*Original Paper*

# To graze or not to graze livestock in public forests.

## Insights from Mau and Aberdares forest ecosystems in Kenya

*Sylvester Chisika, Chunho Yeom*

**Received:** 21 June 2024 | **Accepted:** 25 August 2024 | **Published:** 3 September 2024



**Keywords:** biodiversity; community rights; ecosystem services; environmental impact; sustainable forest management.

**Abstract.** *Forest ecosystems are important for the social, economic, and environmental well-being of many people globally. However, with the growing human needs and the impacts of climate change, there is an emerging forest policy discourse on whether to allow or disallow livestock grazing in public forests. This study used a case study research design and document content analysis to share comparative insights on the effects of forest grazing in two critical forest ecosystems in Kenya. The key documents reviewed included official government publications, policy papers, strategic plans, academic articles, relevant case studies from government websites, academic databases, international organizations, and research institutions specializing in sustainable forest management. The findings indicate that Kenya is endowed with diverse forest capital with immense potential for contributing to sustainable development. However, there is a complex interplay between livestock grazing and forest ecosystems. Insights from Mau and Aberdares indicate that livestock grazing in the two ecosystems under the current grazing system has a positive socio-economic impact. However, due to overgrazing by livestock, there are significant negative environmental impacts such as soil degradation, compaction, and erosion, reducing the forest land's ability to retain water and support plant growth, reduction in biodiversity, exacerbating the spread of invasive species, and increased vulnerability to natural disasters such as floods and landslides besides increased carbon emissions. Moreover, despite deploying several strategies to enhance sustainability, there is no adequate monitoring framework for the indicators of grazing impacts. Based on the precautionary principle, this study recommends banning livestock grazing in the two ecosystems. However, a "win-win" arrangement should be developed to enhance the "cut and carry system" for fodder from the two forests to promote livelihoods and socio-economic empowerment. These findings are critical for promoting the sustainable management of critical water towers with similar contexts in the country and enhancing the achievement of various national development aspirations, such as the aspiration to plant 15 billion trees by 2032 and a host of climate-related commitments.*

## 1. Introduction

Forests constitute 31% of the earth's land surface (4.06 billion ha) and are an economic and environmental lifeline for many people (FAO, 2022). However, with the growing human population, needs, and the impacts of climate change, livestock grazing in public forest ecosystems is increasingly becoming a pervasive practice globally with multifaceted and complex impacts (FAO 2018). Studies show that forest grazing, influenced by the grazing regime and species sensitivity, can significantly modify the structure, composition, and dynamics of forest ecosystems (FAO, 2018; Herrero & Thornton, 2013). It can lead to adverse long-term effects on plant communities, soil health, water quality, and, consequently, the overall provision of ecosystem services. Grazing intensity influences soil structure, function, and soil organic carbon storage capacity within livestock-plant-soil systems (Conant, 2010; Eldridge et al., 2016; Paz-Kagan et al., 2016). As a result, Abdalla et al. (2018) note that grazing degradation is becoming a global concern, with an estimated 20-35% of the world's permanent pastures affected.

On the contrary, some emerging studies increasingly advocate for forest grazing after reporting positive impacts. Wang et al. (2016) established that over the past 70 to 80 years, the Northern Great Plains grasslands had sequestered carbon and nitrogen, effectively recovering the losses incurred during widespread grassland degradation. The study notes that implementing sustainable grazing management practices after deterioration enhanced carbon and nitrogen levels in the degraded grasslands. Consequently, the grassland soils offset approximately 5.84 Mg C ha−1 CO2-equivalent anthropogenic CO2 emissions. However, this paper agrees with studies that note that the impact of grazing on forests from livestock grazing depends on many factors, such as the type of livestock, grazing intensity, plant productivity levels, and the evolutionary history of grazing (Nordberg & Röös, 2016). But, in general, from the literature review, many of the existing studies are largely regional, with mixed and inconclusive results largely based on single case study analysis. There is thus a lack of clear policy guidance on whether to continue or discontinue livestock grazing in public forests in many developing countries, necessitating the need for comprehensive, multi-site research for effective, location-specific strategies that balance livestock grazing in public forests with forest conservation goals.

Kenya has 12.13 % of tree cover and 8.83% forest cover (Kenya Forest Service [KFS] Strategic Plan 2023-2027). However, trees and forest resources in the country are increasingly under the pressure of degradation due to the rapidly

growing population (GOK, 2016). To avert further degradation and loss, the country launched the National Landscape and Ecosystem Restoration Strategy for 2023-2032, which seeks to increase Kenya's tree cover to 30% by planting 15 billion trees on public, private, and community lands. It is hoped that this action will accelerate actions toward enhancing climate-reliant national economic growth and development goals within the context of many national and international development aspirations. In forest grazing, the existing forest law allows community members registered as Community Forest Associations (CFAs) living adjacent to gazette public forest areas to graze their livestock (cattle and sheep) in the public forests. But, over time, with changes in environmental and socio-economic conditions in the country, there are increasing calls for banning livestock grazing in public forests (The Star Newspaper, 2024). It has led to a raging forest policy debate amongst forestry stakeholders on whether to endorse a government policy direction that bans the grazing of livestock in public forests or not. On the one hand, the proponents of the ban argue that forest grazing reverses the gains of government-led forest ecosystem restoration efforts, increasing carbon emissions and jeopardizing the achievement of key forestry development agendas such as the presidential directive on achieving 30% tree cover by the year 2032. On the other hand, the opponents argue that besides the ecological benefits of forest grazing, such as reducing the risk of forest fires, livestock grazing in the forest was important for the socio-economic empowerment of many forest-adjacent communities. The opponents argue that instead of banning grazing, it can be transformed to become compatible with forest management in a manner that achieves the broader government environmental conservation goals and community empowerment role if the current management practices are enhanced. To contribute to the emerging discourse on whether to allow or disallow livestock grazing in gazetted public forests, unlike other studies, this paper used the case study research design to investigate two cases of forest grazing in Kenya to contribute to the current debate and provide policy recommendations on sustainability. This study used literature review and document content analysis to explore the current grazing system and identify the impacts of forest grazing on two key forest ecosystems from the theoretical background of sustainable management of forest ecosystem services. Key empirical literature and specific grazing cases in Mau forest complex and Aberdares were examined to elucidate how grazing influences public forests. Mau and Aberdares forest ecosystems were chosen for this study because they have experienced significant degradation due to illegal grazing. These forests are critical water catchment areas, and their degradation has far-

reaching consequences for water availability and quality in the East African region and beyond. Moreover, few studies have been conducted on the effect of livestock grazing in water towers where Mau and Aberdares belong (Kenya Forestry Research Institute, 2023).

### *1.1. The impacts of livestock grazing in forest ecosystems*

#### 1.1.1. Theoretical background

The theoretical framework for understanding the impact of livestock grazing on forest ecosystems encompasses several ecological principles embodied in the concept of sustainable forest management. Grazing affects ecosystems primarily through herbivory, trampling, nutrient deposition, and the alteration of plant community composition (Sharma et al. 2024). Herbivory directly reduces plant biomass, which can lead to shifts in plant species dominance and a reduction in plant diversity (Sharma et al. 2024). Trampling by livestock and wild herbivores compacts the soil, reducing its porosity and water infiltration capacity, which can lead to increased runoff and soil erosion. Nutrient deposition through animal excreta can enrich the soil locally but may also contribute to the eutrophication of nearby water bodies if not properly managed (Crovo et al., 2021). Grazing intensity and frequency are critical determinants of its ecological impact. Light to moderate grazing can promote plant diversity by preventing any species from becoming overly dominant, a concept known as the intermediate disturbance hypothesis. However, heavy grazing often leads to vegetation degradation, soil erosion, and reduced ecosystem services, including carbon sequestration and water regulation (Crovo et al., 2021; Ren et al., 2024).

There are various sustainable forest management models in the context of forest livestock grazing. These models can balance ecological health, economic viability, and social acceptance. Forests on farmlands agroforestry systems can be adapted to integrate trees, forage, and livestock, promoting biodiversity and reducing soil erosion while providing economic benefits (Timsina, 2024). Silvopastoral systems can combine forestry and grazing, enhancing soil fertility and habitat diversity. Moreover, rotational grazing prevents overgrazing and supports ecosystem resilience. Riparian buffer zones protect water quality and aquatic habitats by restricting grazing. Community-based forest management can also be adapted to engage local communities, aligning grazing with conservation goals (Timsina, 2024). Lastly, conservation grazing, which uses livestock to manage and conserve habitats, requiring careful planning and monitoring, can also be adopted to promote sustainability. These models emphasize an integrated approach to achieve effective forest management with livestock. Together, these

models leverage ecological balance, economic viability, and social acceptance, thereby supporting sustainable forest management (Timsina, 2024). Therefore, expanding on how forest policy on grazing can be improved to address specific challenges such as forest health, socio-economic empowerment, and enhancing environmental management would be valuable. For instance, forest grazing can be streamlined to highlight the practical benefits of sustainable forest management in Mau and Aberdares forest ecosystems.

#### 1.1.2. Empirical literature review

Empirical studies have shown that grazing impacts vary widely depending on the ecosystem and management practices. This section highlights studies on the varying impacts of grazing across the world. These studies are critical in shaping the policy recommendations that will be generated from lessons learned. Existing literature on the impacts of forest grazing shows diverse results for both developed and developing countries, with some supporting forest grazing on account of positive symbiotic relationships. At the same time, some oppose it based on the negative impacts on forest ecosystems. For example, Etchebarne & Brazeiro (2016) examined that in Uruguay, livestock intervention, based on grazing regimes and species sensitivity, altered forest ecosystems' structure, composition, and dynamics, negatively impacting plant communities, soil, and water quality. This study investigated livestock exclusion effects on forest dynamics in Uruguay, focusing on tree regeneration and soil properties. Six paired grazed-ungrazed sites (4-17 years exclusion) were analyzed. Exclusion improved soil conditions by increasing leaf litter cover and reducing erosion, and tree regeneration increased, with a 20% rise in seedlings and 60% in saplings. Species composition was largely unaffected, but *Styrax leprosus* Hook. & Arn was nearly absent in grazed sites. The findings indicated livestock exclusion benefits the soil and shade-tolerant species' regeneration.

In Argentina, Trigo et al. (2020) evaluated the effects of 7-8 years of livestock exclusion on the understory plant community in Argentina's dry Chaco forest. Understory plant life forms were categorized as shrubs, succulents, and herbs. The study compared five excluded plots with five grazed plots. Livestock exclusion increased grass species richness, grass cover, and lower understory biomass while decreasing bare soil. Dominant herbs in excluded plots included *Setaria nicorae* José Francisco Pensiero. Grazed plots had *Stenandrium dulce* Nees as the dominant species. Exclusion did not significantly affect shrubs, succulents, horizontal vegetation structure, or soil hardness. The grass assemblage showed quick recovery when grazing ceased, indicating exclusion's effectiveness in recovering grass cover and promoting certain grass species. Loydi (2019)

established that grazing increased bare ground, reduced plant cover, and decreased grass species richness in the seed bank while increasing shrub richness and density. Vegetation and seed bank compositions were not directly related. Shrubs and non-palatable or annual grasses, 2-year enclosures by forbs, and 12-year enclosures by perennial grasses dominated grazed areas. Herbivore removal altered vegetation and seed bank composition, suggesting controlled grazing might help maintain species and life form diversity.

In Mexico, Encina-Domínguez et al. (2022) observed that pine forest disturbances from cattle, horse, goat, and sheep grazing, especially in communal lands, led to low tree recruitment, invasive shrub establishment, species composition changes, and weed invasions. The study in Sierra de Zapalinamé, a protected mountain range, compared a 25-year grazing-excluded forest (1,200 ha) with a nearby grazed area. Analysis of forest structure, tree species richness, total understory species richness, and understory composition showed grazing altered understory species composition and reduced evenness in control plots. The study concluded that restricting extensive grazing or reducing animal numbers in ecologically valuable areas is necessary to maintain species diversity and forest structure.

Gomez et al. (2024) evaluated livestock effects on riparian forests, soil, and water in Nothofagus Silvopastoral systems across three river basins with varying stocking rates. Over three years, soil and water's physical, chemical, and bacteriological properties were assessed. The basin without livestock had the best water and riparian forest quality. Higher stocking rates caused forest degradation, reduced canopy cover, and increased water contamination from sediment, nitrogen, phosphorus, and bacteria. Water quality declined particularly during hot, dry years. Streams showed self-purification over distances greater than 1,000 m without livestock, eliminating beneficial bacteria. High stocking rates also led to increased water turbidity. To balance Silvopastoral production and ecosystem services, the study recommended excluding livestock from riparian zones, controlling stocking rates, and implementing a monitoring program to prevent ecosystem dysfunction.

In another study, Kimuyu et al. (2014) investigated understory vegetation response to 5-year spring and fall prescribed fires and cattle grazing exclusion in *Pinus ponderosa* Douglas ex Lawson stands, reporting long-term effects nearly two decades post-fire. In fall burn areas open to grazing, understory cover was 12% lower than in areas where cattle were excluded. Fire and grazing appeared to interact numerically rather than functionally, with post-fire green-up concentrating herbivores in burned areas, limiting understory response. Fall fires

and grazing increased annual forbs and resprouting shrubs, while spring burns had minor effects. *C*heatgrass invasion was linked to fall burns but not grazing. The study suggested that frequent fall fires and grazing might reduce understory resilience in dry pine forests, recommending longer fire intervals, post-fire resting, virtual fencing, or burning entire pastures to mitigate these effects.

In Spain, Isabel et al. (2024) used a multiparametric soil quality index (SQI) to gauge livestock impacts on soil in the Mediterranean forest. Control areas without livestock included forest stands of varying ages, compared with areas subjected to various grazing intensities. The SQI effectively detected changes in forest ecosystems based on stocking rates. The SQI was recalibrated to create the Soil Status Index by Livestock (SSIL) for greater precision. The correlation between the indices' quality ranges suggested SSIL is a reliable indicator of livestock impact on Mediterranean forest soils.

Similarly, Candel-Pérez et al. (2024) investigated grazing's impact on soil physicochemical and biological properties and vegetation richness in Spain. Grazing significantly reduced soil water content by 53% and available water by 59%, though hydraulic conductivity remained unaffected, and soil water repellency disappeared. Grazed soils had a slight pH increase (+18%). Dehydrogenase activity increased (+100%), while basal respiration decreased (-24%). Plant species richness dropped by 34%, indicating biodiversity loss. These significant changes suggest grazing modifies overall soil quality, with certain variables serving as indicators for effective land management to mitigate degradation in Mediterranean forests.

In South America, Sandoval-Calderon et al. (2024) conducted a meta-analysis of experiments excluding livestock grazing to assess its impact on plant diversity and productivity in South American mountainous grasslands. The findings showed that herbivore exclusion increased aboveground biomass but decreased species richness and Shannon diversity. These effects intensified over longer exclusion periods and were resilient to various climatic conditions. Unlike temperate grasslands, the reduction in species richness was not linked to increased biomass, indicating different governing processes. Further research was needed to understand the factors influencing plant diversity and productivity in these ecosystems and the ecological implications of herbivore exclusion. The study noted that overgrazing was generally associated with negative ecosystem outcomes. Teague et al. (2020) demonstrated that continuous grazing led to a decline in soil health and increased erosion, while rotational grazing practices could mitigate some of these effects by allowing recovery periods for vegetation.

In the African context, a study conducted in South Africa noted a significant difference between a conventionally grazed site and one overgrazed. The conventional site had a larger $CO_2$ than the overgrazed site over two years. When sheep were reintroduced to the previously overgrazed site, the net emission effect difference decreased, but the overgrazed site remained resilient. These findings suggested that plant species composition and rainfall distribution were crucial factors affecting $CO_2$ sequestration and ecosystem status. A west African forest study that analyzed multi-annual eddy covariance data for a grazed Sahelian semi-arid savanna in Senegal established that high $CO_2$ fluxes were attributed to dense C4 vegetation, high soil nutrient availability, and grazing pressure. Despite high peak net $CO_2$ uptake, the annual budget was comparable to other semi-arid savannas due to the short rainy season. Soil data indicated a substantial increase in soil organic carbon. These findings significantly impacted the perception of the Sahelian carbon sink/source and its response to climate change (Yayneshet & Treydte, 2015).

From the above review, the studies highlight the complex interplay between livestock grazing and forest ecosystems. However, findings collectively underscore the importance of adaptive management strategies that consider ecological, economic, and social factors to sustainably manage forest livestock grazing, given the negative and positive impacts.

### 1.1.3. Forest grazing and sustainable forest management in Kenya

Kenya is endowed with diverse natural capital, rich cultural heritage, and immense potential for sustainable development. The country ranks among the world's richest biodiversity nations and hosts over 35,000 species, including more than 7,000 plant species and many endemic, rare, endangered, and threatened species. These resources provide critical ecological goods and services that support the country's socio-economic development. The country depends on these ecosystem services as natural capital for economic growth. Forest ecosystems, for example, are a livelihood base of over 82% of Kenya's households and offer direct employment to over 4 million Kenyans, besides contributing about USD 365 million (3.6%) to the Gross Domestic Product (GDP).

Moreover, forest ecosystems contribute more than USD 140 million worth of goods annually to other productive sectors of the economy, such as agriculture, fisheries, livestock, energy, wildlife, water, tourism, trade, and industry. In the same vein, the Water Towers Ecosystem of Kenya, which includes Mount Kenya, Aberdares, Mau Forest, Mount Elgon, and Cherangany Hills, among others,

provides necessary recharge for rivers draining into several water basins and providing water for domestic use, agriculture, wildlife, and the manufacturing industry. These ecosystems interlink well with the agroecosystem, the largest contributor to Kenya's GDP at 33% directly and 27% indirectly through agro-based industries and service sector (GOK, 2016). Specifically, the agriculture sector in the agroecosystem employs more than 40% of the total population and about 70% of the rural population (GOK, 2018b). Small-holder farmers largely dominate this proportion, accounting for over 75% of the total agricultural output and over 70% of the marketed agricultural produce.

Several policy and legal reforms have been rolled out in the country to promote the sustainable management of these forests. Key among these reforms was the enactment of the Forest Conservation and Management Act 2016, which initiated a paradigm shift in forest management from the initial "command and control approach" to a "community involvement approach." In this new legal dispensation, forest-adjacent communities participate in forest management through legal frameworks that empower local communities and enhance their roles in forest governance. The Act recognizes Community Forest Associations (CFAs), which allow community members to actively engage in the sustainable management, conservation, and utilization of forest resources. These associations can enter into management agreements with the Kenya Forest Service (KFS), enabling them to participate in decision-making processes, benefit-sharing, and conservation activities. The Act also encourages the development of community-based forest management plans and supports capacity-building initiatives to enhance local knowledge and skills in forest conservation. By involving communities directly, the Act aims to foster a sense of ownership and responsibility among local populations, ensuring that forest management practices are ecologically sustainable and socially equitable. This participatory approach not only helps preserve forest ecosystems but also improves the livelihoods of the communities through access to forest resources and involvement in conservation-related economic activities. The Act allows controlled grazing within forest reserves under specific conditions outlined in management agreements between Community Forest Associations (CFAs) and the Kenya Forest Service (KFS). These agreements stipulate the carrying capacity of grazing areas, the timing and duration of grazing periods, and the communities' responsibilities. By setting these guidelines, the Act aims to prevent overgrazing and land degradation while supporting the livelihoods of pastoral communities that depend on forest resources. Additionally, the Act encourages the integration of sustainable agroforestry practices, which combine grazing with tree planting and forest regeneration efforts.

However, Kenya's natural capital, including public forests, is rapidly depleted due to various factors that have led to degradation and loss of biodiversity. They include a growing human population, poverty, inequality in access to resources and lack of regulatory capacity, changes in production and consumption patterns, human population and settlement, and environmental deterioration. These challenges threaten the livelihoods of millions of Kenyans, especially the rural poor who depend on natural resources for survival. Kenya's forest ecosystems are particularly vulnerable to grazing pressures due to high livestock densities and reliance on pastoralism. Recent studies show an emerging trend of negative impacts of livestock grazing in forest ecosystems. Grazing in Kenyan forests has been linked to forest density and carbon storage reductions. Overgrazing by livestock reduces tree recruitment and decreases tree density, affecting the carbon sequestration capacities of these forests (Cierjacks and Hensen, 2004). This impact is critical given the role of forests in mitigating climate change through carbon storage.

Moreover, studies have documented that grazing leads to soil compaction, reducing water infiltration and increasing runoff. This effect is particularly pronounced in forested areas where the soil structure is crucial for maintaining hydrological cycles (Webber et al., 2010). The loss of soil structure due to grazing has been linked to reduced plant water availability and increased soil erosion, exacerbating land degradation. However, other studies on grazing impacts on biodiversity are mixed, with impacts depending on grazing intensity. The studies show that while moderate grazing can maintain or even increase plant species diversity, heavy grazing typically reduces biodiversity. In Kenyan forests, heavy grazing has been associated with a decline in understory plant species and an increase in invasive species, which can outcompete native flora and alter ecosystem functions (Archer et al., 2017).

To avert further crisis, the Kenya Government recognizes that the sustainable management and conservation of natural capital and biodiversity is essential for maximizing the production of natural resources and sustaining growth. To this end, Kenya drew up the 10-year ambitious and visionary strategy to restore 10.6 million hectares of degraded landscapes and ecosystems. The strategy aims to increase the tree cover of the country from the current 12.13 percent to 30 percent by 2032 while restoring degraded landscapes and ecosystems. The strategy was formulated based on the principles of the Theory of Change, which calls for accelerated approaches to address the key drivers of degradation in each of the seven ecosystems to prevent, halt, and reverse landscape and ecosystem degradation. Some of the activities to achieve this goal include growing 15 billion

trees, promoting sustainable agricultural practices, soil and water conservation, sustainable livelihood options, proper land use planning, and waste disposal. Implementation of this strategy is based on the principle of the "whole of government, whole of society approach," which calls for the participation and contribution of all Kenyans. It leverages technology and innovations such as the Jaza Miti App, which enables the tracking and monitoring of the trees planted across the country.

From this review, the authors opine that a complex interplay between livestock grazing and forest ecosystems in Kenya has significant ecological and socio-economic impacts. Key ecological impacts include overgrazing, diminished carbon storage and soil degradation, decreased tree recruitment, and soil compaction. Hence, there is a need for case studies to formulate robust strategies for managing the impacts.

## 2. Materials and Methods

### *2.1. Research design*

A case study research design was used to investigate the effects of forest grazing on Kenyan forests. A case study approach was ideal in this study because it provides an in-depth, contextualized understanding of complex ecological and socio-economic dynamics. This research design allowed for a detailed examination of specific forest areas where grazing practices vary, facilitating a detailed analysis of their impact on biodiversity, soil health, tree regeneration, and local communities' livelihoods. The study compared different management practices and their outcomes by focusing on multiple sites, thereby identifying best practices and key challenges. The case study approach also supported the inclusion of qualitative data from local stakeholders, offering insights into community perceptions and traditional knowledge, which were crucial for developing sustainable forest management strategies. This method's flexibility in integrating various data sources ensured a holistic understanding of the multifaceted effects of livestock grazing, making it a robust and appropriate research design for this context.

### *2.2. Case studies*

#### 2.2.1. Aberdare Forest Reserve

The Aberdare Forest Reserve is one of the five main water towers in the country alongside Mt Elgon, Cherangani Hills, Mau Complex, and Mt Kenya. It has 19

forest stations. It covers Nyandarua, Nyeri, Muranga, and Kiambu counties and has an acreage of 103,024.930 hectares. It is gazetted under Legal Notice 48/1943 (KFS 2018). It comprises various vegetation types such as Natural forests, plantation, bamboo, bush, teazones, and moorland. It has five forest blocks: South Laikipia, Kipipiri, Nyeri, Kikuyu Escarpment, Aberdare Forest, and Aberdare National Park. The Aberdare ecosystem also designated a Key Biodiversity Area (KBA), is in the central highlands of Kenya and forms part of the eastern escarpment of the Rift Valley. This area features a spectacular landscape where lush forests, expansive grasslands, bamboo thickets, montane moorlands, and misty peaks merge to create a unique sanctuary. It includes 76,600 hectares of National Park and 108,400 hectares of Forest Reserve. As one of Kenya's five primary 'water towers,' this ecosystem serves as a catchment area for dams supplying water to Nairobi, the Athi-Galana-Sabaki River draining into the Indian Ocean, the Ewaso Nyiro River leading to Lorian Swamp, and the Malewa River flowing into Lake Naivasha. The Aberdares KBA is home to diverse wildlife, including the critically endangered Mountain Bongo. More than 300 bird species, such as the rare and globally threatened Aberdare Cisticola, Abbott's Starling, Jackson's Widowbird, and Sharpe's Longclaw, have been recorded here. Endemic species such as the Aberdare shrew, Aberdare mole rat, and the Aberdare frog underscore the area's evolutionary significance. This biodiversity hotspot is a living laboratory for scientists, providing valuable insights into ecological processes, species interactions, and the complex web of life-sustaining this remarkable ecosystem.

Despite its exceptional importance, the KBA faces numerous threats, including illegal logging, unauthorized grazing, wildlife poaching, illegal water extraction, destruction of riparian zones, forest encroachments, and climate change. There is also a looming threat from infrastructure development. In January 2024, the National Environment Management Authority (NEMA) approved the construction of a 49-kilometer road cutting through the forest to connect Nyandarua and Nyeri counties. An Environmental Impact Assessment (EIA) report indicated that 104 hectares of vegetation, including 75 hectares of bamboo, 14 hectares of forest, and 14 hectares of moorland, would be cleared for this project. Therefore, protecting this vital site requires robust collaboration among government agencies, conservation organizations, local communities, and other stakeholders. The conservation community and other stakeholders have undertaken numerous restoration initiatives due to the site's significance and uniqueness. Currently, the Conservation Alliance of Kenya, which includes 73 member organizations such as Nature Kenya, has appealed to the National Environment Tribunal to halt the road construction. The Alliance has

emphasized the road's negative impact on the KBA and proposed an alternative route that would minimize effects on biodiversity while being equally effective for travel. The Aberdare Forest is a key water catchment area for several major rivers in Kenya (Kinyanjui, 2011).

2.2.2. Mau Forest Complex

The Mau Forest Complex is situated in Kenya's Rift Valley region, between latitudes 0°91' N - 1°49' S and longitudes 34°9' - 36°6' E, encompassing approximately 24,000 km². The complex borders 13 counties of Kenya, namely Baringo, Bomet, Elgeyo Marakwet, Kericho, Kiambu, Kisumu, Nakuru, Nandi, Narok, Nyamira, Nyandarua, and Uasin Gishu. The predominant land use in this area around the complex is small-holder agriculture (50.7%), followed by rangeland (23.7%) and forest (17.7%). Several rivers traverse the Mau forest complex. Key urban centers around the complex include Nakuru and Kericho. The altitude of the Mau region varies from 1000 to 3200 meters above sea level, with the highest elevations found in the central part of the study area, particularly in the northern part of Narok County and the western regions of Nakuru. Annual temperatures vary significantly by location: the highly elevated regions have low annual temperatures with minimums of 10.6°C. Meanwhile, the northern areas in Elgeyo Marakwet and Baringo experience high annual temperatures with maximums of 24.6°C. The estimated total population in the Mau region is about 4.8 million people, with Nakuru being the most populous county.

The Mau Forest Complex is vital not only for the livelihoods of the local population but also for people in the broader Rift Valley province and western Kenya (KWS, 2009). Agriculture, the predominant land use, is crucial for food security and a significant source of income, with most agricultural products being exported to other regions within Kenya. Additionally, the study area holds international importance for the tea industry and tourism. The region falls into different climate zones: equatorial tropical rainforest climates with high monthly rainfall and tropical savannah climates with dry seasons. The rainfall pattern in the study area is bimodal, with the long rainy season occurring from March to May and the short rainy season from October to December. Generally, the dry seasons span from January to March and May to September, though this varies by location. Annual rainfall is higher in the western counties (western parts of Kisumu, Kericho, and Bomet). In contrast, the northern and southeastern counties (such as Baringo and Elgeyo Marakwet) tend to be drier.

The Mau Forest Complex, Kenya's largest water tower, is crucial for the provision of critical ecosystem goods and services. However, human activities

such as logging, charcoal burning, and settlement have drastically reduced their area from over 273,300 hectares in the 1990s to just over 160,000 hectares by 2018. This deforestation has diminished the forest's ability to act as a carbon sink, exacerbating climate change. Livestock grazing further reduces tree cover, impacting carbon sequestration and water regulation. Previous studies have demonstrated loss of biodiversity, changes in tree composition and richness, invasion by alien plant species, and loss of catchment services (Kinyanjui, 2011; Mullah et al., 2011; Mullah et al., 2014). Restoration efforts have focused on reforestation and controlled grazing, with mixed results due to ongoing pressures from surrounding communities (Chumo, 2016). Figure 1 shows the location of Mau and Aberdares forest ecosystems in Kenya. As the deep green color shows, both ecosystems are in dense natural forest areas.

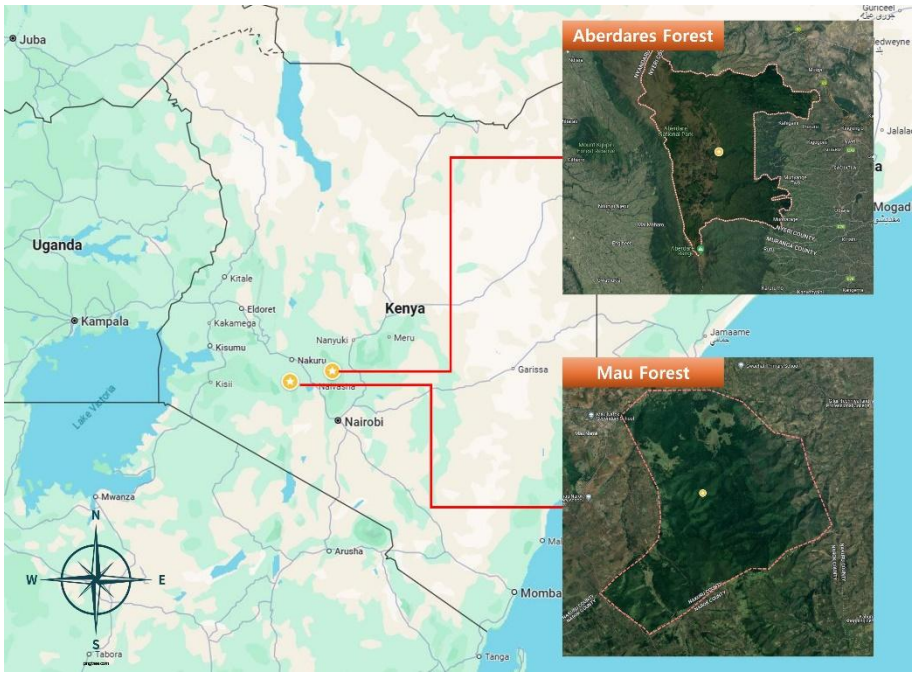


**Figure 1.** Location of Mau and Aberdares forest ecosystems in Kenya.

### *2.3. Data collection*

A meticulous document content analysis process was employed to study the effects of livestock grazing in public forests. Initially, the document selection process began by defining clear criteria to ensure relevance and comprehensiveness. The criteria focused on documents that discussed environmental impacts, grazing management practices, and ecological assessments within public forest lands. A broad search was conducted across multiple databases, including academic journals, government reports, environmental assessments, and grey literature from conservation organizations. The documents analyzed included peer-reviewed articles, policy papers, environmental impact statements, and technical reports. These documents provided diverse perspectives and comprehensive insights into the effects of livestock grazing. After gathering an extensive list of potential documents, a convenience sampling strategy was used to cover different geographic regions, types of public forests, and varying grazing intensities. Both qualitative and quantitative techniques were employed during content analysis to identify recurring themes, keywords, and patterns across the documents. Initially, documents were coded manually to establish a preliminary framework through notetaking. Key concepts such as soil erosion, vegetation change, wildlife habitat alteration, and water quality were systematically examined. In total, 15 documents were analyzed and sourced from academic databases such as JSTOR and ScienceDirect, government repositories, and organizational archives. The sampling strategy ensured that the documents represented various ecological zones and management practices. The analysis yielded a comprehensive understanding of the varied impacts of livestock grazing, highlighting both detrimental effects and potential mitigation strategies. This structured and detailed approach provided robust evidence to inform public forest policy recommendations and management practices. The Key documents reviewed are shown in Table 1 (see Appendix 1).

### *2.4. Data analysis*

The effects of livestock grazing in Kenya's public forests were explored from the perspective of sustainable forest management, as shown in Figure 2.

The sustainable forest management concept emphasizes the balance between ecological, economic, and social functions of forests, aiming to maintain their biodiversity, productivity, and regeneration capacity. In Kenya, where public forests are critical for local livelihoods and biodiversity conservation, a holistic approach is provided to evaluate grazing impacts. If not managed properly,

livestock grazing could lead to soil compaction, erosion, and loss of vegetation cover, undermining the forest's ecological integrity. However, when integrated into a sustainable management plan, grazing is controlled to prevent overuse and promote regeneration. It involves setting grazing limits, rotational grazing systems, and monitoring ecological indicators. Under sustainable forest management, stakeholders can ensure that grazing practices support forest health rather than degrading it.

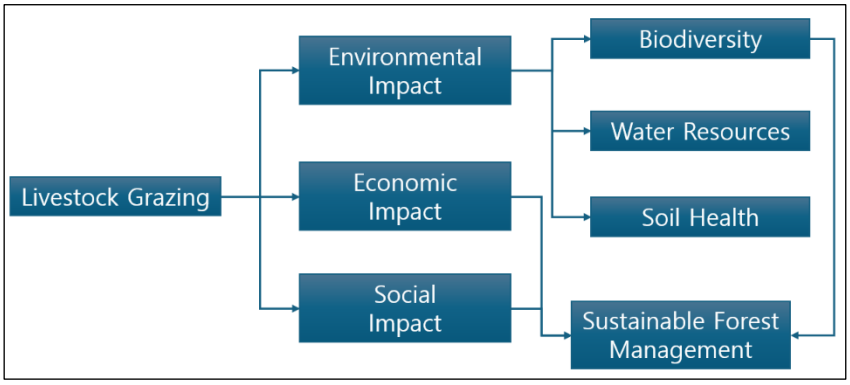


**Figure 2.** Conceptual framework for the effects of livestock grazing in public forests in Kenya.

Additionally, sustainable forest management promotes the inclusion of local communities in decision-making processes, recognizing their dependence on forest resources and traditional knowledge. This participatory approach enhances the effectiveness of management strategies. It fosters a sense of stewardship among local populations, ensuring the long-term sustainability of public forests amidst the pressures of livestock grazing. The effects of forest grazing were presented in three broad thematic areas: social, economic, and environmental impacts.

## 3. Results

### *3.1. The current system of livestock grazing in Mau and Aberdare public forests*

The Forest Conservation and Management Act 2016 ensures the participation of duly registered Community Forest Associations (CFAs) in the conservation and management of public forests, as per Section 48(2). This participation aligns with the Constitution of Kenya's 2010 national values and principles of governance.

Furthermore, Section 49(1)(b) mandates that CFAs involved in forest management or conservation must develop and implement sustainable forest programs that respect the traditional user rights of their communities. Among these rights, outlined in Section 49(2)(d), are grass harvesting and grazing. Under Section 49(3)(b), the Chief Conservator of Forests has established rules for grazing to ensure proper implementation of this user right. These rules include forest zonation and mapping to identify suitable grazing areas and prohibit grazing in young plantations, rehabilitation zones, and ecologically sensitive areas. Each forest station must maintain a grazing register, and the land's carrying capacity determines the number of grazing animals. Grazers must obtain monthly permits, and the CFA management committee and the Forest Station Manager supervise grazing. Grazing is restricted to daylight hours, and violations of the guidelines result in penalties, including the loss of grazing rights and potential prosecution in a court of law. The Service may also withdraw grazing rights to protect biodiversity if necessary.

In Mau and Aberdares forest ecosystems, the above community-based forest management model governs grazing activities. The forest estate is zoned into various use levels in both Mau and Aberdares. Typically, these zones include conservation areas, where strict protection measures are enforced to preserve sensitive habitats and rare species, and sustainable use zones, where controlled human activities such as selective logging, non-timber forest products collection, and ecotourism are permitted. Buffer zones are also designated to mitigate conflicts between conservation and human activities. Delineating these zones involves extensive consultation with local communities, indigenous groups, conservationists, and policymakers to ensure the management plan reflects diverse interests and perspectives.

In the Mau Forest Complex of Kenya, the existing livestock grazing system is deeply intertwined with local livelihoods and resource management practices. Communities residing in and around the complex heavily rely on forest grazing for their economic sustenance, with a significant portion of households depending on it for their livestock, including cattle, sheep, goats, and donkeys. In the Aberdare Forest Complex of Kenya, the existing livestock grazing system plays a vital role in local livelihoods and socio-economic dynamics. Adjacent communities heavily rely on forest grazing as a livelihood diversification, with a significant portion of households depending on it for their cattle and sheep. Livestock keeping is an important economic activity, contributing substantially to household incomes, particularly in poorer households.

### *3.2. Impacts of livestock grazing in Mau and Aberdares forest ecosystems*

The impacts of livestock grazing on the Aberdare Forest Ecosystem and the Mau Forest Complex exhibit similarities and differences across social, economic, and environmental dimensions. For social impact, both ecosystems see communities relying significantly on forest grazing for livelihood diversification, fostering socio-economic stability. However, while grazing activities in the Aberdares promote community cohesion, those in the Mau Complex emphasize shared resource management. Economically, livestock grazing contributes substantially to both ecosystems, with studies estimating its economic value and significant role in household income, particularly in poorer households. Nonetheless, environmental repercussions vary; overgrazing risks forest regeneration and biodiversity in both ecosystems, but its specific effects on soil carbon stocks and riparian plant diversity differ.

### *3.3. Strategies for enhancing sustainability in Mau and Aberdares ecosystems*

Various strategies have been identified for managing the impacts of livestock grazing in forests based on the provided sources (Table 1). These strategies encompass a range of approaches to promote sustainable practices and mitigate negative effects on forest ecosystems. The National Landscape and Ecosystem Restoration Strategy 2023-2032, advocates for promoting sustainable agricultural practices and livelihood options to restore degraded landscapes and ecosystems. Similarly, the Forest Conservation and Management Act 2016 regulates grazing activities within forest areas, emphasizing the need for permits and conducting grazing that does not harm the forest ecosystem. The Forest Policy 2023 encourages adopting controlled grazing practices aligned with forest management plans to safeguard biodiversity and regeneration.

Additionally, the Aberdare Ecosystem Management Plan, 2010-2020, establishes multiple-use zones to balance ecological sustainability with socio-economic needs, permitting grazing only in designated areas. Strengthening livestock extension services, as recommended by the Report of the Prime Minister's Task Force on the Conservation of the Mau Forests Complex, 2009, aims to alleviate pressure on forests and enhance food security. Furthermore, establishing sustainable grazing thresholds (Leley et al. 2022) and education on riparian management practices (Ruto et al. 2023) contribute to forest regeneration and mitigate adverse effects on riparian plant diversity. These multifaceted strategies reflect a comprehensive approach to sustainable forest management in the face of livestock grazing impacts.

## 4. Discussion

Forests are important for sustainable development as they contribute to ecological stability and socio-economic empowerment (FAO, 2022a; GOK, 2018a; GOK, 2018b). However, deforestation has been severe due to agricultural expansion, livestock grazing, firewood collection, charcoal production, and forest fires (FAO 2018). Such depletion of forest vegetation is particularly severe in the key water towers in Kenya (KWTA 2014). This depletion will consequently have a major impact on other natural resource uses and sectors of the economy, such as agriculture, water resources, energy, and biodiversity conservation. Forests and woodlands, predominantly common-pool or open-access resources in the country, face widespread over-exploitation, leading to significant environmental problems, including soil erosion, soil nutrient depletion, moisture stress, deforestation, and overgrazing (Mullah, 2016). As these resources are overused, the negative effects ripple through various sectors, exacerbating environmental degradation and undermining the sustainability of essential economic activities and ecological functions (Abdalla et al., 2018).

Forest grazing is widely practiced in the water towers of Kenya. It is a crucial element of household income for many forest-adjacent communities, whose livelihoods depend on livestock and forests (Kenya Forest Service [KFS] Strategic Plan 2023-2027). A severe shortage of feed sources is the major constraint to livestock production, leading rural communities to increasingly depend on remnant forest stands. This dependency underscores the importance of sustainable forest management practices to balance the needs of local communities with the preservation of these vital ecosystems. This reliance on forest resources for grazing sustains the socio-economic well-being of communities, contributing significantly to their livelihoods (GOK, 2018b). Policies such as the Forest Conservation and Management Act 2016 further promote community involvement in forest management through mechanisms like Community Forest Associations (CFAs), empowering locals to engage in decision-making, benefit-sharing, and conservation activities related to forest resources (GOK, 2018a). Economically, forest ecosystems, including those utilized for livestock grazing, significantly contribute to Kenya's GDP, providing direct employment to over 4 million people and contributing about USD 365 million annually (GOK, 2018a). Livestock grazing in public forests supports the livelihoods of millions, particularly small-holder farmers, with forest income, including revenue from grazing, significantly bolstering household incomes, especially in rural areas where agriculture is predominant (GOK, 2018b). However, these practices also have environmental repercussions, including

degradation and biodiversity loss. Studies indicate reductions in forest density, diminished carbon storage, and soil degradation due to grazing activities (Cierjacks & Hensen, 2004; Webber et al., 2010). Soil compaction and erosion, attributed to grazing, exacerbate land degradation, reduce plant water availability, and pose significant environmental challenges, particularly in forested areas. Balancing socio-economic benefits with environmental conservation is imperative for sustainable forest management in Kenya. Effective management can help ensure that forest resources continue to support the region's ecological health and the economic well-being of its inhabitants. However, it is important to conduct case studies on the location-specific impacts of livestock grazing in key water towers in the country to improve the sustainability of forest grazing management initiatives, hence the successive discussion in this study.

### *4.1. Impacts of livestock grazing in Mau and Aberdares forest ecosystems*

When the conceptual framework (Figure 2) was applied in the case of Mau and Aberdares forest ecosystems, results showed that both Mau and Aberdares have a similar livestock grazing management system, which is community-based. The Forest Conservation and Management Act 2016 involves Community Forest Associations (CFAs) in public forest management, aligning with Kenya's 2010 Constitution. Section 49(1)(b) mandates CFAs to implement sustainable forest programs that respect traditional user rights, including grass harvesting and grazing. The Chief Conservator of Forests has established rules for grazing, such as forest zonation and mapping, prohibiting grazing in young plantations, and maintaining grazing registers. Grazing is allowed only during daylight hours, with penalties for guideline violations. Grazers must obtain monthly permits, and the Forest Station Manager supervises grazing activities. Grazing rights may be withdrawn to protect biodiversity.

The current grazing system has impacted Mau and Aberdares forest ecosystems. Results from Table 2 (see Appendix 2) indicate that livestock grazing impacts the Aberdare Forest Ecosystem and the Mau Forest Complex similarly and differently across social, economic, and environmental dimensions. Socially, both ecosystems rely on forest grazing for livelihood diversification and socio-economic stability, with the Aberdares promoting community cohesion and the Mau Complex emphasizing shared resource management. Economically, grazing is vital, especially for poorer households. Environmentally, overgrazing threatens forest regeneration and biodiversity in both areas, but its specific effects on soil carbon stocks and riparian plant diversity differ. Overgrazing in forest ecosystems, exacerbated by livestock grazing, poses several risks to forest

biodiversity, productivity, and regeneration capacity. Overgrazing leads to soil degradation, compaction, and erosion, reducing the forest land's ability to retain water and support plant growth. This degradation disrupts the natural regeneration processes of forests, resulting in the loss of native vegetation and a decline in forest cover. The reduction in plant diversity adversely affects the habitat of various wildlife species, leading to decreased biodiversity. Overgrazing also exacerbates the spread of invasive species, which can outcompete native plants and further alter the ecosystem balance. The loss of vegetation and soil stability increases the vulnerability of forests to natural disasters such as floods and landslides. Overgrazing can also contribute to increased carbon emissions, as degraded forests lose their capacity to act as carbon sinks, exacerbating climate change. The negative environmental impacts of forest grazing in the two ecosystems are consistent with findings from other global reviews such as Sharma et al. (2024), Crovo et al. (2021), and Timsina (2024). Negatively altered forest structure, composition and dynamics due to forest grazing has been reported in many countries across the globe (Etchebarne & Brazeiro, 2016; Trigo et al., 2020; Loydi, 2019; Encina-Domínguez et al., 2022; Gomez et al., 2024; Kimuyu et al., 2014; Candel-Pérez et al., 2024; Yayneshet & Treydte, 2015).

To achieve sustainability, the two ecosystems have deployed several strategies. The Aberdare Ecosystem Management Plan (2010-2020) designates multiple-use zones to balance ecological sustainability with socio-economic needs, allowing grazing only in specified areas. As recommended by the Prime Minister's Task Force on the Conservation of the Mau Forests Complex (2009), strengthening livestock extension services aims to reduce forest pressure and improve food security. Additionally, establishing sustainable grazing thresholds (Leley et al., 2022) and educating on riparian management practices (Ruto et al. 2023) contribute to forest regeneration and protect riparian plant diversity. These strategies reflect a multifaceted approach to sustainable forest management amidst the challenges of livestock grazing. Authors opine that even though these strategies appear adequate in addressing the challenges of livestock grazing and promoting sustainable forest management, there is a need to review some of the strategies based on the fact that some are developed based on expired management plans such as the Aberdare Ecosystem Management Plan (2010-2020).

Moreover, there are limited studies on monitoring livestock grazing indicators in the two forest ecosystems. One of the salient features of Figure 2 is the requirement for a robust monitoring system that governs setting grazing limits, rotational grazing systems, and monitoring ecological indicators. However, in

both forest ecosystems, there is a weak monitoring system for the effects of livestock grazing. A robust monitoring system for livestock grazing requires specific indicators to ensure sustainable practices and minimal environmental impact. Key indicators include vegetation cover and composition, such as baseline vegetation assessments to measure plant species types and abundance before, during, and after grazing, and vegetation recovery rates to track post-grazing recovery. Soil health indicators involve monitoring soil erosion, such as rills and gullies that indicate overgrazing, and assessing soil compaction levels, which affect water infiltration and tree root growth. Animal health and productivity indicators include regularly checking livestock weight and health to ensure grazing benefits and tracking reproductive rates as an indicator of sufficient nutrition. Carrying capacity indicators involve comparing stocking rates to the land's carrying capacity to prevent overgrazing and measuring grazing intensity. Biodiversity indicators include monitoring species richness to ensure grazing does not negatively impact ecosystem diversity and tracking specific indicator species sensitive to grazing pressure as early warning signs of ecosystem stress. Water resources indicators involve testing water quality for contamination and ensuring water availability is not depleted by grazing activities. Ecological health indicators include monitoring invasive species' presence and assessing habitat conditions. Compliance and management indicators involve ensuring all grazers adhere to permit terms and using GPS tracking and field observations to monitor grazing patterns and ensure they align with designated areas. Socio-economic indicators include assessing the socio-economic benefits to local communities from grazing activities and tracking any conflicts between grazers and other forest users or conservation goals. These indicators collectively help manage livestock grazing sustainably, maintain ecosystem health, and ensure that the rights and needs of local communities are respected. Reviewed literature agrees with these interventions and has called for prioritizing adaptive management of forest grazing based on regular monitoring and adaptive management based on these indicators are crucial for achieving long-term sustainability (Cierjacks and Hensen, 2004; Table 1; Encina-Domínguez et al., 2022; Gomez et al., 2024; Kimuyu et al., 2014; Candel-Pérez et al., 2024; Yayneshet & Treydte, 2015).

### *4.2. Ban or not to ban livestock grazing in Mau and Aberdares forest ecosystems?*

Deciding whether to ban livestock grazing in public forests requires a comprehensive assessment of various facts. From the reviewed literature, scientific research plays a crucial role, providing insights into the ecological impacts of grazing on forest ecosystems, including biodiversity loss, soil erosion,

and carbon sequestration. Additionally, ongoing monitoring and data collection efforts help track changes in vegetation, soil quality, and wildlife populations over time, offering empirical evidence of grazing impacts. Stakeholder input from local communities, environmental groups, and government agencies provides valuable perspectives on social, economic, and cultural considerations. Legal and policy frameworks guide decision-making by outlining permissible activities and regulatory measures, while economic analyses assess the costs and benefits associated with grazing. Social impact studies delve into the livelihoods and socio-economic dynamics of affected communities, while risk assessments evaluate potential environmental, social, and economic risks. By integrating these diverse sources of evidence, policymakers can make well-informed decisions that balance conservation goals with the needs of stakeholders and the broader ecosystem. In the absence of accurate scientific data on the above decision-making criteria on whether to ban livestock grazing in forests, the authors recommend applying the precautionary principle to safeguard the ecosystem integrity of the forest ecosystems. The precautionary principle is a strategy for approaching environmental management that emphasizes caution, prevention, and risk avoidance in the face of uncertainty. It advocates taking proactive action to prevent environmental harm even when scientific evidence about potential risks is inconclusive.

In the context of livestock grazing in the Mau and Aberdares forests, this principle can be applied through measures such as controlled grazing, establishing sustainable grazing thresholds, and creating multiple-use zones. These strategies aim to prevent overgrazing, protect biodiversity, and ensure ecosystem resilience, minimizing potential long-term damage to these forest ecosystems. However, having evaluated the current community-based grazing system and the grazing impacts against the yardstick for banning grazing or not, this study recommends banning livestock grazing in Mau and Aberdares forest ecosystems. Banning livestock grazing in Mau and Aberdares forest ecosystems will provide an opportunity for the natural regeneration of vegetation, enhancing forest cover and biodiversity. This regeneration will improve soil health and stability, reduce erosion, and increase forest land's water retention capacity. Removing livestock will support native wildlife, creating healthier ecosystems.

Additionally, increased forest cover enhances carbon sequestration, mitigating climate change. Whereas there is debate about forest-adjacent communities losing out on grazing livelihood, this study submits that this will not be entirely the case. The Forest Conservation and Management Act 2016 still allows communities to cut and carry forest grass as fodder for livestock from the two

forest ecosystems. The cut-and-carry system of grass in public forests offers several benefits. This method involves harvesting grass from designated areas and transporting it to feed livestock elsewhere, reducing the direct impact of grazing on forest ecosystems. It prevents overgrazing, allowing natural vegetation to regenerate and maintain biodiversity. Soil health and stability are preserved, minimizing erosion and improving water retention. The system also helps control invasive species, as livestock are not directly grazing on forest flora. Additionally, it supports sustainable livestock management by providing a reliable feed source, promoting the balance between agricultural needs and environmental conservation.

## 5. Conclusion and policy implications

Forests are important for environmental stability and the socio-economic empowerment of millions of people worldwide. However, with the growing population and the impacts of climate change, human activities such as livestock grazing in public forests are increasingly exacerbating forest degradation. Results from Mau and Aberdares forest ecosystems have demonstrated that livestock grazing impacts the two ecosystems similarly and differently across social, economic, and environmental dimensions. Forest grazing in the Aberdares and Mau Complex provides socio-economic benefits by diversifying livelihoods and fostering community cohesion and shared resource management. Economically, grazing is essential for poorer households. However, overgrazing poses significant environmental risks, including threats to forest regeneration, biodiversity, and soil health. It leads to soil degradation, compaction, erosion, and a decline in forest cover, negatively impacting wildlife habitats.

Overgrazing also promotes invasive species spread, further disrupting ecosystems. This degradation increases the vulnerability of forests to natural disasters and reduces their capacity to sequester carbon, exacerbating climate change. Even though various strategies have been deployed to enhance forest grazing based on the negative environmental impacts, a weak monitoring system for an indicator of forest grazing, weak enforcement of grazing regulations, and the precautionary principle, this study has recommended banning livestock grazing in Mau and Aberdares forest ecosystems. While moderate grazing can be compatible with forest conservation in the two ecosystems, overgrazing degrades soil, vegetation, and ecosystem services. However, to maintain the livelihood and the positive socio-economic impacts of grazing, this study encourages the need to promote the "cut and carry" system where grass is harvested sustainably by

forest adjacent communities and used for feeding livestock outside public forest ecosystems. During the ban period, efforts should be concerted to strengthen policies and enforcement mechanisms to control illegal grazing and deforestation, involving enhanced capacity and funding for forest management agencies. However, future research and monitoring are essential to understand long-term grazing impacts and develop evidence-based management strategies. Studies on livestock grazing in the Mau and Aberdares should focus on the long-term ecological impacts, including soil health, carbon sequestration, and biodiversity. Research should also explore effective management practices, community engagement strategies, and the socio-economic implications of grazing restrictions to inform sustainable land-use policies. The study on livestock grazing in the Mau and Aberdares is limited by short-term data, which may not capture long-term ecological changes. Additionally, variability in grazing practices and socio-economic factors across different communities complicates the generalization of findings.

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## Authors

**Sylvester Chisika** sylvesterchizika@gmail.com
International School of Urban Sciences, University of Seoul, 02504 Seoul, Korea.

**Chunho Yeom** (*corresponding author*) chunhoy7@uos.ac.kr
International School of Urban Sciences, University of Seoul, 02504 Seoul, Korea.

## Funds

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2020S1A5C2A01092978).

## Competing Interests

The authors hereby state that there are no financial or non-financial competing interests.

## Citation

Chisika, S. & Yeom, C. (2024). To graze or not to graze livestock in public forests. Insights from Mau and Aberdares forest ecosystems in Kenya. *Visions for Sustainability*, 22, 10540, 377-408. http://dx.doi.org/10.13135/2384-8677/10540

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