LAND COVER, WOODY PLANT DIVERSITY AND ANTHROPOGENIC DISTURBANCE ON TULIMANI HILL ECOSYSTEM IN MAKUENI COUNTY, KENYA.

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DECLARATION

This is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

I dedicate this thesis to God Almighty, the source of my inspiration, to my parents, husband, siblings, children, extended family members and church family.

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First and foremost, I thank God for His blessings and the far He has brought me in my academic journey. Special thanks to my supervisors, Dr. Emily Wabuyele and Dr. Paul Muoria for their time, helpful ideas, advices, patience, dedication, inspiration, encouragement and guidance in this study. Your great insights contributed to the quality of my work. You have never turned me down despite the countless drafts, inquiries and consultations. Your feedbacks provided me with valuable suggestions to complete the work successfully.

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ABBREVIATIONS AND ACRONYMS

IUCN: International Union for Conservation of Nature.

UNCCD: United Nations Convention to Combat Desertification.

BCSF: Bristol Conservation and Science Foundation.

GPS: Global Positioning System

GIS: Geographic Information System

KFS: Kenya Forest Service

LULCC: Land Use and Land Cover Changes

DBH: Diameter at Breast Height

ASAL's: Arid and Semi-Arid Lands

AHN: ASAL Humanitarian Network

PAST: Paleontological Statistics

DPSIR: Driver-Pressure-State-Impact-Response Framework
.

UNDP: United Nations Development Programme

NASA: National Aeronautics and Space Administration

CFA's: Community Forest Associations

DEFINITION OF TERMS

Shrub- Is a woody plant that is smaller than a tree and typically has multiple stems arising near the ground.

Tree- is a perennial woody plant, typically characterized by a single main trunk or stem that supports branches and leaves.

Invasive species- is a plant, animal, fungus, or microorganism that is not native to a specific location and causes harm to the environment, economy, or human health when introduced.

Frequency refers to the percentage or probability of a particular plant species occurring within a given number of sample plots or quadrats in a surveyed area.

Density refers to the number of individuals of a particular plant species per unit area in a given habitat.

Basal area refers to the total cross-sectional area of tree trunks or stems per unit ground area, usually measured at breast height (1.3 meters or 4.5 feet above ground level).

Cover refers to the proportion of ground area occupied by a particular plant species or vegetation type, usually expressed as a percentage.

Species diversity refers to the variety and relative abundance of different plant species within a given ecosystem or habitat.

ABSTRACT

Despite its designation as a forest reserve by the Kenya National government in 2018, very limited information existed on the composition, diversity and patterns in the plant and animal life of Tulimani Hill. This research aimed at addressing the gaps by documenting the land use and land cover changes on Tulimani Hill, assessing woody plant diversity and abundance and identifying indicators of anthropogenic disturbance. Global Information Systems (GIS) techniques were used for land cover mapping using satellite images. Data collection involved 24 plots, each 20m x 20m, systematically placed along six line transects of 600m laid from the forest edge to hilltop. The first plot on every transect was set up 100m from the forest boundary followed by additional plots at intervals of 150m. The distance between the transects was 200m. In all plots, the woody plants were identified, counted and recorded. For species with difficulties in identification, the voucher specimens were collected for further analysis and determination at the National Museum of Kenya. Diameter at breast height (DBH) for trees above 10cm in diameter was measured and recorded. Percentage cover of species was estimated visually. Indicators of human impact were noted in each plot to gauge the extent of human influence. Arc Map version 10.8 software was used to process Landsat satellite images. Analysis of vegetation data were done using PAST 4.17 software, where data from the plots were organized into four categories based on the distance from the forest boundary (100m, 250m, 400m and 550m). Kruskal Wallis Test was used to determine variations in the species mean diversity indices, species mean densities, mean basal area of trees and mean cover with distance from the forest boundary to the hilltop. Dunn's Post hoc test was done to separate the means. Shannon –Wiener Diversity index was used to compute species diversity. Spearman's rank correlation was used to test the relationship between the indicators of human disturbance with distance from forest boundary. Land cover types on Tulimani Hill have undergone changes since 2012. Agricultural land increased by 113 hectares, built-up areas increased by 3.08 hectares and barren land increased by 27.84 hectares. Woody vegetation decreased between 2012 and 2022 by 102.42 hectares. Shrubland and grassland increased between 2012 and 2017 by 4.15 hectares but decreased between 2017 and 2022 by 45.64 hectares. The study recorded 50 species from 23 families with Fabaceae, Euphorbiaceae and Lamiaceae being the dominant families. Tree basal area, plant frequency, density, and cover were found to be variable among species. The correlation between the number of cut stems with distance up the hill was significant ($r=-0.400$, $P=0.025$). There was a significant correlation between the number of footpaths, charcoal kilns, and beehives with distance up the hill ($r=-0.800$; $P=0.022$), ($r = 0.800$; $P=0.026$) and ($r=0.900$, $P=0.029$) respectively. There was a significant reduction in evidence of cattle grazing and spread of invasive species with distance from the forest boundary ($r=-0.100$; $P=0.023$), ($r=-0.900$; $P=0.040$). The hill hosts a diverse array of woody plant species and indicators of human-related disturbances were more pronounced closer to the forest edge. The people in the local community are urged to plant more trees to alleviate degradation of Tulimani Hill forest. Public awareness, education and alternative livelihood projects can mitigate human impact, while a management plan is essential to combat illegal activities on the hill.

CHAPTER ONE: INTRODUCTION

1.1 Background

Dry lands have an ecological, economic and social value as they provide livelihood and habitat to about a quarter of Earth's population (Bonkoungou, 2001). They provide human communities with ecosystem goods and services including food, water, fodder, gum arabic, shelter, fuel wood, frankincense, herbal medicine and spring water that are vital for human survival (Benny, 2001; Kamotho *et al.*, 2008; Muller & Anderson, 2018). In addition, dry lands and their rangelands are valuable for carbon storage (Muller & Anderson, 2018) and provide opportunities for trade, tourism and services (Hesse, 2020).

The dry land ecosystems have low and unpredictable rainfall and inter- annual climate changes (Hesse, 2020). Drylands by estimate occupy a third of the entire global land surface with approximately half of the zone being used economically as agricultural land (United Nations Convention to Combat Desertification, 2017). Despite their importance, these drylands face degradation through a combination of climate and anthropogenic factors, such as unsustainable farming techniques, mining and overgrazing (Chakrabarti, 2016). Efforts to protect and sustainably use these ecosystems have been overlooked (Bonkoungou, 2001).

Changes in land cover profoundly impact processes like soil erosion and biogeochemical cycling, making it a critical factor in biodiversity preservation over the next century (Foody, 2002). Loss of vegetation contributes to global issues in environment, like changes in climate, emissions of greenhouse gases, erosion, and biodiversity loss (Andrade & Rhodes, 2012). Therefore, having up-to-date land cover information is crucial for environmental and socioeconomic applications like resource conservation and regional planning. Floristic studies are preconditions for protection of plant species (Bano *et al.*, 2018).

More than 80% of Kenya's landmass is classified as dryland (UNDP, 2010). These dryland areas, particularly hills, may host unique plant populations of plants and animals. Botanical studies of the drylands in Makueni county are limited, their floral and faunal diversity status is unknown and protection efforts are low, sometimes, non- existent (Cheruto *et al*., 2016). This study focused on mapping land cover changes that have occurred on Tulimani hill, assessing the diversity, abundance and woody species composition and documenting the signs of human disturbance. The information obtained from this study, will assist in future management and conservation programmes of Tulimani Hill since it's said to be gazetted "with high degree of protection" but it's highly disturbed.

1.2 Statement of the Problem

Globally, the most important threats to conservation of biodiversity are degradation, loss and fragmentation of habitats which are contributed mainly by human activities. Human activities that have influence on forest vegetation include wood collection (Kiprotich, 2016 ; Gojamme & Tanto, 2016), tree debarking, charcoal burning, footpaths, extensive deforestation (Tolera *et al*., 2008; Gojamme & Tanto,2016), overgrazing (Jarenkow & Waechter, 2001; Gojamme & Tanto, 2016; Bano *et al*, 2018 and Maestre *et al*., 2019), logging and development (Meguro *et al*., 2018; Alelign *et al*., 2007), shifting cultivation (Kimaro & Lulandala, 2013) and expansion of agricultural fields for increased agricultural productions due to increased population and scarcity of land (Cheruto *et al*., 2016).

ASALs in Kenya also face ecological deterioration, mainly due to overgrazing, rapidly increasing population. The deterioration extends to the hilltop forests in the ASALs as individuals look for livelihood in the 'savior sites '(Mutiso *et al*., 2015; Musau & Mugo, 2020). For this reason, dryland hilltops are among the most threatened ecosystems in Kenya perhaps due to ignorance and poverty among the neighboring communities (Malonza *et al.,* 2006; Makau, 2014).

These Arid and semiarid lands (ASALs) in Kenya, including their hilltop forests, are known to harbor unique biodiversity that warrants conservation and sustainable use. Ecosystems such as the Mbooni Hills in Makueni County have demonstrated the potential for high ecological and biodiversity value, suggesting that the Tulimani Hill ecosystem may also support significant biological diversity that has yet to be thoroughly documented (Makau, 2014).

Despite its recognition as a forest reserve and a water catchment area, no systematic studies have been done to establish the composition and diversity of plants and animals of Tulimani Hill ecosystem, yet anecdotal evidence indicates continued degradation of the ecosystem in response to societal demand for ecosystem goods and services. Lack of such important information is a serious problem that can lead to insufficient management and conversation of the ecosystem. This research aimed to bridge the gap on knowledge of the flora by assessing diversity and abundance of woody species on the Tulimani Hill.

1.3 Justification and Significance of the Study

Conservation of biodiversity is critically dependent on identifying its important components. In many cases, availability of basic biodiversity data supports effective conservation action for a given ecosystem (Sousa-Baena *et al*., 2013). As noted by Haq *et al*. (2023) information on floristic composition and distribution of species enhances rational utilization of resources. Awareness of species composition through time allows for improved understanding of the current species assemblages and may provide meaningful clues for the preservation of unique communities (Thompson *et al*., 2013).

Floristic data, is a fundamental tool for biodiversity assessment and monitoring. It will serve as a foundation for evaluating the ecological health of Tulimani Hill and guiding its conservation efforts. Conducting this study will contribute valuable information to fill knowledge gaps on and support informed decision-making for biodiversity conservation and development of management plan in this dryland hill ecosystem.

Understanding the importance of preserving plants and the impacts of human disturbances on forest vegetation structure and tree diversity is essential for effective conservation. Such knowledge provides critical insights for planners, decision-makers, and resource managers to develop sustainable management strategies tailored to the specific needs of ecosystems (Kimaro & Lulandala, 2013). It is therefore crucial to evaluate changes in vegetation patterns and monitor human disturbance on Tulimani hill considering its significance in biodiversity conservation.

1.4 Research questions

a) What land use and land cover types exist on Tulimani Hill and how have they changed over the past 10 years (2012-2022)?

b) What is the diversity and distribution patterns of the woody plants on Tulimani Hill?

c) What anthropogenic activities impact the woody plant species in Tulimani Hill ecosystem?

1.5 Hypotheses

a) The land use and land cover types on Tulimani Hill have not changed between 2012- 2022.

b) Woody plant species of Tulimani Hill ecosystem have low diversity and abundance and are not uniformly distributed.

c) There is no relationship between human activities and vegetation characteristics in Tulimani Hill ecosystem.

1.6 Objectives

1.6.1 General Objective

To establish changes in land cover types, determine woody plant diversity and document human disturbance levels on Tulimani Hill ecosystem.

1.6.2 Specific Objectives

a) Determine land use and the distribution of various land cover types on Tulimani Hill and changes that have occurred for the period 2012 to 2022.

b) Determine the composition, diversity and abundance of woody plant species on Tulimani Hill ecosystem.

c) Document the indicators of anthropogenic activities and their possible impact on the vegetation of Tulimani Hill.

1.7 Outputs of the study

- Three Vegetation Cover Maps for Tulimani Hill ecosystem (at 5-year interval) showing vegetation types, their distribution and how they have been changing were developed.
- A checklist of the woody plant species in Tulimani Hill forest was also developed (Appendix 1) which will be used to make the management plan of the forest.
- MSc Thesis.
- Published journal.
- Information from this research can be used in drafting a policy brief of conserving Tulimani Hill.

CHAPTER TWO: LITERATURE REVIEW.

2.1. Mapping of Land Cover Changes in Tulimani Hill ecosystem.

Vegetation mapping is a process of outlining the extent, landscape patterns and geographical distribution of vegetation types and structural characteristics. It is done in three ways; using Global Information System- GIS, a phytosociological basis and use of remote sensing (Hasmadi *et al*., 2010, Balaguru *et al.*, 2003). It is commonly used to determine the vegetation of an area, show plant species distribution, show tree and shrubs damages and to predict future vegetation changes.

Both satellite data and ground-truth data are needed to generate a vegetation map (Munywoki *et al*., 2021, Malombe *et al*., 2020, NASA Earth Observatory, 2025). Ground-truth data is collected using sample plots with visual inspection and unsupervised pixel-based classifications of the Google Earth scenes and Rapid Eye imagery being used to identify the sites. GPS units help pinpoint the exact locations of sample plots. GPS information is then transferred to ArcGIS software where it is manually digitized into polygons of specific habitat. Google Earth scenes and Rapid Eye imagery are used to make sure the locality of the GPS figures is accurate and for urban areas digitizing roads (Wampler *et al*., 2013; Hu *et al*.,2013; Bedair *et al*.,2021).

Land cover is regarded as a significant factor that affects and connects nature with humans (Maina *et. al*., 2020). Various land cover classes may include snow and ice, bare lands, impervious surfaces, shrublands, wetlands, water bodies, croplands, forests, and grasslands (Yuanyuan *et al*., 2018; Horning, 2004). Land cover changes, often driven by human activities, have a significant impact on biodiversity (Malombe *et al*., 2012).

Detection of changes in land cover with time gives knowledge on the connection between humans and nature and offers a guide in resource use and its management. Geographic Information System (GIS) has proved a practical tool and has gained wide acceptance in analysis of land use/cover changes, allowing for comparisons between different time periods. It utilizes various data sources like classified images, hydrology, soil maps, and maps on topography to detect changes in specific areas. Repeated satellite coverage is vital for monitoring changes in a given region (Alqurashi& Kumar, 2013).

Land cover changes that have occurred due to natural factors or caused by humans are a continuous process worldwide (Zoncova, 2020). Dryland regions, in particular, are experiencing significant land use and land cover changes due to various socioeconomic activities and environmental events (Cheruto *et al*., 2016). Over the years, various and intensive degradation of lands have increased in dryland regions due to anthropogenic activities and climate changes leading to biodiversity loss in some regions (Mulinge *et al*., 2016).

Makueni County has experienced changes in land cover for years (Cheruto *et al*., 2016; Makueni County Government, 2020). The rapid loss of vegetation cover especially in Africa is alarming (Mainga, 2011). The present forest conversions and associated loss of biodiversity in dry lands are believed to be fueled by population increase and agriculture (Malombe *et al*., 2012; Mengich *et al*., 2013), and Tulimani Hill is no exception. This study focuses on analyzing the changes in land cover on the hill using GIS. This is crucial for management of the resource and diversity preservation (Yuanyuan *et al*., 2018).

2.2. Assessment of Composition, Diversity and Abundance of Woody Plant Species.

In the field of community ecology, conducting a floristic inventory is a fundamental step in understanding species distribution patterns and modeling species diversity (Jayakumar & Heo, 2011). Floristic composition, which includes indices of species abundance, richness, frequency, and dominance, is a key aspect of plant community anatomy (Danjuma, 2017). It is essential to comprehend vegetation types, and plant species composition and diversity plays a significant role in this regard (Kayombo *et al.*, 2020). The patterns of abundance of species and their distribution influence plant diversity in any given location.

Trees, woody climbers (lianas) and shrubs are the woody plant species and plays major role in the process and maintenance of ecosystems since they are sources of important products like pulp, lumber, medicines, food for humans and wildlife, fuel, gums, waxes, oils, resins and tannins. They play a considerable role in forest regeneration too and in whole-forest processes such as prevention of soil erosion, carbon sequestration and transpiration (DeFries *et al*., 2010).

Floristic diversity can be studied by use of various sampling methods like systematic sampling (Tolera *et al.*, 2008; Kangabam & Kangaraj, 2016) through establishment of line transects in the forest which are used as baseline where sampling plots are located using systematic random sampling technique to quantify vegetation dominance and species distribution patterns (Wetang'ula *et al.*, 2014; Melese & Ayele 2017).

Sampling can also be done by locating belt transects in the forest (Wanjohi *et al.*, 2017) or by establishing nested quadrants along transects (Malombe *et al.*, 2012). Agro-climatic maps on existing vegetation and Landsat imageries can also be used (Edwards *et al.*, 2013) where data can be collected by creating selected plots and estimating species totals and breadth at chest height. Relative dominance, basal area, corresponding abundance, importance value indices and relative frequency for a particular species at any given site are then computed (Mengich *et al.*, 2013).

Diversity indices measure species diversity and provide insights into community composition at different taxonomic levels, from families to genera to species. Knowledge of species diversity is valuable for understanding biotic disturbances, environmental stability, and ecological succession (Korner, 2007; Zhang & Dong, 2010; Hawkins & Diniz, 2004). Spatial variations in species diversity reveal important patterns in vegetation in the study area, with higher species diversity indicating greater species abundance (Wanjohi *et al*., 2017).

Abundance of species, which includes measures like density, biomass, basal area, frequency, cover, and presence, is essential for assessing biological diversity and informing conservation efforts (Dubey, 2023). Density, for example, reflects the number of individuals of a particular species in a certain region, and higher density indicates greater abundance. Basal area gives details about the tree size and indicates the tree health status in an ecosystem. It is a more comprehensive measure than simple stem counting (Kent & Coker, 2014).

Understanding vegetation cover, or the area occupied by various plant species in a plot, is vital for ecological descriptions and range condition assessments. It can be estimated visually or quantified using point or line interception methods. Vegetation cover data helps to record the relative abundance of different plants in a community, and the total cover should not exceed 100 percent in a plot (Drezner & Farnum,2021). Changes in vegetation cover are often influenced by various human activities (Jiang *et al*., 2017).

Frequency, which indicates distribution patterns and the heterogeneity of a stand, provides insights into the mechanisms of seed dispersal for different species. Distance to communities is an important factor which influences forest composition and species distribution in ecosystems (Thammanu *et al*., 2021; Lhoest *et al*., 2020; Burgi *et al*., 2000).

Although there is inadequate exploration of diversity of plant species in many dryland ecosystems including hilltops in Ukambani region (Makueni, Machakos and Kitui Counties (Musau & Mugo, 2020), some studies have been done on plant diversity status including Musila & Mwangangi (2014) on Makongo forest and Malombe *et al*., (2012) in Nthangu, Kitondo, Makongo and Makuli Hills of Makueni County and a large number of plant species was noted. This study aims to enhance knowledge on the distribution and patterns of woody plant species on Tulimani Hill, which is crucial for managing and conserving these plants (Panda *et al*., 2013).

2.3. Documentation of Anthropogenic Disturbances in Tulimani Hill ecosystem.

Arid and semiarid lands are fragile and vulnerable to degradation, and this reduces the productivity of the lands (Mulinge *et al*., 2015). Dryland forest ecosystems are areas for diversity preservation in ASAL's. They contribute to livelihoods of inhabitants within the areas. Unfortunately, fast reduction in forest cover is occurring in these areas due to unsustainable exploitation of natural resources, leading to habitat destruction and degradation (Musau, 2013).

Human disturbances lead to degradation of forest ecosystems (Kiprotich, 2016), alters ecosystems and their functions (Bohn & Huth, 2017) and negatively affect the livelihoods of the surrounding local communities (Kimaro & Lulandala 2013). Deterioration and loss of vegetation causes soil erosion and depresses the quality of the forests (Meguro *et al.*, 2018). During logging, tree felling damages the crowns of neighboring trees (Medjibe *et al.*, 2011). Logging also leads to destruction of habitats and declines the abundance and diversity of forest species (Bicknell *et al*.,2014). Over-exploitation of a species may lead to its extinction (Vuyiya *et al.,* 2014; Lalfakawma *et al.*, 2009).

Disturbance hampers regrowth of under storey plants that are not pioneers (Kwit *et al.*, 2003), reduces diversity of species, affect forest ecological operation and biodiversity integrity of forests due to unexpected changes on their composition and structure (Kimaro & Lulandala 2013; Molino & Sabatier, 2001; Vuyiya *et al.,* 2014). Human activities cause disturbances mainly at the plots near the forest boundaries due to proximity and accessibility by neighboring communities (Yirga *et al.*, 2019; Kimutai & Watanabe, 2016; Abunie, 2016).

In Makueni County, studies on anthropogenic impacts on woody plant species on hill forests are minimal although hill forests face threats and challenges (Malombe *et al*., 2020) and locals extract forest provisioning ecosystem services from the hill forests as evidenced in a study done by Musyoka *et al*., (2019) in Chyulu Hills and Malombe *et al*., (2012) on Nthangu, Kitondo, Makongo and Makuli Hill forests. This study therefore aims at documenting the human disturbances that affect biodiversity in Tulimani Hill. This will help conservation managers to improve ways of protecting the plant species.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

Tulimani Hill, located in Mbooni Sub County within Makueni County, Kenya (Figure 3.1), covers an area of 325.8 hectares. It is positioned at approximately 01°51'07" South latitude and 037°04'02" East longitude, with an elevation of 1153 m above sea. This Sub-County had a population of approximately 225,000 people, according to the 2019 Kenya Population and Housing Census (Kenya National Bureau of Statistics, 2019). The population is predominantly rural, with most people living in villages and small towns spread across the sub-county. The majority of the people are the Kamba ethnic group. The Akamba people are known for their agricultural practices (crop farming and livestock farming). They are also engaged in other socioeconomic activities like business and trade, construction and tourism.

The region experiences average yearly temperatures which fluctuate with higher temperatures during the dry seasons, particularly in August, September, and partially in October. Annual precipitation averages between 530mm and 625mm, and it varies inconsistently across different seasons. The primary rainy season spans from March to May, whereas the short rains occur between October to December. The soils in this area consist of sandy clay.

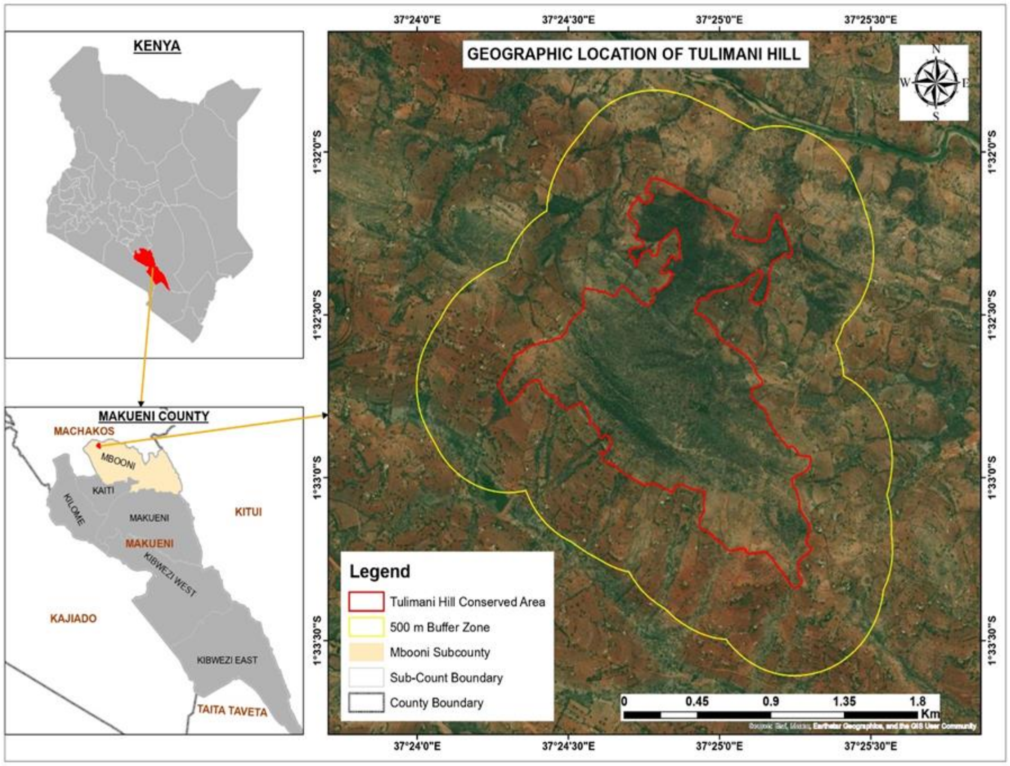

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Figure 3.1: Location of Tulimani Hill in Makueni County (Approximately 20km South East of Machakos town).

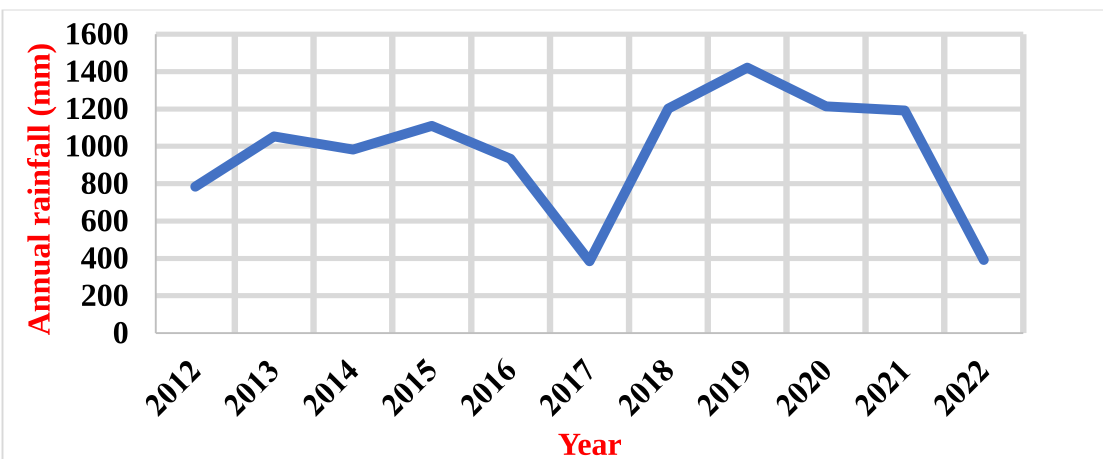

Figure 3.2: Rainfall data for Tulimani hill for the year 2012-2022 obtained from Katumani Meteorological station.

3.2 Sampling design and data collection.

3.2.1 Mapping of land use and land cover types that exist on Tulimani Hill forest.

To evaluate alterations in land cover within the Tulimani Hill ecosystem, satellite images and geographic coordinates of specific ground reference points were acquired and employed for processing and categorization. The year 2012 was selected as the baseline year for the study because, at that time, there had been minimal changes in land cover. Subsequently, human activities led to notable changes**.**

Landsat images were utilized due to their appropriateness for analyzing vegetation cover, including distinguishing between vegetation, measuring chlorophyll absorption, and assessing vegetation types and biomass content (Yanapa, 2024**).** The Landsat images chosen encompassed the years 2012, 2017, and 2022 as these intervals were deemed adequate to capture substantial shifts in land cover. Different months were used across the years (Banskota *et al*., 2014) as detailed in Table 3.1. The images were downloaded from USGS Earth explorer, processed, classified to get the vegetation cover changes (Figure 3.3). All selected satellite images had a resolution of 30 meters to ensure high accuracy in the analysis.

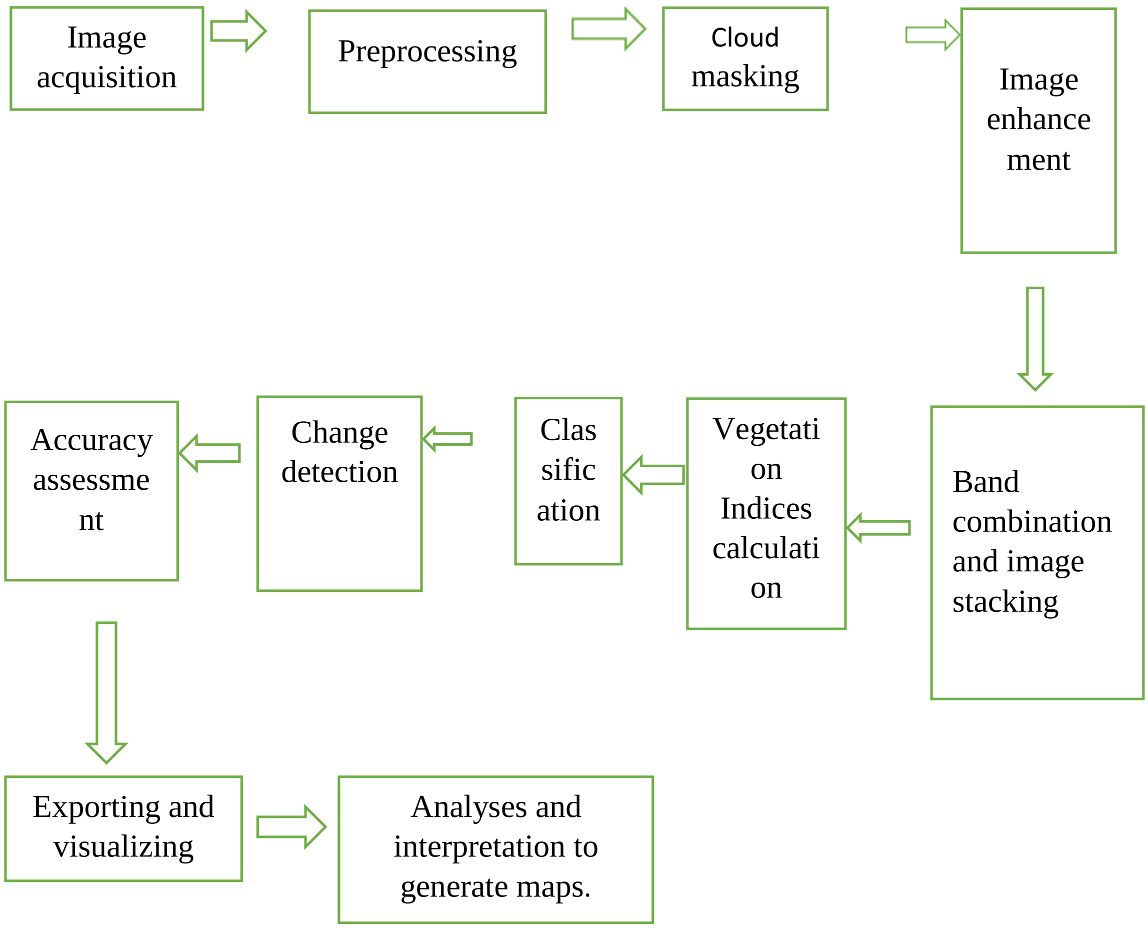

Figure 3.3: Analyses performed on the Landsat images acquired to produce Tulimani Hill Forest land use /cover maps.

Table 3.1: Satellite Data used in the Study

Data Type	***Year of Production***	***Source***
Landsat ETM+	February, 2012, 30x30 Metres	USGS Earth Explorer: (http://glovis.usgs.gov).
Landsat ETM+	December, 2017 30x30 Metres	
Landsat ETM+	January, 2022, 30x30 Metres	

3.2.2 Assessment of diversity, abundance and composition of woody species on Tulimani Hill.

Vegetation data for this study were collected using a systematic sampling method, with the official permission of the Kenya Forest Service (permit number RESEA/KFS/VOL-V11/89) (Appendix 4). Six transect lines, each approximately 600m, running from the bottom to the top of the hill, were established. Along these transects, four sampling plots measuring 20 meters by 20 meters (400 square meters) were established (Zekele *et al*., 2022). The first plots on each transect were laid at 100 meters inside the forest border to avoid extremely disturbed areas (Porensky, 2013), with additional plots set up at intervals of 150 m (as depicted in Figure 3.2). All sampled areas were geographically referenced using handheld Garmin 12- channel GPS device to facilitate manipulation within a GIS environment and for future monitoring.

The transects extended from the lowland to the hilltop, with a 200-meter spacing between them. In every sampled plot, the woody plant species were identified, tagged, and documented. The number and diameter at breast height (DBH) of trees with a diameter exceeding 10 centimeters were recorded, with DBH measurements taken using calipers.

Visual estimation of plant cover for all the species was done within the sampled plot with ranges 1% to 38%.

Identification of species was done with the assistance of taxonomic and floristic experts affiliated to the University of Nairobi Herbarium. Two reference manuals, Agnew & Agnew, 2010) and Beentje, 2010), were utilized in the identification process. For species that were challenging to identify or had uncertain identifications, voucher specimens were collected, labeled, pressed, dried, and subsequently identified in Botany department at the National Museums of Kenya. Botanical names were documented, with local names used when available.

Altitude measurement for each plot was documented by use of a Garmin 12- channel GPS device (Latitude: -1.545154^0 and longitude:37.413084^0). The habit of each species was noted, categorizing them as trees, shrubs, or tree/shrubs (Appendix 5). A checklist of woody plant species was compiled to reflect the floristic composition of the Tulimani Hill ecosystem (Appendix 1). Frequency was determined by counting how often a species was found in all plots within a zone, expressed as percentages. Density was determined by counting the number of individual species within a single plot, following the method by Kent & Coker (2011).

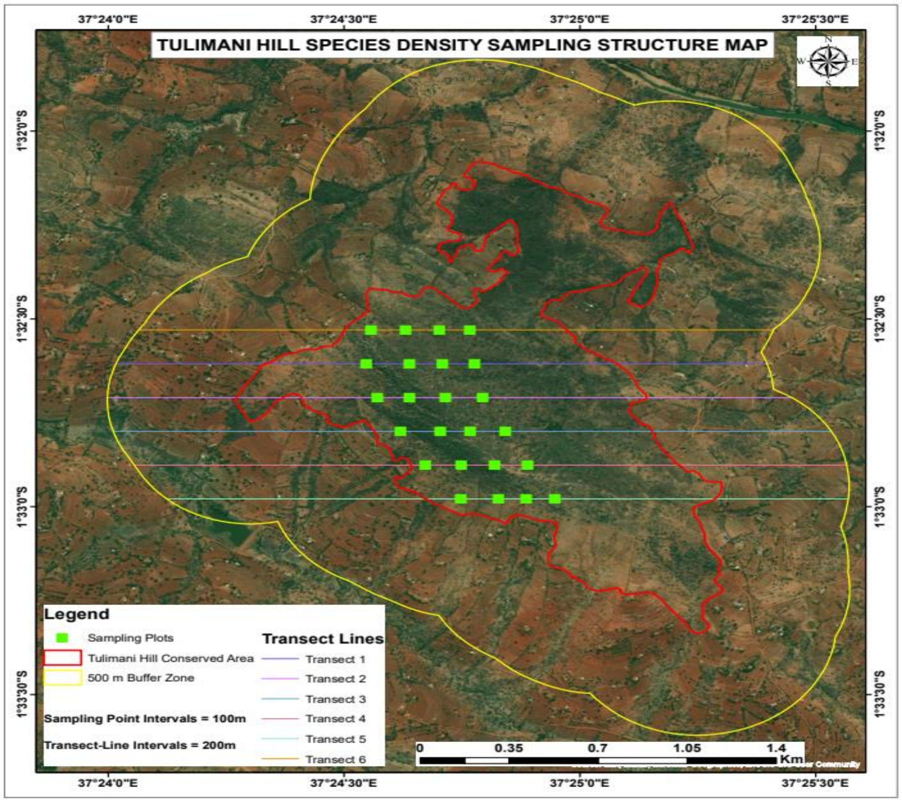

Figure 3.4*: *Tulimani hill vegetation sampling map showing layout of transects from the base of the hill to the apex.

3.2.3 Documenting indicators of anthropogenic impacts on the vegetation of Tulimani Hill forest.

Within the Tulimani Hill forest, the study identified various indicators of human activities, including evidence of cattle grazing, honey harvesting, wood harvesting, footpaths, and charcoal kilns. These indicators were observed directly in each plot along the transects and documented as present/ absent. Cut stem stumps in every sampled plot were tallied and recorded (Musau & Mugo, 2020).

3.3 Data analysis

The analysis of data was carried out using the following methods:

3.3.1 Mapping and description of the land cover types that exist on Tulimani Hill forest.

Data obtained from GPS was transferred to ARC/INFO GIS software to generate land use and land cover maps which revealed the major spatial patterns of vegetation distribution (Esri, 2024). Results on the extent of different vegetation types in 2012, 2017 and 2022 were presented in tables. Changes in area covered by vegetation, agricultural land and built-up area between 2012 and 2022 in the study area were quantified and expressed as percentages in tables.

3.3.2 Variation in species diversity, abundance and composition of woody plant species of Tulimani Hill Forest.

Data obtained from the sampled plots were organized and grouped into four categories based on the distance from forest boundary: 100m, 250m, 400m and 550m for substantial comparison of vegetation structure and species composition closer to the forest edge and areas further on the hill where conditions are more stable and less affected by the edge. Data on frequency, diversity, tree basal area, density and cover were compiled and analyzed using PAST 4.17 Software (Hammer *et al*., 2001). Tree basal area per hectare was computed using Equation 1 from the measured DBH values (Kayombo *et al*., 2022).

$$BA = \frac{\pi \times (DBH/2)^2}{1000} \qquad \text{(Equation 1)}$$

Where;

BA = Basal area

Π = 3.142

DBH = Diameter at breast height

Woody species diversity within each zone was quantified using the Shannon-Wiener diversity index (H’) (Van der Maarel & Franklin, 2013). The Shannon index, denoted by Equation 2, factors in species abundance, evenness, and highlights the importance of rare species (Tolera *et al*., 2008).

$$H = -\sum_{i=1}^{S} PiInPi \qquad \text{(Equation 2)}$$

- S, representing the total number of observed species.

- ln, the natural logarithm function.

- Pi, which is the proportion of individuals from a specific species (n) divided by the total number of individuals found (N). The product of pi ln pi for each species in the plots will be summed up and multiplied by -1 to give *H’*.

Data on basal area, diversity, cover, frequency, and density were presented using bar graphs and tables. Mean diversity indices, mean density, mean cover, and mean basal area were calculated for the four regions up the hill. Kruskal Wallis Test was used to determine variations in mean diversity indices, mean density, mean basal area of tress, and mean cover of plants with increasing distance up the hill (Smith & Jones, 2023). Dunn’s Post hoc test was done to separate the means (Smith & Jones, 2023).

3.3.3 Indicators of anthropogenic activities on the vegetation of Tulimani Hill forest.

Data on indicators of human disturbances were summarized using descriptive statistics like mean and findings presented in bar graphs. A Spearman’s rank correlation test was utilized to assess whether there was a significant relationship between the human activities observed and distance up the hill (Smith & Johnson, 2023). Photographs were used to visually depict observed ongoing human activities in Tulimani Hill. The significance threshold for all statistical tests were set at $P < 0.05$.

CHAPTER FOUR: RESULTS

4.1 Land cover types on Tulimani Hill and changes that have occurred for the period 2012 to 2022

Thematic land cover classes for the Tulimani Hill ecosystem in 2012, 2017, and 2022 were generated from Landsat imagery, as shown in Figure 4.1. Five distinct land cover categories were identified based on Landsat image classification: woody vegetation, shrubland and grassland, agricultural land, built-up area, and bare land (Coulter *et al*., 2016). Woody vegetation included trees and thickets while Shrubland and Grassland comprised short shrubs and scattered grasses respectively. Agricultural land represented cultivated crops, and the built-up area included housing and other human-made structures. Bare land encompassed open ground, rocky surfaces, and footpaths (as detailed in Table 4.1).

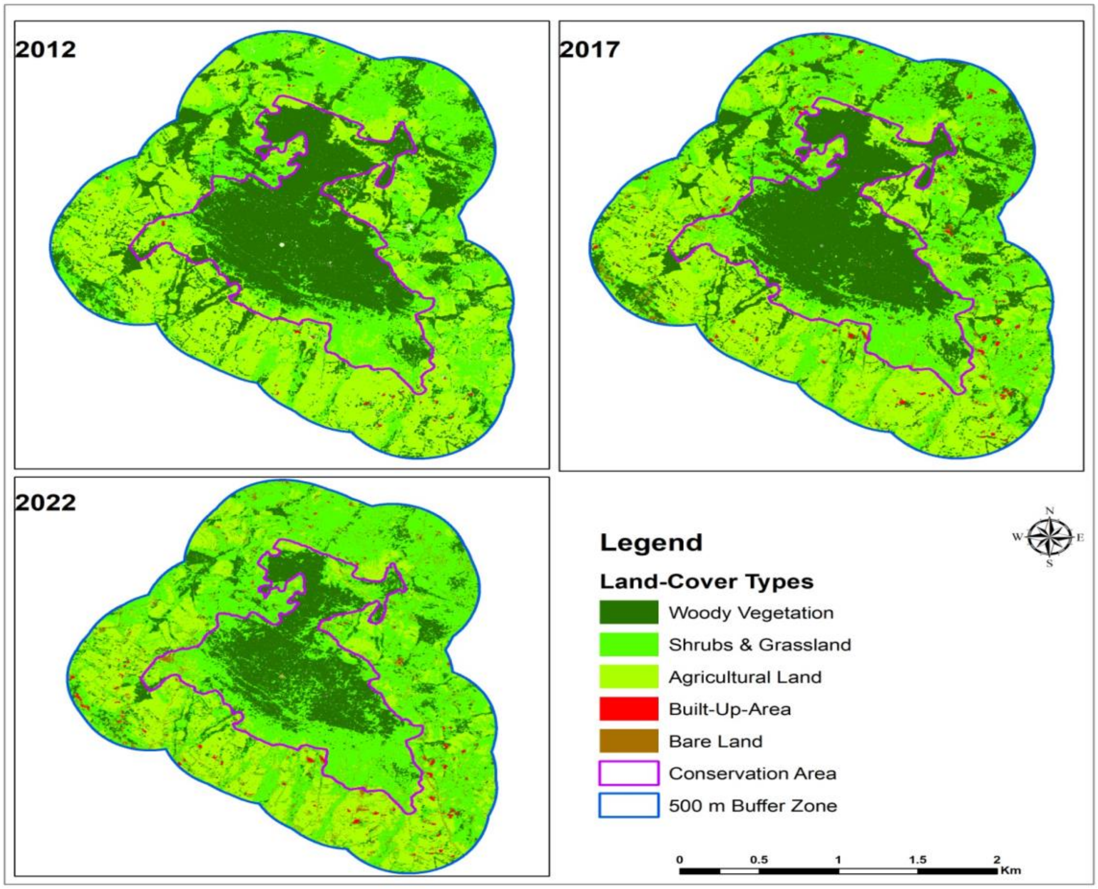

Figure 4. 1*:* Land-Cover Change in Tulimani ecosystem from 2012 to 2022.

Table 4.1*:* Thematic Land Cover Class Areas, Trends and Magnitude of Land Cover Change for Tulimani Hill for the years 2012, 2017 and 2022.

Land Cover Type (Class)	**Area in Hectares**			**Change from 2012 – 2017**		**Change from 2017 – 2022**	
	2012	**2017**	**2022**	**Area in hectares**	**% change**	**Area in hectares**	**% change**
Woody vegetation	230.23	201.80	127.81	-28.43	-14.09	-73.99	-57.89
Shrubland and grassland	196.32	200.47	154.83	4.15	2.07	-45.64	-29.48
Agricultural Land	216.48	224.47	329.48	7.99	3.56	105.01	31.87
Built-up Area	1.81	3.38	4.89	1.57	46.45	1.51	30.88
Bare Land	7.23	21.96	35.07	14.73	67.08	13.11	37.38

The woody vegetation experienced its most significant loss during the period from 2017 to 2022 (-57.9%) accounting for about 73.99 hectares of land being converted to the other land cover types mainly agricultural land. It is however noted that since 2012, woody vegetation has been declining at an annual rate of -14.09% (28.43 hectares per year) (Table

4.1) loss for the period between 2012 and 2017. Shrubland and grassland which mainly comprises of short and scattered shrubs and grasses are noted to have increased by 4.15 hectares (2.07%) between 2012 and 2017. This can be associated with the loss of trees within the ecosystem increasing area under shrub and grass vegetation. However, this land cover class transformation escalated with the conversion of land into agricultural use or settlement thus resulting in the -29.48% (45.64 hectares) loss of shrubland and grassland observed in the period between 2017 and 2022.

With the increase in the anthropogenic activities, agricultural land, built-up area and bare land are observed to have a consistent increase in area coverage. In 2017, agricultural land had increased to 224.47 hectares form the initial 216.48 hectares in 2012 (a 3.56% increase). There was a continued increase to 329.48 hectares (31.87%) with the intensification of crop farming for the duration between 2017 and 2022. Similarly, built-up area and bare land are observed to have a 46.45% and 67.08% increase respectively in the period between 2012 and 2017. It is further observed that in the period between 2017 and 2022 an additional 1.51 hectares (30.88%) was converted to built-up area to offer room for settlement. More land was also being converted to bare land as noted from the analysis where there is a 37.38% (13.11 hectares) increase. This compromises the sustainability of the ecosystem leading to decrease in species density and diversity.

4.2 Floristic composition, diversity and abundance of woody plant species of Tulimani Hill Ecosystem.

In this study, a total of fifty (50) plant species were identified, comprising 33 shrubs and 17 trees, originating from 41 genera and 23 families, as documented in Table 4.2 and Table 4.3. The most prominent family was Fabaceae, with 8 genera and 14 species, followed by

Euphorbiaceae (4 species), Lamiaceae (4 species), and Rubiaceae (3 species). Asteraceae, Capparaceae, Combretaceae, Burseraceae, Malvaceae, and Solanaceae had two species. Acanthaceae, Anacardiaceae, Apiaceae, Asparagaceae, Balanitaceae, Boraginaceae, Celastraceae, Convolvulaceae, Labiatae, Phyllanthaceae, Sapindaceae, Thymelaceae and Verbenaceae were all represented by a single species as shown in Table 4.2 and 4.3. Out of these species, ten trees and fifteen shrubs were found to be common across the four different regions within the forest.

Notable tree species that were common to all four regions included *Commiphora indensis, Vachellia mellifera, Vachellia seyal, Vachellia tortilis*, and *Terminalia brownie.* The common shrub species encompassed *Acalypha volkensii, Asparagus africanus, Croton dichogamus, Flueggea virosa, Gnidia latifolia, Hibiscus fuscus, Hoslundia opposita, Lantana camara, Maytenus heterophylla, Microglossa pyrifolia, Pavetta abyssinica, Premna resinosa, Rhus natalensis, Senna singueana, Solanum incanum, Tinnea aethiopica, Vachellia brevispica* and *Vachellia nilotica.*

4.2.1 Wood plant species diversity

The study conducted found a total of 33, 31, 35 and 36 recorded plant species at 100m, 250m, 400m and 550m respectively. The highest species diversity was observed at 550m and 400m. This suggests a relatively high diversity of woody plant species in plots far away from forest edge.

The diversity of woody species showed no significant variation in relation to distance up the hill (P=0.516). The mean diversity indices ranged between 1.8 and 2.1 across different distance intervals (specifically 1 .8, 1.9, 2.0 and 2.1) which indicates a relatively balanced distribution of individual plants among most woody species within the sampled plots as shown in (Figure 4.2).

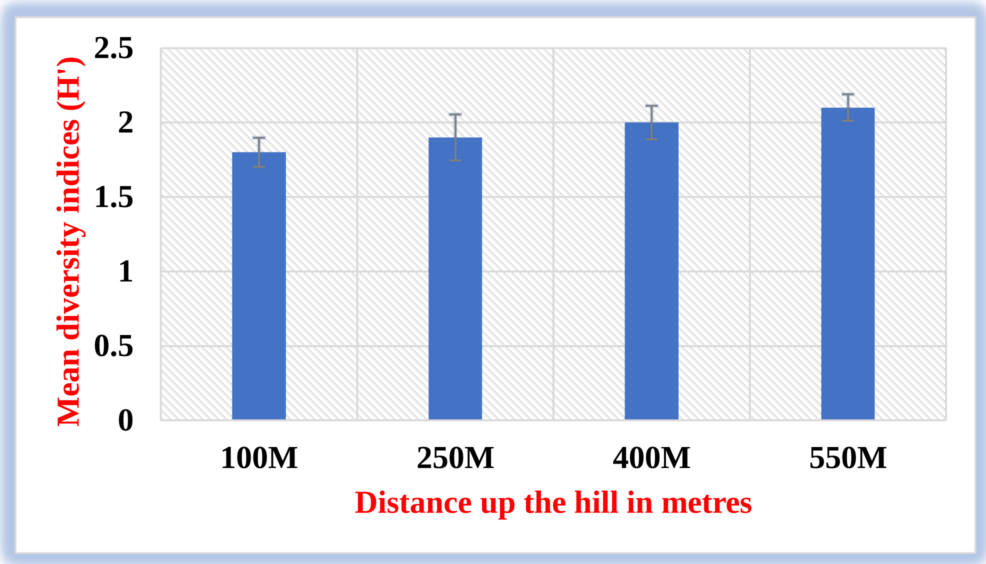

Figure 4.2: Variation of Mean Diversity Indices (SE -/+) with increasing distance up the hill (SE+/-).

4.2.2 Frequency of woody plant species

In terms of habit, the encountered species were composed of 36 shrubs and 17 trees. The most frequent tree species were *Vachellia mellifera* (Family Fabaceae). Another species that was frequently encountered was *Terminalia brownie* (Family Combretaceae) and *Vachellia seyal* (Family Fabaceae) as shown in Figure 4.3.

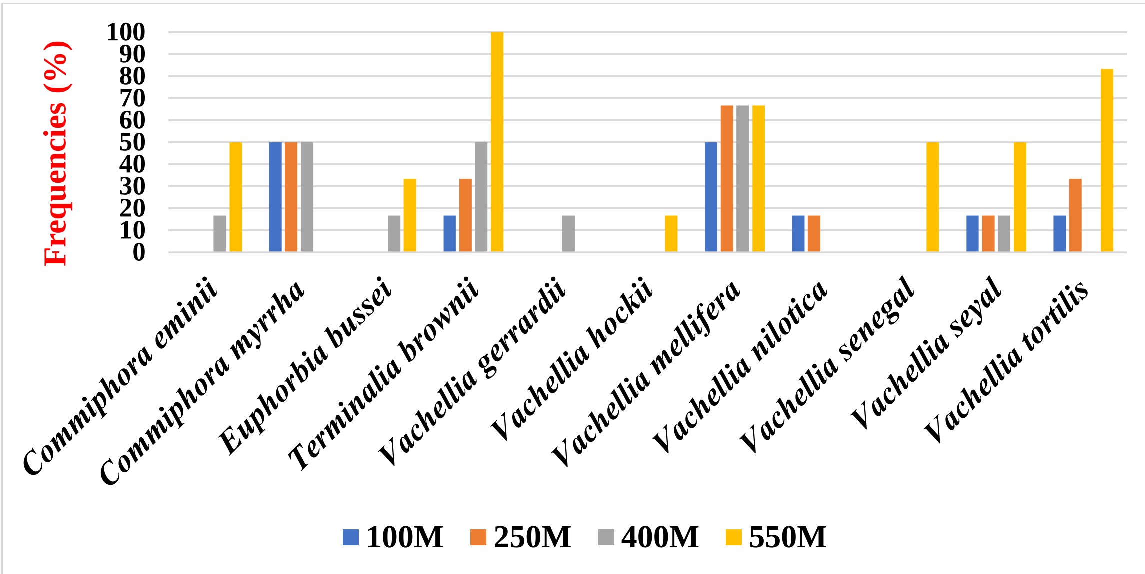

Figure 4.3: Tree species frequencies (%) in different distance intervals up the hill.

The most common shrub species were as follows *Gnidia latifolia* (Family Thymelaceae) had a (100.0% presence at 100m, 250m, 400m and 550m). It was followed by *Lantana camara* (Family Verbenaceae) (100.0% occurrence at 100m, 83.3% at 250m, 100.0% at 400m and 100.0% at 550m. *Rhus natalensis* (Family Anacardiaceae) was present ,100.0% at 100m, 83.3% at 250m, 83.3% at 400m and 100.0% at 550m). *Croton dichogamus* (Family Euphorbiaceae) had a presence of 100.0% at 100m, 66.7% at 250m, 100.0% at 400m and 83.3% at 550m. *Maytenus heterophylla* (Family Celastraceae) was found at 83.3% at 100m, 83.3% at 250m, 66.7% at 400m and 100.0% at 550m.

On the other hand, the least frequent shrubs included *Crotalaria axillaris* (Family Fabaceae) being absent at 100m and 250m, 16.7% at 400m and 16.7% at 550m). *Grewia similis* (Family Malvaceae) was found absent at 100m and 250m, but had a presence of 16.7% at 400m and 16.7% at 550m). *Cordia monoica* (Family Boraginaceae) was absent at 100m, 250m and 400m and had 50.0% presence at 550m. *Solanum taitense* (Family

Solanaceae) being absent at 100m and 250m, with a presence of 16.7% at 400m and 16.7% at 550m) as indicated in Table 4.3.

Furthermore, some species exhibited an increase in frequency with increasing distance up the hill (Table 4.3) i.e *H. foliolosum, V. hockii, V. senegal, V. seyal, Asparagus africanus, Aspilia mossambicensis, C. eminii, C. monoica, C. axillaris, Tinnea aethiopica E. bussei, G. similis, Hibiscus fuscus, Solanum incanum, S. taitense, S. araliacea* and *T. brownie.*

Table 4.2: Tree species and the families they belong to.

	TREE SPECIES NAME	**FAMILY NAME**
1	*Albizia anthelmintica*	Fabaceae
2	*Balanites aegyptiaca*	Zygophyllaceae
3	*Commiphora eminii*	Burseraceae
4	*Commiphora myrrha*	Burseraceae
5	*Euphorbia bussei*	Euphorbiaceae
6	*Haplocoelum foliolosum*	Sapindaceae
7	*Lonchocarpus eriocalyx*	Fabaceae
8	*Vachellia nilotica*	Fabaceae
9	*Steganotaenia araliacea*	Apiaceae
10	*Terminalia brownie*	Combretaceae
11	*Vachellia gerrardii*	Fabaceae
12	*Vachellia hockii*	Fabaceae
13	*Vachellia mellifera*	Fabaceae
14	*Vachellia senegal*	Fabaceae
15	*Vachellia seyal*	Fabaceae
16	*Vachellia tortilis*	Fabaceae
17	*Ormocarpum trichocarpum*	Fabaceae

Table 4.3: Shrub species frequencies (%) up the hill.

	SPECIES NAME	FAMILY	100m	250m	400m	550m
1	*Acalypha volkensii*	Euphorbiaceae	83.3	83.3	66.7	83.3
2	*Asparagus africanus*	Asparagaceae	16.6	16.6	16.6	66.7
3	*Aspilia mossambicensis*	Asteraceae	0.0	0.0	0.0	33.3
4	*Capparis tomentosa*	Capparaceae	0.0	0.0	16.6	0.0
5	*Afrocanthium keniense*	Rubiaceae	16.6	16.6	0.0	16.6
6	*Combretum paniculatum*	Combretaceae	0.0	0.0	33.3	0.0
7	*Cordia monoica*	Boraginaceae	0.0	0.0	0.0	50.0
8	*Crotalaria axillaris*	Leguminosae	0.0	0.0	16.6	16.6
9	*Croton dichogamus*	Euphorbiaceae	100.0	66.7	100.0	83.3
10	*Dyschoriste radicans*	Acanthaceae	0.0	16.6	16.6	0.0
11	*Entada abyssinica*	Fabaceae	0.0	0.0	16.6	0.0
12	*Flueggea virosa*	Phyllanthaceae	66.7	66.7	50.0	50.0
13	*Gnidia latifolia*	Thymelaceae	100.0	100.0	100.0	100.0
14	*Grewia similis*	Malvaceae	0.0	0.0	16.6	16.6
15	*Hibiscus fuscus*	Malvaceae	33.3	50.0	66.7	83.3
16	*Hoslundia opposita*	Lamiaceae	16.6	16.6	16.6	16.6
17	*Ipomoea fistulosa*	Convolvulaceae	33.3	16.6	0.0	50.0
18	*Lantana camara*	Verbenaceae	100.0	83.3	100.0	100.0
19	*Maerua crassifolia*	Capparaceae	16.6	0.0	0.0	16.6
21	*Microglossa pyrifolia*	Asteraceae	16.6	16.6	16.6	16.6
22	*Ocimum gratissimum*	Lamiaceae	83.3	50.0	50.0	0.0
23	*Pavetta abyssinica*	Rubiaceae	33.3	16.6	16.6	100.0
24	*Pentas lanceolata*	Rubiaceae	33.3	16.6	0.0	0.0
25	*Plectranthus barbatus*	Lamiaceae	16.6	16.6	0.0	0.0
26	*Premna resinosa*	Lamiaceae	16.6	33.3	16.6	33.3
28	*Senna singueana*	Fabaceae	16.6	16.6	50.0	33.3
29	*Solanum incanum*	Solanaceae	16.6	33.3	50.0	16.6
30	*Solanum taitense*	Solanaceae	0.0	0.0	16.6	16.6
31	*Tinnea aethiopica*	Lamiaceae	16.6	50.0	100.0	100.0
32	*Vachellia brevispica*	Fabaceae	83.3	50.0	66.7	50.0

4.2.3 Species Abundance

4.2.3.1 Woody plant species Density

At 100m, species like *A. volkensii, C. dichogamus, G. latifolia* and *L. camara* had notably high average densities. Moving to 250m, *A. volkensii, C. dichogamus, L. camara, G, latifolia, O. gratissimum* and *S. incanum* exhibited high mean density values. At 400m, *A. volkensii, C. dichogamus, L. camara, T. brownie, O. gratissimum* and *H. fuscus* had high mean density values. At 550m, *A. volkensii, C. dichogamus, L. camara, T. brownie, E. bussei* and *T. aethiopica* had high mean density values as shown in Table 4.4 and Table 4.5. *L. camara* was the most prevalent weed in the area.

Kruskal Wallis Test analysis revealed notable differences ($P<0.05$) in mean density values for several species in the four regions. Specifically, *V. tortilis* (P =0.038), *V. senegal* (P=0.019), *C. monoica* (P= 0.018), *T. brownie* (P = 0.027), *T. aethiopica* (P= 0.002), *S. araliacea* (P=0.019). and *P. abyssinica* (P=0.001) exhibited significant differences. Some species did not show significant variation in mean densities with increased distance up the hill (P>0.05). Tables 4.4 and Table 4.5 summarizes this information.

Table 4.4: Variation in mean densities for trees with distance from the forest boundary in Tulimani Hill.

DISTANCE IN METRES	100m		250m		400m		550m		
SPECIES NAME	**M**	**SE**	**M**	**SE**	**M**	**SE**	**M**	**SE**	***P***
A. anthelmintica	4.2	4.2	0.0	0.0	4.2	4.2	0.0	0.0	0.554
B. aegyptiaca	8.3	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.392
C. eminii	0.0	0.0	0.0	0.0	4.2	4.2	0.0	0.0	0.649
C. myrrha	54.2	36.2	37.5	20.2	16.7	8.3	33.3	17.9	0.214
E. bussei	0.0	0.0	0.0	0.0	8.3	8.3	70.8	61.4	0.248
H. foliolosum	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	0.392
L. eriocalyx	4.2	4.2	0.0	0.0	8.3	5.3	4.2	4.2	0.513
V. nilotica	4.2	4.2	8.3	5.3	4.2	4.2	20.8	4.2	0.062
S. araliacea	0.0	0.0	0.0	0.0	0.0	0.0	12.5	5.6	**0.019**
T. brownie	8.3	8.3	25.0	20.4	45.8	21.8	129.2	49.8	**0.027**
V. gerrardii	0.0	0.0	0.0	0.0	4.2	4.2	0.0	0.0	0.392
V. hockii	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	0.392
V. mellifera	29.2	13.6	33.3	13.9	20.8	7.7	108.3	40.1	0.369
V. senegal	0.0	0.0	0.0	0.0	0.0	0.0	12.5	5.6	**0.019**
V. seyal	4.2	4.2	4.2	4.2	12.5	8.5	12.5	5.6	0.556
V. tortilis	4.2	4.2	20.8	13.6	0.0	0.0	20.8	4.2	**0.038**

M = mean; S.E = Standard Error of the mean; F = F-Statistic; *P* =Significance level

Table 4.5: Variation in mean shrub densities with distance from forest boundary in Tulimani Hill.

DISTANCE IN METRES	**100m**		**250m**		**400m**		**550m**		
SPECIES NAME	**M**	**SE**	**M**	**SE**	**M**	**SE**	**M**	**SE**	***P***
A. volkensii	1070.8	328.5	768.3	392.2	979.2	442.7	729.2	274.7	0.861
A. africanus	16.7	16.7	4.2	4.2	8.3	8.3	54.2	20.8	0.108
A. mossambicensis	0.0	0.0	0.0	0.0	0.0	0.0	33.3	24.7	0.099
C. tomentosa	0.0	0.0	0.0	0.0	4.2	4.2	0.0	0.0	0.392
C. keniense	8.3	8.3	8.3	8.3	0.0	0.0	8.3	8.3	0.778
C. paniculatum	0.0	0.0	0.0	0.0	8.3	5.3	0.0	0.0	0.099
C. monoica	0.0	0.0	0.0	0.0	0.0	0.0	8.3	5.3	**0.018**
C. axillaris	0.0	0.0	0.0	0.0	12.5	12.5	25.0	25.0	0.553
C. dichogamus	283.3	145.4	116.7	49.4	262.5	63.8	416.7	105.4	0.167
D. radicans	0.0	0.0	25.0	25.0	83.3	83.3	0.0	0.0	0.553
E. abyssinica	0.0	0.0	0.0	0.0	4.2	4.2	0.0	0.0	0.392
F. virosa	70.8	26.2	75.0	28.1	54.2	33.2	41.7	20.1	0.745
G. latifolia	208.3	48.6	225.0	39.8	150.0	33.5	233.3	57.3	0.610
G. similis	0.0	0.0	0.0	0.0	4.2	4.2	25.0	25.0	0.553
H. fuscus	20.8	13.6	104.2	80.2	225.0	80.4	341.7	103.4	0.079
H. opposita	4.2	4.2	12.5	12.5	16.7	16.7	25.0	25.0	0.100
I. fistulosa	25.0	15.8	8.3	8.3	0.0	0.0	25.0	11.2	0.256
M. crassifolia	8.3	8.3	0.0	0.0	0.0	0.0	12.5	12.5	0.553
M. heterophylla	195.8	98.0	129.2	40.0	195.8	91.4	100.0	21.4	0.961
M. pyrifolia	8.3	8.3	8.3	8.3	4.2	4.2	16.7	16.7	0.998
O. gratissimum	200.0	45.2	250.0	137.8	475.0	286.9	0.0	0.0	0.091
O. trichocarpum	4.2	4.2	4.2	4.2	0.0	0.0	0.0	0.0	0.554
P. abyssinica	16.7	12.4	8.3	8.3	8.3	8.3	100.0	0.0	**0.001**
S. singueana	12.5	12.5	12.5	12.5	45.8	36.2	20.8	16.4	0.612
S. incanum	8.3	8.3	233.3	148.8	45.8	22.7	33.3	33.3	0.566
S. taitense	0.0	0.0	0.0	0.0	8.3	8.3	8.3	8.3	0.554
T. aethiopica	16.7	16.7	29.2	16.4	170.8	116.4	354.2	126.1	**0.002**

M = mean; S.E = Standard Error of the mean; F = F-Statistic; *P* =Significance level.

The density of species varied among different species across the different regions. Dunn's Post hoc analyses revealed that some of the species exhibited significant difference in densities between 100m, 250m, 400m in comparison to 550m (*P*< 0.05) as shown in table 4.6.

Table 4.6 Dunn's Post hoc *P* values for species densities.

SPECIES NAME	100m vs 250m	100m vs 400m	100m vs 550m	250m vs 400m	250m vs 550m	400m vs 550m
V. tortilis	0.350	0.589	0.305	0.140	0.219	**0.007**
V. senegal	1	1	**0.010**	1	**0.010**	**0.010**
C. monoica	1	1	**0.010**	1	**0.010**	**0.010**
P. abyssinica	0.679	0.679	**0.002**	1	**0.001**	**0.001**
S. araliacea	1	1	**0.010**	1	**0.010**	**0.010**
T. brownie	0.599	0.205	**0.004**	0.457	**0.020**	0.115
T. aethiopica	0.573	**0.049**	**0.003**	0.162	**0.003**	0.108

Some species, including *V. senegal, A. mossambicensis, C. monoica, V. hockii, H. foliolosum* and *S. araliacea* were exclusive to the upper zone. The plots near forest edge had species with low density (Table 4.4), some of which had medicinal uses or were used for charcoal and firewood *like V. mellifera, T. brownie, V. brevispica, R. natalensis, C. dichogamus, V. nilotica, V. seyal, M. heterophylla*.

4.2.3.2 Tree species basal area

The basal area calculations focused specifically on trees revealing significant variations in mean basal area across species at different distances from the forest boundary. Measurements varied from 0.0008 m^2/ha to 0.045 m^2/ha, and they varied among species in the different regions. The average basal area covered by trees was determined to be 0.08 m^2/ha at 100m, 0.051 m^2/ha at 250m, 0.162m^2/ha at 400m and 0.150 m^2/ha at 550m.

At 100m, *B. aegyptiaca* (0.024 m^2/ha), *C. myrrha* (0.016 m^2/ha) and *A. anthelmintica* (0.011 m^2/ha) had the highest average basal area values. At 250m, *V. mellifera* had the greatest average basal area (0.017m^2/ha). At 400m, *V. gerrardii* and *V. mellifera* had the greatest average basal area (0.045m^2/ha and 0.039m^2/ha). at 550m, *V. seyal* and *V. mellifera* had the greatest average basal area (0.033m^2/ ha and 0.026m^2/ha). Among all species *V. gerrardii*, stood out as the most significant species in the forest due to its substantial total basal area of 0.045 m^2/ha.

Basal area of some trees showed an increasing trend with increasing distance from the forest edge (Figure 4.4). Some tree species like *V. senegal*, *H. foliolosum* and *E. bussei* exhibited an increasing trend in basal area with increase with distance up the hill, but this increase was statistically insignificant (P =0.392, 0.392 and 0.392) respectively. This increase in tree basal area was statistically significant with increasing distance from the forest edge (P<0.05) for species like *V. tortilis* (P=0.008) and *V. nilotica* (P=0.049).

Dunn's Post hoc analysis revealed that there was a significant difference in basal area for *V. tortilis* between 100m, 250m ,400m when compared to 550m (P=0.009, P=0.012, P=0.002) respectively. Basal area for *V. nilotica* showed a significant difference between 100m and 440m when compared to 550m (P=0.009 and P=0.032).

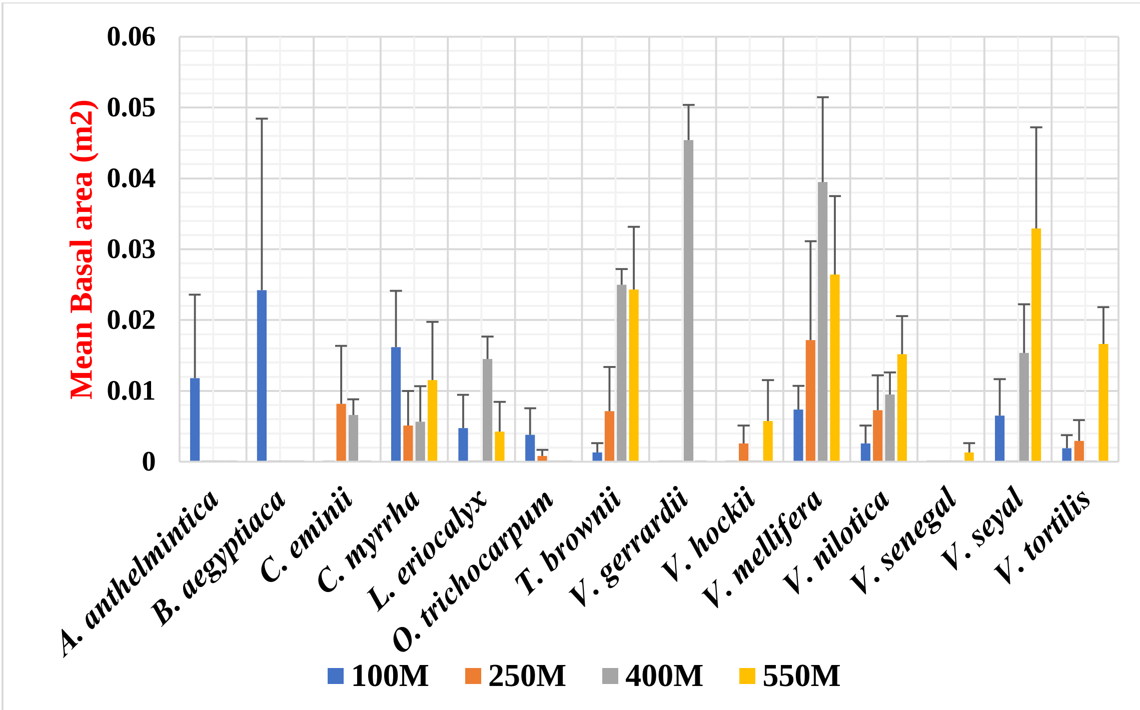

Figure 4.4: Mean tree basal area (+/-SE) variations with distance up the hill.

4.2.3.3 Woody plant species cover

The mean cover of woody species exhibited significant variation with changes in distance from forest boundary, as depicted in Figure 4.5 and Figure 4.6. Specifically, for species like *S. araliacea* (*P*=0.019), *V. tortilis* (P=0.036), *G. latifolia* (*P*=0.050), *T. brownie* (*P*= 0.025) and *T. aethiopica* (*P*=0.005) their mean cover values showed statistically significant differences with changes in distance. Following the Dunn's Post hoc analysis, it was determined that some species had greater plant cover at 550m when compared to 100m, 250m and 400m (Table 4.7).

Table 4.7: Dunn's Post hoc *P* values for species cover.

Species name	**100m vs 250m**	**100m vs 400m**	**100m vs 550m**	**250m vs 400m**	**250m vs 550m**	**400m vs 550m**
V. tortilis	0.642	0.478	**0.035**	0.240	0.101	**0.005**
G. latifolia	0.089	0.309	0.950	**0.006**	0.101	0.281
T. aethiopica	0.385	0.008	**0.002**	0.072	**0.027**	0.679
T. brownie	0.305	0.256	**0.003**	0.913	**0.049**	0.063
S. araliacea	1	1	**0.010**	1	**0.010**	**0.010**

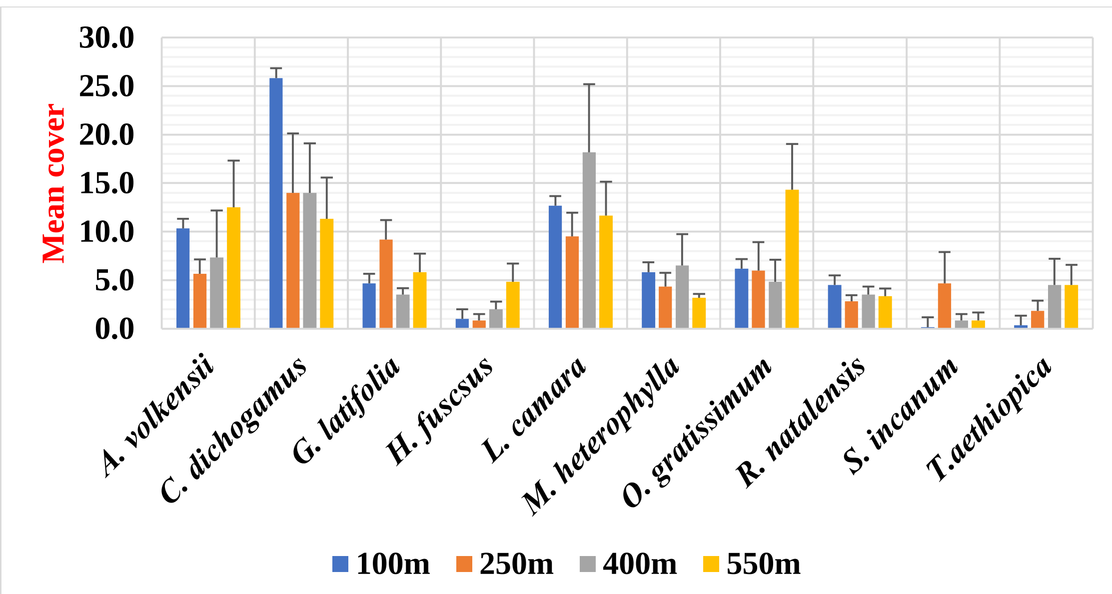

Figure 4.5: Mean cover values (+/-SE) for shrubs in Tulimani Hill.

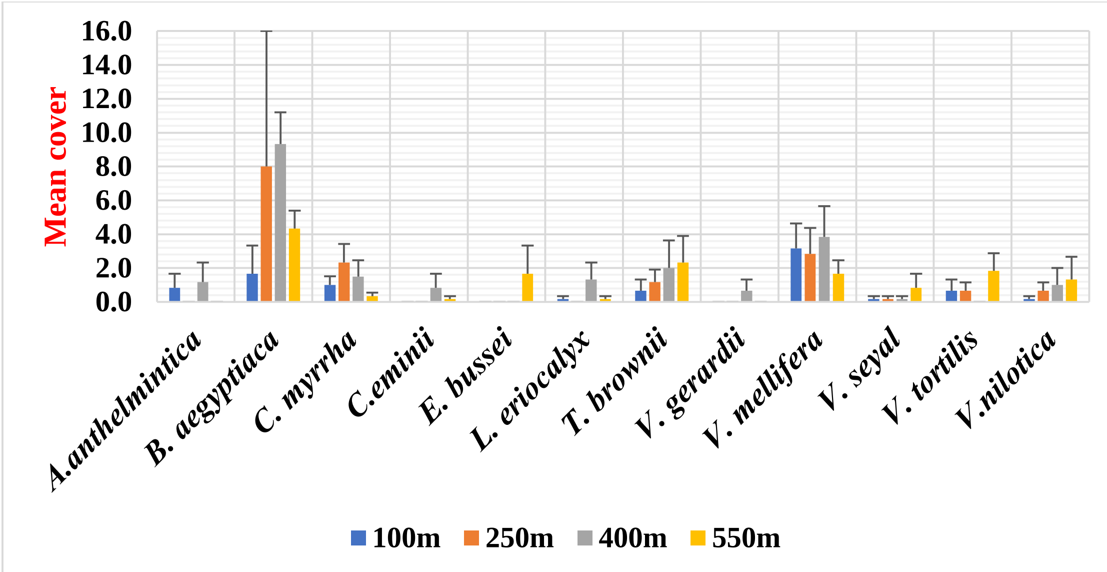

Figure 4.6: Mean cover values (+/-SE) for trees in Tulimani Hill

4.3 Anthropogenic activities in Tulimani Hill forest.

Within the 24 plots studied, various human activities were observed, including the presence of cut stumps, beekeeping, cattle grazing, as indicated by the presence of cattle, evidence of plants being bitten off, excrement, and animal tracks, firewood collection, the existence of footpaths, charcoal kilns, and the spread of invasive species like *L. camara* and *I. fistulosa* as depicted in Figure 4.7.

a

b

c

d

a– cut tree stump

b—goat pellets

c-cow grazing

d– cow's dung

e– foot path

Figure 4.7: Some of the anthropogenic activities observed in Tulimani Hill forest.

Generally, plots situated far from the forest edge tended to have fewer signs of anthropogenic activities. In contrast, those located near forest edge and in closer proximity to communities exhibited a higher prevalence of these activities, as illustrated in Figure 4.8.

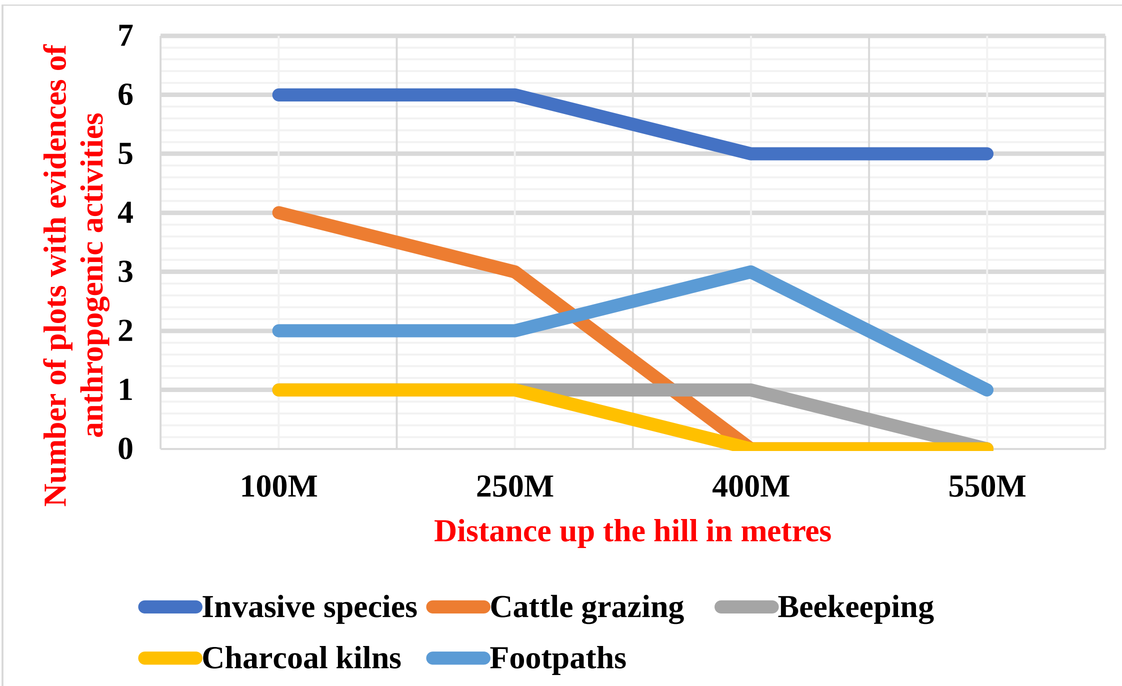

Figure 4.8: Number of plots with evidences of anthropogenic activities at different distance intervals up Tulimani hill.

4.3.1 Cut stumps

The average number of cut stumps was greatest at the forest edge, gradually decreasing as distance from the forest boundary increased (Figure 4.9). A notable finding was a strong and statistically significant negative correlation between the mean number of cut stems and the distance up the hill (r=-0.4, *P*=0.025**).**

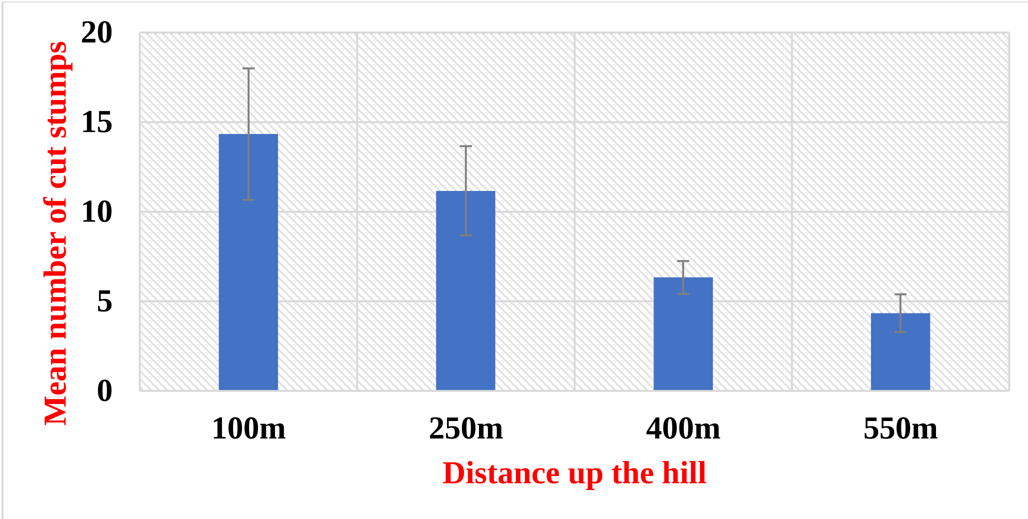

Figure 4.9: Average count of cut tree stumps with distance up the hill.

4.3.2 Cattle grazing

The number of plots with evidences of cattle grazing like cow dung, goat pellets or the animals showed a statistically significant decrease with increase in distance up the hill (r=-0.1, *P*=0.023) (Figure 4.8). The evidences of cattle grazing were found in plots at 100m and 250m.

4.3.3 Bee keeping

There was a strong correlation between beehive presence and distance up the hill and the relationship was statistically significant (r=0.9, *P*= 0.029) (Figure 4.8). Beehives were observed in plots located at 100m, 250m and 400m from the forest boundary.

4.3.4 Footpaths

The correlation between the distance up the hill and the number of plots with footpaths showed variation, and this relationship was statistically significant (r=0.8, *P*= 0.022) (Figure 4.8).

4.3.5 Invasive species

The presence of invasive species in plots showed a notable decrease with increase in distance up the hill, and this correlation was found to be statistically significant (r= 0.9, *P*=0.040) (Figure 4.8).

4.3.6 Charcoal kilns

There was a statistically significant strong correlation between presence of charcoal kilns and the distance up the hill (r=0.8, *P*=0.026). Number of plots with charcoal kilns decreased with increase in distance from the human settlements as shown in Figure 4.8. Kilns were observed in plots located at distances of 100m and 250m.

CHAPTER FIVE: DISCUSSION.

5.1 Discussion

5.1.1 Land cover changes in Tulimani Hill ecosystem.

The Tulimani Hill ecosystem in Makueni County has experienced significant changes in its landscape patterns as exhibited by various land uses. According to the 2022 land cover map, the larger part of the study area was covered by agricultural land, shrubland, grassland, and woody vegetation. Notably, there were substantial increases in agricultural land, built-up areas, and barren land from 2012 to 2022, while woody vegetation increased between 2012 and 2017 but decreased between 2017 and 2022. Shrubland and grassland decreased during this period, likely due to various human activities such as land clearance for agriculture, settlement expansion, grazing, overexploitation. These led to increase in bare land between 2012 to 2022 too. The decline in woody vegetation between 2017 to 2022 and shrubland and grassland between 2012 and 2022 within the Tulimani area is consistent with the worldwide loss of forest cover between 2001 and 2022 where 459 million hectares of tree cover were lost globally (Mwacharo, *2*024).

Other studies showing similar trends of forest loss and changes in land cover on changes in dryland regions using time-series analysis have been done by Malombe *et al*., (2020) in Kitondo and Nthangu forests, where cropland increased, forest decreased and grassland decreased. The conversion of grasslands to croplands has significantly impacted various regions in Kenya. In the Ngutw'a-Nzaui area, forest loss was reported by Munywoki *et al*. (2021). Vuria and Chawia forests experienced substantial forest cover losses of 43.0% and 32.7%, respectively. Similarly, in Taita, Fururu, Mbololo, and Ngangao forests lost 3.2%, 13.7%, and 16.8% of their forest cover, as noted by Wekesa *et al*. (2016). Forests in Makuli

and Nzaui Hills were also converted to croplands and grasslands (Malombe *et al*., 2020), with similar trends observed in Shimba Hills, Kwale County (Malombe *et al*., 2020).
In 2012, a larger part of Tulimani area was covered by woody vegetation with fewer human settlements and cultivations. Due to increasing human population with time, there was also increased demand for land to settle and to cultivate. Population increase is a major driving force to loss of forests since it entails extraction of resources, conversion of forests to make a way for settlements, agriculture and other developments in infrastructure (Crooks *et al*., 2011).

Another cause of the changes maybe climate change because the weather conditions also became drier. According to Mutua *et al*., 2016 and AHN ,2022 Kenya has recently encountered three serious droughts between 2010-2011, 2016-2017 and 2020- 2022. The 2020-2022 drought has been extremely bad and very long with many loses of lives and many people were displaced.

Makueni County has also suffered many severe and extreme drought conditions, whose nature and impacts are not known and are not documented (Mutua *et al*., 2016). Land resources have been overexploited for alternative sources of income in times of the drought (Government of Kenya ,2023). This could be the major cause of loss of land cover in Tulimani Hill ecosystem between 2012 to 2022.

These droughts might have been followed by a severe famine that made majority of the neighboring communities to start engaging in destructive actions like burning of charcoal and illegal logging as alternative livelihoods due to crop failure affecting agricultural enterprises. This is supported by the findings by Kiruki *et al*. 2016; Kigomo, 2003, that cutting of trees especially for fuel in ASAL's is a main cause of changes in land cover and drylands degradation.

5.1.2 Floristic composition, Diversity and Abundance of woody plant species in Tulimani Hill ecosystem.

5.1.2.1 Floristic composition of Tulimani Hill ecosystem

Tulimani Hill ecosystem exhibits a prevalence of plant families such as Fabaceae, Euphorbiaceae, and Lamiaceae, a pattern that has been observed in various dryland ecosystems. This is supported by studies done in Makuli, Katende, Kitondo and Nzaui hill forests, (Munywoki *et al*.,2021; Malombe *et al*., 2015), Nthangu, Kathonzweni and Kibwezi forests (Mengich *et al*., 2013), Taita hills (Watuma *et al*., 2022), in dryland hills of Mutha, Endau, Nuu, Mutito, and Mumoni in Kitui and Mwingi districts (Malonza *et al*.,2006) and Wof- Washa forest in Ethiopia (Fisaha *et al*., 2013).

The dominance of these species could be due to their adaptability to the local environmental conditions, efficient dispersal mechanisms, or the overall favorability of growth conditions for these families (Ensermu & Teshome, 2008). Bekele (2000) observed that the Fabaceae family tends to dominate in the early stages of ecological succession, with numerous pioneer species thriving in abundance until they reach the climax stage, marked by fierce competition and restricted individual growth.

The study notes variations in woody species across different hill regions, with higher diversity at 400m and 550m possibly due to increased human activities near the forest boundary. This finding contrasts with a study done by Zeleke in 2022 in Werganbula forests, where the highest number of woody species was observed near the forest edge, as altitudinal influences on woody species were possibly less pronounced in these areas. Another factor contributing to the lower number of species near the forest boundary could be associated with damage by wild animals, leading to the loss of more vulnerable tree and shrub species (Cheruto *et al*., 2016).

However, the total number of woody species in Tulimani Hill was comparatively lower (50 species) than other ASAL's forests like Nthangu Forest with 292 species, Makongo with 274 species, Makuli with 264 species, Kitondo with 196 species (Malombe *et al*., 2012), Kibauni Hill forest (155 species) (Mainga, 2011), Mazowe Botanical reserve in Zimbabwe (108 woody species) (Mapaura *et al*.,2013), Wof-Washa forest in Ethiopia (62 species) (Fisaha *et al*., 2013) ,Ngangao hill forest (76 woody species) (Bytebier, 2001), Nthangu forest (77 species) Kathonzweni forest (69 species), Kibwezi forest (70 species) (Mengich *et al*.,2013) and Semi-arid Miombo woodland area of Eastern Tanzania (86 trees) (Stromquist & Backeus 2009). This disparity in species count can be linked to differences in vegetation communities, protection status, habitat diversity, altitudinal ranges, climatic conditions, and levels of human disturbance. The presence of anthropogenic activities in this area of study result to elimination of trees and shrubs through harvesting of wood, fires, grazing of livestock and agricultural activities. This concurred with researches done by Vuviya *et al*., (2014) on the richness and diversity of tree species in Kakamega Forest. Elmugheira *et al*. (2021) did a similar study in Dinder Biosphere Reserve which revealed that there was anthropogenic Pressure on tree species diversity and composition.

The low species diversity in the study area may also be attributed to recurring droughts and the damage caused by wildlife (Mert & Yalcinkaya, 2017), resulting in the loss of more susceptible tree and shrub species. The soil's salinity may also limit its ability to support a wide variety of resilient and well-adapted species (Bui, 2013). Notably, *Vachellia* was the most commonly found genus in Tulimani Hill, which aligns with arid northern Kenya findings, where the genus *Vachellia* was prevalent and dominated in 29 out of 30 vegetation study sites (Benyahia *et al*., 2022). *Vachellia* comprises salt-tolerant and xerophytic species (Dillon, 2023).

Based on the findings from this study, Tulimani hill ecosystem has a higher abundance of shrubs than trees. A similarity was noted in Kibauni Hill forest where the shrub layer dominated (Mainga, 2011). The predominance of shrubs over trees in Tulimani Hill may be influenced by factors like elevation, slope, rainfall fluctuations and selective cutting of larger trees for construction and firewood (Ensslin *et al*., 2015). According to the University of Gothenburg. (2016, September 26), shrubs are more widespread in nature and on earth. The shallow, rocky soils in the area might also limit the growth of large tree roots.

The study suggests that environmental factors, anthropogenic activities, and climate variability have played significant roles in shaping the land cover and woody plant species diversity in the Tulimani Hill ecosystem.

Plate 1: Rocky soil of Tulimani Hill ecosystem.

5.1.2.2 Diversity of woody species with distance from forest boundary.

The research focused on the diversity of woody plant species along Tulimani Hill's gradient. Results indicated an increase in species diversity up the hill from the forest boundary. The highest species diversity observed at 550m and 400m suggests a relatively high diversity of woody plant species in plots far away from forest edge.

Stehn *et al*. (2010) did a study, with a similar pattern of plant species diversity increasing with distance being observed. According to Schulze *et al*., 2018 and Giliba *et al*., 2011, Shannon-Wiener values exceeding 2 indicate a medium to highly diverse range of species. The current research thus indicates a highly species-diverse ecosystem, emphasizing the need for improved conservation and management strategies for Tulimani Hill.

A high level of species diversity typically falls within the range of 1.5 to 3.5, occasionally extending beyond 4.5 but not surpassing 5.0 (Arzamani *et al.*, 2018). A high H' value reflects a balanced relative abundance of different species (Magurran, 2011) and (Kent &

Coker, 2011). The diversity index from this study ranges from 1.8 to 2.1 and this reflects a high species diversity. An increase in the species diversity index indicates both a rise in species richness and evenness (Molles & Cahill, 2007). It is likely that the ongoing selective felling of tree species in Tulimani Hill has contributed to this situation. Destructive human actions have had substantial effects on the composition, variety, and diversity of tree species in forests worldwide, particularly in tropical regions (Obiri, 2011), (Morris, 2010) and (Mahbud, 2008).

Diversity values from the this study are less than those reported by Malombe *et al*., 2012 in Nthangu (4.96), Kitondo (4.54), Makongo (4.46) and Makuli (4.55) hill forests in Makueni, Wof- Washa highland of Ethiopia (4.02) (Yirga *et al*.,2019), Mazowe botanical reserve in Zimbabwe (Mapaura *et al*.,2013) (H' value ranged between 1.85 and 3.42) and Zeleke *et al*., 2022 on Werganbula forest that plants near forest edge had diversity index of 3.35, followed by 3.26 and those far away from forest boundary 3.21. Low diversity indices in Tulimani hill maybe because it's in earlier stages of succession than other studied sites or due to ongoing disturbances like charcoal making and grazing. Hughes (2010) observed a decrease in species diversity linked to increased disturbance.

In the study area, species diversity increase from the edge of the forest up the hill can be attributed to variations in human-induced disturbances. Zegeye *et al*. (2006) noted that species diversity and richness are influenced by the degree of human disturbance, with the highest number of species recorded at low disturbance levels, although there are exceptions as noted by Bellwood *et al*., 2004 in a study done on diversity in tropical rain forests and coral reefs. According to Hughes, 2012 and Dumbrell *et al*., 2008, highly disturbed areas tend to have lower species diversity. However, Kayombo, 2020 reported that moderate disturbance can actually promote higher diversity.

Interestingly, this contradicts the findings of Zeleke *et al*., 2022 and Tamene, 2016, which observed a decrease in species diversity with increase in distance in different forests. A study in Ngomakurira Mountain in Zimbabwe by Zimudzi & Chapano, 2016 also reported that the Shannon-Wiener diversity index was higher in the zones near forest edge, compared to zones far away from forest edge. This phenomenon can be attributed to the challenging conditions in areas away from forest edges, such as lower soil temperatures, reduced air, harsh climates with strong winds and solar radiation, and less fertile soil, which limits plant growth.

The study also revealed that distance up a hill plays a crucial role in species composition, with longer distances having more species. Environmental and anthropogenic factors are main parameters that determine plant species survival and dispersal in a forest (Colwell & Lees, 2000). The variation in species diversity at 100m, 250m, 400m and 550m in the study area were attributed to the effect of altitudinal gradient on the composition of woody species and impacts of minimal human disturbances to the vegetation in the plots at 550m. This stimulates the growth of more woody plant species at the hilltop.

5.1.2.3 Density of woody species in Tulimani Hill ecosystem.

The density of plants in an ecosystem can indicate its overall health (Baker *et al*., 2004). This research revealed statistically significant differences in the density of woody plant species across different distances on Tulimani Hill. Highest density of species at the top of the hill suggests that more species are found near the hill's summit, possibly due to fewer human activities (Fox, 2005) such as tree cutting, wood harvesting, fires, grazing. Similar trends were observed in Mutuluni and Museve forests in Kitui by Musau & Mugo, 2019. Introduction of invasive species in the regions near forest edge and natural factors like drought and wildlife impact the species near forest edge.

Human interference can influence vegetation density and tree populations at both local and regional scales (Wright, 2002) and (Musau & Mugo, 2019). Sumina (2009) noted that these interferences shape the composition of plant communities. There was insignificant variation between the species richness and distance from the edge of the forest; this could be due to unevenness in plot locations due to geographical constraints (Popradit *et al.*, 2015). These aligns with findings from Birhane, 2020 study which indicated higher woody species density and richness in areas distant from settlements in North-Western Tigray, Ethiopia. However, they contradict Zeleke *et al*., 2022 study in Werganbula forest in the Sude District of the Arsi Zone in the Oromia Region of Ethiopia, which showed the highest woody species density in plots near forest edge. The findings also differ from the density of woody species (699m^2/ha) in Wof-Washa forest in Ethiopia, as reported by Yirga *et al*., (2019), possibly due to variations in plot sizes.

Acalypha volkensii dominated across all regions of the hill due to its high numbers per plot as compared to other species. Economically valuable trees and shrubs were scarce, attributed to high utilization (Aigbe & Omokhua (2015). Species being found only in the upper zone could be attributed to reduced human disturbances in that area.

5.1.2.4 Basal area of tree species of Tulimani Hill ecosystem.

This study calculated the basal area of tree species in the Tulimani Hill ecosystem across its four regions based on recorded DBH (diameter at breast height) values. The trees near forest edge were affected by various human activities, such as wildfires, illegal cutting, and overgrazing, leading to many of them succumbing to damage. In contrast, trees at hilltop experienced less disturbance, with more old and large trees, resulting in higher basal area values (Coomes & Allen, 2007)

These findings corroborate a previous study by Jimenez-Paz, (2016), indicating that trees at near forest edge typically have lower basal areas compared to those far away from forest boundary in forests. They are also consistent with a study done by Lovett *et al*., (2005), which observed that total basal area in plots increased with distance. However, they contradict the results of Wiafe, 2015, who reported larger basal areas for trees in plots near forest edge compared to those far away. Zekele (2022), also reported higher tree basal areas in plots near forest edge in Werganbula forest.

In this study, *V. mellifera* contributed the most to the total basal area across all regions of the hill, considered the most significant due to highest basal area (Mekonnen *et al*.,2022). Conversely, species like *V. hockii, E. bussei, H. foliolosum, O. trichocarpum* and *S. araliacea* had the lowest basal areas. Notable species in terms of large basal area in the ecosystem include *T. brownie, C. indensis, V. seyal, V. senegal, V. nilotica* and *V. mellifera*.

The total basal area occupied by trees with a DBH of 10cm or greater was 39.2m²/ha, exceeding that of Mutuluni and Museve forests (6.05m²/ha and 5.82m²/ha, respectively). However, the total basal area for Tulimani Hill forest was lower than Nthangu and Kibwezi forests (16.7m²/ha and 19.3m²/ha, respectively), likely due to pioneer, secondary, and primary forest species dominating those forests. The basal area in Tulimani Hill was also less than that in Ngangao hill forest (46.4m²/ha) (Bytebier, 2001) and Kathonzweni forest (76.8 m^2ha^{-1}) (Mengich *et al*.,2013), which can be attributed to human activities in

Tulimani Hill. This aligns with findings by Mullah, (2011) and Mutiso *et al*., (2013), suggesting that human pressures negatively affect basal area density in ecosystems.

5.1.2.5 Frequency of woody species in Tulimani Hill forest

The study examined the frequency of woody plant species in the Tulimani Hill forest across its four regions. Santamaria (2002) and (Burnham &Santanna, 2015), noted that frequency indicates the distribution of a plant species within the study area. In Tulimani Hill, some species occurred in the four regions, other species were found only at the hilltop and some near the forest edge.

Interestingly, more woody species were noted at the hilltop compared to those near forest edge in Tulimani Hill. This contradicts previous studies by Zeleke et *al*., 2022 and Tamene, 2016, where a higher species numbers were found in the plots near forest edge. The abundance of woody species at hilltop of Tulimani Hill suggests a greater diversity of species in those areas, while near forest edge indicates a more uniform composition of species. These differences in species frequencies among the various distance intervals up the hill may be attributed to various factors such as habitat preferences, environmental influences (including altitude and slope), commercial utilization, adaptation of species, the extent of disruption and the presence of necessary conditions required for regeneration.

5.1.2.6 Cover of woody plant species in Tulimani hill

The cover of woody plant species in Tulimani Hill displayed an increase in some species as distance increased. Jiang *et al*. (2017) highlighted that plant cover is significantly affected by various human-induced factors. The higher plant cover observed at 400m and 550m may be linked to anthropogenic activities occurring at 100m and 250m, such as charcoal burning, resulting in sparse woody plant cover near forest boundary. Sahoo &

Davidar, (2013) also noted a decline in vegetation cover in India, attributing it to unsustainable fuelwood extraction for domestic purposes. Sanjari *et al*. (2009) emphasized that reduced plant cover can worsen raindrop impact, decrease water infiltration, elevate surface runoff, and contribute to soil degradation, ultimately risking biodiversity loss. Inadequate plant cover exposes the surface to adverse weather effects, hindering plant regeneration and growth (Gandapa, 2017).

5.1.3 Anthropogenic Activities in Tulimani Hill forest

The presence of anthropogenic activities was clearly observed in all the sampled plots within Tulimani Hill forest. Mligo (2011) highlighted that forest species face threats due to practices like cultivation, collecting firewood, making charcoal, and expanding settlements. Similar studies conducted in drylands have also indicated the existence of anthropogenic activities. For instance, Malonza *et al*., 2006 documented such activities in dryland hills in Kitui and Mwingi districts, including Mutha, Endau, Nuu, Mutito, and Mumoni. Other studies by Musyoka *et al*., (2019) and Malombe *et al*., (2020) found evidence of these activities in Chyulu Hills forests, Kayombo *et al*., (2020) reported them in the Mahungu Green Belt Forest Reserve, and Makau, (2014) documented such activities in Mbooni hilltop forests.

The frequency and intensity of anthropogenic activities were higher near forest edge, with plots found far away from forest edge; mostly were devoid of anthropogenic activities, primarily because of their proximity to neighboring communities. This aligns with research by Hersi & Kangalawe, (2016), which noted that people living near forests tend to extract resources from them, even if it goes against regulations. Similar studies, such as Rajat, (2021) on Kaya forests in Kilifi County, Nzinzi *et al*., (2016) concerning Kibauni hill forest in Machakos County, and Emerton, 2001 research in Eastern Kenya, Southern Rift, and Mt. Kenya, have emphasized the importance of local communities utilizing forest resources for their livelihoods. Hassan *et al*. (2002), in Swaziland, also found that forests provide direct benefits to local residents.

5.1.3.1 Cattle grazing

The community around Tulimani Hill area commonly engages in cattle grazing, a practice associated with lower species diversity and density in the plots near forest edge in the hill. Similar reports by Munywoki *et al*., (2021) and Mainga, (2011) have documented livestock grazing in other forest hills, such as Makuli and Nzaui, as well as Kibauni hill forest. Overgrazing is also evident in various other hill forests, including Nthangu, Kitondo, Makongo, Katende, Mutula, Kilala, Matha, Nguuta, and Makuli, (Malombe *et al*., 2012). Grazing animals often crushes young plant seedlings underfoot obstructing their development (Tsingalia, 2009), and in some cases, leading to significant changes in the vegetation and soil damage. Cherlet *et al*. (2018) conducted studies indicating that overgrazing results in deforestation and degradation, particularly in areas categorized as arid and semi-arid lands (ASALs), which aligns with the findings of this study.

5.1.3.2 Presence of stumps

The presence of stumps and the frequency of stem cuttings in all sampled plots indicate illegal tree cutting for various purposes, including charcoal and firewood. Plots at 100m had a higher frequency of stem cuttings compared to the plots at 550m, resulting in a greater tree density in the plots away from the forest edge. Woody plant species like *V. mellifera, T. brownie, V. brevispica, R. natalensis, C. dichogamus, V. nilotica* and *V. seyal* were commonly cut for charcoal, building poles, roofing material, fuelwood, and medicinal purposes, as reported in various studies (Mutie *et al*., 2020; Makau, 2014; Nzinzi *et al*., 2016; Malombe *et al.*,2020).

Similar studies on stem cutting in forests were conducted in Museve and Mutuluni forests (Musau & Mugo, 2019), Ngangao hill forest (Bytebier, 2001) (where *T. brownie* was the preferred species for firewood), and Katende forest (Makau, 2014). In Nthangu, Kitondo, Makongo, Katende, Mutula, Kilala, Matha, Nguuta, and Makuli hill forests, illegal cutting of trees for timber and firewood collection (Malombe *et al*., in 2012). Illegal logging was also reported in Kakamega 55 Forest (Vuyiya *et al*., 2014), Kibauni Hill forest (Mainga, 2011), and various other forests like Ngangao, Fururu, Chawia, Mbololo (Wekesa *et al*., 2016), and Shimba hills (Malombe *et al*., 2020).

These extensive cuttings may have occurred due to the easy availability of firewood from the forest, lack of alternative energy sources for the local communities, and the high cost of other energy options. Additionally, there appears to be little regulation of access and harvest of trees in these areas. Free access to forests can result in overexploitation and unsustainable resource use. Extracting wood in this manner may result in decreased basal area and stem density, causing alterations in the structure and composition of tree species as reported in several studies (Hitimana *et al*., 2004, Omeja *et al*., 2004, Kacholi, 2014, and Musau & Mugo, 2019).

These findings highlight the widespread presence of anthropogenic activities in Tulimani Hill, which are significantly impacting the forest ecosystem. It is imperative to implement conservation and sustainable management measures to address these challenges.

5.1.3.3 Charcoal making

The study identified charcoal making as a prevalent activity in the plots near the forest edge in Tulimani Hill, particularly in areas closer to human settlements where transportation of charcoal is more accessible. Observations showed that trees were being cut down probably for fuel and charcoal burning. Similar findings regarding charcoal making in other dryland forests have been reported by other studies in Makuli and Nzaui forest hills (Munywoki *et al.*, 2021), Kakamega 55 Forest (Vuyiya *et al.,* 2014), and Kibauni Hill forest (Mainga, 2011).

Sedano *et al*. (2016) stated that the selection of kiln sites for charcoal production is influenced by the presence of appropriate trees for burning and convenient access to transportation routes. This activity negatively impacts species diversity and richness as certain species are excessively exploited for charcoal production. It also adversely affects seedling density, as the removal of mature trees hinders effective seed dispersal. Furthermore, the extraction of mature trees disrupts the forest canopy, impacting the overall structure of the ecosystem.

Yadeta *et al*. (2011) however presents an opposing viewpoint, proposing that eliminating large trees for charcoal production can open up space and foster the regeneration of seedlings, as long as there is an ample supply of mature trees for seed production.

5.1.3.4 Foot paths

Footpaths created by human activity damage young plant seedlings and increase the spread of invasive species like *L. camara* and *I. fistulosa* (Barros *et al*., 2022), reduces vegetation, promotes surface runoff and results in reduction of biogenic activities due to the hindering of oxygen and water supply from the surface (Nir *et al*., 2022).

5.1.3.5 Invasive species

Alien species pose a significant threat to native biodiversity. During the study, two invasive species, namely *L. camara* and *I. fistulosa*, were observed. Interestingly, *L. camara* was even found in plots at hilltop during fieldwork, suggesting its ongoing spread, possibly due to animal dispersal. Similar studies have indicated that the removal of large woody vegetation in Nthangu, Kitondo, Makongo, and Makuli hill forests has exposed the soil to erosion and facilitated the invasion of *L. camara* (Malombe *et al*., 2012). Invasions by species like *S. mauritianum* Scop. were also recorded in Kakamega and Mt. Elgon forests (Mutiso *et al*., 2013). Alien species negatively impact native species (Bedair *et al*., 2021).

Human activities, whether legal or illegal, have a significant influence on plant species diversity (Beentje, 2010, Gonzalez, 2001, MEA, 2005), leading to the degradation of forest ecosystems (Hitimana *et al*., 2004, Omeja *et al*., 2004), damage to tree species (Garcin *et al*., 2018, Kleinschroth and Healy, 2017), and harm to other biological diversities (Gogoi and Sahoo, 2018).

Anthropogenic activities can also cause immediate environmental changes by excessively extracting resources like medicinal plants, wild edibles and fuelwood by communities living near forests (Popradit *et al*., 2015, Opuni-Frimpong *et al*., 2021). The loss of vegetation can lead to soil loosening, resulting in soil erosion during the rainy season. Overexploitation may result in the loss of many versatile plants that have not been explored in Tulimani Hill forest.

However, the hilltop of the study area, with minimal human disturbance, displayed higher diversity, indicating that controlled disturbances can benefit species diversity. In contrast, excessive disturbances, like cattle grazing and tree cutting, led to lower diversity, underscoring the importance of conservation and sustainable management practices. Excessive disturbance can lead to the local extinction of plant species (Omeja *et al*., 2004, Hitimana *et al*., 2004), resulting in the dominance of shrubs rather than trees in an area (Kikoti & Mligo, 2015).

Malik *et al*. (2014) contrary reported that disturbances in a forest ecosystem can positively change species diversity, composition, and structure. Minimal disturbances and tree removal leads to openings that facilitate the growth of additional tree species to colonize these open spaces (Kpontsu, 2011; Giliba *et al*., 2011; Fletcher *et al*., 2018, and Mligo, 2018).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i) Land cover for Tulimani Hill ecosystem has changed since 2012. The major land cover includes woody vegetation, shrubland and grassland, barren land, built-up area, and agricultural land. Increased human population has led to decrease in vegetation and increase in bare-land, built -up area and agricultural land.

ii) Tulimani Hill hosts a diverse array of woody plant species across different families, with lower species diversity, density, frequency, cover, and basal area observed near the forest edge compared to the hill's summit.

iii) Indicators of anthropogenic disturbances in the study area included cut stem stumps, charcoal kilns, footpaths and cattle grazing. They were more intense in the plots near forest edge hence reduction of species diversity in those regions.

6.2 Recommendations

To reduce the anthropogenic pressures in the study area;

1. Public participation of the local community members in Tulimani Hill ecosystem in sustainable forest practices including tree planting is encouraged according to Section 4(b) of the Forest Conservation and Management Act, 2016.
2. The role of Community Forest Associations (CFAs), in collaboration with the Kenya Forest Service to manage forests sustainably is also encouraged. This collaboration can include activities such as tree planting especially those used for wood and charcoal, so as to minimize over reliance of Tulimani forest.
3. Raising awareness and educating Tulimani local community about the significance

of preserving plant life, understanding the ecological consequences of vegetation loss, and promoting sustainable attitudes toward ecosystem resource utilization is encouraged. This is in accordance to Section 5(1) of The Forest Conservation and Management Act, 2016 which mandates that the Cabinet Secretary, in consultation with county governments and relevant stakeholders to develop a national forest policy for the sustainable use of forests and forest resources.

4. Tulimani Hill management should help the local people to establish alternative livelihood projects and use alternative sources of energy to reduce charcoal burning and illegal cutting of trees from the hill according to Section 48(1) of the Forest Conservation and Management Act, 2016 which allows the KFS to enter into management agreements with CFAs like development of alternative livelihoods to reduce dependence on forest resources. Section 49(3)(e) of the Act also permits CFAs to assist in the development of community projects consistent with the traditional forest user rights, which can involve establishing alternative livelihood projects and promoting alternative energy sources.
5. A management plan for Tulimani Hill forest should be developed and implemented to ensure sustainable forest use and conservation in accordance to Section 35(1) of the Forest Conservation and Management Act, 2016 which mandates that the KFS to prepare management plans for all public forests to regulate illicit activities, implement conservation measures, and prevent issues such as vegetation degradation and species loss. Additionally, Section 36(1) of the Act requires that all indigenous forests and woodlands be managed sustainably.

6.3 Recommendations for further research.

i) Determination of all plant forms of the hill as only woody plant species were considered in this study.

ii) A study on the floristic diversity of Tulimani Hill with reference to aspects and habitat since this study was based on distance up the hill.

iii) Conduct biodiversity assessments to understand changes in species composition and habitat loss adopting the DPSIR framework.

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APPENDICES

Appendix 1: The tree and shrub species of Tulimani Hill Forest, Makueni County

No.	Species botanical name	Local name	Family name	Habit
1.	*Vachellia brevispica*. (Harms) Seiglerand	Mukuswi	Fabaceae	S/T
2.	*Vachellia drepanolobium* Sjostedt.		Fabaceae	S
3.	*Vachellia gerrardii*. Benth.		Fabaceae	T
4.	*Vachellia hockii* De Wild	Munyua	Fabaceae	T
5.	*Vachellia mellifera* (M. Vahl) Benth.	Muthiia	Fabaceae	S/T
6.	*Vachellia nilotica* (L.) Willd. ex Delile	Musemei	Fabaceae	T
7.	*Vachellia Senegal* Del.	Mungoli	Fabaceae	T
8.	*Vachellia seyal* Del.		Fabaceae	T
9.	*Vachellia tortilis (*Forrsk) Hayne	Mwaa	Fabaceae	S/T
10.	*Acalypha volkensii* Pax.		Euphorbiaceae	S
11.	*Adenium obesum* Roem /Schults		Apocynaceae	S
12.	*Albizia amara* Roxb.B. Boivin	Kiundwa	Fabaceae	T
13.	*Albizia anthelmintica* Brongn.	Kyoa isama	Fabaceae	T
14.	*Allophylus rubifolius* (Hochst.Ex A. Rich)	Muvau	Sapindaceae	S/T
15.	*Asparagus africanus*		Asparagaceae	S
16.	*Aspilia mossambicensis* (Oliv) Wild	Muti	Asteraceae	S
17.	*Balanites aegyptiaca* Del	Mulului	Balanitaceae	T
18.	*Becium filamentosum* (Forssk) Chlov		Labiatae	S
19.	*Boscia angustifolia* A. Rich	Kiluli	Capparaceae	S/T
20.	*Afrocanthium keniense* Bullock.		Rubiaceae	S/T
21.	*Capparis tomentosa* Lam.	Kitanda mboo	Capparaceae	S/T
22.	*Cissus quadragularis* L.	Uswe	Vitaceae	S
23.	*Clerodendrum myricoides* Vatke.		Verbenaceae	S/T
24.	*Combretum paniculatum*	Kiongwa	Combretaceae	S
25.	*Combretum molle* R. Br ex. G. Don	Kiama	Combretaceae	S/T
26.	*Commiphora africanus* Engl.	Ikuu	Burseraceae	T
27.	*Commiphora campestris* Engl.	Iulu	Burseraceae	T
28.	*Commiphora eminii* Engl.		Burseraceae	T
29.	*Commiphora myrrha* Engl.		Burseraceae	S/T
30.	*Cordia monoica* Roxb.	Kithea	Boraginaceae	S/T
31.	*Crotalaria axillaris* Aiton.		Fabaceae	S
32.	*Croton dichogamus* Pax.	Mwalula	Euphorbiaceae	S/T
33.	*Croton megalocarpus*	Muthulu	Euphorbiaceae	T
34.	*Dalbergia melanoxylon* Guill and Perr	Muvingo	Fabaceae	T
35.	*Dyschoriste radicans* (Hochst.ex. A. Rich)		Acanthaceae	S
36.	*Dichrostachys cinerea* Wight and Arm	Muvua mathoka	Fabaceae	T
37.	*Diospyrus abyssinica*		Ebenaceae	T
38.	*Dodonaea angustifolia* L.F. Benth.	Kithongoi	Sapindaceae	S/T
39.	*Entada abyssinica* A. Rich	Mukondilu	Fabaceae	S/T
40.	*Erythrina abyssinica* D.C	Muvuti	Fabaceae	T
41.	*Euclea divinorum* Hiem.	Mukinyai	Ebeneceae	S/T

42. *Euphorbia bussei* Pax.		Euphorbiaceae	T
43. *Euphorbia polyantha* Pax.		Euphorbiaceae	S/T
44. *Euphorbia scheffleri* Pax.		Euphorbiaceae	T
45. *Fagaropsis fistulosa* Engl.		Rutaceae	S/T
46. *Ficus natalensis* Hochst	Yumbu	Moraceae	S/T
47. *Flueggea virosa* (Wild) Voigt	Kikuluu	Euphorbiaceae	S
48. *Gnidia latifolia*	Musensili	Thymelaceae	S
49. *Grewia bicolor* Juss.	Mulawa muka	Malvaceae	S/T
50. *Grewia similis*		Malvaceae	S/T
51. *Grewia tembensis* Fres.		Tiliaceae	S
52. *Grewia villosa*	Muvuu	Tiliaceae	S
53. *Haplocoelum foliolosum* Bullock	Mukume	Sapindaceae	S/T
54. *Harrisonia abyssinica* Oliv.	Mukiliuli	Rutaceae	S
55. *Heteromorpha trifoliata* Eckland Zeyh		Apiaceae	T
56. *Hibiscus fuscus*		Malvaceae	S
57. *Hoslundia opposita* Vahl.	Musovi	Lamiaceae	S
58. *Hymenodictyon floribundum* (Hochst. and Steud)	Mulinditi	Rubiaceae	S/T
59. *Hymenodictyon parvifolium* Oliv.		Rubiaceae	S/T
60. *Indigofera arrecta* Hochst. Ex A. rich		Fabaceae	S
61. *Ipomea fistulosa* Vatke.		Convolvulaceae	S
62. *Jasminum abyssinicum* DC.		Oleaceae	S
63. *Lannea schweinfurthii* Engl	Kyuasi	Anacardiaceae	S/T
64. *Lantana camara* L.	Musomolo	Verbenaceae	S
65. *Lippia javanica* Spreng.		Verbenaceae	S
66. *Lonchocarpus eriocalyx* Harms	Mung'uthe	Fabaceae	S/T
67. *Maerua triphylla*	Kyenzenze	Capparaceae	S/T
68. *Maerua crassifolia* Forssk		Capparaceae	T
69. *Maerua parvifolia* Pax		Capparaceae	S
70. *Maytenus heterophylla* Eckl. and Zeyh.	Kithunzi	Celastraceae	S/T
71. *Microglossa pyrifolia* (Lam) o. kuntze	Mukutu	Asteraceae	S
72. *Nuxia congesta* Benth.		Stilbaceae	S/T
73. *Ochna holstii* Engl.		Ochinaceae	S/T
74. *Ocimum gratissimum* L.		Labiatae	S
75. *Ormocarpum trichocarpum* Engl.		Fabaceae	S/T
76. *Ormocarpum kirkii* S. Moore	Muthingii	Fabaceae	S/T
77. *Ozoroa insignis* Delile		Anacardiaceae	S/T
78. *Pappea capensis*	Kiva	Sapindaceae	T
79. *Pavetta abyssinica* Fres.		Rubiaceae	S
80. Pentas lanceollata		Rubiaceae	S
81. *Phyllanthus sepialis* Mull.Arg.		Phyllanthaceae	T
82. *Plectranthus barbatus* Andr.		Lamiaceae	S
83. *Premna resinosa* (Hochst.)	Mukaka	Lamiaceae	S
84. *Rhus natalensis* Bernh.		Anacardiaceae	S/T
85. *Ricinus communis* L.		Euphorbiaceae	S
86. *Scutia myrtina*	Mutumbuu	Rhamnaceae	S/T
87. *Senna didymobotrya* Irwin and Barneby	Muthaaa	Fabaceae	S

88. *Senna singueana* (Delile) Lock	Mukenga aka	Fabaceae	S/T
89. *Solanum incanum* L.	Mutongu	Solanaceae	S
90. *Solanum taitense* Vatke.		Solanaceae	S
91. *Steganotaenia araliacea* Hochst		Apiaceae	T
92. *Strychnos henningsii* Gilg.	Muteta	Loganiaceae	T
93. *Terminalia brownie* Fresen.	Muuku	Combretaceae	T
94. *Tinnea aethiopica* Kotschy ex Hook.f		Lamiaceae	S
95. *Triumfetta tomentosa* Bojer.		Malvaceae	S
96. *Vangueria madagascariensis* Gmel.	Kikomoa	Rubiaceae	T
97. *Vernonia brachycalyx* O. Hoffm		Asteraceae	S/T
98. *Ximenia americana* L.	Mutula	Oleaceae	S/T
99. *Zanthoxylum chalybeum* Engl.		Rutaceae	S/T
100. *Caucanthus auriculatus*		Malpighiaceae	S
101. *Ziziphus mucronata* wild	Kiae	Rhamnaceae	T

S=Shrub, T=Tree, S/T=Shrub/Tree

Appendix 2: Research Permit-NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 267235

Date of Issue: 19/October/2022

RESEARCH LICENSE

This is to Certify that Ms.. EUNICE mutio MULE of Kenyatta University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Makueni on the topic: VEGETATION TRENDS, FLORISTIC DIVERSITY AND ANTHROPOGENIC DISTURBANCE ON TULIMANI HILL ECOSYSTEM-MAKUENI COUNTY for the period ending : 19/October/2023.

License No: NACOSTI/P/22/20669

267235

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)

Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was the established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
    i. Endanger national security
    ii. Adversely affect the lives of Kenyans
    iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
    iv. Result in exploitation of intellectual property rights of communities in Kenya
    v. Adversely affect the environment
    vi. Adversely affect the rights of communities
    vii. Endanger public safety and national cohesion
    viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
7. Excavation, filming, movement, and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
8. The License does not give authority to transfer research materials.
9. The Commission may monitor and evaluate the licensed research project for the purpose of assessing and evaluating compliance with the conditions of the License.
10. The Licensee shall submit one hard copy, and upload a soft copy of their final report (thesis) onto a platform designated by the Commission within one year of completion of the research.
11. The Commission reserves the right to modify the conditions of the License including cancellation without prior notice.
12. Research, findings and information regarding research systems shall be stored or disseminated, utilized or applied in such a manner as may be prescribed by the Commission from time to time.
13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and
Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
P. O. Box 30623 - 00100 Nairobi, KENYA
Telephone: 020 4007000, 0713788787, 0735404245
E-mail: dg@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix 3: Research Permit -KFS

KENYA
Forest Service

Kenya Forest Service Hqs
Karura, Off Kiambu Rd
P.O. Box 30513 - 00100
Nairobi, Kenya

Ref: No......RESEA/1/KFS/VOL. VII/89

Date:...9th November 2022

Eunice Mule
Kenyatta University
P. O. Box 69
Makindu.

RE: PERMIT TO CONDUCT BOTANICAL RESEARCH IN TULIMANI HILL FOREST, MAKUENI COUNTY.

Reference is made to your letter of 3rd August 2022 requesting for permit to access Tulimani Hill forest in Makueni County for research project "*Vegetation trends, floristic diversity and anthropogenic disturbance on Tulimani hill ecosystem, Makueni County*".

Permission is hereby granted for you to access Tulimani hills forest in Makueni County.

The following conditions shall apply;

I. No sample shall be collected in such a way that will threaten or be detrimental to the supply of that material in the wild.
II. No information detrimental or of a confidential manner shall be shared publicly without written permission from Kenya Forest Service.
III. Intellectual property rights arising from the study of the materials will be jointly shared by the Kenya Forest Service and yourself.
IV. You shall acknowledge the Kenya Forest Service in all and any publications, patents or presentations involving the use of the information or materials.
V. You shall indemnify and keep the Kenya Forest Service and the State harmless from any claim, action and damage or cost deriving from or in connection with the use of the information or materials.
VI. No commercialization shall take place without clearance from Kenya Forest Service.

Trees for better lives

Tel: (254)020-3754904/5/6, (254)020-2014663, (254)020-2020285, Fax: (254)020-2385374
Email: info@kenyaforestservice.org. Web: www.kenyaforestservice.org

VII. Materials (including derivatives arising from) obtained under this permit may only be transferred to a third party with prior written authorization from Kenya Forest Service.

VIII. You shall provide a copy (either hardcopy or softcopy of link) of the report on completion of your work.

IX. Notwithstanding this validity period, the conditions above (ii -vii) shall hold throughout the existence of the materials and their derivatives.

This permit is valid from 7th **November 2022** to 6th **November 2023**.

By a copy of this permit, the County Forest Conservator and respective Forest Manager are hereby instructed to facilitate access.

JULIUS KAMAU, EBS
CHIEF CONSERVATOR OF FORESTS

Copy to: RFC – Eastern
CFC – Makueni

JM/sa

Appendix 4: Data Sheet used in Data Collection for Objective 2 and 3.

ASSESSING WOODY PLANT DIVERSITY AND ANTHROPOGENIC DISTURBANCE ON TULIMANI HILL ECOSYSTEM IN MAKUENI COUNTY, KENYA.

Date:

Transect no:

Plot no:

GPS Co-ordinate:

Altitude:

Habitat:

Species present	Individuals present	No. of individuals	Habit	DBH at 1.3m	Anthropogenic disturbance noted

Appendix 5: Voucher numbers of specimen identified at National Museums of Kenya

NATIONAL MUSEUMS OF KENYA

HERE HERITAGE LIVES ON

Voucher numbers/information for specimens identified at EA NMK

Student: Mule Eunice Mutio

I. *Senegalia brevispica* (Harms) Seigler & Ebinger, **Mule E. M. 001**, 15thJanuary, 2024.

2. *Croton dichogamus* Pax, **Mule E. M. 002**; 15th January, 2024.

3. *Caucanthus auricuatus* (Radlk.) Nied. **Mule E. M. 003**, 15th January, 2024.

By

Dr. Paul Musili

East African Herbanium

NATIONAL MUSEUMS OF KENYA
26 JAN 2024
HERBARIUM NAIROBI

1910-2010

CELEBRATING A CENTURY OF HERITAGE MANAGFMF NT

THANK YOU