Risk of Climate-Related Impacts on Global Rangelands – A Review and Modelling Study

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Abstract

Climate change threatens the ability of global rangelands to provide food, support livelihoods and deliver important ecosystems services. The extent and magnitude of potential impacts are however poorly understood. In this study, we review the risk of climate impacts along the rangeland systems food supply chain. We also present results from biophysical modelling simulations and spatial data analyses to identify where and to what extent rangelands may be at climatic risk. Although a quantification of the net impacts of climate change on rangeland production systems is beyond the reach of our current understanding, there is strong evidence that there will be impacts throughout the supply chain, from feed and animal production to processing, storage, transport, retailing and human consumption. Regarding grazing biomass production, this study finds that mean herbaceous biomass is projected to decrease across global rangelands between 2000 and 2050 under RCP 8.5 (-4.7%), while inter- (year-to-year) and intra- (month-to-month) annual variabilities are projected to increase (+21.3% and +8.2%, respectively). These averaged global estimates mask large spatial heterogeneities, with 74% of global rangeland area projected to experience a decline in mean biomass, 64% an increase in inter-annual variability and 54% an increase in intra-annual variability. The potentially most damaging vegetation trends for livestock production (i.e., simultaneous decreases in mean biomass and increases in inter-annual variability) are projected to occur in rangeland communities that are currently the most vulnerable (here, with the lowest livestock productivities and economic development levels and with the highest projected increases in human population densities). Large uncertainties remain as to climate futures and the exposure and responses of the interlinked human and natural systems to climatic changes over time. Consequently, adaptation choices will need to build on robust methods of designing, implementing and evaluating detailed development pathways, and account for a wide range of possible futures.

1. Introduction

The various contributions of rangelands to the economy, human livelihoods and other ecosystems services highlight the importance of better understanding the potential impacts of climate change on rangeland production systems. In this article, we first review the potential impacts of climate change along the rangeland systems food supply chain (section 2). We then present results from biophysical modelling simulations and spatial data analyses to identify where and to what extent rangelands may be at climatic risk (sections 3 and 4). Further details about the findings are presented in Godde et al. (2020) and Godde et al. (2021). This study is framed around the concept of risk of climate-related impacts, as defined by the Intergovernmental Panel on Climate Change Working Group II (IPCC, 2014). Risk results from the interaction of climate-related hazards with the exposure and vulnerability of human and natural systems. We use the term hazard to refer to climate-related physical events or trends that impact livestock systems (IPCC, 2014). Exposure refers to the parts of the livestock supply chain that could be adversely affected, while vulnerability encompasses humans' capacity to cope and adapt to changes. While we recognize that climate adaptation strategies and the impacts of livestock on climate change are significant considerations, these are not covered here.

2. Potential impacts of climate change throughout the value chain

Major climate trends that can impact the livestock food supply chain are increases in atmospheric carbon dioxide (eCO_2) and tropospheric ozone (O_3) concentrations; changes in both mean and variability of temperature and precipitation; sea level rise and storm surges; and increased risk and frequency of extreme weather events.

These climate change hazards may adversely affect the different stages of the livestock supply chain, from the availability and quality of resources such as animal feed and water, to the welfare and productivity of animals. For instance, droughts, fires, storms, flooding events, surface melt and icing events can disturb crop growth, reduce arable land and restrict animal access to pastures. Although less documented in the literature, climate

change also has implications for human labour and the processing, storage, transport, retailing and consumption of livestock products. For example, higher temperatures, increased humidity, increased frequency of extreme weather events, and rising sea levels are likely to put additional stress on built-up capital such as machineries, transportation infrastructures, electricity networks and telecommunications. Commodity prices are also likely to increase and be more volatile under climate change. Key potential impacts are summarised in Figure 1 and further detailed in Godde et al. (2021).

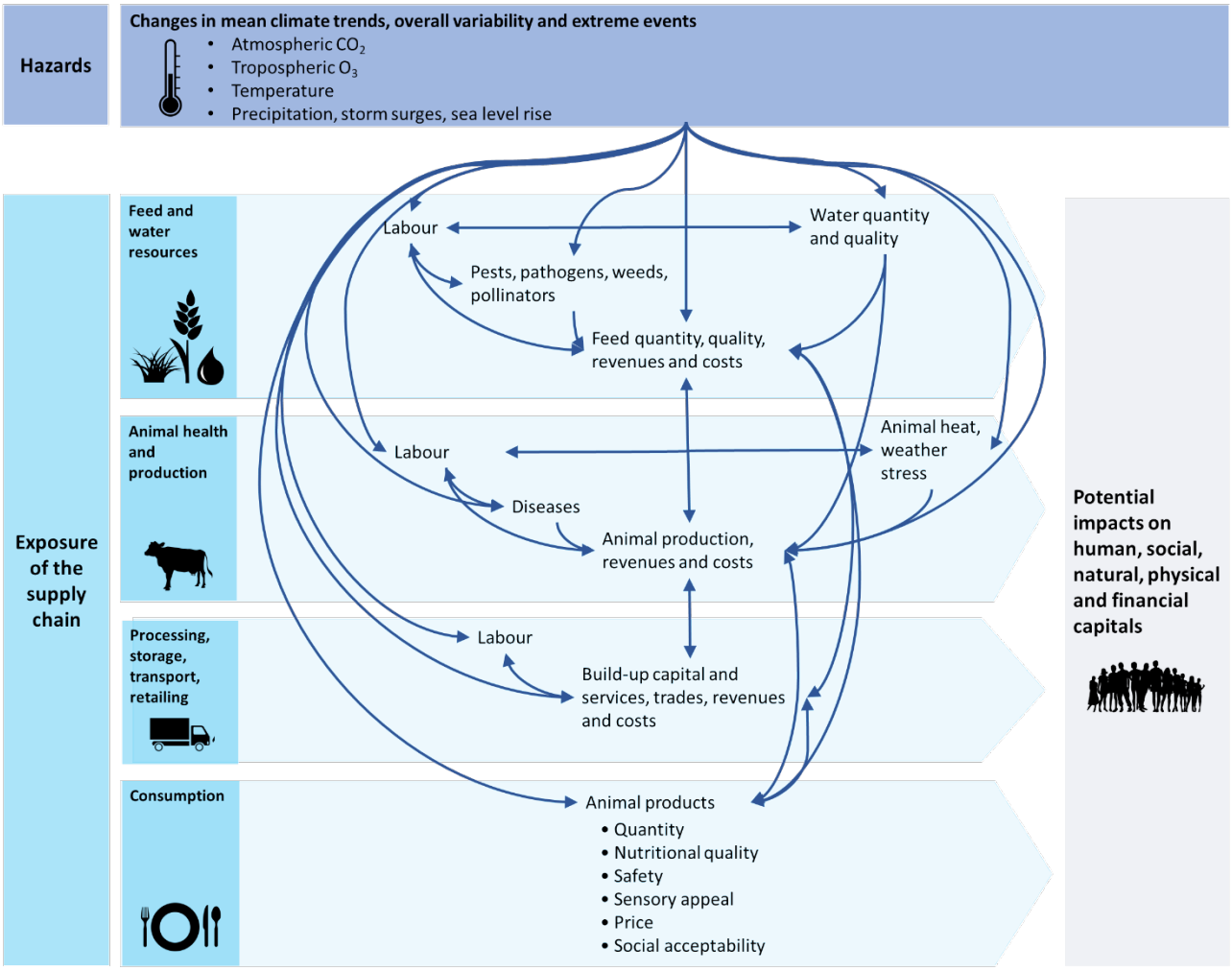


Figure 1: Potential impacts of climate-related hazards on the livestock land-based food supply chain. Reproduced from Godde et al. (2021).

3. Rangelands biomass production under climate change – insights from biophysical modelling

To better understand the extent to which climate change may impact on rangelands grazing biomass production, the global rangeland model G-range (Boone et al., 2018) was run under climate change scenarios. Findings are summarised below and further detailed in Godde et al. (2020). Overall, mean herbaceous biomass is projected to decrease across global rangelands between 2000 and 2050 under Representative Concentration Pathways (RCP) 8.5 (−4.7%), while inter-(year-to-year) and intra-(month-to-month) annual variabilities are projected to increase (+21.3% and +8.2%, respectively – standard deviation divided by mean). These averaged global estimates mask large spatial heterogeneities, with 74% of global rangeland area projected to experience a decline in mean biomass, 64% an increase in inter-annual variability and 54% an increase in intra-annual variability (Figure 2). Half of global rangeland areas are projected to experience simultaneously a decrease in mean biomass and an increase in inter-annual variability—vegetation trends both potentially harmful for livestock production. These regions include notably the Sahel, Australia, Mongolia, China, Uzbekistan and Turkmenistan and support 376 million people and 174 million ruminant Tropical Livestock Units.

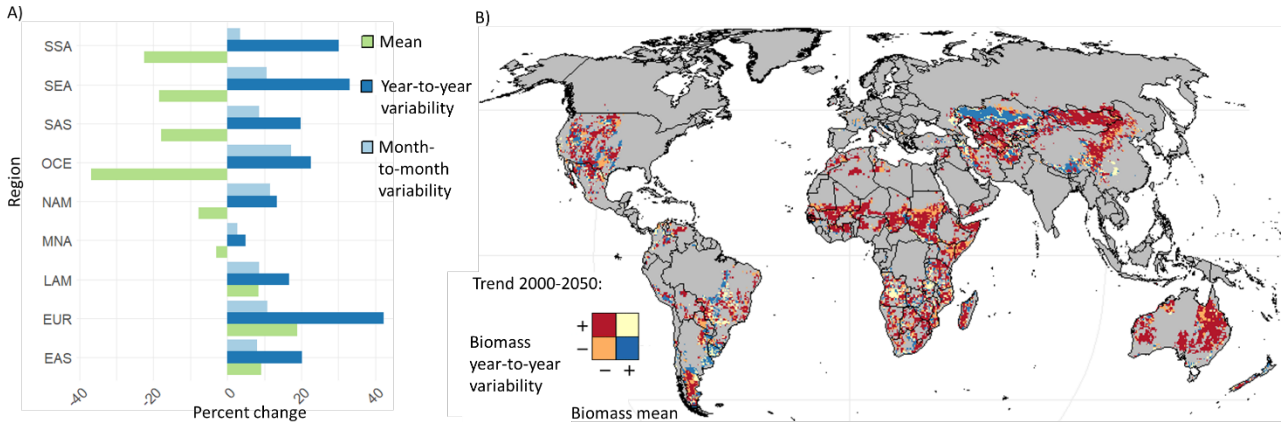
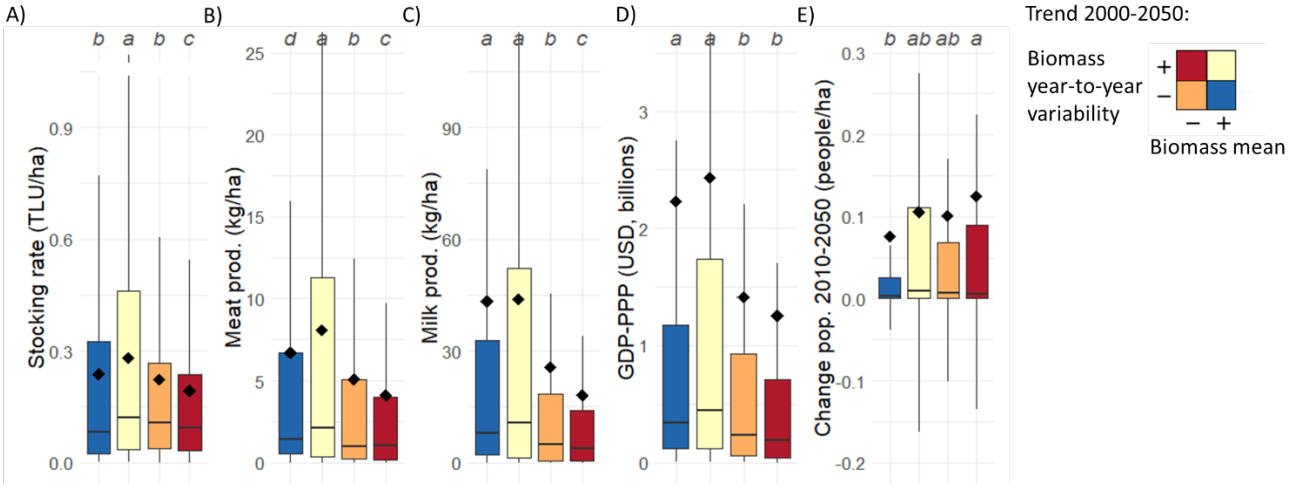


Figure 2: Trends in herbaceous dynamics as projected by G-Range by 2050. Panel A shows regional percent changes (data-points weighted by their amount of land devoted to rangelands). Panel B highlights dynamics at the pixel resolution. The sign (+) indicates an increase in the vegetation variable value by 2050 and (-), a decrease. EAS: Eastern Asia, EUR: Europe and Russia, LAM: Latin America and the Caribbean, MNA: the Middle East-North Africa, NAM: North America, OCE: Oceania, SAS: South Asia, SEA: Southeast Asia, SSA: sub-Saharan Africa. Climate scenario: HadGEM2-ES RCP 8.5 with atmospheric CO_2 effects enabled. Adapted from Godde et al. (2020).

4. Rangelands risk of climate-related impacts – insights from spatial data analyses

The vulnerability of rangeland communities depends not only on the potential impacts of climate change on the various stages of the supply chain, but also on the ability of these communities to cope with changes. We couple the above-described modelled vegetation trends with spatially-explicit livestock, demographic and economic datasets. We find that the vegetation trends potentially most damaging for livestock production are projected to occur in rangeland communities that are currently the most vulnerable according to the variables considered. These communities have, on average, the lowest livestock productivities and economic development levels and the highest projected human population growth by 2050 (Figure 3, red bars). The greatest rates of decrease in herbaceous biomass by 2050 are also projected to occur in regions with currently the highest stocking rates, lowest livestock productivities and GDP-PPP and highest population growth by 2050 (not shown here).



5. Discussion

Climate-related risks in rangeland systems result from the interaction of climate hazards with the exposure and vulnerability of human and natural systems. Risks will be context specific, but also greatly influenced by global socio-economic trends and shocks. Differences in risks arise from both climatic and non-climatic factors as

well as from uneven socio-economic development processes. These context specificities highlight the importance of renewed attention to the diversity of systems and contexts within the livestock sector and its multiple socio-economic and environmental contributions.

While it is certain that climate change will impact rangeland systems throughout the livestock value chain, large uncertainties remain as to the nature, extent and magnitude of these impacts. Uncertainties relate to the future climate as well as exposures and responses of the interlinked human and natural systems to climatic changes over time.

Increases in inter-annual variability of forage availability is especially a concern for the grazing sector. The increase in frequency, intensity and duration of heat waves also poses a major threat to animal health and human labour where access to mechanisation and cooling systems is limited. These climate-related hazards can exacerbate other stressors with negative impacts, especially for people living in poverty. The nature and extent of such impacts are however still largely unknown and require further research.

In the face of global warming, the existing suite of adaptation strategies and coping range that have been developed in response to existing weather patterns may not be enough. Barriers to implementation are also significant and may be stronger in areas with low economic development, which this study finds to also potentially experience the most harmful vegetation trends for livestock production. The deepening of our understanding of the climate hazards, exposure and vulnerability of the ecological and socio-economic components of rangelands, is a necessary step to identify successful adaptation pathways in times of climate change and other future uncertainties.

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