



Science

THE EFFECT OF CLIMATE CHANGE ON RANGE LAND AND BIODIVERSITY: A REVIEW

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Abstract

Rangelands are estimated to store up to 30 percent of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses. Therefore this review was conducted to show the effect of climate change on range land and biodiversity. Climate change can have significant negative impacts on the natural environment including the loss of biodiversity and changes in ecosystems. The achievement of sustainable rangeland ecosystems remains a challenge for the world; rangeland degradation has not been arrested and the ecosystem services provided by the rangelands are not valued by the people in general or Governments in particular. The stresses imposed on rangeland by livestock production continue to rise, driven by rapid economic development and growing demand by urban people for more meat in diets. Many species around the world are now affected by the combined impacts of natural climate variability and anthropogenic climate change and their interactions with other human stressors such as the encroachment, fragmentation and destruction of natural habitats. Because of climate changes, species may no longer be adapted to the set of environmental conditions in a given region and could therefore fall outside its climatic niche. Climatic changes such as increased atmospheric concentration of CO₂, changes in temperature, and changes in precipitation patterns have the potential to affect rangeland ecosystems. The direct effects of climate and climate change on rangeland ecosystem processes are fairly well described, have relatively short response times, and are somewhat easier to predict than the indirect effects. The evidence for human-induced climate change at the global level increases every day, yet it remains difficult to credibly predict how climate change will play out for any particular area.

Keywords: Biodiversity; Climate; Pasture; Rangeland.

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1. Introduction

Rangelands are estimated to store up to 30 percent of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses (White, *et al.*, 2000; Grace, *et al.*, 2006). In view of the vast extent of grasslands and rangelands and the degraded nature of large areas of these systems, the potential to sequester carbon through improved management is significant. Such management practices include restoring organic matter to soils, reducing erosion, and decreasing losses resulting from burning and overgrazing.

The capacity to sequester carbon depends on the climatic zone, the past history and status of the land resources such as soil and vegetation, and the opportunities available to change management practices (management techniques, competition with other land uses, economic tradeoffs, land tenure, social organization, incentives and political will). Rangelands are lands on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs or shrubs and is managed as a natural ecosystem. They include grasslands, savannas, shrublands, deserts, tundras, marshes and meadows. Therefore the objective of this review was to review the effect of climate change on range land and biodiversity.

Climate change is altering the global hydrologic cycle and is expected to have substantial and diverse effects on precipitation patterns in different regions. Predictions include increased intensity of precipitation events worldwide, increased wet days at high latitudes, and increased drought across many mid-latitude continental interiors. However, there is still considerable uncertainty regarding rates of changes in temperature and the direction of precipitation responses in many regions (Christensen *et al.* 2007). This uncertainty greatly complicates our ability to develop specific management practices to cope and adapt. The aims of this paper are to: Review the effect of climate change on range land issues.

African ecosystems comprise a variety of flora and fauna, which constitute about 20 percent of all known species in the world (Biggs *et al.*, 2004). Several of these species are under threat from a changing climate. Climate change is likely to affect most of Africa's natural resources with a range of potential impacts on both terrestrial and aquatic ecosystems (Leemans and Eickhout, 2004; Boko *et al.*, 2007). Climate change impacts such as rising temperatures and declining rainfall in combination with other stresses could result in the shifting of ecological zones, loss of flora and fauna and an overall reduction in ecological productivity in Africa (Boko *et al.*, 2007). The impacts of climate change can also create increasing friction between protected area managers and local communities bordering protected areas as wild animals and community increasingly compete for the scarce resources (Lovejoy *et al.*, 2005).

Predictions play an important role in alerting scientists and decision makers to potential future risks, provide a means to bolster attribution of biological changes to climate change and can support the development of proactive strategies to reduce climate change impacts on biodiversity (Pereira *et al.* 2010; Parmesan *et al.* 2011). Although there is relatively limited evidence of current extinctions caused by climate change, studies suggest that climate change could surpass habitat destruction as the greatest global threat to biodiversity over the next few decades (Leadley *et al.* 2010). However, the multiplicity of approaches and the resulting variability in projections make it difficult to get a clear picture of the future of biodiversity under different

scenarios of global climatic change (Pereira et al. 2010). Hence, there is an urgent need to review our current understanding of the effects of climate change on biodiversity and our capacity to project future impacts using models.

Climate change caused a global average surface temperature increase of about 0.6°C during the twentieth century (IPCC, 2001), and current temperatures are predicted to increase further – between 1.4 and 5.8°C by 2100 – depending largely on the level of fossil-fuel combustion. Most of the observed increase in temperature will likely be due to the increase in anthropogenic greenhouse gas concentrations (IPCC, 2007). Besides a temperature increase of some 1 to 2.5°C by 2030, it is predicted that during this period, billions of people – particularly those in developing countries – will face changes in rainfall patterns and extreme events, such as severe water shortages, droughts or flooding. These events will increase the risk of land degradation and biodiversity loss. Climate change also will affect the length of growing seasons, and crop and livestock yields, and bring about increased risk of food shortages, insecurity, and pest and disease incidence, putting populations at greater health and livelihood risks. The effects of climate change on productivity and carbon sequestration potential will depend significantly on location, management system and species.

Global warming is expected to increase plant productivity in areas that will benefit from longer growing seasons and CO₂ fertilization (Cantagallo, *et al.*, 1997; Travasso, *et al.*, 1999). Temperature increases up to 3.0–3.5°C may increase productivity of crops, fodders and pastures (both C31 and C42 plant species). Increases in CO₂ levels also will have a positive impact on the productivity of C3 species. In semi-arid rangelands where shorter growing seasons are likely, rangeland productivity may decrease (Thornton, *et al.*, 2008).

Where reliable growing days drop below the day's necessary for maize production in East and Southern Africa, livestock may become a more appropriate food and income source, especially for those farmers close to urban populations with higher demand for meat and dairy products (Thornton and Jones, 2009). Grazing with domestic livestock (mainly sheep and cattle) is the major land use of Australian rangelands. The number of animals that can be sustained without irreversible damage to the soil and vegetation resource is strongly controlled by climate, particularly rainfall and its seasonal distribution (Wilson and Harrington 1984).

To achieve sustainable use, state agencies have developed quantitative approaches to estimate grazing capacity using combinations of grazer experience, land-type attributes, historical climate data and simulation of forage production (e.g. Condon 1968; Johnston *et al.* 1996a). IPCC (2007, p. 8) states that warming of the global system is occurring and that further warming and other climate changes (increase in drought) are likely to occur as human-induced greenhouse emissions increase. Thus, the assessment of current climatic trends/fluctuations and future climate change projections is an important challenge for grazers, public policy and rangeland science in addressing issues of current and future rangeland use by livestock.

Climate change can have significant negative impacts on the natural environment including the loss of biodiversity and changes in ecosystems. According to the Intergovernmental Panel on Climate Change (2007a), any increase in global average temperature above the range of 1.5-2.5°C is likely to result in significant alterations in the structure, function and geographical

ranges of ecosystems, thus negatively influencing species distribution and survival. In developing countries with a greater dependence on natural resource based livelihoods, this can impact the socio-economic status of communities, hamper progress towards development goals and present an overall threat to sustainable development (IPCC, 2007a). Several species around the world are now affected by the combined impacts of climate factors and their interactions with other anthropogenic stressors such as encroachment, land fragmentation and destruction of natural habitats. Together, climate and non-climatic stressors may have considerable impacts on the ecosystems functions and on ecosystem services (Lovejoy *at al.*, 2005).

2. Situation of Climate Change

The achievement of sustainable rangeland ecosystems remains a challenge for the world; rangeland degradation has not been arrested and the ecosystem services provided by the rangelands are not valued by the people in general or Governments in particular. The stresses imposed on rangeland by livestock production continue to rise, driven by rapid economic development and growing demand by urban people for more meat in diets. The tension between production and the health of the environment is shared by people throughout the world in this 21st century. It is time in the world to focus review, research and development on sustainable rangeland industries and to develop policy and strategies for connecting grazing/cropping/forage systems that relieve disturbance of rangelands and permit the repair of stressed and dysfunctional rangelands.

The term climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 1996, 2007b). It is largely attributed to changes in atmospheric concentrations of greenhouse gases and aerosols, in solar radiation and in land surface properties. Since pre-industrial times a marked increase has been noted in the atmospheric concentrations of greenhouse gases such as carbon dioxide, methane and nitrous oxide primarily due to human activities such as fossil fuel burning, land-use change and agricultural activities. This has resulted in the alteration of the energy balance of the climate system and manifesting as increases in temperature, changes in rainfall patterns, and more frequent and severe extreme events among other effects (IPCC, 2007b).

According to observations reported by the IPCC (2007b), the lower atmosphere is warming up faster than anticipated and an increase in global surface temperature of about 0.76°C has been noted between the 1850-1899 and the 2001-2005. A warming of 0.2°C is projected for the next two decades at a rate of about 0.1°C per decade. Trends in precipitation over the 1900-2005 period showed an increase in the eastern parts of North and South America, northern Europe and northern and central Asia and a decrease in the Sahel, the Mediterranean, southern Africa and southern Asia. Future precipitation projections suggest a high likelihood of increases in the higher latitudes and decreases in subtropical regions.

An increase in the frequency and intensity of extreme events has also been noted since the last century. Overall it is projected that the increasing concentration of greenhouse gases would result in several changes in the global climate system over the course of the 21st century that are expected to be larger than those observed over the 20th century (IPCC, 2007b). This has

significant implications for the survival of natural systems, many of which are already being affected by the temperature increases (IPCC, 2007a).

3. Climate Change in Africa

Africa is one of the most vulnerable regions in the world to climate change mainly due to poverty, lack of awareness, lack of access to knowledge and a high dependence on natural resources and rain-fed agriculture. About 70% of people in Africa depend on agriculture for their livelihood, while 40% of all exports are of agriculture produce (WRI, 1996; Mugabe *et al.*, 2000; McCarthy *et al.*, 2001; IPCC 2001; WWF, 2002). The historical climate record for Africa shows increased warming rates since the 1960s with a warming of approximately 0.7°C over most of the continent noted during the twentieth century. A decrease in rainfall over large portions of the Sahel (the semiarid region south of the Sahara) and an increase in rainfall in east and central Africa has also been observed (WWF, 2002). This is already impacting critical sectors such as water resources, food production, human health and biodiversity and resulting in increased desertification trends across the continent (IPCC, 2007a; McCarthy *et al.*, 2001).

4. Climate Change Impacts on Biodiversity

Many species around the world are now affected by the combined impacts of natural climate variability and anthropogenic climate change and their interactions with other human stressors such as the encroachment, fragmentation and destruction of natural habitats (Hananh 2005). Often various wild animal species respond to climatic stressors by migrating and shifting their ranges to areas with more favorable conditions.

This has already been noted in the case of birds, marine life forms, butterflies and insects in response to the changes in climate that have already taken place, particularly the increase in temperature (Hananh *et al.*, 2005). Besides, many range-restricted species, chiefly polar and mountaintop species, show severe range contractions and have been the first groups among which entire species extinctions have been noted due to the recent changes in climate (Parmesan, 2006). It has also been observed that, tropical coral reefs and amphibians have been the most negatively affected. The differential responses of species to warming have also been reported to have disrupted predator-prey and plant-insect relationships (Parmesan, 2006).

According to the IPCC (2007a), any increase in global average temperature above the range of 1.5-2.5°C is likely to result in significant alterations in the structure, function and geographical ranges of ecosystems thus negatively influencing species distribution and survival. In most cases ecosystem responses to climate change and increased atmospheric CO₂ concentrations are expected to be non-linear in nature and the surpassing some of critical threshold values are likely to induce sudden transitions in state. Terrestrial ecosystems are also likely to initially experience increased growth from CO₂ fertilization effects but these benefits are projected to be soon overshadowed by the negative impacts of increased temperature by the end of the 21st century.

Overall a very high possibility of irreversible losses of biodiversity as a result of such changes in climate are projected with many terrestrial, freshwater and marine species being placed at a much greater risk of extinction than before (Fischlin *et al.*, 2007). The impacts of climate change

are likely to be highly spatially variable, but developing countries, many in Africa, generally are considered more vulnerable than developed countries due to their lower capacity to adapt. Poor people are particularly vulnerable and population growth is an added challenge that exacerbates pressures on natural resources and poverty. Africa's population has been projected to more than double – from 0.9 to 2 billion – from 2005 to 2050.

Climate change and variability will have serious implications, impacting on ecosystems goods and services upon which poor people and livestock keepers depend, thus exacerbating current development challenges. Soil carbon sequestration may serve as a bridge in addressing the global issues of climate change, desertification and loss of biodiversity, and is thus a natural link among the three related UN conventions (Lal, 2004). Co-benefits of carbon sequestration also may provide a direct link to the Millennium Development Goals (MDGs) through their effects on food security and poverty. To tackle development challenges effectively in the context of climate change, it will be necessary to demonstrate the linkages among land-use change (deforestation and conversion among forest, grasslands and croplands), land resources management (soil, water, vegetation and biodiversity management) and the vulnerability or resilience of local livelihoods.

5. Range Land Degradation and Soil Erosion

Pressures on resources from expanding human and livestock populations and inappropriate land resources management practices are exacerbating land degradation which, in turn, affects capacities to cope with drought. Reduction or loss of surface vegetative cover is a critical factor as it results in accelerated runoff and erosion which increases the severity and extent of degradation and further reduces resilience to drought. Estimates of more than 70 percent water loss to evaporation have been noted on bare ground (Donovan, 2007) an unaffordable loss at a time of increasing drought risk. Resource degradation and impacts on ecosystem services and vulnerability can only be addressed through a major change in the behavior of the populations concerned both sedentary and nomadic peoples.

The recent Global Assessment of Land Degradation and Improvement (GLADA) study (Bai, *et al.*, 2008) estimated that some 22 percent of drylands were degraded, with some 8 percent of degradation found in the dry subhumid regions, 9 percent in the semi-arid regions, and 5 percent in arid and hyper-arid regions.³ The various land degradation processes are being driven mainly by poor land management. Despite the always gloomy predictions of land degradation, GLADA found that drylands do not figure strongly in ongoing land degradation. The recovery of the Sahel from the droughts of the 1980s is a notable example (Bai, *et al.*, 2008).

6. Biodiversity Responses to Climate Change

Because of climate changes, species may no longer be adapted to the set of environmental conditions in a given region and could therefore fall outside its climatic niche. As other components of the ecological niche of species are not supposed to change directly, we will hereafter refer only to climatic niches of species (i.e. the climatic components of the n-dimensional hyper volume sensu Hutchinson). To persist, individuals, populations or species

must produce adaptive responses, which can be of several types, and are provided by two categories of mechanisms.

In the glossary of technical terms published by the Society of American Foresters range condition is defined as “The state of health or productivity of both soil and forage of a given range, in terms of what it could or should be under normal climate and best practicable management”. This article describes a system for determining range condition which considers climate, soil, and vegetation both present and potential. It includes a review of researches that provide a scientific foundation for the system, and shows how earlier qualitative applications have been replaced by quantitative ones. An actual example is used to demonstrate practical application of the system to range management.

7. Impacts on Rangelands

Climatic changes such as increased atmospheric concentration of CO₂, changes in temperature, and changes in precipitation patterns have the potential to affect rangeland ecosystems. Detailed reviews and studies regarding these processes can be found in IPCC (1996) and Breymeyer et al. (1996). The direct effects of climate and climate change on rangeland ecosystem processes are fairly well described, have relatively short response times, and are somewhat easier to predict than the indirect effects. The evidence for human-induced climate change at the global level increases every day, yet it remains difficult to credibly predict how climate change will play out for any particular area.

However, by examining how rangelands in various regions have responded to climatic events of the past, it is possible to develop a reasonably accurate picture of how different scenarios may play out in the future. In general, it is safe to assume that climatic variability will increase in the future. That is, the frequency and severity of extreme events (droughts, floods, etc.) are likely to increase. It is during those types of extreme events that rangeland degradation is more likely to occur. Thus, it is prudent to assume that increased climatic variability will increase the risk that most rangelands will be affected by conditions that lead to degradation. Decades of research have shown that rangelands can sustainably produce a variety of goods and services even in the face of extreme climatic events, if managers respond quickly and appropriately to changes.

8. Socio-Economic Impacts

Climate induced changes on rangelands and livestock production would have effects on economies and societies at farm, national, and international levels. These impacts are likely to be seen as changes in income and prices, and hence changes in livelihood, employment, and investment. Analyzing such impacts would require an economic model, more specifically a (recursive) applied (or computable) general equilibrium model. Such models have been applied to climate change impacts on agriculture, though not on livestock.

9. Livestock Response to Climate Change

Livestock can also be affected by climate. Specifically, livestock can be affected in 2 ways by climate change: the quality and amount of forage from grasslands may be affected and there may

be direct effects on livestock due to higher temperatures. There are few studies which address climate change effects on livestock, but those which do show effects on performance. For example, warmer summer temperatures are estimated to have a suppressing effect on livestock appetite, which leads to lower weight gain (Adams et al. 1998).

The number one challenge in managing arid and semi-arid rangelands is to avoid degradation. This requires that planning, decision making and implementation focus on rapid management responses to relatively subtle changes in the environment. Monitoring systems are currently inadequate to identify these ‘thresholds’ as triggers for rapid, decisive actions. Ranch/allotment level monitoring systems that focus on soil/vegetation relationships are incapable of detecting change in time for responses. Monitoring systems must be more interactive with management and focus on detecting the need for action in response to climatic versus disturbance combinations before they are expressed as changes in the soil and vegetation.

10. Conclusion

Many species around the world are now affected by the combined impacts of natural climate variability and anthropogenic climate change and their interactions with other human stressors such as the encroachment, fragmentation and destruction of natural habitats. The achievement of sustainable rangeland ecosystems remains a challenge for the world; rangeland degradation has not been arrested and the ecosystem services provided by the rangelands are not valued by the people in general or Governments in particular.

Climatic changes such as increased atmospheric concentration of CO₂, changes in temperature, and changes in precipitation patterns have the potential to affect rangeland ecosystems. The stresses imposed on rangeland by livestock production continue to rise, driven by rapid economic development and growing demand by urban people for more meat in diets. The tension between production and the health of the environment is shared by people throughout the world in this 21st century.

It is time in the world to focus review, research and development on sustainable rangeland industries and to develop policy and strategies for connecting grazing/cropping/forage systems that relieve disturbance of rangelands and permit the repair of stressed and dysfunctional rangelands. Many species around the world are now affected by the combined impacts of natural climate variability and anthropogenic climate change and their interactions with other human stressors such as the encroachment, fragmentation and destruction of natural habitats.

Therefore, the following recommendations are forwarded for future action:

- The development, validation and implementation of a spatially explicit national soil/vegetation database that describes how climatic change interacts with soils, vegetation and management should be the highest priority for professional rangeland managers and the government organization Management.
- Training about the effect of climate change must be given for the concerned body.
- The choice of representative climate stations for livestock enterprises, particularly in the arid and semi-arid regions must be considered.

- The recordation of additional inputs to range land and pasture, especially in climatically favorable zones must be applied.
- Managing rangelands in the face of global change requires a shift in focus toward the restoration and enhancement of ecosystem resilience must be get care.
- Evaluating rangeland ecosystem resilience generally involves defining the capability of an ecosystem or community to withstand stress and/or disturbance and recover to its original condition.

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