

Climate change, drought and pastoralism in the Sahel

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Questions on adaptation

With the recent Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Nairobi (November 2006), significant international attention has been drawn to the issue of climate change. It is widely recognised that developing countries stand to suffer disproportionately from the effects of climate change, they are in the weakest position to mitigate the adverse effects and stand to lose some of the current development gains that have been made as a result.

In the build up to the UNFCCC meeting, a number of NGOs began to voice their concerns about the impact of climate change on pastoral livelihoods, particularly in parts of the world where droughts lead to famine and poverty for pastoralists. However, the role of climate change in undermining pastoral livelihoods remains unclear, particularly given the multitude of other factors that contribute to pastoral poverty. The World Initiative for Sustainable Pastoralism therefore commissioned a paper from Nick Brooks¹ to learn more about the realities of climate change and adaptation in the drylands.

For pastoralists the situation is complex. Their production system is already an adaptation to hostile environments: according to Nick Brooks' paper pastoralism in Africa arose 5000 years ago precisely as an adaptation to climate change at that time. However, with the current marginalisation of pastoralists, their adaptive capacities may have been eroded and they may be more susceptible to climate change than other communities. Conversely, climate change could conceivably lead to the creation of more dryland resources that are suited to pastoralism, thus creating new opportunities for pastoralists to exploit. However, the likelihood and the implications of such changes are very uncertain.

This paper has been drafted partly to stimulate discussion on this complex, but very current topic. A number of questions remain difficult to answer, or at least contentious. Other important questions may yet to be brought into current debates. For example, what is adaptation in the pastoral context? How does it manifest itself? Do pastoralists have first hand experience of climate change yet and how are they adapting? How has their adaptive capacity been curtailed and how can it be restored? Is there a difference between adaptation and development or is adaptive capacity merely an indicator of development?

Introduction

Between the early 1970s and the mid 1990s the African Sahel experienced one of the most dramatic long-term changes in climate observed anywhere in the world in the twentieth century, with rainfall declining on average by more than twenty per cent (Hulme et al., 2001). This period of climatic desiccation was associated with a number of very severe droughts, most notably in the early 1970s and 1980s, during which hundreds of thousands of people and millions of animals died (Glantz, 1976, 1996).

Since the early 1970s there has been extensive discussion about the causes of the Sahelian desiccation. Early theories such as that of Charney pointed the finger at land degradation and desertification caused by overgrazing and "inappropriate land use" (Charney et al., 1975, 1977). However, while soil erosion and over-exploitation of resources are undoubtedly problems in some areas, the evidence for anthropogenically-driven land degradation leading to drought throughout the Sahelian region is lacking. It is now well established that, rather than being a consequence the abuse of the land by humans and animals, the late twentieth century Sahelian desiccation was a product of long-term climate variability driven by changes

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in patterns of global surface temperature. Dry conditions in the Sahel occur during periods in which the southern hemisphere oceans and northern Indian Ocean are warmer than the remaining northern hemisphere oceans, and it is a shift to such a pattern of global temperature distributions that is now widely accepted as being responsible for the turn towards aridity in the Sahel from the late 1960s (Giannini et al., 2003).

Long-term climate variability in northern Africa

The relationship between a relatively warm southern hemisphere and cool northern hemisphere and dry conditions over northern Africa is robust on multiple timescales, from years to millennia, and is expressed most dramatically in the multi-millennial changes associated with glacial cycles. During the last glacial maximum, when the northern hemisphere was significantly colder than the southern hemisphere due to the growth of huge ice sheets, the Sahara desert was much larger and more arid than today (Talbot, 1983). After the end of the last ice age, intense summer heating of the northern hemisphere (caused by changes in the tilt of the Earth on its axis) intensified the African monsoon, transforming the Sahara into a landscape of lakes, savannah and open woodland by around 10,000 years before present (Szabo et al., 1995). After a period characterised by generally drier conditions, and punctuated by severe and abrupt arid crises, monsoon rainfall finally collapsed in most of the Sahara around 5000 years ago. This transition occurred earlier in the eastern Sahara, and in some areas winter rainfall persisted in highland regions after the collapse of the monsoon (see Brooks et al., 2005 and Brooks, 2006, for a review of climatic and environmental change in the Sahara over the past 10,000 years).

Environmental data, supported by computer modelling studies of the global and regional climate, suggest that the collapse of the Saharan monsoon occurred in one or two abrupt episodes associated with rapid changes in vegetation systems (Claussen et al., 2003; Brooks, 2006). As the strong solar heating that initially led to monsoon intensification after end of the last ice age declined due to further changes in the Earth's inclination to the sun, it appears that the monsoon system may have been sustained by feedbacks involving the recycling of moisture via vegetation. With weaker solar heating of the northern African landmass in summer the monsoon was particularly susceptible to climatic shocks, such as those associated with quasi-periodic cold episodes originating in the North Atlantic Ocean,

These cold episodes have occurred every one to two thousand years since the end of the last ice age, and are associated with aridity throughout the northern hemisphere sub-tropics (Bond et al., 1997; Brooks, 2006). One of these events occurred around 8000 years ago, leading to a period of aridity in the Sahara and elsewhere that lasted for several centuries, before the monsoon system recovered due to the strong summer solar heating of northern Africa that still pertained at this time. A similar, but weaker, Atlantic cooling event occurred around 6000 years ago, and coincided with a shift towards aridity throughout the northern hemisphere monsoon belt (Brooks, 2006). It appears that monsoon recovery after this event was partial at best, in the regime of weakening solar heating. The final collapse of rainfall in the Sahara some thousand years later may have been associated with a similar climatic shock after which summer solar heating over northern Africa was insufficient to drive a recovery of the monsoon, or simply with a reduction in the strength of summer solar heating below a certain threshold, beyond which collapse was inevitable.

The origins of African pastoralism

Today's African pastoral systems have their origins in the prehistoric Sahara, where they emerged as a means of securing food resources in a drying and increasingly variable and unpredictable climate. The earliest evidence of cattle domestication comes from the Eastern Sahara, where climatic desiccation advanced most rapidly (Nicholl, 2004). As drier conditions spread into the central Sahara between about 7000 and 6000 years ago, so did cattle herding. Increased aridity is believed to have played a key role in encouraging the integration of cattle herding with existing hunting and foraging systems (Holl, 1998; Hassan, 2002). As rainfall declined and became temporally and spatially more variable, plant resources and wild animals would have become scarcer. Cattle pastoralism enabled people to track increasingly elusive water and pasture, increasing flexibility through an enhanced ability to respond to a rapidly changing, and increasingly unpredictable environment (Marshall and Hildebrand, 2002). Radiocarbon dating of archaeological sites suggests discrete episodes of migration spanning short periods, implying rapid, intermittent movements of small groups of herders,

colonising new and unfamiliar environments as they were forced to move in search of water and pasture during arid crises (di Lernia, 2006). The importance of cattle as a source of food security in this highly variable and rapidly changing environment is underlined by the existence of numerous ritual cattle burials, and by the ubiquity of cattle in prehistoric Saharan rock paintings and engravings.

As conditions became drier sheep and goats featured more prominently in the Sahara resource base, and archaeological studies indicate increased transhumance, with lowland pasture being reserved for cattle and the tending of sheep and goats focused on highland areas (di Lernia and Palombini, 2002). After the collapse of the monsoon in the central Sahara around 5000 years ago cattle were confined to oases regions and formed the basis of an increasingly sedentary economy that ultimately culminated in the emergence of agriculture in certain locations around 3000 years ago. However, this increase in sedentism around the remaining surface water was complemented by increased mobility based on sheep and goat herding in highland areas that still attracted winter rainfall. This “adaptation in situ” occurred in locations where sufficient water and pasture remained to sustain human and animal populations. However, such areas represented a small fraction of the Sahara, large tracts of desert were simply abandoned; analysis of the distribution of archaeological sites indicates a general southwards displacement of human activity as people migrated with the southward retreating monsoon rains. After 5000 years before present cattle herders migrated into the Sahel, and ultimately throughout the African continent.

Lessons from the past

Studies of past environmental change and the northern African archaeological record indicate just how variable climatic and environmental conditions are in the Sahel-Sahara zone on timescales of centuries to millennia. Such studies also illustrate the sensitivity of rainfall in this region to hemispheric and global-scale changes in climate. The archaeological evidence overwhelmingly indicates that pastoralism in Africa developed in direct response to long-term climate change and variability, and spread throughout northern Africa as a means of coping with an increasingly unpredictable and arid climate. Pastoralism has provided food security for African populations for over seven thousand years.

While pastoral systems in other parts of the world (e.g. western Asia) co-evolved with agriculture, and depended to a large extent on relations between sedentary farmers and mobile herders, cultivation emerged rather later in Africa. In the prehistoric central Sahara pastoralism predated agriculture by at least four thousand years, and coexisted instead with hunting and foraging. More than once pastoralism provided a means through which fairly sedentary populations could increase their mobility in order to survive in the face of deteriorating climatic conditions. In areas such as the Fezzan region of modern-day Libya, mobile pastoralism proved more sustainable than the development of urban societies, as demonstrated by the decline of the Garamantian civilisation contrasted with the survival of sheep and goat herding to the present day (Brooks, 2006).

The very different development trajectories of pastoralism in Africa and, for example, western Asia, reflect the very different environments of these regions. In western Asia and the other “cradles of civilisation”, pastoralism was from the outset linked with sedentary agricultural systems and urban settlements that were sustained by the rivers along which they coalesced. There is growing evidence that the emergence of the first large, complex, urban societies – the “great civilisations” of antiquity – was driven by a combination of climatic and environmental desiccation, and the existence of environmental refugia in the form of river valleys (Brooks, 2006). The complex societies of Egypt, Mesopotamia and elsewhere developed as people migrated away from desiccating rangelands and into riverine areas. The resulting need to organise densely packed populations in order to manage scarce resources in restricted areas (rather than some nebulous force of “progress” or advancement) has been identified as the main driving force behind the development of the earliest large urban civilisations (Brooks, 2006).

Away from the Nile and the Niger, northern Africa has no major permanent rivers. This fact, coupled with the highly variable nature of the rainfall, meant that northern African populations had to rely on different strategies to secure food resources. The option of developing large urban societies based on irrigated agriculture was simply not open to them away from the Nile and Niger. The lack of development of large urban civilisations in many parts of Africa prior to

the colonial period reflects the fact that loosely dispersed, highly mobile populations fare better than sedentary populations in highly variable environments. Pastoralism was simply the most sensible and viable option in the unpredictable northern African environment, where reliable supplies of large quantities of permanent water simply did not exist. Far from being a poor substitute for agriculture or urban living, or the result of a backwardness that prevented the peoples of the time from advancing, pastoralism was a superior system for ensuring food security in the African environment (Marshall and Hildebrand, 2002).

Development programmes based on imported models of extensive urbanisation and large-scale sedentary agriculture, originating in the much more predictable and much less marginal environments of temperate European latitudes, have generally failed to grasp the role of the environment in shaping African development. Colonial and post-colonial governments, mistrusting mobile populations, have long tried to settle nomadic peoples in the name of progress and modernity, erroneously portraying pastoralism as somehow “backward”, a “primitive” state predating agriculture and urbanisation. A shift from mobility to sedentism, and the marginalisation of nomadic peoples, has done much to exacerbate vulnerability in a part of the world where flexibility, in the face of a high degree of spatial and temporal variability in climatic and environmental conditions, is the norm (Glantz, 1996).

Drought and development in the twentieth century

Prior to the late twentieth century desiccation, the Sahel experienced unusually large amounts of rainfall (relative to the twentieth century mean) during the 1950s and 1960s. This period was characterised by the transition to independence for many African nations, optimism about the ability of technology to deliver widespread benefits, and an ambitious drive for economic development both inside and outside Africa. Newly independent African nations focused on modern, technocratic solutions to development aimed at delivering economic growth, and traditional approaches to resource management and food security were increasingly marginalised. The coincidence of this period of political and economic transition, when considerations of environmental variability and sustainability were minimal, with increased rainfall, resulted in the northward expansion of agriculture in the Sahel into historically marginal areas, with profound implications for the vulnerability of agriculturalists and pastoralists alike (Glantz, 1996; Thébaud and Batterby, 2001).

Pastoral livelihoods in the Sahel historically were underpinned by systems of negotiated access to water and pasture that did not assign exclusive rights, and by reciprocal arrangements between pastoralists and agriculturalists. The expansion of agriculture during the wet 1950s and 1960s and a shift to agropastoralism pushed pastoralists into more marginal regions and led to a breakdown in the networks connecting herders and farmers, further contributing to conflict between these groups (Thébaud and Batterby, 2001). Pushed into more marginal areas, and with their access to pasture regulated and restricted by both colonial and post-colonial government, pastoral communities became more vulnerable to drought. When rainfall returned to more “normal” conditions in the late 1960s, and then declined dramatically to culminate in the severe droughts of the early 1970s, the over-extension of agriculture and the marginalisation of pastoralists had catastrophic effects that destroyed. While they were undoubtedly triggered by drought, the famines of the 1970s were as much the result of massively inappropriate development practices as they were of inadequate rainfall. The over-extension of agriculture, and consequently of pastoralism, into historically marginal areas as a result of a failure to appreciate the nature of long-term (i.e. multi-decadal scale) climatic variability in the Sahel, resulted in massive loss of life and livestock, the destruction of communities and livelihood systems, and massive societal disruption on a regional scale. In some areas drought also helped to trigger conflict, for example in the case of the “Second Tuareg Rebellion” in Mali in 1990 (Keita, 1994).

Despite the disastrous consequences of this unsustainable development, governments, aid donors and academics were slow to learn the real lessons of the droughts of the 1970s. Rather than recognising the role of agricultural extension, observers tended to write off the drought as a purely natural disaster, or to lay the blame for the catastrophe at the feet of pastoralists, who were accused of systematically overgrazing the land or otherwise engaging in “inappropriate land use” practices. Articles in academic journals and other publications spoke of the need to “educate” local people about the need not to abuse the land (e.g

Lamprey, 1975). The real need is to educate governments, NGOs and foreign donors about the realities of development in a highly variable, semi-arid environment.

The notion that drought and large-scale desertification in the Sahel has been caused by systematic abuse of the land by pastoralists has now been roundly refuted in the scientific literature (e.g. Mace, 1995; Fairhead and Leach, 1996a, b), but persists as a popular myth, and may even be found in undergraduate geography course, particularly in the United States. Among the research community, apparent desertification in the Sahel is now generally viewed as a transient response to a decline in rainfall (Tucker et al., 1991, 1994). A number of studies have demonstrated that this “degradation” of the land surface is not irreversible, with vegetation systems recovering once rainfall has returned. Of course “desertification” in the form of wind erosion and deposition, and the encroachment of dunes in settlements continues in some areas as a function of the naturally dynamic nature of the environment in this semi-arid region.

Future climate change in the Sahel

The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change suggests that climate change is likely to be associated with increased water stress in much of Africa. However, the IPCC TAR reports that scenarios for the Sahel region, based on Hulme et al. (2001) are ambiguous (IPCC, 2001: p496). Since the publication of the TAR, a number of modelling studies have examined the possible climatic consequences for northern Africa of anthropogenic global warming resulting from increased concentrations of atmospheric greenhouse gases. These studies have used models which include dynamic representations of vegetation and land-atmosphere interactions, and some of them have been demonstrated to capture past humid-arid transitions. These new modelling studies increasingly suggest a “greening” of the Sahel and parts of the Sahara in response to anthropogenically driven climate change.

Claussen et al. (2003) report a potential increase of vegetation cover of up to 10 % of the Saharan land area per decade as a result of increased CO² concentrations which trigger increased rainfall which is then sustained through vegetation-atmosphere feedbacks. In this model vegetation spreads through up to 45% of the Sahara. Other modelling studies suggest that the Saharan climatic zone will shift north, resulting in increasingly humid conditions in the Sahel and southern Sahara, and desiccation along the northern fringes of the desert in the Mediterranean zone of North Africa (Liu et al., 2002).

Maynard et al., (2002) find that the monsoon is enhanced over West Africa towards the end of the twenty first century as atmospheric CO² concentrations increase to 577 parts per million (ppm). Their model does not represent vegetation-atmosphere interaction; such feedback processes may lead to further strengthening of the monsoon system. Wang and Eltahir (2002) perform a modelling study that reproduces the observed dry period in the Sahel during the late twentieth century, when atmospheric CO² concentrations are fixed at 300 ppm, representing “pre-industrial” levels. When the CO² concentration is increased to 350 ppm and the simulation is repeated for the same period, there is no prolonged dry episode. The authors of this study therefore conclude that the Sahelian “biosphere-atmosphere system at higher CO² levels is more resilient to drought-inducing external forcings,” and suggest that global warming will be associated with more prolonged humid periods and shorter dry episodes in the Sahel. They suggest that vegetation changes associated with this increased resilience are partly the result of an enhanced CO² fertilisation effect.

A simplistic reading of these results suggest that the Sahel might actually benefit from anthropogenic climate change. Indeed, an increase in Sahelian rainfall over the coming decades does seem a very real possibility. However, it must be noted that the above modelling studies examine the impacts of increases in atmospheric CO² concentrations to levels that are almost certain to be exceeded by the middle of the 21st century. The 350 ppm of Wang and Eltahir (2002) and the 577 ppm of Maynard et al., (2002) should be compared with the current atmospheric CO² concentration of around 380 ppm, and an anticipated concentration of 550 ppm before 2050. Without drastic action in the very near future, concentrations are likely to continue to rise beyond 600 ppm.

A modelling study by Mitchell et al. (2000) suggests that stabilising atmospheric CO² concentrations at 550 and 750 ppm by the end of the twenty first century will result in a

warming of the southern hemisphere oceans and northern Indian Ocean relative to the remaining northern hemisphere oceans. This configuration of global temperatures is associated with dry conditions in the Sahel, so higher (and perhaps more likely given the slow progress in reducing greenhouse gas emissions) stabilisation levels may see a return to drought in northern Africa. Mitchell et al. (2000) report that at higher levels of atmospheric CO² (representing no attempt to reduce greenhouse gas emissions) this relative warming of the southern hemisphere does not occur, suggesting that the Sahel is more likely to experience aridity at “intermediate” levels of anthropogenic greenhouse warming. Such a conclusion must remain tentative however; atmospheric greenhouse gas concentrations over the coming decades will significantly exceed those of the past several hundred thousand years, and it cannot be assumed that the behaviour of the global climate system will be similar to that of the periods for which past analogues are available.

It might also be noted that climate models have difficulty representing the type of abrupt, non-linear changes in climate and related physical systems that are apparent in the palaeoclimatic record, such as transient cold, arid events associated with changes in North Atlantic circulation. The probability of such events under different greenhouse gas emissions scenarios is not known, but it appears that events such as abrupt weakening of the thermohaline circulation may have occurred in the past with little or no external forcing (Alley, 2003; Alley et al, 2003). Anthropogenic climate change may well increase the likelihood of such events occurring in the future, and it is reasonable to assume that the probability of abrupt climate shifts increases with increasing rates and magnitudes of greenhouse gas emissions and consequent increases in global mean surface temperature. The consequences of such events for the Sahel would be dramatic; palaeoclimatic analogues indicate that the result would probably be a rapid onset of aridity lasting decades to centuries.

In summary, computer simulations of future climate change increasingly indicate that an intensification of the African Monsoon, and a greening of the Sahel and southern Sahara, is a plausible consequence of anthropogenic greenhouse warming. However, it is unclear how robust such a greening would be in the long-term, and if atmospheric CO² concentrations approach or exceed 600 ppm, as currently seems plausible if not likely. There is a very real possibility that a period of increased rainfall across the region may be followed by a further weakening or collapse of the monsoon system in the foreseeable future, driven by changes in global temperature patterns, abrupt climate change associated with changes in the North Atlantic circulation, or other changes in the behaviour of the global or regional climate system as greenhouse gases and global temperatures reach values that are unprecedented in millions of years. Given the climatic history of the Sahel-Sahara zone, the sensitivity of the African monsoon to external climatic drivers, and the large and rapid forcing of the global climate system by anthropogenic greenhouse gas emissions, such a reversal of any greening process is inevitable at some point in the future.

Future development and pastoralism in the Sahel

Although the Sahel is still subject to drought and widespread food insecurity, increases in rainfall have been observed across the region since the mid-1990s, consistent with modelling studies that predict an increase in rainfall as a result of anthropogenically-driven climate change. If the region continues to become wetter due to an intensification and northward incursion of the monsoon, current development models are likely to result in an expansion of agriculture into newly productive but historical marginal areas, as occurred in the 1950s.

Any future northern extension of agriculture, and associated displacement of mobile pastoralists further into the Saharan zone, could result in acute food insecurity and catastrophic famine if the predicted future greening of the Sahel and southern Sahara is subsequently reversed. The greater the extent of the “greening” of the Sahel and southern Sahara, the greater any over-extension of agriculture is likely to be, representing a systematic increase vulnerability to changes in the monsoon regime. The droughts and famines of the 1970s could be repeated on a massive scale if development continues without any attention being paid to longer-term climate variability.

Given our knowledge of long-term global and regional climate change and the driving factors behind such change we can say with confidence that any greening of the Sahel and Sahara in the near future will eventually be reversed, if not this century then at some time in the (possibly distant future). While the timing of any future return to aridity (assuming the

predicted greening materialises) cannot be determined with anything approaching confidence, model simulations of future climate, coupled with an assessment of past climate change and variability in northern Africa, provide reasons for concern.

As noted above, changes in sea-surface temperature patterns associated with drought in the Sahelian zone are predicted by some models for atmospheric greenhouse gas concentrations that are plausible in the latter half of the twenty first century. Some researchers argue that a weakening or even collapse of the North Atlantic circulation is increasingly likely as greenhouse gas concentrations increase, although most believe that such an event is unlikely to occur this century. Studies of past such events tell us that any such changes in the Atlantic circulation are likely to be associated with increased aridity in northern Africa and throughout the northern hemisphere sub-tropics. Given the large uncertainty associated with future climate change in the Sahel and the northern hemisphere sub-tropical zone in general, the most reliable basis for development will be an assumption of continued (and possibly enhanced) climatic variability on a range of timescales. Even if the region becomes wetter, climate change is likely to affect phenomena such as the onset and termination of the wet season.

In order to avoid a systemic increase in regional vulnerability to future changes in the monsoon regime, Sahelian societies need to maximise their ability to respond to climate change and variability on multiple timescales, while exploiting any opportunities provided by increases in rainfall. Developmental models based on high densities of people and livestock and permanent, sedentary agriculture in historically or potentially marginal areas are unlikely to deliver sustainable development in the long term. In the Sahelian environment, systems based on flexibility, mobility, and low-intensity use of natural resources are much more likely to deliver a sustainable future. Such systems, based on mobile pastoralism, have developed autonomously in this region in the past, in response to precisely the kinds of changes in climate that may be experienced in the foreseeable future. Instead of attempting to settle nomadic and semi-nomadic peoples in towns and villages, whether for purposes of political control or because nomadic pastoralism is seen as somehow “backward”, governments and the development community in the Sahel might seek to rehabilitate pastoral livelihoods through a combination of traditional and novel approaches to land and livestock management.

One possible solution to the problem of agricultural overextension during wet periods might be to cede significant control of historically marginal areas to pastoral peoples. Pastoralists could “lease” land in these areas to agriculturalists during humid periods, when there is a surplus of resources. The type of agriculture practiced in such areas should be appropriate to the marginal environment and not result in irreversible land degradation or soil loss, allowing soils and vegetation systems to recover between periods of cultivation. In drier periods the control of potentially marginal areas by pastoralists would prevent pastoral populations being pushed into extreme marginal environments, minimising the potential for famine and conflict. Pastoralism in such areas, and the control of these areas by pastoralists, would therefore provide a “buffer zone” between more reliable agricultural areas and the extreme desert margins, maximising the use of a variable resource base while reducing large-scale vulnerability to drought and climatic desiccation.

Pastoralists could be left to develop their own systems of resource management: where governments have attempted to deliver development to pastoral peoples their attempts have often backfired. For example, in some regions the replacement of hand-dug wells with boreholes and cement-lined wells, as part of development programmes driven by central government, has resulted in the breakdown of access regimes due to the difficulty of regulating use of boreholes and new wells at sustainable levels. The breakdown of existing regimes based on relations between different pastoral groups has resulted in conflict in some instances. The development of informal social institutions to regulate access to resources at sustainable levels is generally preferable to simplistic attempts to increase productivity through expanded access to resources such as water. The former approach could be based on traditional institutions for regulating resource use, perhaps informed by modern approaches such as seasonal or long-range forecasts. Crucially, successful pastoralism in the Sahel will require that pastoral populations maintain their freedom of movement, both within countries and across national borders in some areas.

Future development in the Sahel will also build on existing adaptations and innovations following the droughts of the 1970s, 80s and 90s. For example, in parts of Niger and northern

Nigeria, innovation and diversification have allowed farmers to maintain productivity and soil fertility while intensifying agricultural activity (Mortimore and Adams, 2001). Increases in population density have provided a pool of labour as well as market opportunities for the sale of agricultural surplus. Historically, social networks and relations between rural and urban areas have facilitated temporary migration enabling households to alter the balance between agricultural activity and salaried employment as a response to environmental variable and the associated viability of agriculture. Reciprocal relationships between pastoralists and agriculturalists will play a key role in future development: just as pastoralists may grant farmers the right to engage in agriculture on their lands in wet periods, so agriculture in less marginal areas might provide temporary employment to pastoralists during dry periods, reinforcing their food security.

Whatever form future development in the Sahel takes, the variable and unpredictable nature of the climate and environment of the region means that development will be more successful, and sustainable, if it is based in large part on pastoral systems that have demonstrated their success in sustaining human populations in semi-arid environments over thousands of years.

Wider considerations

The Sahel is one of many regions where pastoralism is practiced on a large scale that is likely to experience significant climate change in the foreseeable future. The lessons drawn in this paper will be applicable wherever pastoralists, or pastoralists and agriculturalists, face increase climatic variability and unpredictability on timescales ranging from seasonal to multi-decadal, particularly at or near the semi-arid fringes of monsoonal climate regimes.

Climate change may have more problematic consequences for pastoralists elsewhere, and in some instances may drastically undermine the viability of pastoral systems. For example, simulations of future climate change indicate an average reduction of rainfall in the Maghreb of some 40% for an increase in global mean surface temperature of around 2°C, which is very likely by the middle of the twenty first century (Warren, 2006). This is likely to have a severe impact on rangelands and food security, particularly in the pastoral sector. This scenario is consistent with the general observation that the Saharan climatic zone is likely to shift northwards, with an increase in rainfall along the southern fringe of the Sahara and increased aridity in the Mediterranean region (Liu et al., 2002; Giorgi, 2006).

Another area where pastoralism is likely to be adversely affected is southern Africa, where recent studies suggest that for global mean temperature increases of more than 2°C vegetation systems may collapse resulting in the remobilisation of currently stable dune fields (e.g. in the Kalahari) (Thomas et al., 2005). Such a process would have severe problems for countries such as Botswana, which depend heavily on cattle ranching. Declines in rainfall in other semi-arid regions may also have negative impacts on pastoralism, particularly where pastoralists are restricted in their movement and livelihood options.

Nonetheless, where climatic conditions become more variable without leading to the collapse of rangeland, pastoral livelihoods have the potential to sustain populations in the face of climate change. Pastoralism may also provide a viable livelihood alternative where the climate change and other pressures on ecosystems result in the transformation of forest into savannah. Such transitions are anticipated in some forest areas, as for example in the Amazon, where modelling studies suggest that increases in global mean temperature of 2-3°C will lead to the widespread loss of rainforest (and perhaps the total collapse of the Amazon ecosystem as presently established), or in China where boreal forests are at risk of collapse (Warren, 2006).

Drying trends have also been observed in the northern Congo basin, and may continue, resulting in a transition to savannah in this region (Warren, 2006). Emerging savannah environments may provide suitable conditions for an expansion of pastoralism and the securing of livelihoods and food resources where climate change is associated with dramatic changes in landscapes and ecosystems. Transitional periods associated with these kinds of changes are likely to be associated with considerable climatic variability as coupled land-atmosphere systems attempt to evolve towards new quasi-equilibrium states. Continued anthropogenic forcing of the climate system, coupled with the possible triggering of global climate feedback mechanisms, is likely to result in enhanced short-term and long-term climate

variability for many decades or centuries to come. In this more dynamic climatic environment, the flexibility and mobility afforded by pastoralism may increasingly provide a means of providing security where other more sedentary models fail.

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