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Climate Change in Sub-Saharan Africa: consequences and implications for the" Future of Pastoralism"

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Introduction

Managing climate variability and climate risk is at the heart of pastoralism. Both traditional nomadic or mobile pastoralism and mixed or agro-pastoral systems have been supreme adaptations to cycles of drought, floods and "normal" rainfall years, most often in areas that do not receive more than 600 mm rainfall annually and more often make do with 200 to 300 mm. Pastoral herders balance herd size, species and breed composition, grazing patterns as well as other livelihood options with an eye to managing climatic risk, even if other risks such as social, economic or conflict are more immediate. Decisions to crop in wet years or areas are also in part influenced by climate variability. The consequences and implications of 21st century global warming and the resulting changes in climatic patterns that will occur are therefore of paramount importance to pastoral livelihoods, productions systems and landscapes. Adaptation choices made now will have implications for the coming decades, as climate change unfolds and pastoral communities continue to transform.

This paper explores the current state of research knowledge about climate change and its consequences in pastoral areas of sub-Saharan Africa. This includes gaps and uncertainties in such knowledge. We first review traditional and current pastoral climate risk management strategies in a changing economic and political context. Second we present downscaled climate projections out to 2050, describing several different types of impact thresholds. The interpretation of as well as the uncertainties in these projections are explained. Thirdly we present evidence on how climate change might affect pastoral systems through changes in vegetation, frequency of drought, and livelihood transitions in marginal cropping areas. The final section discusses the importance of adaptation strategies to the ultimate future consequences and implications of climate change for the future of pastoralism.

How pastoralists manage climate risk

We begin with an understanding of how pastoralists currently managing climate risk, as any future climate change must be managed from these current capacities, practices and understandings. Climate risk in pastoral landscapes is a product of low precipitation that is highly temporally and spatially variable. Water is always underlying scarce resource, since rainfall varies between years, with the variability (CV) increasing with aridity (Homewood, 2008). Hence the more arid a pastoral environment, the less predictable is the rainfall. This variability between years shows serial autocorrelation, as years with above and below normal rainfall come in cycles. The underlying process is that variability in rainfall between years is related to temperatures of the southern oceans, with series of drier and wetter years associated to El Niño in West and East Africa respectively, the being latter also influenced by Indian Ocean temperature anomalies. Thus in East Africa, El Niño events tend to be associated with wetter rainfall events, while La Niña events often bring drought, as we have just seen in 2010. However in West Africa, El Niño events are associated with drier than normal conditions. The El Niño Southern Oscillation (ENSO) influence on interannual variability is not completely understood, as Indian Ocean temperature anomalies also play a role. Thus dry and wet years can also occur in the absence of an ENSO event. The ENSO cycle is more influential on short rather than long rains in East Africa. Apart from these cycles longer term trends in rainfall have been reported for the West African Sahel where rainfall has decreased between 1931–60 and 1968–97 by 20–49% (Desanker and Magadza, 2001, cited in Homewood 2008). The picture for the rest of the continent is less clear, while although Desanker and Magadza (2001) reported a 5–10% decline for the rest of Africa this does not hold for southern Africa as a whole nor for localised areas of East Africa (Homewood, 2008).

Investigation of a 28 year time series of Normalized Difference Vegetation Index (NDVI) data (Fig 1) for Kajiado district in Southern Kenya, for example, reveals that droughts (e.g. 1984, 1995, 2000, 2005/6) occur at irregular rather than regular intervals, with periods with above normal NDVI associated to El Nino years (for example 1998, 2006) . NDVI is a remotely sensed index that indicates how green the biomass in a landscape is. It is highly correlated with rainfall in arid and semi-arid areas, and as there is a 30 year record of it with full spatial coverage it is a better tool for analyzing the impacts of climate variability on rangeland vegetation than precipitation data. Weather stations are not sufficiently distributed in many parts of dryland Africa and observed precipitation records often have gaps of several years.

Figure 1 HERE

A similar analysis of NDVI for two sites in Southern Niger showed that NDVI values of 0.2and 0.14 could be considered as thresholds to distinguish between drought years and average to above average years for Fakara and Gabi respectively. Based on these thresholds, drought years in Fakara were 1983, 1985, 1988, and 1991 (and 2005). For Zermou, the drought years were 1983, 1984, 1985, 1991, 1994, 1997 and 1998 (and 2005) (Gerard 2008, cited by Ayantunde et al in prep). The differences in the thresholds for these two sites, are due to the differences in aridity; Fakara receives about 550 mm rainfall annually, while Zermou receives only 350 mm.

Figure 2 HERE

The impacts of this variable precipitation on forage are that grazing landscapes are highly heterogeneous. The primary production of rangelands is highly variable in time and space, primarily in response to water available for transpiration and plant production. The relation between above ground biomass and rainfall varies from 2kg.ha^{-1} of above ground biomass per mm of rainfall in West and 4 kg.ha in North Africa (Le Houerou and Hoste 1977, cited in Homewood 2008), to 8 kg.ha^{-1} for every mm of rainfall above 20 mm in East Africa (Desmukh 1984, cited in Homewood 2008), a difference attributed to the generally higher fertility of soils in East Africa. Availability of forage and shortages (whether from drought or constrained access or change in palatability, as well as differences in soils) are the primary driver of variability in livestock production in pastoral lands, and most range areas include a mix of vegetation types and productivity.

In severe or prolonged droughts, forage and water scarcity combine and livestock mortality rates increase. Nkedyinae et al (2010) report mortality rates of 14 to 43 % in southern Kenya in 2005; livestock losses were as high as 80% in 2009. Huho et al (2011) cite 30% losses in 2001 and 2005 losses in Northern Kenya of 30-40% of cattle and shoats. Here we present two the relationship between total animal biomass and NDVI. Figure 3 shows that in Kajiado, Kenya, total animal biomass was surprisingly poorly related to short term variation in NDVI, which is a good indicator of drought, but related very well to a five year running average of NDVI.

Figure 3 HERE

These findings suggest that livestock population dynamics in Southern Kenya are not only determined by short term losses of livestock during drought, high and low in years of below and above normal resource condition respectively, but instead track the history of resource condition over a longer time period of five years. Taking a five year running average makes sense as given low reproduction rates it may take 4 to 5 years for a herd to recover after a major drought. The analysis of animal biomass reveals cycles of high animal biomass of approximately 8 $g.m^{-2}$ (corresponding 1 TLU per 3ha, the stocking density recommended for Kadjiado rangelands), with lower interludes, a cyclic patterns which connects to El Nino events in 1989, 1998 and 2006. Higher NDVI values and thus forage availability around El Nino (or other wet) years apparently pulls the livestock populations out of lower biomass phase towards a phase with higher biomass densities, presumably because of positive effects of forage availability on animal reproduction and population size during years of good biomass. This pulling up of animal biomass did not happen during the El Niño year of 2006, which came with high NDVI. The 2006 El Niño was however preceded and followed by severe droughts that lasted more than one rainy season. We suggest this rapid succession of droughts, although interrupted by an El Niño, kept the herd system in a low biomass phase. Extrapolating the 2009 biomass from the 2007 animal density and the 80% mortality that has been reported in Kadjiado leads to an estimated biomass of 1 $g.m^{-2}$, a density of 1 TLU / 25 ha^{-1}; a situation that has never before been encountered over the last 30 years.

However, for a different district, Laikipia in northern Kenya, the relationship was better for a two year running average, which suggests that multiple factors such as herd composition, access to remote grazing areas, as well as stocking densities and migration from other areas also affect the NDVI and mortality relationship, as Nkedianye et al (2010) also discuss. We observe the peaks in 1989 and 1998, and the smaller peak in 2006, as well as the historic lows of 2009.

Pastoralists manage this climate risk in context of other factors, particularly land tenure, security, economic opportunities, but spatial and temporal flexibility is critical to their ability to keep their herds healthy and productive. This is not only a matter of grazing rights and negotiations but also protection of and access to key resource areas (Little 2002; Ngugi and Conant, 2008). Little (2002) compares Marsabit, Kenya to southern Somalia and finds that ability of herders to maintain mobility and access to key resource areas reduces negative ecological impacts on grazing areas. Ngugi and Conant (2008) mapped key resource areas in Kenya and discuss how herders value and negotiate access to them. Thus we must be careful interpreting situations from average biomass for an area only.

Pastoralists are also encouraged to use markets as a method of destocking during droughts (e.g. Turner and Williams 2002, Abebe et al 2008), although often terms of trade have by then turned against them and as McPeak (2004) points out herders manage asset risk differently from income risk, and they have reasons for holding on to animals. In addition, the last two decades have seen many more external emergency interventions both food aid and other types such as veterinary services and destocking programmes, but these are often plagued by issues of timeliness and coverage.

One often cited coping strategy for dealing with increased frequency and impact of drought is to change herd species composition. Figure 4 shows the change in the ratio of shoats to cattle across Kenya between 1977 /78 and 2005/2010. Goats, as well as camels are more drought tolerate than cattle, and also have different fodder preferences, preferring browse to grasses.

Figure 4 HERE

Downscaled climate projections for SSA

The multi-model means of surface warming (relative to 1980–1999) for the SRES scenarios A2, A1Band B1 from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment show increases of about 1–2◦C to the 2050s and about 1.5–3◦C for the 2080s (Meehl et al, 2007). ILRI colleagues have been working on the implications of climate change for agropastoral and pastoral systems in SSA for several years. They translate the results of multiple Global Circulation Models (GCM) scenarios by "downscaling" them to regions in the global tropics. The technical procedures they use to generate downscaled climate scenarios are explained in Jones et al (2009). Their results indicate that climate change will bring about three types of changes that can affect pastoral systems: increases in maximum and minimum temperatures; changes in the duration, frequency and intensity of precipitation events, and increase in the CO^2 concentrations in the atmosphere (above 350 ppm).

Multiple climate change exposure threshold that can be calculated from downscaled GCMs, for example changes in maximum or minimum average annual temperatures. We calculated places in the global tropics where maximum temperatures are predicted to flip from less than 30 degrees C to greater than 30 degrees C by 2050. This temperature threshold is a limit for a number of staple crops, including maize, beans, and groundnut. Heat stress also affects grasses and livestock, although this is an under-researched area. Although the results are not shown here, large areas in East Africa as well as parts of West Africa will undergo this flip (Ericksen et al 2011).

A different sort of threshold is shown in figures 8 and 9. The most difficult characteristic of precipitation patterns for the GCMs to simulate in variability. Here we show two approximate indicators: increases in rainfall per rain event, and decreases in rainfall per rain event, for East and West Africa (from Ericksen et al 2011). Large areas of East Africa will experience greater rainfall intensity, while decreases in rainfall per rainy day are less common. In West Africa, increases in intensity will be common across Niger, Mali and Burkina Faso, while Senegal and southern Nigeria may see decreases in rainfall per rainy day.

Figures 8 and 9 here.

Another measure of how climate change will affect productions systems is shown in Figure 10. This is an estimate of areas in Africa that will experience a greater than 20% reduction in the Length of the Growing Period (LGP). LGP is the average number of growing days per year, and can be interpreted as (among other things) a proxy for the number of grazing days. A growing day is a day in which the average air temperature exceeds 6 degrees C and the ratio of actual to potential evapo-transpiration exceeds 0.35 (Jones and Thornton 2009). Note that this figure was generated from only one GCM and one scenario, so must be interpreted with caution. The figure shows the changes in LGP for different types of livestock production systems and agroclimatic conditions, based on the work of Thornton et al 2009. This illustrates significant changes are possible across livestock production systems in Africa.

Figure 10 here

A major difficulty in interpreting and using climate change model results is the uncertainty in the calculations. This arises not only from the different GHG emissions scenarios and GCM combinations used but also the uncertainties associated with downscaling. The table below shows the level of agreement among the IPCC AR4 ensembles by region and by season for precipitation which is much harder to predict than temperature.

Region	**Jun-Aug**	**Dec-Jan**
Sahara	Small decrease (5-20%)	Inconsistent
West Africa	Inconsistent	Inconsistent
East Africa	Small increase (5-20%)	Inconsistent
Southern Africa	Inconsistent	Large decrease (>20%)

Table 1: GCM consistencies in regional precipitation projections for 2090-2099 (SRES A1B). IPCC, 2007

To assess the uncertainty in agreement among the GCMs, Thornton et al (2010) estimated the standard deviation of the mean estimate of change in LGP for each pixel from the seventy-fifth percentile of the ensemble distribution (14 climate models and three emission scenarios). These represent the variability of estimates of LGP primarily in relation to the different climate models (there is only limited difference between the three emission scenarios in the first half of the current century). The results are not shown here, but variability among the climate models is relatively small for large areas of central and eastern SSA (20% or less), higher (to 40%) for the crop and agro-pastoral lands of West Africa and parts of southern Africa, and highest (>50%) in arid and semi-arid rangelands in south-west Africa and the central desert margins in the north, where LGP is short and highly variable anyway. These results highlight both the reasonable consensus among the climate models for shifts in conditions in East Africa and the lack of consensus as to changes in agricultural conditions in some of the higher-rainfall areas of West Africa in particular. However, new research by Williams and Funk (2010) presents evidence of a recent historical drying trend in East Africa, a result of warming in the Indian Ocean, which is an effect not captured in most GCMs. This suggests that as regional climate models improve, earlier GCM results may become outdated.

Consequences of climate change for pastoralism

Vegetation response: Increases in maximum and minimum temperatures, combined with increased CO2 which improves water use efficiency could increase net primary productivity (NPP) in rangelands in the presence of more rainfall. However the impact on species composition is mixed and much more dependent on precipitation and evapotranspiration; hence the outcomes for grazing systems in pastoral drylands are mixed. The proportion of browse could also increase in combination with more competition if dry spells are more frequent (as they will be in Southern Africa), and the IPCC AR4 predicts overall negative impacts on pasture productivity in arid and semi-arid regions (IPCC 2007). The overall impact is made more complex by the difficulty of estimating livestock response and the corresponding interactions with vegetation; hence changes in variance may be more important than changes in means as grazing systems are so heterogeneous to begin with (Thorton et al 2009). Doherty et al (2009) used the LPJ dynamic global vegetation model to estimate impacts of a warmer, wetter climate on rangeland vegetation in East Africa, where the GCMs are fairly consistent. These results indicate that C4 grasses are likely to decrease in productivity while tropical broadleaf growth increases. A decrease in grass cover could mean more competition among grazing species for forage. See Figure 12.

Figure 12 HERE.

Changes in species type and availability will have implications for livestock productivity and nutrition, as well as milk production. Without more sophisticated dynamic rangeland vegetation models we are not yet able to estimate these combined impacts.

Herd dynamics: Changes in herd dynamics can also be expected from climate changes, as both animals and pastoralists respond to increased temperatures, changes in precipitation patterns and changes in vegetation type and biomass. Thornton and Herrero (2010) investigated the impacts of increased frequency of drought on livestock herd dynamics. They ran a herd dynamics model (Lesnoff et al., 2006) to investigate the impacts of increased drought frequencies on herd dynamics and livestock numbers, based on baseline information on mortality, reproduction and herd structures from pastoralist herds in Kajiado, Kenya. The model was run for 20 years assuming a herd baseline size of 200 animals, of which 60 where adult females. They ran 2 scenarios: A baseline scenario simulating realistic weather variability of 1 drought every five years (Orindi et al 2007) and an alternative scenario of increased frequency of droughts – one year in three. Their results indicate that drought every five years keeps the herds stable as it allows sufficient time for the herds to re-establish. A once in 3 year drought interval by contrast drives livestock density to lower levels, as a result of increased mortality and poorer reproductive performance. Hence, greater frequency of drought under climate change might have lasting impact on stocking density, and the productivity of pastoral production systems.

They extrapolated these results to all arid and semi-arid districts in Kenya and estimated that 1.8 million animals could be lost by 2030 due to increased drought frequency, with a combined value of $630 million due to losses in animals, milk and meat production (Herrero et al 2010).

Adaptation

The next question is how these possible climate change impacts could bring about social and economic transitions in pastoral systems. Although as we know, pastoralists are accustomed to dealing with change, their options are restricted in many places, as mobility is constrained, and herd sizes are decreasing for many. Pastoral households may also be finding themselves settling for various economic and social reasons. In West Africa the differentiation between pastoral and agropastoral is far more blurred (Ayantunde et al in prep; Turner et al 2011) although herder / cropper conflicts do still occur.

One analysis by Jones and Thornton (2009) examines the areas where climate change could produce flips growing seasons sufficiently sever that cropping would become too risky and livestock production might be the best alternative. They focused on areas where cropping is already quite risky, meaning that probability of crop season failure is high; thus a decrease in LGP would mean cropping becomes too risky, encouraging transitions to livestock based systems. Again in West Africa some former "pastoral" groups have been incorporating cropping activities into their livelihoods. This illustrates that pastoral systems will not only be affected by changes in their own areas but also by adaptation responses to climate changes in other nearby regions.

Final message: How to make choices today given uncertainties of future? We suggest a need for scenarios that engage number of actors, because of the many unknowns and the complexity of pastoral systems. We also need better empirical research that accompanies pastoralists through adaptation over the next decade.

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