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Research

Climate Factors Play a Limited Role for Past Adaptation Strategies in West Africa

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ABSTRACT. The Sudano-Sahelian zone of West Africa has experienced recurrent droughts since the mid-1970s and today there is considerable concern for how this region will be able to adapt to future climate change. To develop well targeted adaptation strategies, the relative importance of climate factors as drivers of land use and livelihood change need to be better understood. Based on the perceptions of 1249 households in five countries across an annual rainfall gradient of 400-900 mm, we provide an estimate of the relative weight of climate factors as drivers of changes in rural households during the past 20 years. Climate factors, mainly inadequate rainfall, are perceived by 30-50% of households to be a cause of decreasing rainfed crop production, whereas a wide range of other factors explains the remaining 50-70%. Climate factors are much less important for decreasing livestock production and pasture areas. Increases in pasture are also observed and caused by improved tenure in the driest zone. Adaptation strategies to declining crop production include 'prayer' and migration in the 400-500 mm zone; reforestation, migration, and government support in the 500-700 mm zone; and soil improvement in the 700-900 mm zone. Declining livestock holdings are countered by improved fodder resources and veterinary services. It is concluded that although rainfed crop production is mainly constrained by climate factors, livestock and pasture are less climate sensitive in all rainfall zones. This needs to be reflected in national adaptation strategies in the region.

Key Words: *adaptation; climate variability; livestock; rainfed crops; West Africa*

INTRODUCTION

Climate change and variability and their impact on human populations in sub-Saharan Africa are a major global concern. Calls for large-scale international assistance to finance adaptation to climate change have been reinforced in recent years (Parry et al. 2009, Patt et al. 2010). The Sudano-Sahelian zone of West Africa is an area of particular interest because of the recurrent drought periods commencing in the early 1970s (Nicholson 1978, Rain 1999) and the efforts in this area to adapt to drought. Averaged over 30-year intervals, annual rainfall in this area fell by between 20 and 30% between the 1930s and the 1950s and the three decades following the 1960s, prompting Hulme (2001:20) to state that "the African Sahel therefore provides the most dramatic example worldwide of climatic variability that has been directly and quantitatively measured." It is repeatedly argued that this change in rainfall had major consequences for the populations of the Sudano-Sahelian zone, already under stress from difficult economic conditions (Roncoli et al. 2001), even if a recovery of annual rainfall, particularly in the eastern part of the West African Sahel, has been observed during the past decade (Lebel and Ali 2009).

The question remains, however, to what extent climate factors have influenced development in the

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region. Although there is an increasing realization of the interplay of different driving forces for rural development and environmental change in the tropics (Lambin et al. 2001, Reynolds et al. 2007, Turner et al. 2007, Mbow et al. 2008), understanding the relative impact of climate factors is not straight forward (Reenberg 2001, Mortimore et al. 2005, Reid and Vogel 2006, Ziervogel et al. 2006, Reynolds et al. 2007, Thomas et al. 2007, Tschakert 2007, Barbier et al. 2009, Mertz et al. 2009*b*). This debate has gained increasing importance as it is realized that the impacts of climate change, all other things equal, will require significant adaptation in many different sectors of society (Adger et al. 2007, Mertz et al. 2009*a*). In developing countries, many of the impacts are likely to be more severe than elsewhere, and because of the low adaptive capacity especially in the least developed countries, the costs and scale of the needed adaptation strategies may be prohibitive for many people, communities, and nations (Adger et al. 2006, Mertz et al. 2009*a*). For that reason it is essential that adaptation strategies are either very specific and well targeted toward a very pressing need or designed in such a way that they become 'no regret' actions, which solve more general development problems while at the same time addressing impacts of climate change. Because of the triple exposure to accelerating population pressure, adverse economic conditions, and climatic variability (Leichenko and O'Brien 2008, Reenberg 2009), the development of narrow solutions to climate induced problems are likely to be ineffective or even counterproductive unless links to and feedbacks from other drivers of change are included. Therefore, to develop appropriate adaptation strategies, it is essential to obtain a better understanding of how important climate factors are in determining change.

The issue has been frequently debated using qualitative information (Mortimore and Adams 2001, Nielsen and Reenberg 2010*a*,*b*) and relatively small samples or localized field sites (Tschakert 2007, Mbow et al. 2008, West et al. 2008, Barbier et al. 2009, Mertz et al. 2009*b*). The general conclusions have often been that it is too complex and difficult to isolate the climate factor from other driving forces of change because decisions taken are often influenced by many nonclimatic conditions, some of which often appear to be more important than the climate factors (Eakin 2005, Ziervogel et al. 2006, Reid and Vogel 2006, Tschakert 2007, Mbow et al. 2008). Understanding the direct impact of climate factors on specific human populations thus requires the unraveling of a complex intertwinement of physical, biological, and socio-cultural systems (Oliver-Smith and Hoffman 2002). It is an exercise with which many studies on vulnerability, resilience, and adaptation to climate change struggle (Reid and Vogel 2006, Thomas et al. 2007, Leichenko and O'Brien 2008, Adger et al. 2009, Mertz et al. 2009*b*) and that is central to sustainability science (Turner et al. 2003, Turner et al. 2007).

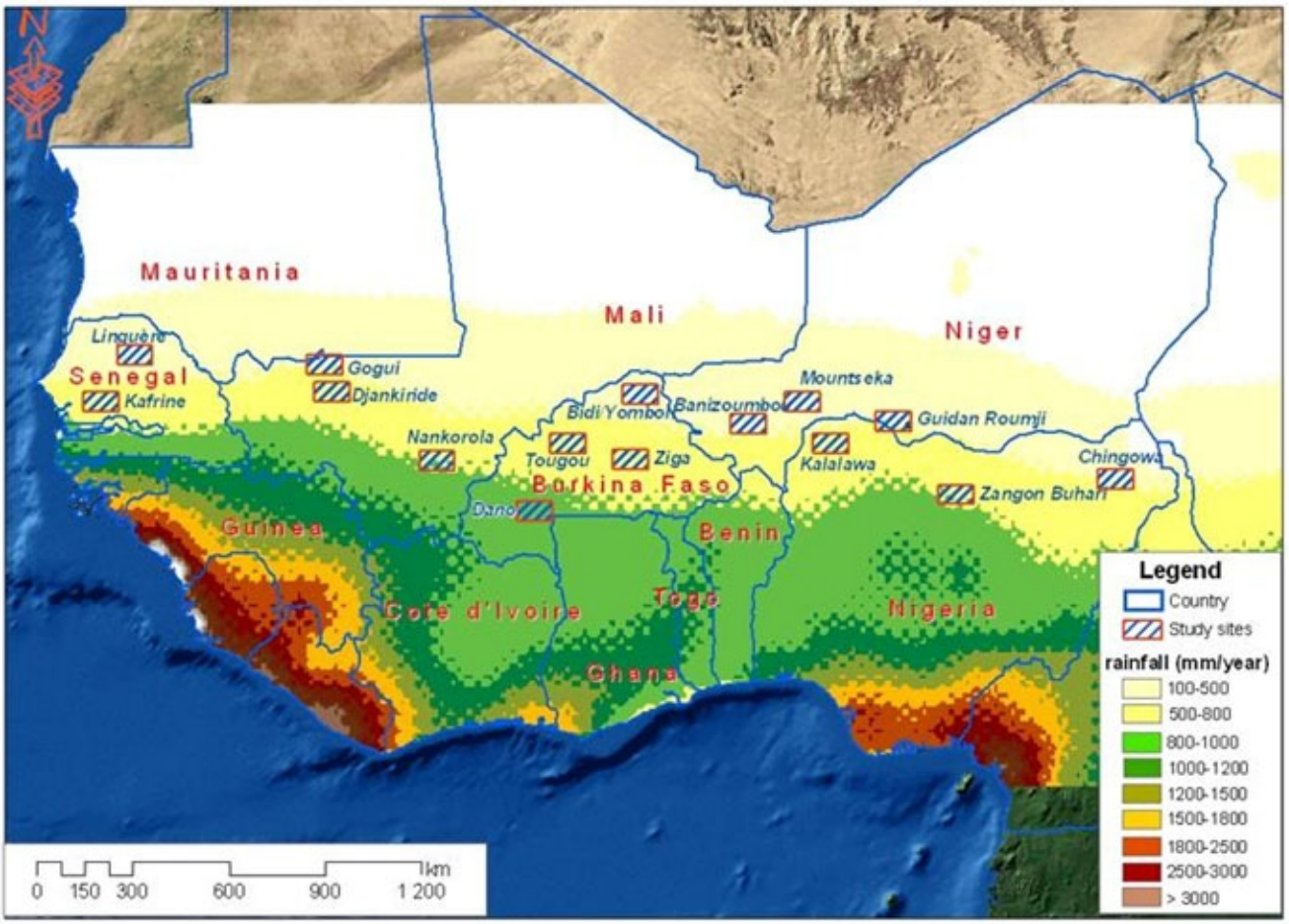
In this paper, we provide an estimate of the relative weight of climate factors as a driver of change in rural households in the Sudano-Sahelian zone of West Africa during the past 20 years. We analyze perceptions of change in household income, crop production, livestock, and pasture as well as the causes of these changes.

STUDY SITES AND METHODS

This study took place in 15 sites in West Africa covering five countries, Senegal, Mali, Burkina Faso, Niger, and Nigeria, and three agroecological zones ranging from 400 to 900 mm of annual precipitation (Fig. 1). The rainy season is generally from June to September, longest in the wettest sites and shortest in driest areas. Based on an analysis of local rainfall data, average total rainfall has increased slightly in all sites since the droughts of the 1980s, but August rains have decreased in most sites. The rainfall patterns determine the choice of rainfed crops, which are mainly pearl millet (*Pennisetum typhoides*), sorghum (*Sorghum bicolor*), and cowpea (*Vigna unguiculata*) in the driest sites and also include maize (*Zea mays*) and peanuts (*Arachis hypogaea*) in the intermediate and wetter sites. Livestock is more important in the driest areas, but is found throughout all sites.

The field sites and sampling overview are presented in Table 1. A total of 1249 household questionnaires were administered as well as focus group discussions with separate groups of men and women in each community. The selection of households was, to the extent possible, completely randomized, but in the field certain households were unavailable and other households had to be included according to local leaders. For each site, the households from several villages or hamlets are merged in the analysis, mainly because intra-village differences between hamlets are often greater than intervillage differences.

Fig. 1. Location of field sites in West Africa with isohyets. Source of isohyets: NASA gridded rainfall data in the GLOBAL GIS database (GlobalGISdatadatabasemapbasec_atmos). Acquired in 2005.



The household questionnaire was developed jointly by all authors and was implemented either by the authors or by trained research assistants in each community during the period of November 2007 to June 2008. The questionnaire was structured in such a way that for each category of questions, the respondents were asked to assess the current situation., e.g. main income source, number of animals, field size, etc., then to describe the main changes, if any, over the past 20 years (1987-2007), and finally to assess the main causes of these changes, if any. No indication of the focus on climate factors was presented for respondents at this stage to avoid biases in the answers. Toward the end of the questionnaire and to triangulate with responses in the first part of the questionnaire, the respondents were asked to directly assess positive and negative climate impacts on crop production and livestock production and, if negative, their adaptive actions to respond to these impacts. This was done as a free listing and responses were not ranked because there was rarely more than one to two adaptation measures mentioned. For all data, differences between rainfall zones were tested for significance using chi-square tests.

Most responses in the questionnaire are based on households' perceptions, which are used as a best-bet proxy for understanding causal relationships for changes. Perceptions are of course subjective and can be influenced by local or broader narratives and may also reflect the mind-set of individual farmers,

Table 1. Field sites in West Africa with location, annual precipitation, and number of households (HH) sampled.

Country	Site	Location, UTM coordinates	Avg. annual precip., mm	HH sampled
Burkina Faso	Bidi-2†	30P, 786000 E, 1590000 N	450	41
	Yomboli †	30P, 786000 E, 1621000 N	400	40
	Dano §	30P, 494000 E, 1231000 N	900	105
	Tougou ‡	30P, 581000 E, 1513000 N	650	98
	Ziga §	30P, 736000 E, 1396000 N	750	99
Mali	Dianguirdé ‡	29P, 500000 E, 1603000 N	600	106
	Gogui ‡	29P, 465000 E, 1734000 N	600	99
	Nankorola §	29P, 856000 E, 1401000 N	800	100
Niger	Banizoumbou †	31P, 493000 E, 1529000 N	450	86
	Guidan Roumji †	32P, 251000 E, 1511000 N	450	71
	Mountseka †	31P, 610000 E, 1522000 N	450	93
Nigeria	Chingowa †	33P, 267000 E, 1334000 N	500	45
	Kalalawa §	31P, 719000 E, 1460000 N	750	50
	Zangon Buhari §	32P, 452000 E, 1289000 N	800	47
Senegal	Barkedji †	28P, 514000 E, 1688000 N	400	45
	Kaffrine ‡	28P, 457000 E, 1570000 N	630	124
TOTAL				1249

† 400-500 mm rainfall zone, total households sampled: 383
‡ 500-700 mm rainfall zone, total households sampled: 472
§ 700-900 mm rainfall zone, total households sampled: 404

because some may be more prone to mention concrete causes that can be remedied, e.g. soil fertility, whereas others are more fatalistic, attributing causal factors beyond their control, e.g., weather. However, it can be reasonably assumed that households act on their perception of reality (Vedwan 2006, Slegers 2008) and for the complex analysis of what drives change and adaptive responses in rural Africa, there appears to be few other methods available. Moreover, research on traditional ecological knowledge shows that local people in general have a very good understanding of their biophysical surroundings and the changes to them, as well as the impacts of change over time and space (Inglis 1993, Berkes 1999).

RESULTS

The household income sources across the Sudano-Sahelian region are dominated by rainfed crop production and livestock, which are mentioned by more than 80% and 45% of respondents, respectively (Fig. 2a). Income from rainfed crops and livestock are most frequently mentioned in the wettest rainfall zone. The migration-based income is most important in the driest and intermediate zones. Although rainfed crops and livestock remain the two most important income sources, a majority of respondents claim that both have decreased over the past 20 years (Fig. 2b). A decline in income from crop production is mentioned by more than 70% of respondents and almost 50% mention decreased livestock income. An increase in remittance income from migrants, vegetable farming, and various craftsman activities, e.g. carpenter, butcher, hairdresser, is mentioned by more than 40% of respondents.

Farmers' perceptions of change in the production of major rainfed crops, livestock, and the change in pasture areas are presented in Figure 3. There is an almost unanimous agreement across rainfall zones that all types of crop production per household have declined during the past 20 years. According to the perceptions of households, there has been an overall decrease in livestock numbers (Fig. 3). The number of cattle has decreased in all three rainfall zones but most significantly in the drier areas where more than 60% of households mention this decrease. In the 700-900 mm zone one third of the households have increased their cattle numbers, though this is surpassed by almost 50% that report a decrease. The situation is similar for goats (not shown in Fig. 3), whereas for sheep, the sharpest decrease is seen in the 500-700 mm zone, though almost 40% of households in the 700-900 mm zone report an increase.

Another key element for crop production and livestock in the region is the availability of good quality pastures. Even for settled farmers, most livestock is dependent on movement between pastures and animals are often commissioned to herders to ensure adequate nutrition. The household perceptions of change in permanent pastures and livestock corridors are also shown in Figure 3. There are very clear differences between the rainfall zones. In the dry zone, there is a relatively positive view because in all cases more than 50% of the households stated that the areas or corridors have remained stable or have increased during the past 20 years. Responses in the 500-700 mm rainfall zone are almost equally divided between positive and negative views of the changes, whereas in the wettest zone there is a very negative view of the development.

The respondents' perceptions of why income, crop and livestock production, and pasture have changed are shown in Fig. 4, where the relationship between climate and nonclimate factors attributed as causes of change are shown. Only causes of the most important trends are shown. The decrease in income from rainfed crop production is attributed to climate factors, mainly inadequate rainfall, in about 50% of the responses. The nonclimatic causes occur each with lower frequency, decreased soil fertility, pests, and reduced use of fertilizer being the most important. The income data are corroborated by the crop production data as inadequate rainfall again was the single most frequently mentioned production constraint for pearl millet, sorghum, and maize; pearl millet and sorghum show almost identical outcomes (only the former is shown in Fig. 4). On average 40% of households considered climate factors to have caused a decreased production of pearl millet, 30% in the wettest zone and 50% in the intermediate zone. Some maize growers in the driest zone also mentioned too much rain and flooding. Among the nonclimatic factors, soil fertility decline is also frequently mentioned as a cause and in the 700-900 mm zone it is ranked as high as inadequate rainfall. The last major cause observed is pest infestation, especially by larger animals, i.e., mammals and birds, which is considered a large problem for pearl millet by 30% of households in the intermediate zone. Poverty is

Fig. 2. Household income sources in the Sudan-Sahel zone of West Africa. a) Percent of households mentioning the six most important income sources (N=2477, $p < 0.05$). b) Percent of households expressing changes in the six main household income categories during the past 20 years.

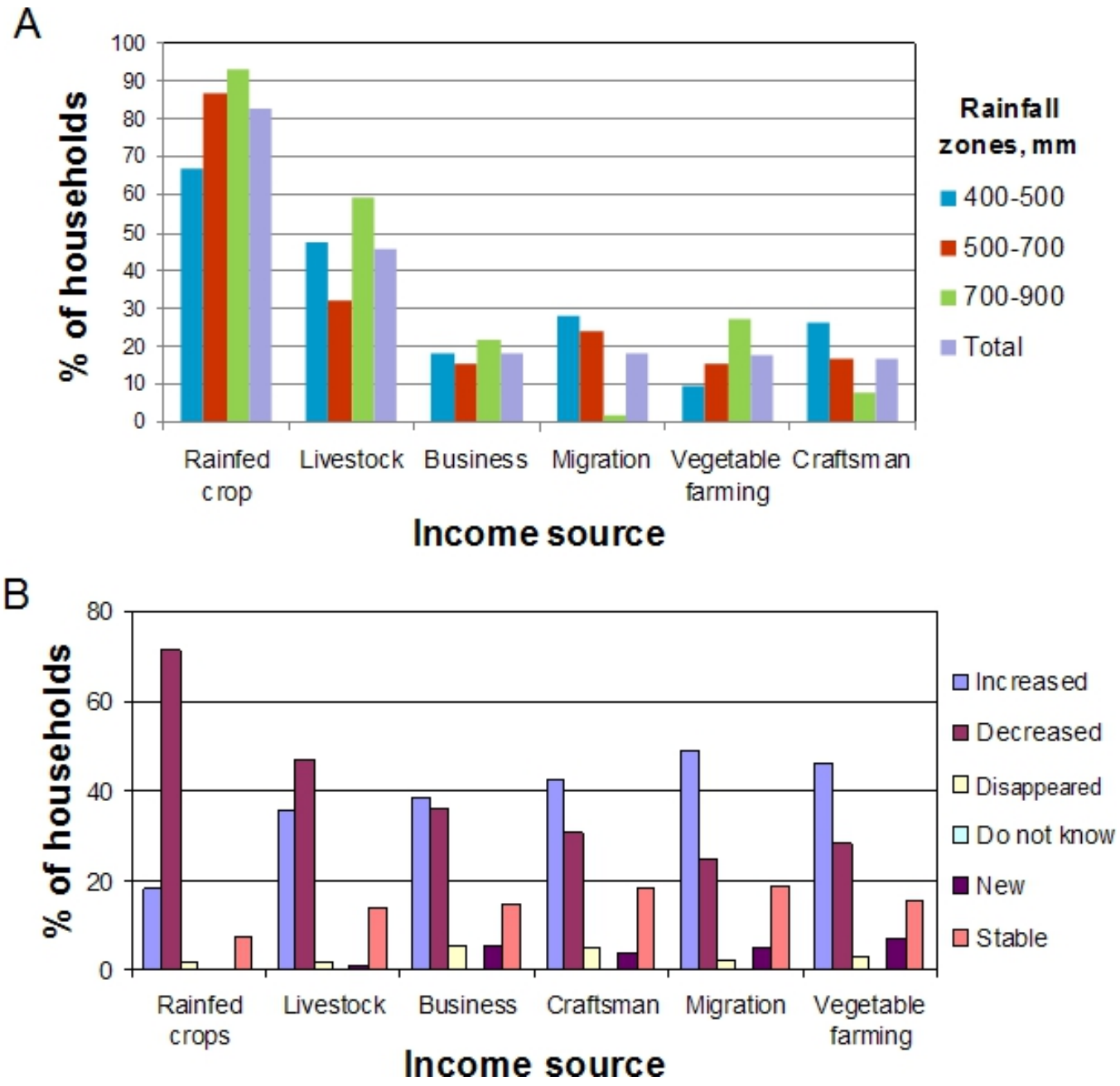
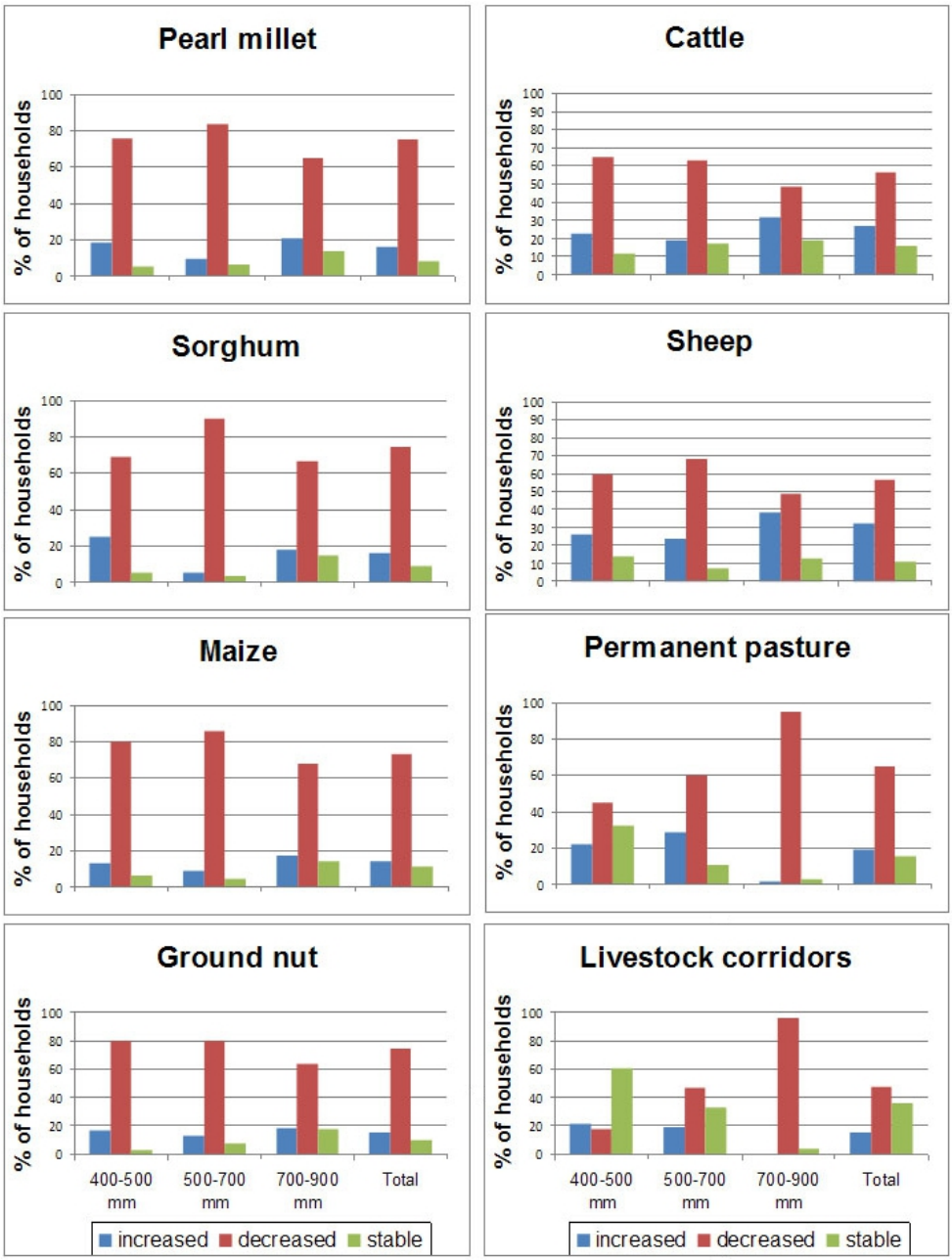


Fig. 3. Percent of households in three rainfall zones stating a change or no change during the past 20 years in crop production (pearl millet, N=1056, $p < 0.05$; sorghum, N=770, $p < 0.05$; maize, N=468, $p < 0.05$; and groundnuts, N=553, $p < 0.05$), livestock production (cattle, N=575, $p < 0.05$ and sheep, N=601, $p < 0.05$) and change in availability of permanent pasture (N=860, $p < 0.05$), and livestock corridors (N=852, $p < 0.05$). Significance levels refer to differences in perceptions between rainfall zones.



also mentioned by many farmers in the dry zone, and 8% mention lack of project support as a cause for the reduction of maize production.

The single most frequently mentioned cause of decreasing income from livestock is also inadequate rainfall. However, a wide range of nonclimatic causes including reduced pasture, livestock diseases, and sale of livestock because of family needs represent more than 70% of responses (Fig. 4). The main causes mentioned for a decrease in cattle, sheep, and goat numbers are not directly related to climatic factors and are highly dependent on the rainfall zone; in the dry zone the sale of livestock mostly because of increased family needs is by far the most important cause of cattle and goat decreases (goats not shown in Fig. 3). In the driest zone, the reduction in sheep is not caused by sell-off to the same extent, but mainly attributed to rainfall decrease. Livestock diseases in cattle and goats are very frequent problems in the two wetter zones, whereas sheep are not as affected by disease. In the wettest zone, inadequate pasture, in terms of quality and quantity, and animal theft are also main problems leading to reductions in numbers. Overall, nonclimatic causes largely outweigh climatic causes of change.

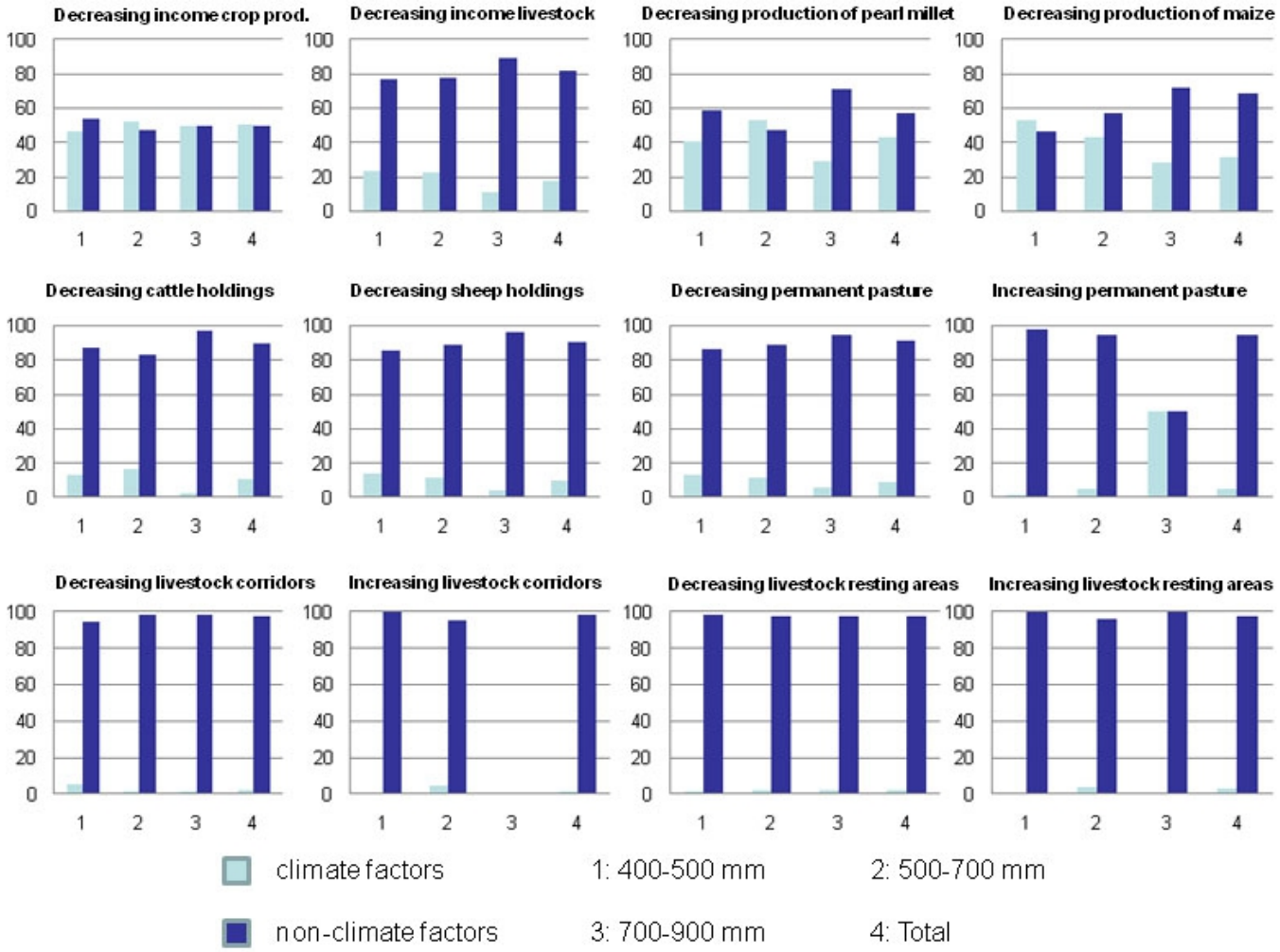
The perceived causes of a reduction in the livestock pastures, corridors, and resting places are very clear. Agricultural expansion is mentioned in more than 60% of the total responses in all three categories (Fig. 4). Only in the driest zone does this figure drop below 50% for the resting areas, but otherwise there is general agreement across the rainfall zones. This of course must be seen against the much higher proportion of respondents in the humid zone suggesting negative trends in all three categories. Population increase is overall the second most frequently mentioned cause and this can in many ways be considered a proxy for agricultural expansion, thus reinforcing this driver of perceived decreases in the pastoral areas. Climate factors are weakly represented in the responses, especially for resting areas and corridors. In the driest zone, about 14% of respondents who mentioned a decline in permanent pasture found insufficient rainfall to be its cause, but because only 40% of respondents found pasture to be declining, this represents a small number of responses in the sample. Flooding is mentioned by few households to occur in corridors and resting areas. Many households in the dry and intermediate zones stated that permanent pasture had increased or remained stable (Fig. 3). Very few provided causes for the stability, but increasing pastoral areas were frequently attributed to four similar causes: 1) rainfed crop cultivation has been reduced, 2) pastoral areas have been marked, 3) pastoral areas have been developed by the state and 4) land tenure issues have been resolved.

Finally, more than 70% of the households interviewed indicated that they have actively implemented some adaptation measure within rainfed crop production and livestock production in response to the negative trends in production (Fig. 5). Marked differences between the rainfall zones and a large diversity of answers, especially for crop production, are apparent. In the driest zone, there is a resigned attitude toward crop production as most households resort to prayer, increased food purchases, and migration. In the intermediate zone, many households also focus on migration, livelihood diversification, and government support, but the largest group see reforestation as the main adaptation strategy. In the wettest zone, the focus is much more on soil improvement as fertilization and soil and water conservation come out as the most cited strategies. For livestock, the overall diversity of answers is lower, although it is still high in the driest zone, where improved fodder, increased transhumance, and sale of livestock are the main responses. In the intermediate zone, almost half of the households pointed to the need for better veterinary services and in the wettest zone focus was on the fodder improvements, including further use of agricultural residues.

DISCUSSION

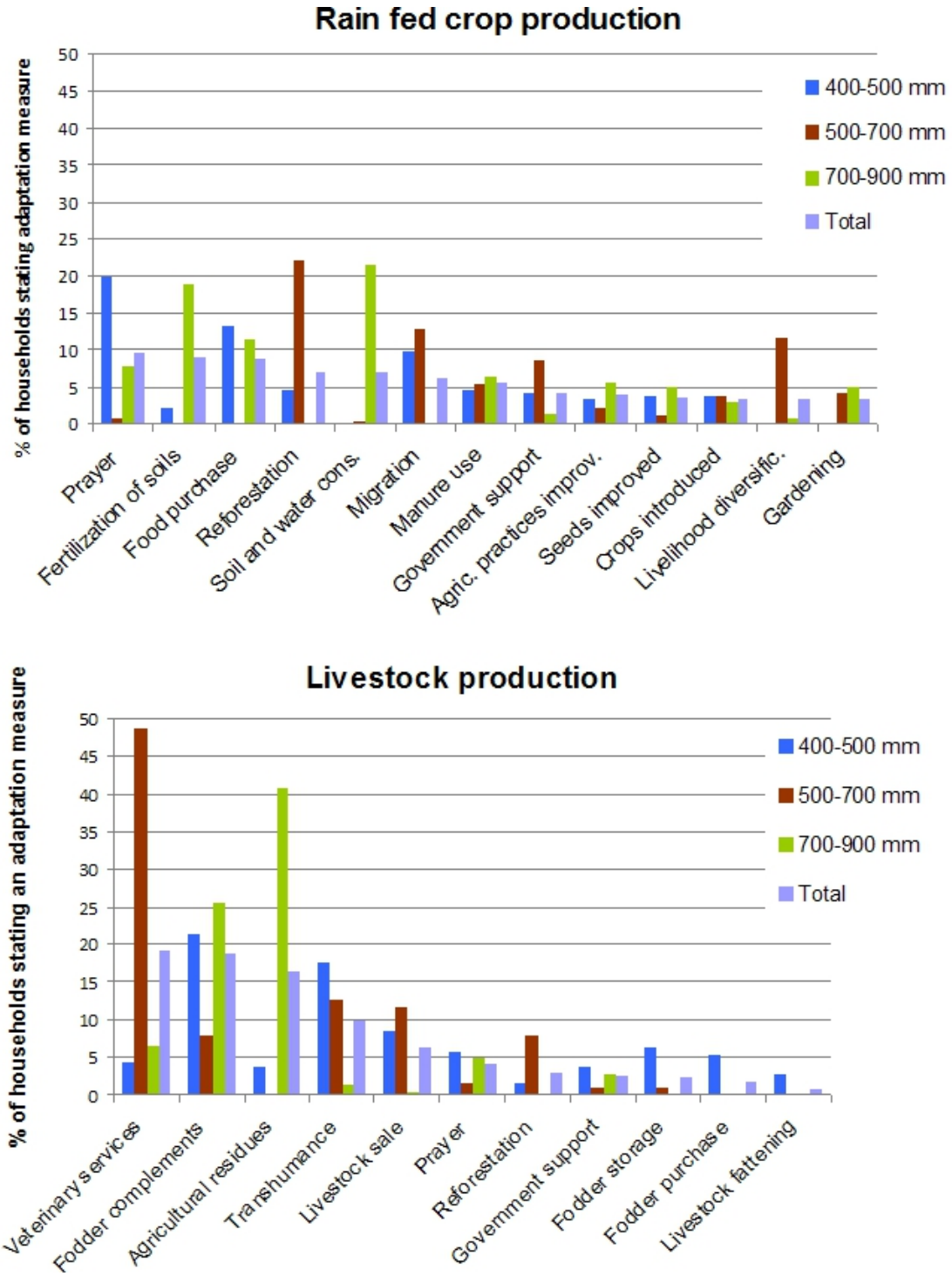
It is difficult to determine whether the perceived decline in rainfed crop production is correct in absolute terms. A main caveat to be observed relates to the propensity of farmers to say that yields were always better in the past and that farmers may not distinguish between yield (harvest per area unit) and total harvest. Thus, our question on total harvest may in some cases have been interpreted as pertaining to yield. However, the decline is highly likely to be correct in relative terms. Farmers may have related the production decline to the combination of increasingly large family size and migration of the labor force. Both of these factors may have caused the self-sufficiency in crop production to decline as fewer able-bodied people have to farm for a larger household composed of

Fig. 4. The causes of change due to aggregated climate factors (rainfall, wind, temperature, drought, flooding, etc.) and aggregated nonclimate factors: decreasing income from crops (N=1044, p=0.37, nonsignificant) and livestock (N=311, p < 0.05), decreasing crop production (pearl millet, N=2501, p < 0.05; maize, N=917, p < 0.05) and livestock production (cattle, N=515, p < 0.05; sheep, N=571, p < 0.05), and change in pasture areas: permanent pasture (increasing N=134, p < 0.05; decreasing N=560, p < 0,05), livestock corridors (increasing N=108, p < 0,05; decreasing N=438, p=0.21, nonsignificant), and livestock resting areas (increasing N=111, p < 0.05; decreasing N=392, p=0.93, nonsignificant). Significance levels refer to differences in perceptions between rainfall zones.



children and elderly persons. The perception of declining income from rainfed crops also corroborates the data. Climate data show that during the past 20 years there has been a recovery rather than a decline in total precipitation (Lebel and Ali 2009), but the decline in August rainfall is crucial for yields as it coincides with grain development. Finally, the negative perception of production change by farmers is partly corroborated by national statistics on yield and production. Pearl millet production and yields have, for example, remained stable during the past 20 years in four of the five countries despite high population growth; only Nigeria has experienced production and yield

Fig. 5. Household perceptions of adaptation measures in response to negative trends in rainfed crop production and livestock production, by rainfall zone.



growth (generated from FAOSTAT data from 1988-2008, http://faostat.fao.org/).

It is not surprising that the relative weight of climate factors as perceived determinants of decline in crop production is in the range of 30-50%. Interannual rainfall variability in the Sahel is very high and increasing (Ali and Lebel 2009), and higher wind speeds during rain events may also affect crops negatively (Mertz et al. 2009*b*). Moreover, rainfall in the Sahel fluctuates across the region and over time "leaving some areas in some years well supplied, yet other regions and other years dry and parched" (Hulme 2001:19). What characterizes the region is thus a high degree of spatial and temporal variability in precipitation. The large number of other factors affecting crop production, however, shows that focusing adaptation options narrowly on climate variability and change will not be sufficient. Household perceptions of current and future adaptation needs point to important measures that are not directly climate related. First of all, it is interesting that the most cited adaptation measure is prayer. This suggests that almost 10% of households, and 20% in the driest zone, appear to be unable to see any technical solution to their difficulties related to rainfed crop production. However, they are 'still in business' as farmers (Mortimore and Adams 2001) and the answer 'prayer' may also reflect a lack of understanding of the more subtle connections between lack of rain and technical solutions to adapt to this problem; people feel, rightly, that they can do nothing about the weather. The importance of soil improvement is emphasized by the group of adaptation measures composed of 'soil fertilization', 'soil and water conservation', 'manure use', 'fertilizer use', and 'mulching'. Unfortunately, we do not have data on changes in soil fertility, but it is likely that limited use of fallowing and fertilizers has caused a decline in soil fertility in many areas (Tilander and Bonzi 1997, Reij et al. 2005). Also, the proposed adaptation measures suggest a strong interest in agricultural intensification, which can indeed improve soil fertility (Rovere et al. 2008). Intensification includes crop-livestock interaction and mechanization, as observed in many other studies (Adams and Mortimore 1997, Piraux et al. 1997, Mortimore and Turner 2005), and are not closely linked to climate; soil fertilization is of course beneficial if the rain falls as expected, but can also be a costly investment if the rains fail. The reforestation suggested by households in the intermediate zone may be linked to the high population density and higher degree of deforestation in this zone. The strong focus by many projects and extension workers on tree planting in this zone and a rather strong 'reforestation discourse' (Reenberg et al. 2003, Ozer 2004) probably have influenced farmers' views on how reforestation can benefit agriculture.

The general perception of decreasing livestock numbers may be affected by the fact that counting livestock is a very sensitive issue in the region and farmers may see an advantage in claiming a decline rather than an increase in case the data should serve as basis for a project or taxation. However, the data corroborate the trend of livestock increasingly being owned by fewer larger investors (Turner 2009) rather than the smallholders interviewed in this study.

The perceived increase in land used for pasture, livestock corridors, and resting areas in the dry zone corresponds well with the recovery observed in the natural vegetation in the northern parts of Sahel during the past decades (Olsson et al. 2005, Bolwig et al. 2011). However, farmers mainly attributed this to the government-driven development of pastoral areas as well as land tenure policies, which have provided better protection of pasture from agricultural expansion. Abandonment of fields due to lack of labor, seed supply, and farm equipment was also mentioned by households in Senegal as a cause of increased pasture areas. The decrease in the 700-900 mm rainfall zone is corroborated by studies showing agricultural expansion onto bush land (Reenberg et al. 2003), which leads not only to limitations on pastoral movements but also to a diminishing potential for fertilization based on crop-livestock interaction. The mainly nonclimatic causes of the decline in animal numbers suggests a rather climate robust livestock sector, particularly in the driest zone, where mobility is an important element in adapting to a variable climate. However, plenty of other problems such as veterinary services, livestock theft, and availability of fodder, which may or may not be climate related, appear to be more important to address. The most important constraint on natural fodder availability from pasture and on the movement of cattle is without doubt agricultural expansion.

The differences in perceptions between the rainfed crop and livestock sectors and between the different rainfall zones of the Sudano-Sahelian region leads to a complex dilemma for adaptation, especially in

the wettest zones studied. Rainfed crop production, which is constrained by climate factors, is apparently expanding at the expense of livestock numbers, which in turn are much less sensitive to climate factors. In the driest zone, the picture is clearer as livestock seems to be the only sustainable solution if agriculture is to persist in the future. Moreover, the importance of income sources seems to be shifting toward nonfarm or small-scale dry season vegetable horticulture, indicating that people are slowly moving out of agriculture.

These differences and dilemmas present important challenges for the development of national adaptation strategies such as National Adaptation Programs of Action (NAPA) as well as efforts to mainstream adaptation to climate change and variability in general development strategies (Halsnæs and Trærup 2009). Such national approaches will naturally focus on more aggregate levels and it is not always possible to directly link local and national strategies because some of the latter may only be felt indirectly in local areas. However, the local perceptions presented in this study can serve to guide the national strategies and especially test their potential success of outreach. For example, it is obvious that in the sites included in this study, the information obtained from national and regional efforts on seasonal weather forecasting and early warning systems has not been embedded in local perceptions as being important elements for decision making. Moreover, local farmers' increasing inclination toward nonfarm activities as an adaptation to unstable agricultural production needs to be reflected in development strategies.

CONCLUSION

Although a number of recent papers have questioned whether the importance of climate factors relative to other driving forces is really as significant as 'conventional wisdom' would say (Mortimore and Adams 2001, Tschakert 2007, Mertz et al. 2009*b*), the results of this paper show that climate factors, mainly inadequate rainfall distribution, are mentioned by 30% (wettest zone) to 50% (intermediate zone) of households as a cause of the decline in rainfed crop production. A wide range of other factors make up the remaining 50-70%, each represented with a much lower frequency of replies. In the livestock sector, climate factors are much less important and only 20% of households attribute the perceived decline in livestock numbers to be caused by inadequate rainfall.

The differences between the rainfed crop and livestock sectors as well as those between the driest and wettest zones studied illustrate the difficulty faced by people on the agricultural margins in the driest part of the Sahel to successfully develop their rainfed agriculture. Whether this is because many areas are simply unsuitable for agriculture or it reflects the inability of agricultural development schemes to effectively comply with the perceived needs of farmers in these areas (or both) is not known. Livestock remains much more important and the state-funded protection of pastoral areas seems to have been the major driver of improvement in this sector. In the wettest zone, people seem still to be confident in agriculture as a livelihood strategy as they propose soil fertilization and soil and water conservation as key measures to improve productivity.

The results of this paper call for developing rainfall zone-specific adaptation strategies to climate change and variability in the Sudano-Sahelian region. This is most likely also the case in similar regions in other parts of Africa and the tropics. The livestock sector should receive top priority in the driest areas, but even in the other rainfall zones it is perceived to be a less climate sensitive activity, mainly under pressure from agricultural expansion. It will be more difficult and costly to adapt the rainfed crop production sector, which is already under considerable stress from climate variability in all zones, to future negative impacts of climate change.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol15/iss4/art25/responses/

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