

Managing Social-ecological Change and Uncertainty: Floodplain Agriculture and Conservation in Dryland Northern Cameroon

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Abstract

Managing change and uncertainty is important for effective environmental conservation, especially in semi-arid areas. This paper explores farmers' strategies adopted for managing change and uncertainty inherent in social-agricultural interactions in the Logone floodplain of the Lake Chad basin. We do this through ethnographic participant observations, surveys and latent variable modelling. Among four categories of strategies, those adopted to spread risks were shown to negatively impact farmers' efforts to manage change and uncertainty. Risk-spreading strategies relying on social networks, credit, common-pool resources, cultivation of multiple species and varieties, and alternative income-generating activities were seldom ineffective. In part, the ineffectiveness of risk-spreading strategies is explained by the fact that these strategies were subjected to similar human-environment conditions as agriculture. However, development interventions, corruption, democratic reform, re-negotiation of the commons and reluctance to seize risk-spreading opportunities have undesirable consequences for agro-ecological risk management. We discuss local potential and the role of external agents in enhancing management of change and uncertainty.

Keywords: change, uncertainty, risk-spreading, common-pool resources, traditional institutions

INTRODUCTION

IN THE DRYLANDS of the Logone floodplain in north Cameroon, natural and social conditions are constantly in flux and uncertainty looms around human-environment interactions. The region's history of hydrologic variability is characterised by droughts and persistent decreases in annual precipitation (Scholte 2005). However, major development initiatives within the region, in the name of conservation and improvement of livelihood strategies, exacerbate social-ecological change and uncertainty. The most prominent development intervention was the construction of the Maga dam upstream from the floodplain. Initiated by the French colonialists, before Cameroon's

independence, the goal of the Maga dam project was to modernise and expand agricultural practices to ensure food security within and beyond the region. In 1979, Cameroon, through the Rice Development Authority [Society for the Expansion and Modernization of Rice in Yagova, Cameroon (SEMRY)], completed construction of the Maga dam, creating a reservoir (Lake Maga) for rice irrigation upstream from the floodplain (Loth 2004). A significant decrease in annually flooded area resulted from construction of the dam and coincided with the droughts of the 1980s (Mouafo *et al.* 2002). Also reported were fish stock declines and increased scarcity of arable and grazing land because of the construction of the Maga dam (World Bank 2003).

In 1992, the International Union for the Conservation of Nature (IUCN) in partnership with the Cameroonian government and other institutions began efforts to rehabilitate the hydrologic regime of the floodplain (Loth & de Longh 2004). In part, these efforts sought to define mechanisms and strengthen local capacity for conservation and sustainable resource use. The floodplain rehabilitation, in and of itself, constitutes another dimension of change for which the farmers have to cope and adapt. Faced with the construction of the Maga dam, rehabilitation of the floodplain and associated ecological changes, local communities persist and struggle to cope and adapt to sustain their livelihoods through farming, pastoralism and fishing. This paper explores how Logone farmers are adapting, mitigating and accommodating changes and uncertainties imposed by human and non-human factors. It identifies and elaborates on key strategies and their influence on management of agro-ecological change and uncertainty.

In efforts to simultaneously understand the mutually interacting effects of social and ecological factors on conservation, natural resource scholars and managers are increasingly linking social and ecological functions as one system, that is, a linked social-ecological system (SES) (Berkes *et al.* 2003). This SES approach holds considerable promise for meaningful adaptive management and sustainability. The consideration that elements of ecological change and uncertainty are multifaceted, interconnected and incompletely understood without attention to social, political, cultural and economic factors, is inherent in a SES approach. To analyse farmers' management of change and uncertainty, we applied the SES framework proposed by Folke *et al.* (2003). The framework enabled us to configure and study social-agricultural change and uncertainty as it relates to the multiplicity of inherent human, biotic and abiotic factors.

In the following sections, we present, in brief, the study area and the theoretical framework. Next, we explain our approach to, and results of, preliminary qualitative field inquiry. Then we illustrate how those results informed the development and administration of survey instruments. Subsequently, we explain how we used data from survey instruments to generate a Confirmatory Factor Analysis (CFA) model of change and uncertainty. A CFA model is a measurement model of relationships between latent variables and their respective manifest variables (Bartholomew & Knott 1999). A latent variable is a hypothetically existing theoretical construct or proposition such as change and uncertainty in SESs. The framework is thus empirically estimable as a CFA model depicting relationships between change and uncertainty, and its manifest variables (the four categories of strategies). The estimated CFA model shows that the strategies adopted by farmers to prepare for social-agricultural surprises hinder adaptation to change and uncertainty. We use field notes and interview transcripts to illustrate fac-

tors explaining this hindrance. We suggest ways to enhance farmers' adaptation to social-agricultural change and uncertainty. We conclude that the mix of qualitative and quantitative methods improves social-ecological system analysis, monitoring and assessment. This mixed method approach facilitates a nested analysis necessary for improved understanding and management of local scale social-agricultural processes.

Study Area and Participants

We conducted research in three villages (Lahay, Araynaba and Patmangay) in the Zina district in the Logone floodplain within the Lake Chad basin. The Logone floodplain, located south of Lake Chad, is approximately 800,000 ha in size and is ecologically and culturally diverse. The region inhabits a biosphere reserve, the Waza National Park and the Kalamaloue National Park, with restricted access for adjacent communities. The floodplain remains dry most of the year but is variably flooded between August and December every non-drought year (Scholte 2005). Approximately seventy-five communities, of a population of about 800,000 people, occupy the floodplain (including urban populations), relying upon seasonal floods to sustain their livelihoods (Mouafo *et al.* 2002). Agriculture constitutes the rural economic mainstay of the Logone; rice is the most commonly produced and marketed agricultural product (Loth *et al.* 2004). Agriculture is inseparable from fishing and livestock breeding, making a social-agricultural system configuration even more appropriate for the study of human-nature interactions in this area. Most farmers fish during the flood season and some invest in animal production; cattle, small ruminants and multiple species of domestic birds. Individuals rather than families predominantly own Logone farms. Study participants were local paddy rice farmers 18 years and older, both male and female. Selection of participants was based on the criterion that they interacted with at least one paddy rice field.

Theoretical Framework

As proposed by Folke *et al.* (2003), resilient SESs transform change and uncertainty to opportunities for sustainability through four categories of strategies. These categories include practices and social mechanisms employed to: (1) evoke disturbances in ways that mimic natural patterns; (2) prepare for surprises (spread risks); (3) learn from crises; and (4) participate in resource related activities including conflict management. Accordingly, these four categories of strategies represent social mechanisms essential in a SES's ability to deal with change and uncertainty. That is, a SES deals with change and uncertainty, to the degree that it effectively evokes disturbances, prepares for surprises, learns from crises and accommodates social mechanisms that enhance par-

ticipation and conflict management. It is a comprehensive framework because it incorporates political, economic and cultural dimensions of human-environmental change and uncertainty. The framework emphasises the necessity that society adapts, re-organises and continues to exist while adjusting to change and uncertainty (Gunderson & Folke 2005).

As elaborated by Folke *et al.* (2003), the framework entails complexity warranting a mix of qualitative and quantitative methods to better understand resource management and conservation (Creswell 2003; Cundill *et al.* 2005). We combined observations of field practices and farm related social activities, with interviews, survey questionnaires and CFA. Based on the framework, we designed and conducted qualitative field observations, including key informant and focus group interviews (Weiss 1995). We used findings from these observations and interviews to design and administer survey instruments to a random sample of farmers. We used the surveys to fit a CFA model explaining the relative influence of each of the four categories of strategies to social-agricultural change and uncertainty. We used notes from observations of field practices and related social activities, and interview transcripts to interpret the CFA model. The aim of this mixed method approach was to reduce the complexity of these strategies to manageable amounts of empirically communicable information and to integrate variance among individual-agricultural interactions into coarse-scale inference. This combination of methods enabled us to determine the relative influence of each of the four categories of strategies adopted to deal with social-agricultural change and uncertainty; it allowed us to focus our discussion on the most important category of strategies.

METHODS AND RESULTS

Qualitative Inquiry

We informed participants of the nature of the study and sought informed consent to participate. Field observations and the interview guide focused on local strategies adopted to deal with social-ecological change and uncertainty according to the framework proposed by Folke *et al.* (2003). We observed farm practices and farm related social processes during farm preparation and planting season (Weiss 1995). We conducted discussions with four focus groups of an average size of thirteen, and six in-depth key informant interviews (Krueger & Casey 2000). Field observations included participatory inquiry, soliciting inputs from local farmers on-site, non-governmental organisation (NGO) field staff engaged in related activities within the area and state officials with appropriate natural resources jurisdiction. Interviews and focus group discussions consisted of detailed conversations about the nature of evoked ecological disturbances, risk-spreading

strategies, how participants could tell they were learning from crises, and opportunities for, and nature of, community participation in agricultural activities including conflict management. Following discussions of each category of strategy, we asked open ended questions allowing participants to comment on the essence of that category of strategy. Community members were therefore directly involved in determining the site specific nature of strategies adopted to manage change and uncertainty. Through this approach, we brought together scientific and traditional world views about indigenous human-environment interactions (Grenier 1998). The open ended questions enabled us to substantially tap into the social, cultural and political dimensions of social-agricultural change and uncertainty.

Preliminary Qualitative Inquiry Findings

The inhabitants of the Logone have developed practices and cultural institutions, which by design or default allow them to manage social-agricultural change and uncertainty, and correspond closely with four components of Folke *et al.*'s (2003) framework. These communities adopt fine-scale management practices that evoke release in ecosystems and mimic natural disturbance regimes (Fowler 2000). Farmers commonly use farm fires to mimic similar ecological disturbances within our study area. They burn their fields before ploughing, targeting drought tolerant grass and shrub species that infested the floodplain during the mid-1980s drought (Scholte 2005). When left unattended or during unfavourable weather conditions (wind, temperature and time of day or year), farm fires spread to burn neighbouring fields. Accidental fires sometimes cause conflict between burners and their neighbours. Thus, weeds are stacked into piles before burning to contain fires within fields. Most farmers wait until the fire is out or are certain that fires will not spread after they leave. Burning stacks of plant debris ensures patchy distributions that mimic natural patchiness of wildfires. Although farmers do not induce floods, they construct earth dykes and canals to mimic timing and quantity of flooding required for optimum rice cultivation. By mimicking fine-scale natural disturbances, these release-evoking practices hasten local renewal cycles and minimise accumulation of coarse-scale disturbances (Folke *et al.* 2003), thereby enhancing management of change and uncertainty.

Farmers make efforts to build social-ecological resilience in the context of change and uncertainty by developing mechanisms to anticipate and absorb surprises, particularly by spreading social-agricultural risks. Logone farmers spread risks by supplementing subsistence and income with activities such as fishing, cattle rearing and local trading of agricultural, livestock and fish products. Due to uncertainty associated with variability of rainfall, some farmers cultivate low yield short season varieties as

insurance against inadequate hydrologic conditions and pest events that might affect high yield varieties. Farmers cultivate other crops (sorghum and millet) and multiple varieties of rice. Community members engage in reciprocal food sharing, which is particularly useful during times of poor harvests due to shorter than expected flood periods, droughts and/or spatial heterogeneity of water availability. Some farmers cultivate crops during the dry season (recession cropping) and have facilities allowing them to store harvest for off-season and emergency food supplies. External agents and, to a lesser extent, local community members provide credit to farmers for purchase of farm inputs, other goods and amenities.

Use of common-pool fish and forest reserves for supplementary subsistence goods and services play a major role in buffering agricultural risks within this region. Forest reserves provide game for food and sale, wood for fuel and construction, off-season fodder and wild edible plant species. Resource chiefs (chiefs of forests and chiefs of fisheries) appointed by village chiefs (locally called *blamas*) to whom the former are accountable, supervise management of resource reserves. Sanctions against violations could involve restrictions that are more stringent, denial of access, community service and financial charges. Fish reserves are canals (locally called *avaye*) dug by the inhabitants and linked to creeks and/or water courses; canals trap fish for communal harvest during flood recession. As the flood recedes, water levels decrease and canals become accessible on foot thereby prompting communal fishing using spears and baskets. The chiefs of fisheries organise collective fishing and distribution of the catch. Farmers sell part of the fish catch and use the revenue for community projects.

Adaptive learning is a critical strategy adopted by farmers in dealing with change and uncertainty. Through experimentation, adaptive learning enables farmers to develop innovative practices and social mechanisms to deal with crises. Crises within these villages include droughts, wildfires, excessive floods, disputes among farmers, and between farmers and pastoralists. Individual responses to these crises may fall within three generic categories (Folke *et al.* 2003). No response options are often associated with inadequate resources. Responding without the benefit of experience is a likely option among beginning farmers. The third option, to respond with experience, is common among more seasoned farmers. Variability of rainfall patterns in this semi-arid area leads to unpredictability of the farming season and imminent poor harvest. Besides altering practices, farmers pay close attention to timing of farm activities and choice of varieties.

The farmers adopt mechanisms to foster participation in community resource management and conflict management. Most Logone farmers have labour cooperatives functioning as local management institutions by making decisions about allocation of group labour. By so doing, these micro-scale indigenous institutions foster collective

participation in agricultural and related activities. These institutions mediate resolution of conflicts among group members, and between group members and 'outsiders' including farmer-grazer conflicts. Individuals may initiate the resolution of conflicts between them and others. Composition and consequent institutional functions change as farmers switch cooperatives during the year based on socio-cultural and related affinities such as satisfaction with conflict management processes and outcomes. Most farmers belong to multiple cooperatives during farming season. By frequently altering composition and function, these micro-institutions actively behave like disturbances. Such behaviours enhance resilience (Berkes *et al.* 2003) by providing learning opportunities via exposure to knowledge across groups. Beyond these micro-institutions, opportunities for participation and conflict management exist at the village level mediated by traditional (resource and village chiefs) and state (district and divisional officers) authorities.

Survey Instrumentation

Based on preliminary qualitative findings and grounded in the theoretical framework, we developed a survey questionnaire consisting of four psychometric instruments, each assessing a category of strategies. The complexity inherent in these categories of strategies warrants the use of psychometric instruments, which are one instrument used to measure complex, dynamic and often intangible theoretical phenomena (DeVellis 2003). The pilot questionnaire contained four instruments, each comprising multiple statements with different units of measurement, and/or differing precision. Most statements were in the Likert scale format with five response choices. Agreement statements had the following response options: (1) strongly disagree; (2) disagree; (3) neutral; (4) agree; and (5) strongly agree. The frequencies of occurrence of events and practices were rated in five response options: (1) never; (2) rarely; (3) sometimes; (4) almost always or almost every year; and (5) always or every year. We asked respondents to choose the response options that best fit their agreements or endorsements of the statement (Alreck & Settle 1995). Other ratings, such as duration (years, months and weeks), number of entities and activities, were included in the questionnaire (See Table 1 for sample statements for each instrument). Through these instruments, individuals can rate multiple statements about their practices as well as their knowledge, beliefs and attitudes regarding strategies to manage social-agricultural change and uncertainty.

The first instrument assessed the category of strategies by which farmers evoke ecological disturbances, particularly fires and floods. We relied on surrogates such as frequency and appropriateness (e.g. timing, control and patchiness) of fires, and earth dyke functioning. We included statements that measured fire and dyke related as-

Table 1
*Examples of statements from the instruments assessing categories of strategies and social mechanisms**

Category of adaptive strategy	Sample statements in instruments
Evoking social-agricultural disturbances	I pile field debris before burning them.
	I am satisfied with the functioning of dykes around my fields.
	My fields get burnt by fire from neighbouring fields.
Preparing for surprises/risk-spreading	In addition to farming, I am engaged in <i>n</i> other lucrative activities.
	In addition to rice I cultivate <i>n</i> other crop species.
	I am satisfied with what I get from community forest reserves.
Learning from crises	I plant the wrong variety for that year.
	I have changed some practices in my fields because of floods.
	I adopt certain practices in my fields to avoid conflict with my field neighbours.
Participation and conflict management	I try to resolve conflict between me and my field neighbours.
	I am satisfied with the way traditional authorities resolve disputes.
	I attend farmers' group meetings.

*For copy of complete instruments, contact the corresponding author

pects of neighbour disputes, particularly frequency of across field fires, importation of burning material and functioning of earth dykes.

The second instrument targeted risk-spreading strategies to assess the degree to which farmers are prepared for and can absorb uncertainty. We included statements that assessed farmers' involvement in alternative income-generating activities and strategies such as diversification of varieties and species, cultivation of short season varieties, access to fish and forest reserves, and sources of credit and reciprocal food sharing. We included statements that assessed farmers' post-harvest storage practices to meet emergency and off-season food supplies and income. In addition, we included statements that assessed their appraisal of the relevance and functioning of these risk-spreading practices and mechanisms.

The third instrument targeted the processes through which farmers learn from crises. Participants in focus group discussions and key informant interviews revealed that changing practices and social mechanisms in response to crises were manifestations of learning. Statements were then included that assessed the extent to which they alter practices and social mechanisms in response to crises such as droughts, wildfires, farmer-grazer and field neighbour disputes, post-harvest losses and floods. In addition, we included statements that measured the 'no response to crises option' by assessing the frequency with which farmers are still victims of minor crises such as floods and other effects of seasonal variability.

Finally, farmers revealed that the essence of social mechanisms for participation and conflict management lies in their involvement in and appreciation of these processes. We then included statements that sought to capture farmers' participation in conflict management and group activities at various levels (farm neighbours,

neighbourhoods, and other groups based on age and gender) within the village community. Statements that assessed the farmers' appreciation of traditional and state institutional approaches to conflict management and group structure and function were included in this fourth instrument.

To ensure construct validity, experts from disciplines within the broad area of human-environment interactions and psychometric instrumentation reviewed and helped revise the questionnaire. We administered a pilot questionnaire to a sample of farmers and held discussions about the content, comprehension and structure of the questionnaire with pilot survey participants. The questionnaire was revised based on discussions with pilot survey participants; this helped ensure face validity and enhanced comprehension and response rate. Following these revisions, the number of response options for Likert scale formatted statements in the final questionnaire was reduced to four: (1) strongly disagree; (2) disagree; (3) agree; and (4) strongly agree and (1) never; (2) sometimes; (3) almost always or almost every year; and (4) always or every year. We administered the final questionnaire, containing sixty-eight questions, to a purposeful random sample of 271 farmers within the villages. Farmers were surveyed on-site in their fields with every third male and every other female as a purposeful sampling procedure to obtain sufficient gender representation (given Logone's 3:1 male: female ratio of farmers) in our samples (Kalton 1983).

Instruments Analyses and Confirmatory Factor Analyses

We assessed each of the four instruments for precision of measurement using Cronbach's alpha (α), a measure of internal consistency reliability with values of ≥ 0.6 con-

Table 2
Precision of measurement and relative determination of each category of adaptive strategies

Category of adaptive strategies	Standardised Cronbach alpha (α)	Coefficient of determination (β^2)
Evoking disturbance	0.60	0.10
Preparing for surprises	0.69	0.34
Learning from crises	0.83	0.04
Participation and conflict management	0.80	0.52

sidered acceptable precision (DeVellis 2003). We summed the ratings of statements within each instrument into metric free indices of that category of strategy (following Spector 1992). We used a covariance matrix of these indices as input, in a CFA model, to estimate correlation coefficients between each category of strategy and management of change and uncertainty (Maruyama 1998). Using the LISREL (Linear Structural Relations version 8.72) software package (Jöreskog & Sörbom 2005), we modelled categories of strategies as functions of change and uncertainty plus random error (du Toit & du Toit 2001) using the following equation:

$$Y_i = \beta_i f + \delta_i$$

where Y_i is a metric free sum of the statements within each category of strategy, β_i is the regression (path) coefficient between change and uncertainty and respective categories of strategies, f represents the latent construct of change and uncertainty and δ_i is the error (residuals) associated with using these indices to represent categories of strategies. We used the maximum likelihood method to estimate model parameters because input variables (metric free statement sums) showed mild departures from normality with absolute univariate skewness and kurtosis of ≤ 1.0 (Fouladi 2000; Nevitt & Hancock 2001). Given data for Y_i , LISREL estimates values for β_i and δ_i from which we deduced the relative determination (β^2) of each category of strategies (Shipley 2002).

We gauged model adequacy using two fit indices: the standardised root mean square residual (SRMR) and the comparative fit index (CFI). The SRMR is highly sensitive to model misspecification (Hu & Bentler 1998) in judging whether the unexplained variance remaining after model fitting is significant enough to reject the model. Models with values of $SRMR \leq 0.08$ are acceptable fits (Hu & Bentler 1998). The CFI is a good judge of how well a particular model explains a set of observed data compared with other possible sets of models (Maruyama 1998). Models with values of $CFI \geq 0.90$ are acceptable (Bentler & Bonett 1980). We inferred, from correlation coefficients, the influence of each of the four categories of strategies on the farmers' ability to manage change and uncertainty. Field notes and interview transcripts were used to elaborate on the significance of each category of adaptive strategies and social mechanisms employed in the management of change and uncertainty.

Instruments and Confirmatory Factor Analyses Results

All instruments used to measure categories of strategies were acceptably precise with all Cronbach alpha (α) values ≥ 0.60 (Table 2).

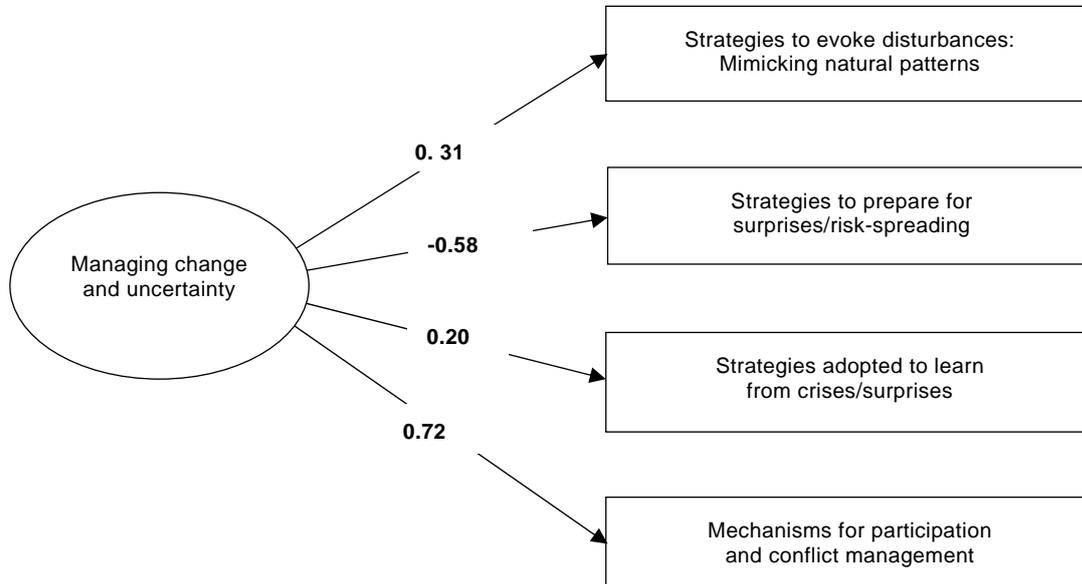
The LISREL outputs include visually explicit graphical expressions of correlation coefficients between managing change and uncertainty and the four categories of strategies (Figure 1). The values on the arrows between change and uncertainty and its respective categories of strategies are correlation coefficients, β_i . The model for assessing change and uncertainty did have acceptable fit and showed all four categories of strategies to be significantly relevant to the farmers' ability to manage change and uncertainty. Based on the correlation coefficients, we deduced the coefficients of determination for each category of strategy. As Table 2 indicates, the coefficient of determination for category of strategies is β^2 .

As shown by the coefficients of determination in Table 2, 52 per cent (of determination) of the farmers' ability to manage change and uncertainty accrues from mechanisms for communal participation in agricultural and related conflict management activities. The second most important category of strategies (34 per cent of determination) is the practices and mechanisms through which farmers prepare for surprises. The third most influential category (10 per cent of determination) is the strategies adopted to evoke disturbances and the fourth is the category of strategies adopted to manifest learning from crises (4 per cent of determination). Risk-spreading strategies have a negative ($\beta = -0.58$) impact on the farmers' ability to manage change and uncertainty (Figure 1).

We expected that social mechanisms that encourage community participation in agricultural and related conflict management activities would be the most influential category of strategies for managing change and uncertainty within these villages. As Folke *et al.* (2003) point out, community participation in resource related activities, including conflict management, boost learning. Farmers reported that community participation helped execute agricultural and related conflict management practices as well as enabled learning how to appropriately evoke disturbances, and prepare for and accommodate crises. The observed strong influence of social mechanisms for participation and conflict management reflects

Figure 1
Visual output of confirmatory factor analysis model, showing correlation coefficients between change and uncertainty, and categories of strategies.

*Model Fit Statistics: Standardised Root Mean Square Residual (SRMR)=0.05;
 Comparative Fit Index (CFI)=0.93; Degrees of freedom=2.0; $\chi^2=7.18$*



this dual influence on management of change and uncertainty. Similarly, timing, control and patchiness of evoked fires as well as appropriateness with which farmers constructed earth dykes and canals positively informed efforts to deal with change and uncertainty. Likewise, trial and error alterations of practices and social mechanisms with or without experience with crises had a positive influence on the farmers' ability to manage change and uncertainty. These findings are consistent with theories of processes involved in the management of social-ecological change and uncertainty (Folke *et al.* 2003).

In ideal social-agricultural interactions, we would expect all four categories of practices and social mechanisms to have strong and positive influences (correlation coefficients) on farmers' efforts to manage change and uncertainty. However, risk-spreading strategies, the second most influential category of strategies, have negative effects on those efforts. Risk-spreading is thus the key leverage point for interventions targeting improvements in the farmers' ability to manage change and uncertainty, i.e., this category of strategies have the greatest potential to enhance farmers' efforts to deal with change and uncertainty. Therefore, in the next section, we explain model deviations from the ideal with particular focus on risk-spreading strategies. We give details, based on qualitative field observations and interviews, as to why current risk-spreading practices and mechanisms are negatively affecting efforts to manage change and uncertainty within these villages. Details focus on the social, economic, po-

litical and ecological ramifications of risk-spreading strategies.

Qualitative Insights into Risk-spreading Strategies

Despite engaging in diverse practices and social mechanisms aimed at preparing for surprises, existing risk-spreading strategies negatively affect farmers' efforts to manage change and uncertainty. Several factors account for these findings. Like agriculture, risk-spreading options such as fishing, livestock breeding, multiple species cultivation, credit acquisition, and forest and fish reserves are all dependent, to different degrees, on the drought prone ecology of the Logone. As a result, farmers could not rely on diversifying crop species and varieties, fishing, animal breeding or forest reserves as insurance for long term agro-ecological risks such as droughts. Off-season cropping, gift sharing networks, cultivation of multiple species/varieties, storing harvest, forest and fish reserves all became remote adaptive possibilities, thereby hindering their utility for coping, in the short term, with agro-ecological risks.

Also tied to agro-ecological risk-spreading within these villages, and the Logone at large, are credit mechanisms. Most creditors offer credit at the beginning of the growing season in the form of input materials such as fertilisers. Farmers report that they use their harvests to repay credit. During unfavourable ecological conditions (false start of the rainy season and/or drought threats), external creditors have little interest in providing credit to farmers

because of the low likelihood of profit from such transactions. According to one credit agent:

This credit business is our lives too... we can't just give them materials when we know that we will get nothing back... when the signs for a bad season are obvious we have to be more cautious about giving credit because when they don't harvest much it is hard for them to pay back... it is a risky business in an area like this, some years are good and others not so good.

Capital for local creditors is accrued from the sale of ecologically dependent products (fish and crops). These products are not guaranteed during unfavourable ecological conditions making local credit also unavailable to community members during these conditions. In addition, during favourable ecological conditions (non-drought and adequate flooding), credit provided to farmers in the form of farm inputs is strategically used towards the beginning of the growing season, when input prices are almost triple their cost during the off-season. In return, farmers pay their creditors with farm produce immediately after harvest, when farm products are at their lowest prices, usually a quarter of their costs at the start of the growing season. Due to the wide price swings in the input and product markets, farmers pay the maximum price for inputs and obtain minimum financial returns from harvests. Consequently, even under favourable ecological conditions, credit mechanisms were detrimental to local risk-spreading initiatives. Compounding the problem, traditional feasting season begins right after harvest with most ceremonies (marriage, birth and death) requiring considerable financial expenses. To meet these financial needs, many confirmed selling almost all their rice immediately after harvest. Farmers report that lack of appropriate storage facilities partly motivates their decision to sell early:

It is our tradition here, after harvest we have to celebrate... people can afford to pay dowries and so they get married, others celebrate the birth and death of their family members. As a member of this community, we have to participate in the feast, we need good clothing to dress for these occasions and we have to show our support with gifts. You see that we need money so we sell our rice and fish... besides, if you don't sell them they will get bad... things will eat the harvest if you try to store them for too long (Focus group interview with farmers at the village of Araynaba, 11 July 2004).

Construction of Maga dam by the Rice Development Authority had negative effects on agro-pastoralism as insurance against agro-ecological surprises. Typical of Soudano-Sahelian ecologies, Logone agro-pastoralists al-

located significant family labour to nomadic pastoralism (Niamir-Fuller 1998) and used nomadic mobility as a strategy against ecological change (Pamo 1998). The SEMRY project promised provision of employment opportunities, food security and other socio-economic benefits through capital intensive agricultural development. These promises triggered a switch from nomadic to sedentary agro-pastoralism, with more family labour re-oriented towards rice production and concomitant reductions in herd sizes. Unfortunately, SEMRY did not live up to expectations (Muofo *et al.* 2002), but rather fostered ecological degradation through decreased area and duration of floods in the floodplain:

They told us that modern rice cultivation is the solution to our problems... that SEMRY will allow us to have more food, jobs and money... moving from one place to another with cattle will have less benefits to us... We sold most of our cattle and went to get jobs at the SEMRY... some of us stopped growing our traditional rice varieties in our personal farms in favour of SEMRY varieties... At the beginning it all seem to work well but now you see... we don't even have enough water during the floods, there are no jobs at the SEMRY, all the tractors are beyond repairs, and the fields are given only to the friends and relatives of the director of SEMRY... (Focus group interview at the village of Lahay, 13 July 2004).

Transition to sedentary agro-pastoralism had negative consequences for long term agro-ecological risk-spreading. The farmers noted that nomadic mobility allowed them to wander beyond sedentary reaches in search of pasture during the dry season. This coping and adaptive mechanism was appreciably restricted by the absence of significant herd sizes to merit such mobility. Consequently, there is a considerable reduction in the exposure of younger generations to traditional ecological knowledge for livestock and range management, making nomadic pastoralism a less realistic insurance against agricultural surprises. Similar to Turner's (1999) findings, reduction in herd sizes also meant a decrease in the amount of manure, and consequently soil fertility, that cattle provided to agricultural fields. Reduced soil fertility resulted in increased use of chemical fertilisers to meet production needs, which added greater economic vulnerability for agricultural risk-spreading initiatives, through increased production costs.

Democratic forces at the intersection of state and indigenous institutions are also negatively affecting farmers' efforts to manage risks. In line with Ribot's (2004) findings, democratic change across Cameroon, which started in the 1990s, continues to reshape traditional institutional mechanisms for managing community-based fish and forest resources within these villages. Before democracy, traditional authorities were effective as multi-

purpose institutions with discretionary powers over local natural resource governance, particularly common-pool resources. In addition, traditional authorities served as decentralised units of state administrative government to whom they were upwardly accountable. Democracy saw rise in organised grassroots opposition to state rule fuelled by increased awareness of corruption of those in power (Shu 2006; Weinberger 2006). Corruption awareness and the devastating ecological and socio-economic consequences of the state-run SEMRY project painted a negative picture of state government, including traditional authorities that served as state administrative auxiliaries in the Logone. As a result, grassroots pressures on traditional authorities for downward accountability increased. To regain village respect and trust (a cultural virtue) and to ensure downward accountability, traditional authorities either sided with the locals or adopted a neutral stance in state politics. In attempts to recoup influence on traditional authorities, provincial government made significant efforts to co-opt traditional authorities including appointing rural leaders against traditional customs. The rural populace further perceived traditional authorities that succumbed to state co-option, as corrupt and acting against rural interests. As one farmer stated:

People do not trust the blamas [village chiefs] anymore because they will rather listen to the provincial authorities than do things that are good for us... These days with democracy our tradition is gone... instead of the normal traditional lineage enthronement, parliamentarians influence the appointment of blamas. In order to keep their thrones, blamas are more likely to act in favour of political interests than local interests... It is hard to even think about respecting these political figureheads.

Correspondingly, the chiefs in our study villages were widely reported to receive bribes from pastoralists who then engage in indiscriminate use of community forests for fodder. Knowledge of bribery and evidence of indiscriminate use of forest reserves by pastoralists fortified perceptions of traditional authorities as contributing to ecological degradation:

The blamas [village chiefs] are not doing us any good... They take bribes from cattle people and allow them to take their cattle to the community forest without any control... Cattle will eat and destroy everything and now we do not have much firewood anymore... Corruption in this country is everywhere... It's a shame we used to trust these people and now we don't... That is not good for our native resources and culture (Key informant interview at village of Padmangai, 12 July 2004).

These perceptions and consequent adaptations occurring at the interface between state, traditional institutional domains and community at large represent a re-negotiation of the commons. Although such re-negotiation can potentially lead to transformations to a more desired state (Folke *et al.* 2005) of managing the commons, they currently have reduced the capacity of common property to serve as insurance against agricultural risks.

Re-negotiation of the commons and socio-political changes within the Logone has included change in the influence of resource chiefs in governing common-pool resources. Like many community-based resource management regimes in Cameroon (Oyono 2004a), there was little or no downward accountability of resource chiefs to community members. Upward accountability to village chiefs with little downward accountability led to local perceptions of resource chiefs as representing state interests. Consequently, resource chiefs lost respect, resulting in non-adherence to cultural norms governing access and use of communal resources. This has led to widespread uncontrolled access, use and abuse of forest and fish reserves. For example, pervasive forest fires occur in the Lahay-Araynaba community forest because forest chiefs have no interests in fulfilling their duties regarding the implementation of practices to evade wildfires. According to a community forest chief:

Why should I work to prevent fires when the people do not respect me [forest laws?].... The cattlemen [pastoralists] go to the blamas instead of me for access and use rights. Money, corruption and mismanagement has ruined everything for us in the forest... People will tell you that.

More policy emphasis on fishing for commercial purposes at the expense of subsistence agriculture (IUCN 2003) partly explains the unreliability of common-pool fisheries as insurance against risks. Since the re-inundation of the Logone, respect and enforcement of the customs of traditional fishing have declined. The freedom to establish privately owned fish canals and lack of restrictions on fishing gear has led to proliferation of privately owned fishing canals, indiscriminate use of fishing gear with smaller mesh sizes and a premature start of the fishing season. These practices have led to severe reductions in fish yields within the entire Logone. Due to the higher density of fishermen in common-pool canals, reductions in fish catch are proportionately greater in common-pool fish canals than in private ones, thereby enriching a few at the expense of the commons. Drijver *et al.* (1995) report similar inequities in the claims and catches of the Logone fisheries. The failure of traditional institutional mechanisms to govern the commons makes reliance on fish and forest reserves for agro-ecological risk-spreading less feasible, even from a short term (coping) perspective:

Those who have money and large families can dig canals anywhere on their lands and catch more fish but those of us who depend on the avayes [public fish canals] have less water and less fish... It's not fair but who are you going to complain to? (Focus group interview at the village of Lahay, 12 July 2004)

This situation is exasperated by the fact that during peak floods extensive fishing is possible only with the use of canoes and motorboats, which many cannot afford. Additionally, increased numbers of fish canals significantly obstruct the circulation of cattle during the dry season, thereby restricting the distribution of cattle manure needed for soil enrichment and agricultural productivity. At a landscape level, farmers report that these canals are severely altering the hydrology of the floodplain such that peripheral fields experience increased delays in flooding and premature flood recession. According to one farmer:

I don't get enough water on my farm early enough because water has to fill all those canals over there before reaching my farm... I hope that someday somebody will do something to stop these canals; they are not good for us down here.

Democratic reforms targeting decentralisation of forest management in Cameroon, particularly the 1994 forestry law, have decreased the ability of community forests to absorb agro-ecological risk. Procedures required by that law are complex, tedious and ill adapted to local realities (Ribot 2001). As expressed by Oyono (2004b), required procedures entail bureaucratic and legal hurdles that only amount to re-centralisation of state control over community forests with communities having to request and obtain access and use rights from state government even for forests that existed prior to this law (Collomb & Bikie 2003). These hurdles hamper local capacity to create and govern community forest reserves and their subsequent utility for agro-ecological risk-spreading. As stated by a member of a locally based NGO:

It's very difficult to get community forest approved, we've been working for three years now to try and get some forests certified but it's a tough process... We don't want to bribe and even if we do, how may people will you bribe? There are too many different offices that you have to go to and none of them really wants to help... It is hard to own the forest that they have had for years let alone create a new one (Conversations with a staff member of the Cameroon Association for Environmental Education, an NGO that conducts environmental education and outreach work within the Logone region, 17 May 2005).

Another detrimental implication of the 1994 forestry law is that without state recognition and approval, community forest reserves are public domain (Collomb & Bikie 2003). As a result, these forests are liable to state prescribed and/or open access and use rights involving exploitation by agents and norms that are external to these communities. Thus, it is legally wrong for locals to enforce territoriality (Acheson 1990) and other traditional institutional mechanisms to manage these forests. Logone communities find themselves competing for exploitation unfavourably with external agents:

They [state authorities] know what they are doing... They know that if we have control over our forests then we will make it hard for other people [outsiders] to harvest our trees without respect because we will have the right to check according to the new forestry law... So they make it hard for us and easy for them [commercial interests]... The sad thing is that we really need to protect and create new forests in this area of the country where it is almost like a desert... Our lives are also in danger because of the forest laws...in 2004 two people at Kidam in Zimado were shot by Chadians exploiting forest for charcoal... They [Chadians] know that we can't stop them from harvesting our trees for charcoal but they cannot do that in their own country [Chad] because they will go to prison (Conversations with a staff member of the Cameroon Association for Environmental Education, an NGO that conducts environmental education and outreach within the Logone region, 17 May 2005).

Chad uses stringent measures (including prison sentences) to discourage deforestation in the Chad section of the Lake Chad basin. As a result, Chadian charcoal hunters go to the Cameroon section of the basin, where local communities are less capable of using territoriality as a conservation strategy. The consequence is deterioration (total loss in some villages) of these reserves, thereby hampering their usefulness for agro-ecological risk-spreading.

Besides re-negotiation of the commons, development interventions, and the dependence of risk-spreading options on the drought prone ecology of the Logone, most farmers in our study villages did very little to spread agro-ecological risk. Most farmers reported that they rarely cultivated crops other than rice and none within these villages practiced recession agriculture. These factors explain why risk-spreading strategies have negative effects on the farmers' ability to deal with social-agricultural change and uncertainty. In the following sections, we discuss possible ways to enhance management of change and uncertainty, and conclude with implications of our multiple methods approach to comparative social-ecological system assessment and analyses.

Enhancing Agro-ecological Risk-spreading

Central to our analysis is the recognition of the need for policies and decisions that strive to improve the effectiveness and efficiency of risk-spreading strategies of Logone farmers. Logone farmers should be encouraged to embark on subsidiary activities that do not depend entirely on the natural resource base of the region. Such activities would include trade in non-agricultural and fisheries goods and services. For the majority of villagers for whom agriculture is a major component of their livelihood, there are a variety of strategies that need to be modified. Creating autonomous credit mechanisms such as local cooperatives from which farmers can obtain credit under more favourable terms would be helpful in easing credit-related vulnerabilities. Enhanced planning will enable purchase of farm inputs in the off-season when prices are low. Improvement of post-harvest storage practices would enable farmers to take full advantage of market forces of demand and supply by storing significant portions of their harvest to sell them during the off-season when prices are higher. Increased storage capacity and efficiency would enable farmers to acquire greater returns for their products and reduce dependency on credit, thereby alleviating associated socio-economic vulnerabilities. Pastoralism has the potential to buffer some agro-ecological surprises and efforts to counter development policies that discouraged nomadic mobility could be useful. According to informants, increased herd sizes would justify re-allocation of substantial family labour towards nomadic mobility. Increased herd sizes also mean increased supply of farm manure, thereby enhancing the utility of pastoralism for agro-ecological insurance.

Adoption of recession agriculture, use of multiple varieties, and establishment and fortification of autonomous credit and savings systems at the village level should be encouraged. These changes would ensure that risk-spreading strategies are helpful especially in instances where surprises are limited to agriculture. Such surprises may include species specific pest and disease attacks, and spatially variable poor harvest due to spatial variation in precipitation and flooding.

Careful extraction of natural resources may provide some capacity to adapt to agricultural change and uncertainty. Common-pool fish and forest resources are a viable option for agro-ecological risk-spreading. Efforts to enhance the ability of Logone inhabitants to manage common-pool resources, including devolution of substantial powers regarding access and use rights should be encouraged. Unlike southern Cameroon with its abundant tropical forest, northern Cameroon is semi-arid and current forestry laws place inadequate emphasis on the need to create and protect forest resources within this region. Current laws reflect the exploitation potential of the southern Cameroon green forest. Forest policies should

be flexible and made to co-evolve with local situations such that in the semi-arid conditions of northern Cameroon, the establishment and direct management of community forests are encouraged. These policies should encourage re-negotiation of the commons and allow the emergence of autonomous management institutions that thrived in these communities before the influences articulated in our discussion. For instance, under the auspices of the Cameroon Association for Environmental Education (ACEEN), a partner NGO, two villages (Lahay and Kasire) in the Logone have re-established and fortified constitutive and legislative rules governing access and use of fish resources. Traditional ecological knowledge and institutional mechanisms for managing common property are the basis of these emerging institutions. In collaboration with state government, ACEEN has prompted a ban on construction of new private fish canals. The stage is thus set for the proliferation of the Lahay and Kasire examples within the entire floodplain; this must happen if the anticipated benefits are to be regionally sustainable.

CONCLUSIONS

The major goal of this study was to combine qualitative and quantitative methods to determine the state of processes involved in the management of agro-ecological change and uncertainty based on Folke *et al.*'s (2003) framework. Through the mix of methods we found that processes, particularly risk-spreading strategies, adopted to manage change and uncertainty are ineffective. The study demonstrates that large scale decisions and processes reduce the effectiveness of, and are sometimes inappropriate for, individual and local scale strategies. However, the complexity and dynamism of these nested interactions across scales allows for the potential emergence of positive local outcomes as exemplified in the re-negotiation of the commons. A nested analytic approach is therefore necessary for improved understanding and management of local scale social-agricultural processes.

Although quantitative ranking identified a leverage point (risk-spreading strategies) for management and policy intervention, qualitative analysis revealed details of the site specific realities of agro-ecological risk-spreading. The direct involvement of farmers in questionnaire development ensured a combination of traditional ecological knowledge and scientific knowledge (Moller *et al.* 2004). As emphasised by Walker *et al.* (2002), this participatory approach minimises expert knowledge biases and mismatches between decision-making and locally affected communities. This study demonstrates the use of merging qualitative and quantitative approaches to obtain a more comprehensive understanding of complex human-environmental dynamics. In addition, although stand-alone ethnographic and other qualitative analyses provide valid inferences, they are less inclusive of variance

among the smallest units of human-environment interactions. We show how variance among individual-agricultural interactions is incorporated into coarse-scale analyses and inference, and how intervention efforts can be prudently and effectively employed.

The acceptable fit of the CFA model demonstrates that the theoretical assertions regarding the practices and social mechanisms adopted to manage change and uncertainty put forward by Folke *et al.* (2003) are empirically verifiable within field settings in the Logone. Like most models (Moran 2000), ours is a simplification of the complexity and multi-dimensionality inherent in the practices and mechanisms for managing change and uncertainty in social-ecological systems. However, once we identified the process with negative influence on efforts to deal with change and uncertainty, we reverted to detailed qualitative analysis using field notes and transcripts. This use of qualitative and quantitative insights allowed us to focus on revealing the complexity of the process most needy of attention.

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