Sokoine University of Agriculture

MSc Dissertation

Deforestation Drivers and Effects of Livestock Grazing on Forest Structure and Composition in the Coastal Forests of Kilwa District Tanzania

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Deforestation Drivers and Effects of Livestock Grazing on Forest Structure and Composition in the Coastal Forests of Kilwa District Tanzania

Dissertation Submitted to Sokoine University of Agriculture in Partial Fulfillment of the Requirements for the Degree of Master of Science in Forestry

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EXTENDED ABSTRACT

Coastal forests of Eastern Africa hold considerable importance for the communities residing adjacent or within including forage provision to both domestic and wild ungulates among other ecosystem services. However, the coastal forest ecosystems of Tanzania are facing pressure due to increasing detrimental anthropogenic activities including massive livestock influx which may affect its integrity and vital roles. The present study aimed to provide a better understanding of the effects of livestock grazing on the woody plant composition, vegetation structure, and regeneration capacity of the coastal forests and local communities' perception of the contribution of livestock grazing and other human activities to the change in land cover of landscape comprising coastal forests in southern Tanzania. The study was conducted in Kilwa District, Lindi, Southern Tanzania. Data collection involved a household survey and ground vegetation survey and analysis of Landsat satellite images. Results indicated that coastal forests at the study site had experienced a 45% decline in cover between 2007 and 2022 at the rate of -3% loss per year, to which interviewed respondents also agreed. Further, 29% of farmland area has increased within the past 15 years. The results revealed further that crop cultivation, livestock grazing, and charcoal production are among the major drivers for forest cover loss. Furthermore, results indicated no and low grazing intensity had higher plant species richness, density, and diversity contrary to moderate and heavy grazing intensities. The moderate and heavy grazing intensities also had low seedling density and diversity. Livestock grazing has also negatively affected the stem distribution of seedlings, saplings, poles, and trees indicating degradation of the coastal forests. It can be concluded from these findings that grazing affected plant species composition, diversity indices, and stem densities in the studied coastal forests. Low grazing intensity had higher diversity indices, stem density, and regeneration status similar to or better than no grazing. Therefore, low grazing is suitable under low stocking rates for livestock due to

its insignificant effect on woody species structure, composition and regeneration potential/seedling, and sapling density. It is suggested that urgent interventions are required to ensure controlled grazing that halts heavy grazing and detrimental human activities in the coastal forests within village lands. Also, further research involving large-scale study and long-term cattle and goat grazing experiments with varied grazing intensities/stocking rates to discern proper carrying capacities and effects on biophysical factors such as soil, water, vegetation, and wildlife resources in the landscapes with ample coastal forest resources. This information is useful for informing sustainable conservation strategies of coastal forests at the study site and elsewhere with similar environments.

KISIRI KUU

Misitu ya pwani ya Afrika ya mashariki ina umuhimu mkubwa kwa jamii zinazoishi karibu au ndani ya eneo lake kwa kutoa chakula cha mifugo na wanyama pori. Hata hivyo, inakabiliwa na shinikizo kutokana na ongezeko la mifugo na shughuli mbalimbali za kibinadamu ambazo zinaweza kuathiri jukumu lake muhimu. Lengo la utafiti huu lilikuwa ni kutoa uelewa bora wa athari za nguvu tofauti za malisho ya mifugo kwenye muundo wa mimea ya kudumu, miundo ya mmea na uwezo wa kupona wa misitu ya pwani na mtazamo wa jamii za mitaa kuhusu mchango wa malisho ya mifugo na shughuli nyingine kwa mabadiliko katika kifuniko cha misitu ya pwani katika pwani ya kusini mwa Tanzania. Utafiti ulifanyika Wilaya ya Kilwa, kusini mwa Tanzania. Ukusanyaji wa takwimu ulihusisha utafiti wa kaya na utafiti wa mimea na uchambuzi wa picha za satellite za Landsat. Matokeo yalionyesha kuwa uoto wa asili unaofunika ardhi kiliashiria kuwa misitu ya pwani ilikuwa imepungua kwa 45% kati ya mwaka 2007 na 2022 kwa kasi ya -3% kwa mwaka, ambayo washiriki waliohojiwa pia walikubaliana nayo. Zaidi ya hayo, 29% ya eneo la ardhi linalolimwa liliongezeka kwa miaka 15 iliyopita. Matokeo yalionyesha pia kuwa malisho ya mifugo, uzalishaji wa mkaa na upanuzi wa mashamba kutokana na ukuaji wa idadi ya watu ni mchango wa mabadiliko ya kupungua kwa eneo la misitu. Kwa upande mwingine, maeneo ambayo hayakuwa na ulishaji wa mifugo na ulishaji mdogo wa mifugo yalikuwa na aina kubwa tofauti ya mimea, ujazo na baionauai yakilinganishwa na meneo yenye wastani na ufugaji mkubwa wa mifugo. Zaidi ya hayo, matokeo yalionyesha upungufu wa spishi za mimea na utajiri wa spishi uliopungua kulinganna na kuongezeka kwa kasi ya ulishaji wa mifugo. Malisho ya wastani na mazito pia yamepunguza idadi ya mimea inayokua na aina za miti. Nguvu ya malisho pia imeathiri kwa hasi usambazaji wa shina la vijiti, miche, nguzo, na miti ikionyesha uharibifu wa misitu ya pwani. Inaweza kuhitimishwa kutokana na matokeo haya kwamba nguvu ya malisho katika eneo la utafiti ilikuwa inaathiri muundo wa mimea, viashiria vya utajiri wa spishi na

msongamano wa shina katika misitu ya pwani iliyochunguzwa. Kuwa na kiasi kidogo au kutokuwepo kabisa kwa shughuli za ufugaji katika malisho umesababisha kwa kiasi kikubwa urejeshaji wa spishi za mimea za misitu ya pwani na umechangia zaidi ya upungufu wa nusu ya ukataji miti. Nguvu ya chini ya malisho ilikuwa na viashiria vya utajiri wa spishi, msongamano wa shina na hali ya kupona sawa au bora kuliko malisho yasiyokuwepo. Kwa hiyo, malisho ya chini ni kiwango cha kufaa kwa mifugo kutokana na uhifadhi wake wa huduma nyingine za mfumo wa ikolojia katika misitu. Zaidi ya hayo, hatua za haraka zinahitajika kuhakikisha uhifadhi endelevu wa misitu ya pwani inayoharibika. Taarifa hii ni muhimu kwa kuboresha mikakati endelevu ya uhifadhi wa misitu ya pwani kutoa huduma zake. Kulingana na hitimisho hizi, napendekeza kwamba malisho endelevu ni muhimu ili kuzuia athari mbaya zaidi kwa mazingira. Ninapendekeza maendeleo na kuhamasisha sera ambazo zinajenga fursa na faida kwa wafugaji. Fursa au faida zinaweza kuundwa kupitia uboreshaji wa maeneo ya malisho, ulinzi wa haki za kibinafsi za ardhi na rasilimali na utoaji wa huduma za mifugo za kuaminika na mfumo wa habari.

DECLARATION

I, **Salhina Shaban Kashenge** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and it has neither been submitted nor being concurrently submitted in any other institution.

Salhina Shaban Kashenge
(MSc. Candidate)

Date

The declaration above is confirmed by;

Dr. Mbeyale Gimbage
(Supervisor)

Date

Dr. Maleko David
(Supervisor)

Date

LIST OF MANUSCRIPTS

Manuscript I: Local communities' perceptions of livestock grazing on coastal forest degradation in southern Tanzania

Manuscript II: Woody species composition and structure in the coastal forests in relation to livestock grazing intensity in Southern Tanzania.

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The dissertation stands as a testament to the collective effort of numerous individuals who, each in their own capacity contributed significantly to its successful completion. It is with deep appreciation that I extend my heartfelt thanks to each of them. Foremost, I am profoundly grateful to God Almighty for allowing me to embark on and conclude my educational journey. My sincere gratitude goes to my supervisors, Dr. Gimbage E. Mbeyale and Dr. David Maleko, for their unwavering collaboration and support throughout the research process.

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DEDICATION

This dissertation is devoted to my dear wife Najma Kashenge and our children for their unwavering support, prayers, and bravery.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ANOVA	Analysis of Variance
BA	Basal area
DBH	Diameter at Breast Height
EAC	East African Community
M	Meters
GEE	Google Earth Engine
NAFORMA	National Forest Resources Monitoring and Assessment
REDD+	Reducing emissions from deforestation and forest Degradation
SE	South East
TAFORI	Tanzania Forest Research Institute
TFS	Tanzania Forest Service Agency
TM	Thematic Mapper
VNRC	Village Natural Resource Committee
TLU	Tropical Livestock Unit
LF	London Forest
OLI	Operational Land Imager
%	Percentage
cm	Centimeter
SPSS	Statistical Package for Social Sciences

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Coastal forests are home to numerous unique and endangered plant and animal species that are native to the region (Habel et al., 2017; Kibet, 2011; Prins and Clarke, 2006; Wegner et al., 2009). These forests are protected within forest reserves and national parks that were established during the colonial era in some parts of Tanzania (Burgess *et al.,* 2017). Although several sites are currently without the reserve status or were removed from reserve status in the past (Ligate *et al.,* 2018). Nonetheless, coastal forests are of high ecological significance and deliver different ecosystem services directly or indirectly to the surrounding communities (Godoy *et al.*, 2011; Kibet, 2011; Kimaro and Lulandala, 2013). human economic activities such as charcoal production, logging, livestock grazing, and agricultural expansion pose significant threats to forest sustainability (Burgess *et al.,* 2017; Sheil, 1992; Wegner et al., 2009). Despite, severe degradation due to population pressure, expansion of agricultural land, poor governance, climate change, unsustainable land-use practices such as grazing, and lack of appreciation for the critical role of coastal forests in improving human well-being have threatened the sustainable provision of goods and services which has subsequently jeopardized the value of coastal forest ecosystems (CEPF, 2005).

Furthermore, livestock grazing management has variable effects on plant communities and is a subject of debate in the scientific community. The effects depend on grazing frequency, duration, intensity, and other factors such as climate, fire, soil, and vegetation type (Ligate *et al.,* 2018; Mtimbanjayo and Sangeda, 2018). Consequently, grazing can have positive effects in dry and wet miombo woodland due to the existing plant communities and vegetation structure (Chidumayo and Kwibisa, 2003; Ruvuga *et al*., 2021). Nevertheless, heavy livestock grazing has been linked to changes in vegetation composition from palatable grasses and sedges to less palatable forbs in different landscapes (Aynekulu *et al.,* 2017; Fynn and O'Connor, 2000; Nduwamungu *et al.,* 2009). There is a need to manage livestock grazing properly to ensure sustainable resource management of coastal forests in Tanzania.

Since grazing pressure leads to varying responses to the plant communities whereby plant species richness tends to rise as grazing intensity decreases resulting from a lack of selection of some plant species preferred by cattle, goats, and sheep (Mtimbanjayo and Sangeda, 2018; Nduwamungu *et al.,* 2009).

Heavy and prolonged grazing reduces species richness through the selection of some species over other plant species and the trampling of tender plants (Dunne *et al.,* 2011). Also, light distribution, soil nutrients, and the dynamics of vegetation communities can vary due to grazing practices (Egeru *et al.,* 2015; Lulandala *et al.,* 2022). Consequently, the patchy nature of vegetation reduces competition among plants for resources. Nonetheless, coastal forests are threatened by the increased presence of livestock in Tanzania (Ngailo, 2011). This is because Tanzania is home to 33.9 million cattle, 24.6 million goats, and 8.5 million sheep which is the third largest population in Africa (NBS, 2021). Similarly, available grazing areas have gradually diminished due to land reallocation and climate impacts, resulting in reduced forage yield, low carrying capacity, higher rates of livestock mortality, and increased livelihood vulnerability (Godde *et al.,* 2018; Sewando *et al.,* 2016). These factors significantly intensify pressure on farmers' crops, protected areas, and forest reserves (Benjaminsen *et al.,* 2009; Nindi *et al.*, 2014).

Tree regeneration is one of the fundamental elements of sustainability in all forest management regimes. Recent research has demonstrated that the current rate of natural regeneration in Tanzanian forests is neither quick nor abundant enough to make up for the losses, particularly in areas with extensive animal grazing and numerous annual fires (Njoghomi *et al.,* 2020). Understanding tree regeneration is crucial for understanding the structural and compositional changes that can account for ecological stability. Evaluating grazing intensity and the impact of grazing pressure and deforestation drivers on forested areas is vital for comprehending the dynamic between livestock and available land resources. Light grazing levels can enhance plant diversity within patches, whereas heavy grazing can displace grazing-intolerant plant species, thereby

favouring the proliferation of grazing-tolerant and unpalatable plant species (Kikoti and Mligo, 2015).

1.2 Problem Statement and Study Justification

Grazing by livestock alters the structure and composition of the floral community. The majority of studies have shown how livestock grazing affects grasslands and forests' vegetation. There hasn't been much done to fill the knowledge gaps about how livestock grazing affects the diversity of plant species in Afromontane forests and coastal forests (Njoghomi *et al.,* 2020; Kikoti & Mligo, 2015). Biological surveys to date have largely been restricted to (1) the vicinity of the major transport routes, (2) the relatively well-known Rondo, Ngarama south, and Litipo Forest Reserves, and (3) areas surrounding sisal plantations due to the limited knowledge of the distribution and status of forest in South Eastern Tanzania as well as the logistical difficulties of accessing this remote and isolated area (Jilala, 2015). Beyond these areas, Kitope Forest Reserve's and surrounding village forests' vegetation and flora resources remain under study despite the emerging livestock grazing pressure and other anthropogenic activities.

According to Tanzania Wildlife Act No. 5(2009), Forest Act No. 14(2002), Energy and Mineral Act No. 10(2010), and Land Act No. 5(1999), grazing in protected areas, reserved forests, and mining areas are strictly not allowed. Despite these regulations, some districts and communities have allowed grazing activity in the dry season when there is a shortage of pasture to minimize conflict in the community. However, there is little knowledge of ecological effects and community perception of cattle grazing in coastal forests specifically SE of Tanzania where most pastoralists from Ihefu/Usangu Wetlands with their herds relocated.

The scarcity of reliable information about the flora and fauna present in southern Tanzania has impeded efforts to conserve effectively coastal forests. The majority of biological surveys that have ever

been carried out in the region that contains coastal forests have been extremely unequal and selective. For instance, in Tanzania, the majority of these surveys have been carried out on the northern coast of the country (Tanga and Pwani regions), with little information on the forests in the south-east of the country being surveyed even though these regions have higher floristic endemism (Prins and Clarke, 2007), It is well known that Tanzania's coastal Forest is home to a variety of endemic species, of both scientifically and culturally importance (Howell *et al*., 2012; Clarke *et al*., 2011; Kibet, 2011).

Their distribution, precise borders, and available forest resources are still not well understood (Dallu, 2004). One of the 66 coastal forests controlled by Tanzania's government under the Tanzania Forest Service (TFS) is the Kitope Forest Reserve, located in Kilwa District, Lindi region (Howell *et al*., 2012; Jilala, 2015). Although Southern coastal forests are influenced by anthropogenic stresses on the forest, such as illicit logging, charcoal making, and forest clearing and burning for simsim (*Sesame sesame*) cultivation are widely acknowledged (Godoy *et al*., 2011; Jilala, 2015).

Farming and logging have been the main drivers of forest loss in the areas that once had extensive coastal forests, such as the lowland of the Matumbi Hills (Kitope Forest Reserve), the Rondo Plateau, and the Makonde Plateau. (Jilala, 2015) Understanding the current dynamics of the state of floristic composition and the impact of pastoralist activities on forest conditions is essential for management and conservation strategies that seek to preserve the remaining threatened biodiversity that is potentially beneficial to the livelihoods of local peoples living near these forests (Godoy *et al*., 2012, Godoy *et al*., 2011).

Concerning the delineation and state of the forest, little has been done to determine the extent to which these actions have impacted the floristic composition and stocking of this forest (Hassan *et al*.,

2013; Clarke *et al*., 2011; Burgess *et al.*, 2010). Additionally, Migration of Livestock from the Ihefu plains in the Mbeya region in 2016 to the Lindi region there is a limited study conducted to assess any vegetation changes. However, there is a knowledge gap concerning the impacts of livestock grazing on plant species composition and community perception of forest land cover change in coastal forests. This study therefore aims to bridge the information gap on the impacts of livestock grazing on forest floor vegetation in the coastal forest of southern Tanzania. The findings of this study will provide information that can be used to develop appropriate conservation plans and a routine monitoring schedule for the Southern zone coastal Forest.

1.3 Objectives

1.3.1 Main objective

To assess the effects of livestock grazing on structure, diversity, and cover of wood species in southern zone coastal forests of Tanzania

1.3.2 Specific objectives

i. To assess the local communities' perceived drivers of deforestation and degradation of selected coastal forests

ii. To determine the effects of livestock influx on land cover change in selected villages with coastal forests adjacent to Kitope Forest Reserve

iii. To assess the effects of livestock grazing on woody species composition, structure, and regeneration.

1.4 Limitations of the Study

This study encountered some challenges and limitations which may affect the interpretation of the results.

- The fieldwork covered only four months from November to February, thus does not capture the full range of variability

throughout the year due to the time frame allocated for this study.

- The Four-month period for assessing grazing is relatively shorter than in other studies. The study may have been limited by the sample size of the study plots, which could affect the generalizability of the results to broader coastal forest ecosystems could assess the effects of grazing for two years consecutively for the assessment of livestock grazing on coastal Forests.
- Some of the respondents were not flexible in responding to the question as they thought that they were going to be evicted.
- The assessment of land cover change in the coastal forest was conducted within a specific timeframe. This timeframe may not capture longer-term trends or variations in land cover change.
- The study may not have adequately controlled for confounding variables such as natural disturbances or anthropogenic activities that could influence both grazing intensity and the variables measured.
- External factors beyond the scope of the study, such as governmental policies, socio-economic changes, or climate variability, may also influence grazing intensity, land cover change, and the dynamics of coastal forest ecosystem.

1.5 Dissertation Structure

The dissertation is divided into five chapters and is structured as a series of publishable manuscripts. The first chapter provides an introduction to the study, including background information, the problem statement and study justification, study objectives, and limitations. Chapter two is a manuscript on Local communities' perceptions of livestock grazing on coastal forest degradation in southern Tanzania. This chapter has already been submitted to the journal for publication. Chapter three presents manuscript two on Woody species composition and structure in the coastal forests

concerning livestock grazing intensity in Southern Tanzania. Also, this chapter has already been submitted to the journal for publication. Chapter four presents a general discussion of the study's findings and chapter five provides a summary of the major contributions, conclusions, and recommendations moving forward.

CHAPTER TWO

MANUSCRIPT ONE

2.0 Local Communities' Perceptions of the Effects of Livestock Grazing on Coastal Forest Degradation and Deforestation in Southern Tanzania

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Abstract

Coastal forests are a unique terrestrial ecoregion on the East African coast threatened by livestock grazing due to an increase in immigration rate in southern Tanzania. This study assessed local communities' perception of livestock grazing and other activities to changes in forest cover. This study used household questionnaires and direct observations to explore how local communities in the Coastal forests perceive the contribution of livestock grazing and

other economic activities to changes in forest cover around the Kitope forest reserve. Further, the study used satellite imagery (2007-2022) to ascertain changes in land use. It also evaluated land cover changes in the past 15 years from the start of livestock immigration. The coastal forests had a 45% decline in cover between 2007 and 2022 at -3% per year, to which interviewed respondents agreed. Respondents mentioned livestock grazing, charcoal production, and cropland expansion as the main drivers for changes. These attributes were supported by a land cover map, which showed an increase in farmland area at 29% per year. Built areas did not follow a linear increase as was expected due to underlying socio-economic factors. Many respondents mentioned soil compaction, erosion, water- pollution, disappearance, and loss of native species as the impacts of livestock grazing in the area. It was concluded that coastal forests in southern Tanzania were degraded, and rapid interventions are required to ensure their sustainability.

Keywords: Forest disturbance; Land cover and land use changes; Livestock migration; Ecosystem services.

2.1 Introduction

Coastal forests are unique terrestrial ecoregions characterized by closed canopy forests with dense shrubs and thickets, excluding mangrove forests and other deciduous woodlands (Burgess *et al.,* 1992; Godoy *et al.,* 2012; Tabor *et al.,* 2010). The Eco region is found in small patches (less than 2 km^2) of scrub forest, dry forest, riverine forest, swamp forest, groundwater forest, and coastal transition forest in East Africa (Kibet, 2011; Tabor *et al.,* 2010). The coastal forests provide a habitat for different flora and fauna endemic to the ecoregion (Rija *et al.,* 2015; Sheil, 2022; Wegner *et al.,* 2009). Furthermore, they perform other ecosystem services such as carbon sequestration and stocking, and recreational and educational activities (Godoy *et al.,* 2012; Ntukey *et al.,* 2022). However, coastal forests face ever-increasing degradation threats indirectly due to human-induced climate change or directly via human encroachment due to population growth (Habel *et al.,* 2017; Wegner *et al.,* 2009). The human encroachments include clearing of forests for farming, logging, fire burning for hunting, and interruption of water supply for irrigation, which affects other ecosystem services as mentioned earlier (Godoy *et al.,* 2012; Kashaigili *et al.,* 2014; Ligate *et al.,* 2019).

Nonetheless, livestock grazing is an extraordinary threat facing coastal forests under village authority, termed general or traditional coastal forests (Kibet, 2011; Ligate *et al.,* 2019). It is an extraordinary threat because coastal forests have dense shrubs and closed canopy, making it hard for livestock to graze, especially cattle, unlike in miombo woodlands (Ligate *et al.,* 2019; Mtimbanjayo and Sangeda, 2018). The livestock grazing difficulty can lead to the cut down of trees to the open canopy and allow the growth of herbaceous grasses or the use of goats to control shrubs (Hilario *et al.,* 2017; Ligate *et al.,* 2019). Livestock overgrazing can change the coastal forest ecosystem significantly by facilitating soil erosion and compaction, trampling on the seedlings, interfering with the nutrient cycle, and loss of biodiversity (Dunne *et al.,* 2011; Ligate *et al*.,

2019; Mtimbanjayo and Sangeda, 2018). These attributes can lead to the conversion of coastal forests into woodlands and then open grasslands. The transition is good from an animal production perspective due to an increase of available forage biomass that is achieved at the expense of other ecosystem services and precious Eco regions, as it has also been noted in miombo (Chidumayo and Kwibisa, 2003; Ligate *et al.,* 2019). Consequently, it is crucial to limit grazing practices in the coastal areas; however, most livestock keepers in East Africa operate under traditional low-input systems and depend on communal rangelands, including wooded landscapes, for livestock grazing (Ruvuga *et al.,* 2020). The extensive livestock production system has led to regular conflicts among livestock keepers and other land users (Kajembe *et al.,* 2003; Nindi *et al.,* 2014).

For example, traditional livestock keepers in Tanzania were evacuated in 2006 from Usangu Plain (an ecosystem hotspot) due to large herd sizes (Ngailo, 2011). The evicted livestock keepers were reallocated to the southeast of the country where coastal forests are located (Kajembe *et al.,* 2003; Mwambene *et al.,* 2014; Ngailo, 2011). The migration put further pressure on an already strained ecoregion, and livestock grazing could push it past the breaking point. Consequently, the government implemented a land use plan and allocated grazing lands for an incoming livestock population (Mwambene *et al.,* 2014). The existing land use plan was expected to limit livestock activities into a small area, allowing other conservation activities and reducing conflicts among land users. Similarly, livestock keepers possess various management strategies that can be employed to improve forage availability and livestock performance (Ruvuga *et al.,* 2020). However, there is limited information on the current situation in the protected areas, e., Kitope forest reserve and traditionally managed coastal forests in southern Tanzania, where livestock keepers were reallocated. Therefore, the study assessed local communities' perception of the contribution of livestock grazing and other economic activities to changes in forest

cover around the Kitope forest reserve. It also aimed to evaluate land cover changes around Kitope forest reserves in the past 15 years from the start of livestock immigration. The findings would enable decision-makers and policymakers to understand local perceptions and coastal forest changes for future interventions.

2.1 Materials and methods

2.2.1 Study area

The study was conducted in Kilwa district (8°15′-10°00′S and 38°40′-39°40′E) in southern Tanzania. The district has an area of 13,348 km^2 and a population of 297,676 per the 2022 national census (United Republic of Tanzania, URT *et al.,* 2022). Crop cultivation, fishing, and trade are the main economic activities in the Kilwa district, but forest-dependent livelihood strategies such as charcoal making and timber extraction are rising (Kalonga and Kulindwa, 2017). Annual rainfall and temperature are 1,000-1,400mm and 22-30 °C, respectively, in the northeast of the district where coastal forests are found (Kilwa District Council, KDC, 2008). The soil in and around the forests is alluvial in river valleys and chromic vertisols between coastal plains and plateaus. Kitope Forest Reserve is the largest coastal forest in the area under the custody of the Tanzania Forestry Service (TFS). Also, there are smaller forests in Kinjumbi, Marendego, and Somangasimu villages surrounding the reserve (Figure 2.1). The villages allocated land for livestock grazing in 2007 which is communally owned and managed by the village natural resource committee (VNRC). Similarly, there has been an influx of livestock that were evicted in the Usangu plain in the southern highlands of Tanzania (Ngailo, 2011). The livestock immigration, presence of allocated grazing land, and proximity to the forest reserve warranted the selection of Kinjumbi, Marendego, and Somangasimu villages for the current study.

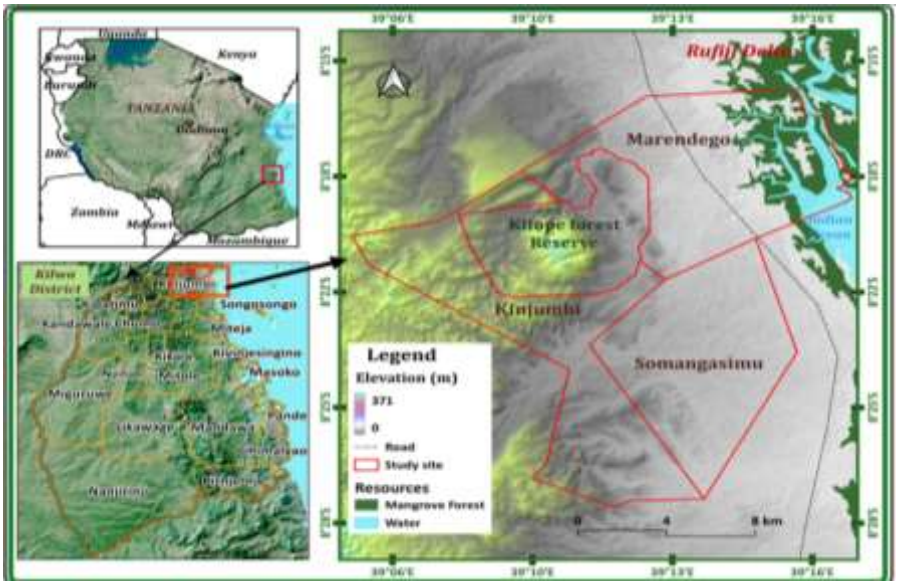

Figure 2.1: **Map of the Kitope forest reserve and the surrounding study villages**

2.2.2 Research design and data collection

A research design of both qualitative and quantitative nature (Schoonenboom and Johnson, 2017) was used in this study. Data were collected through household questionnaire surveys (HHQ) and field observations. A mixture of these methods was used to cross-check and validate the collected information. Before the data collection, respondents were informed about the purpose of the study and requested their consent to participate. The HHQ respondents were randomly selected with the help of village leaders, for interview and discussion. The village registrars found in each village were used to identify households in the studied area. A researcher physically visited the selected households with accompanying village officials. The interview was voluntary, and households were asked to consent to participate in the study. Similarly, a household was not included if adults (> 18 years) were not available to answer questions, village officials could not physically locate it, or no one was at home during the visit. A total of

90 households were interviewed, of which 31 were from Marendego, 30 were from Kinjumbi, and 29 were from Somangasimu. The interview was conducted in Swahili using a pretested questionnaire containing open- and closed-ended questions. The questions were related to livelihood strategy, household income, livestock grazing, perception of land cover changes, forest degradation (i.e., when forest ecosystems lose their capacity to provide important goods and services to people and nature), and deforestation (i.e., when forests are converted to non-forest uses such as grazing and agriculture) drivers. The respondents were encouraged to share the questions with other individuals in the same house to capture different information regarding households' perceptions and practices in the respective area.

2.2.3 Land classification and cover changes

Google Earth Engine (GEE) was employed during land classification with image data retrieved from Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) while correcting for surface reflectance and terrain. Landsat 5 T.M. was used to obtain images for 2007 and 2012, while Landsat 8 OLI was used to retrieve images for 2017 and 2022. The images had a resolution of 30 m, and only those with 20% cloud cover were included in the analysis. A pixel quality assessment band was employed to detect cloud shadows within the retrieved images to remove data with errors. Also, radiometric correction was applied to different Landsat sensors to improve data quality and account for variations between Landsat 5 T.M. and Landsat 8 OLI for direct comparison. Synthetic multispectral bands (Normalized Difference Vegetation Index, Enhanced Vegetation Index, and Soil Adjusted Vegetation Indices) were computed and mosaicked to composite selected features for land cover classification. Land cover was put into different classes (Table 2.1), namely, coastal forest, mangrove forest, woodlands, farmland, wetland, and built area, following supervised machine learning based on field survey and nature of the studied area. The Random Forest (R.F.) was applied as the classifier, while a

multispectral composite was used as the input feature for land cover classification. The R.F. classified land cover by creating 350 estimators, each generating six random predictors. The classified maps were tested for accuracy and Kappa coefficient by confusion matrix computation using 10% of the labelled test dataset.

Table 2.1: **Description of different land classes in southern Tanzania**

Land class	Description
Coastal forest	Land dominated by woody plants with > 40% canopy cover
Mangrove forest	Intertidal area in the ocean dominated by woody plants with > 40% canopy cover
Woodland	Land dominated by woody plants with canopy cover ranges from 10% to 40%
Farmland	Land prepared and used for crop cultivation exclusively.
Wetland	The area around the river delta is characterized by exposed wet soil.
Built area	Human residence and other human-made structures, such as salt production facilities

2.2.4 Data analysis

Household survey data were coded and categorized into native residents and immigrants based on the duration of residence (native > 10 years and immigrants ≤ 10 years) and self-identification. The respondents were categorized into two groups due to their differences in utilization of the allocated grazing land and reliance on livestock for their livelihoods. The coded household data were analyzed using Statistical Package for Social Sciences (SPSS version 20). Descriptive statistics determined the mean and frequency of responses regarding household characteristics and local communities' perceptions. The mean and percentages were presented and tested for statistical differences between the two groups by chi-square and student t-test, respectively. The two inferential tests were selected because of the differences in the data

types, i.e., nominal versus numerical. The results were considered statistically significant at a 95% confidence interval ($p < 0.05$).

2.3 Results

2.3.1Household characteristics

The average respondents' age was 38 years, and most (87%) had formal education, of which 58% were primary, 38% were secondary, and 4% were tertiary. The mean household size was significantly lower ($p < 0.001$) in the immigrants (5.3 people) than in the native residents (7.7 people). Livestock keeping was the major economic activity among immigrants (59%), and crop cultivation was common among native residents (96%). Furthermore, respondents who immigrated to the studied area were motivated by available grazing land for livestock. Many immigrants had higher income ($p < 0.001$) than the native residents, as is shown in Table 2.2.

Table 2.2: **Household characteristics of the interviewed respondents in southern Tanzania**

Parameter	**Residents (n = 56)**	**Immigrants (n = 34)**
Household size	5.3[b]	7.7[a]
Livelihood strategy		
Farming	96[b]	41[a]
Livestock	2[b]	59[a]
Herd size		
Cattle	75[b]	207[a]
Goat	0[b]	29[a]
Sheep	0[b]	26[a]
Income per month		
50 000-199 000	76[b]	3[a]
200 000-599 000	20[b]	38[a]
600 000-1 990 000	4[b]	53[a]

a, b Means in the same row with different letters were different statistically at $p = 0.05$

2.3.2 Communities' perceptions of forest cover and livestock grazing

The 98% of native residents mentioned that the forest cover has been severely declining, like 91% of immigrants. These responses did not vary statistically ($p = 0.317$) among the two groups in the studied area. However, there were variations ($p < 0.05$) regarding their perception of the reasons behind observed forest cover and land use changes (Table 2.3). Many native residents mentioned livestock grazing, charcoal production, cropland expansion, and human population growth as the reasons for changes (in descending order). Alternatively, in descending order, immigrants said cropland expansion, charcoal production, and livestock grazing were the major causes. Other reasons for land use changes were cutting trees to control wildlife, rainfall variability, and prolonged droughts.

Table 2.3: **Perceptions of local communities (percentage) on causes of coastal forest changes**

Outcome	Residents (n = 56)	Immigrants (n = 34)
Livestock grazing	100[a]	88[b]
Cropland expansion	98	100
Charcoal production	100	97
Human population growth	98[a]	72[b]
Rainfall variability and prolonged droughts	93[a]	66[b]
Cutting trees to control wildlife	96[a]	81[b]
Firewood collection	89[a]	94[b]

Means in the same row with different letters were different statistically at $p = 0.05$

Otherwise, livestock grazing was conducted in the communal rangelands (82%), private forage reserves (55%), and the forest (49%), as mentioned by immigrants and native residents who owned livestock. Other grazed areas were croplands after harvesting and illegal trespassing into protected areas, especially during the dry periods. Many responding native residents perceived soil

compaction, water pollution and disappearance, and loss of native species as the negative results of livestock grazing. Immigrants mentioned poor plant species regeneration, water pollution, soil erosion, and water disappearance as the negative outcomes of livestock grazing. Other negative results of livestock grazing mentioned by respondents are shown in Figure 2.2 below.

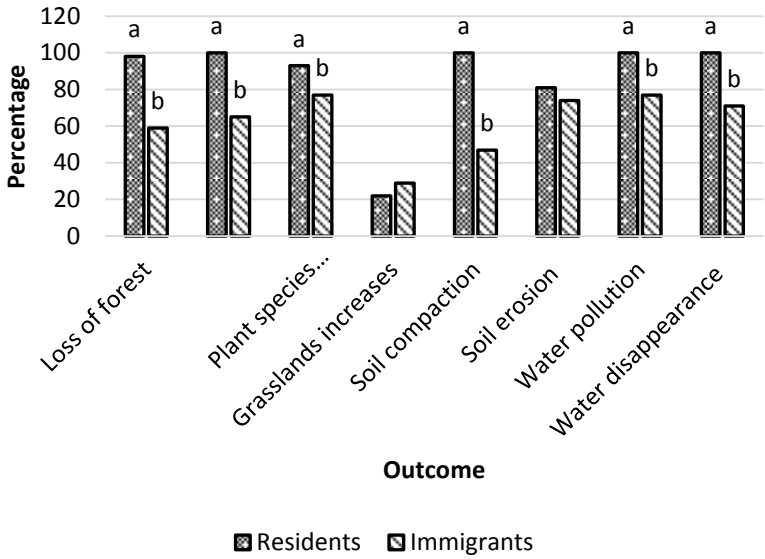

Figure 2.2: **Perceptions of local communities in percentage on impacts of livestock grazing in the coastal forest. Bars in the same outcomes with different letters were different statistically at p = 0.05**

2.3.3 Land cover and use changes

Table 2.4, Figures 2.3 and 2.4 show changes in the land use and cover in the studied area, whereby coastal forest experienced a 45% decline in cover between 2007 and 2022 at the rate of -3% per year. Alternatively, mangrove forests and woodlands experienced positive cover changes with an increase of 13% (+0.9% per year) and 70% (+4.7% per year), respectively, in the mentioned period. Farmland areas had quadrupled at the rate of +29% per year in the past 15

years, while wetlands had increased from 2007 until 2017, followed by a decline in recent years. Otherwise, built areas expanded between 2007 and 2012, followed by a decrease in 2017 and a recent rise (Table 2.4). The overall accuracy of the processed land cover was 91-97%, and the kappa coefficient was 0.88-0.98.

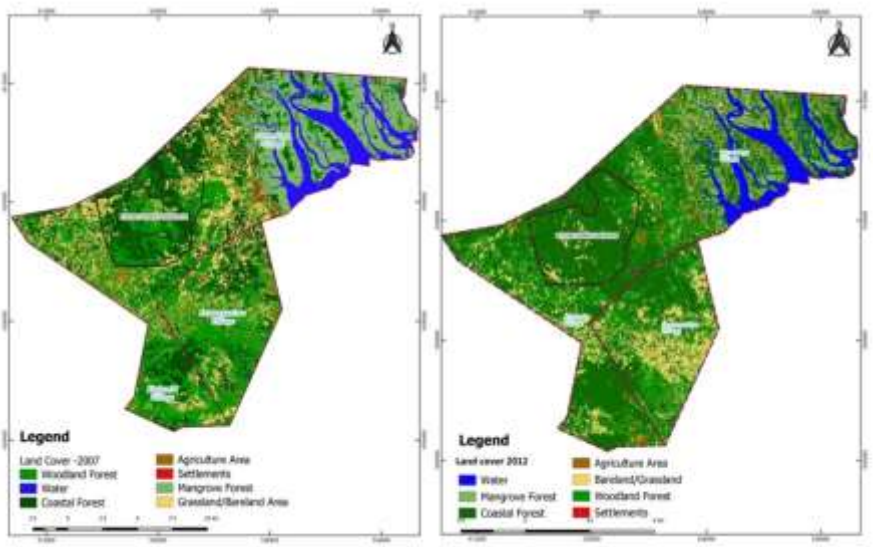

Figure 2.3: **Land use and cover change in the Kitope forest reserve and the surrounding villages from 2007 to 2012**

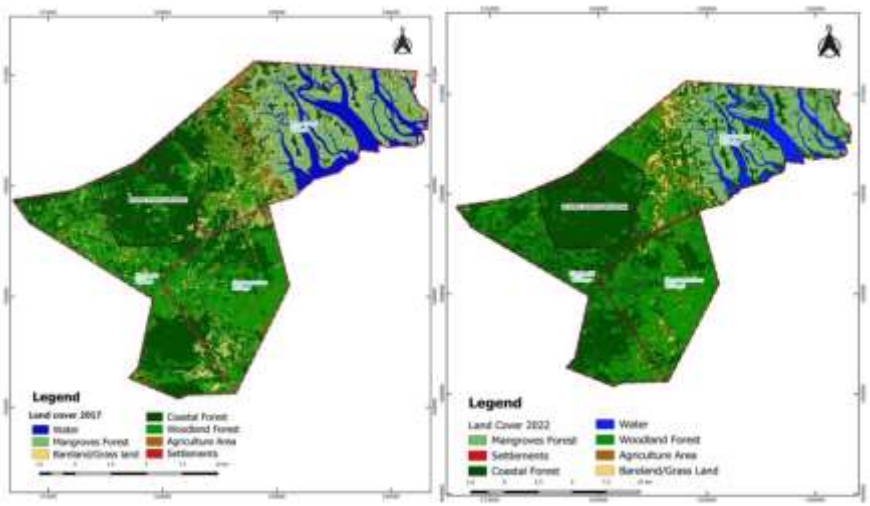

Figure 2.4: **Land use and cover changes in the Kitope forest reserve and the surrounding villages from 2017 to 2022**

Table 2.4: **Land use and cover changes in the studied area from 2007 to 2022**

Land use class	2007	2012	2017	2022
Coastal forest	63.1	57.6	39.6	35.0
Mangrove forest	5.3	5.3	5.4	6.0
Woodland	26.3	25.6	43.9	44.8
Farmland	1.7	6.2	5.0	9.1
Wetland	0.9	1.7	2.8	1.8
Built area	0.7	1.3	1.2	1.3

2.4 Discussion

The coastal forest cover declined in the studied area (Figures 3 and 4), similar to the findings by Tabor et al. (2010) on identical forest types in Kenya and Tanzania. However, this study's reported -3% per year decline was higher than 0.2-0.8% per year noted in the Tanzanian coastal forests (Godoy *et al.,* 2012; Tabor *et al.,* 2010). The forest cover loss variations were due to the differences in

management between the current and former studies since the present study included both protected and general forests. However, the annual forest loss in this study was still very high compared to -1.3% per year reported by Godoy *et al.* (2011) in general coastal forests. The variations can be attributed to location differences, prevalent socio-economic activities like grazing or charcoal making, human population growth, and increasing effects of climate change (Burgess *et al.,* 2017). Nonetheless, these findings indicate the dire state of the coastal forests in Tanzania, whereby necessary measures such as livelihood diversification are required to ensure their sustainability. Alternatively, mangrove forests and woodlands increased in the current study compared to other African findings (Carney *et al.,* 2014; Kirui *et al.,* 2013; Mesfin *et al.,* 2020). The mangrove forest increase was attributed to the different protection measures in the country and/or their relatively small cover (Table 4), which made it hard for individuals to utilize them (Gayo, 2022). The woodland increase could be due to the clearing of individual trees in the coastal forest, which reduced canopy cover; hence, the land classification algorithm considered them as woodlands in this study.

Consequently, the current study indicated that coastal forests were degraded and converted into woodlands. The respondents in the present study also shared the verdict, who mentioned a severe change in forest cover. The respondents said livestock grazing, cropland expansion, charcoal production, and human population growth influenced land use changes, which are well substantiated elsewhere (Burgess *et al.,* 2017; Tabor *et al.,* 2010). Population growth affected land cover in the studied area through large household size (Table 2.1) and immigration of livestock keepers from the Usangu plains (Ngailo, 2011). However, built areas did not show a linear increase to reflect the mentioned human population growth in the studied area (Table 2.4). The observed trend was because the built area included other human-made structures, such as salt production facilities (Table 2.1). However, the salt-making facilities are constructed in the intertidal zone, which affects

mangrove forests with new regulations limiting the activity, causing some people to abandon them, which explains the regression in the built area between 2012 and 2017 (Liingilie *et al.,* 2015). Also, large household sizes were close to or within 5.9-9.3 people for farmers and livestock keepers, respectively. Large household sizes could have reduced the number of houses built in the area, which explains why most immigrants did not consider population increases to cause land cover change (Kazungu *et al.,* 2020; Kimaro *et al.,* 2017). More native residents mentioned livestock grazing as the cause of forest cover loss than immigrants because the latter were livestock keepers (Table 2.2 and Figure 2.2) and refuted the claim to avoid eviction or destocking as was the case in Usangu and Kilombero valleys in Tanzania (Ngailo, 2011; Nindi *et al.,* 2014).

Furthermore, number of livestock reported in this study was within 20-600 noted among livestock keepers in northern Tanzania (Kimaro *et al.,* 2017). However, cattle ownership among native residents was contrary to the report by Mwambene *et al.* (2014), who mentioned that natives in southern Tanzania were farmers and did not own large stock. The variations could be because the criteria for categorizing natives and immigrants was based on self-identification and residence duration. Nonetheless, large numbers of livestock can lead to overgrazing, affecting other ecosystem services in the wooded landscape (Lulandala *et al.,* 2022). This can also explain why most respondents thought that livestock grazing can cause loss of grasses due to overgrazing (Pfeiffer *et al.,* 2019). Also, livestock overgrazing in the coastal forest, as was mentioned by respondents, can contribute to the tree cover losses due to browsing of thickets by goats and trampling of seedlings and coppices by cattle (Hilario *et al.,* 2017; Mtimbanjayo and Sangeda, 2018). Similarly, livestock grazing in protected areas can lead to conflict between utilization and forest protection and biodiversity loss (Young *et al.,* 2018). However, fewer immigrants mentioned livestock grazing led to the disappearance of native plant species (Figure 2.2) because they had recently arrived in the studied area, which might have limited their

ethnobotanical knowledge (Naah and Guuroh, 2017). There was perception variation between native residents and immigrants on the soil compaction as the result of grazing, with the latter not agreeing with it, contrary to other studies (Dunne *et al.,* 2011; Ngenzi *et al.,* 2023). The immigrants had different perceptions because most were not farmers, while those who farmed used livestock as the draught power (Abdul Rahman and Reed, 2014).

Livestock grazing was mentioned to pollute water in the studied area, which showed the significant impact of livestock in the forest cover and risking disease outbreaks such as Cholera and antibiotic-resistance Escherichia coli (Lupindu *et al.,* 2015). Also, the response indicated the sharing of watering points between humans and livestock, which is common in most of Sub-Saharan Africa (Carbonell *et al.,* 2021; Egeru *et al.,* 2015). Consequently, there is a need to invest in infrastructure for sustainable livestock production, which would account for environmental protection and public health through food safety. As in Miombo woodlands, strengthening the existing land use plan would guarantee grazing rights and limit land cover changes to the allocated grazing lands only (Mwambene *et al.,* 2014; Ruvuga *et al.,* 2021). It was believed that the land use plan would encourage private investment because many immigrants who were livestock keepers had significantly higher incomes than native farmers. The higher income was possibly due to the higher value of livestock and their products distributed throughout the year compared to the seasonal crops such as pigeon peas cultivated in southern Tanzania (Gichohi-waiting *et al.,* 2022). Also, household income was higher among immigrants because of the high number of livestock, which indicates wealth among livestock keepers (Woodhouse and Mccabe, 2018). Generally, respondents' perception of land cover change was founded on the decline in forest cover, hence the need to reduce existing pressure, such as cropland expansion, charcoal making, and livestock grazing. Future studies should investigate the effects of the current livestock density

on tree distribution and diversity in the coastal forest to identify the scope of degradation.

2.5 Conclusion

Coastal forest cover had declined in the studied area, as was determined by the satellite imagery and confirmed by the respondents in the studied area. However, woodlands had increased substantially in the area. Many respondents perceived livestock grazing, cropland expansion, charcoal production, and human population growth as the primary drivers behind the observed changes. These attributes were further attested by increased farmland and built area in the land cover maps. Moreover, livestock grazing was perceived by respondents to cause soil compaction, loss of native plant species, water pollution, and water disappearance. There were differences in the perception of the livestock grazing impacts on coastal forests among native residents and immigrants due to underlying socio-economic differences. Therefore, it was concluded that southern Tanzania's coastal forests were degraded, and rapid interventions are recommended to ensure their sustainability.

Declaration of interest

Authors declare no potential conflict of interest

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References

Abdul, R. S., & Reed, K. (2014). The management and welfare of working animals: identifying problems, seeking solutions and anticipating the future. *Rev. sci. tech. Off. int. Epiz 3*3, 41–45.

Burgess, N.D., Malugu, I., Sumbi, P., Kashindye, A., Kijazi, A., Tabor, K., Mbilinyi, B., Kashaigili, J., Wright, T.M., Gereau, R.E., Coad, L., Knights, K., Carr, J., Ahrends, A., & Newham, R.L. (2017). Two decades of change in state, pressure and conservation responses in the coastal forest biodiversity hotspot of Tanzania. *Oryx* 51, 77–86.

Burgess, N.D., Mwasumbi, L.B., Hawthorne, W.J., Dickinson, A., & Doggett, R.A., (1992). Preliminary assessment of the distribution, status and biological importance of coastal forests in Tanzania. *Biol. Conserv.* 62, 205–218.

Carbonell, V., Merbold, L., Díaz-Pinés, E., Dowling, T.P.F., & Butterbach-Bahl, K. (2021). Nitrogen cycling in pastoral livestock systems in Sub-Saharan Africa: knowns and unknowns. Ecol. Appl. 31, e02368.

Carney, J., Gillespie, T.W., & Rosomoff, R. (2014). Assessing forest change in a priority West African mangrove ecosystem: 1986 – 2010. *Geoforum*, 53, 126–135.

Chidumayo, E.N., & Kwibisa, L., (2003). Effects of deforestation on grass biomass and soil nutrient status in miombo woodland, Zambia. *Agric. Ecosyst. Environ.* 96, 97–105.

Dunne, T., Western, D., & Dietrich, W.E. (2011). Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical rangeland. *J. Arid Environ.* 75, 58–69.

Egeru, A., Wasonga, O., Macopiyo, L., Mburu, J., Tabuti, J.R.S., & Majaliwa, M.G.J. (2015). Piospheric influence on forage species composition and abundance in semi-arid Karamoja sub-region, Uganda. *Pastoralism* 5, 12.

Gayo, L. (2022). Local community perception on the State Governance of mangroves in Western Indian coast of

Kinondoni and Bagamoyo, Tanzania. *Glob. Ecol. Conserv.* 39, e02287.

Gichohi-wainaina, W.N., Mremi, R., Chande, M., Msuya, J.M., Kumwenda, N.C., Muzanila, Y.C., Msere, H., & Muhimbula, H. (2022). Drivers of Pigeon Pea Consumption Among School-Aged Children in Central Tanzania. Front. Sustain. Food Syst. 5, 726404.

Godoy, F.L., Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., & Steininger, M.K., (2012). Deforestation and CO_2 emissions in coastal Tanzania from 1990 to 2007. *Environ. Conserv.* 39, 62–71.

Habel, J.C., Casanova, I.C.C., Zamora, C., Teucher, M., Hornetz, B., Shauri, H., Mulwa, R.K., & Lens, L., (2017). East African coastal forest under pressure. Biodivers. Conserv.

Hilario, M.C., Wrage-Mönnig, N., & Isselstein, J. (2017). Behavioral patterns of (co-)grazing cattle and sheep on swards differing in plant diversity. *Appl. Anim. Behav. Sci.* 191, 17–23.

Kajembe, G.C., Mbwilo, A.J., Kidunda, R.S., & Nduwamungu, J. (2003). Resource use conflicts in Usangu Plains, Mbarali District, Tanzania. *Int. J. Sustain. Dev. World Ecol. 10*, 333–341.

Kalonga, S.K., & Kulindwa, K.A., (2017). Does forest certification enhance livelihood conditions? Empirical evidence from forest management in Kilwa District, Tanzania. For. *Policy Econ*. 74, 49–61.

Kashaigili, J.J., Levira, P., Liwenga, E., & Mdemu, M. V. (2014). Analysis of Climate Variability, Perceptions and Coping Strategies of Tanzanian Coastal Forest Dependent Communities. *Am. J. Clim. Chang.* 03, 212–222.

Kazungu, M., Zhunusova, E., Yang, A.L., Kabwe, G., Gumbo, D.J., & Günter, S. (2020). Forest use strategies and their determinants among rural households in the Miombo woodlands of the Copperbelt Province, Zambia. *For. Policy Econ,* 111, 102078.

KDC, (2008). Social economic profile of Kilwa district. Kilwa, Tanzania.

Kibet, S. (2011). Plant communities, species diversity, richness, and regeneration of a traditionally managed coastal forest, Kenya. *For. Ecol. Manage.* 261, 949–957.

Kimaro, E.G., Mor, S.M., Gwakisa, P., & Toribio, J.A. (2017). Seasonal occurrence of Theileria parva infection and management practices amongst Maasai pastoralist communities in Monduli District, Northern Tanzania. *Vet. Parasitol*, 246, 43–52.

Kirui, K.B., Kairo, J.G., Bosire, J., Viergever, K.M., Rudra, S., Huxham, M., & Briers, R.A., (2013). Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. *Ocean Coast. Manag*, 83, 19–24.

Ligate, E.J., Wu, C., & Chen, C. (2019). Investigation of tropical coastal forest regeneration after farming and livestock grazing exclusion. J. For. Res. 30, 1873–1884.

Liingilie, A.S., Kilawe, C., Kimaro, A., Rubanza, C., Jonas, E., & Centre, W.A. (2015). Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. *Mediterr. J. Biosci,* 1, 27–31.

Lulandala, L., Bargués-Tobella, A., Masao, C.A., Nyberg, G., & Ilstedt, U. (2022). Excessive livestock grazing overrides the positive effects of trees on infiltration capacity and modifies preferential flow in dry miombo woodlands. L. Degrad. Dev. 33, 581–595.

Lupindu, A.M., Dalsgaard, A., Msoffe, P.L.M., Ngowi, H.A., Mtambo, M.M., & Olsen, J.E., (2015). Transmission of antibiotic-resistant Escherichia coli between cattle, humans and the environment in peri-urban livestock keeping communities in Morogoro, Tanzania. *Prev. Vet. Med*, 118, 477–482.

Mesfin, D., Simane, B., Belay, A., Recha, J.W., & Taddese, H. (2020). Woodland Cover Change in the Central Rift Valley of Ethiopia. *Forests,* 11, 916.

Mtimbanjayo, J.R., & Sangeda, A.Z. (2018). Ecological Effects of Cattle Grazing on Miombo Tree Species Regeneration and Diversity in Central-Eastern Tanzania. *Journal of Environmental Research,* 2, 3.

Mwambene, P.L., Mbwile, R.P., Hoeggel, F.U., Kimbi, E.C., Materu, J., Mwaiganju, A., & Madoffe, S. (2014). Assessing dynamics of forced livestock movements, livelihoods and future development options for pastoralists/agro-pastoralists in Ruvuma and Lindi Regions, in the Southern Tanzania. Livest. Res. Rural Dev. 26, #4.

Naah, J.B.S.N., & Guuroh, R.T. (2017). Factors influencing local ecological knowledge of forage resources: Ethnobotanical evidence from West Africa's savannas. *J. Environ. Manage.* 188, 297–307.

Ngailo, J.A. (2011). Assessing the effects of eviction on household food security of livestock keepers from the Usangu wetlands in S.W. Tanzania. Livest. Res. Rural Dev. 23, #65.

Ngenzi, O.D., Ruvuga, P.R., Msalya, G.M., & Maleko, D.D. (2023). Participatory establishment of Cenchrus ciliaris forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. African J. Range Forage Sci.

Nindi, J.S., Maliti, H., Bakari, S., Kija, H., & Machoke, M., (2014). Conflicts over land and water resources in the kilombero valley floodplain, Tanzania. *Afr. Study Monogr.* 50, 173–190.

Ntukey, L.T., Munishi, L.K., & Treydte, A.C. (2022). Land Use Land / Cover Change Reduces Woody Plant Diversity and Carbon Stocks in a Lowland Coastal Forest Ecosystem, Tanzania. *Sustainability,* 14, 8551.

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J.C., Higgins, S.I., Mudongo, E.I. & Scheiter, S. (2019). Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-

based dynamic vegetation model. *Ecol. Modell.* 395, 11–22.

Rija, A.A., Mgelwa, A.S., Modest, R.B., & Hassan, S.N. (2015). Composition and Functional Diversity in Bird Communities in a Protected Humid Coastal Savanna. *Adv. Zool.* 2015, 864219.

Ruvuga, P.R., Wredle, E., Mwakaje, A., Selemani, I.S., Sangeda, A.Z., Nyberg, G., & Kronqvist, C. (2020). Indigenous Rangeland and Livestock Management Among Pastoralists and Agro-pastoralists in Miombo Woodlands, Eastern Tanzania. Rangel. *Ecol. Manag.* 73, 313–320.

Ruvuga, P.R., Wredle, E., Nyberg, G., Hussein, R.A., Masao, C.A., Selemani, I.S., Sangeda, A.Z., & Kronqvist, C. (2021). Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements. *J. Environ. Manage.* 290, 112635.

Sheil, D. (2022). Tanzanian coastal forests - unique, threatened and overlooked. 26pp.

Schoonenboom, J.; Johnson, R.B. (2017). How to Construct a Mixed Methods Research Design. Kolner Z. Soz. Sozpsychol. 69, 107–131.

Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., & Steininger, M.K. (2010). Forest and Woodland Cover and Change in Coastal Tanzania and Kenya, 1990 to 2000. *J. East African Nat. Hist.* 99, 19–45.

URT, MFP, NBS, PO-FP, OCGS, (2022). The 2022 Population and Housing Census: Administrative Units Population Distribution Report. Dodoma, Tanzania.

Wegner, G., Howell, K.M., Davenport, T.R.B., & Burgess, N.D. (2009). The Forgotten 'Coastal Forests' of Mtwara, Tanzania : A Biologically Impoverished and Yet Important Ecosystem and yet important ecosystem. *Journal of East African Natural History,* 98, 167–209.

Woodhouse, E., & Mccabe, J.T. (2018). Well-being and conservation: diversity and change in visions of a good life among the Maasai of northern Tanzania. *Ecol. Soc.* 23, 43.

Young, T.P., Porensky, L.M., Riginos, C., Veblen, K.E., Odadi, W.O., Kimuyu, D.M., Charles, G.K., & Young, H.S. (2018). Relationships between Cattle and Biodiversity in Multiuse Landscape Revealed by Kenya Long-Term Exclosure Experiment. Rangel *Ecology Management, 7*1, 281–291.

CHAPTER THREE

MANUSCRIPT TWO

3.0 Woody species composition, structure and regeneration status in relation to livestock grazing intensity in the coastal forests of Southern Tanzania

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Abstract

Coastal forests are a unique biome in East Africa, threatened by excessive livestock grazing. The study was conducted to assess the effects of various livestock grazing intensities on the woody plant composition, vegetation structure, and regeneration capacity of the coastal forests. The study was conducted in the forest reserve and grazed village forests in Kilwa district, southern Tanzania. Two strata were established systematically and divided into clusters within grazed forest and ungrazed reserve (control). Eight 10 m radius concentric circular plots were established per cluster and used as

the sampling unit. Individual plots were categorized as no, low, moderate, and heavy grazing based on herbaceous plant defoliation, presence of dung, livestock tracks, and foraging livestock. Woody plant information was collected in the respective plots, with plants grouped into seedlings, saplings, poles, and trees. Stem density and diversity indices were estimated in the individual plant group and grazing intensity. There were 97 species in no, 47 in low, 35 in moderate, and 44 in heavy grazing plots. The diversity of trees and seedlings varied significantly among grazing intensities. Moderate and heavy grazing had the lowest seedlings and tree diversity indices, which are unsuitable for biodiversity conservation. Trees and seedlings' density differed in the grazing intensity, with the lowest values in moderate and heavy grazing due to the possible trampling of the plants in the area. The stem distribution of seedlings, saplings, poles, and trees indicated forest degradation in moderately and heavily grazed plots. Low grazing intensity had diversity indices, stem density, and regeneration status similar to or better than no grazing. Low grazing intensity was the suitable grazing regime for livestock due to its maintenance of other ecosystem services in the forest.

Keywords: Forest disturbance, Livestock-forest interaction, Ecosystem services, Forest regeneration, Grazing regime, Plant community, Biodiversity conservation, Tree cover

3.1 Introduction

Coastal forests are the remnants of a once vast biome covering Eastern Africa (EA) from Somalia to Mozambique (Kibet, 2011). The biomes are defined by closed-canopy, evergreen trees with dense shrubs and thickets found in the swamps, riverine, and coastal transitional areas, excluding mangrove forests (Tabor *et al.*, 2010; Kibet, 2011). These forests are under two managerial systems in EA: protected coastal forests under state-funded conservation

agencies and village forests managed by local communities (Burgess *et al.*, 2017; Kibet, 2011). The forests are among the biodiversity hotspots due to their status as habitats for various endangered or threatened endemic species of plants, mammals, birds, amphibians, and reptiles (Burgess *et al.,* 2017; Gereau *et al.*, 2016). Consequently, they contribute to biodiversity conservation, recreational activities, nutrient recycling, carbon stocking, and many more ecosystem services (Burgess *et al.*, 2017; Ntukey *et al.*, 2022; Wegner *et al.*, 2009). However, there is a conflict between the utilization and protection of this biome due to increased forest disturbances (deforestation and livestock grazing), especially in the village forests, as the result of population growth and the climate change effects (Ligate *et al.,* 2018; Wegner *et al.,* 2009). The disturbances have led to a 29% decline in the tree cover in the past 20 years, threatening forest sustainability and associated ecosystem services (Ntukey *et al.*, 2022).

Human activities (except tourism and research) are restricted in the protected coastal forests as a result, while a land use plan is promoted in village forests under the reduced emissions and forest degradation (REDD+) scheme to ensure sustainability (Burgess *et al.,* 2017; Ntukey *et al.,* 2022). However, livestock grazing is acceptable in many wooded landscapes of southern Africa due to the degradation and decline in the size of grasslands (Chidumayo & Kwibisa 2003; Mtimbanjayo & Sangeda, 2018). Nonetheless, livestock grazing and its relation to wooded biomes sustainability is debated among foresters, and animal- and rangeland scientists. Foresters argue that heavy livestock grazing reduces soil water infiltration, tree regeneration, and tree cover and increases biodiversity losses (Ligate *et al.*, 2018; Lulandala *et al.*, 2022; Ntukey *et al.,* 2022). Alternatively, animal and range scientists argue that livestock grazing in wooded-landscape simulates wildlife foraging behavior and distributes nutrients and seeds (Mouissie *et al.*, 2005; Mtimbanjayo & Sangeda, 2018; Mayengo *et al.,* 2020). It is also evident that grazing livestock reduces herbaceous biomass

(fuel for the fire), which reduces fire- frequency, and intensity that maintains tree cover (Tarimo *et al.,* 2015; Mligo, 2019). Low to moderate livestock grazing (fewer numbers over a long time or large numbers in a short time) can maintain the existing tree cover and other ecosystem services (Mtimbanjayo & Sangeda, 2018). Also, goats can maintain tree cover in the coastal forest, unlike cattle with large body sizes and tramps on the seedlings or sprouts, *i.e.* regenerates (Liao *et al.,* 2016; Mohammed *et al.,* 2020).

However, animal and range scientists' arguments are derived from dry miombo woodlands with an open-canopy (10 - 40%), and herbaceous plants are abundant, contrary to the coastal forests with closed-canopy and dense shrubs or thickets (Lupala *et al.,* 2015). Likewise, foresters' arguments are derived partly from the dry miombo woodlands (Lulandala *et al.,* 2022), while the studies in coastal forests (Ligate *et al.,* 2018; Ntukey *et al.*,2022) did not assess the different levels of grazing intensities (number of grazing livestock per unit area). Therefore, the current study assessed the effects of various livestock grazing intensities on the woody plant composition, vegetation structure, and regeneration status in the coastal forest of southern Tanzania. The findings would contribute to the ongoing debate on the relevance of livestock grazing in the coastal forests and similar biomes in EA. Also, the study will inform policy and decision-makers on sustainable practices for coastal forest management to ensure the current and future delivery of different ecosystem services.

3.2 Methods

3.2.1 Description of the study area

The study was conducted in the coastal forests found in Kilwa district (8°15′ - 10°00′S and 38°40′ - 39°40′E), southern Tanzania. The area has chromic vertisol soil, an annual temperature of 22 - 30^{o}C, and rainfall of 1 000 – 1 400mm. The coastal forests in the district include the Kitope forest reserve managed by the Tanzania Forest Service (TFS) and individual village forests under the

respective village natural resource committee (VNRC). The forest reserve has a management plan that follows national guidelines and conservation policies prohibiting destructive human activities, such as timber harvesting, farming, and grazing. Alternatively, village forests are communal, whereby all individuals in the respective village can access the forest, and the entire village decides on uses. Moreover, local laws are enacted by villagers and enforced by VNRC to ensure compliance with the assigned forest uses (Kalonga & Kulindwa, 2017).

A land use plan was introduced in 2007 in Kinjumbi, Marendego, and Somangasimu villages within the district, whereby village forests were divided into areas for livestock grazing and non-charcoal utilization (fire woods, timber, and beekeeping). Kinjumbi, Marendego, and Somangasimu have grazing areas of 450ha, 1 500ha, and 355ha, respectively. The presence of grazing land had attracted livestock immigration in the area due to their eviction from Usangu wetlands in southern Tanzania (Ngail, 2011). The livestock population is 5 600 cattle, 3 860 goats, and 1 123 sheep in Kinjumbi, 15 560 cattle, 950 goats, and 1 090 sheep in Marendego and 26 160 cattle, 1 310 goats and 109 sheep in Somangasimu. The stocking rate is estimated at 9.8 TLU (Tropical Livestock Unit ≈ 250kg live weight)/ha for Kinjumbi, 7.4 TLU/ha for Marendego and 52 TLU/ha for Somangasimu. The high stocking rate has added utilization pressure on the available forest resources and jeopardized local community livelihoods. Therefore, the presence of forest reserve and ongoing livestock activities in the village forests offered a unique opportunity to assess the effects of grazing on woody vegetation in the coastal forests; hence, the area selection.

3.2.2 Study design and data collection

The vegetation study was conducted from February to March 2023 before the long rain season began in the area. Two different strata were established systematically in the studied area (Figure 3.1); Strata one was located in the grazed village forests of Kinjumbi,

Marendego, and Somangasimu, while Strata two was in the Kitope forest reserve that was used as the control. Strata one covered a 2 305 ha area with six clusters (two in each village), and strata two covered 3 385 ha with four clusters.

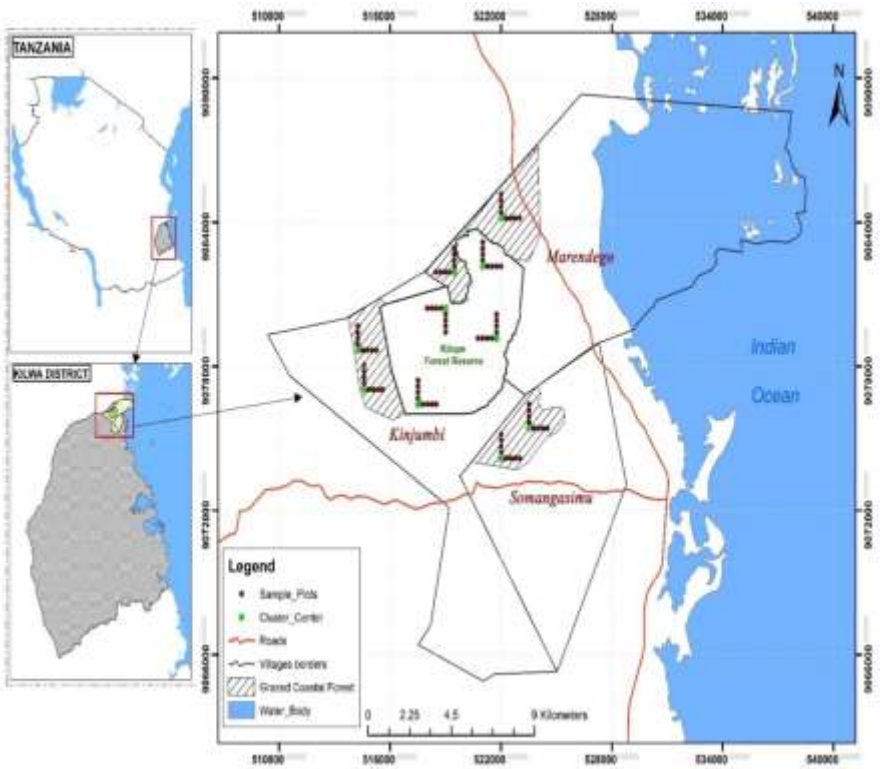

Figure 3.1: **Map of the studied area showing cluster layouts and plot locations in the coastal forests of southern Tanzania**

A total of 80 concentric circular plots (8 plots per cluster) with a 10 m radius were established and used as the sampling unit following NAFORMA (National Forest Resources Monitoring and Assessment) procedures (TFS, 2015). Individual plots were first assessed for livestock grazing activities by looking for signs of herbaceous plant defoliation, the presence of- dung, livestock tracks, and any foraging livestock nearby. The grazing intensity was categorized as no (30

plots), low (15 plots), moderate (15 plots), and heavy (20 plots) grazing (Table 3.1).

Moreover, the plot radius was divided into 2m, 5m, and 10 m radii, which were used to collect different types of vegetation data. The 2m radius plot was used to collect the number of seedlings (plants with a diameter of <2cm) that were measured using a caliper. Plants with 5 - 10 cm in diameter at breast height (DBH, ~1.3m) were counted in the 5 m radius plots. All trees with >10cm DBH were counted within the 10 m radius plot in the studied area. The counted plants in the plots were identified on-field by an experienced botanist from the Tanzania Forest Research Institute (TAFORI). The stem numbers of individual woody plants were recorded per plot area (calculated with radius) and superimposed in 10,000m^2 to determine the stem densities per hectare.

Table 3.1: Description of the different grazing intensity categories in the coastal forests of Southern Tanzania

Grazing intensity	Description
No grazing	Lack of livestock track or foraging livestock, no visible sign of herbaceous plant defoliation, and absence of livestock dung
Low grazing	Livestock track, herbaceous plant defoliation, and livestock dung were barely seen in the plot, and no foraging livestock was found in the plot or the proximity.
Moderate grazing	Few livestock were seen foraging, dungs were seen quickly, and there were clear signs of herbaceous plant defoliation, but the herbaceous biomass was still intact with small patches of bare land.
Heavy grazing	Many livestock were seen foraging, the presence of permanent livestock tracks, and herbaceous biomass was depleted with large patches of bare land.

3.2.3 Data analysis

The identified woody plants were categorized according to their DBH classes: seedlings (<2cm), saplings (2-5cm), poles (6-10cm), and trees (>10cm) to assess vegetative parameters in different ages. The basal area and volume were only calculated in the sapling, poles, and tree classes. Basal area was calculated in hectares as $BA = (\pi \times DBH^2)/(4 \times 10{,}000)$, and the volume was $V = 0.00016 \times DBH^{2.472}$ for woodlands in southern Tanzania (Mauya *et al.,* 2014). The diversity indices (species- diversity, dominance, evenness, and richness) were calculated independently in the respective DBH classes. The Shannon-Wiener index was used to estimate species diversity as described by Ligate *et al.* (2018), whereby the index increases with the number of wood species. The species' evenness or equitability was computed using the Shannon equitability index Mauki *et al.* (2023), whose values are between zero and one, with one showing complete evenness. At the same time, richness was estimated as the total number of species found in the plot.

Likewise, the species percentage of occurrence was estimated as the number of individual species to the total number of plants found in the respective grazing intensity in each DBH class. The R Statistical program (version 4.2.3 for Windows) was used to analyze the data for stem densities, DBH, basal area, volume, and diversity indices. The analysis of variance mixed effect model (ANOVA type III) was used to analyze data: Y (stem density, DBH, basal area, volume, and diversity indices) = grazing intensity $_{(\text{Fixed effect})}$ + location $_{(\text{Random effect})}$ + residual error. Location (Kinjumbi, Somangasimu, Marendego, and Kitope forest reserve) was used as the random effect to generalize results over the whole forest in southern Tanzania. Turkey's test without adjustment was employed during the mean comparison, which was declared significant at $p < 0.05$.

3.4 Results

3.4.1 Plant Species Composition and Diversity

A total of 118 tree species (Appendix 1) were identified in the area, with 97 species in no grazing (control), 47 in low grazing, 35 in moderate grazing, and 44 in heavy grazing. These species belonged to 32 families, with Fabaceae (25%), Rubiaceae (8%), Combretaceae (7%), Malvaceae (7%), and Phyllanthaceae (6%) as the most prevalent families. *Pteleopsis myrtifolia* (6%), *Diplorhynchus condylocarpon* (15%), *Margaritaria discoidea* (15%) and *Tricalysia ovalifolia* (14%) were the most dominant trees (DBH, >10cm), poles (DBH, 6-10cm), saplings (DBH, 2-5cm) and seedlings (DBH, <2cm) species, respectively, in no grazing plots.

Low grazing plots were dominated by *Hymenocardia ulmoides* (9%) in trees, *Grewia platyclada* (20%) in poles, *Combretum hereroense* (24%) in saplings, and *Antidesma venosum* (14%) in seedlings. *Combretum molle* (10%) in trees, *Vachellia nilotica* (26%) in poles, and *C. hereroense* in saplings (18%) and seedlings (23%) were the most dominant species in moderate grazing plots. Heavy grazing plots had *Anacardium occidentale* (13%), *Lonchocarpus capassa* (22%), *Dalbergia nitidula* (10%), and *Tetracera litoralis* (25%) as the dominant trees, poles, saplings, and seedlings, respectively. Appendix 2 shows the frequency of occurrence of other species in the different grazing intensities.

The diversity indices did not differ ($p > 0.05$) in saplings and poles, but trees and seedlings had significant variations ($p < 0.05$) among different grazing intensities, as shown in Table 3.2. No grazing had the highest tree species- diversity (0.07), richness (7.1), and evenness (0.012), while moderate grazing had the lowest with low and heavy grazing plots in between the two. Otherwise, low grazing had the highest seedling diversity indices, followed by no, moderate, and heavy grazing plots. Generally, seedling diversity indices varied among grazed plots, unlike tree diversity indices.

Table 3.2: **Diversity indices of trees, poles, saplings and seedlings in different grazing intensities in the coastal forests of southern Tanzania**

Diversity indices	Grazing intensity				p-value
	No grazing	Low grazing	Moderate grazing	Heavy grazing	
Trees					
Species diversity	0.07 ± 0.01[a]	0.06 ± 0.01[a,b]	0.03 ± 0.01[b]	0.04 ± 0.01[b]	0.004
Species evenness	0.012 ± 0.002[a]	0.010 ± 0.002[a,b]	0.006 ± 0.002[b]	0.007 ± 0.002[b]	0.004
Species richness	7.1 ± 1.1[a]	5.4 ± 1.2[a,b]	2.7 ± 1.3[b]	3.5 ± 1.0[b]	0.004
Poles					
Species diversity	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.797
Species evenness	0.011 ± 0.002	0.013 ± 0.003	0.011 ± 0.002	0.011 ± 0.002	0.797
Species richness	3.6 ± 1.0	4.4 ± 1.0	3.5 ± 1.0	3.5 ± 0.9	0.865
Saplings					
Species diversity	0.08 ± 0.01	0.05 ± 0.02	0.06 ± 0.01	0.08 ± 0.01	0.162
Species evenness	0.016 ± 0.003	0.010 ± 0.003	0.012 ± 0.003	0.015 ± 0.002	0.162
Species richness	5.1 ± 1.1	2.8 ± 1.2	3.4 ± 1.1	4.7 ± 1.0	0.218
Seedlings					
Species diversity	0.07 ± 0.01[b]	0.11 ± 0.01[a]	0.04 ± 0.01[b]	0.03 ± 0.01[b]	<0.001
Species evenness	0.015 ± 0.003[b]	0.026 ± 0.003[a]	0.009 ± 0.003[b,c]	0.007 ± 0.002[c]	<0.001
Species richness	7.2 ± 2.0[b]	15.1 ± 2.2[a]	3.6 ± 2.0[b]	2.5 ± 1.7[b]	<0.001

a, b, c Means in the same row with different superscripts were statistically significant at p = 0.05

3.4.2 Stem densities, mean DBH, basal- area and volume

Figure 3.2 shows stem densities of saplings, poles, and trees in the different grazing intensities. Sapling density was higher than poles but lower than trees in no grazing, while the arrangement in low grazing (in ascending order) was saplings, poles, and trees. Otherwise, trees had the lowest density, followed by saplings and poles in moderate grazing; in contrast, the order was poles<trees<saplings in heavy grazing. Overall, there were no significant differences in the densities of poles ($p = 0.865$) and saplings ($p = 0.218$) among the grazing intensities.

Tree density differed ($p = 0.004$) among different grazing intensities, which was about three- and four times higher in no grazing than moderate and heavy grazing, respectively. However, low grazing did not differ in tree density with the control or other grazed plots. Seedling density differed statistically ($p < 0.001$) among the grazing intensities, whereby low grazing had a density that was four and six folds higher than moderate and heavy grazing, respectively (Figure 3.2).

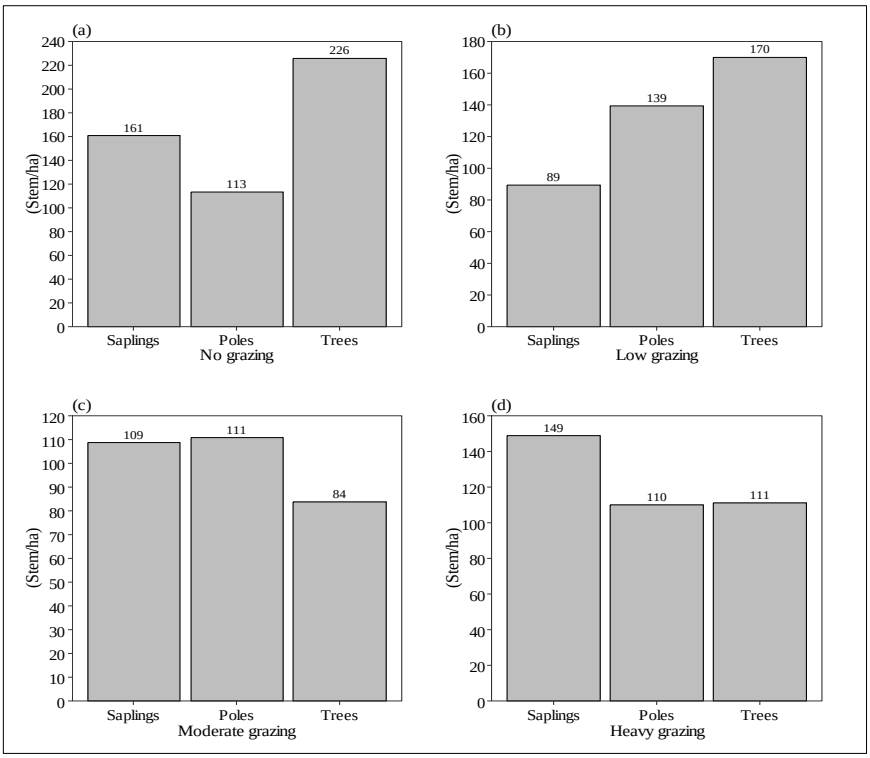

Figure 3.2: **Stem densities of saplings, poles and trees in different grazing intensities in coastal forests of southern Tanzania.**

Mean DBH, basal area, and volume in saplings and poles did not differ statistically ($p > 0.05$). Trees had significant variations ($p < 0.05$) in mean DBH, basal area, and volume among the different grazing intensities (Table 3.3). The tree DBH, area, and volume were highest in no grazing and lowest in moderate grazing for 5.5 cm, 10.7 m^2/ha, and 120.4 m^3/ha, respectively. Moreover, mean DBH, basal area, and tree volume did not vary among the grazed plots in the studied area.

Figure 3.3: **Mean diameter at breast height (DBH), basal area and volume of trees, poles and saplings in different grazing intensities in the coastal forests of southern Tanzania**

Parameters	Grazing intensity				p-value
	No grazing	Low grazing	Moderate grazing	Heavy grazing	
Trees (DBH, >10cm)					
Mean DBH (cm)	23.7 ± 1.8[a]	19.0 ± 2.1[b]	18.2 ± 2.7[b]	20.4 ± 1.9[a,b]	0.044
Basal area (m^2/ha)	13.1 ± 2.4[a]	5.8 ± 2.7[a,b]	2.4 ± 2.9[b]	4.6 ± 2.0[b]	<0.001
Basal volume (m^3/ha)	141.3 ± 29.4[a]	55.8 ± 33.7[a,b]	20.9 ± 35.8[b]	50.2 ± 24.3[b]	<0.001
Poles (DBH, 6-10cm)					
Mean DBH (cm)	7.9 ± 0.3	8.1 ± 0.3	8.1 ± 0.3	8.3 ± 0.3	0.517
Basal area (m^2/ha)	0.5 ± 0.2	0.8 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.790
Basal volume (m^3/ha)	3.0 ± 1.1	4.3 ± 1.1	3.4 ± 1.0	3.6 ± 1.0	0.773
Saplings (DBH, 2-5cm)					
Mean DBH (cm)	3.7 ± 0.2	3.7 ± 0.3	3.9 ± 0.2	4.1 ± 0.2	0.196
Basal area (m^2/ha)	0.18 ± 0.05	0.11 ± 0.06	0.15 ± 0.05	0.21 ± 0.04	0.378
Basal volume (m^3/ha)	0.70 ± 0.22	0.44 ± 0.24	0.62 ± 0.20	0.90 ± 0.19	0.363

a, b Means in the same row with different superscripts were statistically significant at p = 0.05

3.5 Discussion

The assessed coastal forests had plants that are common in the biome and other wooded landscapes in the tropics (Kibet 2011; Burgess *et al.,* 2017; Ligate *et al.,* 2018; Mtimbanjayo & Sangeda, 2018), except for *Anacardium occidentale* in the heavy grazing. Although *A. occidentale* was the dominant species in heavy grazing, livestock had no contribution to its spread because the leaves and fruits of the plant contain anti-nutritional compounds that are toxic to animals (Filho & Soto-Blanco 2012; Costa *et al.,* 2020). Consequently, the presence of *A. occidentale* in this study was attributed to its use as a cash crop and farming activities in the village forest before introducing the land use plan in 2007 (Wegner *et al.,* 2009). Nonetheless, the species diversity in this study was lower than 0.7 - 2.9 while evenness was within 0.01 - 0.95, and richness was higher than 2.5 - 5.7 except for low (trees only), moderate, and heavy grazing plots that were within the range reported in the conserved and disturbed coastal forests (Ligate et al. 2018; Ntukey *et al.,* 2022).

The diversity and richness variations between the studies were attributed to the differences in the level of human disturbances and the size of the sampling unit, which was smaller in the current study than in the former (Ligate *et al.,* 2018). However, the species diversity (0.03 - 0.11, Table 2) was remarkably lower than 1.0 - 3.7 (Kimaro & Lulandala, 2013; Mauki *et al.*, 2023) due to the differences in disaggregation (seedlings, saplings, poles, and trees) that was done to show the succession trends in the studied area. Otherwise, the tree diversity variations between no-grazing and moderate or heavy grazing meant moderate and heavy stocking rates were inappropriate for plant diversity conservation in the coastal forests, as noted by Ligate *et al.* (2018) and Ntukey *et al.* (2022). However, the lack of variations in the tree diversity between no (conserved forest) and low grazing plots meant no grazing was the appropriate stocking rate that protected tree diversity in the coastal forest. Similarly, no grazing had the highest seedling

diversity, in contrast to the trend in trees (no grazing had the highest diversity indices) due to the recruitment of pioneer plant species similar to other reports in the coastal forests (Mligo, 2019). Also, the pioneer plant recruitment explained the lack of variations in saplings and pole diversity indices in the current study.

Tree density in this study was within 130 - 554 stems/ha and 30 - 390 stems/ha for conserved and disturbed coastal forests, respectively (Kimaro & Lulandala, 2013; Mligo 2015; Ligate *et al.,* 2018; Mauki *et al.,* 2023). The saplings and pole densities were higher than 15 - 65 stems/ha but lower than 240 stems/ha, respectively (Ligate et al., 2018; Mligo, 2019). Similarly, seedling density in the current study was higher than 10 - 3,800 stem/ha except for moderate and heavy grazing that were within the range (Rocky & Mligo, 2012; Ligate *et al.,* 2018; Mligo, 2019). Sapling, pole, and seedling variations in stem densities between the current and the former studies can be attributed to the differences in plant species composition and forest management. Otherwise, tree density did not vary between no and heavy grazing, which was in contrast to the study in miombo (Mtimbanjayo and Sangeda, 2018), likely due to the presence of *A. occidental*, an exotic tree species, in the heavily grazed plots. The *A. occidental* presence and long-term grazing (16 years since land use inception) explained the higher tree density in heavy than moderate grazing, contrary to the findings in miombo woodlands (Mtimbanjayo & Sangeda, 2018; Ruvuga *et al.,* 2021). The lowest tree density (84 stems/ha) in moderate grazing and lack of variations between no-grazing and low grazing showed that low grazing was appropriate for tree cover protection in the coastal forests of Eastern Africa.

Likewise, low grazing had higher seedling density than no grazing, similar to Ligate *et al* (2018) findings due to the relatively higher tree density in the conserved forest (no grazing, Figure 2). Consequently, higher tree density resulted in large canopy cover, which limited available space and light for seedlings in no grazing. Lower seedling

density in moderate and heavy grazing could be due to the livestock trampling of the regenerates, limiting their development (Dunne *et al.,* 2011; Mtimbanjayo & Sangeda, 2018). Also, low seedling density could be due to the increased soil erosion, compaction, and prolonged effects of grazing in moderate and heavy grazing (Dunne *et al.,* 2011; Lulandala *et al.,* 2022). These findings indicated that moderate and heavy grazing affects the regeneration potential of coastal forests in EA. The distribution of plant densities (Figures 2 and 3) showed that moderate and heavy grazed plots are degraded despite the lack of variations ($p > 0.05$) in saplings or pole density among the treatments. The claim is derived from the relatively lower number of seedlings, saplings, poles, and trees, which would be unsustainable in the current grazing regimes. Therefore, low grazing intensity is recommended due to its ability to maintain tree cover in the coastal forests, which is essential in carbon sequestration, recreational activities, nutrient recycling, and other provisional ecosystem services.

The suitability of low grazing is substantiated by its similarity in tree basal area and volume with no grazing. Basal area and volume influence above-ground biomass carbon storage (Ntukey *et al.,* 2022); hence, low grazing maintained coastal forests' potential for carbon stocking and climate change mitigation. Moreover, the variations in tree basal area and volume among the grazed plots in this study, despite heavy grazing possessing higher mean DBH than low or moderate grazing, were attributed to their differences in density. Nonetheless, this study's trees and saplings basal area were within 0.8 - 34.6 m^2/ha for the conserved but higher than 0.2 - 0.7 m^2/ha for disturbed coastal forests, respectively (Ligate *et al.,* 2018; Mauki *et al.,* 2023). The volume was within 0.5 - 633 m^3/ha for woody plants in the conserved forest and 0.2 - 31.5 m^3/ha (except for low and heavy grazing that were higher) for disturbed coastal forest (Mligo 2015; Ligate *et al.,* 2018; Jilala *et al.,* 2019). The basal area and volume variations between the current and former studies were attributable to the differences in plant species composition,

stem density, and criteria for woody plant disaggregation. These attributes also explained lower DBH than 7 - 12cm for saplings, while trees had DBH within 13 - 78 cm (Ligate *et al.,* 2018).

Overall, livestock grazing, even at a moderate rate, affected woody plant densities, diversity indices, and regeneration capacity (seedlings), as was argued by Ligate *et al*.(2018) in coastal forests and Lulandala *et al*. (2022) in miombo woodlands. Therefore, livestock grazing should be limited to low grazing intensity in the forest, unlike in miombo woodlands, as Ruvuga *et al*. (2021) noted. If livestock grazing intensity were to be increased to a moderate stocking rate due to the existing livelihood vulnerability and livestock immigration in southern Tanzania (Ngailo, 2011), herd structure should be changed. This is because cattle dominated the herd in the three studied villages, and their large body size could reduce regeneration capacity due to the trampling effects (Dunne et al. 2011; Mtimbanjayo & Sangeda, 2018). Alternatively, goats have small body sizes that may reduce seedlings trampling and soil compaction (Chidumayo & Kwibisa, 2003; Liao *et al.,* 2016). Herd shift from cattle to goats and their effect on plant composition, diversity indices, and regeneration capacity require further studies to ensure coastal forest sustainability in the EA. Generally, field observations showed the presence of other anthropogenic activities, such as illegal tree clearing for farming, charcoal making, and timber in the village forest. Therefore, future studies should investigate the effects of integrated livestock-crop cultivation on vegetation structure in coastal forests.

3.6 Conclusion

Generally, livestock grazing intensity affected plant species composition, diversity indices, and stem densities in the studied coastal forests. Moderate and heavy grazing resulted in lower stem density, diversity indices, and regeneration capacity, threatening coastal forest sustainability and other ecosystem services. The low stem densities in the moderate and heavy grazing were attributed to

livestock trampling and the possible soil erosion in the forest. Consequently, moderate and heavy grazing plots were denoted as degraded due to their relatively lower numbers of seedlings, saplings, poles, and trees in the studied area. Otherwise, low grazing intensity had species diversity indices, stem densities, regeneration capacity, basal- area, and volume similar to or even better than no grazing (conserved forest). Therefore, low grazing intensity was the appropriate grazing regime in the coastal forests of EA due to its potential to maintain other ecosystem services such as carbon sequestration and stocking and biodiversity conservation.

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Authors' contributions
Kashenge S.S. conceived the research idea and collected data, writing - an original draft, formal analysis and visualization. Ruvuga P. R. methodology, data analysis, visualization and writing - review and editing. Maleko D. D. and Mbeyale E. E. conceptualization, methodology, supervision and writing - review and editing. All authors read and approved the manuscript for submission.

Data availability statement
The dataset used in this study and statistical codes are available from the corresponding author on request.

Conflicts of interest

Mr. Salhina S. Kashenge is employed permanently by the Tanzania Forest Service (TFS), which is responsible for forest protection in the country. However, TFS did not participate in the study design, data analysis or manuscript development.

References

Abdul Rahman, S., & Reed, K., (2014). The management and welfare of working animals: identifying problems, seeking solutions and anticipating the future. *Rev. sci. tech. Off. int. Epiz 33*, 41–45.

Andrew, S.M., 2021. Effects of Plant Species Diversity and Biomass on Grazing Patch Selection by Semi Free-Ranging Cattle, *47*, 282–295.

Aynekulu, E., Mekuria, W., Tsegaye, D., Feyissa, K., Angassa, A., de Leeuw, J., & Shepherd, K., (2017). Long-term livestock exclosure did not affect soil carbon in southern Ethiopian rangelands. *Geoderma, 307*, 1–7. https://doi.org/10.1016/j.geoderma.2017.07.030

Benjaminsen, T.A., Maganga, F.P., & Abdallah, J.M., (2009). The Kilosa Killings: Political Ecology of a Farmer-Herder Conflict in Tanzania. *Dev. Change* 40, 423–445. https://doi.org/10.1111/j.1467-7660.2009.01558.x

Burgess. N., Muir. C, (Ed.), (1994). Coastal Forest of Eastern Africa: Biodiversity and Conservation, in: Proceedings of the Coastal Forests of Eastern Africa Workshop. Royal society for the Protection of Birds, UK, pp. 1–112.

Burgess, N.D., Malugu, I., Sumbi, P., Kashindye, A., Kijazi, A., Tabor, K., Mbilinyi, B., Kashaigili, J., Wright, T.M., Gereau, R.E., Coad, L., Knights, K., Carr, J., Ahrends, A., & Newham, R.L., (2017). Two decades of change in state, pressure and conservation responses in the coastal forest biodiversity hotspot of Tanzania. *Oryx,* 51, 77–86. https://doi.org/10.1017/S003060531500099X

Carney, J., Gillespie, T.W., & Rosomoff, R., (2014). Assessing forest change in a priority West African mangrove ecosystem : 1986 – 2010. *Geoforum 53,* 126–135. https://doi.org/10.1016/j.geoforum.2014.02.013

Chidumayo, E.N., & Kwibisa, L., (2003). Effects of deforestation on grass biomass and soil nutrient status in miombo woodland, Zambia. *Agric. Ecosyst. Environ. 96*, 97–105. https://doi.org/10.1016/S0167-8809(02)00229-3

Clarke, G.P., Burgess, N.D., Mbago, F.M., Mligo, C., Mackinder, B., Gereau, R.E., & Hermitage, T., (2011). Two ‘ Extinct ’ Trees Rediscovered Near Kilwa , Tanzania. pp. 133–140.

Costa, A.R., Silva, J.R. de L., de Oliveira, T.J.S., da Silva, T.G., Pereira, P.S., Borba, E.F. de O., de Brito, E.S., Ribeiro, P.R.V.,

Almeida-Bezerra, J.W., Júnior, J.T.C., de Menezes, I.R.A., Kamdem, J.P., Duarte, A.E., Barros, L.M., 2020. Phytochemical profile of Anacardium occidentale L. (cashew tree) and the cytotoxic and toxicological evaluation of its bark and leaf extracts. *South African J. Bot., 135,* 355–364. https://doi.org/10.1016/j.sajb.2020.09.017

Dallu, A., (2004). A national synthesis report for the preparation of WWF—EACFE Programme. Coast. For. Tanzania. pp. 1–29.

Dickinson. A., Burgess. N. D., Clarke .G. P., (2010). Status and biological diversity. Tanzania Coast. For. pp.1–15.

Dunne, T., Western, D., Dietrich, W.E., (2011). Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical rangeland. *J. Arid Environ. 75*, 58–69. https://doi.org/10.1016/j.jaridenv.2010.09.001

Egeru, A., Wasonga, O., Macopiyo, L., Mburu, J., Tabuti, J.R.S., & Majaliwa, M.G.J., (2015). Piospheric influence on forage species composition and abundance in semi-arid Karamoja sub-region, Uganda. *Pastoralism 5,* 12. https://doi.org/10.1186/s13570-015-0032-y

Filho, M.R.R., & Soto-Blanco, B., (2012). Poisoning by cashew apple (*Anacardium occidentale* L.) in cattle. *Acta Sci. Vet.* 40, 1083.

Fynn, R.W.S., & O'Connor, T.G., (2000). Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. *J. Appl. Ecol., 37*, 491–507. https://doi.org/10.1046/j.1365-2664.2000.00513.x

Gayo, L., (2022). Local community perception on the State Governance of mangroves in Western Indian coast of Kinondoni and. Glob. *Ecol. Conserv., 39,* e02287. https://doi.org/10.1016/j.gecco.2022.e02287

Gereau, R.E., Cumberlidge, N., Hemp, C., Hochkirch, A., Jones, T., Kariuki, M., Lange, C.N., Loader, S.P., Malonza, P.K., Menegon, M., Ndang, K., Rovero, F., & Shirk, P., (2016). Globally Threatened Biodiversity of the Eastern Arc Mountains and Coastal Forests of Kenya and Tanzania. *J. East African Nat. Hist. 105*, 115–201. https://doi.org/10.2982/028.105.0104

Gichohi-wainaina, W.N., Mremi, R., Chande, M., Msuya, J.M., Kumwenda, N.C., Muzanila, Y.C., Msere, H., & Muhimbula, H., (2022). Drivers of Pigeon Pea Consumption Among School-Aged Children in Central Tanzania. Front. Sustain. *Food Syst*. *5*, 726404. https://doi.org/10.3389/fsufs.2021.726404

Godde, C.M., Garnett, T., Thornton, P.K., Ash, A.J., & Herrero, M., (2018). Grazing systems expansion and intensification: Drivers, dynamics, and trade-offs. *Glob. Food Sec. 16,* 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

Godoy, F.L., Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., & Steininger, M.K., (2011). Deforestation and CO_2 emissions in coastal Tanzania from 1990 to 2007. *Environ. Conserv.*, *39*, 62–71. https://doi.org/10.1017/S037689291100035X

Habel, J.C., Casanova, I.C.C., Zamora, C., Teucher, M., Hornetz, B., Shauri, H., Mulwa, R.K., & Lens, L., (2017). East African coastal forest under pressure. Biodivers. Conserv. https://doi.org/10.1007/s10531-017-1375-z

Hassan, S.N., Salum, A.R., Rija, A.A., Modest, R., Kideghesho, J.R., & Malata, P.F., (2013). Human-induced Disturbances Influence on Bird Communities of Coastal Forests in Eastern Tanzania. *3*, 48–64.

Hilario, M.C., Wrage-Mönnig, N., & Isselstein, J., (2017). Behavioral patterns of (co-)grazing cattle and sheep on swards differing in plant diversity. *Appl. Anim. Behav. Sci., 191,* 17–23. https://doi.org/10.1016/j.applanim.2017.02.009

Howell. K.M. , Msuya. C.A., (2002). UTUMI Biodiversity Surveys Tanzania Annexes Final. pp.1–72.

Howell, K.M., Msuya, C.A., Mligo, C., Werema, C., Kihaule, P., Honorati, M.K., & Suleiman, H.O., (2012). Biodiversity Surveys of Poorly Known Coastal Forests of Southeastern Tanzania and Zanzibar. Wwf Final vers, 171p.

Jilala, Z.J., (2015). Effects of human activities to the composition of woody plant species of Ngarama south forest reserve in Kilwa district, Tanzania. *2,* 108–118. https://doi.org/10.13057/ asianjethnobiol/y020205

Jilala, Z.J., Mwakalukwa, E.E., & Chamshama, S.A.O., (2019). Human activities outcomes on the composition of woody plant species of Ngarama Southern Forest Reserve in Kilwa District, Tanzania. *Asian J. Ethnobiol. 2,* 108–118. https://doi.org/10.13057 /asianjethnobiol/y020205

Kalonga, S.K., & Kulindwa, K.A., (2017). Does forest certification enhance livelihood conditions? Empirical evidence from forest management in Kilwa District, Tanzania. *For. Policy Econ. 74*, 49–61. https://doi.org/10.1016/j.forpol.2016.11.001

Kazungu, M., Zhunusova, E., Yang, A.L., Kabwe, G., & Gumbo, D.J., Günter, S., (2020). Forest use strategies and their

determinants among rural households in the Miombo woodlands of the Copperbelt Province, Zambia. For. Policy Econ. 111, 102078. https://doi.org/10.1016/j.forpol. 2019.102078

Kibet, S., (2011). Plant communities, species diversity, richness, and regeneration of a traditionally managed coastal forest, Kenya. For. Ecol. Manage. 261, 949–957. https://doi.org/10.1016 /j.foreco.2010.11.027

Kikoti, I.A., Mligo, C., (2015). Impacts of livestock grazing on plant species composition in montane forests on the northern slope of Mount Kilimanjaro, Tanzania. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* 11, 114–127. https://doi.org/10.1080/ 21513732.2015.1031179

Kimaro, E.G., Mor, S.M., Gwakisa, P., & Toribio, J.A., (2017). Seasonal occurrence of Theileria parva infection and management practices amongst Maasai pastoralist communities in Monduli District, Northern Tanzania. Vet. Parasitol. 246, 43–52. https://doi.org/ 10.1016/j.vetpar. 2017.08.023

Kimaro, J., & Lulandala, L., (2013). Human Influences on Tree Diversity and Composition of a Coastal Forest Ecosystem: The Case of Ngumburuni Forest Reserve, Rufiji, Tanzania. Int. J. For. Res. 305874. https://doi.org/10.1155/2013/305874

Kirui, K.B., Kairo, J.G., Bosire, J., Viergever, K.M., Rudra, S., Huxham, M., & Briers, R.A., (2013). Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. Ocean Coast. *Manag. 83,* 19–24. https://doi.org/10.1016/j.ocecoaman.2011.12.004

Liao, C., Ruelle, M.L., & Kassam, K.A.S., (2016). Indigenous ecological knowledge as the basis for adaptive environmental management: Evidence from pastoralist communities in the Horn of Africa. *J. Environ. Manage.* 182, 70–79. https://doi.org/10.1016/J.JENVMAN.2016.07.032

Ligate, J.E., Wu, C., &Chen, C., (2018). Investigation of tropical coastal forest regeneration after farming and livestock grazing exclusion. *J. For. Res. 30,* 1873–1884. https://doi.org/10.1007/ s11676-018-0792-5

Liingilie, A.S., Kilawe, C., Kimaro, A., Rubanza, C., Jonas, E., Centre, W.A., Box, P.O., & Salaam, D., (2015). Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. Mediterr. J*. Biosci. 1,*

27–31.

Lulandala, L., Bargués-tobella, A., Nyberg, G., Ilstedt, U., & Masao, C.A., (2022). Excessive livestock grazing overrides the positive effects of trees on infiltration capacity and modifies preferential flow in dry miombo woodlands. *L. Degrad. Dev. 33,* 581–595. https://doi.org/10.1002/ldr.4149

Lupala, Z.J., Lusambo, L.P., Ngaga, Y.M., & Makatta, A.A., (2015). The Land Use and Cover Change in Miombo Woodlands under Community Based Forest Management and Its Implication to Climate Change Mitigation: A Case of Southern Highlands of Tanzania. *Int. J. For. Res. 459102*, 11. https://doi.org/10.1155/2015/459102

Mauki, D.G., Kinyero, O., & Meela, F., (2023). The influence of Brachylaena huillensis O. hoffm on diversity, abundance and structure of Mtunguru Forest Reserve in Tanzania. *Environ. Sustain. Indic. 19,* 100273. https://doi.org/10.1016/j.indic.2023.100273

Mauya, E.W., Mugasha, W.A., Zahabu, E., Bollandsås, O.M., Eid, T., 2014. Models for estimation of tree volume in the miombo woodlands of Tanzania. *South. For. 76,* 209–219. https://doi.org/10.2989/20702620.2014.957594

Mayengo, G., Armbruster, W., & Treydte, A.C., (2020). Quantifying nutrient re-distribution from nutrient hotspots using camera traps, indirect observation and stable isotopes in a miombo ecosystem, Tanzania. *Glob. Ecol. Conserv. 23,* e01073. https://doi.org/10.1016/j.gecco.2020.e01073

Mesfin, D., Simane, B., Belay, A., Recha, J.W., & Taddese, H., (2020). Woodland Cover Change in the Central Rift Valley of Ethiopia. *Forests 11,* 916. https://doi.org/doi:10.3390/f11090916

Mligo, C., (2019). Post fire regeneration of indigenous plant species in the Pugu Forest Reserve, Tanzania. *Glob. Ecol. Conserv. 18,* e00611. https://doi.org/10.1016/j.gecco.2019.e00611

Mligo, C., (2015). Conservation of plant biodiversity of Namatimbili forest in the southern coastal forests of Tanzania. Int. J. Biodivers. *Conserv. 7,* 148–172. https://doi.org/10.5897/ijbc2014.0771

Mohammed, A.S., Animut, G., Urge, M., & Assefa, G., (2020). Grazing behavior, dietary value and performance of sheep, goats, cattle and camels co-grazing range with mixed species of grazing and browsing plants. *Vet. Anim. Sci. 10,* 100154.

https://doi.org/10.1016/j.vas.2020.100154
Mouissie, A.M., Vos, P., Verhagen, H.M.C., Bakker, J.P., 2005. Endozoochory by free-ranging, large herbivores: Ecological correlates and perspectives for restoration. *Basic Appl. Ecol.* 6, 547–558. https://doi.org/10.1016/j.baae.2005.03.004
Mtimbanjayo, J.R., Sangeda, A.Z., 2018. Ecological Effects of Cattle Grazing on Miombo Tree Species Regeneration and Diversity in Central-Eastern Tanzania. *J. Environ. Res*. *2*, 3.
Mwambene, P.L., Mbwile, R.P., Hoeggel, F.U., Kimbi, E.C., Materu, J., Mwaiganju, A., & Madoffe, S., (2014). Assessing dynamics of forced livestock movements, livelihoods and future development options for pastoralists/agro-pastoralists in Ruvuma and Lindi Regions, in the Southern Tanzania. *Livest. Res. Rural Dev. 26*, #4.
Naah, J.B.S.N., & Guuroh, R.T., (2017). Factors influencing local ecological knowledge of forage resources: Ethnobotanical evidence from West Africa's savannas. *J. Environ. Manage. 188,* 297–307. https://doi.org/10.1016/j.jenvman.2016.11.064
NBS, (2021). National Sample Census of Agriculture 2019/20, The United Republic of Tanzania. Dodoma, Tanzania.
Nduwamungu, J., Munishi, P.K.T., Bloesch, U., Hagedorn, F., & Lulu, K., (2009). Recent Land Cover and Use Changes in Miombo Woodlands of Eastern Tanzania. *Tanzania J. For. Nat. Conserv, 78*, 50–59.
Ngailo, J.A., (2011). Assessing the effects of eviction on household food security of livestock keepers from the Usangu wetlands in SW Tanzania. *Livest. Res. Rural Dev. 23*, #65.
Ngenzi, O.D., Ruvuga, P.R., Msalya, G.M., & Maleko, D.D., (2023). Participatory establishment of Cenchrus ciliaris forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. *African J. Range Forage Sci.* https://doi.org/10.2989/ 10220119.2023.2219700
Nindi, J.S., Maliti, H., Bakari, S., Kija, H., & Machoke, M., (2014). Conflicts Over Land and Water Resources in the Kilombero Valley Floodplain, Tanzania. *Afr. Study Monogr, 50,* 173–190.
Njoghomi, E.E., Valkonen, S., Karlsson, K., Saarinen, M., Wilson A, M., Pentti, N., Celestino, B., & Rogers E, M., (2020). Regeneration Dynamics and Structural Changes in Miombo Woodland Stands At Kitulangalo Forest Reserve in Tanzania. *J. Sustain. For. 40,* 1–19. https://doi.org/10.1080/ 10549811. 2020.1789478

Ntukey, L.T., Munishi, L.K., & Treydte, A.C., (2022). Land Use Land/Cover Change Reduces Woody Plant Diversity and Carbon Stocks in a Lowland Coastal Forest Ecosystem, Tanzania. *Sustainability 14,* 8551. https://doi.org/doi.org/10.3390/su14148551

Perkin. A., Leonard, C., Doggart. N., (2008). Landscape Profile of Kilwa. Doc. Prep. as an input to GEF PPG Process to Dev. a full sized Propos. Tanzanian Coast. For. 1–28.

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J.C., Higgins, S.I., Mudongo, E.I., & Scheiter, S., (2019). Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-based dynamic vegetation model. *Ecol. Modell. 395,* 11–22. https://doi.org/10.1016/j.ecolmodel.2018.12.013

Prins, E., & Clarke, G.P., (2007). Discovery and enumeration of Swahilian Coastal Forests in Lindi region, Tanzania, using Landsat TM data analysis. *Biodivers. Conserv. 16,* 1551–1565. https://doi.org/10.1007/s10531-006-9047-4

Prins, E., & Clarke, G.P., (2006). Discovery and enumeration of Swahilian Coastal Forests in Lindi region, Tanzania. Biodivers. Conserv. Volume 16, 1551–1565. https://doi.org/10.1007/s10531-006-9047-4

Rocky, Mligo, 2012. Regeneration pattern and size-class distribution of indigenous woody species in exotic plantation in Pugu Forest Reserve, Tanzania. Int. J. Biodivers. Conserv. 4, 1–14. https://doi.org/10.5897/IJBC11.198

Ruvuga, P.R., Wredle, E., Nyberg, G., Hussein, R.A., Masao, C.A., Selemani, I.S., Sangeda, A.Z., & Kronqvist, C., (2021). Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements. *J. Environ. Manage., 290,* 112635. https://doi.org/10.1016/j.jenvman.2021.112635

Sewando, P.T., Mutabazi, K.D., & Mdoe, N.S., (2016). Vulnerability of agro-pastoral farmers to climate risks in northern and central Tanzania. *Dev. Stud. Res. 3,* 11–24. https://doi.org/10.1080/21665095.2016.1238311

Sheil, D., (1992). Tanzanian coastal forests - unique , threatened , and overlooked. *Oryx 26,* 107–114. https://doi.org/10.1017/S0030605300023425

Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., Marc, K., & Burgess, N.D., (2010). Forest and Woodland Cover and

Change in Coastal Tanzania and Kenya, 1990 to 2000. J. East *African Nat. Hist. 99,* 19–45. https://doi.org/ 10.2982/028.099.0102

Tarimo, B., Dick, Ø.B., Gobakken, T., & Totland, Ø., (2015). Spatial distribution of temporal dynamics in anthropogenic fires in miombo savanna woodlands of Tanzania. *Carbon Balance Manag. 10,* 18. https://doi.org/10.1186/s13021-015-0029-2

TFS, (2015). National Forest Resources Monitoring and Assessment of Tanzania Mainland.

Wegner, G., Howell, K.M., Davenport, T.R.B., & Burgess, N.D., (2009). The Forgotten 'Coastal Forests' of Mtwara, Tanzania : A Biologically Impoverished and Yet Important Ecosystem. *J. East African Nat. Hist. 98,* 167–209. https://doi.org/10.2982/ 028.098.0202

Young, T.P., Porensky, L.M., Riginos, C., Veblen, K.E., Odadi, W.O., Kimuyu, D.M., Charles, G.K., & Young, H.S., (2018). Relationships Between Cattle and Biodiversity in Multiuse Landscape Revealed by Kenya Long-Term Exclosure Experiment. Rangel. Ecol. Manag. 71, 281–291. https://doi.org/10.1016/j.rama.2018.01.005

Appendices

Appendix 1: **Woody species distribution in relation to grazing intensity in the coastal forests of southern Tanzania**.

No grazing		Low grazing		Moderate grazing		Heavy grazing	
Species	**Family**	**Species**	**Family**	**Species**	**Family**	**Species**	**Family**
Afzelia quanzensis	Fabaceae	*Afzelia quanzensis*	Fabaceae	*Albizia petersiana*	Fabaceae	*Albizia adianthifolia*	Fabaceae
Albizia adianthifolia	Fabaceae	*Albizia adianthifolia*	Fabaceae	*Annona senegalensis*	Annonaceae	*Albizia petersiana*	Fabaceae
Albizia petersiana	Fabaceae	*Albizia petersiana*	Fabaceae	*Antidesma venosum*	Phyllanthaceae	*Albizia zimmermannii*	Fabaceae
Albizia zimmermannii	Fabaceae	*Alchornea laxiflora*	Euphorbiaceae	*Brachystegia boehmii*	Fabaceae	*Anacardium occidentale*	Anacardiaceae
Alchornea laxiflora	Euphorbiaceae	*Annona senegalensis*	Annonaceae	*Brachystegia spiciformis*	Fabaceae	*Annona senegalensis*	Annonaceae
Amblygonacarpus andongensis	Sapotaceae	*Antidesma venosum*	Phyllanthaceae	*Brackenridgea zanguebarica*	Ochnaceae	*Antidesma venosum*	Phyllanthaceae
Antidesma venosum	Phyllanthaceae	*Brachystegia spiciformis*	Fabaceae	*Cassia abbreviata*	Fabaceae	*Brachystegia boehmii*	Fabaceae
Baphia kirkii	Fabaceae	*Caloncoba welwitschii*	Achariaceae	*Celtis zenkeri*	Cannabaceae	*Combretum hereroense*	Combretaceae
Brachystegia spiciformis	Fabaceae	*Canthium zanzibaricum*	Rubiaceae	*Combretum hereroense*	Combretaceae	*Commiphora africana*	Burseraceae
Brackenridgea zanguebarica	Ochnaceae	*Cleistanthus schlechteri*	Phyllanthaceae	*Combretum molle*	Combretaceae	*Crossopteryx febrifuga*	Rubiaceae
Burkea africana	Fabaceae	*Combretum hereroense*	Combretaceae	*Commiphora africana*	Burseraceae	*Dalbergia alata*	Fabaceae

Caloncoba welwitschii	Achariaceae	*Combretum zeyheri*	Combretaceae	*Crossopteryx febrifuga*	Rubiaceae	*Dalbergia melanoxylon*	Fabaceae
Canthium zanzibaricum	Rubiaceae	*Commiphora schimperi*	Burseraceae	*Dalbergia alata*	Fabaceae	*Dalbergia nitidula*	Fabaceae
Carpodiptera africana	Malvaceae	*Crossopteryx febrifuga*	Rubiaceae	*Dalbergia melanoxylon*	Fabaceae	*Deinbollia borbonica*	Sapindaceae
Cassia abbreviata	Fabaceae	*Dalbergia alata*	Fabaceae	*Dalbergia nitidula*	Fabaceae	*Diplorhynchus condylocarpon*	Apocynaceae
Celtis zenkeri	Cannabaceae	*Deinbollia borbonica*	Sapindaceae	*Deinbollia borbonica*	Sapindaceae	*Flueggea virosa*	Phyllanthaceae
Cleistanthus schlechteri	Phyllanthaceae	*Diospyros verrucosa*	Ebenaceae	*Diplorhynchus condylocarpon*	Apocynaceae	*Grewia bicolor*	Malvaceae
Cola minor	Malvaceae	*Diplorhynchus condylocarpon*	Apocynaceae	*Flueggea virosa*	Phyllanthaceae	*Harrisonia abyssinica*	Rutaceae
Combretum collinum	Combretaceae	*Dombeya acutangula*	Malvaceae	*Hymenocardia ulmoides*	Phyllanthaceae	*Hymenocardia ulmoides*	Phyllanthaceae
Combretum molle	Combretaceae	*Flueggea virosa*	Phyllanthaceae	*Hyphaene compressa*	Arecaceae	*Kigelia africana*	Bignoniaceae
Combretum zeyheri	Combretaceae	*Grewia bicolor*	Malvaceae	*Lannea schweinfurthii var. acutifoliolata*	Anacardiaceae	*Lannea schweinfurthii var. acutifoliolata*	Anacardiaceae
Croton sylvaticus	Euphorbiaceae	*Grewia platyclada*	Malvaceae	*Margaritaria discoidea*	Phyllanthaceae	*Leptactina platyphylla*	Rubiaceae
Dalbergia boehmii	Fabaceae	*Heinsia crinita*	Rubiaceae	*Markhamia zanzibarica*	Bignoniaceae	*Lonchocarpus capassa*	Fabaceae
Dalbergia melanoxylon	Fabaceae	*Holarrhena febrifuga*	Apocynaceae	*Piliostigma thonningii*	Fabaceae	*Lonchocarpus eriocalyx*	Fabaceae
Desmanthus virgatus	Fabaceae	*Hymenaea verrucosa*	Fabaceae	*Pseudolachnostylis maprouneifolia*	Acanthaceae	*Margaritaria discoidea*	Phyllanthaceae
Dialium holtzii	Fabaceae	*Hymenocardia ulmoides*	Phyllanthaceae	*Pteleopsis myrtifolia*	Combretaceae	*Markhamia zanzibarica*	Bignoniaceae

Dichrostachys cinerea	Fabaceae	*Julbernardia globiflora*	Fabaceae	*Rourea orientalis*	Connaraceae	*Pseudolachnostylis maprouneifolia*	Phyllanthaceae
Diospyros consolatae	Ebenaceae	*Lecaniodiscus fraxinifolius*	Sapindaceae	*Salvadora persica*	Salvadoraceae	*Pteleopsis myrtifolia*	Combretaceae
Diospyros verrucosa	Ebenaceae	*Lonchocarpus capassa*	Fabaceae	*Senegalia polyacantha*	Fabaceae	*Rourea orientalis*	Connaraceae
Diplorhynchus condylocarpon	Apocynaceae	*Lonchocarpus eriocalyx*	Fabaceae	*Sorindeia madagascariensis*	Anacardiaceae	*Salvadora persica*	Salvadoraceae
Dombeya acutangula	Malvaceae	*Manilkara zenkeri*	Sapotaceae	*Strychnos innocua*	Loganiaceae	*Sclerocarya birrea*	Anacardiaceae
Dombeya shupangae	Malvaceae	*Margaritaria discoidea*	Phyllanthaceae	*Terminalia sambesiaca*	Combretaceae	*Senegalia polyacantha*	Fabaceae
Dracaena mannii	Asparagaceae	*Markhamia zanzibarica*	Bignoniaceae	*Tetracera litoralis*	Dilleniaceae	*Sorindeia madagascariensis*	Anacardiaceae
Erythrina burttii	Fabaceae	*Mimusops kummel*	Sapotaceae	*Vachellia nilotica*	Fabaceae	*Strychnos innocua*	Loganiaceae
Erythroxylum emarginatum	Erythroxylaceae	*Ochna holstii*	Ochnaceae	*Vitex zambesiaca*	Lamiaceae	*Tamarindus indica*	Fabaceae
Fernandoa magnifica	Bignoniaceae	*Paropsia braunii*	Passifloraceae			*Tetracera litoralis*	Dilleniaceae
Grewia bicolor	Malvaceae	*Piliostigma thonningii*	Fabaceae			*Trichilia emetica*	Meliaceae
Grewia platyclada	Malvaceae	*Pteleopsis myrtifolia*	Combretaceae			*Vachellia nilotica*	Fabaceae
Harrisonia abyssinica	Rutaceae	*Pterocarpus angolensis*	Fabaceae			*Vangueria madagascariensis*	Rubiaceae
Harungana madagascariensis	Hypericaceae	*Senegalia polyacantha*	Fabaceae			*Vismia orientalis*	Hypericaceae
Heinsia crinita	Rubiaceae	*Sorindeia madagascariensis*	Anacardiaceae			*Xylopia collina*	Annonaceae

Holarrhena febrifuga	Apocynaceae	*Suregada zanzibariensis*	Euphorbiaceae		*Xylopia parviflora*	Annonaceae
Hugonia castaneifolia	Linaceae	*Terminalia sambesiaca*	Combretaceae		*Xylotheca tettensis*	Achariaceae
Hymenaea verrucosa	Fabaceae	*Tetracera litoralis*	Dilleniaceae		*Zanthoxylum chalybeum*	RUTACEAE
Hymenocardia ulmoides	Phyllanthaceae	*Vachellia nilotica*	Fabaceae			
Julbernardia globiflora	Fabaceae	*Vangueria madagascariensis*	Rubiaceae			
Lannea schweinfurthii var. acutifoliolata	Anacardiaceae	*Xylopia parviflora*	Annonaceae			
Lannea schweinfurthii var. Stuhlmannii	Anacardiaceae					
Lecaniodiscus fraxinifolius	Sapindaceae					
Leptactina platyphylla	Rubiaceae					
Lonchocarpus eriocalyx	Fabaceae					
Manilkara zenkeri	Sapotaceae					
Margaritaria discoidea	Phyllanthaceae					
Margaritaria eriocalyx	Phyllanthaceae					
Markhamia lutea	Bignoniaceae					
Markhamia zanzibarica	Bignoniaceae					
Milicia excelsa	Moraceae					
Nesogordonia holtzii	Malvaceae					
Newtonia paucijuga	Fabaceae					

Ochna holstii	Ochnaceae			
Olax dissitiflora	Olacaceae			
Ozoroa obovata	Anacardiaceae			
Pancovia holtzii	Sapindaceae			
Paropsia braunii	Passifloraceae			
Paropsia vareciformis	Passifloraceae			
Philenoptera eriocalyx	Fabaceae			
Pseudolachnostylis maprouneifolia	Phyllanthaceae			
Psydrax faulknerae	Rubiaceae			
Pteleopsis myrtifolia	Combretaceae			
Pteleopsis stuhlmannii	Combretaceae			
Pterocarpus angolensis	Fabaceae			
Ricinodendron heudelotii	Euphorbiaceae			
Rothmannia manganjae	Rubiaceae			
Rourea orientalis	Connaraceae			
Sorindeia madagascariensis	Anacardiaceae			
Spirostachys africana	Euphorbiaceae			
Sterculia schliebenii	Malvaceae			
Strychnos innocua	Loganiaceae			
Suregada zanzibariensis	Euphorbiaceae			
Tamarindus indica	Fabaceae			

Tarenna nigrescens	Rubiaceae			
Terminalia brownii	Combretaceae			
Terminalia sambesiaca	Combretaceae			
Tetracera litoralis	Dilleniaceae			
Trema orientale	Cannabaceae			
Tricalysia ovalifolia	Rubiaceae			
Vachellia nilotica	Fabaceae			
Vachellia robusta	Fabaceae			
Vangueria madagascariensis	Rubiaceae			
Vepris nobilis	Rutaceae			
Vismia orientalis	Hypericaceae			
Vitex mombassae	Lamiaceae			
Vitex mombassae	Lamiaceae			
Vitex zambesiaca	Lamiaceae			
Xylopia arenaria	Annonaceae			
Xylopia collina	Annonaceae			
Xylotheca tettensis	Achariaceae			

Appendix 2: Frequency of occurrence of woody plant species in different grazing intensities in the coastal forests of southern Tanzania

No grazing		Low grazing		Moderate grazing		Heavy grazing	
Species	**Percentage**	**Species**	**Percentage**	**Species**	**Percentage**	**Species**	**Percentage**
Trees							
Pteleopsis myrtifolia	6.0	*Hymenocardia ulmoides*	8.9	*Combretum molle*	9.5	*Anacardium occidentale*	12.7
Hymenaea verrucosa	4.7	*Pteleopsis myrtifolia*	8.9	*Hyphaene compressa*	9.5	*Lonchocarpus capassa*	12.7
Hymenocardia ulmoides	3.9	*Crossopteryx febrifuga*	7.1	*Salvadora persica*	9.5	*Lannea schweinfurthii var. acutifoliolata*	11.1
Xylopia collina	3.9	*Grewia bicolor*	7.1	*Senegalia polyacantha*	9.5	*Dalbergia melanoxylon*	9.5
Baphia kirkii	3.4	*Grewia platyclada*	7.1	*Strychnos innocua*	9.5	*Strychnos innocua*	6.3
Dialium holtzii	3.4	*Afzelia quanzensis*	5.4	*Albizia petersiana*	4.8	*Combretum hereroense*	4.8
Diospyros consolatae	3.4	*Combretum hereroense*	5.4	*Annona senegalensis*	4.8	*Sclerocarya birrea*	4.8
Carpodiptera africana	3.0	*Lecaniodiscus fraxinifolius*	5.4	*Brachystegia boehmii*	4.8	*Albizia zimmermannii*	3.2
Cleistanthus schlechteri	3.0	*Manilkara zenkeri*	5.4	*Brachystegia spiciformis*	4.8	*Commiphora africana*	3.2
Lannea schweinfurthii	3.0	*Commiphora schimperi*	3.6	*Brackenridgea zanguebarica*	4.8	*Pseudolachnostylis maprouneifolia*	3.2

var. Stuhlmannii							
Terminalia brownii	3.0	*Markhamia zanzibarica*	3.6	*Cassia abbreviata*	4.8	*Pteleopsis myrtifolia*	3.2
		Paropsia braunii	3.6	*Celtis zenkeri*	4.8	*Salvadora persica*	3.2
		Senegalia polyacantha	3.6	*Dalbergia melanoxylon*	4.8	*Senegalia polyacantha*	3.2
				Lannea schweinfurthii var. acutifoliolata	4.8	*Tamarindus indica*	3.2
				Terminalia sambesiaca	4.8		
				Vachellia nilotica	4.8		
Poles							
Diplorhynchus condylocarpon	15.3	*Grewia platyclada*	19.6	*Vachellia nilotica*	26.2	*Lonchocarpus capassa*	21.8
Hymenocardia ulmoides	15.3	*Hymenocardia ulmoides*	10.9	*Combretum molle*	14.3	*Lannea schweinfurthii var. acutifoliolata*	14.5
Diospyros consolatae	11.8	*Pteleopsis myrtifolia*	10.9	*Dalbergia alata*	11.9	*Grewia bicolor*	10.9
Terminalia brownii	7.1	*Diplorhynchus condylocarpon*	8.7	*Albizia petersiana*	7.1	*Diplorhynchus condylocarpon*	7.3
Combretum zeyheri	4.7	*Lecaniodiscus fraxinifolius*	8.7	*Hymenocardia ulmoides*	7.1	*Hymenocardia ulmoides*	7.3
Brachystegia spiciformis	3.5	*Vachellia nilotica*	8.7	*Pteleopsis myrtifolia*	7.1	*Albizia petersiana*	3.6
Margaritaria discoidea	3.5	*Annona senegalensis*	6.5	*Combretum hereroense*	4.8	*Anacardium occidentale*	3.6
Markhamia	3.5			*Lannea*	4.8	*Dalbergia*	3.6

zanzibarica				*schweinfurthii var. acutifoliolata*		*melanoxylon*	
Trema orientale	3.5			*Salvadora persica*	4.8	*Kigelia africana*	3.6
						Markhamia zanzibarica	3.6
						Pteleopsis myrtifolia	3.6
						Salvadora persica	3.6
						Vachellia nilotica	3.6
Saplings							
Margaritaria discoidea	14.7	*Combretum hereroense*	24.0	*Combretum hereroense*	17.8	*Dalbergia nitidula*	9.6
Dichrostachys cinerea	10.3	*Caloncoba welwitschii*	12.0	*Dalbergia nitidula*	13.3	*Combretum hereroense*	8.2
Diospyros consolatae	10.3	*Grewia platyclada*	12.0	*Albizia petersiana*	11.1	*Lannea schweinfurthii var. acutifoliolata*	8.2
Caloncoba welwitschii	8.8	*Heinsia crinita*	8.0	*Diplorhynchus condylocarpon*	11.1	*Lonchocarpus capassa*	8.2
Hugonia castaneifolia	5.9	*Hymenocardia ulmoides*	8.0	*Margaritaria discoidea*	8.9	*Albizia petersiana*	6.8
Hymenocardia ulmoides	5.9	*Pteleopsis myrtifolia*	8.0	*Pteleopsis myrtifolia*	8.9	*Diplorhynchus condylocarpon*	6.8
Ozoroa obovata	5.9	*Combretum zeyheri*	4.0	*Commiphora africana*	6.7	*Grewia bicolor*	6.8
Olax dissitiflora	4.4	*Dalbergia alata*	4.0	*Crossopteryx febrifuga*	4.4	*Kigelia africana*	6.8
		Deinbollia borbonica	4.0	*Dalbergia alata*	4.4	*Pteleopsis myrtifolia*	5.5

		Diospyros verrucosa	4.0	*Strychnos innocua*	4.4	*Xylotheca tettensis*	5.5
		Lecaniodiscus fraxinifolius	4.0			*Zanthoxylum chalybeum*	5.5
		Lonchocarpus eriocalyx	4.0			*Commiphora africana*	4.1
		Margaritaria discoidea	4.0			*Lonchocarpus eriocalyx*	4.1
Seedlings							
Tricalysia ovalifolia	13.9	*Antidesma venosum*	13.9	*Combretum hereroense*	23.1	*Tetracera litoralis*	25.0
Diospyros consolatae	6.0	*Flueggea virosa*	9.6	*Dalbergia melanoxylon*	17.9	*Rourea orientalis*	12.5
Lecaniodiscus fraxinifolius	5.4	*Pteleopsis myrtifolia*	7.8	*Commiphora africana*	7.7	*Albizia petersiana*	10.0
Cleistanthus schlechteri	4.8	*Alchornea laxiflora*	7.2	*Deinbollia borbonica*	7.7	*Sorindeia madagascariensis*	10.0
Pteleopsis myrtifolia	4.8	*Tetracera litoralis*	6.6	*Markhamia zanzibarica*	7.7	*Tamarindus indica*	10.0
Xylotheca tettensis	4.8	*Caloncoba welwitschii*	5.4	*Albizia petersiana*	5.1	*Dalbergia melanoxylon*	7.5
Tetracera litoralis	4.2	*Margaritaria discoidea*	5.4	*Antidesma venosum*	5.1	*Grewia bicolor*	5.0
Canthium zanzibaricum	3.6	*Deinbollia borbonica*	4.8	*Flueggea virosa*	5.1	*Kigelia africana*	5.0
Harungana madagascariensis	3.6	*Holarrhena febrifuga*	4.8	*Piliostigma thonningii*	5.1		
Strychnos innocua	3.6	*Mimusops kummel*	4.2	*Pseudolachnostylis*	5.1		

				maprouneifolia		
Cola minor	3.0	*Sorindeia madagascariensis*	4.2	*Sorindeia madagascariensis*	5.1	
Hymenocardia ulmoides	3.0	*Grewia bicolor*	3.6			
Xylopia collina	3.0	*Vachellia nilotica*	3.6			
		Dalbergia alata	3.0			
		Hymenocardia ulmoides	3.0			
		Markhamia zanzibarica	3.0			
		Suregada zanzibariensis	3.0			

CHAPTER FOUR

4.0 GENERAL DISCUSSION

4.1 Local perception on livestock grazing on coastal forest degradation

The coastal forest cover declined in the studied area similar to the findings reported by Tabor *et al.* (2010) in Kenya and Tanzania. I discovered that the annual decline rate of -3% was greater compared to the range of 0.2 - 0.8% per year observed in the coastal forests of Tanzania (Godoy et al., 2011; Tabor et al., 2010). I found high t annual forest loss compared to -1.3% per year reported by Godoy *et al*. (2011) in general coastal forests. Burgess *et al.* (2017) revealed that, location, prevalent socio-economic activities such as grazing or charcoal production, growth in human population, and escalating impacts of climate change. These findings underscore the critical condition of Tanzania's coastal forests, highlighting the need for urgent measures such as livelihood diversification to safeguard their sustainability. Alternatively, mangrove forests and woodlands increased in the current study compared to other African findings (Carney *et al*., 2014; Kirui *et al*., 2013; Mesfin *et al*., 2020). The mangrove forest increase was attributed to the different protection measures in the country and/or their relatively small cover (Table 4), which made it hard for individuals to utilize them (Gayo, 2022).

The increase in woodlands observed in this study may be attributed to the clearance of individual trees within the forest, resulting in reduced canopy cover. Consequently, the land classification algorithm categorized these areas as woodlands. This suggests that coastal forests have been degraded and transformed into woodlands, as indicated by the findings of the current study. The people interviewed also agreed with these findings, saying they noticed big changes in the forest area. They mentioned that things like animals grazing, farmers making more fields, making charcoal, and more people moving in all played a part in these changes. This

matches what other studies have found *(Burgess et al., 2017; Tabor et al.,* 2010).

Furthermore, population growth affected land cover in the studied area through large household size and immigration of livestock keepers from the Usangu plains (Ngailo, 2011), however did not show a linear increase to reflect the mentioned human population growth in the studied area. The observed trend was because the built area included other human-made structures, such as salt production facilities The salt-making facilities are constructed in the intertidal zone, which affects mangrove forests with new regulations limiting the activity, causing some people to abandon them, which explains the regression in the built area between 2012 and 2017 (Liingilie *et al.*, 2015).

Moreover, farmers and livestock keepers typically had large household sizes, ranging from approximately 5.9 to 9.3 people. This significant household size may have led to fewer constructed houses in the region, which could explain why many newcomers did not attribute the changes in land cover to population growth, as reported in studies by Kazungu *et al*. (2020); Kimaro *et al*. (2017). Native residents were more likely to attribute forest cover loss to livestock grazing compared to immigrants. This was because many immigrants were themselves livestock keepers, as indicated in To avoid eviction or having their livestock reduced, similar to what occurred in Usangu and Kilombero valleys in Tanzania, immigrant respondents often denied the role of livestock grazing in forest cover loss (Ngailo, 2011; Nindi *et al*., 2014).

Moreover, the number of livestock reported in this study fell within the range of 20-600 similar to (Kimaro *et al.*, 2017) findings however, cattle ownership among native residents was contrary to the report by Mwambene *et al*. (2014), who mentioned that natives in southern Tanzania were farmers and did not own large stock. The

variation could be because the criteria for categorizing natives and immigrants was based on self-identification and residence duration.

It has been reported that, excessive livestock numbers have the potential to result in overgrazing, which can adversely impact other ecosystem services within the wooded landscape (Lulandala *et al*., 2022). This can also elucidate why the majority of respondents believed that livestock grazing could result in the depletion of grasses through overgrazing similar to Pfeiffer *et al*., 2019). Further, livestock overgrazing in the coastal forest, as was mentioned by respondents, can contribute to the tree cover losses due to browsing of thickets by goats and trampling of seedlings and coppices by cattle (Hilario *et al.,* 2017; Mtimbanjayo and Sangeda, 2018). In protected areas, livestock grazing can create tensions between resource use and forest preservation, potentially resulting in biodiversity decline(Young *et al.*, 2018). Nevertheless, fewer newcomers associated livestock grazing with the disappearance of indigenous plant species likely due to their recent arrival and limited familiarity with local plant knowledge (Naah and Guuroh, 2017).

Native residents and immigrants held differing perceptions regarding soil compaction caused by grazing. Contrary to other studies, immigrants did not concur with the notion that grazing leads to soil compaction (Dunne *et al.,* 2011; Ngenzi *et al.,* 2023). The immigrants had different perceptions because most were not farmers, while those who farmed used livestock as the draught power (Abdul Rahman and Reed, 2014).

Similar to the approach taken in Miombo woodlands, reinforcing the current land use plan holds the promise of securing grazing rights and restricting land cover alterations solely to the designated grazing areas (Mwambene *et al.,* 2014; Ruvuga *et al.,* 2021). The belief was that the land use plan could stimulate private investment, particularly as many immigrant livestock keepers boasted considerably higher incomes compared to native farmers. This divergence in income

levels could stem from the greater value of livestock and their products, which are available year-round, contrasting with the seasonal nature of crops like pigeon peas commonly cultivated in southern Tanzania as per findings (Gichohi-wainaina *et al*., 2022).

Overall, respondents' views on changes in land cover were primarily based on the reduction in forest cover, underscoring the importance of alleviating current pressures such as expansion of croplands, charcoal production and livestock grazing. It is recommended that future research explore the impact of current livestock density on tree distribution and diversity within the coastal forest to assess the extent of degradation.

4.2 Diversity, density of wood plants on grazing of coastal forest

It is crucial to comprehend the variety of wood plant species present in coastal forests, especially in relation to varying levels of grazing intensity and the perceptions of local communities. This understanding is essential for effectively conserving and managing these ecosystems, which are rich in diverse wood plant species. Burgess *et al.* (2017; Kibet (2011); Ligate *et al.* (2019; Mtimbanjayo and Sangeda (2018) revealed that, coastal forests have plant species that are prevalent in the biome and similar wooded landscapes across tropical regions. Grazing affects differentially the species and their abundance in the coastal forest and most of species were remained less grazed forest than in ungrazed ones due to the direct impact of herbivores (grazing and trampling). This notably concerns the species less tolerant to disturbance and the most palatable to livestock

Various wood plant species were observed across different levels of grazing intensity, with the A. occidental prevailing notably in areas subjected to heavy grazing. The prevalence of this species in heavily grazed areas could be attributed to the existence of anti-nutritional toxins in its leaves and fruits, which discourage animals from

consuming them as also reported by previous study (Costa *et al.,* 2020; Filho and Soto-Blanco, 2012). Further, the study revealed low species diversity of 0.7 to 2.9, while evenness ranged from 0.01 to 0.95. High species richness was observed throughout the study area, except in areas subject to low (trees only), moderate, and heavy grazing. The study findings are in line with (Ligate *et al.,* 2019; Ntukey *et al.,* 2022) for both conserved and disturbed coastal forests low (trees only), moderate and heavy grazing.

The observed variation in plant species diversity and richness were attributed by the differences in the level of disturbances caused by livestock and other human activities and the size of the sampling unit, which was smaller in the current study than previous study (Ligate *et al.,* 2019). Further the species diversity observes in the study area notably lower compared to previous report (Kimaro and Lulandala, 2013; Mauki *et al.,* 2023). Ligate *et al.* (2018) and Ntukey *et al.* (2022). The absence of significant differences in tree diversity between un grazed (conserved forest) and lightly grazed plots suggests that ungrazing represents the optimal stocking rate for preserving tree diversity in coastal forests. Likewise, ungrazed areas exhibited the highest diversity of seedlings, contrasting with the pattern observed in mature trees where ungrazed areas showed the highest diversity indices. This disparity may be attributed to the recruitment of pioneer plant species, consistent with findings from other studies conducted in coastal forest ecosystem (Mligo, 2019).

Furthermore, the observed tree density ranged from 130 to 554 stems per hectare in conserved coastal forests, and from 30 to 390 stems per hectare in disturbed coastal forests. Similar for tree, sampling and poles study reported similar range, However, the density of saplings and poles ranged higher than 15 to 65 stems per hectare but lower than 240 stems per hectare (Ligate *et al.,* 2019; Mligo, 2019). Seedlings density in the current study was higher than 10 – 3 800 stem/ha except for moderate and heavy grazing similar to Ligate *et al.* (2019; Mligo (2019; Rocky and Mligo (2012).

Differences in plant species composition and forest management may account for the variability in stem densities of saplings, poles, and seedlings observed between the present studies.

Nonetheless in miombo forests (Mtimbanjayo and Sangeda, 2018), tree density remained consistent between areas with no grazing and those subjected to heavy grazing. This discrepancy is likely attributable to the presence of toxic plants species and other factors, in the heavily grazed plots. This finding contrasts with studies conducted in miombo woodlands (Mtimbanjayo and Sangeda, 2018; Ruvuga *et al.,* 2021). In moderate grazing zones, the minimum tree density observed was 84 stems per hectare. No substantial differences were noted between areas with no grazing and those with low grazing. These findings indicate that maintaining low grazing intensity is crucial for conserving tree coverage in Eastern African coastal forests.

Furthermore, the higher tree density led to extensive canopy cover in areas with no grazing, thereby restricting available space and light for seedlings. The reduced seedling density observed in areas with moderate and heavy grazing may be attributed to livestock trampling, which impedes the growth and development of regenerating plants (Dunne *et al.,* 2011; Mtimbanjayo and Sangeda, 2018). Also, low seedling density could be due to the increased soil erosion, compaction and prolonged effects of grazing in moderate and heavy grazing (Dunne *et al.,* 2011; Lulandala *et al.,* 2022). These findings suggest that moderate and heavy grazing have a negative impact on the regeneration capacity. The claim is derived from the relatively lower number of seedlings, saplings, poles and trees, which would be unsustainable in the current grazing regimes. Low grazing intensity is advocated for its capacity to sustain tree cover within coastal forests. This maintenance of tree cover is vital for functions such as carbon sequestration, recreational opportunities, nutrient recycling, and other essential provisional ecosystem services

4.3 Distribution of grazing intensity in coastal forest

Basal area and volume influences above-ground biomass carbon storage (Ntukey *et al.,* 2022) Variations in tree basal area and volume among the grazed areas was found in this study, even though heavily grazed plots had a higher average diameter at breast height (DBH) compared to those with low or moderate grazing intensity. The finding of this study aligns with Ligate *et al.,* 2019; Mauki *et al.,* 2023). Nonetheless, the volume was within 0.5 - 633 m3/ha for woody plants in the conserved forest and 0.2 - 31.5 m3/ha (except for low and heavy grazing that were higher) for disturbed coastal forest. The differences in basal area and volume observed between the present study and previous research can be attributed to variations in plant species composition, stem density, and the criteria used for disaggregating woody plants.

Further, Ligate *et al.* (2019) reported that, sapling had a smaller diameter at breast height (DBH) of less than 7 - 12 cm, whereas trees exhibited a DBH ranging from 13 to 78 cm. In general, it was suggested that livestock grazing, even when moderate, influenced woody plant densities, diversity indices, and the regeneration capacity of seedlings as argued but by Ligate *et al*. (2018) in coastal forests and Lulandala *et al.* (2022) in miombo woodlands. Ruvuga *et al.* (2021) recommended that, livestock grazing in forests should be restricted to low intensity, unlike in miombo woodlands. Suggested that, given the existing livelihood vulnerability and influx of livestock in southern Tanzania (Ngailo, 2011). Further it has reported that, goats have small body sizes that may reduce seedlings trampling and soil compaction, unlike cattle with large sizes (Chidumayo and Kwibisa, 2003; Liao *et al.,* 2016).

CHAPTER FIVE

5.0 KEY CONTRIBUTIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 The major contribution of this study

Key contributions of the study include

- Firstly, the study extended the knowledge on Impact of Livestock Grazing Intensity on plant species composition through highlighting how livestock grazing intensity affects the plant species composition of coastal forests.
- Secondly, the study points out the threats to coastal forest sustainability on moderate and heavy grazing. It emphasizes how these grazing intensities can diminish stem densities, diversity indices, and regeneration.
- Thirdly, the study highlights factors contributing to low stem density, DBH and volume on livestock trampling and potential soil erosion as key factors contributing to low stem densities in areas with moderate and heavy grazing.
- Fourthly, the study advocates for low grazing intensity as the most appropriate stocking rate for coastal forests. It suggests that low grazing intensity can maintain species diversity indices, stem densities, regeneration capacity, basal area, and volume similar to or better than conserved forests, thereby supporting carbon sequestration, stocking, and biodiversity conservation efforts in the region.

5.2 Conclusion

It was found significant variations in plant species diversity, richness, density, Basal area on different grazing regimes of coastal forests because of differences in conservation management practices. Livestock grazing intensity significantly impacted plant species composition, diversity, and stem densities in coastal forests. Moderate to heavy grazing resulted in lower stem density, diversity indices, and regeneration capacity, indicating degradation. The weak impact of grazing found in this study on the species richness of

pools contrasts with general hypotheses on the role of grazing in the disappearance or decline of
Species.
Trampling and potential soil erosion were identified as factors contributing to this degradation. Low grazing intensity maintained or even improved diversity indices, stem densities, and regeneration capacity compared to no grazing, making it the most suitable stocking rate for sustaining ecosystem services like carbon sequestration and biodiversity conservation.

Satellite imagery and local perceptions confirmed a decline in coastal forest cover, with significant increases in woodlands. Livestock grazing, cropland expansion, charcoal production, and population growth were identified as primary drivers of these changes. Respondents highlighted concerns such as soil compaction, loss of native plant species, and water pollution attributed to livestock grazing. Differences in perception were noted among native residents and immigrants, influenced by socio-economic factors. Overall, the study concluded that southern Tanzania's coastal forests were degraded, necessitating urgent interventions for their sustainability.

5.3 Recommendation

Based on the findings and conclusion of this study, it is recommended that

i. Further inventory and livestock grazing experiments involving different stocking rates/intensities is suggested to accurately quantify the long-term impact of livestock grazing on the study area. While the current study provided valuable insights, its limited scope, conducted within a single season, necessitates a more comprehensive examination to yield robust result.
ii. Considering the positive impact observed on the diversity of woody plants through low and medium grazing, it is advisable to permit controlled livestock grazing in forest reserves, particularly during the dry season.

iii. Land use plan should be implemented in all villages, as indicated by the findings that such plans were not executed as intended across the surveyed villages. Efforts should be directed towards effectively enforcing the proposed land use strategies to align with the planned objectives.

iv. Regular monitoring and assessment of livestock populations in all villages are essential to compare them with available grazing land. This proactive approach helps prevent conflicts with farmers and conservation agencies by ensuring a balanced use of land resources.

References

Abdul Rahman, S., Reed, K., 2014. The management and welfare of working animals: identifying problems, seeking solutions and anticipating the future. Rev. sci. tech. Off. int. Epiz 33, 41–45.

Andrew, S.M., 2021. Effects of Plant Species Diversity and Biomass on Grazing Patch Selection by Semi Free-Ranging Cattle 47, 282–295.

Aynekulu, E., Mekuria, W., Tsegaye, D., Feyissa, K., Angassa, A., de Leeuw, J., Shepherd, K., 2017. Long-term livestock exclosure did not affect soil carbon in southern Ethiopian rangelands. Geoderma 307, 1–7. https://doi.org/10.1016/j.geoderma.2017.07.030

Benjaminsen, T.A., Maganga, F.P., Abdallah, J.M., 2009. The Kilosa Killings: Political Ecology of a Farmer-Herder Conflict in Tanzania. Dev. Change 40, 423–445. https://doi.org/10.1111/j.1467-7660.2009.01558.x

Burgess. N., Muir. C, . (Ed.), 1994. Coastal Forest of Eastern Africa: Biodiversity and Conservation, in: Proceedings of the Coastal Forests of Eastern Africa Workshop. Royal society for the Protection of Birds, UK, pp. 1–112.

Burgess, N.D., Malugu, I., Sumbi, P., Kashindye, A., Kijazi, A., Tabor, K., Mbilinyi, B., Kashaigili, J., Wright, T.M., Gereau, R.E., Coad, L., Knights, K., Carr, J., Ahrends, A., Newham, R.L., 2017. Two decades of change in state, pressure and conservation responses in the coastal forest biodiversity hotspot of Tanzania. Oryx 51, 77–86. https://doi.org/10.1017/S003060531500099X

Carney, J., Gillespie, T.W., Rosomoff, R., 2014. Assessing forest change in a priority West African mangrove ecosystem : 1986 – 2010. Geoforum 53, 126–135. https://doi.org/10.1016/j.geoforum.2014.02.013

Chidumayo, E.N., Kwibisa, L., 2003. Effects of deforestation on grass biomass and soil nutrient status in miombo woodland, Zambia. Agric. Ecosyst. Environ. 96, 97–105. https://doi.org/10.1016/S0167-8809(02)00229-3

Clarke, G.P., Burgess, N.D., Mbago, F.M., Mligo, C., Mackinder, B., Gereau, R.E., Hermitage, T., 2011. Two ‘ Extinct ’ Trees Rediscovered Near Kilwa , Tanzania 133–140.

Costa, A.R., Silva, J.R. de L., de Oliveira, T.J.S., da Silva, T.G., Pereira, P.S., Borba, E.F. de O., de Brito, E.S., Ribeiro, P.R.V., Almeida-Bezerra, J.W., Júnior, J.T.C., de Menezes, I.R.A.,

Kamdem, J.P., Duarte, A.E., Barros, L.M., 2020. Phytochemical profile of Anacardium occidentale L. (cashew tree) and the cytotoxic and toxicological evaluation of its bark and leaf extracts. South African J. Bot. 135, 355–364. https://doi.org/10.1016/j.sajb.2020.09.017

Dallu, A., 2004. A national synthesis report for the preparation of WWF—EACFE Programme. Coast. For. Tanzania 1–29.

Dickinson. A., Burgess. N. D., Clarke .G. P., ., 2010. Status and biological diversity. Tanzania Coast. For. 1–15.

Dunne, T., Western, D., Dietrich, W.E., 2011. Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical rangeland. J. Arid Environ. 75, 58–69. https://doi.org/10.1016/j.jaridenv.2010.09.001

Egeru, A., Wasonga, O., Macopiyo, L., Mburu, J., Tabuti, J.R.S., Majaliwa, M.G.J., 2015. Piospheric influence on forage species composition and abundance in semi-arid Karamoja sub-region, Uganda. Pastoralism 5, 12. https://doi.org/10.1186/s13570-015-0032-y

Filho, M.R.R., Soto-Blanco, B., 2012. Poisoning by cashew apple (Anacardium occidentale L.) in cattle. Acta Sci. Vet. 40, 1083.

Fynn, R.W.S., O'Connor, T.G., 2000. Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. J. Appl. Ecol. 37, 491–507. https://doi.org/10.1046/j.1365-2664.2000.00513.x

Gayo, L., 2022. Local community perception on the State Governance of mangroves in Western Indian coast of Kinondoni and. Glob. Ecol. Conserv. 39, e02287. https://doi.org/10.1016/j.gecco.2022.e02287

Gereau, R.E., Cumberlidge, N., Hemp, C., Hochkirch, A., Jones, T., Kariuki, M., Lange, C.N., Loader, S.P., Malonza, P.K., Menegon, M., Ndang, K., Rovero, F., Shirk, P., 2016. Globally Threatened Biodiversity of the Eastern Arc Mountains and Coastal Forests of Kenya and Tanzania. J. East African Nat. Hist. 105, 115–201. https://doi.org/10.2982/028.105.0104

Gichohi-wainaina, W.N., Mremi, R., Chande, M., Msuya, J.M., Kumwenda, N.C., Muzanila, Y.C., Msere, H., Muhimbula, H., 2022. Drivers of Pigeon Pea Consumption Among School-Aged Children in Central Tanzania. Front. Sustain. Food Syst. 5, 726404. https://doi.org/10.3389/fsufs.2021.726404

Godde, C.M., Garnett, T., Thornton, P.K., Ash, A.J., Herrero, M., 2018. Grazing systems expansion and intensification: Drivers,

dynamics, and trade-offs. Glob. Food Sec. 16, 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

Godoy, F.L., Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., Steininger, M.K., 2011. Deforestation and CO2 emissions in coastal Tanzania from 1990 to 2007. Environ. Conserv. 39, 62–71. https://doi.org/10.1017/S037689291100035X

Habel, J.C., Casanova, I.C.C., Zamora, C., Teucher, M., Hornetz, B., Shauri, H., Mulwa, R.K., Lens, L., 2017. East African coastal forest under pressure. Biodivers. Conserv. https://doi.org/10.1007/s10531-017-1375-z

Hassan, S.N., Salum, A.R., Rija, A.A., Modest, R., Kideghesho, J.R., Malata, P.F., 2013. Human-induced Disturbances Influence on Bird Communities of Coastal Forests in Eastern Tanzania 3, 48–64.

Hilario, M.C., Wrage-Mönnig, N., Isselstein, J., 2017. Behavioral patterns of (co-)grazing cattle and sheep on swards differing in plant diversity. Appl. Anim. Behav. Sci. 191, 17–23. https://doi.org/10.1016/j.applanim.2017.02.009

Howell. K.M. , Msuya. C.A., ., 2002. UTUMI Biodiversity Surveys Tanzania Annexes Final 1–72.

Howell, K.M., Msuya, C.A., Mligo, C., Werema, C., Kihaule, P., Honorati, M.K., Suleiman, H.O., 2012. Biodiversity Surveys of Poorly Known Coastal Forests of Southeastern Tanzania and Zanzibar. Wwf Final vers, 171.

Jilala, Z.J., 2015. Effects of human activities to the composition of woody plant species of Ngarama south forest reserve in Kilwa district, Tanzania. 2, 108–118. https://doi.org/10.13057/asianjethnobiol/y020205

Jilala, Z.J., Mwakalukwa, E.E., Chamshama, S.A.O., 2019. Human activities outcomes on the composition of woody plant species of Ngarama Southern Forest Reserve in Kilwa District, Tanzania. Asian J. Ethnobiol. 2, 108–118. https://doi.org/10.13057/asianjethnobiol/y020205

Kalonga, S.K., Kulindwa, K.A., 2017. Does forest certification enhance livelihood conditions? Empirical evidence from forest management in Kilwa District, Tanzania. For. Policy Econ. 74, 49–61. https://doi.org/10.1016/j.forpol.2016.11.001

Kazungu, M., Zhunusova, E., Yang, A.L., Kabwe, G., Gumbo, D.J., Günter, S., 2020. Forest use strategies and their determinants among rural households in the Miombo woodlands of the Copperbelt Province, Zambia. For. Policy Econ. 111, 102078.

https://doi.org/10.1016/j.forpol.2019.102078
Kibet, S., 2011. Plant communities, species diversity, richness, and regeneration of a traditionally managed coastal forest, Kenya. For. Ecol. Manage. 261, 949–957. https://doi.org/10.1016/j.foreco.2010.11.027
Kikoti, I.A., Mligo, C., 2015. Impacts of livestock grazing on plant species composition in montane forests on the northern slope of Mount Kilimanjaro, Tanzania. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 11, 114–127. https://doi.org/10.1080/21513732.2015.1031179
Kimaro, E.G., Mor, S.M., Gwakisa, P., Toribio, J.A., 2017. Seasonal occurrence of Theileria parva infection and management practices amongst Maasai pastoralist communities in Monduli District, Northern Tanzania. Vet. Parasitol. 246, 43–52. https://doi.org/10.1016/j.vetpar.2017.08.023
Kimaro, J., Lulandala, L., 2013. Human Influences on Tree Diversity and Composition of a Coastal Forest Ecosystem: The Case of Ngumburuni Forest Reserve, Rufiji, Tanzania. Int. J. For. Res. 305874. https://doi.org/10.1155/2013/305874
Kirui, K.B., Kairo, J.G., Bosire, J., Viergever, K.M., Rudra, S., Huxham, M., Briers, R.A., 2013. Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. Ocean Coast. Manag. 83, 19–24. https://doi.org/10.1016/j.ocecoaman.2011.12.004
Liao, C., Ruelle, M.L., Kassam, K.-A.S., 2016. Indigenous ecological knowledge as the basis for adaptive environmental management: Evidence from pastoralist communities in the Horn of Africa. J. Environ. Manage. 182, 70–79. https://doi.org/10.1016/J.JENVMAN.2016.07.032
Ligate, J.E., Wu, C., Chen, C., 2018. Investigation of tropical coastal forest regeneration after farming and livestock grazing exclusion. J. For. Res. 30, 1873–1884. https://doi.org/10.1007/s11676-018-0792-5
Liingilie, A.S., Kilawe, C., Kimaro, A., Rubanza, C., Jonas, E., Centre, W.A., Box, P.O., Salaam, D., 2015. Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. Mediterr. J. Biosci. 1, 27–31.
Lulandala, L., Bargués-tobella, A., Nyberg, G., Ilstedt, U., Masao, C.A., 2022. Excessive livestock grazing overrides the positive effects of trees on infiltration capacity and modifies preferential

flow in dry miombo woodlands. L. Degrad. Dev. 33, 581–595. https://doi.org/10.1002/ldr.4149

Lupala, Z.J., Lusambo, L.P., Ngaga, Y.M., Makatta, A.A., 2015. The Land Use and Cover Change in Miombo Woodlands under Community Based Forest Management and Its Implication to Climate Change Mitigation: A Case of Southern Highlands of Tanzania. Int. J. For. Res. 459102, 11. https://doi.org/10.1155/2015/459102

Mauki, D.G., Kinyero, O., Meela, F., 2023. The influence of Brachylaena huillensis O. hoffm on diversity, abundance and structure of Mtunguru Forest Reserve in Tanzania. Environ. Sustain. Indic. 19, 100273. https://doi.org/10.1016/j.indic.2023.100273

Mauya, E.W., Mugasha, W.A., Zahabu, E., Bollandsås, O.M., Eid, T., 2014. Models for estimation of tree volume in the miombo woodlands of Tanzania. South. For. 76, 209–219. https://doi.org/10.2989/20702620.2014.957594

Mayengo, G., Armbruster, W., Treydte, A.C., 2020. Quantifying nutrient re-distribution from nutrient hotspots using camera traps, indirect observation and stable isotopes in a miombo ecosystem, Tanzania. Glob. Ecol. Conserv. 23, e01073. https://doi.org/10.1016/j.gecco.2020.e01073

Mesfin, D., Simane, B., Belay, A., Recha, J.W., Taddese, H., 2020. Woodland Cover Change in the Central Rift Valley of Ethiopia. Forests 11, 916. https://doi.org/doi:10.3390/f11090916

Mligo, C., 2019. Post fire regeneration of indigenous plant species in the Pugu Forest Reserve, Tanzania. Glob. Ecol. Conserv. 18, e00611. https://doi.org/10.1016/j.gecco.2019.e00611

Mligo, C., 2015. Conservation of plant biodiversity of Namatimbili forest in the southern coastal forests of Tanzania. Int. J. Biodivers. Conserv. 7, 148–172. https://doi.org/10.5897/ijbc2014.0771

Mohammed, A.S., Animut, G., Urge, M., Assefa, G., 2020. Grazing behavior, dietary value and performance of sheep, goats, cattle and camels co-grazing range with mixed species of grazing and browsing plants. Vet. Anim. Sci. 10, 100154. https://doi.org/10.1016/j.vas.2020.100154

Mouissie, A.M., Vos, P., Verhagen, H.M.C., Bakker, J.P., 2005. Endozoochory by free-ranging, large herbivores: Ecological correlates and perspectives for restoration. Basic Appl. Ecol. 6, 547–558. https://doi.org/10.1016/j.baae.2005.03.004

Mtimbanjayo, J.R., Sangeda, A.Z., 2018. Ecological Effects of Cattle Grazing on Miombo Tree Species Regeneration and Diversity in Central-Eastern Tanzania. J. Environ. Res. 2, 3.

Mwambene, P.L., Mbwile, R.P., Hoeggel, F.U., Kimbi, E.C., Materu, J., Mwaiganju, A., Madoffe, S., 2014. Assessing dynamics of forced livestock movements, livelihoods and future development options for pastoralists/agro-pastoralists in Ruvuma and Lindi Regions, in the Southern Tanzania. Livest. Res. Rural Dev. 26, #4.

Naah, J.B.S.N., Guuroh, R.T., 2017. Factors influencing local ecological knowledge of forage resources: Ethnobotanical evidence from West Africa's savannas. J. Environ. Manage. 188, 297–307. https://doi.org/10.1016/j.jenvman.2016.11.064

NBS, 2021. National Sample Census of Agriculture 2019/20, The United Republic of Tanzania. Dodoma, Tanzania.

Nduwamungu, J., Munishi, P.K.T., Bloesch, U., Hagedorn, F., Lulu, K., 2009. Recent Land Cover and Use Changes in Miombo Woodlands of Eastern Tanzania. Tanzania J. For. Nat. Conserv. 78, 50–59.

Ngailo, J.A., 2011. Assessing the effects of eviction on household food security of livestock keepers from the Usangu wetlands in SW Tanzania. Livest. Res. Rural Dev. 23, #65.

Ngenzi, O.D., Ruvuga, P.R., Msalya, G.M., Maleko, D.D., 2023. Participatory establishment of Cenchrus ciliaris forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. African J. Range Forage Sci. https://doi.org/10.2989/10220119.2023.2219700

Nindi, J.S., Maliti, H., Bakari, S., Kija, H., Machoke, M., 2014. Conflicts Over Land and Water Resources in the Kilombero Valley Floodplain, Tanzania. Afr. Study Monogr. 50, 173–190.

Njoghomi, E.E., Valkonen, S., Karlsson, K., Saarinen, M., Wilson A, M., Pentti, N., Celestino, B., Rogers E, M., 2020. Regeneration Dynamics and Structural Changes in Miombo Woodland Stands At Kitulangalo Forest Reserve in Tanzania. J. Sustain. For. 40, 1–19. https://doi.org/10.1080/10549811.2020.1789478

Ntukey, L.T., Munishi, L.K., Treydte, A.C., 2022. Land Use Land/Cover Change Reduces Woody Plant Diversity and Carbon Stocks in a Lowland Coastal Forest Ecosystem, Tanzania. Sustainability 14, 8551. https://doi.org/doi.org/10.3390/su14148551

Perkin. A., Leonard. C, Doggart. N, ., 2008. Landscape Profile of

Kilwa. Doc. Prep. as an input to GEF PPG Process to Dev. a full sized Propos. Tanzanian Coast. For. 1–28.

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J.C., Higgins, S.I., Mudongo, E.I., Scheiter, S., 2019. Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-based dynamic vegetation model. Ecol. Modell. 395, 11–22. https://doi.org/10.1016/j.ecolmodel.2018.12.013

Prins, E., Clarke, G.P., 2007. Discovery and enumeration of Swahilian Coastal Forests in Lindi region, Tanzania, using Landsat TM data analysis. Biodivers. Conserv. 16, 1551–1565. https://doi.org/10.1007/s10531-006-9047-4

Prins, E., Clarke, G.P., 2006. Discovery and enumeration of Swahilian Coastal Forests in Lindi region, Tanzania. Biodivers. Conserv. Volume 16, 1551–1565. https://doi.org/10.1007/s10531-006-9047-4

Rocky, Mligo, 2012. Regeneration pattern and size-class distribution of indigenous woody species in exotic plantation in Pugu Forest Reserve, Tanzania. Int. J. Biodivers. Conserv. 4, 1–14. https://doi.org/10.5897/IJBC11.198

Ruvuga, P.R., Wredle, E., Nyberg, G., Hussein, R.A., Masao, C.A., Selemani, I.S., Sangeda, A.Z., Kronqvist, C., 2021. Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements. J. Environ. Manage. 290, 112635. https://doi.org/10.1016/j.jenvman.2021.112635

Sewando, P.T., Mutabazi, K.D., Mdoe, N.S., 2016. Vulnerability of agro-pastoral farmers to climate risks in northern and central Tanzania. Dev. Stud. Res. 3, 11–24. https://doi.org/10.1080/21665095.2016.1238311

Sheil, D., 1992. Tanzanian coastal forests - unique , threatened , and overlooked. Oryx 26, 107–114. https://doi.org/10.1017/S0030605300023425

Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J., Marc, K., Burgess, N.D., 2010. Forest and Woodland Cover and Change in Coastal Tanzania and Kenya, 1990 to 2000. J. East African Nat. Hist. 99, 19–45. https://doi.org/10.2982/028.099.0102

Tarimo, B., Dick, Ø.B., Gobakken, T., Totland, Ø., 2015. Spatial distribution of temporal dynamics in anthropogenic fires in miombo savanna woodlands of Tanzania. Carbon Balance Manag. 10, 18. https://doi.org/10.1186/s13021-015-0029-2

TFS, 2015. National Forest Resources Monitoring and Assessment of Tanzania Mainland.

Wegner, G., Howell, K.M., Davenport, T.R.B., Burgess, N.D., 2009. The Forgotten 'Coastal Forests' of Mtwara, Tanzania : A Biologically Impoverished and Yet Important Ecosystem. J. East African Nat. Hist. 98, 167–209. https://doi.org/10.2982/028.098.0202

Young, T.P., Porensky, L.M., Riginos, C., Veblen, K.E., Odadi, W.O., Kimuyu, D.M., Charles, G.K., Young, H.S., 2018. Relationships Between Cattle and Biodiversity in Multiuse Landscape Revealed by Kenya Long-Term Exclosure Experiment. Rangel. Ecol. Manag. 71, 281–291. https://doi.org/10.1016/ j.rama.2018.01.005