

Resilience Assessment as a tool for understanding the Amazon frontier as a social-ecological system

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doi:10.18472/SustDeb.v7n2.2016.15134

Received 07.05.2015

Accepted 26.04.2016

ARTICLE – DOSSIER

ABSTRACT

This article introduces resilience thinking and a methodology for Resilience Assessment that consists of defining the system (key issue and system boundaries in time and space); looking at history (timely and cross-scale drivers and interactions); specifying resilience of what to what (defining attributes and variables); scenarios (likely future drivers and possible desirable and undesirable future regimes); and developing management considerations to promote desirable scenarios. Resilience assessment for three major social groups of Cotriguaçu municipality in Mato Grosso, Brazil – medium to large landholders, the Rikbaktsa indigenous people, and family farmers – found that each social group has gone through multiple iterations of the growth-collapse-reorganization adaptive cycle and that the dynamics of this system are largely determined by economic and policy drivers that come from a larger scale. Contributions to the resilience assessment methodology are to base the analysis of the system on its historical trajectory, seek to explicitly incorporate the perspectives of local actors, and use scenario analysis to develop possible management interventions.

Keywords: Resilience. Social-ecological systems. Amazon frontier. Resilience Assessment. Drivers. Attributes. Scenarios.



RESUMO

Este artigo apresenta o pensamento de resiliência e uma metodologia para avaliação desta que consiste em definir o sistema (pergunta-chave e limites do sistema no tempo e no espaço); olhando para a história (linha do tempo, fatores desencadeantes e interações entre escalas); especificando a resiliência “do que” e “contra que” (definição de atributos e variáveis); cenários (prováveis fatores desencadeantes futuros e possíveis regimes futuros desejáveis e indesejáveis); e desenvolvimento de considerações de gestão para promover cenários desejáveis. A avaliação de resiliência de três grandes grupos sociais do município de Cotriguaçu em Mato Grosso, Brasil – proprietários de terras médias e grandes, os povos indígenas Rikbaktsa e agricultores familiares – revelou que cada grupo social passou por várias iterações do ciclo adaptativo (crescimento-colapso-reorganização), e que a dinâmica desse sistema é em grande parte determinada por fatores econômicos e políticos que vêm de uma escala maior. Contribuições para a metodologia de avaliação de resiliência incluem basear a análise do sistema em sua trajetória histórica, procurar incorporar explicitamente as perspectivas dos atores locais, e usar a análise de cenários para desenvolver possíveis intervenções de gestão.

Palavras-chave: Resiliência. Sistemas socioecológicos. Fronteira Amazônica. Avaliação da Resiliência. Fatores Desencadeantes. Atributos. Cenários.

INTRODUCTION: RESILIENCE THINKING AND ITS RELEVANCE TO CONSERVATION AND DEVELOPMENT

The Amazon is a complex region where social and economic human activities affect and are affected by biophysical factors such as water, climate, and the biota. Given the interwoven challenges of meeting human needs while maintaining ecosystem services, and the interactions between human and biophysical variables at multiple scales, it is useful to conceptualize the Amazon as a linked social-ecological system (BUSCHBACHER, 2014; REDMAN *et al.*, 2004; LIU *et al.*, 2007). Catalyzed by the first rubber boom of the late 19th century, the construction of the Belem-Brasilia highway in the 1960s, the Greater Carajas project of the 1980s, and many other forces, the Amazon has been a particularly dynamic social-ecological system.

A key characteristic of all complex systems is their potential for unanticipated, rapid (non-linear) change, often the result of positive feedback processes (BUSCHBACHER, 2014). The Amazon has long been characterized as a contested frontier where competing groups struggle to claim land, forest and mineral resources, often under conditions of open access and limited governance (SCHMINK; WOODS, 1992, LITTLE, 2001). While massive infrastructure investments continue (FEARNSIDE; LAURENCE, 2012), there are indications of a possible “tipping point” that could end the process of continuous frontier expansion into open access lands (BROWDER *et al.*, 2008; NEPSTAD *et al.*, 2009; DAVIDSON, 2012): deforestation rates have declined dramatically since 2004 (NEPSTAD *et al.*, 2009), the protected area system now covers 43.9% of the Legal Amazon¹ (VERISSIMO *et al.*, 2011), land tenure is being regularized (BRITO; BARRETO, 2011), fewer agrarian reform settlements are being created (OJEDA, 2012) while urbanization is increasing (SIMMONS *et al.*, 2002), and agribusiness is evolving from spatial expansion to intensification (MACEDO *et al.*, 2012). A “closing of the frontier” - as occurred in North America at the end of the XIX century when westward expansion became consolidated and was considered a major turning point in American history (TURNER, 1893) - could drastically alter the dynamics of the Amazon by intensifying conflict over the limited remaining land and constraining land use strategies that depend on colonization of open access lands.

The thesis is not that this particular transformation is likely, only that there are multiple unexpected possible futures that could radically alter the context of the livelihood strategies that have been implemented by indigenous peoples, colonists, farmers, loggers and ranchers over the past decades. The actors in this system will likely be challenged by the difficulty of anticipating thresholds, the emergence of surprises, and unexpected consequences of climate change, a new wave of infrastructure development, and exacerbated social-ecological conflicts (LEVIN, 2005).

Resilience concepts and thinking can contribute to adaptive management of social-ecological systems (HOLLING, 1973; HOLLING; GUNDERSON, 2002; FOLKE, 2006). Key aspects of resilience thinking are to recognize that human society is embedded in social-ecological systems with strong connections between human-driven (e.g. social, economic and political) and biophysical (e.g. climate, forests, water) processes; that these processes interact at multiple scales from local to global; and that social-ecological systems exhibit emergent properties and non-linear, unpredictable change (WALKER; SALT, 2006). Resilience is the capacity of a system to absorb external disturbances and still maintain essential properties, including ecosystem services essential to human well-being. Resilience is a much more dynamic concept than sustainability; rather than seeking to define some maximum level of disturbance that cannot be exceeded, the focus is on capacity for change (BUSCHBACHER, 2014). Whereas social-ecological systems are often managed to maximize a limited number of resources based on expectations of linear production functions (HOLLING; MEFFE, 1996), resilience thinking seeks to inform management for a system's capacity to learn, self-organize and adapt in the face of unpredictable and non-linear change.

This article opens a Special Issue on the application of resilience thinking as a tool for understanding and, potentially, managing the Amazon frontier. The Special Issue is based on the results of a leadership-training program in which a multi-disciplinary and multi-institutional group of professionals used resilience concepts and methods to analyze the dynamics of complex social-ecological systems in the northwest region of Mato Grosso in the Brazilian Amazon. Participants were motivated to explore resilience thinking and concepts because they were considered potentially relevant to a series of questions that directly affect their work:

- What are the critical drivers of land-use decisions by different agents, specifically medium to large-scale landowners who engage in ranching and logging, the indigenous people, and smallholder colonists? How do individual landowner decisions accumulate to create broader system behavior (social, economic and environmental impacts)?
- What are the key interactions in the system (between landowners, policies, across scales, etc.)? Can we identify potential tipping points (major non-linearities, whereby small changes of inputs create large, sudden changes of outputs)?
- How does the system self-organize and what is the capacity for learning and adaptation? How can these capacities be increased?

This article introduces resilience thinking and its relevance to the work of conservation and development professionals, and presents a Resilience Assessment tool for applying resilience thinking to increase understanding of complex social-ecological systems. This tool was incorporated into a Specialization Course on Collaborative Management of Social-Ecological Systems in the Brazilian Amazon, from which this Special Issue originated. The following five articles present case studies of applying resilience thinking to specific social-ecological systems in the Brazilian Amazon. The concluding article of the Special Issue (BARTELS *et al.*, 2016) presents the pedagogy that was used to co-construct a shared space for reflection and learning about resilience and collaborative management in the course. It describes challenges and lessons learned from applying the Resilience Assessment tool in a participatory process that incorporates diverse interests and worldviews, and reflects on the applicability of the Resilience Assessment tool for territorial management in disputed areas of the Amazon frontier.

This article first presents the regional and institutional context of the Specialization Course, discusses the Resilience Assessment tool that was developed and applied in the course, and concludes with observations about the regional social-ecological system that emerged from the assessment.

REGIONAL AND ORGANIZATIONAL CONTEXT

The four-module, field-based Specialization Course was carried out in the municipality of Cotriguaçu in northwest Mato Grosso, a state within the Brazilian Amazon (see Figure 1). Mato Grosso has seen rapid expansion of agriculture and ranching, and since 2004 has been the state with highest deforestation

rates in Brazil (Baby, 2012). Northwest Mato Grosso is the most isolated region of the state, where extensive colonization has occurred since the 1980s but infrastructure is poor and there is a large area of remaining forest (81% as of 2008, Lentini, 2010). Cotriguaçu has a mix of loggers, ranchers, smallholder colonists, and separate indigenous and conservation protected areas, thereby being representative of many of the social-ecological conflicts and dynamics of the Amazon frontier.

When the course began in 2010, Cotriguaçu had been selected as a target area for development of Mato Grosso's pilot REDD² project (ICV, 2009). Although no REDD payment scheme has gone forward, the regional NGO Instituto Centro de Vida, the state environmental agency SEMA and the municipal government of Cotriguaçu are collaborating on a major project aimed at making land use in the region more sustainable³.

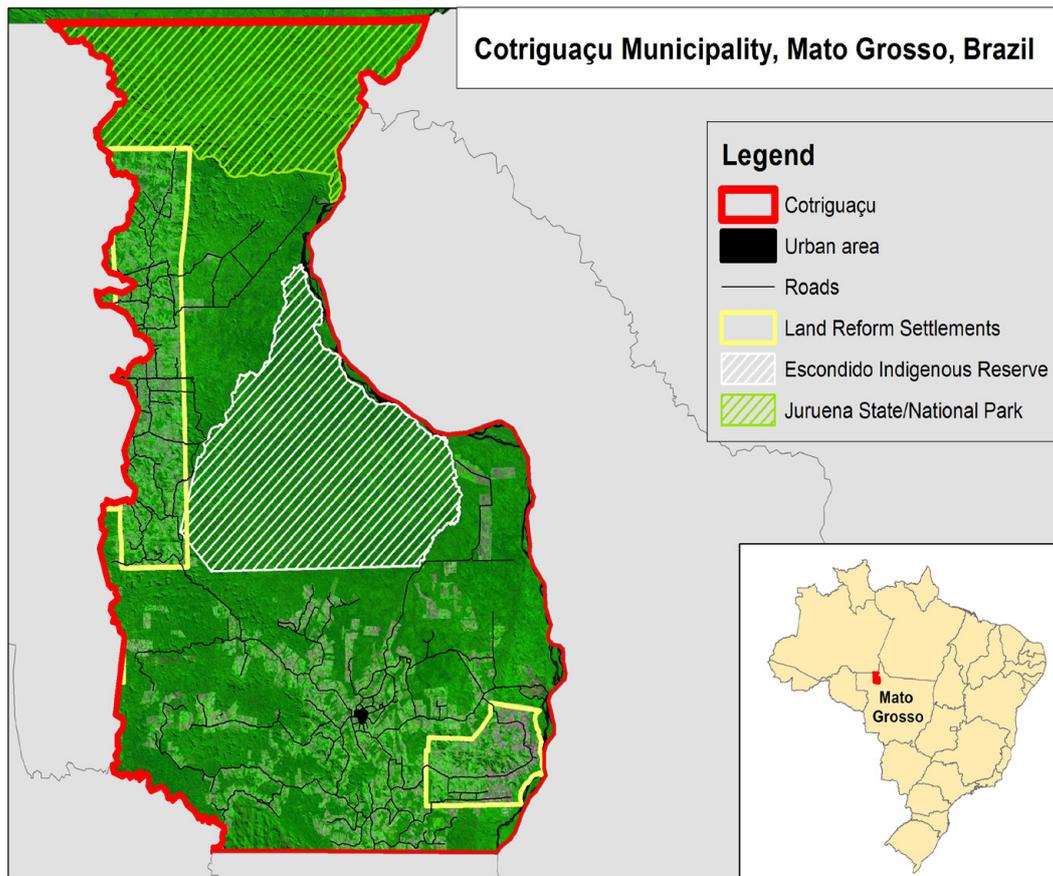


Figure 1 - Map of Cotriguaçu municipality in northwestern Mato Grosso, showing different land tenure and cover categories. Elaborated by Paula Bernasconi based on data from IBGE, Incra, Sema and Funai.

The Specialization Course, while simultaneously addressing themes of collaboration and critical pedagogy (Bartels *et al.*, 2016), was organized around a series of exercises to practice and test the Resilience Assessment methodology presented below. Course participants formed three groups and carried out the resilience assessment exercise for the three major social groups who directly manage resources and make land-use land-cover change decisions in Cotriguaçu: (i) medium to large landholders who engage in logging and ranching, (ii) the Rikbaktsa indigenous people, and (iii) family farmers. These groups of participants worked in parallel to understand the history, characterize key attributes and goals, and consider possible future scenarios for each social group. For the final stage of analysis, the groups came together to consider the interactions between the different social groups of Cotriguaçu municipality and how potential management actions could promote a positive future for the groups both individually and collectively.

The following articles of this Special Issue present the results of the Resilience Assessment exercise for the medium and large landowners of Cotriguaçu (BERNASCONI *et al.*, 2016), and for the Rikbaktsa indigenous people who inhabit Cotriguaçu and other territories in northwestern Mato Grosso (ALMEIDA *et al.*, 2016). In addition to the group exercises, each course participant carried out an individual project applying resilience concepts to their own work as conservation and development professionals, whether in Cotriguaçu or in other communities of the Brazilian Amazon. Olival (2016) adapted the resilience assessment methodology as a tool for strategic and operational planning of Instituto Ouro Verde (IOV), a nongovernmental organization that works with the family agriculture social group in northern Mato Grosso. Simão and Athayde (2016) assessed the resilience of traditional riverine communities that suffered forced relocation due to construction of a hydroelectric dam in Rondônia, with a focus on cultural resilience. Finally, Sobreiro (2016) analyzed system change, reorganizations and resilience throughout the historical evolution of the system of ornamental fisheries in the municipality of Barcelos (Amazonas state).

RESILIENCE ASSESSMENT FRAMEWORK

The Resilience Alliance is a research network comprised of scientists and practitioners from different disciplines working to develop and apply resilience thinking (www.resalliance.org). The Alliance has developed a procedure of “Resilience Assessment” as “an alternative way of thinking about and practicing natural resource management” aimed at “practitioners, managers and stakeholders who have the desire or ability to influence decisions and actions in the system” (RESILIENCE ALLIANCE, 2007a). There are multiple formats for carrying out a resilience assessment, as presented in two versions of a Workbook for Practitioners (RESILIENCE ALLIANCE, 2007a, 2010), a draft Workbook for Scientists (RESILIENCE ALLIANCE, 2007b) and publications such as Walker *et al.* (2009) and Strickland-Munro *et al.* (2010). These are quite consistent in overall approach: a group with expert knowledge defines system boundaries, components and key issues; characterizes actual and potential system dynamics (thresholds and alternative states); and uses this understanding to decide “where and how to intervene in the system in order to enhance resilience” (RESILIENCE ALLIANCE 2007a). However, they vary considerably in terms of organization, sequence and specific steps to be carried out. Furthermore, there is little to no guidance on how to determine the key issues, attributes or desirable system states, but rather an implicit assumption that such determinations can be quickly and objectively made (as indicated by the expectation that the entire assessment can be carried out in a workshop lasting around three days, RESILIENCE ALLIANCE 2007a).

These limitations became clear when we attempted to use the Resilience Alliance Workbook for Practitioners (RESILIENCE ALLIANCE 2007a) as a guideline or “road-map” for carrying out resilience assessments in Cotriguaçu as part of the Specialization Course. Given the highly variable worldviews, perspectives and epistemologies brought to the course by the diverse and multi-disciplinary group of participants, the Workbook was contested, negotiated and revised throughout the process, and was applied differently by each group, reflecting their particular perspectives and the very different situations of the three social groups under study.

Bartels *et al.* (2016) provide a detailed reflection on the challenges and limitations which arose, and the implications of these for using Resilience Assessment as a tool for adaptive co-management. In spite of the difficulties, the group was able to develop its own approach to carrying out the Resilience Assessment, which is presented in Figure 2 and detailed below. This new version of the Resilience Assessment methodology presents several advances. First, it recognizes that there will be diverse perspectives on defining key issues and system boundaries, and allows these to vary across groups. Secondly, it emphasizes understanding the system’s history, and uses the history as a basis for defining key drivers of change and cross-scale interactions. Third, it acknowledges that definition of key system attributes has great significance for characterizing desirable and undesirable system states, and delays this step until a thorough analysis of system history has been carried out. Significantly, the historical analysis and other methods seek to incorporate the perspectives and values of local stakeholders in the definition of key attributes and desirable system states. Finally, it uses scenarios as the key tool for articulating desirable future states and creates the potential for using scenarios to catalyze dialogue among social groups and conflicting interests.

The next section describes the steps of a Resilience Assessment and how they were carried out in Cotriguaçu, following the structure presented in Figure 2.

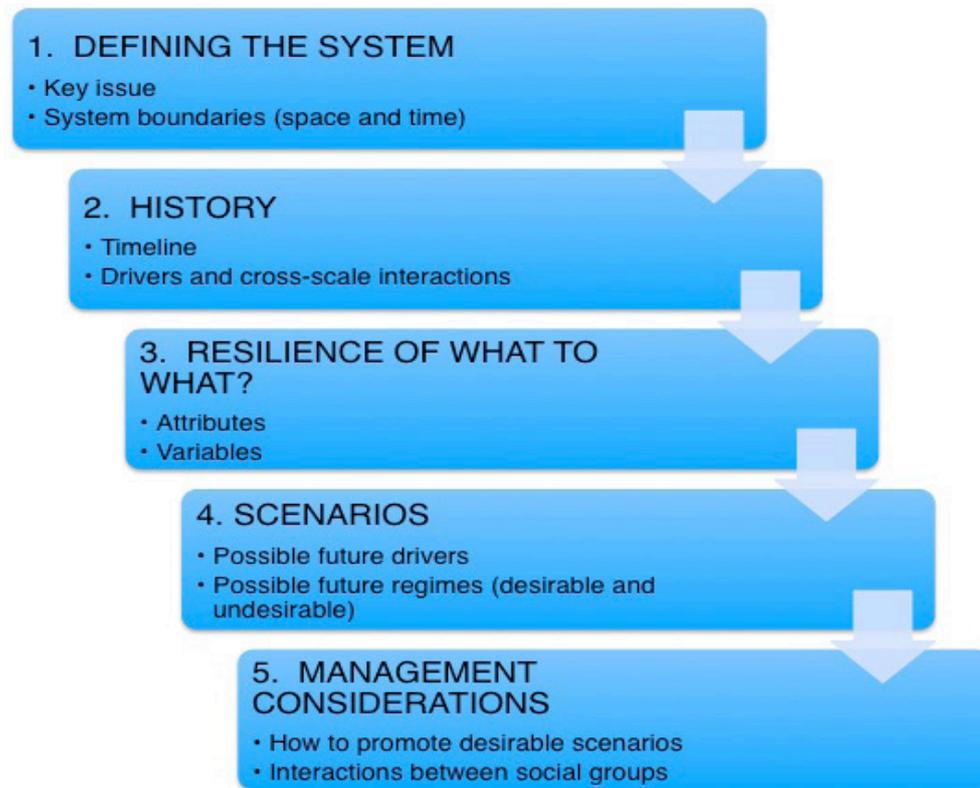


Figure 2 - Resilience Assessment methodology Developed by the authors, adapted from RESILIENCE ALLIANCE 2007a.

DEFINING THE SYSTEM

a. Definition of Key Issue

Resilience assessment starts with definition of a “key issue.” In Cotriguaçu, the key issue was defined as: How to maintain the ecological, economic and social sustainability of the livelihood systems of each major group of social actors. This definition is centered on the social groups and focuses on maintaining their presence and viability. While land use and environmental impacts are explicitly included in the analysis, the emphasis of this framing is much more socially-oriented than in much of the resilience literature (e.g., WALKER *et al.*, 2009). As will be seen in the subsequent articles, this emphasis is consistent with the worldview of the social actors themselves, who emphasize social and economic goals above ecological concerns.

b. System Boundaries and Focal Scale

Barnes and Child (2014) have suggested that “meso” scales play a key mediating role in the dynamics of social-ecological systems by linking and integrating processes across scales. For example, in the Brazilian Amazon municipal level actors and organizations (meso scale) are emerging as a key level of governance that mediates between state and national governmental policies (macro scale) and the land management decisions of individual landowners and producers (micro scale). Recent policy changes associated with Brazil’s successful deforestation reduction have devolved considerable authority and responsibility for environmental management to municipal governments (NEVES 2012). For priority municipalities with high deforestation, including Cotriguaçu, credit and licensing restrictions were put in place in 2006 that required significant advances in environmental management before they could be lifted (MAIA *et al.*, 2011). The focal spatial scale for this exercise was therefore defined as the municipal level. The micro scale was in turn defined as individual families, businesses, ranches or landholdings. Macro scale then refers to state, national or global processes, such as public policies and markets.

The time scale of analysis was defined based on the history of Cotriguaçu and the temporal dynamics of the colonization and land use processes being studied. Thus the historical analysis went back to the early 1980s. The exercises with future scenarios looked at a horizon 10-20 years into the future, in order to be relevant to the current reality of the social groups and their potential planning and investment horizons. As will be described in the article by Almeida *et al.* (2016), these dates were modified by the indigenous group to reflect the specific historical dynamics of this social group.

HISTORY

a. Timeline: Learning about the History from the Actors

The actual analysis of each social-ecological system began with creation of a timeline that described the history of that group since its arrival in Cotriguaçu, based on formal and informal interactions with a sample of the actors in each group. These included visits and interviews carried out with actors at their farms and sawmills, land reform settlements and indigenous territories. The course also included meetings with key informants from the municipal government who represent the interests and provide services to these different social groups. Structured and semi-structured interviews were supplemented by the knowledge of the course participants, based on long experience working with these groups.

Timelines that were produced in this process, as presented in the following articles of this Special Issue, were interpreted and presented in terms of the exploitation-colonization-release-reorganization Adaptive Cycle heuristic model of Holling and Gunderson (2002; see also BUSCHBACHER 2014). They show system change over time as a series of adaptive cycles, and indicate the degree to which changes were gradual or sudden. This brought the focus to key moments at which the system underwent major change, conceived as release and reorganization.

In addition to documenting changes in the social-ecological system over time, this step of the assessment was important for understanding how the actors were affected and how they responded, in order to gain insight into their interests, goals and concerns. Interactions with the actors and the process of studying the history of their social group was an important entry point for understanding the objectives, challenges, values and perspective of the actors in each social group, and thus relevant to defining the key attributes that characterize the system (step 3 of the assessment), as well as the desirable future regimes for the scenarios exercise (step 4).

b. Drivers and Cross-scale interactions

The historical analysis showed how the system has changed over time, and this made it possible to identify the main internal and external causal factors, or “drivers”, that have been prevalent in the past for each social group. These drivers elucidate the interactions between the focal scale (a given social group in Cotriguaçu municipality, for example) and the macro and micro hierarchical scales in which it is nested. Based on this analysis, complemented by discussions with actors about their concerns and expectations for the future, we projected likely future drivers of the system for the scenarios exercise in step 4.

RESILIENCE OF WHAT TO WHAT?

This step is known as defining “Resilience of what to what?” because a set of “attributes” are chosen to characterize the essence of the system and thereby can be used to describe the state of the system at any one point in time (resilience of what), while the drivers indicate the main forces that are affecting the system and may cause the state of the system to change (resilience to what)⁴ (CARPENTER *et al.*, 2001).

a. Attributes

Attributes are key characteristics, relatively few in number, which describe the state of the system. While presented in the Resilience Alliance Workbook as objective and value-neutral, attributes explicitly frame (GOFFMAN 1974) any discussion of the desirable state of the system and therefore incorporate the practitioner's cultural, ethical and epistemological perspective. We therefore aimed to define the attributes, for each social group that we analyzed, from an emic perspective, i.e. as the actors themselves would represent the key characteristics of a desirable or undesirable state. The attributes were therefore key indicators of the persistence of the social groups, relative to their desirable identity characteristics. For example, a diversified productive system was considered a key attribute of family agriculture, whereas medium and large landowners prioritized economic viability over diversification. Because our "key issue" was framed around maintenance of each social group and its livelihood strategy, definition of attributes was integrally related to questions of identity, such as the language and culture of the indigenous group.

Attributes were defined through an intensive process of group discussion during several course modules and online communication between modules, and is based on each group of authors' understanding of the actors' perspective and values, as well as on the theoretical and epistemological approach adopted by those authors. Because it was found to be so determinative of the lens used to look at the system, a considerable amount of discussion and debate went into the definition of attributes in each of the case studies.

b. Variables

An important step in defining attributes is to operationalize them by defining measurable indicators or variables. This was necessary to move beyond having general topics (e.g. labor or profile) to being explicit about how the state of that attribute could be measured. For example, the family agriculture group operationalized "labor" as the proportion of an establishment's labor that is wage-based, while the medium/large landowners group operationalized that social group's "profile" as the degree to which Amazon ranchers are villainized by the media. It is the state of the attribute, i.e. the level of the variable, which is needed to characterize the state of the system. Defining variables to operationalize the attributes was part of the group discussion and was logically necessary in order for the attributes to be applicable to defining the state of the system. Because this work was done as an exercise within a learning process rather than as part of a major data collecting effort, authors frequently used relative terms to characterize the variables, i.e. high/medium/low or increasing/decreasing.

SCENARIO ANALYSIS

While Steps 1-3 of the Resilience Assessment are aimed at characterizing the system and understanding its historical and actual dynamics, Steps 4 and 5 are forward-looking and are meant to guide management action. This phase begins with scenario analysis, which is a forward-looking tool to generate hypotheses about how the system could change in the future (PETERSEN *et al.*, 2003; VAN DER HEIJDEN, 2005). Scenario analysis can be used as a review and integration tool to envision and summarize the whole resilience assessment, and highlight key interconnections, conflicts, synergies and trade-offs between the system "parts" within the multi-stakeholder landscape. The scenarios were developed as a facilitated exercise during course modules, initially focusing on each of the three key social groups of Cotriguaçu municipality. The three sets of scenarios were then used in the final step of the Resilience Assessment as an input to explore interactions between social groups while looking for outcomes that might be desirable for all of the actors.

a. Likely Future Drivers

The scenario analysis started with a review of the main findings from previous steps in the Resilience Assessment: history, drivers and the attributes selected to define the system state. To begin the scenario analysis, the historical analysis and past drivers were combined with the course participants' knowledge of current dynamics of the Amazon region to identify likely drivers of major system change,

at multiple scales, in the next 1-2 decades. These included recent and projected policy changes, market dynamics, infrastructure development, and observed and projected trends in the quality and quantity of natural resources.

b. Possible Future Regimes

The question that scenario analysis brings to the fore is how driving forces will affect the attributes of the system in the future. From a resilience perspective, will the set of attributes remain within the same regime (system resilience), or will there be a fundamental change of regime (transformation)? It is important to recognize that scenario analysis is not an attempt to predict the future, but rather a tool to visualize different possible system trajectories in terms of consistent, plausible stories (RASKIN *et al.*, 2005; VAN DER HEIJDEN, 2005). Therefore, positive and negative scenarios were created for each social group by positing mechanisms by which the potential drivers could lead to desirable or undesirable states for the system attributes. Each of these scenarios consisted of:

- i) an overall description of the hypothetical future system regime;
- ii) the projected state of the variables for each of the attributes defined in step 3 of the Resilience Assessment for that regime; and
- iii) a narrative story - expressed both textually and artistically through drawing or dramatization - recounting how the system could move from current conditions to this possible future regime.

Scenarios for each group included consideration of how a given scenario could affect, or be affected by, the dynamics of the other social groups in the system. For example, a scenario in which government policy changes allow large landholders to harvest timber from the indigenous reserve would not only increase economic opportunities in that sector, but would also increase the supply of off-farm wage labor opportunities for farmers (who often work in sawmills), while reducing the territorial integrity of the indigenous community.

MANAGEMENT CONSIDERATIONS

Resilience Assessment is presented in the Resilience Alliance Workbooks as a process that terminates in a series of management actions. As explained above, the case studies presented in this Special Issue were not engaged in actual management processes, but carried out as an exercise to learn about the Cotriguaçu social-ecological system and the resilience methodology itself. Nevertheless, in this final step of the assessment, the scenario exercise was used to catalyze reflection and discussion among the group members about how the findings of a resilience assessment could be used to promote desirable scenarios. This was first done within each of the three different social groups (medium and large landholders, indigenous community, family agriculture), and then by looking at the entire set of social groups and how they interact.

a. How to Promote the Desirable Scenario?

Based on the awareness of possible future drivers and regimes that emerged from the scenario analysis in step 4, and taking into consideration the possible negative or positive interactions with other social groups, groups were tasked with identifying steps to: move the present system in a direction perceived as positive; prepare for possible future risks, drivers, and alternative scenarios; and/or promote general resilience in terms of learning, capacity, flexibility, etc.

b. Interactions between Social Groups

Until this point, three resilience assessments were carried out in parallel, one for each social group. In this final step, the focus shifted to the question of how the different social groups interacted with each other and, specifically, on how the desirable scenario of one social group would affect the other social groups. Representatives of each group presented their proposed actions to increase their own group's resilience to each of the other groups. Each group then evaluated how the desirable scenarios and

proposed actions of the other groups would positively or negatively affect them (as in the example of logging in the indigenous territory given above). Given an understanding of these interactions, each social group could modify its desirable scenarios and proposed strategies in order to have a more positive interaction with the other sectors, or it could decide to engage in conflict and competition in order to put its own interests above that of the other groups.

GENERAL OBSERVATIONS ON THE COTRIGUAÇU SOCIAL-ECOLOGICAL SYSTEM THAT EMERGED FROM THE RESILIENCE ASSESSMENT EXERCISE

The resilience assessment exercises carried out for three major social groups of Cotriguaçu provided general insights about the regional social-ecological system. General findings for each of the three social groups, and their interaction in the integrated focal system of Cotriguaçu as a whole, are presented below.

HISTORY

The historical analysis revealed that each social group has gone through a series of changes that fit well with the heuristic model of the adaptive cycle. Table 1 presents the major historical cycles identified for each group. Two complete cycles were clearly identified for the system of medium and large landowners, based on the predominant production models (initially agriculture with some logging; then ranching and extensive logging). A third cycle is now under way, with a tendency, not yet consolidated, for more sustainable production systems.

Table 1 - Historical cycles and drivers of system change from the historical analysis, and possible future drivers identified in the scenario exercise, for three social groups in northern Mato Grosso, Brazil.

Social Group	Major Historical Cycles	Principal Drivers of System Change	Potential Future Drivers
Medium and Large Landowners (BERNASCONI <i>et al.</i> , 2016)	Colonization; agricultural production with some timber harvesting (1974 - 1990)	Amazonian colonization policies combined with displacement from southern Brazil; Structural adjustment and Neoliberal policy reform leading to collapse of Cooperative	Positive: <input type="checkbox"/> Global food demand <input type="checkbox"/> Paving of state highways
	Ranching plus extensive timber harvesting (1990-2006)	Global environmental concerns about increased Amazon deforestation; Law enforcement operations against illegal deforestation and logging	Negative: <input type="checkbox"/> Global competition for food supply <input type="checkbox"/> Increased environmental control
	Restructuring of ranching and logging for sustainability (2006-present)	Decentralization of forest licensing; Deforestation control policies; Spittle bug infestation in pastures	
Rikbaktsa Indigenous People (ALMEIDA <i>et al.</i> , 2016)	Time immemorial		Hydroelectric dams
	Colonization of the Juruena Valley	Epidemics Colonization by rubber tappers	Possible weakening of legislative protections
	Missionary pacification (1950s)	Anchieta mission, including transfer of children and youth to Utiariti boarding school	Possible division of Cotriguaçu municipality
	Land regularization and sociopolitical restructuring (1970s-1990s)	Return of children from missionary school Demarcation of indigenous reserves	
	Territorial conflicts (2000+)	Expansion of agribusiness and infrastructure	

Family Agriculture (OLIVAL, 2016)	Antecedents to colonization	History of other regions of Brazil Predominant development model (globalized capitalism)	Increased imposition of environmental controls
	Colonization (1970s)	Private colonization vs. public settlements	Public policies favoring large-scale production
	Community infrastructure development and decay	National Institute for Land Reform (Incra) programs Rural Electrification program	
	Community organization development and decline	Social dynamics within communities	
	Evolution of production systems from agriculture to ranching	Climate Commodity prices Marketing difficulties Government credit programs that favor ranching	
	Gold mining (1980s-1990s)	Discovery of gold and high prices on the world market	
	Support for production and commercialization (since 2004)	National program for Food Acquisition from Family Agriculture (PAA) NGO projects	
	New production challenges	Spittle bug infestation Pasture sudden death syndrome Water scarcity	

The family agriculture group's colonization and settlement process is marked by growth and decline of infrastructure and community organization, and a shift of production systems from diversified agriculture to an emphasis on cattle. The dynamic of this system was strongly marked by a gold mining boom in the region, which depopulated farms, caused a spike in immigration and led to environmental degradation.

The Rikbaktsa indigenous group has a far longer history in the region than any of the other groups, indicated by recognition of history rooted in "time immemorial". This system has suffered a series of reorganizations, including deterritorialization, missionary pacification, and reterritorialization in a subset of their initial homeland; the ongoing history is one of continued struggle for territory, rights, development to meet basic needs, and cultural self-determination. While the family agriculture and medium and large landowner social groups identify a beginning of their history in the region with initial colonization in the 1980s, both also recognize that the "pre-history" in their regions of origin is essential to understanding the groups' dynamics in Mato Grosso.

Looking at all three groups together, it is striking how dynamic this system is: dramatic changes to production systems, land use and territorial control. Nevertheless, the medium and large landowners have persistently maintained an economic, political and culturally dominant position; they have shifted between farming, logging and ranching while maintaining or expanding territorial control and high levels of economic production and political power. The Rikbaktsa, on the other hand, have gone through processes that threaten their very existence. Family agriculture has maintained its presence in the region, but has yet to consolidate a socioeconomic and production model that guarantees a high quality of life; its future persistence and development are therefore uncertain.

DRIVERS AND CROSS-SCALE INTERACTIONS

Review of the principal drivers of historical change in this system (Table 1) calls attention to a striking observation: for every social group, the dynamics of the system are largely determined by factors from a larger scale, i.e. decisions and processes related to global markets, national policies, land use change in southern Brazil, etc.

The Rikbaktsa were influenced by waves of immigration, from early explorers (Bandeirantes) who brought epidemic diseases, to rubber tappers, missionaries and agricultural colonists who invaded their ancient territory. The federal government has had significant impact, by promoting and supporting each of these waves of immigrants, but also by providing rights and demarcation of limited portions of Rikbaktsa territory.

Both family farmers and medium/large landowners initially came to the region because of national development policies and land use dynamics in other parts of Brazil. The history of both of these groups has been profoundly influenced by governmental policy related to infrastructure, economic support, and environmental regulation. For example, Cotriguaçu's agricultural cooperative failed in 1990 due to changes in federal farm policies, and its timber industry was largely shut down by the Curupira law enforcement operation in 2005. On the other hand, arrival of roads, electricity and cellular telephone, all the direct or indirect effect of state and federal policies, have had a large impact on the quality of life in these communities.

This observation does not negate the agency of the local actors. The system is strongly constrained by external policies and forces, and cycles of collapse and reorganization have been driven by events at larger scales. Nevertheless, the history of the region is determined by how local actors organize their farms and communities, learn and adapt to these driving forces. Medium and large landowners not only adapted their production systems in response to prevailing policies and economic opportunities, they organized internally and with political and lobbying groups at state and national scales to influence economic and environmental policies. Indigenous and family agriculture groups also adapted to economic and market forces, for example converting from agriculture to ranching, or producing Brazil nuts for national and global markets. These groups also organize internally and externally, through alliances with NGOs and national organizations, to resist government policies or demand favorable treatment. Nevertheless, it is noteworthy that this local agency is often reactive and generally aimed at influencing the determinative driving factors that come from a larger scale than their own communities or region.

ATTRIBUTES

The key attributes that were considered to best characterize the state of each social group's socio-economic system were defined from an emic perspective, taking into account the perspective of the members of that social group. Nevertheless, the definition of the attributes is very much an interpretation made by the research groups, either based on several rounds of interviews (indigenous and medium/large landowner groups) or defined in a participatory process between community leaders and extension agents (family agriculture group). The definition of attributes was challenging because, as with any ethnographic representation, it is influenced by researchers' conceptual frameworks and the limitations of their analysis (sample size and representativity, communication barriers etc.). Initially focusing the analysis on history was helpful, because identification of key moments and what changed in those moments illustrated key factors and processes.

Table 2 lists the key attributes that were identified for each social group, organized according to three broad categories that were common to all of the groups: access to land and resources; economic; and social organization. These attributes embody the main concerns and interests of each social group, the factors that they prioritize when evaluating the state of the system and the desirability of a system state.

Table 2 - Attributes identified for three social groups in northern Mato Grosso, Brazil, organized by category.

Attribute Categories	Medium and Large Landowners	Rikbaktsa Indigenous People	Family Agriculture
Land rights and access to resources	Control over land	Territorial sovereignty	Relationship with the land
Income and economic	Economic viability	[A consequence of territorial sovereignty]	Use of family labor Production system
Social organization	Social organization Public profile	Socio-cultural self-determination	Social organization

Control over land (medium and large landowners) and territorial sovereignty (indigenous) signify access to key resources. In fact, for the indigenous group, there was no specific attribute identified for economics, because economic development was considered to depend on sovereignty over land. In contrast, the family agriculture group focused on the nature of the relationship with land, i.e. whether it was seen as an investment or a means to social reproduction, highlighting the concern of this group to maintain a peasant rather than a capitalist profile. Similarly, the economic attributes selected for family agriculture were related to diversification and utilization of family labor, whereas the medium and large landowners were more concerned with maximizing income and economic viability.

Social Organization was an important attribute to all groups for two reasons. First, cooperation was seen as key to the group's viability and quality of life, from the ability to influence public policies to the enjoyment of social activities. In addition, all groups prioritize concerns about identity, whether the self-determination of their cultural and linguistic trajectory in the case of the indigenous group or concerns by medium and large landowners about media portrayals and how they are perceived by the public.

Notably, no group identified environmental factors as a key attribute. The environment is seen either as a source of resources, as a threat in terms of environmental regulation, or as a component of the quality of life, but was not identified by the actors as an essential characteristic of the social group or its livelihood system.

INTERACTIONS BETWEEN SOCIAL GROUPS

The prevalence of cross-scale interactions highlighted the influence of larger-scale processes on each social group, with horizontal interactions between social groups not very evident for much of the analysis. The indigenous group were an exception, because of the larger scale of their historical focus - before the history of family agriculture and medium/large landowners in the region even begins, the indigenous people were strongly affected by early non-indigenous exploration of the region. In contrast, the conflict over land between family agriculture and medium/large landowners is less evident because both private and government-led colonization left little undesignated land for open access (unlike the frontier region of other Amazonian states). However, there is a conflict between indigenous and medium and large landowners: the demarcation of indigenous territory in Cotriguaçu did not occur until 1998, well after a colonization company had sold some of the same land. Timber companies still hope to exploit the timber in the indigenous reserve, which is perceived as under-utilized, and there are reports of timber theft and land invasion. Other interactions between social groups include the supply and demand of labor between family agriculture communities and timber companies, as well as the purchasing of timber and building of secondary roads in agricultural settlements.

The scenario exercise brought conflicts between social groups to the fore. The positive scenario for medium and large landowners includes abolition of the indigenous reserve as well as further infrastructure development, whereas the negative scenario for the indigenous group revolves around weakening of their legal protections and building of hydroelectric dams. While there has been small-scale conflict between family agriculture settlements and indigenous groups, the scenarios do not show any inherent or essential conflicts between these groups, and both could benefit from public policies that favor diversified, small-scale production systems. In contrast, while there is potential for peaceful co-existence, there is no win-win solution for the best-case scenarios of the medium/large landowners and the indigenous group.

CONCLUSIONS

This paper provides an analytical framework for characterizing a complex social-ecological system in terms of its historical dynamics and key attributes, including the drivers of change and the interactions across scales and between different social groups. It advances the resilience assessment methodology by basing the analysis of the system on its historical trajectory, seeking to explicitly incorporate the perspectives of local actors, and using scenario analysis to develop possible management interventions.

Resilience is a difficult concept to quantify, and the analysis did not achieve a quantification of resilience. Rather, it brought attention to how the system has changed, how those changes have affected the actors, and, through the scenario exercise, the threats and opportunities of future system change. Participants in the training program in which this methodology was applied consider that the resilience assessment tool, while challenging to apply, provided a unique and useful perspective. Such learning may contribute to anticipation of surprises, adaptation capacity, and thus the general resilience of social-ecological systems.

NOTES

¹ In the case of Conservation Areas, 39.8% of these were created between 2003 and 2006.

² “REDD (Reducing Emissions from Deforestation and Forest Degradation) is an effort to create financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development”. Available at: <<http://www.un-redd.org/aboutredd>> Accessed February 18, 2016.

³ Available at: <http://www.icv.org.br/como_atuamos/cotriguacu_sempre_verde/> Accessed May 7, 2015.

⁴ The “state” of the system is the set of values of the different attributes at a given point in time. The dynamic nature of systems means that the state is constantly changing, moving through a so-called “state-space”. A regime is a portion of state-space, i.e. a set of states, through which a dynamic system may routinely pass. A resilient system will stay in a given region of state-space; if the system jumps to an entirely different area in state-space, it is said to transform or change regimes; in the latter case it is not resilient; a change of regimes is often a non-linear process and may be difficult to reverse. These concepts are further explained in Buschbacher (2014).

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