An analysis of exposure and slope gradient impact on tree layer profile of Maroelakop vegetation in Nylsvley Nature Reserve, Limpopo Province, South Africa

By

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Dissertation submitted in fulfillment of the requirements of Master of Science Degree in Botany

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Declaration

I, Mavhila Tendani {17018012}, an MSc student at the University of Venda, affirm that this master's research is my original dissertation and was not previously submitted for any degree at a different college or institution. This work does not include work produced by others unless it is explicitly mentioned and cited.

Student Signature: Date: 21/02/2024

Dedication

This dissertation is devoted to my loved ones and close friends. A profound feeling of appreciation for my beloved father, Hangwani Mavhila for his words of encouragement, support, guidance, and unconditional love. To my sister, Pfarelo Mavhila, and little brother Andani Mavhila for the moral support and love they showed me throughout this research. To my beloved Khotso Concelia Masipa for the support and unconditional love during the upbringing of our first-born baby girl Rendani Jasmine Mavhila. I will always appreciate all they have done.

Lastly, my dedication goes to my late mother (Khathutshelo Mavhila) and brother (Lufuno Mavhila) for they could have seen the wonderful work I have done.

Acknowledgments

I want to start by expressing my gratitude to God for giving me the courage, strength, and discernment needed to conduct my research.

I'd like to thank the University of Venda's Faculty of Science, Engineering, and Agriculture (Department of Biological Sciences) for allowing me to continue my studies. Nylsvley Nature Reserve is acknowledged for allowing me to collect data for my research on Maroelakop Mountain; without their approval, this study could not have been conducted without their consent. Warm appreciation to the National Research Foundation (NRF) for funding my research.

Also, I'd like to thank my family for their support throughout this journey. My special thanks to my supervisor, Professor MP Tshisikhawe, and co-supervisor, Dr K Magwede, for accepting me as a student and guiding me through data collection in the field and report writing. Their patience and generosity in marking and correcting my work are greatly appreciated.

My appreciation also goes out to Mr. MH Ligavha-Mbelengwa for his assistance with the field survey. I want to express my gratitude and special appreciation to fellow 2022 postgraduate students who helped and encouraged me during my fieldwork.

I'm particularly thankful to Nyadzani Mushadu, Khodani Maumela, Manganye Goodman, and Rebecca Serepa for their support and ideas.

Abstract

Since the 1850s, plant ecologists have been eager to investigate challenges in vegetation communities that are related to slope. The aspect of the slope is crucial in terms of the diversity and distribution of plants. This research was conducted on Maroelakop Mountain within Nylsvley Nature Reserve located in Mookgopong, Limpopo Province. The investigation aimed to assess and contrast the vegetation composition on the north-facing slope with that of the south-facing slope. The specific goals included ascertaining the density and frequency of dominant tree species on each slope, calculating the importance value indices of trees on both slope gradients and analyzing the population structure of the slope gradient. Point Centred Quarter (PCQ) was used in data collection. Shannon-Weiner diversity index, Simpson diversity index, and Evenness index were used to measure plant species diversity. In this study, a total of 600 trees were discovered and identified by their botanical names. The data represented 21 plant species in 17 genera and 12 families. The tree layer of the north-facing slope was dominated by *Diplorhynchus condylocarpon*, whereas that on the south-facing slope was dominated by *Burkea africana.* Both tree species had high-importance value indices. Shannon diversity index of 2.20 was obtained for the North-facing downslope, whereas the South-facing downslope had 1.74. The average Simpson diversity index for the North-facing slope was 0.82 and South-facing slope 0.77. The average Evenness index for the North-facing slope was 0.93 and, on the South-facing slope 0.81. This study concluded that *Diplorhynchus condylocarpon* is the most prevalent species within Maroelakop Mountain in the Nylsvley Nature Reserve.

Keywords: Diversity, Species composition, Importance value index, Slope gradient.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Since the 1850s, plant ecologists have been eager to investigate challenges in vegetation communities that are related to slope aspect (Giliam *et al*., 2014). Mountainous areas, which are distinguished by their steeper slope, experience the consequences to a greater extent (Pepin *et al.*, 2015). When it comes to the variety and abundance of plant species, the slope factor is crucial. The vegetation that is exposed to some of the variables that affect growth, such as the availability of water, the kind of soil, sunlight, environmental gradient, and the tree canopy, is more likely to be found to be flourishing (Kozlowski *et al*., 2012). Temperate forests (Sharma *et al*., 2010), grasslands in the temperate zone (Gong *et al*., 2008), Mediterranean or tropical moist communities (Gilliam *et al*., 2014), tundra and boreal forest ecosystems (Astrom *et al*., 2007), and other arid habitats have all seen extensive research on the impact of topographical conditions on vegetation structure and composition (Singh, 2018, and Wang *et al*., 2024).

The abundance, distribution, and diversity of vegetation in mountainous environments are significantly influenced by the slope gradient (Cantlon, 1953). According to Feng *et al*. (2011), It controls how sunlight, heat, water, and soil nutrients are distributed spatially, resulting in the formation of microclimates with diverse topsoil textures and circulation of nutrient. The significant geographical factors that indirectly affect the distribution patterns and diversity of vegetation in mountainous areas are elevation, slope aspect, slope position, slope degree (Paudel and Vetaas, 2014; Singh, 2018), and variations (Huang, 2002; Sang, 2009). The literature, however, is rather inconsistent when it comes to the impacts of topographic features on biodiversity patterns.

According to Song *et al.* (2008), the most species diversity typically arises in the middle segment of soil nutrient gradients, while Yong *et al.* (2007) stated that it does so in the most fertile areas. Because of the ideal hydrothermal conditions, Chang *et al*. (2004) found that plant species variety was highest at moderate elevation; however, it has also been demonstrated that as altitude increases, plant species richness decreases (Hao *et al*., 2002; Liu, 2017).

Mountains cover about 24% of the planet surface, and they offer support for more than twelve percent of the global populace resides in these regions (Sharma *et al*., 2010; Niu *et al*., 2019). Furthermore, one-fifth of humanity relies on mountains for environmental services such as fresh water, food, oxygen-rich air, biological resources, and spiritual renewal (Sayre *et al*., 2018; Niu *et al*., 2019, and Fischer *et al*., 2022). Therefore, maintaining the livelihoods of mountain communities depends on the responsible management and preservation of mountain environments and their distinctive biological richness (Måren *et al*., 2015). Climate, topography, slope inclination, soil type, and land use are some of the elements that influence diversity, composition, and regeneration of forests.

A variety of microclimates are created in multifaceted landscapes as a result of variations in sunlight period and intensity that fluctuate with slope aspect (Måren *et al*., 2015). Numerous studies concluded that variations in solar radiation received, such as those found in the Himalaya (Ghimire *et al*., 2010; Paudel and Vetaas, 2014) and similar altitude (Måren *et al*., 2015), are what causes variations between two contrasting slope aspects. According to the research by Cantlon (1953), Singh (2018), Pook (1966), and others observed that opposite slopes have different microclimates, amount of light, atmospheric and soil temperature, humidity, water content of the soil and desiccation, and the period of growth (Saeidi *et al*., 2023).

South-facing slopes are generally warmer and more xeric in the Northern Hemisphere due to increased sunlight (Nunes *et al*., 2020), which promotes drought-tolerant plants and inhibits the growth of trees

(Måren *et al*., 2015). On the other hand, North-facing slopes are chilly, damp, and retain humidity, which encourages vegetation that loves moisture (Fadl *et al*., 2021).

Because different micro eco-climatic regions are compressed along topographical gradients, mountain ecosystems have extraordinarily high biological variety (Padalia *et al*., 2023) and the distances between various vegetation types decrease dramatically (Körner *et al*., 2011). Highland ecosystems are among the most susceptible due to the extreme environmental conditions and serious threats posed by human-induced pressures and climate change (Ning *et al*., 2014).

1.2 Problem Statement

Right now, forest protection is the top concern for a large number of worldwide conservation organizations, the government, and other interest groups (Ghimire and Pimber, 2013). The main cause for concern when it comes to forest conservation is usually anthropogenic activities that lead to the depletion of forest resources (Kacholi, 2014, and Kyere-Boateng and Marek, 2021). Tanzania's Eastern Arc and coastal forests including Kilengwe, are known to be diversity hotspots but due to increased anthropogenic activities brought on by population growth and vegetation fragmentation the forests are in risk of losing some of this diversity (Temu and Andrew, 2008; Newmark, 2001; Kacholi, 2013; Kacholi, 2014). Thus, to conserve plant ecology and biodiversity it is essential to understand how plant species diversity and distribution differ within forests (Murcia, 1995; Barbier *et al*., 2008).

The primary causes of habitat change, forest degradation, and biodiversity include the conversion of forests to agriculture, exploitation through selective harvesting, seasonally scheduled fires in the forests, cutting down fuelwood and charcoal manufacturing, cattle grazing in forests, and even going after natural herbivores (Ramirez-Marcial *et al.*, 2001; Reyers, 2004; Banda *et al.*, 2006). At local and regional scales, disturbances brought on by these actions affect vegetation interactions and the density of trees (Hubbell *et al*., 1999) and are crucial for organizing vegetation communities (Sumina, 1994), especially noticeable in the shifting size-class abundance of the desired plant species (Luoga *et al*., 2004; Banda *et al*., 2006). In response to the various issues, conservation biologists have worked to safeguard forests by implementing a variety of tactics (Banda *et al*., 2006), such as stringent protection in national parks, integrated preservation and development initiatives, and appropriate forest management (Bruner *et al*., 2001; Primack, 2002; Borgerhoff *et al*., 2005).

According to Zeng *et al*., (2014) study only a small percentage of species can effectively survive to the tough local environmental circumstances because of the semi-arid climate and limited supplies. Past grazing by both domesticated and wild animals has occurred in Nylsvley Nature Reserve (NNR) (Scholes and walker, 1993; Murungweni *et al*., 2020). Wild animals feed and forage in the Nylsvley wetlands to find food, therefore considering their needs while designing a habitat may be affected by reduced vegetation (Murungweni *et al*., 2020). Additionally, vegetation offers the migratory birds at Nylsvley Nature Reserve with a habitat that draws tourists there to go bird watching, generates income for the area and jobs in the tourism industry (Murungweni *et al*., 2020). Although some research has been done on the savanna species in the NNR and the nearby wetland, no research has been done on the community structure and composition of Maroelakop Mountain.

1.3 Aim and objectives

The purpose of this study was to compare and analyse the vegetation structure of the slope that faces North from the slope that faces South. To fulfil the study's purpose, the following objectives were investigated:

i. To determine density and frequency of tree layer species on opposite slopes.
ii. To determine the importance value indices of tree layer species against opposite slope directions and gradients.
iii. To determine the vegetation structure against slope gradient.

1.4 Research questions

- What are the dominant tree species in the North and South-facing slopes?
- What are the key species in relation to slope directions and gradients?
- What is the effect of slope gradient on distribution of a species?

1.5 Hypothesis

The study hypothesizes that vegetation structure and composition vary between North and South-facing slopes. These differences could require different management approaches.

CHAPTER 2

LITERATURE REVIEW

2.1 Biodiversity

People describe biological diversity (biodiversity) differently (). A systematist may be fascinated with the list of species in a specific taxon or group of taxa (Noss, 1990, and Maiti and Maiti, 2023), whereas a community ecological researcher may be more intrigued in the variety and distribution of species or vegetation type, and allelic variety and heterozygosity may be seen by a geneticist as the two most important manifestations of biological diversity. (Noss, 1990). A plant community comprises various of plant species that coexist in a specific area and interact clearly with one another (Muller-Dombois and Ellengberg, 1974; Sharma *et al*., 2009).

Species are the most popular way to define this diversity at the ecosystem level. The structure and growth of the plant community are examined in terms of diversity of species, which is viewed as a spatial representation of textural diversity (Sharma *et al.*, 2009). However, the representation of variability found in natural communities is generally what the concept of diversity is concerned with. A community's diversity can be learned a lot by comparing species abundance distributions based on models of species abundance and the accompanying diversity indices (Sharma *et al*., 2009; Leinster and Gobbold, 2012).

The level of individual dominance or relative (correlated) abundance among various organisms is another crucial indicator of biodiversity. This gauges how evenly different species are represented within a community and is commonly known as equitability or evenness (Sharma *et al*., 2009). There is a significant link between species abundance and structural diversity (Sahu *et al*., 2008). An increase in habitat complexity and spatial structural variability is equivalent to the provision of resources and niches, which typically results in the enhancement of species (Sharma *et al*., 2009). Conceptual approaches that differentiate between various spatial levels of species abundance and structural diversity suffer from a significant drawback (Bastian, 1990) because they ignore the functional aspect of biodiversity by failing to consider or even mention ecological processes (Noss, 1990).

Biodiversity is thought to be best preserved in protected areas and other areas where land is not destroyed by the pressures of population growth (Brown *et al*., 2009; Watson *et al*., 2010). Conservation of biological diversity outside protected areas is an important issue of international conservation discussions (Niamir-Fuller *et al*., 2012). Loss of wildlife habitat, although rarely studied scientifically, is of concern to conservationists as it can affect local biodiversity (Hansen *et al*., 2002). However, little is currently known about the ecological impact of human development and animal husbandry across different land uses on terrestrial wildlife (Zisadza-Gandiwa *et al*., 2013), although some conservationists have suggested that this could lead to biodiversity loss (Newmark, 2008). According to Franklin (1988) and Noss (1990), composition, structure, and function are three important aspects of entertainment.

2.2 Vegetation structure and composition

A collection's composition refers to the variety and identity of its constituent parts, It encompasses species listings, genetic diversity metrics, and species diversity measures. According to Noss (1990), structure refers to the physical arrangement or pattern of a system, which can range from the pattern of patches and other elements in a landscape to the complexity of the habitat as measured within communities. Along the altitudinal range of its growth, a particular forest type's species diversity varies significantly, depending on a complex array of variables that define each species' particular habitat. Because the plant community's diversity of species and production of biomass differ from one location to another as a result of altitude and hill aspect variations (Niu *et al*., 2019; Ning *et al*., 2014). As intense grazing pressure, mountain rangelands, which are found in mountainous areas, are experiencing a decline in productivity and biodiversity (Pohl *et al*., 2009). The composition and structure of the species are impacted by a variety of processes that are inextricably linked to some changes in space during ecological function. A requirement for the sustainability of a workable system is the fundamental ability of ecosystems to change, evolve, and recognize themselves (Sharma *et al*., 2009), since they have similar environmental requirements for existence, the species in a community thrive together in that environment.

According to Hawkins *et al*., (2003), climate (including temperature and precipitation) plays a significant role in determining the richness of woody species at the regional level. On the other hand, at small scales, plant composition and diversity can be affected by interactions between organisms (Whittaker *et al*., 2001) and the local environment such as lighting (Svenning, 2000), humidity, topography (Moeslund *et al*., 2013) and land use patterns (Sherman *et al*., 2007) (Paudel and Vetaas 2014). Characteristics such as slope and elevation have an impact on the growth of plants, as solar radiation can vary in mountainous regions (Gallardo-Cruz *et al*., 2009). According to Scherrer and Köerner (2010), the temperature difference between small areas can be affected by mountain topography, North and South-facing areas receive different amounts of solar radiation, these rocks may have different microclimates (such as temperature) and water conditions (such as soil moisture), which may affect the composition and abundance of plant communities (Zhuang *et al*., 2012; Moeslund *et al*., 2013).

2.3 Impact of slope gradient

Landscape variables such as slope aspect and topographic position impact plant community disturbance regimes, resource availability, and environmental conditions (Mendez-Toribio *et al*., 2020; Dyer, 2009). As noted by Mendez-Toribio *et al*. (2016), South-facing slopes in the southern hemisphere, near the Equator, tend to be cooler and more humid because they receive less solar energy than North-facing slopes. As stated by Segura *et al*. (2002), the South-facing slope frequently has soil moisture levels below the field capacity, which leads to a greater level of transpiration rates (Mendez-Toribio *et al*., 2016) and slower plant growth. In this study, the slope that receives more solar radiation is the North-facing slope (Liu *et al*., 2018).

Species composition in these areas is influenced by environmental asymmetry between northern and southern slopes, which includes important ecosystem products such as food availability and soil organic matter (Méndez-Toribio *et al*., 2016; Sidari *et al*., 2008). The amount of moisture available varies depending on the topographic position; more water and organic matter tend to accumulate at the bottom of slopes (Méndez-Toribio *et al*., 2016). In addition, activities such as livestock grazing and fuelwood collection are often concentrated in low-lying areas, especially in high-altitude regions (da Silva *et al*., 2014).

The relationship between vegetation and area, and particularly between aspect and topographic position, has been previously studied in temperate, Mediterranean, or tropical humid communities (Badano *et al*., 2005). Carmel and Kadmon's (1999) found that slope aspect significantly impacts the rate of vegetation change, slope aspects have a significant impact on the rate of change, with North-facing slopes showing the greatest change. The most notable differences in soil and vegetation properties along a climatic transect, according to Kutiel and Lavee (1999), were found to exist between North-facing slopes and South-facing slopes in the Mediterranean region. In contrast, the differences in arid and semi-arid zones were small and negligible. Energy inputs may play a significant role in limiting resource availability at higher elevations; as a result, South-facing slopes will support greater species richness due to more energy input (Paudel and Vetaas, 2014; Hawkins *et al*., 2003). Therefore, it is unclear how slopes affect the diversity and structure of plant communities at high elevations. Apart from the aforementioned factors, variations in the land use patterns on different slopes and geomorphological features within slopes can impact the composition and diversity of communities (Paudel and Vetaas, 2014).

The distribution of plants on the mountain is greatly influenced by altitude and microclimate (Cowling *et al*., 2015; Moeslund *et al*., 2013). The aspect and elevation of the land surface are considered important in determining biological processes in mid- and high-latitude regions, as they change the solar radiation received from the region (Niu *et al*., 2019; Bennie *et al*., 2008). They also measure the photosynthetic capacity of plants. The energy balance of the Earth's surface is affected by solar radiation (Bennie *et al*., 2008), and space also has an impact on the microclimate, including the temperature and moisture of the nearby soil (Ning *et al*., 2014). Changes in location and altitude are important for determining mountain vegetation, species distribution, and ecological structure (Niu *et al*., 2019; Bennie *et al*., 2006). The distribution of vegetation generally follows the above pattern (Niu *et al*., 2019; Maua *et al*., 2020), although altitude and mountain topography may differ by several meters (Bennie *et al*., 2008).

CHAPTER 3

METHODOLOGY

3.1 Description of the study area

This project was carried out in the South African province of Limpopo at the Nylsvley Nature Reserve (NNR) on Maroelakop Mountain. Nylsvley Nature Reserve is in the Waterberg Region of the Limpopo province, South Africa. It is roughly 12 kilometres south of Mookgophong and 50 kilometres northeast of Bela-Bela (LEDET, 2013; Tshimomola 2017). 24^{o}36'S/28^{o}40'E and 24^{o}42'S/28^{o}44'E (GPS: S24^{o} 39'50.0 E 28^{o} 39'54.4) are the GPS coordinates that pinpoint the location. Nylsvely Nature Reserve is situated at an average altitude of 1100 meters above sea level, ranging from 1080 to 1154 meters (Dippernaar-Schoeman *et al.,* 2009).

Nylsvely Nature Reserve is in the bushveld. According to Frost (1987), the climate is warm, with an average yearly temperature of 18.7°C. At NNR, daily high temperatures range from 29°C in summer to 21°C in winter, while daily low temperatures range from 17°C in summer to 4°C in winter (Tshimomola, 2017). Nylsvely Nature Reserve receives roughly 648 mm of rain per year on average. Furthermore, it is highly variable, with yearly rainfall ranging from 250 mm to 1100 mm over a 15 to 21-year cycle (Tooth *et al*., 2002 and Havenga *et al*., 2007). Most of the runoff that hydrates the floodplain comes from the Waterberg foothills, which reach a height of over 1600 meters in the Nyl River watershed. Havenga *et al*. (2007), noted that in Limpopo Province, the Nyl River floodplain is a seasonal wetland of significant preservation value.

Nylsvley Nature Reserve is part of South Africa's Savanna Biome. Grass frequently dominates the herbaceous layer of a savanna, which also has a woody component and a tree canopy (LEDET, 2013; Tshimomola, 2017). Dippenaar-Schoeman *et al.* (2009), estimate that the NNR supports approximately 600 plant species. The reserve offers a home for several types of insects, animals, birds, and reptiles (Tshimola, 2017). It is regarded as one of South Africa's best bird-watching destinations due to its rich avifaunal species (Turpie *et al.,* 2010).

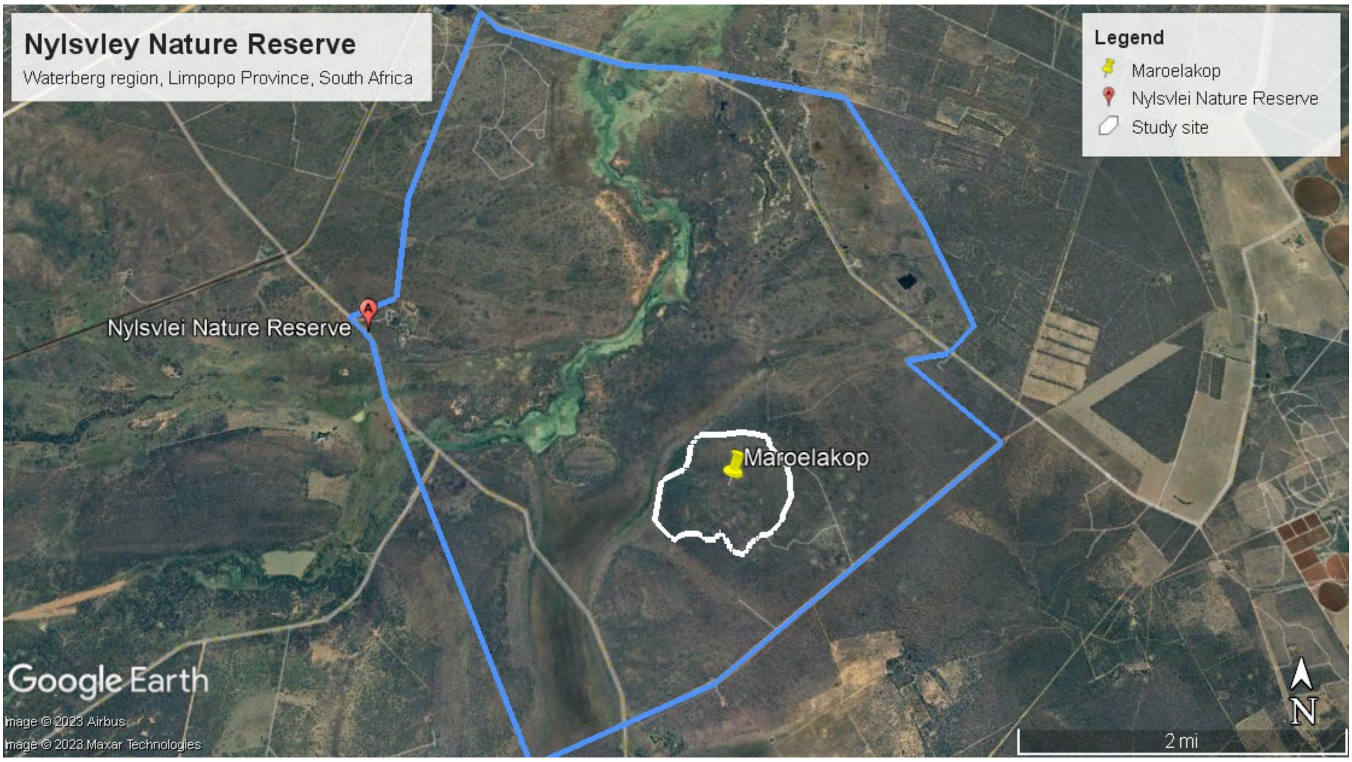

Figure 3.1: Representing the research area in Nylsvley Nature Reserve (Google Earth: Accessed 15 February 2023).

Figure 3.2: Showing the Maroelakop mountain {Photo: Tendani}.

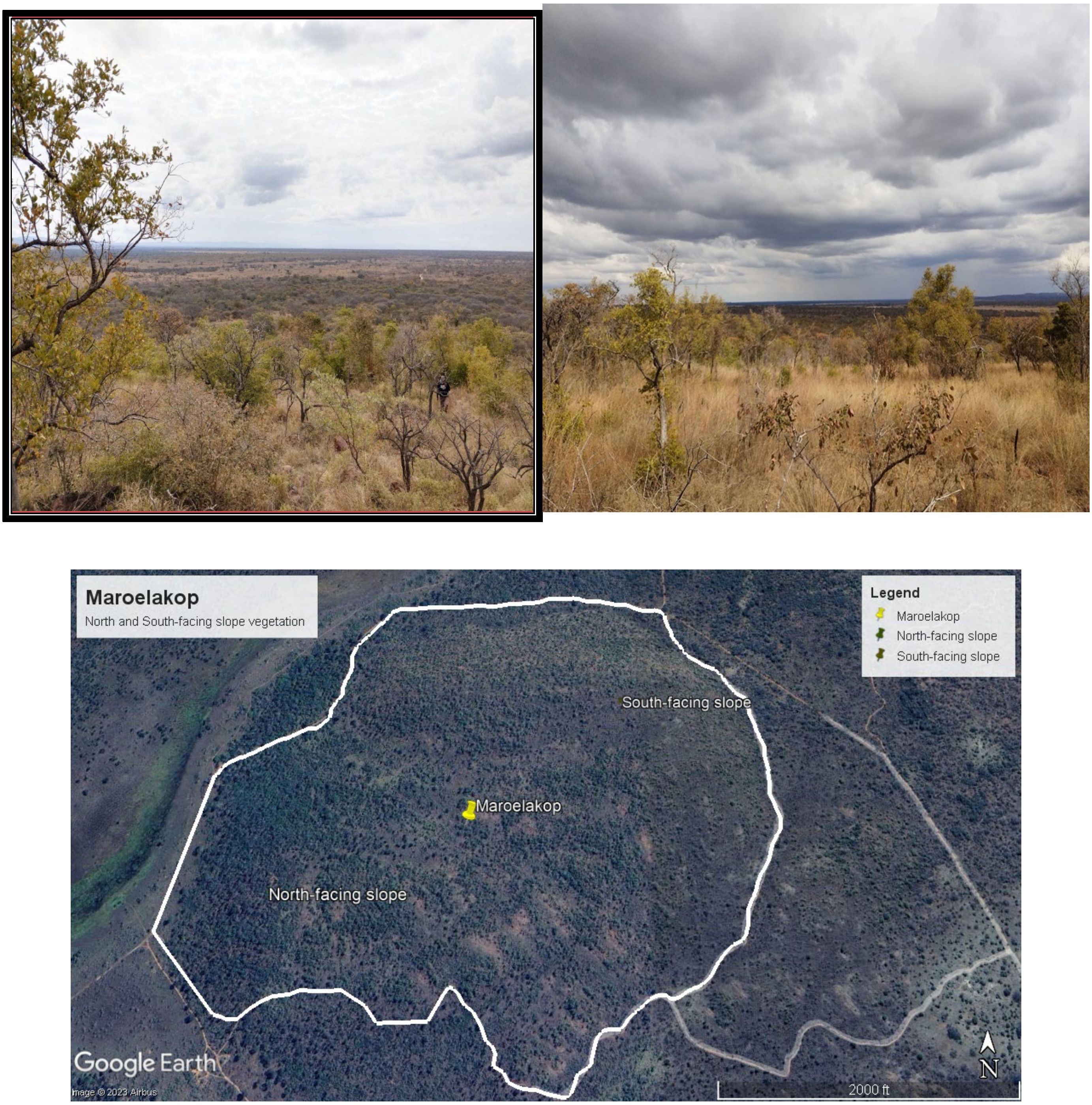

Figure 3.3: (The North-facing slope with a black border that is on the left) (South-facing slope that doesn't have the border line that is on the right). {Photo: Tendani}. Below, Aerial-photograph showing the vegetation density of the North and the South-facing slope {Photo: Google Earth: Accessed 15 February 2023}.

3.2 Data Collection

The Point Centred Quarter (PCQ) on the South-facing slope and North-facing slope was the technique used to gather data on the composition of the tree layer (Cottam and Curtis, 1956). In each of the four quadrats, the distance between the sample point and the centre of the closest tree was measured, and the species was identified (Mueller-Dombois and Ellenberg, 1974; Cottam and Curtis, 1956). In accordance with Mueller-Dombois and Ellenberg (1974), this method provides an estimate of the number of tree species, their dominance, and their frequency. At a distance of 20 meters between points, 30 points were sampled along a straight line (Figure 3.1). The technique enables the sampling of ecological information from a large area. When sampling the quarters, Mueller-Dombois and Ellenberg (1974) identified two general restrictions: (1) Plant species must be present in each quadrat, and (2) Plant species should not be measured more than once, which may present a challenge in sparsely wooded vegetation. When there are no trees or plants in the selected area around the recording location, Dreber *et al*., (2014) recommended that zero plants should be recorded for the specific quadrat as noted by Trollope *et al*. (2004) and Trollope (2011).

The following parameters were recorded:

i. The height (in meters) of each plant, which is the greatest vertical distance between the plant's base and top (Sternberg and Shoshany, 2001). To take measurements, a height rod was used to measure the plants height up next (Figure 3.5).
ii. At the base of the stem, the measuring tape was used to determine the individual plant's basal stem diameter (cm) (Figure 3.6).

iii. Using the measuring tape shown in Figure 3.7, the individual plant's crown diameter (m) was obtained.

Figure 3.4: Showing Point Centred Quater method being applied on *Lannea discolor* {Photo: Tendani}.

Figure 3.5: Height measurements being recorded on *Burkea africana* {Photo: Tendani}.

Figure 3.6: Basal stem diameter being recorded on *Burkea africana* {Photo: Tendani}.

Figure 3.7: Crown diameter measurements being recorded on *Burkea africana* {Photo: Tendani}.

The 600 species that were surveyed for this study made up the entire sampled data of Maroelakop Mountain in the Nylsvey Nature Reserve. Mane *et al.* (2019) suggested that when determining the overall number of species encountered, the number of individuals discovered dead should be excluded.

3.3 Data analysis

In order to analyse the data on the composition and structure of the vegetation across the various slopes (downslope, Middleslope, and upslope) of both North and South-facing slope, Microsoft Excel was used.

3.3.1 Importance Value Index

The dominating species in the plots were described and compared using Cottam and Curtis' Importance Value Index (IVI) (Maua *et al*., 2020), which was modified by Mueller-Dombois and Ellenberg (1974). The most "important" species in a plot had the highest IV indices. This score assesses each species' overall relevance within the community structure.

Table 3.1: Showing the formulas used to calculate IVI.

Index	**Equation**
Importance value index	$Relative\ density + Relative\ Frequency + Relative\ Dominance$
Relative density	$\frac{Density\ of\ all\ species}{Total\ density\ of\ all\ species} \times 100$
Relative frequency	$\frac{Frequency\ of\ a\ species}{Total\ frequency\ of\ all\ species} \times 100$
Relative dominance	$\frac{Dominance\ of\ a\ species}{Total\ dominance\ of\ all\ species} \times 100$
Density	$\frac{Number\ of\ a\ species}{Total\ area\ sampled}$
Frequency	$\frac{Area\ of\ plots\ in\ which\ a\ species\ occurs}{Total\ area\ sampled}$

Dominance	$\frac{Total\ basal\ area\ of\ a\ species}{Total\ area\ sampled}$

3.3.2 Shannon diversity index

The formula for calculating the Shannon diversity index (H') is as follows: H' = -Σpi ln pi

Where I is the ratio of species to all species (pi), divided by the natural logarithm (ln pi) and the final product is divided by -1. The Shannon diversity index can be used to determine the type of community differences between north and South-facing areas. The larger the H value, the more species there are in a community. The lower the H value, the lower the variance. If H = 0, only one species is expected to exist in the community (Shannon and Wiener, 1963).

3.3.3 Simpson index of dominance and Evenness

Simpson's Dominance Index is a measure of species differences in communities between the north and south (Peet, 1974). The value of the Simpson Dominance Index is between 0 and 1 (Thukral *et al*., 2019). The higher the value of this index, the greater the difference between communities. When the difference index approaches 1, it means that there are more species in the community and the proportion of species is equal. When the difference index is zero, only one species is found in the community (Simpson, 1949). It will be calculated as follows:

$$Simpson\ diversity\ index = \frac{\sum n_i(n_i-1)}{N(N-1)}$$

n_i = Number of individuals that are present per species i. N = The total number of species in the sample.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Vegetation structure of Maroelakop mountain in Nylsvley Nature Reserve

Six hundred different plant species were sampled for height, basal stem diameter, and crown diameter from the 150 points that were plotted at Maroelakop mountain. The results showed that the size-classes of 2.0 – 3 m and 3.1 - 4 m contained the greatest amount of the species in all slope directions. The size-class of 2.0 - 3 m had a total frequency of 167 on the North-facing slope, while the size-class of 3.1 - 4 m had a total frequency of 67 (Figure 4.1). The size-class of 2.0 - 3 m had a total frequency of 164 on the South-facing slope, while the size-class of 3.1 - 4 m had a total frequency of 75 across the slope's downslope, middleslope, and upslope. The size-classes 4.1 – 5 m and 5.1 – 6 m were 52 and 37 respectively in total on the North-facing slope (Figure 4.1. On the South-facing slope, the size-class of 4.1 – 5 m had a total frequency of 48 and 45 on size-class 5.1 – 6 m (Figure 4.2).

It is shown by the height size-class distributions that all the trees in the North-facing slope and South-facing slope within the 6.1 – 7 m, 7.1 – 8 m, 8.1 – 9 m and ≥ 9 m size-classes showed the lowest number of species as compared to the other size-classes. North-facing slope, size-class of 6.1 – 7m had a total frequency of 25 whereas size-class of 7.1 – 8 m had total frequency of 7. Size-classes of 8.1 – 9 m and the ≥ 9 size-class had total frequency of 4 and 1 respectively (Figure 4.1). On the South-facing slope, size-class of 6.1 – 7 m had a total frequency of 20 while size-class of 7.1 – 8 m had a total frequency of 6. The size-classes of 8.1 – 9 m and ≥9 had respectively total frequencies of 2 and 0 (Figure 4.2).

Amongst all the size-classes the one with the most individual species was the size-class of 2.0 – 3 m for both slope directions. Upslope had the most species on the North-facing slope while Downslope had the most individual plants on the South-facing slope. For the rest of the size-classes the frequency decreases until a point wherein, there are no individual species found or a point of zero frequency (Figure 4.1 and 4.2). The distribution indicates an inverse J-shaped curve.

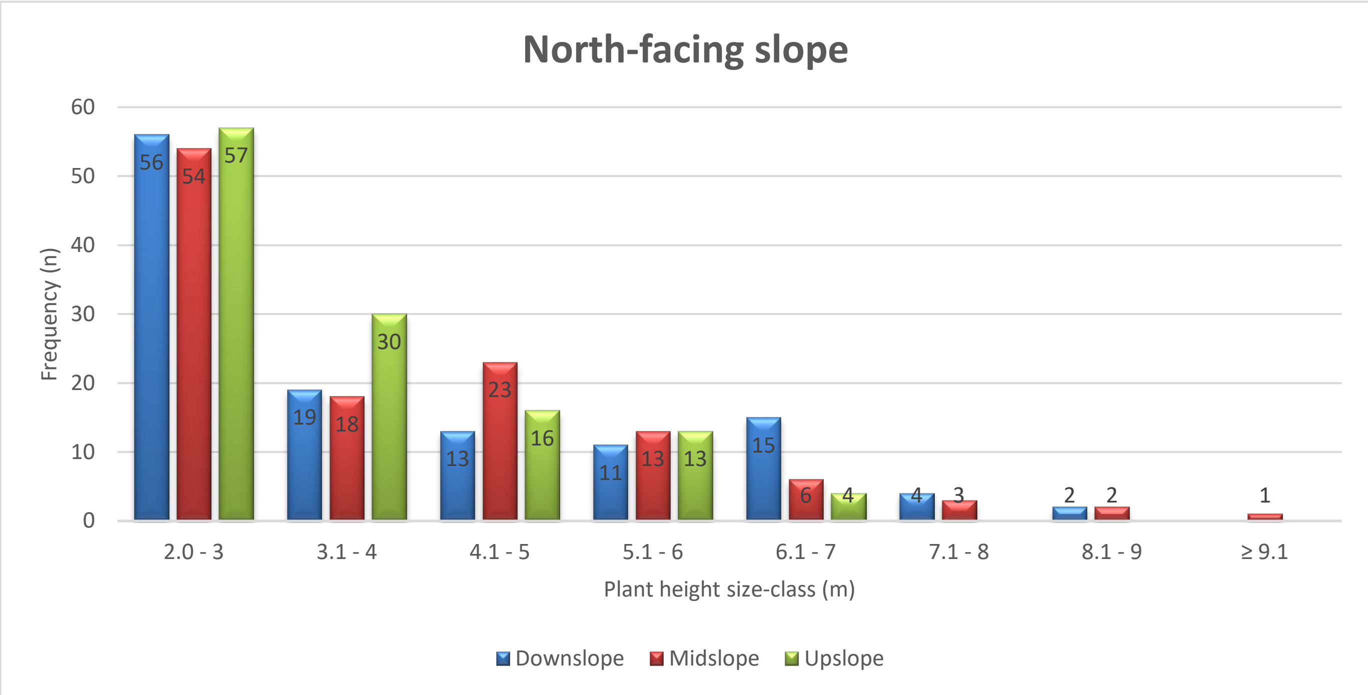

Figure 4.1: Plant height size-class distributions of a North-facing slope vegetation.

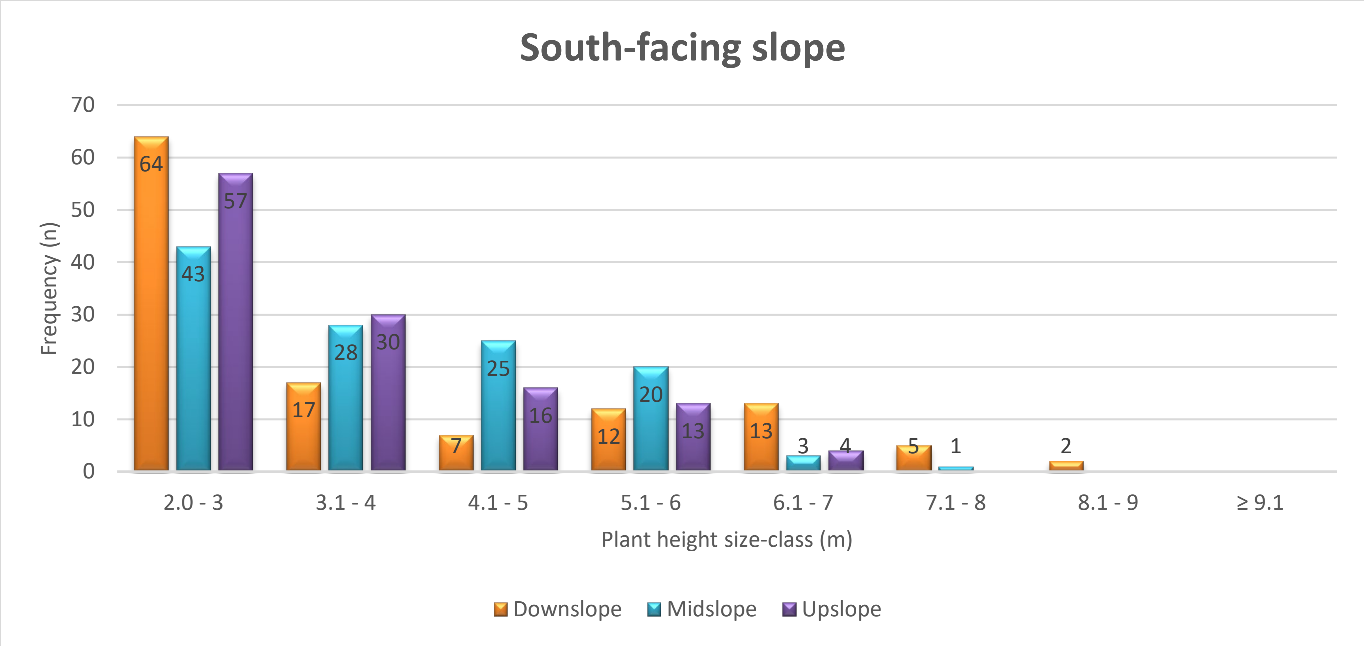

Figure 4.2: Plant height size-class distributions of a South-facing slope vegetation.

A curve with an inverse J-shape represents the height size-class distribution. The tree layer species in Maroelakop mountain's inverse or reversed J-shaped distribution on both the mountain's north and South-facing slopes indicate that regeneration has been hampered as a result of various disturbance factors, including frequent livestock browsing, trimming, and wildfires (Singh *et al*., 2023). According to Jacobsen (2008), the Nylsvley Nature Reserve had experienced periodic fires before the start of their survey, and signs of these fires could still be seen on the tree trunks and other charred logs and stumps nearby.

Fire has a significant influence on both the plants and animals (González *et al*., 2022). This is visible in locations where fire break out every two years, such places have insufficient vegetation cover that, particularly on the steeper slopes, does not recover rapidly enough to burn after one season's growth (Laris, 2002). An inverse J-shape distribution of diameter classes, according to studies by Ghanbari *et* *al*. (2021) and Atsbha *et al*. (2019), suggests that a woody species' population is likely to be stable or to experience continuous, good regeneration. This includes species whose frequency distribution showed a relatively gradual decline in frequency as the height size-classes with the highest frequency were raised (Figures 4.1 and Figure 4.2).

Regarding the North-facing slope, the first three height size-classes account for 76.67% of the total frequency, while the remaining height size-classes (5.1 - ≥9) account for 23.33%. On the South-facing slope, the first, second, and third height size-classes account for 66.38% of the total frequency, while the remaining height size-classes (5.1 - ≥9) account for about 33.62% of the frequency. The species on the North-facing slope were taller than the species that were sampled on the South-facing slope. North-facing slope with total frequency of 37 individual species that were more than six 6 meters, while on the South-facing slope only 28 individual species were recorded. One potential explanation would amongst others be the availability of sunlight in these two parts of the slope, and other factors including temperature, soil type, soil moisture may not be ruled out.

The climate of the Nylsvley Nature Reserve is semi-arid with distinct seasons (Whitecross *et al*., 2016); a hot, wet season runs from October to April, then there's a cool, dry season from May to September (Jacobsen, 2008). It is also shown that from downslope to upslope on both sides of the slope the height of the species decreases remarkably. The density of plant species individuals and the competition of resources may be another cause of the physical differences between the two sides of the slope. In order to thrive and contend for scarce resources, land plants have developed a variety of growth forms and techniques over time (Weigelt *et al*., 2021; Grime, 1977).

Vegetation tends to be higher in elevation on the north side due to denser vegetation that encourages plants to grow so that they can receive adequate sunlight, which is important for the photosynthetic process (Landi *et al*., 2020). According to Yang's research, there are significant differences in species composition, vegetation patterns and biodiversity patterns on hillsides. These findings are consistent with significant changes in soil nutrients (Yang *et al*., 2020).

4.2 Tree species Importance Value Index along Maroelakop mountain

In this study, 600 trees representing 21 species that fall within 17 genera and 12 families have been discovered on Maroelakop mountain. The most prevalent families on the mountain were Fabaceae and Combretaceae, each with a total of four species, subsequently followed by Malvaceae (three species) and Anacardiaceae (two species). Within the families Combretaceae and Malvaceae, the genera Combretum and Grewia have been represented by four and three species, respectively (Table 4.5).

The species singletons and doubletons accounted for 67% and 8% of the total recorded families, respectively, while 25% had more than two species. To the species that were recorded on the North-facing slope (Downslope), it was found that *Diplorhynchus condylocarpon* (58.60), *Combretum molle* (53.39) and *Lannea discolor* (32.90) had higher Importance Value Indices (IVI). Species that showed low IVIs were *Sclerocarya birrea* (2.08), *Grewia flava* (7.68) and *Strychnos madagascariensis* (9.39). On this North-facing slope, *Diplorhynchus condylocarpon* had the highest IVI whereas *Sclerocarya birrea* had the lowest Table 4.1.

On the Middleslope of the North-facing slope species that showed a more substantial Importance Value Index for these species were *Combretum molle* (52.76), *Diplorhynchus condylocarpon* (97.51) and *Lannea discolor* (49.76). There were species that showed a low importance value index which were *Afrocanthium gilfillanii* (4.18), *Dichrostachys cinerea* (2.04) and *Grewia flavescens* (4.04). On this North-facing slope, *Diplorhynchus condylocarpon* had the highest IVI whereas *Dichrostachys cinerea* had the lowest Table 4.2.

On the South-facing slope (Downslope) the following plant species had a higher importance value index, *Burkea africana* (107.65), *Combretum molle* (84.78) and *Diplorhynchus condylocarpon* (39.89). There were also those species that had a low IVI in this part of the slope which are as follows *Dichrostachys cinerea* (2.24), *Grewia bicolor* (2.23) and *Pseudolachnostylis maprouneifolia* (2.39). on this part of the slope, *Burkea africana* had the highest IVI and *Grewia bicolor* with the lowest IVI Table 4.3.

On the Middleslope of the South-facing slope there were plant species that had a higher importance value index which are as follows: *Burkea africana* (57.51), *Combretum molle* (78.10) and *Diplorhynchus condylocarpon* (68.52). There were also species that had a low IVI which are *Englerophytum magalismontanum* (2.10), *Grewia flavescens* (2.06) and *Ochna pulchra* (2.96). On this part of the slope C*ombretum molle* had the highest IVI whereas *Grewia flavescens* had the lowest IVI as per Table 4.4.

Table 4.1: Plant species based on IVI along Moreolakop mountain North-facing slope (Downslope).

Species	**Relative Density**	**Relative Dominance**	**Relative Frequency**	**Importance Value Index**
Albizia tanganyicensis Baker f.	2.50	15.19	2.15	19.84
Burkea africana Hook.	5	9.60	6.45	21.05
Combretum apiculatum Sond.	5.83	6.44	7.53	19.80
Combretum molle R.Br. ex G. Don	26.67	8.45	18.28	53.39
Dichrostachys cinerea (L.) Wight & Arn	8.33	0.71	7.53	16.57
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	15	25.32	18.28	58.60
Grewia flava DC.	3.33	0.04	4.30	7.68
Grewia flavescens Juss.	5	1.20	5.38	11.57
Lannea discolor (Sond.) Engl.	12.50	7.49	12.90	32.90
Pseudolachnostylis maprouneifolia Pax.	1.67	15.56	2.15	19.38

Sclerocarya birrea (A.Rich.) Hochst.	0.83	0.17	1.08	2.08
Strychnos madagascariensis Poir.	1.67	5.57	2.15	9.39
Terminalia sericea Burch. *ex* DC	11.67	4.26	11.83	27.76

Table 4.2: Plant species based on IVI along Moreolakop mountain North-facing slope (Mid-slope).

Species name	**Relative Density**	**Relative Dominance**	**Relative Frequency**	**Importance Value Index**
Afrocanthium gilfillanii (N.E.Br.) Lantz	1.67	0.16	2.35	4.18
Burkea africana Hook.	1.67	4.76	2.35	8.78
Combretum apiculatum Sond.	3.33	8.45	4.71	16.49
Combretum molle R.Br. *ex* G. Don	23.33	8.25	21.18	52.76
Croton gratissimus Burch.	5.00	5.30	5.88	16.18
Dichrostachys cinerea (L.) Wight & Arn	0.83	0.03	1.18	2.04
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	31.67	37.61	28.24	97.51
Grewia bicolor Juss.	2.50	1.03	2.35	5.88
Grewia flavescens Juss.	1.67	0.03	2.35	4.04

Lannea discolor (Sond.) Engl.	18.33	14.96	16.47	49.76
Pseudolachnostylis maprouneifolia Pax.	3.33	7.43	4.71	15.47
Strychnos madagascariensis Poir.	0.83	3.03	1.18	5.04
Terminalia sericea Burch. *ex* DC	2.50	1.05	3.53	7.08
Vitex ferruginea Schumach. & Thonn.	3.33	7.92	3.53	14.78

Table 4.3: Plant species based on IVI along Moreolakop mountain South-facing slope (Downslope).

Species name	**Relative Density**	**Relative Dominance**	**Relative Frequency**	**Importance Value Index**
Burkea africana Hook.	19.17	67.65	20.83	107.65
Combretum molle R.Br. ex G. Don	45.83	4.22	34.72	84.78
Dichrostachys cinerea (L.) Wight & Arn	0.83	0.02	1.39	2.24
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	10.00	17.39	12.50	39.89
Grewia bicolor Juss.	0.83	0.01	1.39	2.23
Grewia flavescens Juss.	1.67	0.04	2.78	4.48
Lannea discolor (Sond.) Engl.	8.33	5.44	11.11	24.89
Pseudolachnostylis maprouneifolia Pax.	0.83	0.17	1.39	2.39

Terminalia sericea Burch. *ex* DC	10.00	3.66	11.11	24.77
Vachellia karroo (Hayne) Banfi & Galasso	1.67	0.89	1.39	3.94
Vitex ferruginea Schumach. & Thonn.	0.83	0.52	1.39	2.74

Table 4.4: Plant species based on IVI along Moreolakop mountain South-facing slope (Mid-slope).

Species name	**Relative Density**	**Relative Dominance**	**Relative Frequency**	**Importance Value Index**
Burkea africana Hook.	12.50	30.73	14.29	57.51
Combretum collinum Fresen.	4.17	7.68	5.95	17.80
Combretum molle R.Br. ex G. Don	33.33	17.38	27.38	78.10
Diplorhynchus condylocarpon Müll.Arg.) Pichon	21.67	23.04	23.81	68.52
Englerophytum magalismontanum (Sond.) T.D.Penn.	0.83	0.08	1.19	2.10
Grewia flavescens Jusss.	0.83	0.04	1.19	2.06
Lannea discolor (Sond.) Engl.	19.17	16.23	16.67	52.06

Ochna pulchra Hook.	0.83	0.94	1.19	2.96
Pseudolachnostylis maprouneifolia Pax.	5.00	3.30	5.95	14.26
Terminalia sericea Burch. *ex* DC	1.67	0.58	2.38	4.62

The importance value index (IVI) facilitates comprehension of a community's ecological importance of different tree species. The highest IVI gauges a species' level of dominance over other species in a reserve stand (Abba *et al*., 2022). According to Ghanbari *et al*. (2021), Species that have greater IVI values are regarded to be more significant than those that have lesser IVI. According to Mao *et al*. (2010) and Tadese *et al*. (2021), the plant species with the greatest IVI are more prevalent in that given flora. IVI may also be utilized to establish priorities for plant species conservation and management (Edwards *et al*., 2000).

According to the results of this study, *Diplorhynchus condylocarpon* had the greatest IVI on the North-facing slope, followed by *Combretum molle* and *Lannea discolor*, while *Dichrostachys cinerea* had the lowest IVI. Plant species with low IVI need significant conservation strategies and as a result, should be given conservation priority (Ghanbari *et al*., 2021). Tables 4.1 and 4.2 demonstrate that *Diplorhynchus condylocarpon* has the highest IVI on this portion of the slope as a result of its high relative dominance and relative frequency. This is due to the fact that *Diplorhynchus condylocarpon* was the most prevalent tree species on the study area's North-facing slope, it occurred in more than 50% of the quadrats. 5% or fewer of the quadrats had *Dichrostachys cinerea.*

Burkea africana, Combretum molle, and *Diplorhynchus condylocarpon* were found to have the highest IVI on the South-facing slope, while *Grewia flavescens, Englerophytum magalismontanum, Pseudolachnostylis maprouneifolia* and *Ochna pulchra* had the lowest IVI (Table 4.3 and 4.4). Numerous species with lower IVI values were found in this study, which suggests that most of the species in this mountain are uncommon. The frequency distribution backs up this finding as well as Figures 4.4 and 4.5. The high relative dominance and relative frequency on this portion of the slope contribute to the species' high IVI. *Burkea africana*, which was present in more than 50% of the quadrats in the study area's South-facing slope, was the most common species, while *Grewia flavescens* was found in fewer than 5% of the quadrats.

With an average of 78.05, *Diplorhynchus condylocarpon* dominated the tree layer on the North-facing slope. In the Nongeni Forest Reserve, *Diplorhynchus condylocarpon* was found to be the prevalent plant species, with an IVI value of 52.18, according to Kacholi's (2019) study. The research by West *et al*. (2000) and Kacholi *et al*. (2015) showed that regeneration (*Diplorhynchus condylocarpon, Combretum molle,* and *Oncoba spinosa*) indicated that they had great capability to reproduce many seedlings, and the seedlings and saplings are able to survive and flourish.

Burkea africana, which has an average IVI of 82.33, was the prevalent species on the South-facing slope. For ecologists and forest managers, their abundance in this community is regarded as an indication of early succession (Ghanbari *et al*., 2021). This study provided evidence that high IVI and abundance are related. According to Woldemichael *et al*. (2010), the Importance Value Index of these plants is greatly increased by their high frequency and density. Vegetation that is dominated by single species often indicates past damage (Swamy, 2000). As a contributing factor, annual wildfires have occasionally occurred in Nylsvley Nature Reserve, because it has been shown that savannas are ecosystems that are prone to fire and that fire is essential to preserving both their structural integrity and floristic makeup Additionally, the lack of fire leads to shrub encroachment and a decrease in the amount of grass and vegetative cover (Tshimomola, 2017).

Reoccurrence of fire may also lead to loss of local biodiversity. Although disturbance may not be the only factor, it may not be the main cause of a single species' dominance on the Maroelakop mountain's north and South-facing slopes. According to Swamy (2000), unfavourable climatic conditions can occasionally lead to single species dominance. Coetzee *et al*. (1976) noted that *Diplorhynchus condylocarpon* had been widely distributed on the Maroelakop mountain's shallow lithosols, supporting the idea that it had been dominant in the mountain because it was discovered thriving there.

The reason for the low IVI value was that the species were sporadic and less common in the Maroelakop mountain, necessitating conservation efforts to keep them from going extinct. In contrast to other species, *Diplorhynchus condylocarpon's* high IVI value was primarily caused by a combination of its greater relative density, basal area, and frequency in the Maroelakop vegetation, also supported by (Pandey *et al*., 2016). The species also showed a strong reoccurrence in the region.

Importance value index is also used to prioritize species conservation; Species with low IVI values require more protection than species with high IVI values (Kacholi 2019). Ghanbari *et al.,* (2021) supported that in terms of conservation species with low IVI need intensive conservation techniques and, hence, should be prioritized for conservation. Several species in this study, such as *Ochna* *pulchra, Dichrostachys cinerea, Englerophytum magalismontanum, Vitex ferruginea, Grewia bicolor, Pseudolachnostylis maprouneifolia,* and *Sclerocarya birrea,* should be given priority for conservation because of their low IVI. The species' sporadic and lower abundance in the forest contributed to its low IVI value; as a result, conservation is necessary to keep it from going extinct (Kacholi 2019).

4.3 Species composition and diversity on Maroelakop slope gradient

Two hundred and forty individual species that were noted on the North-facing slope revealed 17 different species. *Lannea discolor*, *Diplorhynchus condylocarpon,* and *Combretum molle* had a higher relative frequency and relative density. With *Lannea discolor* having the relative frequency of 14.7% and relative density of 15.4%, *Diplorhynchus condylocarpon* with the relative frequency of 23.26% and relative density of 23.33%, and *Combretum molle* with the relative frequency of 19.7% and relative density of 25%. Figure 4.3 shows that *Combretum molle* had the highest relative density and the plant species that was recorded with greater relative frequency was *Diplorhynchus condylocarpon*.

In this study there were plant species with the lowest relative density and frequency which were *Sclerocarya birrea*, *Afrocanthium gilfillanii* and *Strychnos madagascariensis*. With *Sclerocarya birrea* having the relative frequency of 0.5% and relative density of 0.8%, *Afrocanthium gilfillanii* with the relative frequency of 1.2% and relative density of 0.8, and *Strychnos madagascariensis* with relative frequency of about 1.7% and relative density of 0.8%. *Sclerocarya birrea* had the lowest relative frequency amongst all the species and all these three mentioned species had the lowest relative densities (Figure 4.3).

Two hundred and forty individuals were also recorded on the South-facing slope revealing 14 different plant species. The relative frequencies and densities presented on Figure 4.4 showed that *Diplorhynchus condylocarpon, Combretum molle,* and *Burkea africana* had higher values. *Diplorhynchus condylocarpon* had the relative density of 15.8% and relative frequency of 18.2%, *Combretum mole* with relative frequency of 31.1% and relative density of 39.6%, and *Burkea africana* with relative frequency of 17.6% and relative density of 15.8%. Along this slope it is shown on Figure 4.4 that *Combretum molle* had the highest relative frequency and relative density.

On Figure 4.4 there were species with the lowest relative frequencies and densities. The species were, *Ochna pulchra*, *Dichrostachys cinerea, Vitex ferruginea, Grewia bicolor,* and *Englerophytum magalismontanum*. All these species that are mentioned had their relative frequencies and relative densities ranging between 0.4% and 0.7%. Amongst all the species that were found on the South-facing slope it was found that *Englerophytum magalismontanum* had the lowest relative frequency and relative density.

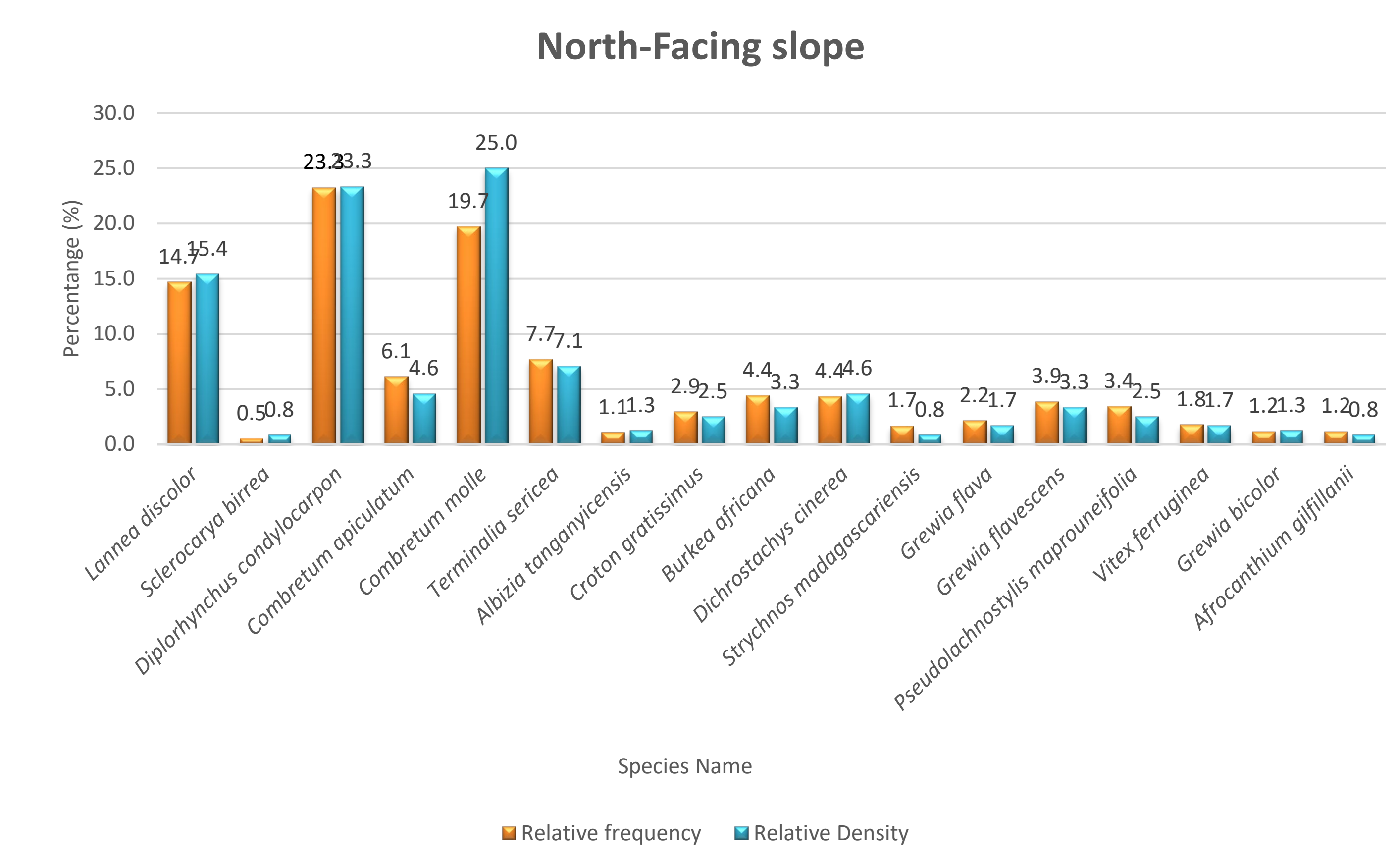

Figure 4.3: Relative frequency and density of North-facing slope.

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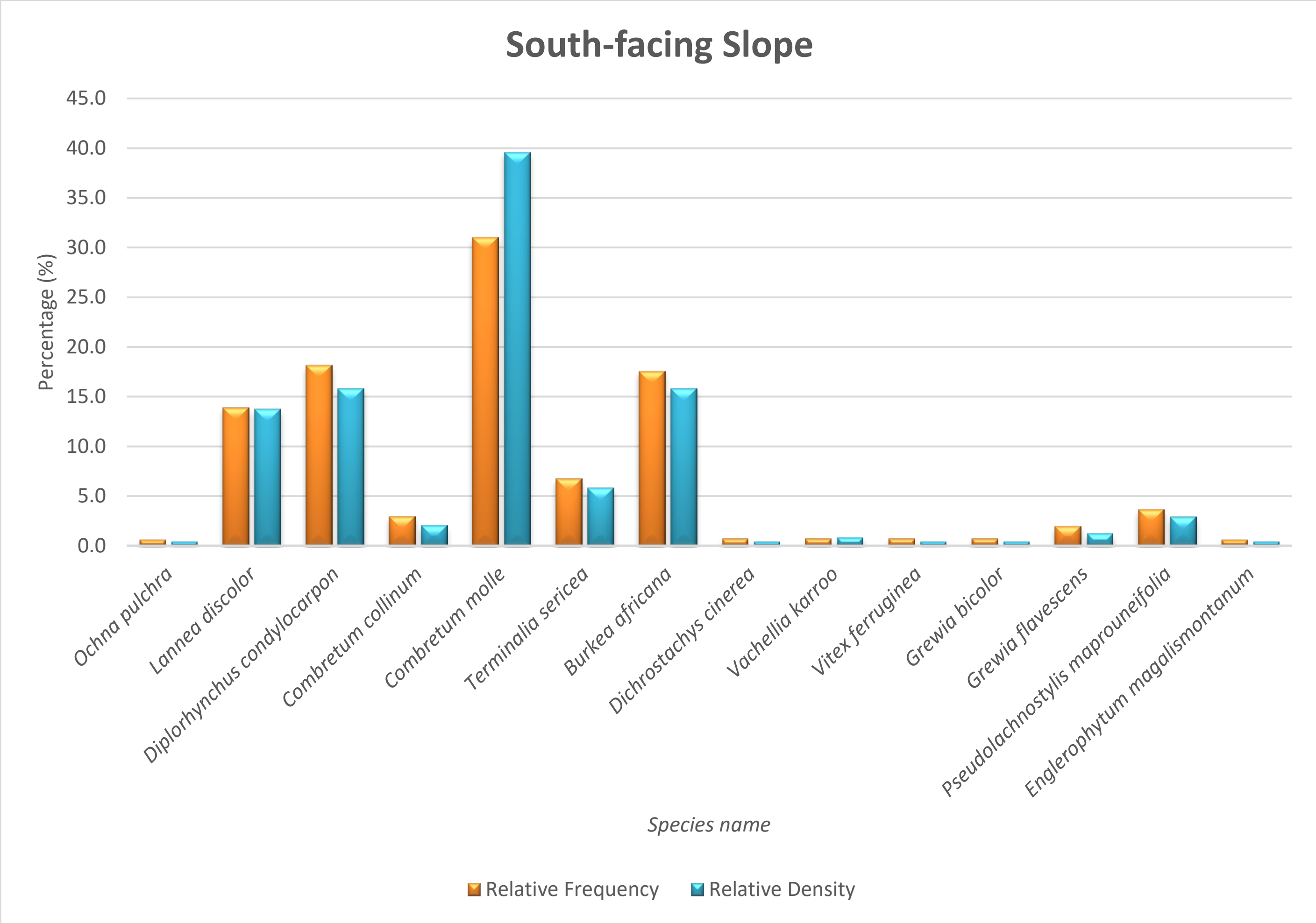

Figure 4.4: Relative frequency and density of South-facing slope in Maroelakop Mountain

Lannea discolor, Diplorhynchus condylocarpon, Combretum molle, and *Burkea africana* were the species that are most abundant in terms of frequency and density on the slopes to the Northern and Southern. Most of these species belong to the families that were noted in Table 4.5 to have the majority of the species. The relative frequency of these plant species also demonstrates that they recurred during sampling, which supports the high IVI values that were recorded for these plant species. The diversity of the species in the study area was demonstrated by the number of species that were found per unit area. The South-facing slope, which has nearly half the number of species per sample size, has the lowest tree density and the North-facing slope has the highest density of trees. The aerial photography of Maroelakop indicates that the North-facing slope has denser vegetation than the South-facing slope. Additionally, the South-facing slope lacks the wetland that is present on the downslope by the North-facing slope, which provides the area with water and nutrients that are necessary for plant growth (Singah *et al*., 2023) (Figures 3.1 and 3.3).

The introduction of fires into the ecosystem's management has an impact on the density of woody species while eradicating many larger shrubs. At the Nylsvley Nature Reserve, frequent fires may lead to a high ratio of shrub plants at the expense of co-dominant species like *Diplorhynchus condylocarpon, Burkea africana, and Combretum molle* (Lubke *et al*., 1983).

The distribution of the species on the northern slope indicates that there are still gaps in the habitat that other species may be able to fill and that the conditions are favourable for the species, such as access to sunlight and minerals. Additionally, it can be predicted that species with low relative frequency, such as *Strychnos madagascariensis and Afrocanthium galfillani*, will have a wide distribution within the upcoming few years. So is the *Englerophytum magalismontanum*, and *Grewia bicolor* on the Southern slope. Fire or the comparatively dry season may be the reason of the variation in species composition and basal cover (Lubke *et al*., 1983).

Given that there are fewer shrubs and more trees on the Southern slope than on the Northern, the species composition of both slopes is essentially the same. In accordance with Kromer et al. (2013), species composition and richness are directly influenced by altitude-variable factors such as temperature and atmospheric pressure, as well as altitude-independent factors such as rainfall and the amount of cloud cover.

According to Sinha et al. (2018), elevational variation encompasses a wide range of climatic and physical variables that change simultaneously. These variables, along with other factors such as human-caused disturbances, ancient impacts species area impacts, and isolation, all have a direct impact on the forest's community composition and structure. On the Northern slope, species decline with an increase in slope gradient.

Table 4.5: Species Composition of Woody Species in Maroelakop mountain.

Family	***Species***	***Habit***	***Genera***	***Common names***	***Venda names***
Anarcardiaceae	*Lannea discolor* (Sond) Engl.	Tree	*Lannea*	Tree grape, Wild plum	Munii
Anarcardiaceae	*Sclerocarya birrea* (A.Rich) Hochst	Tree	*Sclerocarya*	Cider tree	Mufula
Apocynaceae	*Diplorhynchus condylocarpon* (Mull.Arg.)	Tree	*Diplorhynchus*	Rubber tree, horn-pod tree	Muthowa
Combretaceae	*Combretum apiculatum* Sond.	Tree	*Combretum*	Hill combretum, Red bush willow	Mugavhi
Combretaceae	*Combretum collinum Fresen*	Tree	*Combretum*	Whipping bushwillow	Muvuvha
Combretaceae	*Combretum molle* R.Br. Ex G.Don	Tree	*Combretum*	Velvet-leaf willow	Mugwiti
Combretaceae	*Terminalia sericea* Burch. *ex* DC.	Tree	*Terminalia*	Silver cluster-leaf	Mususu

Euphorbiaceae	*Croton grattismus* Burch.	Tree	*Croton*	Lavender fever berry	Maloga
Fabaceae	*Albizia tanganyicensis* Baker F.	Tree	*Albizia*	Paperbark false thorn, sneeswood	Munungufhefhe
Fabaceae	*Burkea africana* Hook.	Tree	*Burkea*	Wild seringa,Burkea	Mufhulu
Fabaceae	*Dichrostachys cinerea* (L.) Wight & Arn	Shrub, Tree	*Dichrostachys*	Sickle bush	Murenzhe
Fabaceae	*Vachellia karroo* (Hayne) Banfi & Glasso	Tree	*Vachellia*	Sweet thorn	Muunga-ludzi
Lamiaceae	*Vitex ferruginea* Schumach. & Thonn.	Tree	*Vitex*	Plum fingerleaf	
Loganiaceae	*Strychnos madagascariensis* Poir.	Tree	*Strychnos*	Black Monkey Orange	Mukwakwa
Malvaceae	*Grewia bicolor* Juss.	Tree	*Grewia*	White raisin	Murabva
Malvaceae	*Grewia flava* DC.	Shrub, Tree	*Grewia*	Velvet raisin, Wild currant	*Muredwa*
Malvaceae	*Grewia flavescens* Juss.	Shrub, Tree	*Grewia*	Sandpaper raisin	Mupharasheni
Ochanceae	*Ochna pulchra* Hook.f.	Shrub, Tree	*Ochna*	Peeling plane	Musuma
Phyllanthaceae	*Pseudolachnostylis maprouneifolia* Pax	Tree	*Pseudolachnostylis*	Kudu berry	Mutondowa
Rubiaceae	*Afrocanthium galfillanii* (N.E.Br.) Lantz	Tree	*Afrocanthium*	Rock elder	Mutomboti
Sapotaceae	*Englerophytum magalismontanum* (Sond.) T.D.Penn	Tree	*Englerophytum*	Traansvaal milkplum	Munombelo

The family Fabaceace and Combretaceae, which has the most species overall, were found to have four different plant species. The Malvaceae family had three plant species, the Anacardiaceae family had two plant species, and the remaining families each had just one species. It is because most of the savanna woodland in Africa contains native species of the Fabaceae and Combretaceae families (Abba *et al*., 2022).

Because of their superior adaptability to a wide range of ecological settings and their effective and successful dispersal capacities, Fabaceae ecology and reproductive biology are important. Except for the Poaceae, no family has a greater global distribution in a wider range of ecosystems than the Fabaceae (Abba *et al*., 2022). Fabaceae is a prevalent family with regard to plant species richness and the biomass in many forests of the Neotropics and Africa including Madagascar (Hassan *et al*., 2022). Fabaceae was also found to be the predominant family in Benue State, Nigeria, by Ikyaagba *et al.* (2019). With 21 plant species, the Fabaceae were found to be the most prevalent family in the study by Kacholi (2014) and Ndah *et al*., (2013), suggesting that the Fabaceae might be the most prevalent tree family in their area.

Table 4.6 also includes Shannon-Weiners diversity indexes for the plant species investigated. The results show that on the North-facing slope, the Downslope had the greatest Shannon Weiners index of 2.2, followed by the Middleslope on the North-facing slope with the diversity of 1.97, while on the South-facing slope, the Downslope (1.64) and the Middleslope (1.74) had the lowest diversity index. The Shannon-Weiners diversity index of 1.77 was measured for tree species on the Upslope. The results suggest that the North-facing slope has a larger diversity (average of 1.98) than the South-facing slope (1.72).

Table 4.6 of this study also includes the Simpson diversity index. The results suggest that Downslope had the greatest Simpson diversity index of 0.87 on the North-facing slope, followed by the Middleslope, which had 0.81 diversity. The Simpson diversity index was low on the South-facing slope, particularly on the Downslope (0.73) and Middleslope (0.79). The Simpson diversity index of 0.79 was likewise found for the tree species on the Upslope. The average Simpson diversity index for both the North and South-facing slopes show that the North-facing slope had the greater diversity index with an average of 0.82, which explain that there is higher diversity of species, and the distribution of the species was even in this slope direction compared to the South-facing slope 0.77.

Table 4.6: Shannon Diversity Index, Simpson diversity index and Evenness index

Part of the slope	**Shannon diversity index**	**Simpson diversity index of dominance**	**Evenness index**
Downslope (North-facing slope)	2.2	0.87	1
Middleslope (North-facing slope)	1.97	0.81	0.9
Upslope	1.77	0.79	0.88
Middleslope (South-facing slope)	1.74	0.79	0.79
Downslope (South-facing slope)	1.64	0.73	0.75

Terrestrial ecosystems' diversity of plant species serves as their foundation (Eyasu *et al*., 2020). The density of the trees varies between the three slopes (downslope, middleslope, and upslope), which is one important characteristic of the forest community according to Ghanbari *et al*. (2020). The diversity and evenness of plant species on the Northern Slope tend to increase with decreasing elevation, but it also shows that dominance tends to decrease with elevation. While dominance also rises with elevation on the Southern Slope, the trend in species diversity and evenness increases.

According to Kumar and Sharma (2015) and Bhat et al. (2020), the diversity of tree components determines the overall biodiversity of an ecosystem, as trees support habitats and provide services to all other animals in the forest. The downslope position on the southern slope has the greater value of evenness, but it has lower Shannon diversity and Simpson diversity of dominance indices compared to the northern slope. The evenness value scales from 1 to 100, with higher values indicating more consistency in plant species distribution (Kacholi, 2019).

Grazing diminishes biological aging of species as well as evenness and plant species diversity by eliminating or decreasing the coverage of certain vulnerable species (Pourbabaei *et al*., 2014). As has been observed in other ecosystems, the largest level of plant species diversity was seen at low disturbance indices. Similar human intervention factors have been demonstrated in numerous other studies to reduce species diversity, leading to the extinction of numerous sensitive species (Ghanbari *et al*., 2021).

This may also be a result of the many species that can be found on this particular mountain side. Trees play an important role in characterizing the environment, function, and complex processes and dynamics of forest ecosystems (Bhat *et al*., 2020). Studying plant diversity and distribution is important for understanding the ecology and structure of forest communities (Bhat *et al*., 2020; Thakur *et al*., 2021).

Compared to biological factors, climate and topography seem to have a bigger impact on landscape diversity, which appear to have a greater impact on diversity at the site level (Abba *et al*., 2022). One of the most crucial objectives in forest management plans is to maintain species diversity in forest ecosystems (Ghanbari *et al*., 2021). With 17 distinct species, the North-facing slope has the greater level of vegetation diversity, while the South-facing slope has the lowest, with only 14 species. The slope aspect and slope gradient/position both have an impact on the variety of plant species. The diversity of plant species in forests varies greatly from one location to another and may be influenced by human activity (Naidu and Kumar, 2016).

4.4 Tree diameter size-class distribution on Maroelakop

In this study the basal stem diameter was measured for all the sampled species found in the study area. On the North-facing slope Maroelakop mountain the basal stem diameter was measured on the Downslope, Middleslope, and Upslope. Figure 4.5 and 4.6 showed that in the size-class 0 – 5 cm the North-facing slope had a frequency of 130 while the South-facing slope had a frequency of 134 for all parts of the slope. The figures (Figure 4.5 and 4.6) also revealed that this size-class (0 – 5 cm) had the most species compared to other size-classes with Downslope being rated the highest from both slope direction.

The graph started to reduce from the size-class 5.1 – 10 cm to 15.1 – 20 cm, this was due by the moderate frequency that was obtained from both slope directions. As the size-class 0 – 5 cm had the highest frequency it caused the decline in both the graphs and as we go up the slope in both slope direction there was less individuals that were matured that's for the size-class 20.1 – 25 cm to ≥35 cm. On the size-class ≥35 cm it was noted that the frequency dropped on the North-facing slope it had a frequency of 3 and it was only for the Downslope. On the South-facing slope the size-class ≥35 cm had a frequency of 5, which was for the Downslope and the Middleslope. From both the Figures it is shown that on the Upslope of all the slope directions there were no individuals that a matured of fully grown. The graph distribution of Figure 4.5 and 4.6 shows the reversed J shaped curve.

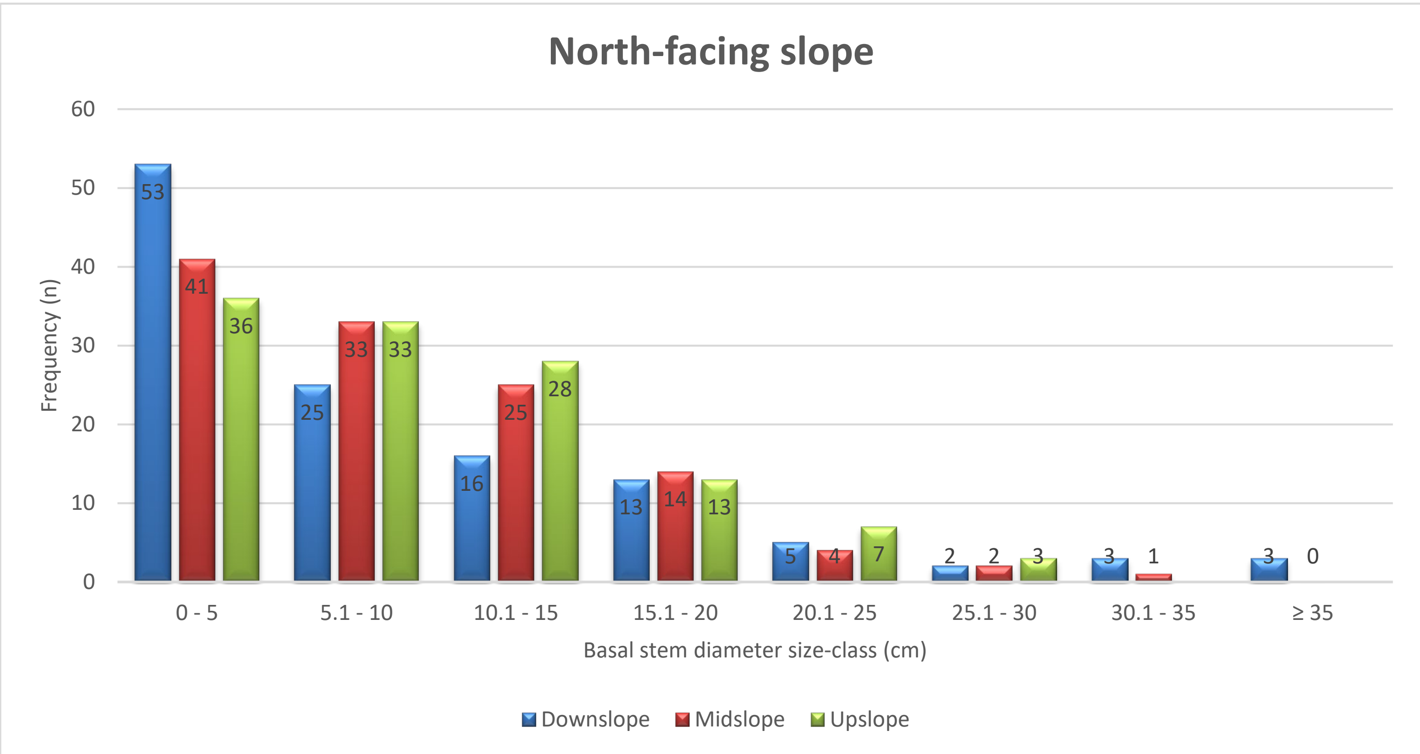

Figure 4.5: Basal stem diameter size-class distribution of a North-facing slope population in Maroelakop mountain in Nylsvley Nature Reserve.

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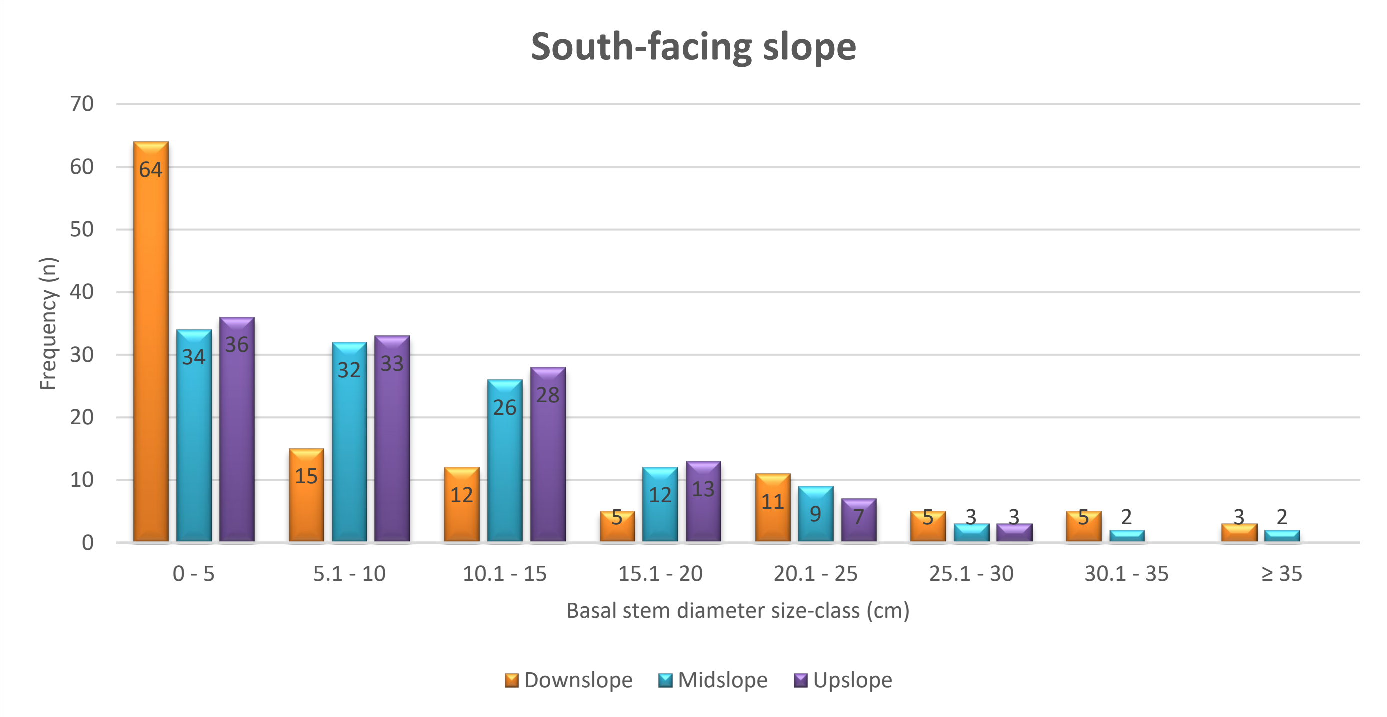

Figure 4.6: Basal stem diameter size-class distribution of a South-facing slope population in Maroelakop in Nylsvley Nature Reserve.

The distribution of tree diameters in this vegetation exhibits an inverse J-shape in the direction of the slope. This includes regions where a species' frequency distribution peaked in size-classes with smaller tree diameters and then declined relatively gradually in size-classes with larger tree diameters. According to Wakjira, (2006), species with this population structural pattern are thought to be in good condition for both reproduction and regeneration. This study also shows that species have been regenerating well in all slope directions, with some species moving from lower to higher size-classes. On the upslope of all slope directions, however, there has been virtually no establishment of plant species with tree diameter size-classes larger than 30 cm.

Which can highlight the fact that Maroelakop plant species grow gradually from downslope to upslope, or plant species with a large tree diameter have difficulty growing larger on the mountain's upper slopes due to the exposure of the slope, edaphic factor, and absorption of resources like water. This also showed that there aren't many fully grown plant species with middle and high tree diameter size-classes throughout the entire slope. Atsbha *et al*. (2019) indicated that villagers, with the permission of community leaders, cut down medium and tall trees for various purposes such as fencing, agricultural implements, new house construction and wood fuel. Because the inverted J shape indicates reproductive success, factors such as seed predation, seedling browsing, canopy cover for seedling recruitment, seed type, dormancy breaking patterns, and environmental factors and pathogen are related to growth and development of a number of seedlings (Kebede *et al*., 2014).

4.5 Crown diameter size-class distribution on Maroelakop

The crown diameter for the individual species was measured for all parts of the slope in both slope directions. On the North and South-facing slope it was found that the size-class 0 – 2 m and 2.1 - 4 had the highest frequency. As presented on Figure 4.7, size-class 0 – 2 m with a frequency of 164, and the size-class 2.1 – 4 m had a frequency of 131. As the size-class increase the frequency was seen to be decreasing. With size-class 4.1 – 6 m with a frequency of 56 and the size-class 6.1 – 8 m with a frequency of 15. The graph dropped as it reach the size-class ≥8.1 m with a frequency of 4 that was recorded for only the Downslope and Middleslope.

Figure 4.8 shows the results of the South-facing slope. That the size-class with the highest frequency was the size-class 0 – 2 m and also 2.1 – 4 m, size-class 0 – 2 m had frequency of 148 and the size-class 2.1 – 4 m it had a frequency of 129. Also, in this Figure it is presented that as the size-class increases the frequency decreases. With size-class 4.1 – 6 m with a frequency of 49 and the size-class 6.1 – 8 m with a frequency of 27. There were few individuals that were found for the size-class ≥8.1 m with a frequency of 7 that was recorded only for the Downslope and Middleslope.

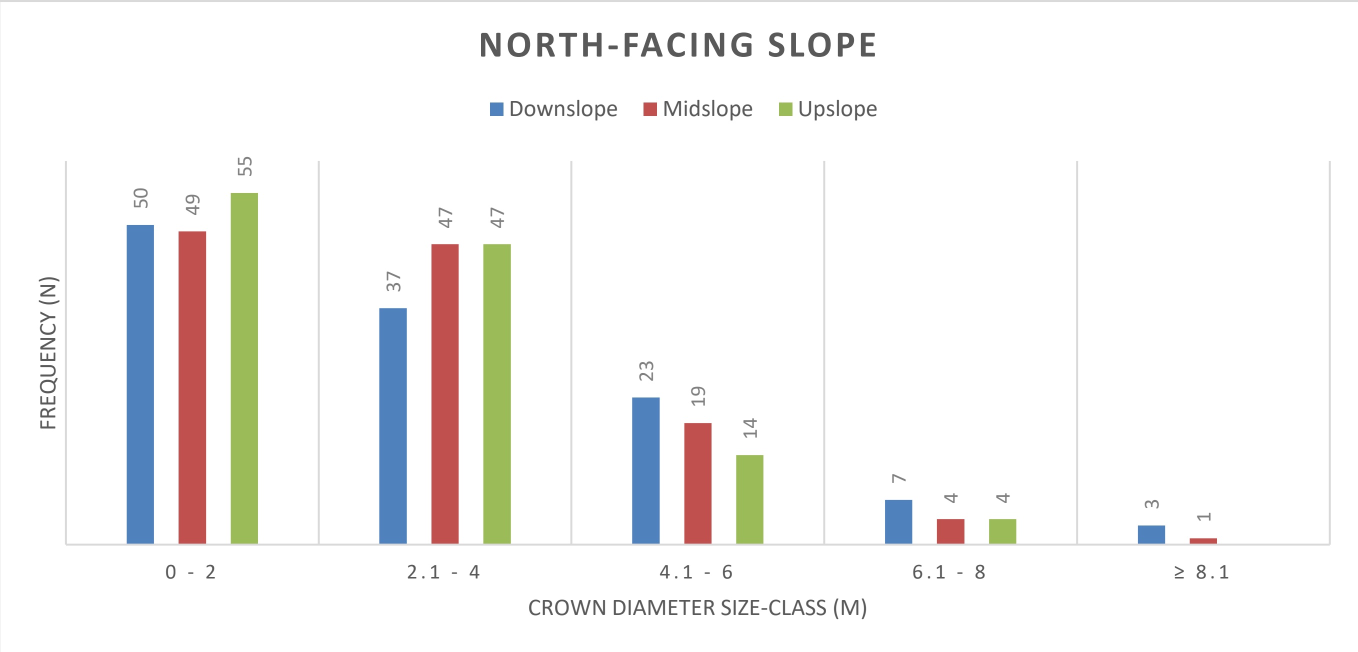

Figure 4.7: Crown diameter size-class distribution of a North-facing slope population in Maroelakop mountain in Nylsvley Nature Reserve.

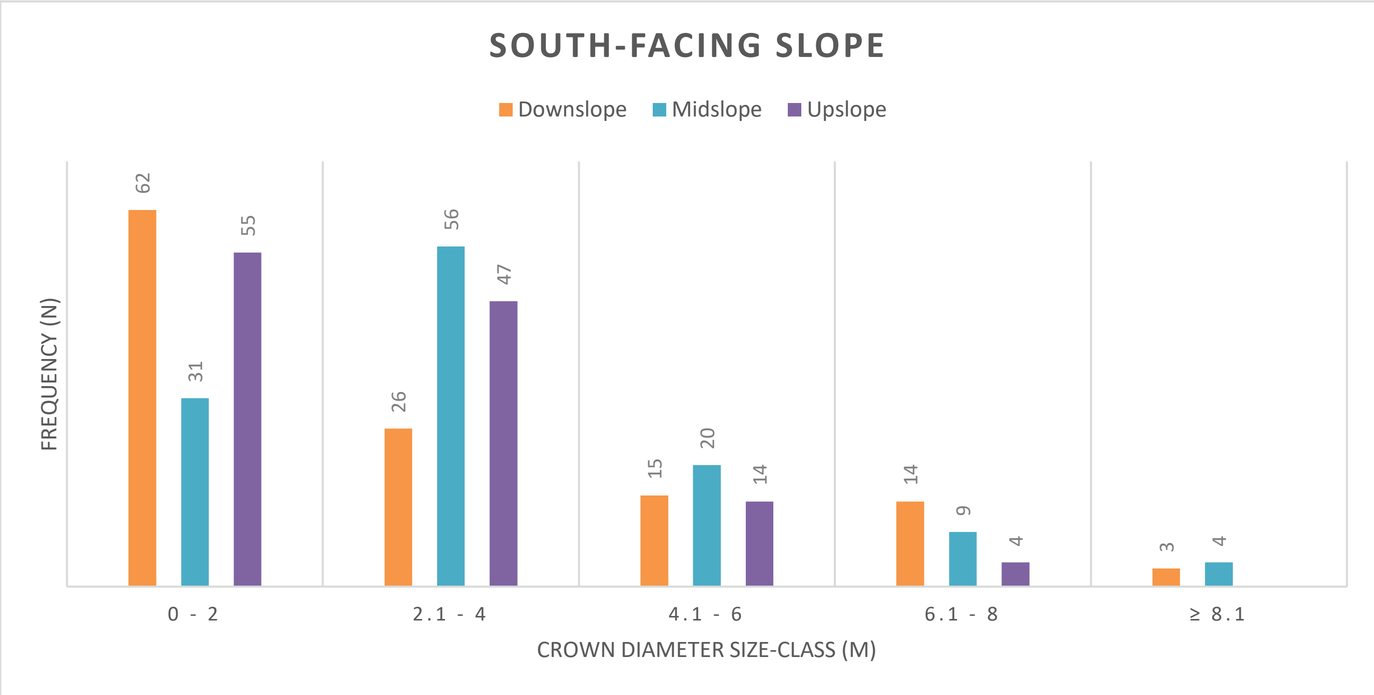

Figure 4.8: Crown diameter size-class distribution of a South-facing slope population in Maroelakop mountain in Nylsvley Nature Reserve.

Avsar (2004) asserts that canopy cover, tree height, and basal diameter are crucial aspects of trees. These data show a close relationship among several parameters, including the basal diameter, height, and canopy cover. The canopy and height increase in proportion to basal diameter. Most of the individuals with a wide canopy cover were tall in stature and had a large basal diameter. Figures 4.7 and 4.8 demonstrate that in both the North-facing slope and the South-facing slope, individual classes between 0 - 4 meters dominate nearly 50% of the canopy cover.

From the canopy data sampled it is shown that on the North-facing slope most of the area was not covered by trees with broad canopies, from the size-class (4.1 – 6) to greater than 8 it had a total average frequency of 75 individual species and on the South-facing slope had average frequency of 83 individual species. Which shows that on the South-facing slope the species were growing with broader canopies leaving out small spaces in between for other plant species to receive resourceful abiotic factors like sunlight and moisture. Leaving the North-facing slope with less individual species without broad canopies that allow other plant species to occupy the area and diversify.

According to Scott *et al*. (2013), plants with established crowns may reduce seedling survival through inhibiting the development of understory species or by releasing allelopathic compounds through the leaf litter. The goal of range ecologists' study is to better understand how biotic and abiotic variables affect savanna dynamics and how old trees like Terminalia sericea, Dichrostachys cinerea, and Acacia mellifera respond to changes in these parameters (Dreber *et al*., 2014). Figures 4.7 and 4.8 demonstrate the new occupants that have established themselves on the upslope of Maroelakop Mountain. These species are less numerous and have narrower canopies, but they appear to be more prevalent.

Less than 40 plant species were recorded on the Middleslope of the South-facing slope (size-classes 0 to 2) and on the downslope (size-classes 2.1 to 4), which suggests that grazing may be taking place. On the drier end, local vegetation patterns are shifting due to increased livestock grazing and browsing pressure. According to Gurevitch (2002), eating leaves, stems, and twigs reduces the photosynthesis surface area, while removing them may change the competitive dynamics between nearby plants. As a result, there may be an increase in erodible soils and a loss of vegetation cover (Rutherford and Powrie, 2010) or thickets of shrubs and trees that grow faster (Dreber *et al*., 2014).

The canopy data also demonstrates that the slope gradient on either side of the Maroelakop mountain is influencing the growth of the plant species present there. As a result, these species are unable to proliferate and develop canopy covers of eight meters or more, indicating that the slope gradient does not affect them. However, the composition of the tree species that make up the Maroelakop mountain's vegetation structure may also have a significant impact, given that only a few numbers of species were discovered to be establishing in this region, implying that the broad canopy covers are from these specific species, namely *Diplorhynchus condylocarpon, Burkea africana,* and *Combretum molle.*

CHAPTER 5

Summary, Recommendations and Conclusion

5.1 Summary

The parameters display most of the species reversed J-shaped distribution on the tree layer on both the mountain's North and South-facing slopes in Maroelakop. It was demonstrated that the species frequency distribution had a peak in the smaller height size-class and a relative gradual decline in frequency as it moved up the classes. In this study, 600 trees representing 21 species that fall within 17 genera and 12 families have been discovered on Maroelakop mountain. The ecological importance of tree species within a community can be comprehended through the use of the importance value index (Ghanbari *et al.,* 2021).

On the North-facing slope it was shown that *Diplorhynchus condylocarpon* had the highest IVI followed by species like *Combretum molle*, *Lannea discolor*. On the South-facing slope, *Burkea africana* was found to have highest IVI followed by species like *Combretum molle* and *Diplorhynchus condylocarpon*. There were species with lower IVI, which is *Grewia flavascens, Dichristachys cinera, Englerophytum magalismontanum, Vitex ferruginea, Grewia bicolor sclerocarya birrea* and *Psuedolachnostylis maprouneifolia.* In overall it was noted that *Diplorhynchus condylocarpon* was the dominant species in Maroelakop as it was found thriving in this area.

It was determined that *Diplorhynchus condylocarpon's* high IVI was primarily caused by a good combination of high density, basal area, and frequency, and the species displayed a strong recurrence in the region. *Lannea discolor, Diplorhynchus condylocarpon, Combretum molle*, and *Burkea africana* were the plant species with the greater relative frequency and density on both the Northern and Southern slope. There is a high abundance of the species on the northern slope, which indicates that other species can occupy the area and that the conditions are favourable, but that there will be spindly growth.

The diversity of species found in the forest is a key feature, and the tree densities in the downslope, Middleslope, and upslope vary from one another. Elevation increases the trend of species diversity and evenness on the northern slope, while elevation increases the dominance on the southern slope. In comparison, the Northern slope had a greater species diversity than the South-facing slope.

The distribution of the basal diameter along an inverse-J curve revealed that Maroelakop's plant species grow gradually from downslope to upslope. It is also demonstrated that the canopy and height increase with increasing basal diameter. The majority of the species were found to have wide canopy covers, but in both parts of the slope, individual classes 0–4 account for 50% of the canopy cover.

5.2 Conclusion

Understanding the diversity and structure of tree species is an essential tool for managing the ecosystems, assessing the sustainability of any vegetation, and preserving species. Ghanbari *et al*. (2021) have documented the structures of tree diversity and the impacts of slope gradient, which provide a useful database for management measures in these forest communities. Woody plant species are crucial components of the forest ecosystem, influencing the overall composition and structure of forest ecosystems.

According to this study's findings, *Diplorhynchus condylocarpon* is the species that is most prevalent in the study area. This species is fire resistant and can withstand repeated burning. It is followed by *Combretum molle, Burkea africana,* and *Lannea discolor*. It can be said that these plant species are adapting well to this rocky area and that the gradient of the slope is not having any negative effects on them. Conservation efforts for low IVI value species must be high priority, while those for high IVI value species must be low priority. The most varied species were found in the Fabaceae and Combretaceae, then Malvaceae.

According to Ghanbari *et al*. (2021), sustaining the socio-ecological balance of the natural environment and conserving dominant plant species are important for the creation of the canopy, minimizing potential losses in environmental services, and preserving the ecosystem's functions and features in complex forests. These goals call for a comprehensive approach to forest management. In this study, the vegetation structure on the north- and South-facing slopes is analysed and compared.

According to the results, there were more species on the North-facing slope than on the South-facing slope, and the species diversity indices indicated that this particular slope had higher diversity and evenness. Since they help us better understand ecosystem conservation and management, species composition and diversity patterns are frequently a major focus of ecological studies.

5.3 Recommendation

It is advised that more thorough research be done in order to compare the vegetation from Maroelakop and Stemmerskop and understand how altitude affects the plant species. This will allow the importance value index species to be understood from all slope directions. The absence of mature adults on the mountain's upslope suggests that the upslope may be influenced by additional ecological factors. In addition to ecological factors, the growth and distribution of plant species on the Maroelakop can also be influenced by eco-physiological factors. Understanding the types of plants that grow in Maroelakop, the influence of fire on the vegetation's structure and composition, how reserve species are affecting the plants there through browsing, and how reserve animals are altering the plants there would all be significant to the reserve management.

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