

Once there was a lake: vulnerability to environmental changes in northern Mali

Houria Djoudi · Maria Brockhaus ·
Bruno Locatelli

Received: 17 May 2010 / Accepted: 19 October 2011 / Published online: 6 November 2011
© The Author(s) 2011. This article is published with open access at Springerlink.com

Abstract Vulnerability assessment is increasingly recognised as a starting point to identify climate adaptation needs and improve adaptive capacity. However, vulnerability assessments are challenging because of the complexity of multifaceted biophysical, human and institutional factors, interacting at different scales and levels within socio-ecological systems. Using a participatory approach across levels and genders, this paper explores the vulnerability of livestock- and forest-based livelihoods to climate variability and change in Lake Faguibine, northern Mali, where drastic ecological, political and social changes have occurred. Our results show that the distribution of vulnerabilities within livelihoods and groups shifted when the ecosystem evolved from a lake to a forest. New vulnerability drivers have emerged, related to resources availability, access and power relations. In addition, political interests and psychological barriers hinder the local transition to an equitable and sustainable use of forest ecosystem services. Divergent perceptions, social identities, interests and power explained why different actors—governmental and non-governmental, men and women, local, sub-national and national—differed in their vulnerability assessments. This is exemplified in the way actors at different levels and of different gender analysed the effects of herders' mobility and in the way women analysed men's migration. This case study confirms the need for participatory and gender-sensitive vulnerability assessments across different scales and levels that consider the interaction between socio-ecological

systems and the dynamics and distribution of vulnerability across different social sub-systems.

Keywords Vulnerability · Climate change · Adaptation · Drylands · Forest-based livelihoods · Ecosystem-based adaptation

Introduction

Appropriate adaptation interventions and policies are needed to protect past and future development from climate variability and change. The design of interventions and policies must rely on analyses of climate risks and vulnerability and include vulnerable groups in adaptation measures (Heltberg et al. 2009). Understanding the causes of vulnerability can help define where and how to reduce climate vulnerability and identify the institutions able to facilitate adaptation (Ribot 2009). In addition, the process of vulnerability assessment can facilitate the involvement of policymakers and people affected by climate in thinking about the transformational change needed to build adaptive capacity (Gardner et al. 2009).

The concept of vulnerability has emerged from different schools of thought, especially from the risk and disaster management community and the political economy community (Eakin and Luers 2006; Füssel 2007). The risk and disaster management community considers vulnerability to be the likelihood of an exogenous hazard occurring (e.g. a cyclone or a storm) and the associated impacts on a system (Carter et al. 1994). Conversely, political economists and human geographers focus on the socioeconomic, political and cultural factors that explain why a system is or is not able to cope with an external threat (Adger and Kelly 1999). Between these two interpretations of vulnerability,

H. Djoudi (✉) · M. Brockhaus · B. Locatelli
CIFOR, Bogor, Indonesia
e-mail: h.djoudi@cgiar.org

B. Locatelli
CIRAD, Montpellier, France

the definition proposed by the Intergovernmental Panel on Climate Change (IPCC) is now widely used in the climate change community (Füssel and Klein 2006). According to the IPCC, vulnerability is ‘the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system’ (McCarthy 2001, p. 995).

Understanding vulnerability is integral to a process of determining actions that facilitate adaptation, but how to characterise vulnerability in theory and practice is still widely debated (Eakin and Luers 2006). Several integrated frameworks have been developed, such as the social risk management framework (Heltberg et al. 2009), the vulnerability scoping diagram (Polisky et al. 2007), the framework for assessing vulnerability in the context of multiple stressors developed by the Southern Africa Vulnerability Initiative (SAVI) (O’Brien et al. 2009) and the vulnerability analysis framework of the Research and Assessment Systems for Sustainability Science Programme (Turner et al. 2003). As in the IPCC definition, these frameworks consider different vulnerability factors: external (exposure) and internal factors (sensitivity and adaptive capacity), as well as socioeconomic and biophysical factors (Füssel 2007). Examples of factors influencing vulnerability are the entitlements and endowments of households, their empowerment, local institutions and the political economy (Sen 1987; Davies 1993; Watts and Bohle 1993; Adger 2006).

Vulnerability assessments should consider the interactions between ecological and human factors; for example, how ecosystems buffer the impacts of climate events on people and how human responses to climate events affect ecosystems (Sudmeier-Rieux et al. 2006; Locatelli et al. 2008). Assessments should thus be conducted at the scales at which humans and the environment interact and at which management is applied (Eakin and Luers 2006). As many interactions between a nature-dependent community and its environment occur at a local level, vulnerability assessments should focus on local drivers and dynamics. Nevertheless, because interactions and management can take place at higher levels and local vulnerability is influenced by factors at national or global levels (Tompkins and Adger 2004), a cross-scale and multi-level¹ approach that is place-based and connected to higher levels is appropriate (Turner et al. 2003). Such an approach catches vulnerability factors that are both internal and external to the communities and

at different levels of detail.² Fekete et al. (2009) highlighted the importance of the interactions between levels and scales in the conceptualisation and the application of vulnerability assessments. Pettengell (2010) emphasised the need for combining bottom-up and top-down processes and approaches for adaptation.

As vulnerability within a group differs according to gender, age, ethnicity and power (Davies 1993), understanding the distribution of vulnerability is crucial (Adger 2006). The perceptual dimensions of vulnerability must also be considered, as differences in perceptions have major implications for the development of adaptation strategies (Adger et al. 2009). Perception generally is intertwined with gender, social status and class, as well as societal and political roles and functions, for which scale and level are highly relevant (Cash et al. 2006). Power relationships, different interests, norms and values may influence the judgment about who is more or less vulnerable, or one’s own vulnerability.

Participatory research is needed for integrating different perceptions and knowledge of adaptation (Lynch et al. 2008). Caution must be exercised when applying vulnerability concepts during a participatory research, because the concepts of climate change, vulnerability or adaptive capacity are subject to different interpretations and may not have any equivalent in local languages (Preston and Stafford-Smith 2009). Therefore, these concepts need to be framed in a way that is relevant to stakeholders at a given level (Gardner et al. 2009).

The drylands of the Sahel are characterised by high rainfall variability. In spite of people’s adaptive capacity observed in the past (Mortimore and Adams 2001; van der Geest and Dietz 2004), unprecedented rates of climate change may jeopardise the capacity to adapt to new conditions (Trench et al. 2007). In the Sahel, exposure is related to the high frequency of droughts; sensitivity comes from the dependence on natural resources and the lack of economic alternatives; and low adaptive capacity can be explained by poor access to services, poor governance and inequitable markets (Trench et al. 2007).

The pastoralist livestock systems common in these areas are highly dependent on natural resources such as pasture, fodder, forest products and water, all of which are directly affected by climate variability. People have developed complex strategies such as mobile pastoral systems to deal with climate variability and change (Brooks et al. 2009). Households have also diversified livelihoods by combining livestock, agriculture and other activities (Mortimore and Adams 2001). The dynamics of the vulnerability of pastoral systems are complex; for example, conflicts are both

¹ Scales are ‘the spatial, temporal, quantitative or analytical dimensions used to measure and study any phenomenon’ and levels are ‘the units of analysis that are located at the same position on a scale’ (Gibson et al. 2000, p. 218).

² In accordance with the hierarchy theory (Allen and Starr 1982), the lower the level of observation, the more detailed the observation.

an outcome of vulnerability or resource scarcity and a driver of institutional change and therewith adaptation by pastoral communities (Turner 2010).

Political and economic changes and power relations influence the dynamics of pastoral systems and their vulnerability. Colonial and post-colonial policies have displaced pastoral communities and reduced their access to traditional resources in the Sahel (Brooks 2006). For decades, policymakers, practitioners and scientists have hotly debated the pros and cons of mobility. On the one hand, pastoralism is judged as ecologically maladapted and economically inefficient and therefore, sedentarisation is seen as a precondition for development (Nunow 2000). On the other hand, a so-called mobility paradigm emerged in the 1990s, when scholars produced evidence of the high adaptive capacity and ecological–economic efficiency of mobile livestock systems in the Sahel (Niamir-Fuller 1999).

The objective of the paper is to assess the vulnerability of local communities depending on livestock and forests in northern Mali, approached at different levels and scales. The field research was conducted in a place where drastic ecological and political changes have taken place recently with the transformation of a lake into a forest. Besides assessing vulnerability and adaptation strategies, the research design facilitated reflection within and across levels and groups.

Study area

The study was conducted in two villages, Tin Aicha and Ras El Ma, in the northern part of Lake Faguibine (16°45'N, 4°W), Goundam district, Timbuktu region, northern Mali (Fig. 1).

Climate and ecology

The area is arid and corresponds to the vegetation of thorn woodland and desert scrub according to the Holdridge classification (Holdridge 1947). Between 1961 and 2002, mean annual rainfall was 170 mm and average temperature was 28.2°C. The climate is characterised by high interannual rainfall variability, with several years in the 1980s having less than 100 mm of rainfall (Fig. 2). Four out of the six climate scenarios used in the WorldClim dataset (Hijmans et al. 2005) show a decrease in rainfall in 2050. The average rainfall variation in all six scenarios is significantly negative ($p < 0.1$), with a 7% reduction in 2050 compared with the baseline (1961–2000).

Two kinds of forests are present in the study area. The natural Acacia forest is dominated by *Acacia tortilis* (subsp. *raddiana*), *Balanites aegyptiaca*, *Pteocarpus lucens* and *Leptodena pyrotechnica*. An introduced species, *Prosopis*



Fig. 1 The study area location in northern Mali

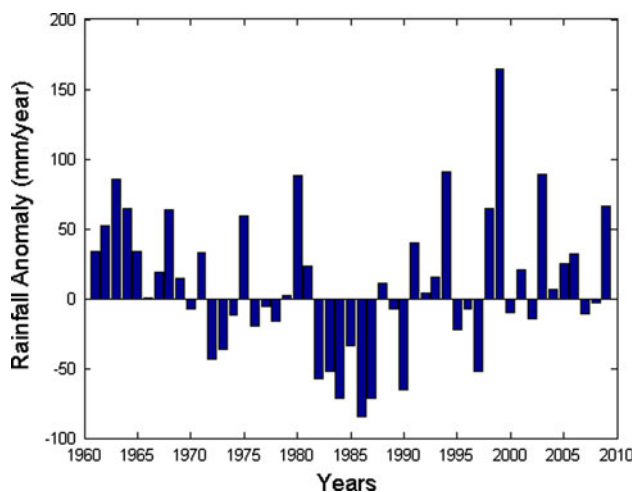


Fig. 2 Annual rainfall anomalies compared with the mean rainfall in Lake Faguibine between 1961 and 2009 (data from the Global Historical Climatology Network; GHCN 2010)

(*Prosopis juliflora*), forms high-density forests in the former lake bed. Two kinds of grasslands are found in temporarily flooded and dry areas. In the flood zones of rivers and lakes, grasslands are composed of perennial herbs such as *Echinochloa stagnina*, *Oryza barthii* and *Vossia cuspidata*. The dry area grasslands are dominated by *Cenchrus biflorus*, *Aristida mutabilis* and *Schoenefeldia gracilis*.

Population and livelihoods

The average population density is low, with 1.1 person/km² in the Timbuktu region and 1.7 person/km² in the Goundam

district (DRPSIAP 2008). The density has high spatial variations, as settlements are concentrated around Lake Faguibine and along the Niger River, with densities as high as 59 person/km² in Diré district, south of Goundam district.

Different ethnic groups with different livelihoods form the population around Lake Faguibine. Mainly Arabo-Berber livestock keepers live in the western and northern parts where research was conducted. In Tin Aicha in the north, most residents are from the Berber ethnic group Kel Tamacheq, with most households belonging to the Iklan class (the lowest social status, descended from slaves). In Ras El Ma in the west, most people belong to the Arab (Moorish) group Tormoz and the Berber ethnic group Kel Tamacheq and are mainly from the Illelan class with a high social status. Members of the Bozo ethnic group are traditionally fishermen.

Livelihoods depend mostly on mobile and sedentary livestock breeding. In the Timbuktu region, around 72% of the land is used as pasture and the rest is reported as forested land use (DRPSIAP 2008). Two kinds of mobile livestock breeding systems are present: transhumant (a seasonal movement of people and livestock over relatively short distances) and nomadic (a migration of people and livestock over longer distances). Livestock breeding is also associated with sedentary agropastoralism. The livestock mix is following a trend towards more small ruminants and fewer cattle. In other African livestock systems, this trend is associated with drought-related adaptation (Sungno Niggol and Mendelsohn 2006; Maddison 2006) or with intra-household struggles between men and women (Turner 1999).

Social and ecological history

Lake Faguibine is part of a Niger River-fed lake system. It was a productive area for agriculture and fishing, but experienced dry phases during the twentieth century; the lake has been almost completely dry since the mid-1970s (UNEP 2009). Lake Faguibine has drastically transformed from a water-based to a forest ecosystem, with *Acacia* and *Prosopis* now covering more than a third of the former lake area (Fig. 3). *Prosopis* was introduced by a development project led by an NGO (Non-Governmental Organisation), the Association Sahel, in the 1980s to counter desertification and protect the lake against siltation. After the lake dried out, the highly invasive *Prosopis* occupied the area more quickly than local species such as *Acacia* (Brockhaus and Djoudi 2008). *Acacia* is prevalent in the western part (Ras El Ma) and *Prosopis* in the northern part (Tin Aicha). High soil fertility and dramatically reduced animal pressure during the rebellion in the 1990s have facilitated forest growth. *Prosopis* is highly controversial and perceived either as a ‘curse or blessing’ (Laxen 2007). Despite its

resistance to drought and provision of multiple products, the invasive character of *Prosopis* has led to elimination programmes in several countries (Pasicznik 1999).

Between 1990 and 1996, Tamacheq groups rebelled against the Malian state, motivated in part by lost livelihood resources due to state interventions and development projects, and by political marginalisation in the postcolonial state (Krings 1995). Migration to neighbouring countries (especially Mauritania) and forced sedentarisation of former mobile herders in refugee camps affected the social and economic structure of the hierarchical Tamacheq communities. Additionally, battles with the Malian authorities and conflicts with local Mauritians caused a massive loss of animals (Randall 2005). Since the early 1990s (Fig. 3), Mali has been in a process of decentralisation, which has created different institutions across levels, including 49 ‘conseils de cercles’ at the district level, where decentralised, elected mayors represent communities. The transfer of resources and rights to the local level was not yet completed at the time of this research.

Various development interventions have taken place in the regions studied. Since the lake dried out, several programmes have sought to bring the water back and restore water-based economic activities. UNEP (2009) describes such projects as aiming to restore the ecosystem functions of Lake Faguibine to prevent conflicts between farmers and livestock keepers and strengthen the national policy dialogue on water and sustainable ecosystem services delivery for human wellbeing. However, some questions related to the sustainability of refilling the lake under continuing climatic change and variability remain to be clarified (Bouard and Tiers 2004).

Methods

Our research took place from July to October 2008. We worked at different levels (Fig. 4): national in the Malian

Years	1970s	1980s	1990s	2000s
Climate	Droughts	Severe droughts		Droughts
Hydrology	Dried lake			
Vegetation		Prosopis introduction	Forest growth in the dried lake	
Politics			Rebellion	Decentralization
External interventions	Refugee camps Food aid			GTZ Program Emergency Development
Population		Emigration (drought)	Emigration (conflict)	

Fig. 3 Historical timeline in the study area (based on community-level workshops)

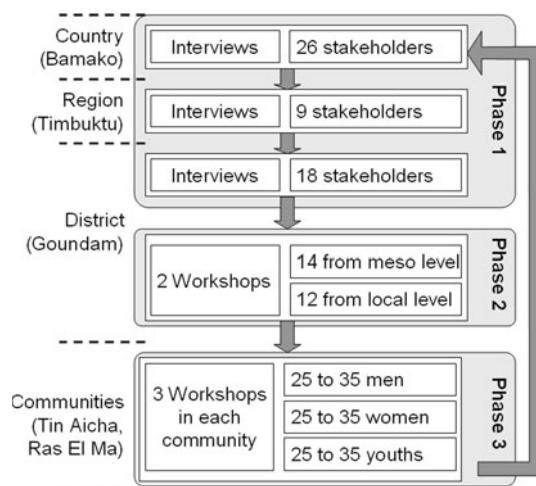


Fig. 4 Overview of the approach

capital of Bamako, meso (regional level at Timbuktu and district level at Goundam), and local level in two communities around Lake Faguibine (Tin Aicha and Ras El Ma). A fourth phase, in which the results were presented back to representatives from government and international development organisations at the national level, is not described here.

Vulnerability and adaptive capacity are subject to different interpretations. Therefore, the use of these concepts was adjusted according to the knowledge, background and perception of the stakeholders. At the local level, we focused our questions first on climate variability, specifically on drought events, since communities in the Sahel have particularly experienced droughts in the last decades. Later, we introduced a long-term perspective in order to bring in climate change. We discussed how communities and people coped with past extreme climate events, how they are coping now and how they will cope in the future with increasing climate risks. We asked questions about the socioeconomic, institutional and political factors influencing coping strategies in the past and the future. At the meso and national levels, we discussed vulnerability and adaptive capacity in terms of resource availability, entitlement and the ability of people to use the resources in case of drought events.

Phase 1: Interviews

We conducted interviews at the national, regional and district levels. At the national level, we interviewed 14 NGO representatives and 12 government representatives from institutions related to climate change, pastoralism and forests. At the regional level, we interviewed three representatives of government institutions (regional offices for forests, livestock and planning) and six NGOs related to

development, aid and livestock. At the district level, we interviewed 18 representatives of decentralised and administrative structures, as well as NGOs. A simplified data analysis on the connectedness between actors was conducted by using the network software package UCINET and NetDraw (Borgatti 2002).

These semi-structured interviews dealt with (i) climate change adaptation in general; (ii) the identification of stakeholders and their policy roles in relation to adaptation, forests or livestock; and (iii) the ongoing national adaptation processes (especially the National Adaptation Programme of Action, or NAPA). The region and sites for the vulnerability assessment were selected based on those interviews.

Phase 2: Workshops at the District Level

We organised two participatory workshops in Goundam. The first one gathered 14 representatives from governmental offices of outreach services and development organisations involved in agriculture, forests and livestock. The participants of this workshop were active at the district level and had a management or technical background. The second workshop gathered 12 local representatives, including leaders from six local communities (village leaders and representatives of herders).

In both workshops, participants identified the different types of ecosystems and livelihoods and developed a matrix of dependence on natural resources for different livelihoods. Then, they identified different climate risks and impacts and built a matrix of impacts on the different livelihoods. Finally, they ranked how the different livelihoods are affected by these impacts. The scoring (1–5) was consensus-based and the aggregated vulnerability score represented the mean of each group scoring. The scoring resulted from an open discussion between participants and allowed us to compare perceptions between groups.

Phase 3: Community workshops

Six participatory workshops were organised in the two communities, Tin Aicha and Ras El Ma, with 25–35 participants in each workshop. Various perspectives were captured by holding workshops with three different groups in each community: adult men, adult women and youths. We assessed vulnerability using different tools from Participatory Rural Appraisal (PRA).

We started with an historical axis, with which people could identify the major climatic (droughts) and other events affecting their local livelihoods. During this exercise, people collectively developed narratives about their experiences with droughts: who responded to climatic stresses, how, what responses were preferred and why,

what factors influenced those responses, and whether those responses are still used today to reduce current vulnerabilities. In addition, we used tools such as fodder calendars and resource maps to capture the role of forest ecosystems and the access and management of the available resources.

Results

Phase 1 (Interviews)

In Mali, activities related to climate change are coordinated by the Permanent Technical Secretariat for the Institutional Framework of Environmental Issues Management (STP/CIGQE), which is well connected to other actors (see Fig. 5, showing connections, distances and similarities between actors at the national and international level, based on the interviews). Another well-connected organisation is the Direction Nationale de la Météorologie (DNMétéo), the governmental organisation in charge of coordinating the relationships with the United Nations Framework Convention on Climate Change (UNFCCC). Other organisations are not well connected to other actors in the policy arena on climate change in Mali, such as the department of animal production, which is not linked directly to the core of the network.

At time of the research (2008), the donor community identified a need for further clarification on additionality of adaptation compared to development, and the linkages and boundaries between adaptation and development. They asked for more guidance and clearer criteria to define

adaptation and tools for steering adaptation funding. At this time only four actors had concrete, ongoing activities on adaptation (e.g. capacity building in cooperation with the Ministry of Forestry and the development of a screening tool for adaptation): Mali-Folkecenter (a Malian NGO that represents the Danish Folkecenter), VSF (Vétérinaires sans Frontières), Intercooperation (a Swiss development organisation) and the Mali climate change focal point ('DNMétéo').

At the national and regional level, the interviews highlighted the lack of information on local climate change vulnerabilities and adaptive responses to existing challenges. Few people in Bamako or Timbuktu knew about the local vulnerabilities and coping strategies of forest live-stock-related communities.

Adaptation needs were mentioned in a few regional and district-level interviews, but they were usually phrased in terms of development needs and regional drought experiences. CARE Timbuktu (Cooperative of American Remittances to Europe) mentioned vulnerability in relation to food security in development projects. At the district level, the emphasis was on links between food security, environment and technological measures, such as agricultural irrigation projects. Both regional and district interviewees mentioned the planned refilling of Lake Faguibine as an adaptation measure that was linked to the national and international level, including to UNEP. At all levels, interviewees highlighted the importance of capacity building and financial needs for adaptation.

Two actors, both from the donor community, mentioned the challenges of coordination and the need to interconnect

Fig. 5 Network of actors in the national adaptation arena

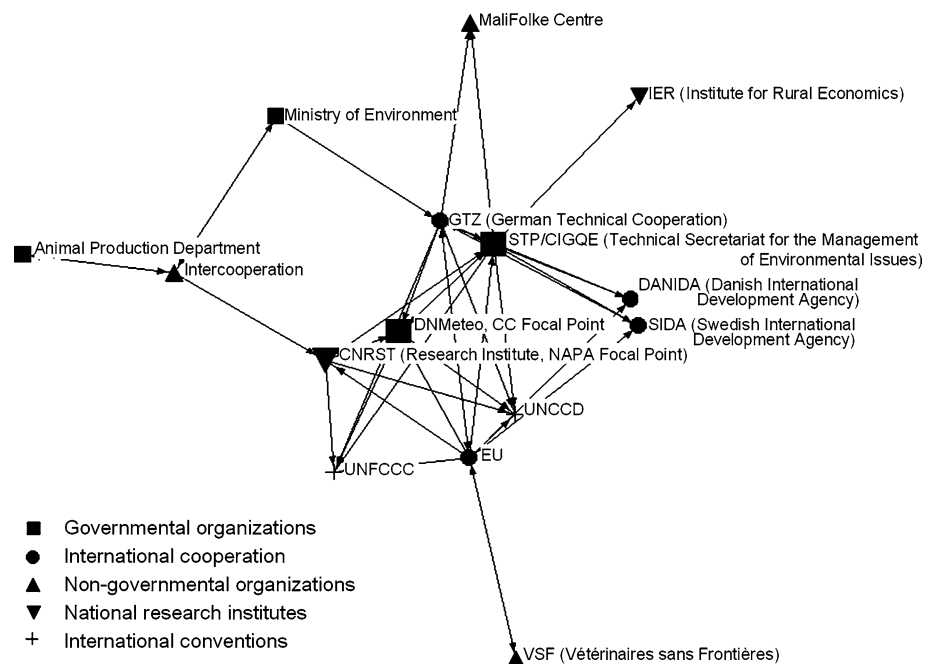


Table 1 Identified livelihoods and the contribution of livestock

Livelihood	Contribution of livestock in livelihoods	Characteristics of the production system
Sedentary agropastoralists	10–50%	Sedentary agropastoralists practising agriculture (often on lands belonging to others and cultivated under share cropping agreements) in areas around Lake Faguibine where water is still available and owning a variable number of animals
Transhumant pastoralists	More than 50%	Transhumant livestock herders (mostly cattle) Seasonal movement of people and livestock over relatively short distances
Nomadic pastoralists	More than 50%	Nomadic livestock herders (mostly small ruminants) Migration of people and livestock over long distances
Mixed livelihoods	Less than 10%	Diversified livelihoods: commerce, small livestock, forest product harvesting for charcoal, firewood, construction timber and handicrafts

institutions for a more effective adaptation. At the sub-national level, interviewees highlighted the lack of horizontal and vertical coordination and information flows between actors. At the national level, interviewees mentioned the NAPA as a first step towards adaptation.³ The NAPA was known only at the national level and was partially criticised; international non-governmental representatives noted that, while the plan mentions the need for local participation and consideration of local specificities, the proposed actions do not reflect this.

Phase 2 (workshops at the district level)

Livelihood system vulnerabilities

At the district level, the local representatives, the governmental agents and the representative of development organisations identified four livelihoods using livestock and forests. Adopting common pastoral livelihood classifications (e.g. Adano and Witsenburg 2008), we grouped these livelihoods into four types: sedentary agropastoralists, transhumant pastoralists, nomadic pastoralists and mixed livelihoods (Table 1).

The workshop participants identified the natural resources crucial for local livelihoods: water, forests, livestock and pastures. The two workshops produced different results (Fig. 6) on the different livelihoods' dependence on natural resources. The governmental and development agents perceived a higher dependency on natural resources by nomadic and transhumant than by sedentary livelihoods. Conversely, the local representatives assessed nomad and transhumant as less dependent on natural resources than sedentary livelihoods.

The participants in both workshops perceived growing climatic risks over the last 40 years with more frequent,

severe droughts and stronger, more destructive winds. The spatial distribution of rainfall was perceived as being more heterogeneous, with some areas not receiving rainfall over the previous 3 years (2005–2008). However, the two workshops produced different results for climatic impacts (Fig. 7). Governmental and development agents identified impacts on livestock, trees and pastures, desertification and water sources. Local representatives went beyond a list of impacts on natural resources and added social impacts of droughts, such as migration, diseases and conflicts.

The governmental and development agents considered that the most severe impact of climate variability was the loss of trees and pasture, while the local representatives highlighted conflicts, soil degradation and lack of water. The local representatives also addressed the quality of natural resources affected by climate variability, as participants considered the invasion by low-value tree species to be more problematic than the loss of trees.

The governmental and development agents considered that the three groups of livestock herders (sedentary, transhumant and nomadic) were similarly sensitive to climatic impacts on livestock, water, pasture and trees. Conversely, the local representatives differentiated livelihoods, for instance considering that sedentary and mixed livelihoods were more sensitive to flood (house damage), wind (desertification) and droughts (dried-up water sources, tree loss) than transhumant and nomadic livelihoods. They also perceived that climate-induced conflicts and soil degradation were affecting all livelihoods. Climate-induced pasture loss was considered to affect transhumant and nomadic herders more than sedentary and mixed livelihoods, because of their higher dependence on pastures. Even though the local representatives assessed the aggregated sensitivity of transhumant and nomadic livelihoods as being almost similar, a higher sensitivity of transhumant livelihoods to livestock loss was mentioned. This was explained as cattle being more sensitive to droughts and the

³ Mali finalised and submitted its NAPA at the end of 2007 but implementation was not expected for another 3 or 4 years.

Fig. 6 Dependence (*dots*) of the four types of livelihoods (*upper row*) on natural resources (*left column*), as expressed (*scoring*) by local and governmental representatives in the district-level workshops in Goundam

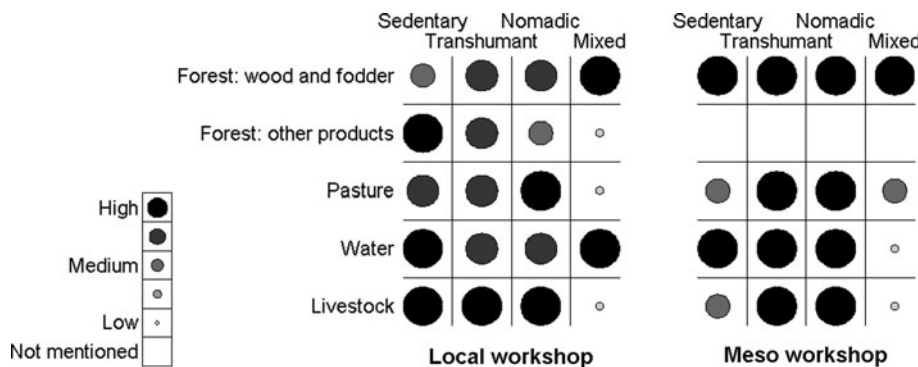
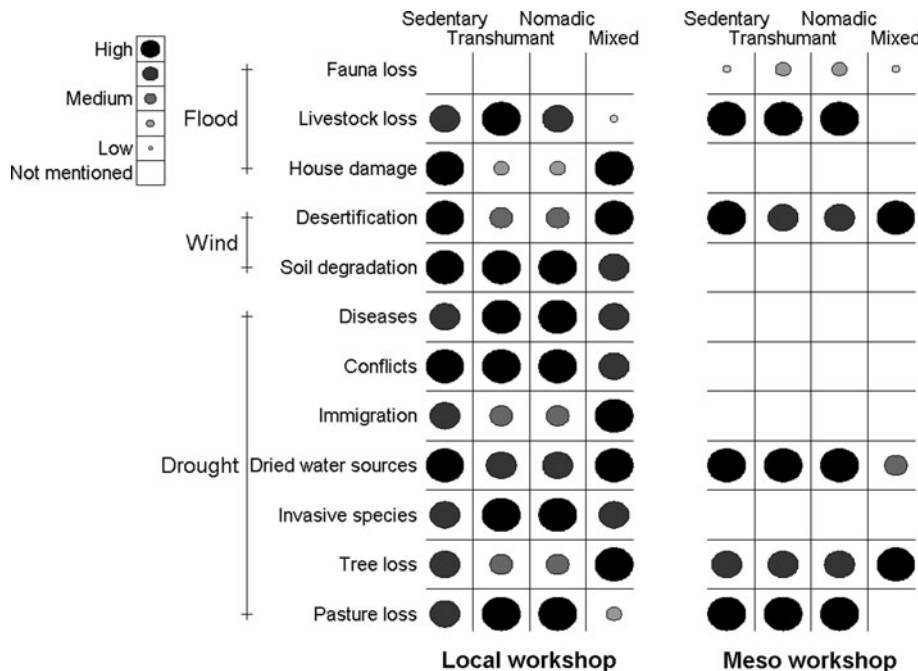


Fig. 7 Sensitivity (*dots*) of the four types of livelihoods (*upper row*) to changes induced by climate (*left column*), as expressed (*scoring*) by local and governmental representatives in the district-level workshops in Goundam



fact that transhumant livestock herders usually keep more cattle than small ruminants.

The two workshops produced very different results for the aggregated climate vulnerability of the four livelihood types. The governmental and development agents attributed higher vulnerability to transhumant and nomadic livestock herders, while the local representatives attributed the highest vulnerability to the sedentary livestock herders (Fig. 8).

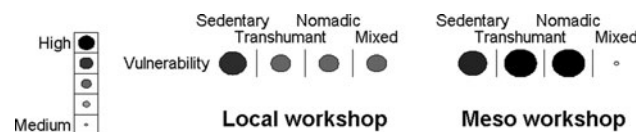


Fig. 8 Aggregated vulnerability (all groups) of four types of livelihoods (*upper row*) to climate change and variability, as expressed (*scoring*) by local and governmental representatives in the district-level workshops in Goundam

Phase 3 (Community Workshops)

Differential vulnerability

During the six community workshops, the participants identified the main events in recent history on an historical axis. In these workshops, people focused on droughts in their analysis and did not mention any other climate events, such as floods. The droughts in the seventies and eighties were always mentioned first, and the participants said they were still facing their consequences.

People adapted spontaneously by diversifying their livelihoods, rebuilding their herds and migrating; but a series of climatic and political events such as the drying out of Lake Faguibine and the rebellion put pressure on the socio-ecological system and reduced its adaptive capacity. Vulnerability has resulted from multiple successive stressors and their cumulative effects. Additionally, as identified in the historical axis, most state or aid organisation

interventions focused on emergency relief without any strategies to increase the community’s adaptive capacity in the medium or long-term.

Livelihoods systems and vulnerability

The community workshop participants identified similar types of livelihoods as identified in the workshops at district level, but with a more dynamic description of livelihoods and vulnerabilities in relation to ecological dynamics such as the transition from lake to forest (Fig. 9), and political-social changes such as decentralisation, land tenure reforms and the rebellion.

With the lake drying out, sedentary agricultural households, mainly from the Iklan social class, lost water and arable land. These farmers adapted by migrating temporarily to the south-east part of the former lake or close to the Niger River to cultivate land under a shared cropping system (link 1 in Fig. 9). In this new system, land access is no longer regulated by traditional mutual arrangements but by annually negotiated monetary contracts. As the demand for land is greater than the supply, financial speculations are common. Thus, changes in resource availability (endowment) or the loss of former assets increase the migrants’ vulnerability. Additionally, there is a high risk of entitlement deprivation because the former traditional arrangements regulating the access are no longer available or applicable for the new resources. The migrants also have limited power because they are newcomers with no previous involvement in the local decision-making structures.

We observed that the social structures in the Tamacheq society, once strongly dominated by class, status and wealth, have eroded due to the migration induced by drought and the rebellion, as well as new national policies related to land access. For example, workshop participants in Tin Aicha mentioned the impact of a 2006 policy (‘Loi d’Orientation Agricole’), which introduced for the first time the notion of equal access to land independent of gender, class and ethnicity. Indeed, societal rules and regulations are evolving, and different groups showed a growing awareness about their rights and resources. However, during the workshops, the Iklan—descendants of former slaves, traditionally farmers but land owners in the Tamacheq society—identified new opportunities in the current socio-political situation. They mentioned new local networks allowing them to play an important role in decision-making, in particular for access to the new forest. Beside the theoretical equal access to land guaranteed by the above-mentioned policy, the most important determinants for access were local regulations, personal networks, wealth and education, which are now influencing land access more than class or ethnicity.

With the lake drying out, fishing as part of a mixed livelihood came to an end and fishermen have adapted by gradually shifting to livestock-based livelihoods, in combination with other activities such as charcoal production (link 2 in Fig. 9). These small-scale, sedentary, livestock-based livelihoods depend on the fodder available in the new forests, but access to this resource is neither clearly regulated nor restricted. Former fishermen also lack experience and knowledge of animal husbandry—another major constraint for this already vulnerable group, particularly as government extension services have not yet adapted to the ‘new’ situation and do not provide adequate support.

The nomadic and transhumant herders who lost their livestock after recurring droughts strived to rebuild their herds. The economic, social and cultural importance of livestock explains its prevalence in adaptive strategies. Some herders received assistance from aid or emergency projects to rebuild their herds. Another strategy to rebuild herds was working as shepherds and being paid in cash or animals (link 3 in Fig. 9). Very few, however, have been able yet to rebuild their herds fully. While they have kept their traditional livelihood system, their vulnerability has grown. With changing climatic conditions, lacking income alternatives and the socially preferred livestock-based adaptation strategies, their adaptive corridor may turn into a vicious circle. Unlike the two other groups, nomadic and transhumant herders are traditionally entitled to access water and grazing land. The vulnerability of this group lies more in the lack of diversification alternatives and manpower, due to the sedentarisation and migration of younger family members. Additionally, the growing scarcity of

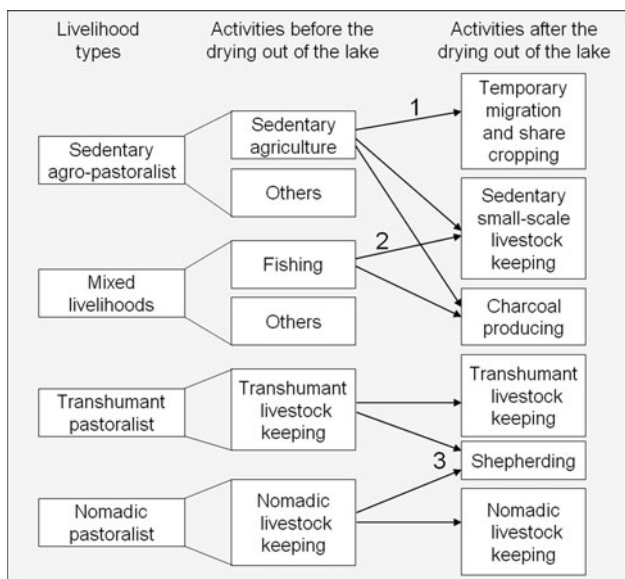


Fig. 9 Dynamics of livelihoods as expressed by the participants in the community workshops (numbers refer to the evolutions detailed in the text)

water resources forces the herders to concentrate grazing areas around available water sources, which can result in conflicts. The strongly expressed preference for continuing their livelihood activities confirms the relevance of mobility as a coping strategy, deeply rooted in the pastoral systems.

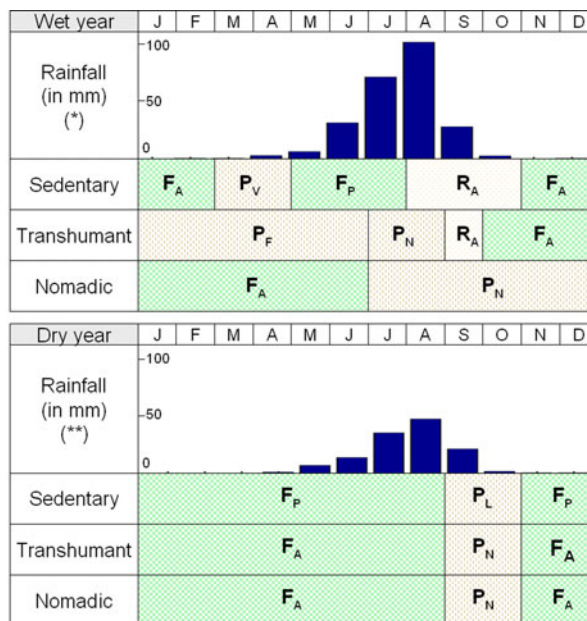
Women and vulnerability

The workload of women has increased with the evolution of adaptive livelihood strategies. For instance, in households with temporarily migrating farmers, women have to manage community activities traditionally undertaken by men. Participants in the women’s workshops explained that their burden is increasing due to the loss of manpower in the household and the need for new income-generating activities from the emerging forest ecosystem such as charcoal production, small ruminant herding and small-scale commercial activities (charcoal and wood). Even though roles have shifted among, and changed within, social classes, ethnic and gender groups, what has not changed is gender inequity regarding access to land. Women in the workshops did not mention the ‘Loi d’Orientation Agricole’ and they did not know about the equal rights theoretically guaranteed by this policy. The women in the local agricultural association in Tin Aicha lost their former agricultural activities after Lake Faguibine dried out and water was no longer available for irrigation, and they are excluded from the new lands in other irrigated areas. Additionally, we observed in the workshop that despite their ‘higher’ societal roles, Illelan women had less concrete adaptive activities. Even though they mentioned the same broader activities as the Iklan women (except charcoal production, which they did not mention at all), how to implement these activities remained unclear to them.

Role of forests in reducing vulnerability

The role of forests in reducing vulnerability to climate variability was emphasised in all workshops. As in the workshops at district level, the community workshops revealed the emerging and changing role of forests in supporting livelihoods (formerly based on water), and the transition from forests as a safety net to a daily subsistence base and a fundamental part of adaptive strategies (Fig. 9). This also implies a growing pressure on the new forest resources during dry years.

The role of forests for livestock herders became clear when community workshop participants discussed the fodder calendar. The contribution of forests to animal nutrition during a typical rainy year differed between the different livestock herders (Fig. 10). The sedentary herders use the Prosopis and the Acacia forest for 7 months, while



F: forests (A: Acacia, P: Prosopis)
 P: pastures (V: various, L: Leptadenia, F: flooded, N: non-flooded)
 R: residues (A: agricultural)
 (*) Average monthly rainfall during the 25% years with highest annual rainfall
 (**) Average monthly rainfall during the 25% years with lowest annual rainfall
 Climate data (years 1961 to 2002) are from CRU TS 2.1 (Mitchell and Jones, 2005)

Fig. 10 The animal fodder calendar: contribution of forests during dry and rainy years for three types of pastoralists

the transhumant and nomadic livestock herders use only the natural Acacia forest, respectively, for 3 and 6 months. In a typical dry year, forest use intensifies, showing clearly its safety net function as a major source of fodder across 10 months.

Even though local people valued forests for their contribution to livelihoods and adaptation strategies, they expressed concerns about the negative consequences of a potential invasion of Prosopis, if the expansion of this highly invasive species is not controlled. Because of their high density, Prosopis forests are accessible only close to their edges for fodder grazing by animals and wood collection by local people. In addition, the invasion could imply the loss of land rights by farmers, as forested lands belong, by law, to the state.

Discussion

The structural and individual drivers of vulnerability of forest-based livelihoods

Results showed that forest resources play a key role in livelihood adaptations in the Lake Faguibine area. Both communities highlighted the importance of forests, but the Tin Aicha community, where Prosopis has been introduced, expressed strong concerns about a further expansion

of the Prosopis forest. The ambivalent relation to this forest became obvious. Even though more pros than cons were mentioned regarding forest goods and services, people were concerned about the loss of agricultural land because of forest expansion and the loss of future opportunities for agriculture in case the lake returns. However, in the current situation, forests support responses to cumulative stressors and play an integral part in the response strategies of the different livelihoods. The sustainable use and provision of forest ecosystem services can be jeopardised because state and development agencies do not consider the new role played by forests. Therefore, the vulnerability of the socio-ecological systems emerges out of a disregard for the potential of forests to minimise vulnerability. Various factors undermine the sustainable use of forest resources and therefore drive vulnerability in the former lake area.

Long-term versus short-term

Forest-based adaptive strategies have enabled people to cope with stress, at least in the short-term. In the long-term, these strategies can have adverse impacts on the resource itself and this could increase vulnerability to climate variability and change, as observed also in other studies (Paavola 2008). In one of the research communities, the Prosopis forest, if well managed, could provide an excellent source of fodder especially as a safety net during drought periods. Ecological studies in Ethiopia showed that the control of Prosopis with animal grazing is an attractive and viable option for taking benefit of the ecological and economical value of Prosopis (Shiferawa et al. 2004). However, as the Prosopis forest of Lake Faguibine has currently a high tree density and lacks an appropriate management, its rapid expansion creates inaccessible forests and an overall loss of grazing resources. To use the potential of the Prosopis forest in the long-term and to avoid further degradation of the natural Acacia forest, short-term investments in management are needed. Such an investment could aim at converting the Prosopis forests into silvopastoral systems, as it has been recommended in other regions (Pasiecznik et al. 2001).

Equity and the lack of clarity in access

Local institutions have not yet responded to the changes in ecosystem and land-use patterns, as property rights for the forest resources are still unclear and adaptive strategies have led to new land and resource uses. This trend, in a context of hierarchical societal structures and marginalisation, can lead to resource-related conflicts and aggravate vulnerability by hindering sustainable forest management. Nevertheless, political ecologists (Turner

2004; Benjaminsen 2008) contested in the last decade the rationale that resource scarcity was the main driver behind conflict in the Sahel. They instead highlighted the strong interdependency between resource access, political disputes and moralities for a conflict genesis. Additionally, the ongoing decentralisation process, with a so far incomplete transfer of resources to the local level, has generated an institutional vacuum that can lead to elites capturing rights, for example, by representation in the newly decentralised structures. This is further aggravated by the unclear legal status of forests. Prosopis-forested land is considered as either a long-term fallow (thus belonging to the state) or as a forest (thus requiring payment of forest-use taxes).

Political promises and psychological barriers

The local groups have all shown a strong preference for the 'return of the lake', rather than keeping the forest. There is a strong discrepancy between the perception of the forest and the de-facto use of its products. This can be explained by individual and community psychological barriers due to the massive change and 'traumatisms' attached to the ecosystem transformation; these may hinder acceptance of the change. In the communities, especially in Tin Aicha, where the experience of the lake drying out is more recent and people are concerned about an uncontrollable expansion of Prosopis, vulnerability is perceived as linked to losing the lake, and only the lake's return can allow for a prosperous future. This wish for the 'return of the lake' could be related to the concept that Albrecht (2005) called 'solastalgia'. This describes the reaction of people who experienced an extreme change in their environment, characterised by a sense of powerlessness or lack of control over the change process. Additionally, various leaders have nurtured the wish for a 'return of the lake' over the past three decades, as many politicians promise, for electoral purposes, to mobilise funds to 'bring the lake back'. These political discourses do not incentivise long-term strategic planning around the now available forest resources and therewith contribute to a politically constructed vulnerability. Similarly, Adger (2006) noted that perceptions of adaptation by the vulnerable themselves could limit adaptive actions even when resources were available.

Lack of capacities and knowledge

The ecosystem transformation has modified livelihood strategies towards more forest-based activities, but the forest users do not have adequate knowledge of forest management. Additionally, the state has not so far facilitated the development of forest management plans or provided adequate technical assistance.

Uncertainty

In an area where not only climate is uncertain but also the societal and political environment (for example, rebellion), long-term planning becomes a very challenging task. Investing in activities with mid- or long-term pay-offs, such as forest management, is limited by the political instability and climatic risks, as well as a lack of financial means.

Vulnerability and the case of mobile versus sedentary pastoralists

Regarding mobility, the differences observed in the two district-level workshops can be explained by the participants' educational and socio-political backgrounds, and the fact that one workshop was attended by meso-level stakeholders and the other by local stakeholders. Meso-level governmental and development agents regarded mobility more as a risk than an adaptive strategy. On the contrary, local participants perceived mobility as a well-established traditional adaptation strategy to climate variability. In communities in the Lake Faguibine area, as elsewhere, the nature, intensity and pathways of mobility in traditional livestock systems are constantly evolving (for example, by shifting between mobility and sedentarisation, moving a part of the herd, or hiring herders). During extreme events or shocks, partial mobility and temporary sedentarisation are important diversification strategies for pastoral livelihoods. The mosaic of locally specific strategies and needs represents a challenge for policy makers to design adequate development policies consistent with both the national goals of rural development and the interests of pastoral people (Mortimore 2000). As development policies have to be aligned with people's strategies, Brooks et al. (2009) suggest building development (and adaptation) around livelihoods and not the contrary. Nomadism may be more adapted to the environmental conditions of northern Mali than sedentarism. For example, the nutrition of children in northern Mali is better among nomadic groups than sedentary ones (Pedersen and Benjaminsen 2008). However, mobility cannot be seen as a single adaptive strategy to avoid vulnerability (Robbins 1998) but as part of the need for flexibility in pastoral livelihoods for dealing with external climatic (drought) or economic (market) change.

Therefore, the contradiction between mobility and development, as perceived by some stakeholders, does not reflect the necessary flexibility of pastoral livelihoods. Godall (2007) argued that sedentarisation was viewed in many governmental circles as a natural consequence of progress and development. This perception has led to rather maladaptive policies and programmes. This marginalisation of pastoral livelihoods has affected their vulnerability

to drought and may lead to increased vulnerability in the future (Brooks 2006).

Besides those power-related factors in the sedentarisation versus mobility debate, and considering that nomadic households in this region have had to cope with severe human and animal loss during past droughts, it is important to consider the role of social identities in vulnerability assessments at the local level. Perception, social and cultural norms defining the Tamacheq social identity ('a nomad will stay a nomad until he dies', as stated several times by community workshop participants) have to be considered when interpreting the local vulnerability assessments. Further comparative studies of different adaptive strategies in mobile and sedentary livelihoods (including the impact of those strategies on ecosystems) are needed.

Vulnerability assessments: multi-level approaches to respond to challenges

A multi-level approach for catching different perceptions

The interviews and workshops at different levels showed different views of vulnerability. The community-level perception in the vulnerability assessments focused more on adaptation strategies, social and ecological interactions, and local dynamics. At the national level, the focus was much more on sectoral and technical adaptation and the linkages between global and national levels, rather than between local and national levels. In addition, the analysis differed between levels in relation to the importance of forests in livelihoods, the degree of dependency of different livelihoods on natural resources and their vulnerability. In addition, even at the same level, social identities and psychological factors influence how people perceive vulnerability, as shown by the example of the conflicting views on mobility and sedentarisation and the wish for the 'return of the lake'. Social identities, expressed in class, gender and ethnicity, determine the bundles of options that are available and socially feasible for a group or individuals at the local level. Similar evidence was also found in other communities in West Africa (Nielsen and Reenberg 2010), which reinforces the need to recognise the role of identities in enhancing or hindering adaptation. Therefore, a more holistic analysis of belief systems and identity, taking into account individual and collective experiences, can help the understanding of adaptive decision-making at different levels and support the implementation of adaptive strategies across scales.

Different temporal scales were considered when working with different stakeholders. In the short-term, forests contribute to local adaptive strategies but, in the long-term, the strategies could lead to forest degradation and higher social vulnerability.

Strategies based on migration were analysed as adaptive in the short-term but also with possible negative consequences in the long-term, especially for women. There is a need to investigate whether the high current vulnerability of women will lead to a higher structural vulnerability or more empowerment by changing gender power relations within the society.

Long-term dynamics must be considered when analysing the possible evolution of women's vulnerability. As a result of male migration, new opportunities could emerge for women regarding the gendered division of labour, the repartition of power, decision-making processes and market access. To support women in turning short-term negative impacts on their vulnerability into a long-term positive development, new opportunities have to be accompanied by gender-sensitive analysis of existing and planned adaptive strategies. However, broader societal and political changes are needed to realise these opportunities. In addition, investments in women's capacity building and knowledge will improve sustainable forest management for charcoal production.

In terms of planning adaptation, different options can be proposed from the multi-level analysis of vulnerability; for instance, an infrastructure-based adaptation by refilling the lake (proposed by regional and district-level stakeholders) or an ecosystem-based adaptation by implementing sustainable forest management (proposed during the community workshops, even if people believed in the political promises for the 'return of the lake'). From a local perspective, adaptation planning should be built on the current adaptive strategies implemented by households, including mobility. From a top-down perspective, sedentarisation was seen as part of an adaptation strategy. Vulnerability assessments have to capture these differences in perception, otherwise they may lead to maladaptation or inefficient adaptation efforts.

A multi-level approach for understanding the role of politics and power in vulnerability

Working at different levels highlighted the role of politics and power in and across levels in explaining vulnerability. For instance, the local workshops showed how important forests were in the adaptive strategies. Most people, however, expressed strong concerns about the newly emerged Prosopis forest, in part because they hoped the lake would return as promised by politicians, in part because of the invasive character of Prosopis in the lake area. The political and power relationships between regional politicians and local people were an impediment to evaluating adaptive strategies based on the current situation (the forests) rather than on a perhaps unreachable future (the return of the lake).

The contrasting views on mobility also reflect political interests in the context of decentralisation, where, for example, the aggregation and redistribution of taxes for financing local infrastructure are based on local 'citizenship'. A governmental agent stated, in the workshop, that 'we must first centralise (sedentarise) the nomads before decentralizing'. Emergency and development programmes have also incentivised sedentarisation, because participation in the programmes requires a physical presence. These programs and projects have been very important for short-term coping with extreme events and external shocks. However, this has changed the incentive structure towards sedentarisation and may have reduced the flexibility and adaptive capacity of the non-equilibrium socio-ecological systems in the long-term.

While the discourse around sedentarisation and mobility appeared strongly in the different perceptions of vulnerability at the sub-national level, its importance and controversial character were not reflected in debates on vulnerability at the national level. This can be interpreted as a disconnection between local realities and national framework policies regarding livestock, forests and vulnerability. Vulnerability assessments have to respond to these political and power issues; otherwise, the resulting adaptive strategies and the competition between stakeholders can deepen existing inequalities or disregard existing strategies whose beneficiaries are without a political voice (Osbahr 2007).

Conclusion

After drastic changes in the ecological, social and economic context, forests have gained importance in adaptive strategies around Lake Faguibine in northern Mali. Those changes have resulted in shifts in endowment, entitlement and power in the different livelihood systems and for different social groups inside those systems.

Our results confirm the importance of analysing the perceptions and social identities of different groups at different levels. For a deeper understanding of vulnerability, our research suggests strongly the use of approaches with four important features: multi-level (from local to national and vice versa); participatory (with different tools for eliciting people's views, depending on level); integrative (with consideration of ecological, social, economic and political factors); and gender-sensitive.

Vulnerability to climate change is dynamic and can shift in response to social, ecological, economic or political changes. Our results show that generic assumptions and conclusions (for example, that higher socioeconomic classes have more assets and therefore higher adaptive capacity) have to be reconsidered; otherwise, this can lead

to biased vulnerability assessments of different groups. Locally specific dynamics with intertwined and evolving interactions between class, gender and ethnicity have to be analysed to generate a differentiated understanding of vulnerabilities in communities.

In the study area, the contribution of forests to reducing future vulnerability will depend on their management. Forest ecosystem services have enabled people to cope with stress—at least in the short-term. In the long-term, these strategies can have adverse impacts on the resource itself, which could be degraded. This could lead to increasing vulnerability to climate variability and change. Even though forests are a key resource for local livelihoods, institutions have not integrated forests into their management frameworks, neither in decentralised institutions at a sub-national level, nor in national action programmes for adaptation.

In addition, stronger information flows are needed from the national or international to the local level; but even more so in the other direction from the local level, where adaptation is needed and happening, up to policymaking at higher levels. This requires much stronger investments by the global and national community (development, research, government and non-government) in local empowerment, to overcome imbalances in voice, participation and decision-making authority. The differences in the perception of mobility and its impact on the vulnerability of both livelihoods and ecosystems illustrate how these information flows across levels are important to avoid maladapted planning.

Current adaptation practices can lead to inequities, with some stakeholders adapting to the detriment of others, as the examples of women or different livelihood groups show. Interactions between the different groups have to be taken into account in planning processes across scales and levels, otherwise competition over natural and economic resources can lead to maladaptation. Different groups with partially conflicting adaptation interests should be involved in the planning of adaptation at the decentralised, sub-national level.

To capture locally specific knowledge, experience and information, we suggest that, complementary to the NAPA process at the national level, vulnerability assessments and adaptation planning are transferred (including the financial resources) to lower levels, for identifying sub-national and local action plans for adaptation. The national level should strengthen its coordination role and facilitate flows of information and finance from the global to the local level.

Acknowledgments The authors thank all participants and interviewees in the local communities (Tin Aicha, Ras El Ma), Goundam, Timbuktu and Bamako. We also thank Moushumi Chaudhury, Denis Gautier and two anonymous reviewers for their useful comments. This document has been produced within the framework of the

‘Tropical Forests and Climate Change Adaptation’ (TroFCCA) project executed by CATIE and CIFOR and funded by the European Commission under contract EuropeAid/ENV/2004-81719. The contents of this document are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the European Union.

Open Access This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

References

- Adano WR, Witsenburg KM (2008) Pastoral sedentarization, natural resource management, and livelihood diversification in Marsabit District, Northern Kenya. Edwin Mellen Press, Amsterdam
- Adger WN (2006) Vulnerability. *Glob Environ Change* 16:268–281
- Adger WN, Kelly PM (1999) Social vulnerability to climate change and the architecture of entitlements. *Mitig Adapt Strateg Glob Change* 4(3):253–266
- Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? *Clim Change* 93(3):335–354
- Albrecht G (2005) ‘Solastalgia’ a new concept in health and identity. *PAN: Philos Act Nat* (3):41–55
- Allen TFH, Starr TB (1982) Hierarchy: perspectives for ecological complexity. University of Chicago Press, Chicago
- Benjaminsen TA (2008) Does supply-induced scarcity drive violent conflicts in the African Sahel? The case of the Tuareg rebellion in Northern Mali. *J Peace Res* 45(6):819–836
- Borgatti SP (2002) NetDraw: graph visualization software. [1.43]. 2002. Analytic Technologies, Harvard
- Bouard S, Tiers S (2004) Le lac Faguibine, un espace agropastoral au nord Mali: dynamiques agraires, gestion des ressources naturelles et stratégies des acteurs. Mémoire ESAT2-DIAT, option AGIR, CNEARC, Montpellier
- Brockhaus M, Djoudi H (2008) Adaptation at the interface of forest ecosystem goods and services and livestock production systems in Northern Mali. CIFOR Info brief No.19. http://www.cifor.cgiar.org/publications/pdf_files/Infobrief/019-infobrief.pdf. Accessed 24 Nov 2009
- Brooks N (2006) Climate change and the Sahel mobility and modernity in a long-term environmental context. SOS Sahel International UK. <http://www.sahel.org.uk/pdf/>. Accessed 20 Nov 2009
- Brooks N, Grist N, Brown K (2009) Development futures in the context of climate change: challenging the present and learning from the past. *Dev Policy Rev* 27(6):741–765
- Carter TR, Parry ML, Harasawa H, Nishioka S (1994) IPCC technical guidelines for assessing climate change impacts and adaptations. Department of Geography, University College London, London
- Cash DW, Adger WN, Berkes F, Garden P, Lebel L, Olsson P, Pritchard L, Young O (2006) Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecol Soc* 11(2). <http://www.ecologyandsociety.org/vol11/iss12/art18/>. Accessed 6 Dec 2009
- Davies S (1993) Are coping strategies a cop out? *IDS Bull* 24:60–72
- DRPSIAP (2008) Annuaire statistique Année 2006. Direction Régionale de la Planification, de la Statistique, de l’Informatique, de l’Aménagement du Territoire et de la Population (DRPSIAP). Tombouctou, Mali
- Eakin H, Luers AL (2006) Assessing the vulnerability of social-environmental systems. *Ann Rev Environ Resour* 31:365–394

- Fekete A, Damm M, Birkmann J (2009) Scales as a challenge for vulnerability assessment. *Nat Hazards*. doi:10.1007/s11069-009-9445-5
- Füssel HM (2007) Vulnerability: a generally applicable conceptual framework for climate change research. *Glob Environ Change* 17(2):155–167
- Füssel HM, Klein R (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. *Clim Change* 75(3):301–329
- Gardner J, Dowd AM, Mason C, Ashworth P (2009) A framework for stakeholder engagement on climate adaptation. Climate adaptation flagship working paper no. 3, CSIRO
- GHCN (2010) 1900–2009 precipitation anomalies. Global historical climatology network (GHCN), National Climatic Data Center, National Oceanic and Atmospheric Administration. <http://www.ncdc.noaa.gov/temp-and-precip/gHCN-gridded-prcp.html>. Accessed 15 Jan 2011
- Gibson CC, Ostrom E, Ahn TK (2000) The concept of scale and the human dimensions of global change: a survey. *Ecol Econ* 32(2):217–239
- Godall SK (2007) From plateau pastures to urban fringe: sedentarization of nomadic pastoralists in Ladakh, North-West India. PhD thesis. University of Adelaide, School of Social Sciences, Geographical and Environmental Studies
- Heltberg R, Siegel PB, Jorgensen SL (2009) Addressing human vulnerability to climate change: toward a ‘no-regrets’ approach. *Glob Environ Change* 19(1):89–99
- Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *Int J Climatol* 25:1965–1978
- Holdridge LR (1947) Determination of world plant formations from simple climatic data. *Science* 105:367–368
- Krings T (1995) Marginalization and revolt among the Tuareg in Mali and Niger. *GeoJournal* 36:57–63
- Laxen J (2007) Is prosopis a curse or a blessing? An ecological-economic analysis of an invasive alien tree species in Sudan. University of Helsinki, Viikki Tropical Resources Institute. *Trop For Rep* 32:203
- Locatelli B, Kanninen M, Brockhaus M, Colfer CJP, Murdiyarto D, Santoso H (2008) Facing an uncertain future: how forest and people can adapt to climate change. CIFOR, Bogor
- Lynch AH, Tryhorn L, Abramson R (2008) Working at the boundary: facilitating interdisciplinarity in climate change adaptation research. *Bull Am Meteorol Soc* 89(2):169–179
- Maddison D (2006) The perception of and adaptation to climate change in Africa. CEEPA discussion paper 10. Special Series on Climate Change and Agriculture in Africa
- McCarthy JJ (2001) Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
- Mortimore MJ (2000) Hard questions for ‘pastoral development’: a northern Nigerian perspective. In: Tielkes E, Schlecht E, Hiernaux P (eds) *Elevage et gestion de parcours au Sahel, implications pour le développement*. Verlag Grauer, Stuttgart
- Mortimore MJ, Adams WM (2001) Farmer adaptation, change and ‘crisis’ in the Sahel. *Glob Environ Change* 11:49–57
- Niamir-Fuller M (1999) Toward a synthesis of guidelines for legitimizing transhumance. In: Niamir-Fuller M (ed) *Managing mobility in African rangelands: the legitimization of transhumance*. FAO and Beijer International Institut of Ecological Economics, London
- Nielsen JØ, Reenberg A (2010) Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. *Glob Environ Change* 20(1):142–152. doi:10.1016/j.gloenvcha.2009.10.002
- Nunow AA (2000) Pastoralists and markets: livestock commercialization and food security in North Eastern Kenya. PhD dissertation, Universiteit van Amsterdam
- O’Brien K, Quinlan T, Ziervogel G (2009) Vulnerability interventions in the context of multiple stressors: lessons from the Southern Africa Vulnerability Initiative (SAVI). *Environ Sci Policy* 12:23–32
- Osbahr H (2007) Building resilience: adaptation mechanisms and mainstreaming for the poor. Occasional Paper, Human Development Report Office, New York
- Paavola J (2008) Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environ Sci Policy* 11(7):642–654
- Pasiecznik N (1999) Prosopis-pest or providence, weed or wonder tree? *Eur Trop Forest Res Netw Newsl* 28:12–14
- Pasiecznik NM, Felker P, Harris PJC, Harsh LN, Cruz G, Tewari JC, Cadoret K, Maldonado LJ (2001) *The Prosopis juliflora—Prosopis pallida* complex: a monograph. HDRA, Coventry
- Pedersen J, Benjaminsen TA (2008) One leg or two? Food security and pastoralism in the northern Sahel. *Hum Ecol* 36:43–57
- Pettengell C (2010) Climate change adaptation. Enabling people living in poverty to adapt. Oxfam international research report, April 2010. Oxfam, London
- Polsky C, Neff R, Yarnal B (2007) Building comparable global change vulnerability assessments: the vulnerability scoping diagram. *Glob Environ Change* 17(3–4):472–485
- Preston BL, Stafford-Smith M (2009) Framing vulnerability and adaptive capacity assessment: Discussion paper. CSIRO climate adaptation flagship working paper no. 2. <http://www.csiro.au/ClimateAdaptationFlagship.html>. Accessed 17 Jan 2011
- Randall SC (2005) Demographic consequences of conflict, forced migration and repatriation: a case study of Malian Kel Tamasheq. *Eur J Popul* 21(2):291–320
- Ribot JC (2009) Vulnerability does not just come from the sky: framing grounded pro-poor cross-scale climate policy. In: Mearns R, Norton A (eds) *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. World Bank, Washington, DC
- Robbins P (1998) Nomadization in Rajasthan India: migration, institutions and economy. *Hum Ecol* 26(1):87–111
- Sen A (1987) Hunger and entitlements: research for action. World Institute for Development Economics Research, Helsinki
- Shiferawa H, Teketayb D, Nemomissac S, Assefac F (2004) Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC. at Middle Awash Rift Valley Area, north-eastern Ethiopia. *J Arid Environ* 58(2):135–154
- Sudmeier-Rieux K, Masundire H, Rizvi A, Rietbergen S (2006) Ecosystems, livelihoods and disasters: an integrated approach to disaster management. IUCN. Ecosystem management series 4
- Sungno Niggol S, Mendelsohn R (2006) Climate change adaptation in Africa: a microeconomic analysis of livestock choice. CEEPA discussion paper 19, special series on climate change and agriculture in Africa
- Tompkins EL, Adger WN (2004) Does adaptive management of natural resources enhance resilience to climate change? *Ecol Soc* 9(2):10 <http://www.ecologyandsociety.org/vol9/iss2/art10>. Accessed 12 Feb 2010
- Trench P, Rowley J, Diarra M, Sano F, Keita B (2007) Beyond any drought: root causes of chronic vulnerability in the Sahel. The Sahel Working Group, Oxfam, CARE international, London
- Turner MD (1999) Merging local and regional analysis of land-use change: the case of livestock in the Sahel. *Ann Assoc Am Geogr* 89(2):191–219
- Turner MD (2004) Political ecology and the moral dimensions of ‘resource conflicts’: the case of farmer-herder conflicts in the Sahel. *Political Geogr* 23:863–889

- Turner MD (2010) Climate change and social resilience: 'adaptive' conflict in the Sahel. Paper prepared for the Berkeley environmental politics workshop. http://globetrotter.berkeley.edu/bwep/colloquium/papers/Turner_ClimateChangeAndSocialResilience.pdf. Accessed 27 Dec 2010
- Turner BL, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L, Eckley N, Kasperson JX, Luers A, Martello ML, Polsky C, Pulsipher A, Schiller A (2003) A framework for vulnerability analysis in sustainability science. *Proc Natl Acad Sci USA* 100(14):8074–8079
- UNEP (2009) Ecosystem management for improved human well-being in the Lake Faguibine system: conflict mitigation and adaptation to climate change (draft). <http://www.unep.org/pdf/Lake-Faguibine.pdf>. Accessed 24 Nov 2009
- Van der Geest K, Dietz T (2004) A literature survey about risk and vulnerability in drylands, with a focus on the Sahel. In: Dietz AJ, Ruben R, Verhagen A (eds) *The impact of climate change on Drylands with a focus on West Africa*. *Environ Policy* 39:117–136
- Watts MJ, Bohle HG (1993) The space of vulnerability: the causal structure of hunger and famine. *Prog Hum Geogr* 17:43–67