Twyman, C., E. D. G. Fraser, L. C. Stringer, C. Quinn, A. J. Dougill, F. Ravera, T. A. Crane, and S. M. Sallu. 2011. Climate science, development practice, and policy interactions in dryland agroecological systems. *Ecology and Society* **16**(3): 14.
http://dx.doi.org/10.5751/ES-04261-160314

Synthesis, part of a Special Feature on Resilience and Vulnerability of Arid and Semi-Arid Social Ecological Systems

Climate Science, Development Practice, and Policy Interactions in Dryland Agroecological Systems

Chasca Twyman [1,2], *Evan D. G. Fraser* [3,4], *Lindsay C. Stringer* [5], *C. Quinn* [5], *Andrew J. Dougill* [5], *Federica Ravera* [6], *Todd A. Crane* [7], *and Susannah M. Sallu* [5]

ABSTRACT. The literature on drought, livelihoods, and poverty suggests that dryland residents are especially vulnerable to climate change. However, assessing this vulnerability and sharing lessons between dryland communities on how to reduce vulnerability has proven difficult because of multiple definitions of vulnerability, complexities in quantification, and the temporal and spatial variability inherent in dryland agroecological systems. In this closing editorial, we review how we have addressed these challenges through a series of structured, multiscale, and interdisciplinary vulnerability assessment case studies from drylands in West Africa, southern Africa, Mediterranean Europe, Asia, and Latin America. These case studies adopt a common vulnerability framework but employ different approaches to measuring and assessing vulnerability. By comparing methods and results across these cases, we draw out the following key lessons: (1) Our studies show the utility of using consistent conceptual frameworks for vulnerability assessments even when quite different methodological approaches are taken; (2) Utilizing narratives and scenarios to capture the dynamics of dryland agroecological systems shows that vulnerability to climate change may depend more on access to financial, political, and institutional assets than to exposure to environmental change; (3) Our analysis shows that although the results of quantitative models seem authoritative, they may be treated too literally as predictions of the future by policy makers looking for evidence to support different strategies. In conclusion, we acknowledge there is a healthy tension between bottom-up/qualitative/place-based approaches and top-down/quantitative/generalizable approaches, and we encourage researchers from different disciplines with different disciplinary languages, to talk, collaborate, and engage effectively with each other and with stakeholders at all levels.

Key Words: *climate change, drylands, scenarios, narratives, development, livelihoods, poverty, policy*

INTRODUCTION

Livelihood sustainability in dryland regions is threatened by a complex and inter-related range of social, economic, political, and environmental changes that present significant challenges to researchers, policy makers, and, above all, rural land users. Assessing these threats, and sharing lessons learned between dryland communities on how to reduce vulnerability, has proven difficult because of multiple definitions of vulnerability, complexities in quantification, and the temporal and spatial variability inherent in the world's drylands (Reynolds et al. 2007). There has been a lack of consistency in approaches to vulnerability assessment and a disconnect between what measurement approaches are applied. For example, food security, at the crux of rural livelihoods and their vulnerability (Stringer 2009), has traditionally been studied from either a top-down quantitative or a bottom-up qualitative perspective (Challinor et al. 2010) with limited integration because of the strong disciplinary grounding of these two approaches and the difficulties of bridging the philosophical gap underlying qualitative and quantitative research. The top-down approach typically uses quantitative data and computer modeling to explain and simulate impacts of climate change, or other variables, on

[1]Department of Geography, University of Sheffield, [2]Sheffield Centre for International Drylands Research, [3]Department of Geography, University of Guelph, [4]University of Leeds, [5]Sustainability Research Institute, School of Earth and Environment, University of Leeds, [6]Institute for Environmental Sciences and Technology, Universitat Autònoma de Barcelona, [7]Technology and Agrarian Development, Wageningen University

agricultural productivity. Bottom-up approaches typically use livelihood assessments, looking at how socioeconomic changes may affect food demand and in this way influence food security (Simelton et al. 2009). The former approach operates best over larger areas and decadal or longer time scales, whereas bottom-up case studies are particularly useful for providing detailed local and seasonal information and ground-truthing at smaller resolutions (Fraser et al. 2006). Bottom up approaches are also well suited for capturing multiple understandings of vulnerability and people's agency in adaptive practice. So far, most attempts to capture the complexity of food security and livelihood sustainability have been conceptual (e.g., Ericksen 2008) because the key explanatory variables vary with spatial and temporal scale (Vincent 2007). Research is needed, therefore, to understand the interrelationships between natural science models that predict change and the experience of farmers directly affected by these changes who often control the impacts of change through management decisions. Evaluating case study research is essential to draw out a more nuanced understanding of the determinants of vulnerability and how they interact, as well as to assist in providing clearer climate change compatible development policy advice and practice (Ford et al. 2010).

This special feature of case study research has enabled us to undertake a structured, multiscale, and interdisciplinary vulnerability assessment of a range of different drylands from West Africa, southern Africa, Asia, Mediterranean Europe, and Latin America (Crane 2010, Dougill et al. 2010, Sallu et al. 2010, Dong et al. 2011, Li and Huntsinger 2011, Máñez Costa et al. 2011, Quinn et al. 2011, Ravera et al. 2011, Sendzimir et al. 2011). These studies each adopt different levels of complexity in assessing vulnerability employing dynamic systems modeling approaches. By comparing both the methods and results across these cases, this editorial reflects on lessons in three areas. First, we assess the utility of using consistent conceptual frameworks for vulnerability assessments even when quite different methodological approaches are taken. Behind this analysis lies the assertion that common frameworks, if applied with transparency and critical reflection, can bring new and informative insights across multiple case studies. Second, we explore the utility of narratives and scenarios as ways of capturing the empirical and conceptual dynamics of dryland agroecological systems. Third, we evaluate whether relationships between climate and vulnerability can be explored effectively through the integration of qualitative narratives with quantitative modeling. We conclude by identifying the key lessons learned that inform the integration of climate science and development planning.

CONCEPTUAL FRAMEWORKS FOR VULNERABILITY ASSESSMENTS

The lessons emerging from this special feature help us reflect on our thinking about conceptual frameworks for vulnerability assessments. Each paper in this special feature adopts a consistent conceptual framework that involves a single definition of vulnerability to climate change: vulnerability occurs when relatively small climatic changes have commensurately large and negative impacts on livelihoods (Fraser 2006). Furthermore, each paper adopts as a starting position that vulnerability is a function of: (a) agroecosystem resilience that measures the extent to which the agroecosystem can tolerate climate shocks and remain productive; (b) socioeconomic affluence that measures the extent to which households will have access to the assets needed to maintain livelihoods in the event of environmental shock; and (c) institutional capacity that measures the extent to which institutions in society will provide effective crisis relief (Fraser 2007). This definition can be visually represented in the form of a cube in which each axis of the cube refers to one of these three factors (Fraser 2007, Fraser et al. 2011). Fraser's cube deliberately simplifies concepts and connections to provide a general analytical framework. Importantly, this enables heuristic comparison independent of scale because we can compare the trajectories of movement (dynamism) in different cases visually with the cube, i.e., the angle or path of the trajectory of the vector in the cube. We advocate that there is a place for simplicity in frameworks to aid explanation if we make transparent the situated and partial types of knowledge inherent by taking such an approach. Furthermore, although the cube allows comparison independent of scale, we still need to engage and reconnect our findings with scale. Our approach has strong synergies with the dynamic sustainabilities approach advocated by Leach et al. (2010).

This special feature contributes to understanding the interrelationships between research, policy, and

practice by bringing together conceptually linked but diverse case studies. Case studies can be viewed as situated types of knowledge and can help illuminate questions of scale and relevance for given topics. Ford et al. (2010) discuss case study approaches and the limits such a research strategy imposes on the ability to create generalizations. They suggest that case studies provide depth in real-life settings whereas larger scale analyses can provide more generalized understandings. Ford et al. (2010) use the idea of case studies as analogues, using knowledge about particular subjects (the base) to improve understandings about other subjects (the target), but recognize that both base and target must have similar structures and organization. Similarly, Adger et al. (2005) highlight that a case study approach provides "actionable information," but this often comes with too much of a focus on local level studies and details, perhaps at the expense of regional and national level insights. This suggests the need for nested studies at multiple scales. However, to make such an approach coherent, case-based research needs to be organized using a linking framework such as we have provided.

Three cases in this special feature show how Fraser's cube can work at different scales to demonstrate and partially explain trajectories or pathways of change, even if each case remains scale-dependent. For example, Sallu et al. (2010) use the concept of trajectories (see also de Haan and Zoomers 2005) to demonstrate the dynamics and uncertainties of individuals and their households, particularly in relation to livelihoods. These livelihood trajectories are captured allowing comparisons of livelihood vulnerability and resilience across categories of wealth, i.e., a wealthy household may have a risky livelihood portfolio and be highly vulnerable to market fluctuations, whereas a poor household may be risk averse and resilient to the shocks and stresses affecting their livelihoods. These comparisons across household typologies are relevant to Hulme et al.'s (2009) call to question constructed norms and baselines within research. Trajectories are particularly helpful for vulnerability assessments as it is often the precariousness of life that most affects household decisions and actions in these agroecological environments.

Sendzimir et al. (2011) build on this by showing that the pattern of interactions between key resources was more important than any single resource itself. In their case study, the regreening of the Sahel in Niger resulted not so much from introducing new technologies or processes, but from reversing the direction of reinforcing feedbacks. Shifts of de- or reforestation were preceded by institutional changes in governance, then changes in livelihoods, and eventually followed by changes in the biophysical environment. Ravera et al. (2011) show that vulnerability assessments need cross-scaled refinement to have policy relevance. Furthermore, they argue, these assessments need to be sensitive so that irreversibility in agroecological environments, i.e., when indicator thresholds are passed, can be explored even if, at different scales, resilience is maintained (Adger et al. 2005). Fraser's cube (2007), and the unifying framework across the case studies, highlight the importance of scale. Whether drawing on the social sciences and concerns about relevance (Marston et al. 2005, Jonas 2006, Chapura 2009) or from the Panarchy School (Holling and Gunderson 2002), scale, in its plurality, is a fundamental concept that is central to assessments and understandings of agroecological systems.

NARRATIVES AND SCENARIOS

In this section we highlight how the papers within this special feature used the concepts and tools of narratives and scenarios within their case study analyses as a first step toward developing conceptual models of agroecosystem functioning. We define narratives as explanatory narratives (Bravo 2009) that provide rich empirical descriptions and story lines of livelihoods, food systems, and their complex links with climate, economy, and politics. Thus, the narratives presented in this special feature provide a baseline understanding of vulnerability to change and were constructed by analyzing qualitative in-depth interview data, collected at the local level, and, in some cases, through deliberative focus groups with communities, extension workers, and policy makers (Abelson et al. 2003).

Overall, each of the narratives constructed as part of this special feature points to a single overarching empirical conclusion: vulnerability to climate change depends more on access to financial, political, and institutional assets than exposure to environmental change. Communities that are able to negotiate complex power relations (Eyben et al. 2006) and command key assets are generally able to adapt to even large changes in the environment such as those seen in Sahelian Africa (Sendzimir et

al. 2011). The implication of this is that climate change adaptation policy needs to draw as much from our understanding of political ecology and power relations as it does from atmospheric and climate science. This is particularly important in providing appropriate support to enhance adaptive capacity and thus reduce vulnerability to future climate changes. However, although this finding is significant, the process of deriving this observation from qualitative narratives also reveals a number of key methodological lessons.

The literature suggests that the development of narratives can be overly descriptive and linear (Rounsevell and Metzger 2010). If appropriately constructed, however, narratives provide detailed explanations and valuable situated accounts of relationships between people, livelihoods, environments, and policies, assisting the integration between top-down and bottom-up research approaches (Fraser et al. 2006). In addition, physical dimensions of climate and environment can be reconnected with interpretive meanings ascribed by different actors using narratives. Thus, narratives provide a tool to address what Hulme (2008) calls the co-construction between the cultural constraints of the social, and the physical constraints of the material, world. The strongest set of narratives within our collection of papers comes from Crane (2010) who shows the importance of social context and spatial scale in understanding social-ecological systems, and demonstrates how starkly different narratives can emerge when different cultural interpretations of a single event arise. The prologue to Crane's paper describes two contrasting accounts of declining soil fertility in central Mali. One group of agropastoralists state that there are not enough cattle and that soil fertility has dropped because there is not enough manure. The agropastoralists, however, believe that soil fertility has suffered because there are too many cows that overgraze and trample the vegetation. The ensuing discussion demonstrates how this juxtaposition of interpretations can have significant consequences for ensuing policy and practice. This strong contrast of narratives demonstrates that knowledge is embedded and partial, and suggests that culture, however defined, clearly has an important role to play (cf. Thomas and Twyman 2004, Nielsen and Reenberg 2010).

Many of the papers in this special feature used the baseline narratives to construct scenarios that are projections of different futures. In this collection of papers, scenarios took the form of both qualitative story lines, which functioned as extensions of the explanatory narratives, as well as some quantitative simulations (see Dougill et al. 2010, and Máñez Costa et al. 2011 for quantitative examples of scenarios; see Carpenter et al. 2006 for a discussion on using scenarios more generally). Although the baseline narratives provide detailed situated explanation, the scenarios, by contrast, are hypothetical. As such, the scenarios involve a very different form of conceptualization (e.g., Newton et al. 2006, Dougill et al. 2010). Our approach builds on Rounsevell and Metzger (2010) who see scenario analysis as characterizing the future and its uncertainties through structured and imaginative processes. Story lines, for them, are qualitative and descriptive components of a scenario. They reflect multiple and sometimes conflicting underlying assumptions, so that they try to stimulate, provoke, and communicate visions of what the future could hold. 'Could' is the key word here; the danger is that scenarios are interpreted as predicted outcomes rather than possibilities. In this sense, scenarios are "neither predictions nor forecasts, but stylized and contrasting desirable or alarming images of how the future might unfold" (Ravera et al. 2011).

As suggested by Rounsevell and Metzger (2010), the underlying purpose of scenario analysis can be explanatory, when scenarios are intuitive, logical, and comparative, as distinct from normative, when they are used to demonstrate how to realize a desired future. The latter is often, but not exclusively, oriented to assist policy making. Participatory scenarios are developed in collaboration with a range of stakeholders and can lead to surprising insights that contribute to the design of policies better suited to serve the needs of those concerned. Participatory scenarios are essentially a form of social learning that can enhance the legitimacy and utility of the results (Reed et al. 2011). In this special feature, Ravera et al. (2011) used the narrative story line to develop participatory scenarios with stakeholders and policy makers to use as tools for exploring short and medium term policy options. This process allowed them to "creatively imagine a proactive and anticipatory, rather than reactive, adaptation window" demonstrating how valuable scenario development can be for understanding decision making within the policy arena.

We need to acknowledge, however, that personal judgment also influences scenarios, especially given that it must be recognized that all knowledge is situated and partial (Crane 2010, Metzger et al.

2010). As a consequence, Metzger et al. (2010) warn of a risk of developing fixed paradigms in scenario development that ignore the possibility of different outcomes within the same story line framework. Conceptual frameworks based on one interpretation of a scenario have the potential to create an artificial and undesirable limit on the range of future worlds explored and, therefore, can limit the range of uncertainty that is covered by the scenario. This raises two issues: the need to make these judgments explicit, and the need to think carefully about unifying conceptual frameworks.

For Sandker et al. (2010), the process of creating the scenarios was the most valued part of the narratives and scenario development exercise. The narratives and scenarios were used to make real and relevant the research findings, in a way that allowed both participants and policy makers to connect with the research process and its outputs. Processes of scenario discussion led to insights for preparedness to tackle vulnerability and uncertainty and helped prioritize adaptation decisions (Ravera et al. 2011). In this way, the process of creating scenarios was used to raise questions, not necessarily to predetermine specific outcomes. As such, scenarios worked as a methodological tool as well as providing specific outputs.

QUANTIFICATION, CLIMATE, AND VULNERABILITY

The main challenge encountered in exploring climate and vulnerability relationships through modeling is how to reconcile the disjuncture between the language of mathematics and climate science, given its aura of precision, with the language of qualitative social sciences and narratives. There is real concern that although the results of quantitative models seem authoritative, they may be treated too literally as predictions of the future by policy makers looking for evidence to support different strategies (Reed et al. 2009). Thus, in the final section of this editorial, we would like to explore the role of quantification in scenario development for thinking about climate, vulnerability, and policy in dryland agroecological systems.

The role of quantitative modeling, through a range of approaches such as dynamic systems models (Checkland and Winter 2006), agent-based models (Parker et al. 2003), or fuzzy cognitive mapping (van Vliet et al. 2010), is increasingly recognized as a powerful mechanism for enabling improved communications between researchers and policy makers. Our closing editorial adds new case study analyses to this debate by drawing across a range of methodological approaches and quantification strategies. In doing so, we raise challenging questions about how we approach and interpret narratives, scenarios, and quantitative models. Máñez Costa et al. (2011) used quantitative modeling to explicitly review and question the assumptions of their stakeholders and, as such, their models were used as a methodological tool. This can be seen as a critical form of triangulation of other data sources. Dougill et al. (2010), by contrast, used modeled scenarios as an academic exercise but recognized the potential policy-relevant process that emerged as a consequence. Dougill et al. quantified highly interpretative concepts from their research to provide inputs into their scenarios but they warn of the inherent dangers and uncertainties of making some of these judgments. Although they have been meticulous in pointing out the limitations of their approach and modeled outcomes, there is an inevitable angst at this level of quantification of highly qualitative assumptions (cf. Rounsevell and Metzger 2010). Such quantification angst, and associated caveats on the strength of policy guidance that should be drawn, is typically felt by social scientists grounded in the details of individual stories, whereas natural scientists are perhaps more used to providing definitive quantified statements out of modeled predictions (as per MEA 2005, IPCC 2007, and many local and regional level examples from which these global reports build). A critical lesson here is that it is essential for social scientists to grasp this quantification challenge while still making explicit statements on the situated and partial types of knowledge that produce the scenarios and model outputs (Haraway 1991, Nightingale 2003, Hulme 2008). These challenges must then be communicated effectively to different audiences. Scenarios, whether driven by qualitative or quantitative models, may be interpreted as predicted outcomes and there will always be some danger in how such outcomes are used and communicated. However, these dangers should not cloud their ability to inform and illuminate policy formulation (Carpenter et al. 2006).

There is a further challenge to push the boundaries between nature, culture, and policy. Acknowledging that policy makers are not the only people for whom models can act as useful guides in decision making, Crane (2010) discusses the importance of

incorporating cultural sensitivity and recognition of multiple narratives informing scenarios. These challenges have been explicitly examined in other subject areas. For example, Stewart (2007) examines weather and climate in the United States and discusses how quantitative information is converted to qualitative information to make it more experiential and relevant to people and policy makers, helping them create personal meanings that would otherwise be shrouded in science. Conversely, Metzger et al. (2010) suggest that the ultimate challenge in modeling is to develop flexible techniques that are able to quantify judgment-related variations for alternative scenarios by incorporating multiple processes within the same scenario. Whether approaching this from the natural or social sciences, we need to heed Ravera et al.'s (2011) call for theory building at the interface between social research and mathematical modeling.

Scenarios and modeling raise another dilemma: upscaling and the ability to generalize. Simplification is an inevitable outcome of generalization and thus the accuracy of models needs to be questioned. Here it is useful to distinguish between probable outcomes (statistically significant) and possibilities (qualitative suggestions). There is a danger in attaching probability of occurrence to any given scenario, though there is pressure to do so. The Intergovernmental Panel on Climate Change (IPCC), for example, gives "likelihoods" to help readers interpret their conclusions, and these are based on a combination of authors' opinions, statistical methods, and the degree of consensus in the literature (IPCC 2007, Metzger et al. 2010).

Quinn et al. (2011) attempted to address the dichotomy of prediction versus possibility within their study presented in this special issue. While researching water-scarcity in rural South Africa, they asked respondents to state their preferences to certain future scenario events. By cross-tabulating different scenarios, they attempted to quantify the causal relationship between scenario choices and responses. Although this exercise provided valuable insights into how people think about vulnerability and preparedness, there were also methodological challenges surrounding the weighting of scenarios, and respondents' own perceptions of risk.

To resolve this debate, Sandker et al. (2010) present the concept of a throw-away model. They outline a process that stimulates information exchange and strategy discussion in building a participatory model, but they state that the model itself should be seen as a disposable tool. In this sense, models can be imagined as complex conceptual frameworks that have utility in explanation and suggestion, but provide less contribution in terms of prediction and truth-making (Epstein 2008). Dougill et al. (2010), Sandker et al. (2010), and Epstein (2008) all raise similar questions, albeit in different ways: can throw-away models have a place in rigorous scientific research? In other words, is it possible that such models will ever be valued by both the social and natural sciences (cf. Hulme et al. 2009)? Based on the case studies in this special feature, we suggest that the development and use of such throw-away models have a valuable role to play as they explicitly focus on the process rather than the outcomes, and in policy contexts, this can also build trust and grounded understandings of policy impacts (Schwarz and McRae-Williams 2008).

CONCLUSION

In this special feature, and through the reflections and discussion in this closing editorial, we have responded to Hulme's (2008:2) call for a new starting point in our re-examination of climate change by starting with "contributions from the interpretative humanities and social sciences, married to a critical reading of the natural sciences, and informed by a spatially contingent view of knowledge." At the core of our paper is a desire to address some pertinent and uncomfortable questions about how we, as academics, deal with complexities of language and justify our organizing concepts within our research. To accomplish this, we have considered how these challenges can both help and hinder our desires to be policy-relevant and inform strategies to reduce vulnerability. As academics, we need to continually challenge ourselves and our preconceived tendencies, to reflect upon how we conceptually organize our findings and how we communicate them to make our research relevant and useful for policy making (cf. Epstein 2008). Hulme (2008) asks for spatially contingent views of knowledge and he asks for transparency in how knowledge is situated, how hegemony is achieved, and, thus, how (un)stable particular types of knowledge may be. It is these challenges we need to address through further analysis of case study experiences.

Climate change cuts across the grain of everyday human experience. These experiences need the social sciences to reveal and elucidate the many different perceptions of, and responses to, climate change around the world (Roncoli et al. 2009, Szerszynski and Urry 2010). Climate is constructed in different ways. To repeat Hulme et al.'s (2009) comment, climate and climate change is a co-construction between cultural constraints of the social, and physical constraints of the material, world. Furthermore, climate has both statistical and social foundations (Hulme 2008). Ironically, there is a dominance of climate as understood by statistics, which are then made qualitative (Hulme et al. 2009). Therefore, as Wynne (2010:295) states, climate change can be seen as "less predictive truth machine and more as reality-based social and policy heuristic," as this special feature has shown.

In this special feature, the papers investigated different dimensions of dryland agroecological systems in very different locations, but in their analyses, they all used similar organizing concepts and frameworks: the vulnerability cube (Fraser 2007). Although the papers show the utility of using conceptual frameworks to explore commonalities in different agroecological systems, Crane's paper (2010) reminds us of the danger of overgeneralization and the presumption of idealistic objectivity. We advocate instead a heightened awareness and reflexivity about organizing concepts and our own position as researchers.

In conclusion, we can reflect upon what our collection of case studies contributes beyond their individual merits. The common framework from Fraser (2007), which allows diversity of interpretation and application, allows comparison across the cases. However, realistically scaling up from a multiple case-study approach to draw lessons that make sense at larger scales is challenging. Furthermore, such an approach risks overwhelming the local context at the expense of generic lessons. To address these challenges, we suggest that there is no resolution between these bottom-up/qualitative/place-based approaches and the top-down/quantitative/generalizable approaches. Rather they are two distinct ways of approaching research and practice and there will always be a tension between them. This tension is, in fact, healthy and the aim is not necessarily to resolve, or find one unified theory, method, or outcome. Instead, we should engage in the process, and encourage researchers from different disciplines with different disciplinary languages, to talk, collaborate, and engage effectively with each other and with stakeholders at all levels.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol16/iss3/art14/responses/

Acknowledgments:

The authors would like to thank all those involved in the special issue, and the helpful comments from the reviewers.

LITERATURE CITED

Abelson, J., P. Forest, J. Eyles, P. Smith, E. Martin, and F. Gauvin. 2003. Deliberations about deliberative methods: issues in the design and evaluation of public participation processes. *Social Science & Medicine* 57(2):239-251. http://dx.doi.org/10.1016/S0277-9536(02)00343-X

Adger, W. N., N. W. Arnell, and E. L. Tompkins. 2005. Successful adaptation to climate change across scales. *Global Environmental Change Part A* 15:77-86. http://dx.doi.org/10.1016/j.gloenvcha.2004.12.005

Bravo, M. T. 2009. Vices from the sea ice: the reception of climate impact narratives. *Journal of Historical Geography* 35:256-278. http://dx.doi.org/doi:10.1016/j.jhg.2008.09.007

Carpenter, S. R., E. M. Bennett, and G. D. Petersen. 2006. Scenarios for ecosystem services: an overview. *Ecology and Society* 11(1): 29. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art29/

Challinor, A., E. Simelton, E. D. G. Fraser, D. Hemming, and M. Collins. 2010. Increased crop failure due to climate change: assessing adaptation options using models and socio-economic data for wheat in China. *Environmental Research Letters* 5 (3):1-8. http://dx.doi.org/10.1088/1748-9326/5/3/034012

Chapura, M. 2009. Scale, causality, complexity and emergence: rethinking scale's ontological significance. *Transactions of the Institute of British Geographers* 34:462-474. http://dx.doi.org/10.1111/j.1475-5661.2009.00356.x

Checkland, P., and M. Winter. 2006. Process and content: two ways of using SSM. *Journal of the Operational Research Society* 57:1435-1441. http://dx.doi.org/10.1057/palgrave.jors.2602118

Crane, T. A. 2010. Of models and meanings: cultural resilience in social-ecological systems. *Ecology and Society* 15(4): 19. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art19/

de Haan, L. J., and A. Zoomers. 2005. Exploring the frontier of livelihoods research. *Development and Change* 36(1):27-47. http://dx.doi.org/10.1111/j.0012-155X.2005.00401.x

Dong, S., L. Wen, S. Liu, X. Zhang, J. P. Lassoie, S. Yi, X. Li, J. Li, and Y. Li. 2011. Vulnerability of worldwide pastoralism to global changes and interdisciplinary strategies for sustainable pastoralism. *Ecology and Society* 16(2): 10. [online] URL: http://www.ecologyandsociety.org/vol16/iss2/art10/

Dougill, A. J., E. D. G. Fraser, and M. S. Reed. 2010. Anticipating vulnerability to climate change in dryland pastoral systems: using dynamic systems models for the Kalahari. *Ecology and Society* 15(2): 17. [online] URL: http://www.ecologyandsociety.org/vol15/iss2/art17/

Epstein, M. 2008. Why model? *Journal of Artificial Societies and Social Simulation* 11(4):12. [online] URL: http://jasss.soc.surrey.ac.uk/11/4/12.html

Eriksen, P. 2008. Conceptualizing food systems for global environmental change research. *Global Environmental Change* 18:234-245. http://dx.doi.org/10.1016/j.gloenvcha.2007.09.002

Eyben, R., C. Harris, and J. Pettit. 2006. Introduction: exploring power for change. *IDS Bulletin* 37(6):1-10. http://dx.doi.org/10.1111/j.1759-5436.2006.tb00318.x

Ford, J. D., E. C. H. Keskitalo, T. Smith, T. Pearce, L. Berrang-Ford, F. Duerden, and B. Smit. 2010. Case study and analogue methodologies in climate change vulnerability research. *WIREs Climate Change* 1:374-392.

Fraser, E. D. G. 2006. Food system vulnerability: using past famines to help understand how food systems may adapt to climate change. *Ecological Complexity* 3:328-335. http://dx.doi.org/10.1016/j.ecocom.2007.02.006

Fraser, E. D. G. 2007. Travelling in antique lands: using past famines to develop an adaptability/resilience framework to identify food systems vulnerable to climate change. *Climate Change* 83:495-514. http://dx.doi.org/doi:10.1007/s10584-007-9240-9

Fraser, E. D. G., A. Dougill, K. Hubacek, C. Quinn, J. Sendzimir, and M. Termansen. 2011. Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. *Ecology and Society* 16(3):3. http://dx.doi.org/10.5751/ES-03402-160303

Fraser, E. D. G., A. J. Dougill, W. Mabee, M. Reed, and P. McApline. 2006. Bottom up and top down: analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management* 78:114-127. http://dx.doi.org/10.1016/j.jenvman.2005.04.009

Haraway, D. 1991. *Simians, cyborgs and women.* Routledge, New York, New York, USA.

Holling, C. S., and L. H. Gunderson, editors. 2002. *Panarchy: understanding transformations in human and natural systems.* Island Press, Washington, D.C., USA.

Hulme, M. 2008. Geographical work at the boundaries of climate change. *Transactions of the Institute of British Geographers* 33:5-11. http://dx.doi.org/10.1111/j.1475-5661.2007.00289.x

Hulme, M., S. Dessai, I. Lorenzoni, and D. R. Nelson. 2009. Unstable climates: exploring the statistical and social constrictions of 'normal' climate. *Geoforum* 40:197-206. http://dx.doi.org/10.1016/j.geoforum.2008.09.010

Intergovernmental Panel on Climate Change. 2007. *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* M. L. Parry, O. F.

Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, editors. Cambridge University Press, Cambridge, UK.

Jonas, A., 2006. Pro scale: further reflections on the 'scale debate' in human geography. *Transactions of the Institute of British Geographers* 31:399-406. http://dx.doi.org/10.1111/j.1475-5661.2006.00210.x

Leach, M., I. Scoones, and A. Stirling. 2010. *Dynamic sustainabilities: technology, environment, social justice.* Earthscan, London, UK.

Li, W., and L. Huntsinger. 2011. China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks. *Ecology and Society* 16(2): 1. [online] URL: http://www.ecologyandsociety.org/vol16/iss2/art1/

Máñez Costa, M. A., E. J. Moors, and E. D. G. Fraser. 2011. Socioeconomics, policy, or climate change: what is driving vulnerability in southern Portugal? *Ecology and Society* 16(1): 28. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art28/

Marston, S., J. P. Jones, III, and K. Woodward. 2005. Human geography without scale. *Transactions of the Institute of British Geographers* 30:416-432. http://dx.doi.org/10.1111/j.1475-5661.2005.00180.x

Metzger, M. J., M. D. A. Rounsevell, H. A. R. M. van den Heiligenberg, M. Pérez-Soba, and P. Soto Hardiman. 2010. How personal judgment influences scenario development: an example for future rural development in Europe. *Ecology and Society* 15(2): 5. [online] URL: http://www.ecologyandsociety.org/vol15/iss2/art5/

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and human well-being: synthesis.* Island Press, Washington, D.C., USA.

Newton, A. C., E. Marshall, K. Schreckenberg, D. Golicher, D. W. te Velde, F. Edouard, and E. Arancibia. 2006. Use of a Bayesian belief network to predict the impacts of commercializing non-timber forest products on livelihoods. *Ecology and Society* 11(2): 24. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art24/

Nielsen, J. Ø, and A Reenberg. 2010. Cultural barriers to climate change adaptation: a case study from northern Burkina Faso. *Global Environmental Change* 20(1):142-152 . http://dx.doi.org/10.1016/j.gloenvcha.2009.10.002

Nightingale, A. 2003. A feminist in the forest: situated knowledges and mixing methods in natural resource management. *ACME: An International E-Journal for Critical Geographies* 2(1):77-90.

Parker, D. C., S. M. Manson, M. A. Janssen, M. J. Hoffmann, and P. Deadman. 2003. Multi-agent systems for the simulation of land-use and land-cover change: a review. *Annals of the Association of American Geographers* 93:314-337. http://dx.doi.org/10.1111/1467-8306.9302004

Quinn, C. H., G. Ziervogel, A. Taylor, T. Takama, and F. Thomalla. 2011. Coping with multiple stresses in rural South Africa. *Ecology and Society* 16(3):2. http://dx.doi.org/10.5751/ES-04216-160302

Ravera, F., D. Tarrasón, and E. Simelton. 2011. Envisioning adaptive strategies to change: participatory scenarios for agropastoral semiarid systems in Nicaragua. *Ecology and Society* 16(1): 20. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art20/

Reed, M. S., K. Arblaster, C. Bullock, R. J. F. Burton, A. L. Davies, J. Holden, K. Hubacek, R. May, J. Mitchley, J. Morris, D. Nainggolan, C. Potter, C. H. Quinn, V. Swales, and S. Thorp. 2009. Using scenarios to explore UK upland futures. *Futures* 41:619-630. http://dx.doi.org/10.1016/j.futures.2009.04.007

Reed, M. S., A. Bonn, K. Broad, P. Burgess, T. B. Burt, I. R. Fazey, K. Hubacek, D. Nainggolan, C. H. Quinn, P. Roberts, L. C. Stringer, S. Thorp, D. D. Walton, F. Ravera, and S. Redpath. 2011. Participatory scenario development for environmental management: a methodological framework. *Journal of Environmental Management, in press.*

Reynolds, J. F., D. M. Stafford Smith, E. F. Lambin, B. L. Turner, II, M. Mortimore, S. P. J. Batterbury, T. E. Downing, H. Dowlatabadi, R. J. Fernández, J. E. Herrick, E. Huber-Sannwald, H. Jiang, R. Leemans, T. Lynam, F. T. Maestre, M. Ayarza, and B. Walker. 2007. Global desertification: building a

science for dryland development. *Science* 316:847-851. http://dx.doi.org/10.1126/science.1131634

Roncoli, C., T. A. Crane, and B. Orlove. 2009. Fielding climate change in cultural anthropology. Pages 87-115 *in* S. Crate and M. Nutall, editors. *Anthropology and climate change: from encounters to actions*. Left Coast Press, San Francisco, California, USA.

Rounsevell, M. D. A., and M. J. Metzger. 2010. Developing qualitative scenario storylines for environmental change assessment. *Wiley Interdisciplinary Reviews: Climate Change* 1:606-619. http://dx.doi.org/10.1002/wcc.63

Sallu, S. M., C. Twyman, and L. C. Stringer. 2010. Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecology and Society* 15(4): 3. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art3/

Sandker, M., B. M. Campbell, M. Ruiz-Pérez, J. A. Sayer, R. Cowling, H. Kassa, and A. T. Knight. 2010. The role of participatory modeling in landscape approaches to reconcile conservation and development. *Ecology and Society* 15(2): 13. [online] URL: http://www.ecologyandsociety.org/vol15/iss2/art13/

Schwarz, I., and P. McRae-Williams. 2008. Closing the loop between research and sustainable regional development. *Proceedings of the Sustainable Economic Growth for Regional Australia Conference*, Australia. [online] URL: http://www.segra.com.au/pdf/SchwarzMcRaeWilliamsRevisedAug08.pdf

Sendzimir, J., C. P. Reij, and P. Magnuszewski. 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. *Ecology and Society* 16(3):1. http://dx.doi.org/10.5751/ES-04198-160301

Simelton, E., E. D. G. Fraser, M. Termansen, P. M. Forster, and A. J. Dougill. 2009. Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China (1961-2001). *Environmental Science & Policy* 12:438-452. http://dx.doi.org/doi:10.1016/j.envsci.2008.11.005

Stewart, A. E. 2007. Linguistic dimensions of weather and climate perception. *Climate and Perception* 52:57-67.

Stringer, L. 2009. Reviewing the links between desertification and food insecurity: from parallel challenges to synergistic solutions. *Food Security* 1:113-126. http://dx.doi.org/10.1007/s12571-009-0016-0

Szerszynski, B., and J. Urry. 2010. Changing climates: introduction. *Theory, Culture & Society* 27(2-3):1-8.

Thomas, D. S. G., and C. Twyman. 2004. Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari. *Land Degradation and Development* 15: 215-231. http://dx.doi.org/doi:10.1002/ldr.610

van Vliet, M., K. Kok, and T. Veldkamp. 2010. Linking stakeholders and modellers in scenario studies: the use of fuzzy cognitive maps as a communication and learning tool. *Futures* 42 (1):1-14. http://dx.doi.org/10.1016/j.futures.2009.08.005

Vincent, K. 2007. Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change* 17:12-24. http://dx.doi.org/10.1016/j.gloenvcha.2006.11.009

Wynne, B. 2010. Strange weather, again: climate science as political art. *Theory, Culture & Society* 27(2-3):289-305. http://dx.doi.org/10.1177/0263276410361499