration, conceptual and knowledge integration. Ostroms´ multitier framework with several layers of abstraction can give a first idea how to structure an integrated framework for the analysis of vulnerability, resilience and sustainability of SES. Her core components of resource systems, resource uses, governance systems and users, describing ecological and social system components and their interactions and outcomes (Ostrom, 2007: 15182), can be used in most forms of vulnerability, resilience and sustainability analysis.

Integrated analysis of vulnerability, resilience and sustainability for agricultural SES

Deficits of prior research

Two European projects from social-scientific rural research illustrate the emergence of ideas for integrated social-ecological frameworks for natural resource management, RURBAN for the analysis of interaction of urban and rural areas and CORASON for rural sustainable development (see project websites). The RURBAN project shows the requirements of balancing rural and urban interests and resources in strategies of sustainable development, with suggestions that can be understood as components of integrated strategies. The CORASON project addressed knowledge issues of rural sustainable development.

The RURBAN-project identified the impact of urban pressure on rural landscapes in a number of rural areas under urban pressure across Europe. The results show that the integration of urban-rural development happens in pluri-functional strategies that serve to some degree requirements of reducing vulnerability, achieving resilience and sustainability (Overbeek, see the final project report: www.rural-urban.org):

Efforts to establish sustainable territorial rural-urban relationships based on trust and understanding, require a balance of urban and rural power, interests, territorial cooperation of actors, and coordination and redistribution of financial resources for urban and rural development:

1. Territorial land-use planning can help to achieve various objectives: to contain urban sprawl, to protect rural landscapes, to solve conflicting demands for rural space by housing, business, agriculture and nature – if they balance conflicting aims in democratic, participatory approaches.

2. The supply of public rural goods and services (RGS) requires the proper management of natural and agricultural land with appropriate (diversified) funding mechanisms to maintain highly valued agricultural and natural landscapes, to develop new nature areas, to trigger local actors to support land management.

3. Public and private RGS can be balanced in cooperative approaches for the supply of RGS to increase the attractiveness of rural areas and to develop "soft" forms of tourism.

The CORASON-project studying rural sustainable development in eleven European countries approached a more interdisciplinary perspective of integrating social and environmental strategies that can be seen as part of integrated forms of vulnerability reduction, resilience and sustainability management. The management approaches found in local case studies showed:

1. Processes of rural sustainable development are guided by two contrasting conceptual models, (a) an institutional (or ecological modernization) discourse with elements of a macro-policy model of government-driven transition to sustainability, and (b) a local, livelihood-oriented model of sustainable resource management which includes more elements of a micro-political, people-centered and governance driven approach.

2. Ideas for sustainable rural development require further framing, e.g., in conceptual models as the ones that Marsden identified as the sequence of modernization, critique of productivism, and sustainable development. At first sustainable development meant nature protection, conservation and environmental policy. Since the 1990s it has been guided by ideas about integrated and trans-sectoral resource management that appear more clearly as transformative components of rural sustainable development.

Two different approaches were found from the European country studies:

- conventional integrated approaches (conservationist for nature protection and economic maximization of yields) and
- new approaches (sustainable resource management for varying purposes (resource renewal, human welfare, both of these, and participatory approaches for balancing contrasting interests).

Comparing the results of both projects with recent ecological analysis of resilience based strategies for high-nature-value farmland (Plieninger and Bieling, 2013) shows: resilience requires advances towards integrated, locally specific and dynamic strategies for sustainable resource management. Additional components to strengthen rural sustainable development, insufficiently addressed in social-scientific research, include the forms of coupling of social and ecological systems; the identification of critical variables for farmland governance (internal and external to the area); stimulating flexibility, learning, continuous adaptation of land use practices; integration traditional or local and scientific knowledge form resource management (Plieninger and Bieling, 2013, table 1).

A case study from the RETHINK-project

The Swedish case study of peri-urban agriculture in the RETHINK-project aims to show requirements of integrated analysis of vulnerability, resilience and sustainability with the criteria for integrated analysis described above (Box 1). The case study focusses on the analysis of changes in agricultural land use and in production of ecosystem services, in response to main drivers (urban development, EU-policies, globalization), using two of the frameworks mentioned above (Binder et al, 2013), ecosystem services and SES, to allow for a more systematic, reciprocal analysis of interaction of social and ecosystems.

The socio-ecological approach chosen can be described methodologically as follows: the sampling is not in terms of farmers or producers, but geographically oriented, in terms of patterns of land use change. Different development trends in an urban and rural region are compared to identify some of the varying trends in these areas. The data analyzed as indicators of changing patterns of agricultural development are from public statistics of governmental institutions, transformed into geographical information systems (GIS); they cover a long period from 1850 until today. The data are interpreted in terms of resilience as core theme, and supplemented by available analyses of vulnerability and sustainable resource management. Resilience analysis is linked "forward" with sustainability analyses and directs other aspects of re-designing agricultural modernization: the forms of prosperity, governance, knowledge and learning that influence rural development. For the analysis of governance, knowledge and learning the case study uses semi-structured expert interviews with representatives of different stakeholder groups (farmers and representatives of farmer associations, nature protection groups, administrators/civil servants, politicians, rural researchers) to identify their perceptions and interpretations of the changes ongoing. To identify possible trajectories of rural development/modernization in future, information from available scenario-analysis is used.

The results expected should help to develop integrated vulnerability, resilience and sustainability analyses, especially regarding the

- classification of land use changes that show trends (supporting or countering requirements of resilience and sustainability),
- evaluation and mapping of ecosystems services for sustainable resource management,
- assessment of drivers of urban-rural development with regard to resilience and sustainability (supporting or blocking effects): urban expansion, EU-policies (especially agricultural and regional policies), globalization (especially global resource flows and dependence of the area from external input of resources).

The following development trajectories should be analyzed in terms of land use change and connected types of farm modernization and agricultural development: (a) intensified food production with different specializations; (b) multifunctional agriculture with different kinds of food production under conditions of various forms of nature and landscape protection; (c) agricultural production as production for recreational purposes; (d) diminishing agriculture in transitional or ephemeral landscapes where urban sprawl is the dominant pattern of development. Potential land use change and agricultural modernization that may also be taken into account includes urban agriculture as this is becoming more important in the region.

Farm management practices are continuously reacting and adapting to manifold exigencies, problems and context factors that are only to a limited degree taken into account in policies for agricultural and rural development. When farm management is connected with multi-scale perspectives, as discussed above for agricultural SES, a more systematic accounting for the heterogeneous requirements of vulnerability reduction, resilience and sustainability management becomes possible.

Discussion and conclusions

In the further elaboration of integrated frameworks for the analysis of vulnerability, resilience and sustainability the following problems need to be discussed:

1. C*onceptual and methodological difficulties to clarify and integrate vulnerability, resilience and sustainability analyses* require other forms than conventional theories (that close the analysis through the selection of one explanatory strategy) and single models or hypotheses to test these, as critically discussed in sustainability science. Continuous search for improved concepts, methods, frameworks, knowledge in cooperative research and resource management requires more open, flexible, multi-faceted approaches.
2. *Trajectories to sustainability* can be sought (a) by "working forward" from vulnerability to resilience to sustainability analyses, and (b) through experimenting or adaptive governance for maintaining ecosystem functions and services. Key criteria for achieving sustainability include reducing quantities and intensities of human resource use and fair distribution of resources. Global sustainability perspectives affect local resource management through institutional mechanisms linking different spatial and temporal scales of resource management.
3. *Designed systems governed by humans* include conscious or planned interventions. These are challenged through the experience of elasticity, variability and modification of resource use practices and reactive mechanisms (buffer capacity) of ecosystems that vary beyond the scope of human action repertoires. Important types of human-dominated SES are resource management systems, agricultural, urban and economic (production) systems. For such systems resilience analysis needs to deal with human intentions, anticipations and reflexivity, with antinomies, non-intended consequences of human action, and socio-cultural variation of human re-

source use. Building resilience capacity in SES requires coping with insecurity, surprise, ignorance, "accounting for the noncomputable" (Carpenter et al., 2009) that remains difficult, also in adaptive management strategies (Hughes et al., 2005: 385).

Concluding from our analysis two points are important:

(1) Resilience as social-ecological resilience is, in difference to resilience of ecosystems that is sometimes described metaphorically as based on the ecological memory of an ecosystem, based on the individual or collective (cultural) memory of social actors. More than scientific knowledge constitutes experience and local knowledge this capacity, as summarized by (Buchmann, 2010: 2249).

(2) Integrated analysis and management of vulnerability, resilience and sustainability requires inter- and transdisciplinary knowledge, developing in continued improving of SES-management, in long-term perspectives. Such improvement is part of a broader *capacity of reflexive thinking and knowledge use.* Strategies of resource management become meta-strategies for which scientists, resource managers and users need to acquire specific capacities and use knowledge tools to deal with complex systems and their interaction.

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