

Adaptation strategies and climate vulnerability in the Sudano-Sahelian region of West Africa

Ole Mertz,^{1*} Cheikh Mbow,² Anette Reenberg,¹ Lorenzo Genesio,³ Eric F. Lambin,⁴ Sarah D'haen,⁴ Malicki Zorom,⁵ Kjeld Rasmussen,¹ Drissa Diallo,⁶ Bruno Barbier,⁷ Ibrahim Bouzou Moussa,⁸ Awa Diouf,² Jonas Ø. Nielsen⁹ and Inge Sandholt¹

¹Department of Geography and Geology, University of Copenhagen, Denmark

²Institut des Sciences de l'Environnement, Faculté des Sciences et Techniques, Laboratoire d'Enseignement et de Recherche en Géomatique, Ecole Supérieure Polytechnique; Université Cheikh Anta Diop de Dakar, Senegal

³Istituto di Biometeorologia, Consiglio Nazionale delle Ricerche (IBIMET CNR), Italy

⁴Department of Geography, Université Catholique de Louvain-La-Neuve, Belgium

⁵International Institute for Water and Environmental Engineering, ZIE, Ouagadougou, Burkina Faso

⁶Département des Sciences de la terre, Université de Bamako, Mali

⁷CIRAD, Ouagadougou, Burkina Faso

⁸Département de Géographie, Université Abdou Moumouni, Niamey, Niger

⁹Department of Anthropology, University of Copenhagen, Denmark

*Correspondence to:

Ole Mertz, Department of Geography and Geology, University of Copenhagen, Denmark.

E-mail: om@geo.ku.dk

Abstract

Rural development in the Sudano-Sahelian region during the past 20 years and future scenarios of change were studied using meta-analysis of case studies, household interviews and scenario assessment. Households have generally increased their wealth, especially when they diversify out of agriculture. Rain-fed crop cultivation is more sensitive to climate factors than livestock, but generally climate factors play a limited direct role for local land use and livelihood strategies. The agricultural sector needs strong support to remain important in the region and off-farm work and migration are likely to continue to increase, which may decrease vulnerability. Copyright © 2011 Royal Meteorological Society

Keywords: adaptation; climate change; livelihoods; poverty; Sahel; vulnerability

Received: 15 February 2010
Revised: 14 October 2010
Accepted: 1 November 2010

1. Introduction

The Sudano-Sahelian region of West Africa, one of the poorest regions in the world, is characterized by high rainfall variability and rapid population growth. Despite centuries of experience adapting to harsh natural conditions (Mortimore and Adams, 2001; Tschakert, 2007; Mertz *et al.*, 2009), the vulnerability of these countries and their populations to increased climate variability and change is of great concern and has attracted considerable research interest over the past decades with calls for increased funding for adaptation (Patt *et al.*, 2010).

The aim of this paper is to provide an overview of the most recent advances within the project African Monsoon Multidisciplinary Analysis (AMMA) on agricultural and climate vulnerability in the Sudano-Sahelian region of West Africa with a particular emphasis on local rural adaptation and coping strategies during the past 20 years. It is based on the latest AMMA research on the West African monsoon systems (Polcher *et al.*, 2011), which is essential for predicting future vulnerability and adaptation, and will be discussed in the context of contemporary research in the region. Section 2 sets the stage of national and regional developments, Section 3 outlines the local perceptions of change and Section 4 summarizes

possible future scenarios for development in the Sahel. We use the terms vulnerability, adaptation and others as they are defined by the IPCC (Adger *et al.*, 2007).

2. Regional and national change – drivers and trends

The Sudano-Sahelian region is very diverse and while agriculture remains the mainstay of the economy, other economic activities are rapidly gaining importance. This was highlighted in a meta-study (Raquez and Lambin, 2006) of more than 80 case studies, which recommended that the traditional focus on land use as determined by subsistence agriculture should be expanded to include the processes of migration, trade and institutional changes that are occurring rapidly. These trends have also been observed in other studies and have guided the empirical research described in Section 3.

The above-mentioned livelihood diversification is part of the risk reduction strategies that local people adopt to reduce their vulnerability (Tarchiani *et al.*, 2006). It is also an underlying socio-economic trend that has been observed in many developing countries, where supplementing agriculture with other activities increases wealth while decreasing vulnerability to climate factors.

The diversification trends are partly in contradiction with analyses of food security in the Sahelian West Africa that are based on assumptions of agricultural production being primarily for self consumption (Egg and Gabas, 1997). This model has been shown not to represent correctly the complexity of the Sahelian system and therefore has limited capability to prevent food crises, as highlighted by the food crises in Burkina Faso in 2000 and Niger in 2005, where the interaction of climatic hazards and other driving forces (political instability, desert locust invasions, market shocks, response failures) were identified as the main causes (Vignaroli *et al.*, 2006; Devereux, 2009). To provide improved instruments to assess and monitor vulnerability, we developed a revised methodology for vulnerability assessment framework based on a holistic approach and taking into account the importance of emerging dynamics in the region (Di Vecchia *et al.*, 2009). This framework will be tested in the near future.

3. Local perceptions of adaptation to climate variability and change

There is a rapidly increasing attention in the literature to how rural people cope with and adapt to climate variability and change, and many studies struggle with determining the importance of climate as a driver of change (Tschakert, 2007; Mertz *et al.*, 2009; Nielsen, 2009; Nielsen and Reenberg, 2010a). Historical overviews indicate the importance of political and economic development for land use change and environmental management (Mbow *et al.*, 2008). Local level studies in Senegal and Burkina Faso on the drivers of adaptation strategies were unable to identify climate as a main driver of change (Barbier *et al.*, 2009; Mertz *et al.*, 2009; Reenberg, 2009).

Identifying the relative weight of climate factors for local change is an important step towards appropriately targeted adaptation actions as limited focus on climate adaptation could be ineffective if other factors are more important (Thomas and Twyman, 2005; Reid and Vogel, 2006; Mertz *et al.*, 2010). Therefore, locally perceived adaptation and coping strategies in rural areas during the past 20 years were identified in an AMMA survey of 1249 households in 15 sites in Senegal, Mali, Burkina Faso, Niger and Nigeria, stratified along both east–west and north–south gradients (Mertz *et al.*, 2010; Mertz *et al.*, 2011). Generally, farmers have a pessimistic view of changes in climate factors, as rainfall is generally viewed as having decreased whereas wind speeds and duration of strong winds as well as temperatures are seen to have increased (Mertz *et al.*, 2011). There is a marked east–west gradient, with farmers in Senegal being most negative about rainfall change, whereas this is less pronounced in Nigeria (Mertz *et al.*, 2011) and this is corroborated by other AMMA work observing differences between eastern and western Sahel (Lebel and Ali, 2009).

On the other hand, climate factors appear only to a limited degree to be perceived as direct drivers of change (Mertz *et al.*, 2010; Zorom *et al.*, 2011). Households mentioning decreases in production and income from rain-fed agriculture largely attribute this to insufficient rainfall (quantity and distribution), whereas decreases in livestock production are perceived to occur for other reasons, e.g. livestock diseases, theft and competition from crop production (Mertz *et al.*, 2010). Another example is change in the quality of areas for pasture and livestock corridors, which in the Sahelian study sites were perceived by the majority of respondents to be stable or increase whereas they were perceived as strongly decreasing in the more humid sites – the latter almost exclusively caused by agricultural expansion (Mertz *et al.*, 2010).

The surveys also indicates a shift towards dry season market gardening and non-farm income sources (Mertz *et al.*, 2010). This is corroborated by additional in-depth studies at local level in northern Burkina Faso, where local people focus on activities that are less dependent on climate (Nielsen and Reenberg, 2010a, 2010b). An analysis of national household survey data in Burkina Faso between 1998 and 2007 showed that the average wealth increased for almost all major livelihood groups and the number of wealthy people steadily increased (D'haen, 2011). Correlation between mean household wealth levels and the average annual coefficient of variation in rainfall was very low for all provinces of Burkina Faso, as was the correlation between average household wealth increase and interannual rainfall variation. These results highlight the importance of off-farm income which generates opportunities, especially in marginal rural areas, for long-term adaptation strategies to climate variability and change (D'haen, 2011).

A wide range of other aspects of rural life can potentially be affected by climate factors. A widely held view is that climate change will create 'climate refugees' (Christian Aid, 2007), but much of the scientific literature indicates that migration from the Sahel and elsewhere is mainly caused by poor prospects for welfare improvements as well as being part of a century-old system of migration to the coastal countries (Henry *et al.*, 2004; Tacoli, 2009). Migrants leaving for Europe also rarely belong to the poorest segment of the population as such departures are very costly. In the AMMA it was not possible to establish direct links between migration and climate variability and change, but the continued low level of rainfall in Senegal and other parts of the western Sahel could become a more important driver of rural–urban migration flows (Mbow *et al.*, 2008).

Perceptions of current adaptation strategies in response to external drivers of change – including climate variability and change – were also identified for the households (Mertz *et al.*, 2010). Within agriculture, there is a large difference in strategies between ecological zones. In the driest zone, people resort to

prayer as well as increased food purchase and migration, both of which corroborate the trend away from agriculture (Nielsen and Reenberg, 2010a, 2010b). People in the intermediate zone have an even stronger focus on migration, but are also engaged in livelihood diversification and reforestation. The latter probably reflects the intensity of agriculture in this zone and the perceived need for more trees in the landscape to assist with the restoration of land productivity. In the wettest of the three areas there is a strong perceived need to improve agriculture by fertilization and soil and water conservation. Only in this zone did household responses indicate a continued potential for profitable agriculture (Mertz *et al.*, 2010).

4. Futures of the Sudano-Sahelian region of West Africa

Based on inputs from the studies mentioned above and a range of other data sources, scenarios for future development in the Sudano-Sahelian region were developed (Lambin *et al.*, 2009). The other data sources included (1) 'what-if' questions posed to farmers showing that households prioritize improvements and adaptation in agriculture both in case of a more humid and more dry future climate, but in case more frequent droughts, migration is the top priority, (2) the long-term regional projections by the IPCC showing that for 2090–2099 there will be an increased temperature of 3–4 K and that annual rainfall, as well as rainfall in the rainy season, will decrease in western Sahel according to the majority of the models, while there is little agreement between models concerning future annual rainfall in the central and eastern West African Sahel (Christensen *et al.*, 2007) and (3) ENSEMBLES data where combinations of four regional circulation models nested in four global circulation models for making projections until 2050 were used (Lambin *et al.*, 2009). They corroborate the IPCC projections and project an increase in the frequency of dry spells and intensive rainfall events.

By combining the socio-economic data in the household studies and the three additional data sources mentioned above, different scenarios for future development in the region emerge: from a national economy closed to outside influences and centred on agriculture, with diverse degrees of rural-urban integration, to a region increasingly open to external forces. The latter case could involve foreign land acquisition and out-migration, or land managed as a carbon sink and converted to bio-energy crops, with the parallel rise in the non-farm rural sector. The studies of past household behaviour suggest that many rural and urban people in the Sahel are increasingly moving towards less climate-dependent livelihood portfolios, with an increasing share of household income coming from non-agricultural sources. However, when requested to assess future activities under different climate scenarios, a strong emphasis on continuation

of agriculture is found, especially in the Sudan zone. The reason for this contradiction may be that rural people still identify themselves primarily as farmers, but are in fact in a process of diversification away from agriculture. Diversification may be a particularly sensible strategy in the western Sahel, where rainfall is most likely to decrease, but with more frequent dry spells and intensive rainfall in the whole region, agriculture may face difficulties everywhere. Economic and political factors are more likely to influence the future of agriculture in the region, however (Lambin *et al.*, 2009).

5. Conclusion and future research needs

The perceived decline in agricultural production expressed in household surveys is corroborated by national statistics in several countries where the total grain production has not increased despite rapid population growth. It is not likely that climate variability and change has been a major driver of these events as none of the multiple approaches employed in this project were able to identify climate factors as having a strong weight in driving change. However, the highly variable climate of the region constitutes an important constraint for agricultural strategies, which have remained unchanged. This apparent resilience of the land use system, however, might hamper transformation into alternative modes of production that are able to meet the growing food demands for a rapidly increasing local population, complicating development efforts.

Hence, we conclude that other political, economic and demographic factors are more important for development pathways in the Sudano-Sahelian region. For the future, climate also may not be the most significant driver of change, perhaps with the exception of the western Sudano-Sahelian region, where a decrease in rainfall is very likely. Moreover, it should be noted that evidence from other regions suggest that even small changes in climate may put further pressure on fragile socio-economic systems in rural areas (Fraser, 2007). If the agricultural sector is to play a role in the future of Sudano-Sahelian zone, strong support to agricultural development and rural adaptive capacity will be needed. This includes better skills and dissemination of seasonal forecasts that can aid farmers with decision-making and a much better infrastructure in terms of seed, fertilizer and pesticide distribution, irrigation, functional credit and insurance institutions and market access. All of these aspects are not new and can be considered 'no-regret' development options that could be beneficial for a reform of the agricultural sector with or without climate change. Otherwise, off-farm work and migration will continue to increase and dominate Sahelian livelihoods in the future and without significant improvements in the agricultural sector, these socio-economic trends may in the end be the most beneficial as they increase wealth and decrease

the vulnerability of Sudano-Sahelian societies to climate change.

As there is still considerable uncertainty about the future climate in the central and eastern part of the West African Sahel, future research needs on impacts of and adaptation to climate variability and change will rely on better skill in climate models for projecting the Sudano-Sahelian climate. In the AMMA, we have uncovered the relative importance of climate factors for past adaptation actions, but more focus should be on the future adaptation needs, e.g. to what extent general development efforts will be sufficient to reduce the vulnerability of rural people to climate change. Better seasonal forecast skills will also be important to accompany research on local decision-making that may improve the already promising potential for farmers' and pastoralists' use of climate information (Roncoli *et al.*, 2009). The environmental consequences of transformation from agriculture to a migration and off-farm-based economy also need to be assessed. Finally, assessing the impacts on livelihoods and environment of the rapid development in certain countries, where land is being bought by or leased to external investors and large areas converted to bio-fuel and other commercial production, should become a major research area.

Acknowledgements

We are grateful for the assistance and hospitality of the local communities that took part in the study. The support of the AMMA project is gratefully acknowledged (see <http://onlinelibrary.wiley.com/doi/10.1002/asl.331/full> for full acknowledgement).

References

- Adger N, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi T. 2007. Assessment of adaptation practices, options, constraints and capacity. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). Cambridge University Press: Cambridge; pp 717–743.
- Barbier B, Yacouba H, Karambiri H, Zorome M, Some B. 2009. Human vulnerability to climate variability in the sahel: farmers' adaptation strategies in Northern burkina faso. *Environmental Management* **43**: 790–803.
- Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon W-T, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P. 2007. Regional climate projections. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds). Cambridge University Press: Cambridge, UK; 847–940.
- Christian Aid. 2007. *Human Tide: The Real Migration Crisis*. Christian Aid: UK; <http://www.christianaid.org.uk/Images/human-tide.pdf>.
- Cissé P, Zorom M, Barbier B, Diouf A, Maiga A. 2011. Les migrations, une stratégie d'adaptation à la variabilité climatique en zone sahélienne. Forthcoming in *Sécheresse*.
- D'haen S. 2011. Household poverty dynamics in a West-African context: the role of an access-to-food component in an asset indicator. *World Development* (submitted).
- Devereux S. 2009. Why does famine persist in Africa? *Food Security* **1**: 25–35.
- Di Vecchia A, Genesio L, Sorbi V, Tarchiani V, Vignaroli P. 2009. *Vulnerability Assessment Framework: Methodological Document*. Istituto di Biometeorologia, Consiglio Nazionale delle Ricerche (IBIMET CNR): Firenze, Italy.
- Egg J, Gabas J-J. 1997. *Preventing Food Crises in the Sahel: Ten Years of Network Experience in Action, 1985–1995*. Club du Sahel OECD: Paris.
- Fraser E. 2007. Travelling in antique lands: using past famines to develop an adaptability/resilience framework to identify food systems vulnerable to climate change. *Climatic Change* **83**: 495–514.
- Henry S, Piche V, Ouedraogo D, Lambin EF. 2004. Environmental influence on migration decisions in Burkina Faso. *Population and Environment* **25**: 397–422.
- Lambin EF, Mertz O, Rasmussen K, Reenberg A, D'haen S, Nielsen JØ. 2009. Scenarios on the future of the African Sahel. AMMA and Université Catholique de Louvain, Belgium.
- Lebel T, Ali A. 2009. Recent trends in the Central and Western Sahel rainfall regime (1990–2007). *Journal of Hydrology* **375**: 52–64.
- Mbow C, Mertz O, Diouf A, Rasmussen K, Reenberg A. 2008. The history of environmental change and adaptation in eastern Saloum-Senegal—driving forces and perceptions. *Global and Planetary Change* **64**: 210–221.
- Mertz O, D'haen S, Maiga A, Moussa IB, Barbier B, Diouf A, Diallo D, Da ED, Dabi D. 2011. Climate variability and environmental stress in the Sudan-Sahel zone of West Africa. *Ambio* (submitted).
- Mertz O, Mbow C, Nielsen JØ, Maiga A, Diallo D, Reenberg A, Diouf A, Barbier B, Moussa IB, Zorom M, Ouattara I, Dabi D. 2010. Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society* **15**(4): 25. <http://www.ecologyandsociety.org/vol15/iss4/art25/>
- Mertz O, Mbow C, Reenberg A, Diouf A. 2009. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management* **43**: 804–816.
- Mortimore MJ, Adams WM. 2001. Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change-Human and Policy Dimensions* **11**: 49–57.
- Nielsen JØ. 2009. Drought and marriage. Exploring the interconnection between climate variability and social change through a livelihood perspective. In *The Question of Resilience. Social Responses to Climate Change*, Hastrup K (ed). The Royal Danish Academy of Sciences and Letters: Copenhagen; 159–177.
- Nielsen JØ, Reenberg A. 2010a. Temporality and the problem with singling out climate as a current driver of change in a small West African village. *Journal of Arid Environments* **74**: 464–474.
- Nielsen JØ, Reenberg A. 2010b. Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. *Global Environmental Change* **20**: 142–152.
- Patt AG, Tadross M, Nussbaumer P, Asante K, Metzger M, Rafael J, Goujon A, Brundrit G. 2010. Estimating least-developed countries' vulnerability to climate-related extreme events over the next 50 years. *Proceedings of the National Academy of Sciences* **107**: 1333–1337.
- Polcher J, Parker DJ, Gaye A, Diedhou A, Eymard L, Fierli F, Genesio L, Höller H, Janicot S, Lafore J-P, Karambiri H, Lebel T, Riedelsperger J-L, Reeves CE, Ruti P, Sandholt I, Thorncroft C. 2011. AMMA's contribution to the evolution of prediction and decision-making systems for West Africa. *Atmospheric Science Letters* **12**: 2–6, DOI: 10.1002/asl.320.
- Raquez P, Lambin EF. 2006. *Meta-Analysis of Land Use and Socio-Economic Changes in West Africa*. AMMA and Department of Geography, University of Louvain: Louvain-La-Neuve, Belgium.
- Reenberg A. 2009. Embedded flexibility in coupled human-environmental systems in the Sahel: talking about resilience. In *The Question of Resilience Social Implications of Environmental*

- Changes*, Hastrup K (ed). The Royal Danish Academy of Sciences and Letters: Copenhagen; 132–158.
- Reid P, Vogel C. 2006. Living and responding to multiple stressors in South Africa—glimpses from KwaZulu-Natal. *Global Environmental Change* **16**: 195–206.
- Roncoli C, Jost C, Kirshen P, Sanon M, Ingram K, Woodin M, Somé L, Ouattara F, Sanfo B, Sia C, Yaka P, Hoogenboom G. 2009. From accessing to assessing forecasts: an end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). *Climatic Change* **92**: 433–460.
- Tacoli C. 2009. Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization* **21**: 513–525.
- Tarchiani V, Di Vecchia A, Genesio L, Sorbi V. 2006. From food security to development in the Sahel region. In *Natural Resource Management in Sahel – Lessons Learnt. Proceedings of the 17th Danish Sahel Workshop, 6–7 November 2006. SEREIN – Occasional Paper No 18*, Møllegaard M (ed). Research Network for Environment and Development (ReNED): Copenhagen; 44–57.
- Thomas DSG, Twyman C. 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change-Human and Policy Dimensions* **15**: 115–124.
- Tschakert P. 2007. Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change* **17**: 381–396.
- Vignaroli P, Tarchiani V, Sorbi V. 2006. *Le Calendrier de Prévision des Crises Alimentaires Une Approche Opérationnelle à Support des Actions de Prévention et Gestion des Crises Alimentaires au Sahel*. SVS Project. OMM-CILSS-Italian Cooperation: Florence.
- Zorom M, Barbier B, Mertz O, Karambiri H, Yacouba H, Some B. 2011. A typology of farmers' adaptation strategies in the Sahel. *Geografisk Tidsskrift-Danish Journal of Geography* (in press).