The possible impact of climate change and adaptation options on African livestock: A review

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Abstract: Livestock systems in developing countries are characterized by a rapid change, driven by factors such as population growth, increases in the demand for livestock products as incomes rise, and urbanization. Climate change has direct and indirect impacts on livestock production. Most direct effects of climate change on animal health, wellbeing and production (e.g. growth, reproduction, milk production) are the result of increased ambient temperature and concurrent changes in heat exchanges between the animal and its environment**.** Therefore**,** successful adaptations may be viewed as those actions that decrease vulnerability and increase resilience overall, in response to a range of immediate needs, risks and aspirations.

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Introduction

The farm animal sector is the single largest anthropogenic user of land, contributing to many environmental problems, including global warming and climate change **(Koneswaran and Nierenberg, 2008)**, which is a complex environmental hazard with a range of side effects that are often difficult to predict. Recent climate model projections suggest an increase in global average surface temperature of between 1.8 and 4.08°C to 2100, the range depending largely on the scale of fossil-fuel burning between now and then and on the different models used **(IPCC, 2007)**. Observations show that the African continent is warmer than 20 years ago, with an average rate of warming of about 0.05°C per decade **(IPCC, 2001)**. Consequently, the overall impact of climate change on animal production and health is expected to be higher than the individual impact ofthe increase in the annual average temperature. Unfortunately, there is little empirical research exploring whether climate change over the past three decades has directly affected animal health in Africa and, if so, in what ways. Furthermore, the indirect effects of climate change on economic, social and demographic sectors and their impact on the African livestock sector have hardly been investigated **(Van den Bossche and Coetzer, 2008)**. Climate change has direct and indirect impacts on livestock production. Most direct effects of climate change on animal health, wellbeing and production (e.g. growth, reproduction, milk production) are the result of increased ambient temperature and concurrent changes in heat exchanges between the animal and its environment **(Reilly, 1996)**.

Extreme weather events, either droughts or floods, will also have considerable direct impacts on livestock in Africa **(Van den Bosscheand Coetzer, 2008)**. The poor will be able to play a greater role in some livestock production and market chain systems than others. Smallholders are major players in the dairy sector, for example – indeed, almost all the meat and milk in Africa is produced in agro-pastoral and mixed systems **(de Haan*et al.,* 1997)** while industrial systems are the major actors in the rapidly growing poultry market. Climate also affects the quantity and quality of feedstuffs such as pasture, forage and grain **(Reilly, 1996 and NiggolSeo, 2010).**

Washington *et al.* (2006) outlined an approach to addressing the challenges of climate change in Africa that depends on a close engagement with climate variability. They argue that addressing climate on one time scale may be the best way to approach the informational and institutional gaps that limit progress at another, longer time scale. This stems from two key constraints: the lack of climate data and the relative scarcity of climate scientists from Africa. Adaptation to climate change requires changes to andbehaviormodifications. Research cannot effectively contribute to the improvement of adaptive capacity without a comprehensive understanding of the context in which decisions about adaptation are made and the possibility of decision makers to change. Adaptation may be constrained by the institutional, social, economic and political environment in which people must operate. There is an urgent need to consider developing collaborative learning processes to support the adaptation of agriculture and food systems to better cope with the impacts of climate change **(Thornton *et al.,* 2009)**.

In Kenya, climate change is likely to lead to increased poverty, vulnerability and loss of livelihoods. Several policy interventions are recommended to counter this impact **(Kabubo-Mariara, 2009).** Furthermore, developing countries are generally considered most vulnerable to the effects of climate change than more developed countries, because of their limited capacity to adapt **(Thomas and Twyman, 2005)**.

Adaptation is a process of deliberate change, often in response to multiple pressures and changes that affect people's lives. Identifying the precise drivers of these changes, whether environmentally, climatically, or economically driven, is extremely difficult **(Adger*et al.,* 2005).** Successful adaptations may be viewed as those actions that decrease vulnerability and increase resilience overall, in response to a range of immediate needs, risks and aspirations **(Van Aalst *et al.,* 2008)**. Indeed, vulnerability depends on: (i) the degree to which a system is exposed to a perturbation; (ii) its sensitivity to that perturbation (i.e. the degree of system change associated with a given degree of perturbation); (iii) its adaptive capacity (the ability – often measured in the time it takes for a system to change its structure to support basic system functions in response to perturbation) and (iv) its resilience (the rate at which a system regains structure and function following a perturbation) **(Holling, 1986; Kasperson*et al.,* 1995).**

Livestock breeds

Livestock genetic adaptation responses will vary from intensifying and managed systems to adaptive systems in more marginal environments. Traditionally, the selection of animals in tropical breeds has been an adaptive one, but in recent times, market pull has stimulated a rapidly changing demand for higher production that could not be met quickly enough by breed improvement of indigenous animals. Widespread cross-breeding of animals, mostly with "improver" breeds from temperate regions, crossed with local animals, has occurred – often with poor results. Little systematic study has been conducted on matching genetic resources to different farming and market chain systems from already adapted and higher producing tropical breeds. However, given the even greater climatic variability and stresses anticipated, this is a most logical response to the adaptive challenges that will be faced **(Thornton *et al.,* 2007)**. The greatest role for using adaptive traits of indigenous animal genetic resources will be in more marginal systems in which climatic and other shocks are more common. Indigenous breeds, which have co-evolved in these systems over millennia and have adapted to the prevalent climatic and disease environments will be essential **(Baker and Rege, 1994)**. These systems are under substantial pressure arising from the need for increased production as well as land-use changes. Under these circumstances, ensuring continuing availability of these adapted animal breeds to meet the needs of an uncertain future is crucial. The adaptive challenge will be to improve productivity traits while maintaining adaptive traits. This co-evolution will take place at different speeds within different systems. Within this context, there will be a constant need to improve productivity since increasing demand will need to be supplied from a relatively non-increasing land and water resource base. Current animal breeding systems are not sufficient to meet this need and the improvement of breeding programs under different livestock production and marketing contexts is a critical area for new research **(Thornton *et al.,* 2007)**.

The overwhelming majority of livestock in Africa is locally bred and kept by small-scale livestock keepers and pastoralists. These breeds may be less productive than their high-yielding 'exotic' relatives, but they are supremely adapted to the harsh environments where they dwell and they can produce under conditions where other breeds cannot survive. Indigenous breeds are more disease resistant and drought tolerant; furthermore, they are crucial to the effective management of the environments in which they were developed. Without resilient livestock that can cope with the rigors of transhumance, rangelands systems collapse and environmental degradation often ensues **(WISP 2008)**. Animals are somewhat able to adapt to higher ambient temperatures with prolonged exposure but production losses will occur **(Adams *et al.,* 1998 and Rötter and Van de Geijn, 1999)**. **Taqi (2012)** reported that the milk production and physiological parameters were affected with climate in two climatic regions in Egyptian buffalo. The milk production was decreased in Upper Egypt than middle Egypt. Also, some physiological parameters (rectum temperature, eye temperature) were increased in Upper Egypt than middle Egypt.

African cattle from the *Bos indicus* line are much more tolerant to heat than the European *Bos taurus* breeds. Nevertheless, extremely hot temperatures will also be beyond the climatic envelope for *B. indicus*, resulting in reduced milk and meat production and reduced time for foraging because the animals prefer to remain in the shade **(Robertshaw and Finch, 1976)**. Examples of local adaptation are the N'Dama cattle and the West African dwarf goats, both of which have been bred in the tsetse infested zones (sub-humid and humid zones) of West and Central Africa where trypanosomiasis is prevalent **(Bosso, 2006)**. These breeds have a proven ability to survive, reproduce and remain productive without using drugs. Djallonke sheep and goats in Central Africa have demonstrated similar resistance to tsetse. The raising of these indigenous, trypanotolerant livestock is one approach to control disease and reduce the risk of inducing drug resistance in trypanosome strains. Also, it has been reported that trypanotolerant cattle, especially the N'Dama breed, show superior heat tolerance than zebu cattle. Plus, they metabolize water with greater economy, making them more adapted to the hot and water-stressed regions of Africa, conferring obvious advantages in the face of climate change **(WISP, 2010)**.

Feed quality and Fodder banking

The combination of generally increasing temperatures and shifting rainfall amounts and patterns will clearly have impacts on crop and livestock agriculture. Feed is and will remain a critical constraint on livestock production in the tropics and crop productivity is a useful proxy for feed availability in most regions. At mid- to high latitudes, crop productivity may increase slightly for local mean temperature increases of up to 1-3 °C, depending on the crop, while at lower latitudes, crop productivity is projected to be decreased for even relatively small local temperature increases (1-2 °C) **(IPCC, 2007)**. In the tropics and subtropics in general, crop yields may fall by 10 to 20% till 2050 because of warming and drying, but there are places where yield losses may be much more severe **(Jones and Thornton, 2003; Thornton *et al.,* 2007)**.

The modeling study of **Hanson *et al.* (1993)** indicates that mean forage digestibility decreased under all considered scenarios. The models simulated an increase in standing biomass but a considerable reduction in the nitrogen concentration of plants during the summer grazing months, large enough to bring about considerable decreases in animal performance. Other studies have shown that increased temperatures increase lignification of plant tissues and therefore reduce the digestibility and the rates of degradation of plant species **(Minson, 1990)**. Also, the **IPCC 2007** has shown that an increase in the legume content of swards may partially compensate for the decline in protein content of the non-fixing plant species under conditions of elevated CO_2 concentrations. At the same time, the decline of C4 grasses (which are less nutritious than C3 plants) may compensate for the reduced protein content under elevated CO_2. However, the opposite effect is expected under associated temperature increases. This leads to reduced nutrient availability for animals and ultimately to a reduction in livestock production, which may have impacts on food security and incomes through reductions in the production of milk and meat for smallholders. Meanwhile, the interactions between primary productivity and quality of grasslands will demand modifications in grazing systems management to attain production objectives.

Institutional changes, including pricing policy adjustments such as the removal or putting in place of subsidies, the development of income stabilization options, agricultural policy including agricultural support and insurance programs; improvements in (particularly local) agricultural markets, and the promotion of inter-regional trade in agriculture **(Kurukulasuriya and Rosenthal, 2003)**.

Pastures/ Rangeland quality (invasive plants & CO_2 enrichment)

Climate change effects will be observed in rangelands. In the semi-arid rangelands of the Sahel, for example, where the ratio of actual to potential evapotranspiration limits plant growth **(Le Houérou*et al.,* 1988)** and length of growing period (LGP) may decrease significantly, rangeland productivity that is likely to decrease. Such changes could have enormous impacts on the livelihoods of pastoralists dependent on these rangelands through the numbers of animals that they can keep, livestock productivity, potential loss of animals during the dry season, and longer transhumance routes in search of feed for animals. Species composition in rangelands and some managed grasslands is an important determinant of livestock productivity. As temperature and CO_2 levels change due to climate change, the optimal growth ranges for different species also change, species alter their competition dynamics, and the composition of mixed grasslands changes. For example, in the temperate regions and subtropics, where grasslands often contain C3 (rice, wheat …..etc.) and C4 (corn, sorghum…etc.) species, some species are more prominent than others in the summer, while the balance of the mix reverts in winter. Small changes in temperature alter this balance significantly and often result in changes in livestock productivity; an implication of this is that significant changes in management of the grazing system may be required to attain the production levels desired. It has also been suggested recently that the proportion of browse in rangelands will increase in the future as a result of increased growth and competition of browse species due to increased CO_2 levels **(Morgan *et al.,* 2007).** This will have significant impacts on the types of animal species that could graze these rangelands and may alter the dietary patterns of the dependent communities. Legume species will also benefit from increases in CO_2 and in tropical grasslands, the mix between legumes and grasses could be altered **(Thornton *et al.,* 2007)**. Also, many of the pastoralist societies in the Horn of Africa living on arid land are used to droughts, changes in the frequency and magnitude of these events, as the result of climate change, have on several occasions resulted in very high mortality in the livestock population **(Van den Bossche and Coetzer, 2008)**. A more recent option for adapting the pastoral sector is commercial pastoralism. It is characterized by the increased herd sizes, the trading of animals for supplementary fodder, the employment additional herders and the use of trucks to move herds to adequate pastures ("truck transhumance"; see **Breuer, 2007** and Fig. 1).

Commercial pastoralism allows livestock owners to decrease dependence from price fluctuations and weather variability. For many pastoralists, commercial pastoralism is seen as an attractive alternative but having sufficient capital is a prerequisite **(Freier*et al.*, 2012)**, which indicates again a problem of social inequality. Commercial pastoralism additionally can cause social conflicts over the access to and property rights of pastures **(Breuer, 2007)**. Further, commercial pastoralism promotes degradation of rangelands if destocking during droughts is insufficient and high stocking rates of local and non-local herds coincide. It is therefore important that innovations emerging from the private sector which have the potential to abate impacts from climate change are examined for possible negative side effects. Regulation of these side effects can then be addressed by communal or governmental institutions **(Schilling *et al.*, 2012)**. In other words, traditional pastoral systems and industrialized rangelands systems have different capacities to adapt to climate change. Pastoral systems have often been defined by their adaptive capacity and can only have survived in highly uncertain and climatically extreme environments by being very adaptive. However, recent decades have seen 'development' approaches that have undermined this adaptive capacity, leaving many pastoralists highly vulnerable to climate change. The key to rebuilding this capacity is to restore governance over natural and human resources that will enable pastoralists to make informed choices using the means they have **(Davies and Nori 2008)**.

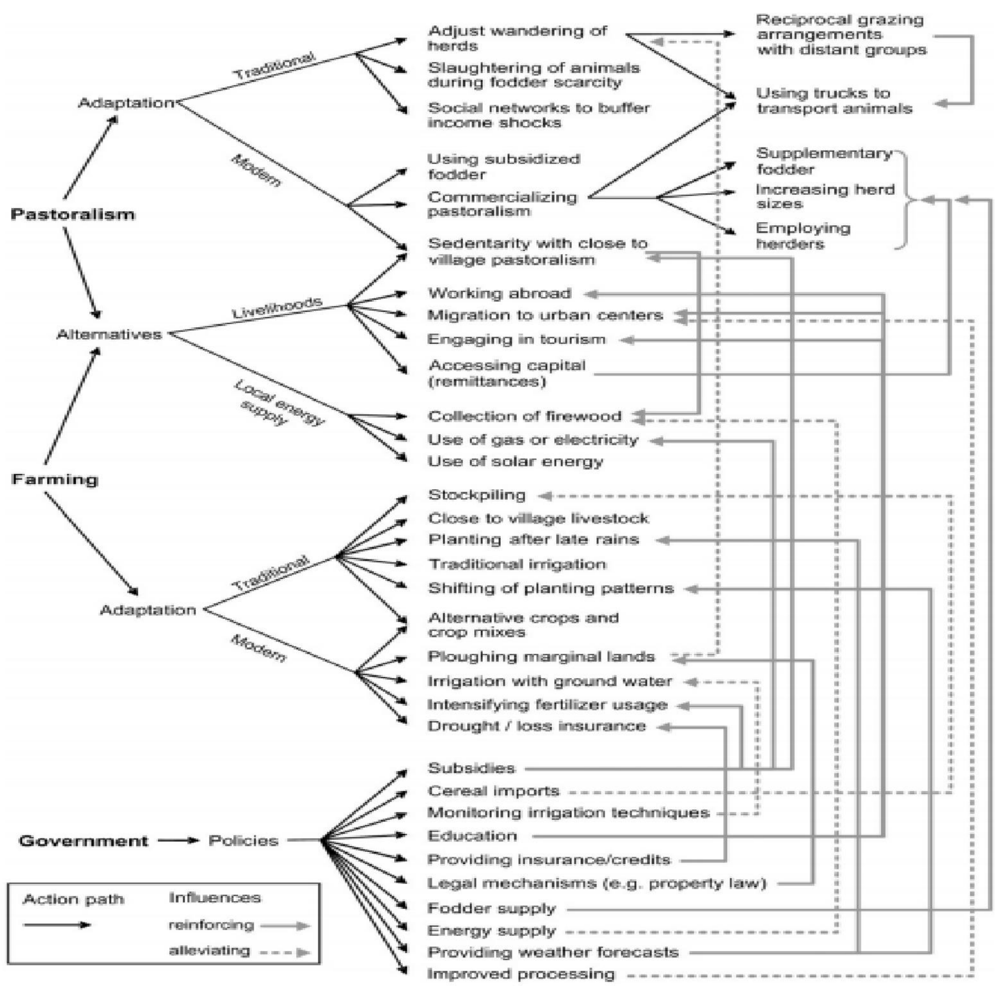

Fig. 1. Adaptation options and action paths of pastoralists, farmers and the government in Morocco (Source: Schilling *et al.*, 2012)

Animal health/ vet service (pest & diseases)

Climate change is bound to have further impacts on heat related mortality and morbidity and on the incidence of climate-sensitive infectious diseases **(Patz *et al.,* 2005)**. Higher temperatures may increase the rate of development of pathogens or parasites that spend some of their life cycles outside their animal hosts, but high temperature and drought will also have a strong disinfecting effect. Changing wind patterns could affect the spread of certain pathogens and vectors, particularly the infective spores of anthrax and blackleg, the wind-borne peste des petits ruminants and dermatophilosis **(Thornton *et al.,* 2008)**. In contrast, diseases such as avian influenza, bovine tuberculosis, brucellosis, foot and mouth disease, Newcastle's disease, which are transmitted through close contact between animals, have been reported to have insignificant associations with climate **(Hager, 2007).**

Temperature and humidity changes will affect the spatial and temporal distribution of the pathogens of non-vector-borne diseases that spend a period of time outside the host and are thus very sensitive to such changes. These pathogens include the viruses causing peste des petits ruminants (PPR) and foot and mouth disease (FMD), contained in wind-borne aerosol droplets the agents causing dermatophilosis, haemorrhagicsepticaemia, coccidiosis and haemonchosis. The prevalence of infections with *Fasciolahepaticamay* increases in areas of Africa where rainfall increases, creating temporary water bodies in which the intermediate snail host of *F.hepatica* survives. The creation of permanent water bodies for irrigation in drier areas may facilitate the survival of the intermediate snail host of *F. gigantic* **(Van den Bossche and Coetzer, 2008).** For example, the impacts of climate change on the range of the tick-borne disease Theileriosis (East Coast fever (ECF)) in sub-Saharan Africa are predicted using a species distribution model and current and future climates simulated. These results, based on the predicted distribution of the main tick vector species (*Rhipicephalus appendiculatus*) and its host, cattle, show that the Northern Cape and Eastern Cape provinces of South Africa, Botswana, Malawi, Zambia and eastern DRC show increases in ECF suitability. Other areas in sub-Saharan Africa show different rates of range alteration. These range alterations are in response to the predicted general change in mean minimum, maximum temperature and rainfall in the months of January and July. The ECF sub-Saharan risk map provided is a necessary tool to complement existing traditional control methods. Understanding and mapping changes in space and time of this disease are a prerequisite to sustainable disease reduction. It will be possible for current and future disease control programs to be timely and directed aimed to specific areas based on risk maps **(Olwoch *et al.,* 2007)**. Changing disease burdens are bound to add considerably to the development problems caused by successive natural disasters and conflicts associated with low levels of adaptive capacity **(Brooks *et al.,* 2005).**

The most important adaptive trait of tropical livestock is disease resistance. Two of the most important resistance traits have been for trypanotolerance in African ruminants and helminth resistance, particularly in certain breeds of sheep across tropical and temperate regions. Particularly for trypanotolerant breeds, climate change may decrease the importance of this trait in sub-humid zones of West Africa. One potential danger is selection against trypanotolerance in the short and medium term because of the lost of these adaptive traits that have developed over millennia. Greater disease risk in the longer-term might be expected **(Thornton *et al.,* 2007).**

The adaptation and possible resistance of Nguni cattle to tick-borne diseases (TBDs) may be due to the ability of indigenous cattle to limit to a sub-pathological level the explosive multiplication of haemoparasites during the acute phase of the disease **(Mattioli *et al.,* 2000)**. Indeed, situations exist where TBDs cause minimal losses and where the infection is usually confined to calves. The factors likely to contribute to this apparent state of 'near equilibrium' between parasite, vector and host (termedendemic stability) have been discussed by **Norval *et al.* (1992)**. These factors include innate resistance of the indigenous cattle to the effects of parasites in the endemic areas through low but almost continual exposure to all instars of ticks; low infection rates of tick-vectors; reduced susceptibility to disease in calves, and possible protection afforded in calves by passively acquired colostral antibodies. They also stressed that a suitable environment (rainfall, humidity, temperature and vegetation cover) capable of sustaining a sufficient population of vectors and hosts at a given threshold is a crucial prerequisite for endemic stability.

Table 1 represents the livestock adaptation strategies in summary according to **Calvosa *et al.,* 2010.**

Conclusion

Climate change has direct and indirect impacts on livestock production. Most direct effects revealed on animal health, wellbeing and production (e.g. growth, reproduction, milk production)**.** These risks are threating the livestock population in Africa**.** Therefore**,** successful adaptations may be shown as the actions that decrease vulnerability and increase resilience overall, in response to a range of immediate needs, risks and aspirations. The adaption strategies should depend on the available sources, such as indigenous breeds insisted of exogenous breeds in breeding programs.

Table 1. Livestock adaptation strategies in summary according to Calvosa *et al.,* 2010.

Production adjustments	- Diversification intensification and / or integration of pasture management, livestock and crop production. - Changing land use and irrigation. - Altering the timing of operations. - Conservation of nature and ecosystems. - Modifying stock routings and distances. - Introducing mixed livestock farming systems such as stall-fed systems and pasture grazing.
Breeding strategies	- Identifying and strengthening local breeds that have adapted to local climatic stress and feed sources. - Improving local genetics through cross-breeding with heat and disease-tolerant breeds.
Market Responses	- For example, promotion of interregional trade and credit schemes.
Institutional and policy changes	- Removing or introducing subsidies, insurance systems. - Income diversification practices. - Livestock early warning systems.
Science and technology development	- Understanding of the impacts of climate change on livestock. - Developing new breeds and genetic types. - Improving animal health. - Enhancing soil and water management.
Capacity building for livestock keepers	- Understanding and awareness of climate change. - Training in agro-ecological technologies and practices.
Livestock management systems	- Provision of shade and water to reduce heat stress from increased temperature. - Reduction of livestock numbers in some cases. - Changes in livestock/herd composition. - Improved management of water resources.

References

1. Adams, R. M.; McCarl, B. A.; Segerson, K.; Rosenzweig, C.; Bryant, K. J.; Dixon, B. L.; Conner, R.; Evenson, R. E. and Ojima, D. (1998). The economic effects of climate change on US agriculture. In The economics of climate change (R. Mendelsohn & J. Neumann, eds). Cambridge University Press, Cambridge.
2. Adger, W. N.; Arnell, N. W. and Tompkins, E. L. (2005).Successful adaptation to climate change across scales. Global Environmental Change, 15: 77–86.
3. Baker, L. R. and Rege, J. E. O. (1994).Genetic resistance to diseases and other stresses in the improvement of ruminant livestock in the tropics.Proceedings of the 5th World Congress of Genetic and Applied Livestock Production.University of Guelph, 7-12 August, 405-412.
4. Bosso, N. A. (2006). Genetic improvement of livestock in tsetse infected areas in West Africa, Doctoral thesis, Wageningen University, The Netherlands.
5. Breuer, I. (2007). Livelihood security and mobility in the high atlas mountains. In: Breuer, I., Gertel, J. (Eds.), Pastoral Morocco –Globalizing Scapes of Mobility and Insecurity. Reichert, Wiesbaden, pp. 165–179.
6. Brooks, N.; Adger, W. N. and Kelly, P. M. (2005).The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change, 15: 151-163.
7. Calvosa, C.; Chuluunbaatar, D. and Fara, K. (2010). Livestock and Climate Change. Livestock Thematic Papers. www.ifad.org/lrkm/index.htm.
8. Davies, J. and Nori, M. (2008). Managing and mitigating climate change through pastoralism. Climate Change, Energy Change and Conservation. Policy Matters 16, October 2008.
9. DeHaan, C.; Steinfeld, H. and Blackburn, H. (1997). Livestock and the Environment: Finding a Balance. WRENmedia, Fressingfield, UK.
10. Freier, K.P.; Brüggemann, R.; Scheffran, J. (2012). Climate change and pre-dictability of future behaviour of transhumant pastoralists in semi-arid Morocco. Technological Forecasting and Social Change, 79: 371–382.
11. Hager, A. L. (2007).Discussion on possible impact of climate change on livestock production in Namibia.
12. Hanson, J. G.; Baker, B. B. and Bourdon, R. M. (1993).Comparison of the effects of different climate change scenarios on rangeland livestock production.Agricultural Systems. 41: 487–502.
13. Holling, C. S. (1986). The resilience of terrestrial ecosystems, local surprise and global change. In: Clark, W.C. and Munn, R.E. (eds.), Sustainable Development of the Biosphere. Cambridge University Press, Cambridge, pp. 292–317.
14. IPCC, Intergovernmental Panel on Climate Change (2001). Climate change 2001: impacts, adaptation and vulnerability (J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken & K.S. White, eds). Cambridge University Press, Cambridge.
15. IPCC, Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for policy makers. Online at http://www.ipcc.cg/SPM13apr07.pdf
16. Jones, P. G. and Thornton, P. K. (2003). The potential impacts of climate change in tropical agriculture: the case of maize in Africa and Latin America in 2055. Global Environmental Change 13: 51-59.
17. Kabubo-Mariara, J. (2009). Global warming and livestock husbandry in Kenya: Impacts and adaptations. Ecological Economics 68: 1915–1924.
18. Kasperson, J.; Kasperson, R. and Turner, B. (1995). Regions at Risk United Nations University Press [Online]. Available on World Wide Web at: http://www.unu.edu/unupress/unupbooks/uu14re/uu14re00.html (accessed 29/12/04).
19. Koneswaran, G. and Nierenberg, D. (2008). Global farm animal production and global warming: impacting and mitigating climate change. Environmental Health Perspectives, 116 (5): 578-582.

20. Kurukulasuriya, P. and Rosenthal, S. (2003). Climate change and agriculture: a review of impacts and adaptations. Climate Change Series Paper No. 91, World Bank,
21. Le Houérou, H. N.; Bingham, R. L. and Skerbek, W. (1988). Relationship between the variability of primary production and the variability of annual precipitation in world arid lands. Journal of Arid Environments 15: 1-18.
22. Mattioli, R.C.; Pandey, V. S.; Murray, M. and Fitzpatrick, J. L. (2000). Review: immune-genetic influences on tick resistance in African cattle with particular reference to trypano-tolerant N'Dama (*Bos taurus*), trypano-susceptible Gobra zebu (*Bos indicus*) cattle. ActaTropica, 75: 263–277.
23. Minson, D. J. (1990) .Forage in Ruminant Nutrition. Academic Press, San Diego, 483 p.
24. Morgan, J. A.; Milchunas, D. G.; LeCain, D. R.; West, M. and Mosier, A. R. (2007). Carbon dioxide enrichment alters plant community structure and accelerates shrub growth in the short grass steppe. PNAS 104, 14724-14729.
25. Niggol Seo, S. (2010). Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture. Food Policy, 35: 32–40
26. Norval, R. A. I; Perry, B. D. and Young, A. S. (1992).The Epidemiology of Theileriosis in Africa. Academic Press, London.
27. Olwoch, J. M.; Reyers, B.; Engelbrecht, F. A. and Erasmus, B. F. N. (2007).Climate change and the tick-borne disease, Theileriosis (East Coast fever) in sub-Saharan Africa. Journal of Arid Environments, 72: 108–120.
28. Patz, J. A.; Campbell-Lendrum, D.; Holloway, T. and Foley, J. A. (2005).Impact of regional climate change on human health. Nature, 438: 310-317.
29. Reilly, J. (1996). – Agriculture in a changing climate: impacts and adaptation. In Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses. Contribution of Working Group II to the 2nd assessment report of the Intergovernmental Panel on Climate Change (R.T. Watson, M.C. Zinyowera & R.H. Moss, eds). Cambridge University Press, Cambridge, 429-467.
30. Robertshaw, D. and Finch, V. (1976).The effects of climate on productivity of beef cattle. In cattle production in developing countries (A.J. Smith, ed.). University of Edinburgh, Edinburgh, 132-137.
31. Rötter, R. and Van de Geijn, S.C. (1999).Climate change effects on plant growth, crop yield and livestock. Climatic Change, 43, 651-681.
32. Schilling, J.; Freier, K. P.; Hertige, E. and Scheffran, J. (2012).Climate change, vulnerability and adaptation in North Africa with focus on Morocco. Agriculture, Ecosystems and Environment,156: 12–26.
33. Taqi (2012). Milk productivity and physiological parameters of Egyptian buffalo under climatic conditions of Giza and Qena governorates. M. Sc. Thesis, Fac. Agric., Cairo Univ., Egypt, 155 p.
34. Thomas, D. S. G. and Twyman, C. (2005). Equity and justice in climate change adaptation amongst natural-resource dependent societies. Global Environmental Change 15: 115-124.
35. Thornton, P. K.; van de Steeg, J.; Notenbaert, A. and Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems, 101: 113–127.
36. Thornton, P. K.; van de Steeg, J.; Notenbaert, A. and Herrero, M. (2008).The Livestock-climate-poverty nexus.A discussion paper on ILRI research in relation to climate change. Discussion paper No. 11.
37. Thornton, P.; Herrero, M.; Freeman, A.; Mwai, O.; Rege, E.; Jones, P. and McDermott, J. (2007).Vulnerability, climate change and livestock – research opportunities and Challenges for poverty alleviation. Open Access Journal, 4(1)1-23.
38. Van Aalst, M. K.; Cannon, T. and Burton, I. (2008). Community level adaptation to climate change: the potential role of participatory community risk assessment. Global Environmental Change, 18: 165–179.
39. Van den Bossche, P. and Coetzer, J.A.W. (2008).Climate change and animal health in Africa. Rev. sci. tech. Off. int. Epiz., 27(2), 551-562.
40. Washington, D. C.; Washington, R.; Harrison, M.; Conway, D.; Black, E.; Challinor, A.; Grimes, D.; Jones, R.; Morse, A.; Kay, G. and Todd, M. (2006). African climate change: taking the shorter route. Bulletin of the American Meteorological Society, 87: 1355–1366
41. WISP, World Initiative for Sustainable Pastoralism (2008) Policy Note 8. Forgotten Services, Diminished Goods: understanding the agroecosystem of pastoralism. http://cmsdata.iucn.org/downloads/forgotten_services__diminshed_goods_understanding_the_agroecosystem_of_pastoralism.pdf
42. WISP, World Initiative for Sustainable Pastoralism (2010): a program of IUCN - The International Union for Conservation of Nature, Eastern and Southern Africa Regional Office, Nairobi, March 2010, viii + 48pp.

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