Climate Change Impacts on Livestock

Working Paper No. 120

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

This Working Paper summarizes projected climate change impacts on livestock across Africa, using a combination of literature review and some new results on the projected impacts of climate change on the rangelands of Africa. Findings show that there are many options that can help livestock keepers adapt, but there appear to be no options that are widely applicable which do not have constraints to their adoption. An enabling technical and policy environment will thus be needed to ensure livestock keepers can adapt to climate change and enhance their livelihoods and food security.

Keywords

Climate impacts, Africa, Livestock, Livelihoods, Climate Change

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Introduction

Livestock systems directly support the livelihoods of at least 600 million smallholder farmers, mostly in sub-Saharan Africa and South Asia (Thornton, 2010). It is a rapidly-growing agricultural subsector, and its share of agricultural GDP is 33 percent and rising, driven by population growth, urbanization and increasing incomes in developing countries. Demand for all livestock products is expected to nearly double in sub-Saharan Africa and South Asia by 2050 (Alexandratos and Bruinsma, 2012). On the other hand, changes in climate over the last 30 years have already reduced global agricultural production in the range 1-5 % per decade. Unlike for cropping systems, there is currently only limited evidence for recent impacts on livestock systems (Porter et al., 2014). For future impacts, projections indicate widespread negative impacts on forage quality and thus on livestock productivity in both high and low latitudes. In much of Africa, where many millions of smallholder farmers on livestock-based systems, this will have cascading impacts on incomes and food security. The negative effects of increased temperature on feed intake, reproduction and performance across the range of livestock species are reasonably well understood (Porter et al., 2014). There is much less certainty concerning the aggregated impacts of climate change on livestock systems with and without adaptation. Livestock are a critically important risk management resource; for about 170 million poor people in sub-Saharan Africa, livestock may be one of their very few assets (Robinson et al., 2010). The lack of knowledge concerning the impacts of increasing climate variability on downside risk and on the stability of livestock production from year to year, and hence on human well-being, should be of significant political concern.

The next section summarizes projected climate change impacts on livestock across Africa, using a combination of literature review and some new results on the projected impacts of climate change on the rangelands of Africa. Some potential avenues for adaptation are then outlined.

Key messages:

- The livestock sector in Africa is growing rapidly, and demand for all livestock products is expected to nearly double by 2050.
- Projections indicate substantial reductions in forage availability in some regions, and widespread negative impacts on forage quality and thus on livestock productivity. These will have cascading impacts on incomes and food security of the many millions of African farmers who depend on livestock-based systems.
- The 2014 IPCC assessment contains only limited information on the projected impacts of climate change on livestock and livestock systems; more robust and detailed information is urgently needed.
- There are many options that can help livestock keepers adapt, but there appear to be no options that are widely applicable which do not have constraints to their adoption.
- An enabling technical and policy environment will thus be needed so that livestock keepers can adapt to climate change and enhance their livelihoods and food security.

Summary of Impacts

There are several ways in which climate change will affect livestock systems (Table 1). In general, higher average temperatures will tend to accelerate the growth and development of plants. Rising temperatures may lead to improved plant productivity in parts of the tropical highlands where cool temperatures currently constrain plant growth. On the other hand, increases in maximum temperatures can lead to severe yield reductions and reproductive failure; in a crop such as maize, for example, each degree day spent above 30 °C can reduce yield by 1.7% under drought conditions (Lobell et al., 2011). For livestock, most species have perform best at temperatures between 10 and 30 °C, and at temperatures above 30 ºC, cattle, sheep, goats, pig and chickens all reduce their feed intake 3-5% for each 1°C increase (NRC, 1981). Robust conclusions can be drawn concerning the negative effects of increased temperature on feed intake, reproduction and performance across the range of livestock species. Changes in rainfall amounts, distribution, and intensity have direct effects on the timing and duration of crop and pasture growing seasons and on plant growth. Impacts of the increases in rainfall variability that are expected are not well understood. The negative effects of climate change on freshwater systems are expected to outweigh the benefits of overall increases in global precipitation due to warming (Dai, 2011). Many studies show a beneficial effect (CO_2 stimulation) on C3 crops and limited if any direct effect on C4 plants, which include the tropical grasses as well as maize and sorghum, for example. However, the impact of increased CO_2 concentrations on plant growth under typical field conditions is uncertain and in some cases not yet fully understood. There are quality issues too: increased CO_2 can benefit grass growth and development but can also affect nitrogen content of plant components. Crop residues are a key dry-season feed resource for ruminants. Currently there is only limited information on possible climate change impacts on stover production and quality. Changes in temperature, rainfall regime and CO_2 levels will affect grassland productivity and species composition and dynamics, resulting in changes in animal diets and possibly reduced nutrient availability for animals (McKeon et al., 2009; Izaurralde et al., 2011).

Table 1. Direct and indirect impacts of climate change on livestock production systems, adapted from Thornton and Gerber (2010).

Grazing Systems	Non-grazing Systems
Direct impacts	
• extreme weather events	• water availability
• drought and floods	• extreme weather events
• productivity losses (physiological stress) owing to temperature increase	
• water availability	
Indirect impacts	
• fodder quantity and quality	• increased resource price, e.g. feed and energy
• disease epidemics	• disease epidemics
• host–pathogen interactions	• increased cost of animal housing, e.g. cooling systems

The emergence, spread and distribution of livestock diseases may all be affected by climate change via pathways such as higher temperatures affecting the rate of development of pathogens or parasites, shifts in disease distribution that may affect susceptible animal populations, and effects on the distribution and abundance of disease vectors. Increasing climate variability and increasing frequency of drought and flood will have substantial impacts on food availability and environmental security for livestock keepers. The nature of these changes and impacts in the future are still largely unknown, though a recent study estimated that a global increase of 1% in annual rainfall variability (expressed as the coefficient of variation) would increase the number of people living in areas of high rainfall variability in developing countries by 100 million, with associated increases in food insecurity as a direct result, particularly in Africa (Thornton et al., 2014). The limited information in the IPCC's Fifth Assessment Report on the projected impacts of climate change on livestock in Africa is summarized in Table 2 (Niang et al., 2014).

Table 2. Projected impacts for livestock in Africa under future scenarios (Niang et al., 2014).

Sub-region	Climate change impacts	Scenarios
Botswana	Cost of supplying water from boreholes could increase by 23% due to increased hours of pumping, under drier and warmer conditions.	A2, B2 2050
Lowlands of Africa	Reduced stocking of dairy cows, a shift from cattle to sheep and goats, due to high temperature.	A2, B2 2050
Highlands of East Africa	Livestock keeping could benefit from increased temperature	A2, B2 2050
East Africa	Maize stover availability per head of cattle may decrease due to water scarcity	A2, B2 2050
South Africa	Dairy yields decrease by 10–25%	A2, 2046–2065 and 2080–2100

Impacts on rangelands

The results of some new simulations of the impacts of climate change on Africa's rangelands are shown in Figure 1. Future projected changes in Aboveground Net Primary Productivity (ANPP) in Africa's rangelands during the present century are shown for two future emissions pathways: intermediate (RCP4.5, blue) and high-end

(RCP8.5, orange). ANPP and livestock production, productivity and profitability are closely linked (Moore and Ghahramani , 2013). The spatial distribution of percentage change in ANPP production by the 2050s and RCP8.5 (high-end emissions) are shown in relation to the mean value of 1971-1980. These simulations were carried out using the model 'G-Range', a moderate-complexity model that simulates the growth of herbs, shrubs, and trees, and the change in the proportions of these plant types through time, as well as tracking changes in carbon and nitrogen in the soil and plant parts; the death of plant parts and establishment and deaths of whole plants, livestock offtake, and fire, are simulated (Boone et al., 2015). Changes in ANPP for RCP4.5 are relatively modest to the end of the century (~20%), with similarly modest changes in herb, shrub and tree cover (in the range 10-24%, results not shown). In contrast, ANPP under RCP8.5 sees a 50% reduction in ANPP by the end of the century, caused for the most part by an 80% reduction in tree cover. Negative changes in ANPP by the 2050s under RCP8.5 are widespread throughout the continent's rangelands, with some positive percentage changes in pockets of central, eastern and northern Africa (Figure 1).

Changes in ANPP in the rangeland areas of each country under RCP8.5 to the 2050s are shown in Table 3, in terms of the mean (across five GCMs) and the standard deviation of the percentage change. Countries are ordered from largest positive to largest negative change. These results are currently being analysed to further to provide details about relative changes in percent coverage of herbs, shrubs and trees.

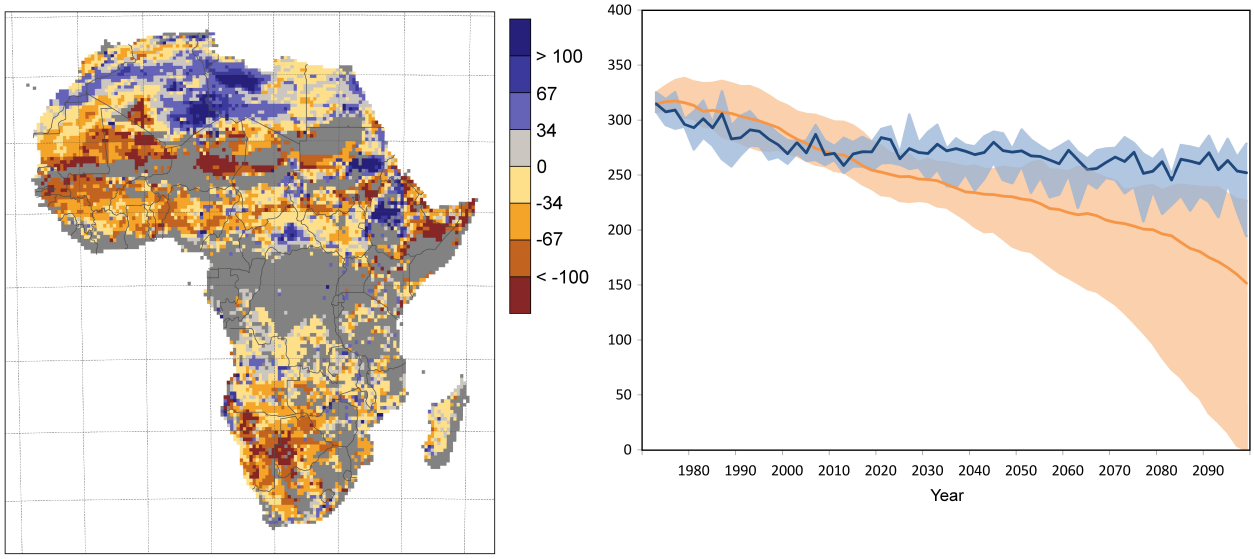

Figure 1. Projected changes Aboveground Net Primary Productivity (ANPP) in Africa's rangelands ANPP is a good proxy for livestock productivity. (A) Future projected ANPP during the 21st century and two future emissions pathways: intermediate (RCP4.5, blue) and high-end (RCP8.5, orange); and (B) spatial distribution of percentage change in ANPP production by 2050s and RCP8.5 (high-end emissions) in relation to the mean value of 1971-1980. These simulations used the weather data from the Agricultural Model Intercomparison and Improvement Project (AgMIP) [see Rosenzweig et al. (2014), available at http://esg.pik-potsdam.de/esgf-web-fe/].

Changes in the balance between herbs and shrubs could provide important insights into changes in suitability of the rangelands for different types of animals (e.g., browsers versus grazers). The results in Figure 1 and Table 3 already indicate clearly, however, that very substantial changes in livestock feed resources will occur during the present century, and in large parts of the continent these changes will be detrimental. Many of these areas in the mixed crop-livestock systems will also see decreases in the quantity and quality of crop residues, putting further pressure on livestock feeding resources, reducing food security, and increasing the risk of hunger and undernutrition for millions of livestock keepers, many of whom will have only limited capacity to adapt.

Adaptation in Livestock Systems

There is a wide range of possible adaption options for livestock keepers, from the genetic selection of robust animals to adaptive management of resources and diversity at farm level and income insurance and market development. Table 4 is from a recent review to evaluate the range of adaptation options for livestock systems (Thornton and Herrero, 2014). No options stand out that have high potential for enhancing food security and addressing resilience, diversification or risk management, that do not also have constraints to their adoption: their feasibility will depend on

Table 3. Mean and standard deviation (STD) of percent change in Aboveground Net Primary Productivity (ANPP) by country under RCP8.5 to the 2050s. Countries ordered by size of change from positive to negative, with changes in the range [-15, +15] % shown in grey. Only rangeland areas are shown.

Country	% Change in ANPP		Country	% Change in ANPP	
	Mean	STD		Mean	STD
Congo	53.0	348.6	Eritrea	-31.5	57.3
Rwanda	49.7	<0.1	South Africa	-33.8	40.1
Libya	31.1	49.1	Uganda	-35.4	41.2
Tunisia	27.3	44.2	Kenya	-36.7	55.3
Algeria	15.9	51.9	Nigeria	-39.2	39.8
Western Sahara	9.4	27.4	Chad	-39.3	43.5
Egypt	5.2	30.4	Cote d'Ivoire	-39.8	27.5
Gabon	3.8	38.2	Swaziland	-43.5	<0.1
Central African Republic	3.2	39.9	Sudan	-45.5	25.7
Morocco	1.9	43.8	Togo	-46.3	31.0
Sudan	-0.4	156.3	Ghana	-47.9	20.4
Malawi	-2.0	22.0	Burkina Faso	-50.0	21.0
DR Congo	-6.5	19.2	Guinea	-51.2	26.3
Ethiopia	-7.2	105.7	Mauritania	-54.1	38.6
Madagascar	-9.2	27.0	Namibia	-62.1	44.3
Liberia	-11.7	13.7	Benin	-64.6	28.6
South Sudan	-13.0	32.2	Djibouti	-64.6	54.0

Mozambique	-13.4	38.0	Somalia	-66.0	50.9
Angola	-14.0	39.0	Mali	-73.1	45.4
Lesotho	-14.8	40.8	Botswana	-74.4	34.1
Sierra Leone	-15.0	26.9	Niger	-82.9	75.4
Tanzania	-15.6	31.5	Senegal	-83.3	38.0
Zambia	-20.9	32.2	Guinea-Bissau	-87.9	8.1
Cameroon	-21.1	31.0	The Gambia	-101.7	4.5
Zimbabwe	-21.2	42.0			

local conditions and their implementation will incur costs. Further, no options stand out that have strong impacts on increasing resilience of households, suggesting that there are limits to what can be achieved in increasing resilience through livestock management. The importance of the policy and enabling environment with respect to adaptation is clear, but identifying the bounds of what endogenous adaptation can achieve in relation to incomes and food security in livestock systems is critical for informing national policy debates. This information does not yet exist.

Many livestock adaptation changes are likely to involve transformation of farmers' livelihoods. Recent examples of such transitions include the adoption of camels and goats in addition to, or as a replacement for, cattle in drylands as a result of changing drought frequency and declining feed availability. Few evaluations of such transformations and their potential impacts on food security

Table 4. Selected adaptation options available to livestock keepers and constraints to their adoption. Based on FAO (2013) and modified from Thornton and Herrero (2014).

Option (with some examples)	Impact on food security	Potential impact on resilience	Potential to promote diversification	Potential for managing risk	Constraints to adoption
Crop residue management (minimum tillage, cover cropping, mulch, storage)	+	+	+	++	Competing demands for crop residue biomass, labor demands
Change livestock breed (use of improved and/or stress-tolerant breeds)	+++	++	++	++	Cost, lack of experience and knowledge
Manure management (composting, improved manure handling / storage / application methods)	+	+	+	+	Labor demands, lack of knowledge
Change livestock species (stress-tolerant species)	+++	++	++	++	Cost, accessibility, lack of knowledge
Improved feeding (diet supplementation, improved grass and fodder species)	++	+	+	++	High cost, labor demands, lack of knowledge
Grazing management (adjust stocking densities to feed availability, rotational grazing)	++	+	+	++	Labor demands, lack of knowledge
Alter integration within the system (add / delete enterprises within the farming system, change ratio of crops to livestock, ratio of crops to pasture, addition of trees / shrubs)	++	++	++	+	Lack of information, lack of fit with household objectives
Use of weather information (to modify livestock management)	+	+	+	++	Reliability, accessibility, timeliness, lack of knowledge
Weather-index insurance (for livestock)	++	++	+	+++	Cost, covariate risk, lack of information, sustainability

and livelihoods exist for livestock systems in Africa. Transition zones, where livestock keeping is projected to replace mixed crop-livestock systems by the 2050s under a high greenhouse-gas emission scenario (A1FI), include the West African Sahel and coastal and mid-altitude areas in eastern and southeastern Africa areas that currently support 35 million people and are chronically food insecure (Jones and Thornton, 2009).

Aggregated summaries of impacts on livestock systems with and without adaptation are still not available. Nevertheless, there are many adaptations possible in livestock systems tailored to local conditions but there is inadequate information to aggregate the possible costs and benefits (both social and private) of these adaptations. As for cropping systems, there is high confidence that they will bring substantial benefit, particularly if implemented in combination, and particularly in relation to the judicious management of the interactions between crops and livestock in mixed systems.

Summary of methods

The impacts of climate change on livestock and livestock systems in Africa are based on a review of recently-published studies and on new CMIP5-based rangeland model simulations targeted to producing country-level information that is relevant to the SBSTA discussions. There is considerably less information on livestock compared with crops, as a quick perusal of Niang et al. (2014) and Porter et al. (2014) makes abundantly clear.

New simulations were carried out using the model G-Range, which is based on the more complex Savanna and Century models (Boone et al., 2015). G-Range was designed as a moderate-complexity model that can be used for global and regional studies of climate change impacts on rangelands. Simulations were conducted continuously for the period 1971-2099, for two representative concentration pathways (RCP4.5 and RCP8.5), and using five Global Climate Models (GCMs). The two RCPs provide contrasting policy scenarios, and hence help in understanding socio-economic uncertainty, whereas the choice of five GCMs provides a realistic representation of the uncertainty associated with climate system response to greenhouse gas (GHG) forcing.

References

Alexandratos N, Bruinsma J, 2012. World agriculture towards 2030/2050: the 2012 revision. FAO, Rome, Italy

Boone RB, Conant RT, Sircely J, 2015. Adjustment and sensitivity analyses of a beta global rangeland model. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Denmark: Copenhagen. Online at http://hdl.handle.net/10568/35129

Dai A, 2011. Drought under global warming: a review. WIREs Climate Change 2011, 45–65.

Food and Agriculture Organization of the United Nations (FAO), 2013. Climate-Smart Agriculture Sourcebook. Rome, Italy.

Izaurralde RC, Thomson AM, Morgan JA, Fay PA, Polley HW, Hatfield JL, 2011. Climate impacts on agriculture: implications for forage and rangeland production. Agronomy Journal 103, 371-381.

Jones PG, Thornton PK, 2009. Croppers to livestock keepers: Livelihood transitions to 2050 in Africa due to climate change. Environmental Science and Policy 12, 427-437.

Lobell DB, Bänziger M, Magorokosho C, Vivek B, 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change 1, 42–45.

McKeon GM, Stone GS, Syktus JI and 14 others, 2009. Climate change impacts on northern Australian rangeland livestock carrying capacity: a review of issues. The Rangeland Journal 31, 1-29.

Moore AD, Ghahramani A, 2013. Climate change and broadacre livestock production across southern Australia. 1. Impacts of climate change on pasture and livestock productivity, and on sustainable levels of profitability. Global Change Biology 19, 1440–1455.

Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P, 2014. Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros VR, Field CB, Dokken DJ and 13 others (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

NRC, 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. Subcommittee on Environmental Stress, National Research Council (NRC). Washington, DC, National Academy Press.

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI, 2014. Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ and 13 others (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533.

Robinson TP, Thornton PK., Franceschini G, Kruska RL, Chiozza F, Notenbaert A, Cecchi G, Herrero M, Epprecht M, Fritz S, You L, Conchedda G, See L, 2011. Global livestock production systems. Rome, Food and Agriculture Organization of the United Nations (FAO) and International Livestock Research Institute (ILRI), 152 pp.

Thornton PK, 2010. Livestock Production: Recent trends, future prospects. Philosophical Transactions of the Royal Society Series B 365, 2853-2867.

Thornton PK, Gerber P, 2010. Climate change and the growth of the livestock sector in developing countries. Mitigation and Adaptation Strategies for Global Change 15, 169-184.

Thornton PK, Ericksen PJ, Herrero M, Challinor AJ, 2014. Climate variability and vulnerability to climate change: a review. Global Change Biology 20 (11), 3313-3328. DOI: 10.1111/gcb.12581

Thornton PK, Herrero M, 2014. Climate change adaptation in mixed crop-livestock systems in developing countries. Global Food Security 3, 99-107.

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