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ORIGINAL ARTICLE

Agriculture, livelihoods and climate change in the West African Sahel

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Abstract The West African Sahel is a harsh environment stressed by a fast-growing population and increasing pressure on the scarce natural resources. Agriculture is the main source of livelihood of the majority of the people living in the area. Increases in temperature and/or modifications in rainfall quantities and distribution will substantially impact on the natural resource on which agriculture depends. The vulnerability of livelihoods based on agriculture is increased and most likely exacerbate and accelerate the current 'downward spiral' of underdevelopment, poverty and environmental degradation. Notably, droughts, a short rainy season and/or very low rainfall will be felt by current systems. To cope with the difficult climatic situation, farm households have developed a range of strategies including selling of animals and on-farm diversification or specialization. At regional level, early warning systems including an operational agro-meteorological information system already provide farmers with crucial information. Substantial political, institutional and financial efforts at national and international level are indispensable for the sustenance of millions of lives. In terms of development, priority needs to be given to adaptation and implementation of comprehensive programs on water management and irrigation, desertification control, development of alternative sources of energy and the promotion of sustainable agricultural practices by farmers.

Keywords Agriculture · Sahel · Livelihoods · Climate change · Food security

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Introduction

The West African Sahel zone borders the extreme fringe of the Sahara. The name "Sahel" is derived from the Arabic word *sahil* and means "border of the desert". The Sahel covers the nine countries Mauritania, Senegal, The Gambia, Guinea-Bissau, Mali, Burkina Faso, Niger, Chad and Cape Verde, has a total area of 5.4 million km^2 and a population of almost 60 million. There are definitions of the extension of the Sahel zone that also include other countries, such as Sudan or the north of Ethiopia; the following discussion is however based on the nine countries of the CILSS (Permanent Inter-States Committee for Drought Control in the Sahel).The Sahel is a transition zone between the arid north and the green tropical forest in the south and borders the maritime coast in the west. Its vegetation is primarily composed of savanna-typical bushes, grasses and trees with increasing density from north to south, representing the change from semi-arid grasslands to thorny savanna.

Annual and decadal rainfall quantity and distribution vary greatly, but water and in particular, potable water is a scarce resource in all Sahel countries. Besides erratic rainfall patterns, poor soils and unfavorable socioeconomic conditions are key constraints to agricultural development (Breman 1990). Especially in dry years, the livelihood, particularly of the rural population, is threatened, contributing to a vicious circle of underdevelopment, poverty and resource depletion (Lüdeke et al. 2004). Changes in rainfall patterns, temperatures and/or in the frequency or severity of extreme events will have direct impacts on crop yields with possibly severe consequences for the food security situation.

The regional economies are strongly rooted in agriculture, including animal husbandry. More than half of the population is employed in this sector that contributes between 35 and 60% to the respective national GDPs (CORAF/WECARD 1998). Continuous growth of populations, as well as a concomitant urbanization trend (Cour 2001), significantly adds to the projected food insecurity for more than 40% of the population (Verhagen et al. 2004).

In this chapter, we analyze the potential effects of climate change on agriculture and livelihoods in Sahelian Africa and provide recommendations for necessary action. It builds on the findings of the “Impact of Climate Change on Drylands (ICCD)” project, carried out in the framework of the Dutch National Programme on Air Pollution and Global Change (Dietz et al. 2004). The project analyzed developments of the past with the objectives to understand the current situation and to identify successful adaptation strategies to future changes in climate (Dietz et al. 2004). The multidisciplinary research group working in the project aimed at identifying different climate-related risk-coping strategies at farm household and individual level for sub-Saharan Africa. Taking the complex nature of adaptation to climate change as a starting point, societal, cultural, geographical, biophysical and economic vulnerability were included in the analysis.

Climate characterization, variability and change

A main characteristic of the West African region is the strong variation (spatially and temporally) in rainfall quantity and distribution, long-term averages ranging from 150 to 1,200 mm year^{-1}: under 150 mm in the Saharan zone, 150–400 mm in the Sahelian zone, 400–600 mm in the Sudano-Sahelian zone, 600–900 mm in the Sudanian zone and 900–1,200 mm in the Sudano-Guinean zone (Penning de Vries and Djitèye 1982). Prolonged dry seasons (up to 10 months annually) with high evaporation rates rotate with short rainy seasons, but regularity is not assured.

For all West African arid environments, rainfall data for the period 1960–1990 show a rather dramatic decline in average precipitation (Dietz et al. 2004; Put et al. 2004) (Fig. 1). Analysis of rainfall variability and drought risk for this period (based on data of 172 rainfall stations in West Africa) revealed a high drought risk due to reduced precipitation (Dietz et al. 2004; Put et al. 2004). Also later research for the Sahel has shown substantial variations in rainfall in the second half of the twentieth century (Held et al. 2005) and a decline for all dryland areas.

A result of the dry episode, that started in the 1960s and culminated in severe droughts in 1973, 1984 and 1990, was a decline in rainfall in the range of 20–30% in the Sahel region (Fig. 1). This can be considered as the most dramatic example of worldwide multi-decadal climate variability (Diallo 2000; Hulme 2001). The prolonged dry period caused a shift in climatic zones from semi-arid to arid and from sub-humid to semi-humid (Put et al. 2004), with serious consequences for agricultural output and human livelihoods (increased drought risk and unfavorable conditions for crops).

In the Sahel zone, a changing climatic situation is affecting the annual mean rainfall variability, its seasonality and its year-to-year trends (Verhagen et al. 2004). A decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20–40% noted between the periods 1931–1960 and 1968–1990 (IPCC 2007; Chappell and Agnew 2004; Dai et al. 2004).

Annual rainfall levels and their regional and temporal distribution have far-reaching impacts on water availability and quality, on crop yield and production and thus on food security at household and national level.

Changes in precipitation directly influence the risk of drought-related crop failure. ICCD used a drought risk index, building on work of Bailey (1979) and FAO (1980),

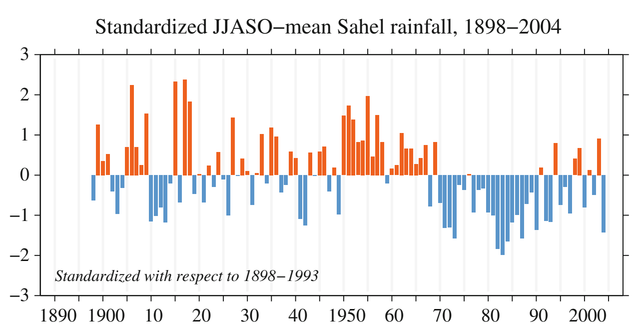

Fig. 1 Rainfall index (June-July-August-September-October) representing the region 20°–10°N, 20°W–10°E, roughly corresponding to the Sahel zone 1898–2004. Source: Joint Institute for the Study of the Atmosphere and Ocean 2005 (Mitchell 2005)

based on monthly precipitation and mean monthly temperatures to differentiate between dry and wet months. The specific combination of dry and wet months during the growing season determines the degree of drought risk, which is differentiated in six classes (Dietz et al. 2004).

Recent work indicates that a significant component of the drying trend in the region in the late twentieth century is attributable to the combined effects of greenhouse gas increase and anthropogenic aerosols (Jenkins et al. 2005; Biasutti and Giannini 2006; Held et al. 2005; Giannini et al. 2003).

Projections for future changes are mixed, however, ranging from a strongly reduced probability of droughts (Haarsma et al. 2005; Paeth and Hense 2004) to severe increases in drought (Cook and Vizy 2006; Held et al. 2005; Paeth and Hense 2004). There is still limited information on extreme events (Christensen et al. 2007), although a recent model study using four GCMs for the Sahel region showed that the number of extremely dry and wet years will increase during the present century (Huntingford et al. 2005).

Agriculture

In most sub-Saharan countries, overuse of land for agricultural purposes has contributed to environmental degradation. Averaged for the whole region, the contribution of the primary sector (arable farming and animal husbandry) to the local economies mostly exceeds 40% of the national GDP (CORAF/WECARD 1998). However, soils are fragile and infertile, with very low levels of organic matter, particularly in the semi-arid zones. The main cause of soil degradation is soil mining, i.e. removal of soil nutrients without replenishment (Gachimbi et al. 2005; Hilhorst and Muchena 2000; Ramisch 1999; Van der Pol 1992). Studies on land degradation in sub-Saharan Africa (Crosson and Anderson 1995; Oldeman et al. 1991) indicate that in the region, 320 10^6 ha are affected by various types of human-induced degradation. Of this area, 34% is moderately to severely affected by water erosion and 23% by wind erosion (Pieri et al. 1998). Furthermore, the rapid population growth further increases the need for food production, which imposes additional stress on limited available land. The livestock population has also increased substantially, as a result of veterinary programs and of investments of farmers in livestock (primarily as a spin-off of successful cash crop programs). The increased livestock densities have contributed to a large extent to ecosystem degradation in the region (Powell et al. 2004; Struif Bontkes and Van Keulen 2003). By undermining the natural resource base on which agriculture depends, the vulnerability of livelihoods based on agriculture is increased. In most of the countries, programs and policies to stimulate agricultural development have been implemented.

Climate change: influence on livelihood and development

In recent years, climate change has evolved from an environmental to a complex development issue (Halsnæs and Verhagen 2007; Dietz et al. 2004). Since the devastating drought of the early 1970s, the emerging environmental and socioeconomic problems have been the subject of intensive study and debate. Realization of the impacts and implementation of actions to alleviate immediate threats and to overcome at least some of the problems have most likely prevented the development of a far worse situation. The Sahel countries created a sub-regional organization for drought control (Permanent Interstate Committee for Drought Control in the Sahel, CILSS) as an institutional response to the crisis.

Adaptation strategies that are already common in the agricultural sector refer to measures that mitigate negative impacts, such as adoption of specific varieties of crops to cope with Sahelian conditions, and/or diversification of agricultural production to reduce the risk of losses.

For a large part of the population in sub-Saharan West Africa, subsistence farming is the main activity on which its livelihood depends. These arid and semi-arid regions are among the harshest and most vulnerable production environments in the world. Less and/or more variable precipitation, higher temperatures and associated higher evaporative demand would threaten crop production and yield, and lead to a decrease in food availability.

Projected climate change is likely to affect farm household livelihoods in the West African Sahel primarily by reducing agricultural production (Ben Mohamed et al. 2001). In addition to climatic factors, other biophysical (soil characteristics, both physical and chemical, incidence of pests and diseases) and socioeconomic (population growth rate, migration, low education level, extension and research, market conditions, use of chemical fertilizers) factors influence the actual level of agricultural production.

Even without climate change, the task of agricultural development in the region is daunting. And although climate change is not recognized as an immediate threat, in many cases, it is expected to exacerbate immediate development stresses through temperature increases, water scarcities and through increased weather variability and more frequent extreme events.

Integrating projected climate change and climate variability into current plans and programs to define adequate adaptation strategies to counteract negative impacts and exploit possible opportunities is perhaps the most logical action to take. The ICCD study tried to identify different strategies to cope with changes, building on the experiences in the Sahelian region.

Adaptation perspectives and strategies

Climate change is likely to create additional stress to this region, which is already under severe pressure as a result of unfavorable environmental conditions and mounting social challenges. Early identification of potential impacts of climate change (including changes in climate variability) and of possible adaptation strategies is important for the sustainable development of the Sahelian region (Dietz et al. 2004). Clearly, the Sahelian population is highly resilient: changes and variations in climate and other environmental factors have always been part of their lives, forcing farmers to adopt specific production strategies, e.g., the choice of specific crops/crop varieties and/or variety mixtures (adapted to the erratic Sahelian conditions) and/or diversification of cropping systems to reduce and spread risks.

Smallholder agriculture in the Sahel is characterized by an enormous spatial heterogeneity (de Ridder et al. 2003). In the least-favorable parts of the region, agricultural systems are characterized by poverty-induced resource overuse (Lopez-Ridaura et al. 2007; Breman 1990). In these conditions, expansion of agricultural activities, necessary because of the poor natural resource quality and the lack of sources of alternative income, leads to land degradation and gradually declining yields and creates therewith a spiral of non-sustainable development (Petschel-Held et al. 1999). When considering different farm types, smaller and poorer farms are characterized by higher risks for food insecurity, even in climatically 'normal' years (Struif Bontkes and Van Keulen 2003; Kruseman 2000; Sissoko 1998). In general, the production levels are low and buffer stocks for poor years cannot be created. Wealthier and larger farm households are more likely to be in a position to implement adaptive strategies, such as storage of food, technical measures to increase and stabilize food production, either by expansion of the land resources or by intensification, or outside agriculture through marketing of non-agricultural products, or selling services and/or labor to reduce or avoid future likelihood of stress and food shortages (Dietz et al. 2004). Although technical options to improve water use efficiency have been developed and could be applied without major financial inputs, adoption levels of such technologies remain low (Amadou et al. 1999). The major reason for low adoption rates lies in the relatively high labor requirements of these technologies. Adaptation strategies are fundamental to reduce the risk of primary production failure, to diversify the sources of food and livelihoods and to create a buffer against future food and livelihood stress.

Typical characteristics of drought situations are a late start and early cessation of the rainy season, i.e. short rainy season and/or very low rainfall. Agricultural production in dry seasons is restricted by low water availability, high temperatures and very low air humidity. The consequences for farm household livelihoods can be serious and may contribute to increased vulnerability and poverty.

To cope with the difficult climatic situation, farm households have developed a range of strategies (Davies 1996; Reardon et al. 1988), which among them are selling of animals and on-farm diversification or specialization.

Risk-coping strategies may involve self-insurance (through precautionary savings) and informal group-based risk sharing. They deal with the consequences (ex post) of income risk ('consumption smoothing'). Households can insure themselves, by building up assets in 'good' years, to use these stocks in 'bad' years. Alternatively, informal arrangements can develop among members of a group or village to support each other in case of hardship. These mechanisms often operate within extended families, ethnic groups, neighborhood groups and/or professional networks. Risk-coping strategies also include attempts to earn additional income in times of hardship, through reallocation of labor, including renting out manpower to bigger farms, out-migration of especially the young skilled male household members, earning income from collecting wild foods (also for own consumption), gathering activities (such as increased firewood collection), etc. Group-based insurance mechanisms are geared toward insuring idiosyncratic shocks, affecting some members, but not all. They obviously cannot provide insurance to deal with shocks common to all members. Self-insurance can, in principle, deal with any type of shock, as long as sufficiently large resources have been built up ex ante. Such short-term coping strategies allow some to survive difficult periods, but do not address the problems in a sustainable way and clearly highlight the high vulnerability of the Sahel population to climate variability and climatic changes.

In order to stabilize and improve livelihoods, as well as responding to the critical impacts of climate change, a number of measures can be initiated and/or developed. Among the possible adaptation measures are identification of drought tolerant crop varieties, irrigation and water management. An operational agro-meteorological information system can provide farmers with advice and warning during the planning phase and the growing season (Roncoli et al. 2003; Roncoli et al. 2001; Konaté 2004; Ingram et al. 2002; FAO 1996).

At regional and national level, policies need to concentrate on food security and economic development. National decision-makers have to develop food aid policies to support vulnerable populations, including programs for food crisis prevention and management. The current cross-border migratory process in case of worsening conditions relocates the problem without solving it, and thus, it is crucial to mitigate negative impacts at regional level.

In terms of economic development, priority needs to be given to adaptation and implementation of comprehensive programs on mainly water management and irrigation, desertification control, development of alternative sources of energy and the promotion of sustainable agricultural practices by farmers (Toulmin 2005; Brooks et al. 2005; Ruben et al. 2004; UNEP 2002). For agriculture, both food and cash crop production should be considered to address the dual targets of food security and economic growth. Impacts on farm household livelihoods should be examined. Policies at the national level should contribute to achieving food security for the majority of the population, regulate and manage water resources and address the issue of energy security and increase the contribution of agriculture to the national GDP.

However, while the resilience of farm households in the Sahelian region is high, adaptive capacity is low and investments will have to be made to reduce the negative impacts of climate change. To stimulate and support the initiatives of farm households, appropriate policies should be implemented at local, national and international scale.

Conclusion

The analyses provided in this chapter have shown the West African Sahel to be a harsh environment, stressed by a fast-growing population and consequently increasing pressure on the scarce natural resources. Increases in temperature and/or modifications in rainfall quantities and distribution will substantially impact on ecosystems and livelihoods in the region and most likely exacerbate and accelerate the current 'downward spiral' of underdevelopment, poverty and environmental degradation. While increases in rainfall as projected in some models would not produce unambiguous benefits, it is clear that a substantial increase in drought frequency and severity would have very damaging consequences. Human coping strategies in response to increasing uncertainty in food supply as a result of climate change and the associated negative effects on the environment put additional and disturbing pressure on the natural resources, leading to accelerated land degradation and desertification and thus create a 'vicious circle of underdevelopment' (Lüdeke et al. 2004; Brooks 2004; Petschel-Held et al. 1999).

Great political, institutional and financial efforts at national and international level are indispensable for the sustenance of millions of lives and to conserve ecosystems and their services. It seems plausible that if some of the climate change projections become reality (severe increase in drought), then international efforts to reduce poverty and to meet the United Nations Millennium Development Goals in this region will be lost, if global warming cannot be contained and/or reversed. Any level of climate change that leads to more drought in this region could be considered dangerous, as it would likely significantly exacerbate the unfavorable conditions in an already very unstable and fragile environment. As a consequence, regional food security, economic development and ecosystems are likely to be further endangered. While the discussions on the 'limits of warming' take their time, the Sahel—representing one of the earths' key vulnerable regions—is in need of the appreciation of its exposure to environmental vulnerability and, therewith, an amplified exposure to human catastrophes. Every degree of warming caused by an increasing greenhouse effect, if accompanied by increased drought in this region, might lead to the loss of unique ecosystems and human beings. Implementation of adaptation strategies is urgent in the Sahel region, but still this remains a financial issue and will not be able to compensate or retract damages or human live losses. It seems urgent that the ambiguity in current model projections of climate change in the Sahel is resolved, so that proper adaptation and response measures can be put in place.

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