

# **Review of adaptive management practices for rangelands restoration under uncertainty of climate change**

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## **Abstract**

*Rangelands are crucial ecosystems covering 54% of the global area, supporting the livelihoods of millions of people through provision of various good and ecosystem services such as food, livestock and wildlife feeds, carbon sequestration, water regulation, medicinal plants, and biodiversity conservation. In Tanzania alone, rangelands cover over 74% of the land, supporting a significant population of livestock and wildlife, with millions of cattle, goats, and sheep managed extensively in these areas, often competing for forage and water resources. However, rangelands are highly susceptible to climate change impacts, leading to continuous degradation and loss of biological resources. Climate change uncertainty further complicates efforts to restore rangelands effectively. This paper addresses the challenges and provides strategies for restoring Tanzania rangelands in the face of climate change. The paper used secondary data through reviewing the impacts of climate change, including extreme weather events like prolonged droughts, increased temperatures, and altered precipitation patterns on rangeland ecosystems. The review suggests restoration strategies such as effective enclosure management, climate-smart pasture renovation, adaptive management practices, ecosystem-based approaches, community involvement, and policy reforms.*

**Keywords:** Adaptive Management, Climate Smart, Ecosystems services, Land Restoration, Policy Reform.

## **1.0 Introduction**

Rangelands are vital ecosystems that cover about 54% of global area (ILRI, 2021) and support the livelihoods of millions of people in addition to delivering of ecosystem services (Godde et al., 2020). Ecologically, rangelands provide essential services such as food for human consumption, feeds for livestock and wildlife, carbon sequestration, water regulation, medicinal plants and biodiversity conservation (Kidegesho et al., 2007; Selemani 2020). Rangeland ecosystems contribute to the economy, social and resilience of many communities in Sub-Sahara Africa especially in low-income regions (Hoffman et al., 2014). In Tanzania, rangeland covers more than 65% (grazing land 10.5%, protection forestry 10.5%, production forestry 22% and wildlife reserves 22.7%) of the total land of 88.6 million hectares (Mwilawa et al., 2008; Chamuya and Mgoo, 2015) supporting large population of livestock and wildlife. Currently, the country is estimated to have about 36.6 million cattle, 26.6 million goats, and 9.1 million sheep (URT, 2023) of which 98% are managed extensively in the rangelands sharing forage and water resources in competitive manner (Nelson, 2012).

Rangelands are vulnerable to the effect of climate change and variability. The continuous degradation and loss of rangeland biological resources is to the large extent attributed to the effects of climate change. The vulnerability of rangeland to the effect of climate change depends on the adaptive capacity of available communities (Stanford et al., 2011). The uncertainty associated with climate change exacerbates the complexity of restoring rangelands effectively (Godde et al., 2020). This paper explores the challenges and strategies for rangelands restoration in the context of climate change uncertainty. The paper first provides descriptions and overview of the impact of climate change on rangeland deterioration in terms of extreme weather events such as prolonged drought, increased temperature, change of precipitation patterns and their subsequent alteration to rangeland ecosystems. Finally, the review recommends for rangeland

restoration strategies such as effective management of enclosures, pasture renovation using climate smart techniques, adaptive management, and engagement of community.

## **2.0 Methodology**

The review was conducted through searching relevant articles from the reputable databases such as Google scholar, science direct, research gate and Wiley online library. The search focused on articles discussing effects of climate change and variability on rangeland healthy, ecological restoration strategies such as effective enclosure management, climate-smart pasture renovation, adaptive management practices, ecosystem-based approaches and participatory rangeland management through effective community involvement.

## **3.0 Review Findings and Discussion**

### **3.1 Impact of Climate Change on Rangelands Ecosystems**

Climate change can significantly impact both the quality and quantity of forage available for livestock and wildlife. Rising temperature and altered precipitation patterns can affect the nutritional content of forage plants. For example, changes in carbon dioxide levels can lead to increased plant productivity but may reduce the protein content of forage plants, affecting their nutritional quality for grazers (Akshith et al., 2020). On the other hand, climate change can lead to changes in plant composition, causing some species to become more prevalent while others decline. This shift can result in changes in the types and levels of toxins present in forage plants, affecting animal health and productivity. A body of literature indicated that environmental stressors such as drought or extreme temperatures can reduce the digestibility of forage plants, making it harder for animals to extract nutrients from the available forage (Giridhar and Samireddypalle, 2015).

Akshith et al. (2020) highlighted that elevation in CO<sub>2</sub> concentration has most disastrous impacts on forage production as

reported to decrease both quality and quantity of various fodder crops. Decline in vegetation cover due to the effect of climate change and variability particularly in semi-arid regions has been an obstacle toward rangeland restoration efforts. Tulu et al. (2023) reported that, availability of plant cover is only seasonal because of rainfall pattern. Most of grazing lands in Tanzania receive short rain seasons of less than five months and prolonged drought exceeding 7 months (Magita and Sangeda, 2017).

Increasing bush encroachment and suppression of herbaceous vegetation has been reported to be associated with the impact of climate change. Although, heavy grazing has been blamed to be the main causative of invasive plants, especially woody encroachment, the impact of climate change has significant contribution to the bush encroachment. According to Angassa and Oba (2010), transformation of savanna grassland to woodland has been linked to climate change and land use pattern. Giridhar and Samireddypalle (2015) reported that developing countries are more vulnerable to these changes than developed countries because of their dependence on rangeland resources. Climate change can further create favorable conditions for invasive species to thrive, impeding restoration efforts (Burgiel and Muir, 2010). The spread of invasive plant species poses a significant threat to rangelands, outcompeting native vegetation and disrupting ecosystem balance.

In Tanzania context, the impact of climate change has been affecting rangeland ecosystems through extinction of important biological resources. Kideghesho et al. (2013) projected that, by year 2050, more than 37% of plants and animals' species will lead to extinction due to impact of climate change. The authors further reported that, the drought episodes in Tanzania occurred between 1990s and 2000s resulted to mass destruction of habitat and hence reduced forage biomass for both livestock and wildlife. Prolonged drought results to pastoral mobility searching for quality forage and water resources which in turn lead to rangeland degradation.

## **3.2 Strategies for Rangelands Restoration**

### *3.2.1 Exclosure management*

Over the past decade or so, numerous research trials have been conducted on various modern technologies aimed at rejuvenating degraded rangelands. These trials have shown that restoring degraded rangelands through technical means is challenging and expensive (ILRI, 2021). A body of literature indicated that the most effective approach for ecological restoration of degraded rangelands involves reverting to traditional deferred grazing or resting practices known as exclosure management (Aerts et al. 2009; Beyene et al., 2009; Aerts et al., 2009) revealed that restoring degraded land in arid and semi-arid areas frequently entails excluding livestock away from the affected sites. These "exclosures" enable the recovery of native vegetation, reduce soil erosion, enhance rainwater infiltration, and create a source of fodder and woody biomass. Exclosure management derived the concept of the ecosystem-based approaches which considers the interconnectedness of ecological processes and aims to restore rangelands' functionality and resilience. This includes promoting native species diversity, restoring hydrological cycles, and enhancing soil health to withstand climate-related stresses.

In Tanzania, exclosure management has been proven to improve vegetation cover, increase above ground biomass and regeneration of fodder trees (Selemani et al., 2013). Traditional exclosures have been practiced by different pastoral groups such as “ngitili” by Sukuma people, “olopololi” by Masaai and “milangi” by Gogo in central Tanzania (Mwilawa et al., 2008) to provide dry season feeds. Traditionally, the land is normally reserved by excluding grazing during rainy season for vegetation recovery and allowed to gaze at the peak of dry season when forage is scarce. However, adoption of this technology is gradual taking into account that most rangelands are managed under communal management. It is therefore recommended up calling these measures through adopting a participatory rangeland management (PRM) approach, whereas community members may form rangeland association or

user groups. These groups should formulate by-laws or regulation to manage their uses according to a shared rangeland management plan.

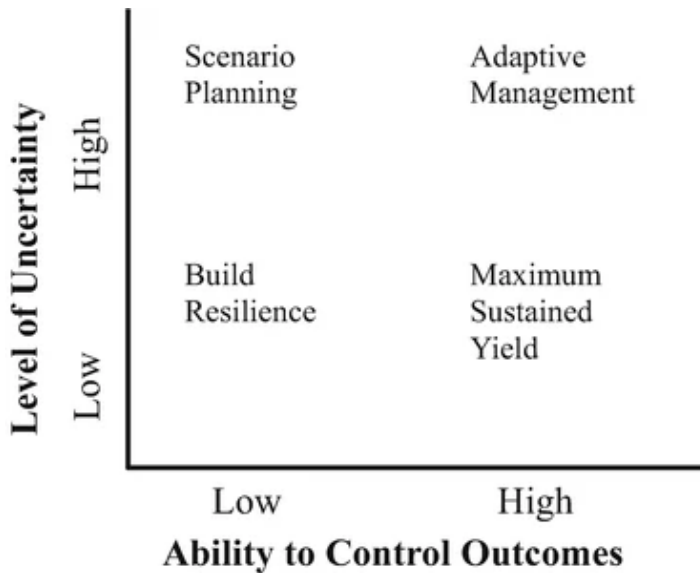
### *3.2.2 Pasture renovation using climate smart practices*

Climate-smart pasture renovation prioritizes soil health as healthy soils are more resilient to climate variability. Practices such as soil testing, nutrient management, cover cropping, and organic matter addition are employed to improve soil fertility, structure, and water-holding capacity (Zougmore et al., 2014). Some technologies such as half-moons, contour farming, pitting and sunken bed techniques, combined with an application of organic fertilizers are recommended as promising climate-smart agricultural practices that could be widely used by smallholder farmers to secure their livelihoods, while contributing to ecosystem services (Zougmore et al., 2014).

In addition, the efficient water use is crucial in climate-smart pasture renovation. Techniques like water harvesting, irrigation optimization, contour farming, and the use of drought-tolerant species help to conserve water and maintain adequate soil moisture levels, especially during dry periods. Therefore, selection of climate-resilient plant species is recommended based on their ability to thrive in changing climate conditions. Drought-tolerant grasses, legumes, and forbs that provide good forage quality are selected to enhance the productivity and sustainability of the pasture. Tulu et al. (2023) strongly suggested that climate-resilient forage species such as Buffel grass, Brachiaria grass, Napier grass, and Rhodes grass be popularized to sustain livestock production and the environment, particularly in arid and semiarid regions. These species are not only resilience to the effect of climate change but also have high yielding potential. Ecological restoration requires establishment of drought tolerance species of high yielding capacity.

### *3.2.3 Adaptive Management*

Adaptive management is an approach to managing natural resources that utilizes organized learning to decrease uncertainties, aiming to enhance management effectiveness over time. Its roots are intertwined with resilience theory and the study of complex systems (Allen et al., 2017). Rangeland management is particularly suitable for adopting adaptive management principles due to its manageable nature and the potential to minimize uncertainties. The methodology of adaptive management involves structured decision-making tools and necessitates continuous monitoring, evaluation, and adjustments to the management strategies (Allen and Garmestani, 2015). Addressing conflicts often requires adaptive governance, which involves the equitable sharing of power and knowledge among relevant stakeholders. Implementing adaptive management strategies is crucial for addressing climate change uncertainty in rangelands restoration. This approach involves flexible decision-making based on changing environmental conditions and feedback. Adaptive management work best when both levels of uncertainty and controllability are high (Figure 1). At this level, there is high level for learning and hence the system can be manipulated because of its flexibility in learning and decision making. For example, when there is high uncertainty due to risk associated to the effect of climate change on rangeland productivity, relevant stakeholders will be flexible to learn alternative ways of adopting to the prevailing situation.



**Figure 1.** Level of uncertainty and ability to control. Adopted from Allen et al. (2017).

Adaptive management involve participatory approaches where communities are full engaged. Involving local communities, indigenous peoples, and stakeholders in restoration planning and implementation fosters stewardship and ensures the sustainability of restoration initiatives (Roba and Oba, 2009). Collaborative efforts can leverage traditional knowledge, enhance social resilience, and promote collective action towards rangelands conservation.

### *3.2.4 Policy reform and governance supportive to rangeland restoration*

Strong policy frameworks and regulations that prioritize rangelands conservation and restoration are essential. Policies should integrate climate change adaptation strategies, incentivize sustainable land management practices, and facilitate funding mechanisms for restoration projects. Whereas the country has well stated policies and acts governing the rangeland

management, their enforcement is lacking. For example, the Grazing Land and Feed Resource Act of 2010 directed the Village Council to limit the stocking rate well below ecological carrying capacity and control encroachment of grazing land by other land uses. This act statement if well implemented could restore degraded rangelands through livestock destocking and prohibit encroachment of rangeland resources. Vetter (2005) highlighted that, intervention toward restoration of rangeland based on equilibrium theory focuses on reducing stocking rate and increasing its stability.

Most of rangeland polices exclude local knowledge which are very crucial on ecological restoration. Roba and Oba (2009) highlighted that, development and implementation of legal framework for integrating local communities and ecological methods has limited progress. The authors pointed out that, in most cases, ecological assessment and monitoring toward restoration of degraded land exclude local existing legal framework and consider scientific methods exclusively. It is therefore recommended that, scientific evidences should be integrated with local knowledge for effective management of rangeland ecosystems.

#### **4.0 Conclusions**

Rangelands restoration under the uncertainty of climate change requires a holistic and adaptive approach that addresses multiple challenges while leveraging local knowledge, scientific expertise, and supportive policy reform. By integrating scientific and local knowledge, community engagement, and adaptive management practices, rangelands can be restored and maintained as resilient and productive landscapes in the face of ongoing environmental changes. This paper recommends the effective collaboration among stakeholders, investment in research and monitoring, and robust policy enforcement for achieving successful rangelands restoration outcomes in a changing climate.

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