BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF NATURAL RESOURCES

INFLUENCE OF VEGETATION TYPE ON TAXONOMIC DIVERSITY AND FUNCTIONAL TRAITS OF GRASSES AND FORBS IN THE SOUTHEAST LOWVELD OF ZIMBABWE

NYATHI MIRACULOUS

B202502B

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONOURS DEGREE IN NATURAL RESOURCES MANAGEMENT

JUNE 2024

DECLARATION

The undersigned certify that they have read through this research project and have approved submitting it for grading, according to the department's rules and requirements.

Student: Nyathi Miraculous

Signature…………………… Date: 02/10/2024

Supervisor: Proffesor L. Jimu

Signature: Date: 02/10/2024

Chairperson: Mr A. Kanda

Signature: Date: 02/10/2024

DEDICATION

This research project is dedicated to my family.

ACKNOWLEDGEMENTS

I am very thankful to my supervisor, Professor L. Jimu, for the help and guidance they provided me throughout this entire study. I also want to express my gratitude to my family for their unwavering love and support during the course of my work on this project. Above all, I give thanks to God for making the successful completion of this research possible

ABSTRACT

A study on the influence of vegetation type on taxonomic diversity and functional traits of grasses and forbs was carried out in Chishakwe Safari, Zimbabwe. Data were collected in February to March 2023. The stratified random sampling was employed. The study area was stratified according to vegetation types that dominated the landscape. Six strata were established namely: *Combretum_apiculatum*- *Colophospermum_mopane, Combretum_apiculatum*- mixed *Grewia*, *Colophospermum_mopane*- *Diospyros_quiloensis*, *Grewia* open shrub land, *Acacia schweinfurthil* and *Dichrostachys cinerea*. For grasses and forbs, a line transect of 100m by 2m was randomly placed in each strata to determine abundance and the functional traits. For trees and shrubs, a line transect of 100m by 4m was also placed in each strata where grasses and forbs transect was positioned. Results from multi-variate analysis in SPSS showed significant differences in tree height, shrub height, DBH, shrub canopy diameter and tree canopy cover. The findings of this study indicated that there was an even distribution of resources hence no differences in vegetation's study variables. This study also exhibited low Shannon diversity indices of both grasses and forbs in all vegetation types. There were no significant differences in height of forbs and leaf thickness of grasses. There were significant differences in the height, pinnacle height, internode length and leaf area of grasses as well as in pinnacle height, internode length, leaf thickness and basal cover of forbs. Results from this study suggests that vegetation type have an influence on the taxonomic diversity and functional traits of both grasses and forbs. It is therefore recommended that ecologists and conservationists should recognize the specific vegetation types that support high diversity and unique functional traits, and prioritize the protection of these habitats to maintain overall ecosystem health and resilience.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMNS AND ABBREVIATIONS

% - Percent

^{0}C – Degrees Celsius

cm- centimetre

DBH – Diameter at Breast Height

mm- millimetre

SPSS - Statistical Package for Social Science

SVC - Save Valley Conservancy

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

The Lowveld area of Zimbabwe is renowned for its abundant biodiversity and distinct types of vegetation (Mashapa, 2018). These various vegetation types, such as grasslands, woodlands, and savannas, play a vital role in supporting a wide array of plant species, particularly grasses and forbs. The diversity of grasses and forbs, both taxonomically and in terms of their functional characteristics, serves as significant indicators of the health and resilience of the ecosystem. Grasses encompass a diverse collection of monocotyledonous plants from the *Poales* order and *Poaceae* family, comprising more than 12,000 species (Watson and Dallwitz, 1988). Forbs, on the other hand, are herbaceous plants (non-woody) that typically possess broad leaves and attractive flowers.

Taxonomic diversity pertains to the quantity and proportional representation of species within a community. According to Hautier *et al.*, 2009, the primary factors constraining plant growth in temperate semi-natural grasslands in humid climates are nutrients and light. The availability of light diminishes in the lower layers of vegetation due to its unidirectional provision. The conditions experienced by individual plants can vary across many different factors. These factors depend on the diversity of the overall plant community.

Functional traits are the physical, biological, or behavioral characteristics of a plant species that affect how it grows, reproduces, or survives (Pérez-Harguindeguy *et al*., 2013). Examples of plant functional traits include things plant height, internode length, leaf size, leaf thickness, pinnacle height, and seed mass. These functional traits are the result of long-term evolutionary adaptations that have allowed the plants to thrive in their environment (Moles *et al*., 2009). They are often used as indicators of how an ecosystem is functioning (Liu *et al.*, 2015). This is because functional traits can directly influence how energy and materials move through the ecosystem, as well as regulate various ecological processes within that system (Jiang *et al*., 2007). Numerous researches have indicated that plant functional traits can establish a link between species and ecosystems (Liu *et al.*, 2015).

Levine and HilleRisLambers (2009) suggested that variations in functional traits among plant species are believed to promote niche differentiation, thereby facilitating the coexistence of species. Chaplin *et al*., (1987) argue that diverse vegetation stands expose plants to a range of environmental factors, as well as temporal and spatial fluctuations in resource availability.

Several studies have provided evidence of positive relationships between diversity and productivity, particularly in grasslands (Grace *et al*., 2016). Leps *et al*., (2006) stated that different species within different regions, or even populations of the same species located in different regions, show diverse functional traits due to limitations in species distribution.

The variability in the expression of functional traits plays a significant role as it enables plants to adapt to environmental fluctuations. Functional traits data provides important information for understanding the ecological characteristics of a specific location and how plant diversity changes in response to shifts in the environment (Dainese *et al*., 2015). The diversity of plant functional traits, like height, leaf size, or seed weight, reflects the variation between different plant species in how they respond to environmental changes. This variation in functional trait diversity has been shown to be a key factor that drives changes in the overall functional diversity of plant communities over time (Pakeman, 2011). There is evidence suggesting that ecological communities with high functional diversity tend to be more resilient and better equipped to withstand the impacts of environmental change (Pillar *et al*., 2013).

To date, no research has been conducted to investigate how vegetation type affects the taxonomic diversity and functional traits of herbaceous plants in the Save Valley Conservancy (SVC), a highly biodiverse region. Consequently, this study was undertaken in Chishakwe Safari, an area located in the northern section of the SVC, with the aim of examining how various vegetation types influence the taxonomic diversity and functional traits of grasses and forbs.

1.2 Problem Statement

Limited knowledge exists regarding the influence of environmental variation on the expression of traits among different species within plant communities. Given the influential role of trees in forests and their effects on diverse ecological factors, it is reasonable to expect that the identity and composition of tree species impact the biodiversity of understory vegetation, encompassing its diversity and composition (Barbier *et al.*, 2008).

1.3 Justification of the Study

Plants hold significant importance to humans for various reasons, encompassing aesthetics, biology, and economics. People derive pleasure from the captivating beauty of plant species, with their vibrant colors, both in natural habitats, cultivated areas, and gardens worldwide. The biodiversity of plants is invaluable, as it plays a crucial role in maintaining ecosystem balance, safeguarding watersheds, preventing erosion, regulating climate, and providing habitat for animals. Herbaceous plants provide important habitats and food sources for various wildlife species. They offer shelter, nesting sites, and food in the form of leaves, flowers, seeds, and nectar, supporting the survival and reproduction of numerous organisms. According to Mc Gill *et al*., (2006), quantifying the expression of functional traits and understanding their variations among and within species is seen as a promising approach to enhance our comprehension of community assembly and ecological processes. The outcomes of this study will contribute to the existing knowledge regarding the ecological dynamics of the Lowveld region and can offer insights for conservation and management initiatives in similar rapidly dilapidating ecosystems. Moreover, this study has the potential to enhance understanding of the intricate nature of herbaceous species. Plant data is crucial for conservationists and environmentalists involved in preserving and protecting plant species and their habitats. It aids in identifying rare and endangered plants, assessing the status and trends of plant populations, and formulating conservation strategies and management plans.

1.4 Aim of the Study

This study aims to investigate the influence of different vegetation types on taxonomic diversity and functional traits of grasses and forbs across multiple ecosystems.

1.5 Research Objectives

1. To assess the taxonomic diversity of grasses and forbs in different vegetation type
2. To compare the functional traits of grasses and forbs in different vegetation types
3. To examine the potential relationship between vegetation types, plant diversity and functional traits of grasses and forbs

1.6 Research Questions

1. How do taxonomic diversity of grasses and forbs vary across different vegetation types?
2. Do functional traits of grasses and forbs differ between various vegetation types?
3. What is the relationship that exists between vegetation types, plant diversity and functional traits of grasses and forbs?

CHAPTER 2: LITERATURE REVIEW

2.1 Influence of Vegetation Type on Taxonomic Diversity of Herbaceous Species

Distinct microhabitats are created by different vegetation types, leading to variations in soil conditions, moisture availability, and light penetration. These factors can significantly impact the establishment and growth of various plant species, ultimately shaping the taxonomic diversity within plant communities. In forest ecosystems, where trees hold a dominant position and influence various ecological gradients, the identity and composition of tree species are likely to affect the biodiversity of understory vegetation, including its diversity and composition (Barbier *et al*., 2008).

Traditionally, the structure and composition of plant communities have been shown to be strongly influenced by interactions between plants, such as competition, parasitism, mutualism, and commensalism. However, the importance of positive interactions, known as facilitation, in shaping community dynamics has also been well established (Mc Intine and Fajardo, 2014). For instance, in Alpine meadows, facilitation plays a crucial role in increasing the richness and diversity of the plant community by helping to reduce stressful conditions (Cavieres *et al*., 2016). Facilitation also affects the functional diversity of plant communities (Butterfield and Callaway, 2013), particularly by mitigating stressful environmental conditions. As a result, facilitation can allow associated plant species to utilize a wider range of ecological niches (Bulleri *et al*., 2016). For example, in an Alpine site in Australia, researchers found that the nurse shrub *Epacris gunni* supported a greater number of plant species that were taller and had larger leaves compared to open areas without the nurse shrub (Ballantyrne and Pickering, 2015).

Solofondranohatra *et al*., (2018) conducted a research in the central highlands of Madagascar, grass functional traits were compared between the forest and savannah ecosystems. The study found that the grass species found in Tapia woodlands had higher species richness and greater diversity in their evolutionary relationships compared to the grass species found in grasslands or forests. This higher diversity of grass species in the Tapia woodlands was attributed to the environmental variation within the woodland, which was supported by the heterogeneity or unevenness in the tree cover. The presence of varied tree cover allowed for the coexistence of a greater number of different grass species (Silvertown, 2004) compared to more uniform grassland or forest habitats.

Barbier *et al*., in 2008 studied how temperate and boreal forests impact the diversity of the understory vegetation, and the mechanisms involved. The study found that coniferous (needle-leaved) forests generally have less diverse vascular plant communities in the understory, compared to broadleaved forests. These findings were attributed to the influence of overstory composition and structure, which affected resource availability (such as light, water, and soil nutrients) and other factors such as the physical characteristics of the litter layer on the vegetation (Barbier *et al*., 2008).

Numerous studies have investigated how vegetation type influences the taxonomic diversity of grasses and forbs. The factors driving species diversity and their relative significance vary at different spatial scales (Siefert *et al*., 2012). High plant species richness, which refers to the total number of plant species in a given sample plot, serves as an indicator of biodiversity and is associated with well-functioning ecosystems (Soliveres *et al*., 2016). As species richness increases, there is often a reduction in light availability due to the development of a taller and denser canopy, resulting in a higher leaf area index (Lorentzen *et al*., 2008).

At a global level, semi-natural grasslands demonstrate the highest species richness within small spatial scales (Wilson *et al*., 2012). However, in the Palaearctic region over the past century, species-rich semi-natural grasslands have undergone a significant decline in both their geographical extent and diversity. This decline can primarily be attributed to the conversion of habitats into arable and urban lands, as well as degradation resulting from changes in land use, such as intensification and abandonment (Dengler *et al*., 2020b).

In a study conducted by Carvalho *et al*., (2020) on peatlands, the significance of using multiple measures of plant diversity was emphasized as crucial for understanding the response of plant communities to changing environmental conditions. The study involved a comparative analysis of woody and herbaceous fen peatlands in East Anglia, United Kingdom, under different management practices (mowing and grazing). The findings indicated that annual grazing led to reduced functional and phylogenetic diversities, although it did not have a significant impact on taxonomic diversity. On the other hand, annual mowing was associated with increased phylogenetic and taxonomic diversities.

Polyakova *et al*., (2016) mentioned that different taxonomic groups, such as vascular plants, bryophytes, and lichens, can be affected differently by both abiotic and anthropogenic factors. Palaearctic semi-natural grasslands are well-known for hosting an exceptionally high plant diversity (Michalcova *et al*., 2014).

Urban areas are often believed to exhibit higher taxonomic diversity (Grimm *et al*., 2008) but lower phylogenetic diversity (Knapp *et al*., 2017) or functional diversity compared to adjacent natural areas.

For forests that are actively managed by humans, which make up a large part of temperate forests and an increasing amount of boreal forests, the choice of which tree species to grow is a critical decision for foresters. According to Palik and Engstrom (1999), this is because the trees play a dominant role in forests and influence various environmental conditions. Therefore, the specific tree species selected, and how they are mixed together, are likely to have an impact on the overall biodiversity of plant life in the forest.

The composition and structure of plant communities are influenced by a combination of different processes and factors that operate at varying spatial scales. Environmental factors act as filters that determine which plant species from the broader regional pool of available species are able to successfully establish and continue to exist within a particular local site or habitat.

2.2 Influence of Vegetation Type on Functional Traits of Herbaceous Species

The connections between plant characteristics and the environment, specifically the specific plant attributes consistently associated with particular environmental conditions, are a result of the filtering impact caused by disturbances in climate and living conditions (Lebrija-Trejos *et al*., 2010). These filters determine which components of a species pool come together to form local communities.

The functional traits of plants directly or indirectly impact plant fitness by affecting survival, growth, and reproduction (Violle *et al*., 2007). The range of trait values within a species emerges from the trade-offs among various functional requirements (Frank *et al*., 2011). Suding *et al*., (2003) emphasized that trait values reflect the strategies employed by species in response to their living and non-living environment. Variations in these strategies among species can enable the complementary utilization of resources, thereby facilitating the coexistence of multiple plant species in a limited geographical area (Silvertown, 2004).

Cayssials and Rodriguez (2013) conducted a comparative analysis to investigate the functional traits of grasses in open grassland and shaded forest habitats in Uruguay. The study revealed that the divergence of grass species between grasslands and forests was accompanied by changes in leaf traits. Species in grasslands favoured narrow and filiform blades with a higher length-to-width ratio, while species in forests favoured wider and oval blades. These observations suggested that leaf blade responses in forests were likely aimed at maximizing light capture, whereas in grasslands, they may be linked to water and heat loss.

Plant functional traits data plays a crucial role in understanding the ecology of a particular site and how plant diversity responds to changes in environmental conditions (Dainese *et al*., 2015). The diversity of plant functional traits such as leaf shape, root structure, growth habits captures the variability in how different plant species respond and adapt to environmental changes. This variability in trait diversity is recognized as a key factor that drives changes in the overall functional diversity of the plant community over time (Pakeman, 2011).

Plant functional traits, such as leaf shape, root structure, and growth habits, provide insights into how plants directly adapt their physiology and biology in response to changes in environmental conditions. This creates a direct link between the plants and the prevailing climatic factors. According to Meng *et al*., (2009), this information about plant functional traits can be used to predict future shifts in the distribution of vegetation due to climate change. Variations in trait values occur among plant species living in both similar and contrasting environments. This is because these functional traits arise from evolutionary and ecological adaptations that allow plants to thrive in different settings (Reich et al., 2003). Plant species with functional traits that are well-suited to a particular environment are more likely to become dominant and successful within that plant community (Shipley, 2010). The variation observed in functional traits among the coexisting plant species at a given site is influenced by environmental drivers operating at multiple spatial scales. Understanding these multi-scale environmental filters is crucial for predicting how plant communities will respond to future changes in their abiotic conditions.

Schob *et al*., (2012) demonstrated that the direct facilitation by the Alpine cushion species *Arenaria tetraquetra* resulted in changes in the functional diversity of associated communities. This was particularly evident through the expansion of trait ranges for lateral spread, specific leaf area (SLA), and leaf dry matter content (LDMC) due to the relaxation of environmental filtering.

In order to accommodate the multiple changes in the living and non-living aspects of their environment as community diversity increases, plants need to respond with coordinated adjustments in various traits to achieve a balance among different functions. These adjustments can ultimately impact the division of niches among coexisting plant species. Valladares and Niinemets (2008) suggest that smaller plants growing in the shade of taller neighbours in the canopy may modify their morphological traits to either avoid or tolerate low light availability. This can be achieved through the development of longer and thinner leaves or an increase in stem length.

Grasses exhibit adaptations in their functional traits that allow them to thrive in the specific environmental conditions of different vegetation types. Along environmental gradients, the functional traits of plant species show variations in response to the influence of environmental filters. These environmental filters selectively determine which species from the regional species pool are able to persist at a particular site (De Bello *et al.,* 2006; Diaz *et al.,* 2007). The filters directly select for certain functional traits and filter out species that lack the traits suitable for the site's conditions.

According to Douma *et al*., (2012), the environmental filters retain only those species that possess specific combinations of functional traits that enable them to adapt and acclimate to the unique conditions present at a given location. This filtering process shapes the plant community composition by favouring the species best equipped to cope with the local environmental pressures.

Plant functional traits serve as an important link between the environmental conditions of a given ecosystem and the performance and success of the plant species within it. This connection provides a foundation for understanding how the specific traits of individual plants contribute to overall ecosystem processes and functions (McGill *et al*., 2006). Notably, plant traits have been found to exhibit consistent relationships with non-climatic environmental variables across a wide range of taxonomic groups. This indicates that there are broad functional relationships between plant traits and the abiotic environment.

Analysing plant functional trait data plays a crucial role in evaluating the ecology of a particular site and examining how plant diversity responds to changing environmental conditions (Dainese *et al*., 2015). The variation observed in plant traits enables researchers to make predictions about community structure and describe the factors that influence the geographic ranges and distributions of different plant species (Read et al., 2014).

2.3 Implications for Ecosystem Functioning

Biodiversity plays a crucial role in driving ecosystem functions, which are responsible for various processes that directly or indirectly influence the flow of energy and materials within ecosystems (Diaz *et al*., 2015). The connection between species and ecosystem services is mediated by specific traits known as effect traits, which have an impact on ecosystem processes (Violle *et al*., 2007). Species possess multiple effect traits that can independently or collectively contribute to ecosystem services (Gamfeldt *et al*., 2008). Ecosystem services serve as the link between ecosystems, their biodiversity, their functioning, and human society, encompassing a wide range of benefits such as food production, climate regulation, water quality regulation, pollination, and aesthetic and recreational values (Millennium Ecosystem Assessment, 2005).

The relationship between biodiversity components and ecosystem function varies, with positive, negative, or no relationship observed. As an example, in the primary *Pinus kesiya* forest in Yunnan, southwest China, Li *et al.*, (2018) identified a positive association between species richness and aboveground biomass.

The role of species diversity in ecosystem dynamics, processes, and functioning is often explained by two prominent ecological hypotheses: niche complementarity and selection effect hypotheses (Mensah *et al*., 2016). The selection effect hypothesis proposes that in a diverse species assemblage, the presence of dominant species or traits, resulting from competitive interactions, can influence ecosystem functioning (Fox, 2005). On the other hand, the niche complementarity effect hypothesis suggests that increasing diversity facilitates a broader array of functional traits, allowing species to more efficiently utilize resources, thereby enhancing ecosystem functioning and reducing competition (Cadotte, 2017).

The use of functional traits presents promising opportunities to explore how community composition and diversity contribute to defining ecosystem functioning and the delivery of ecosystem services (Hanish *et al*., 2020). According to Olden *et al*., (2004), an increase in functional diversity similarity indicates a simplification of ecosystem resilience in natural environments.

Biodiversity plays a critical role in driving ecosystem functions that underpin the provision of ecosystem services (MEA, 2005). By influencing ecosystem processes that directly or indirectly impact energy and material flows, biodiversity influences the delivery of these services (Diaz *et al*., 2015). Species traits reflect how species influence ecological processes within a given community, including important functions like pollination and seed dispersal

(Luck *et al*., 2013). These traits are instrumental in determining ecosystem functioning as well as the provision of services to humans.

The provision of crucial ecosystem services in agroecosystems would be adversely impacted by a decrease in plant diversity (Guerra *et al*., 2022). Anthropogenic activities are rapidly altering ecological communities worldwide, and this change in biodiversity is not random. The functional traits of organisms, which drive their growth, survival, and reproduction, play a pivotal role in determining which species thrive and which decline under global change (Funk *et al*., 2017). This has significant implications, as traits not only influence the performance of individual plants but also shape various ecosystem properties such as biomass production and the services these properties provide for human well-being (Violle *et al*., 2007). Previous studies have demonstrated associations between plant traits and species-level variations in photosynthetic rate, growth, and reproductive output across the plant kingdom (Reich, 2014). Within natural communities, plants interact with individuals from other species, making the identity, abundance, and diversity of traits all relevant factors for ecosystem-level properties.

With biodiversity undergoing an alarming decline, there is an urgent scientific challenge to comprehend and anticipate the ramifications of biodiversity loss on multiple ecosystem functions (Leps *et al*., 2018). The temporal stability of ecosystem functioning holds great significance for both intrinsic and human purposes. Stability is maintained by populations, communities, and ecosystems that possess the ability to buffer the effects of environmental variations, thus preserving crucial ecosystem functions such as productivity, carbon sequestration, and pollination. The concept that greater biodiversity enhances the stability of natural communities and ecosystems (Isbell *et al*., 2015) has sparked an ongoing debate regarding the relationship between species diversity and stability (Leps, 2013). Simultaneously, there is a growing recognition that the functioning of ecosystems depends not solely on species diversity but on the functional traits of species, leading to the emergence of a dominant paradigm (Cernansky, 2017).

Trait-based approaches, in conjunction with traditional taxonomic approaches, have been developed to unravel the mechanisms of species coexistence (Kraft *et al*., 2015) and predict ecosystem functions and services at specific time points (de Bello *et al*., 2010). Communities dominated by slow-growing and conservative species exhibit greater stability over time and are more resilient to extreme events (Karlowsky *et al*., 2018). The response of species to environmental fluctuations, including disturbances, and biotic interactions depends on their response traits (Garnier *et al*., 2016). This differentiation between response and effect traits enables predictions about community structure, the description of factors influencing species' geographical ranges, and an understanding of why processes such as nutrient cycling and plant productivity vary among different systems (Read *et al*., 2014). It is important to note that species with similar responses to environmental changes may not necessarily have the same effects on ecosystem properties (Reich *et al*., 2003).

For instance, certain plant traits associated with drought tolerance, such as succulence (Diaz *et al*., 2004), or the capacity of isopods to retain water (Dias *et al*., 2013), are linked to the increased fitness of species in arid conditions (Veldhuis *et al*., 2019). Similarly, species possessing traits related to higher intrinsic relative growth rates recover more rapidly from environmental disturbances (Oliver *et al*., 2015), but their abundance may vary more over time (Majekova *et al*., 2014). Certain functional traits also have the potential to impact other trophic levels and multiple ecosystem functions (Garnier *et al*., 2016). For example, secondary compounds present in leaves not only provide defence against herbivory but can also slow down the decomposition of litter (Chomel *et al*., 2016), while floral traits affect pollination processes (Lavorel *et al*., 2013).

A growing body of research indicates that functional diversity, as opposed to species diversity, plays a crucial role in enhancing various ecosystem functions. Studies have shown that higher functional diversity can increase overall ecosystem productivity (Hooper *et al*., 2005), improve the resilience of the system to disturbances or biological invasions (Bellwood *et al*., 2004), and regulate the cycling of matter and nutrients (Villéger *et al*., 2008). Consequently, it is widely believed that functional diversity has the potential to act as a critical link between the variations observed in individual plant traits (morphological, physiological, and phenological) and the larger-scale ecosystem processes and patterns that emerge (Petchey *et al*., 2009).

On the other side, individual plant traits can also have a direct impact on ecosystem processes by influencing abiotic environmental factors. These plant traits include modifications that affect the availability and utilization of soil resources like water and nutrients, changes to the trophic structure within a community, and influences on the frequency, severity, and extent of disturbances (Castro, 2008). For example, a plant community rich in nitrogen-fixing legume species can increase the overall availability of nitrogen in the soil, thereby accelerating the nitrogen cycle. Plant traits can also impact resource availability by influencing the quality of the litter they produce, which in turn affects the rate of nutrient turnover in the litter and soil organic matter.

Plant functional traits have been shown to play a significant role in predicting how plants may respond to environmental changes and climate variability (Jamil *et al*., 2012). For example, shifts in factors like temperature, precipitation, and resource availability can impact plant traits such as seed size, leaf thickness, seed shape, and seed mass. Specifically, reduced water availability resulting from environmental changes can lead to a decrease in a plant's specific leaf area (the ratio of leaf area to dry mass). This can subsequently impair the plant's ability to acquire nutrients, ultimately reducing its primary production. These changes in individual plant traits can then have cascading effects on overall ecosystem functioning (Valladares *et al*., 2015).

Trait diversity encompasses the range of interspecific variations resulting from species-specific responses to environmental changes, and it is recognized as a crucial factor influencing changes in the functional diversity of plant communities (Pakeman, 2011). Studies indicate that ecological communities characterized by high functional diversity tend to exhibit greater resilience and enhanced buffering capacity against the uncertainties associated with environmental change (Pillar *et al*., 2013). Furthermore, alterations in the distribution and variability of plant functional traits have been identified as influential drivers of ecosystem processes (de Bello *et al*., 2010).

Previous research has emphasized the importance of taxonomic diversity, or the number of different species, in relation to ecosystems productivity (Tilman *et al*., 2014). Studies have found a positive correlation between plant species richness and primary production, (Marquand *et al*., 2009). The proposed mechanisms behind this relationship include greater species richness leading to higher plant nitrogen pools and more efficient nutrient utilization by the resident plant community (Fargione *et al*., 2007). Additionally, complementarity effects among different plant species may enhance carbon uptake and translocation rates, resulting in increased biomass production per unit of nutrient in the plant tissue (De Deyn *et al*., 2012). Regardless of the specific mechanisms involved, it is clear that high plant diversity, whether measured through functional, phylogenetic, or taxonomic diversity, is crucial for the proper functioning of ecosystems. This includes the provision of important ecosystem services such as biomass production and nutrient cycling.

Plant functional traits are considered essential for predicting significant ecosystem and community characteristics across resource gradients within and among biogeographic regions (Violle *et al*., 2014). Trait-based approaches enable comparisons of vegetation responses across biogeographic regions that possess different species pools (Bernhardt-Romermann *et al.*, 2011).

CHAPTER 3: MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted within Chishakwe Safari, a game reserve covering 57,600 hectares of land situated in Bikita, Masvingo Province, Zimbabwe. Chishakwe Safari is positioned between 7794000S, 396000E and 7731000S, 432000E, located in the northern part of the renowned Save Valley Conservancy situated in the south-eastern Lowveld of Zimbabwe (Figure 3.1). The reserve is situated at an elevation of 1,106 meters above sea level and experiences a single rainy season from October to March. The northern part of Save Valley Conservancy, consists of deciduous woodland savannah characterized by low and variable rainfall (474-540mm per year) and soils of poor quality (Pole, 2006). The SVC falls within the natural agro-ecological region IV, known as one of the driest regions in Zimbabwe (Lindsey *et al*., 2009). Chishakwe Safari sees its highest temperatures in September and lowest temperatures in July, with an average temperature of 30°C. The climate in Chishakwe Safari is typical of an African savannah, characterized by hot and dry winters and wet summers.

Study Area Map

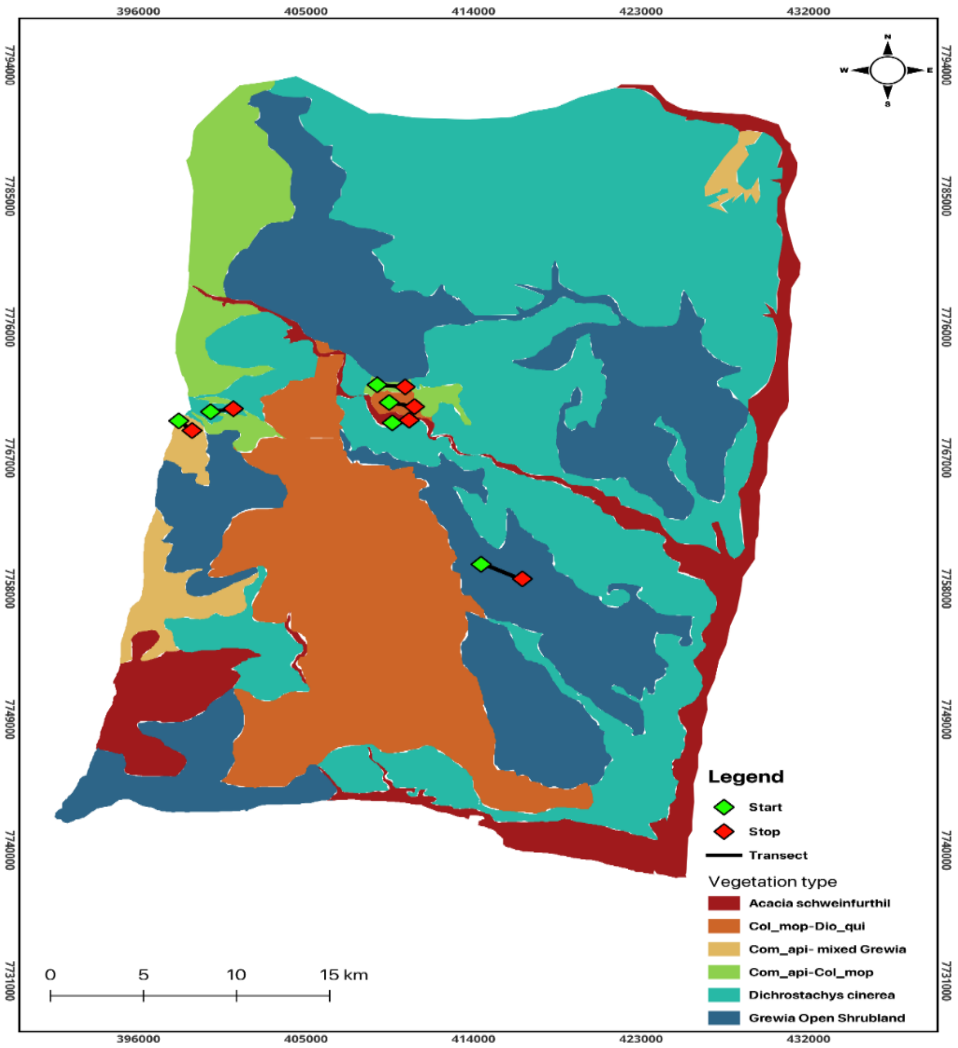

Figure 1: Chishakwe Safari and the sampled locations

3.2 Research Design

Data were collected during late February and early March of 2023. The study was conducted using a stratified random design. The strata were the six different vegetation types that dominated the landscape. These vegetation types were *Combretum-apiculatum_ Colophospermum-mopane*, *Combretum-apiculatum_mixed-Grewia*, *Colophospermum-mopane_Diospyros-quiloensis, Grewia* open shrub land, *Acacia schweinfurthil* and *Dichrostachys cinerea.*

3.2.1 Sampling Design for Trees and Shrubs

Randomly established transects measuring 100 meters in length and 4 meters in width were employed to collect data across vegetation types. The identification and documentation of trees and shrubs encountered within transects were carried out. Trees were identified using the field guide to trees of Southern Africa by Van Wyk (2000). For each tree species present within the plot, measurements of height, diameter at breast height (DBH), and canopy cover were recorded. Shrubs were assessed for height, as well as the extent of long and short canopy cover.

3.2.2 Sampling Design for Grasses and Forbs

Data were collected by establishing transects measuring 100 meters in length and 2 meters in width, randomly distributed across each vegetation type. These transects were further divided into 10 small plots, each covering an area of $20m^2$ (10 meters by 2 meters). Within each plot, quadrats measuring 1 meter by 1 meter were placed. The identified plant species were classified as either grasses or forbs. The grasses and forbs present in each quadrat were documented. Any unidentified species were marked and later identified using the reference book "Grasses of Southern Africa" by Oudtshoorn (2012). Forb species identification was conducted using the book "Field guide to wild flowers of Southern Africa" by J.C Manning (1999). The identification process involved assigning botanical names to the species. Functional traits of the grasses and forbs were assessed, including plant height, internode length, pinnacle height, leaf thickness, leaf area, aerial cover, and basal cover.

3.3 Data Analyses

Data was analysed using the multi-variate analysis in Statistical Package in Social Sciences (SPSS) version 2020. The confidence level was 95%. The Shannon Wiener index was used to calculate diversity of plant species. The Shannon Index of diversity (H’) which is an information-based statistical metric that assumes all species are represented in the sample being analysed was calculated using the formula: $H' = \sum pi(Inpi)$: where *pi* is the proportional abundance of a species and *In* is the natural logarithm (Morris *et al*., 2014).

CHAPTER 4: RESULTS

4.1 Comparison of Species Status in Different Vegetation Types

A total of 310 individual woody plants were assessed from the 6 sampling locations, 36% (n=15) of these were trees and 64% (n=22) were shrubs. We recorded 33 woody plant species, 19 grass species and 25 forb species in the six study strata.

For trees, significant differences were recorded on most study variables namely species composition (Fig 2), canopy cover (Fig 3), diameter at breast height (DBH) (Fig 4) and height (Fig 5) across different vegetation types. All vegetation types' showed very low tree species diversity. *Dichrostachys cinerea* showed H'= 0.5. *Acacia schweinfurthil* showed H'= 0.4. Grewia open shrub land showed H'= 0.5. *Combretum-apiculatum*_mixed *Grewia* recorded H'= 0.5. *Colophospermum-mopane_Diospyros-quiloensis* showed H'= 0.4. *Combretum_apiculatum_Colophospermum-mopane* showed H'= 0.5. Highest species richness (n=6) was recorded in *Combretum-apiculatum*_mixed *Grewia* and *Grewia* open shrub land whereas lowest species richness (n=3) was recorded in *Acacia schweinfurthil* vegetation type (Fig 1).

For shrub species, significant differences were recorded on all study variables namely species composition (Fig 6), canopy diameter (Fig 7) and height (Fig 9). All vegetation types showed very low shrub species diversity. *Dichrostachys cinerea* showed H'= 0.7. *Acacia shweinfurthil* showed H'= 0.6. Grewia open shrub land showed H'=0.8. Combretum-apiculatum_mixed Grewia recorded H'= 0.3. *Colophospermum-mopane_Diospyros-quiloensis* recorded H'= 0.5. *Combretum-apiculatum_Colophospermum-mopane* recorded H'= 0.8. Highest species richness (n=12) was recorded in *Combretum-apiculatum_Colophospermum-mopane* and *Dichrostachys cinerea* whilst lowest species richness (n=6) was recorded in *Colophospermum-mopane_Diospyros-quiloensis* and *Combretum-apiculatum*_mixed *Grewia* (Fig 6).

All vegetation types recorded very low grass species diversity. *Dichrostachys cinerea* recorded H'= 0.6. *Acacia shweinfurthil* recorded H'= 0.4. *Grewia* open shrub land recorded H'= 0.4. *Combretum-apiculatum*_mixed *Grewia* recorded H'= 0.5. *Combretum-apiculatum_Colophospermum mopane* recorded H'= 0.8. *Colophospermum _mopane-Diospyros_quiloensis* showed H'= 0.5.

All vegetation types also showed very low forb species diversity. *Dichrostachys cinerea* recorded H’= 0.5. *Acacia schweinfurthil* recorded H’= 0.5. *Grewia* open shrub land recorded H’= 0.9. *Combretum-apiculatum*_mixed *Grewia* recorded H’= 0.4. *Combretum-apiculatum_Colophospermum-mopane* recorded H’= 0.8. *Colophospermum-mopane_Diospyros-quiloensis* showed H’= 0.5.

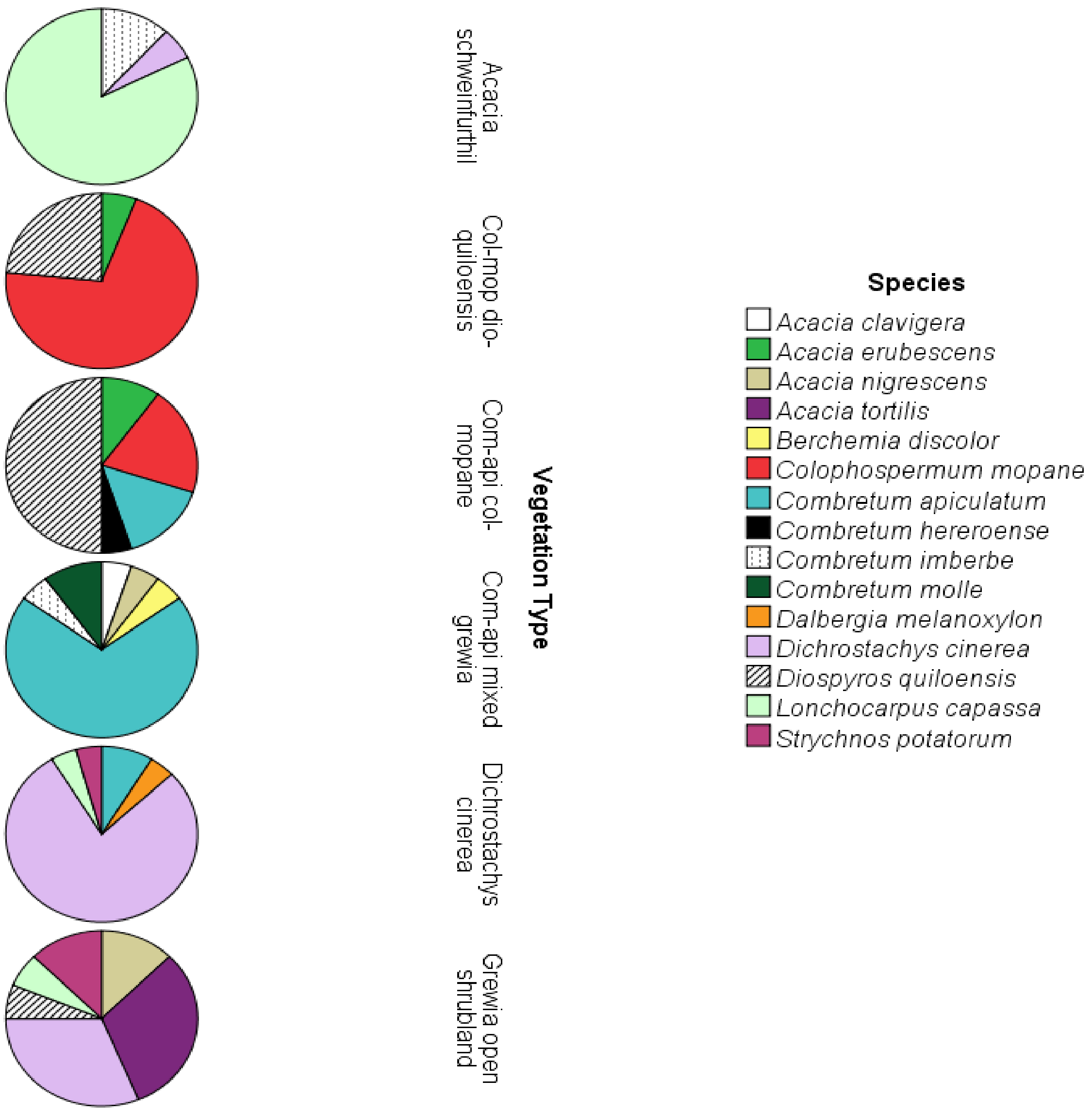

Figure 2: Tree species composition across different vegetation types

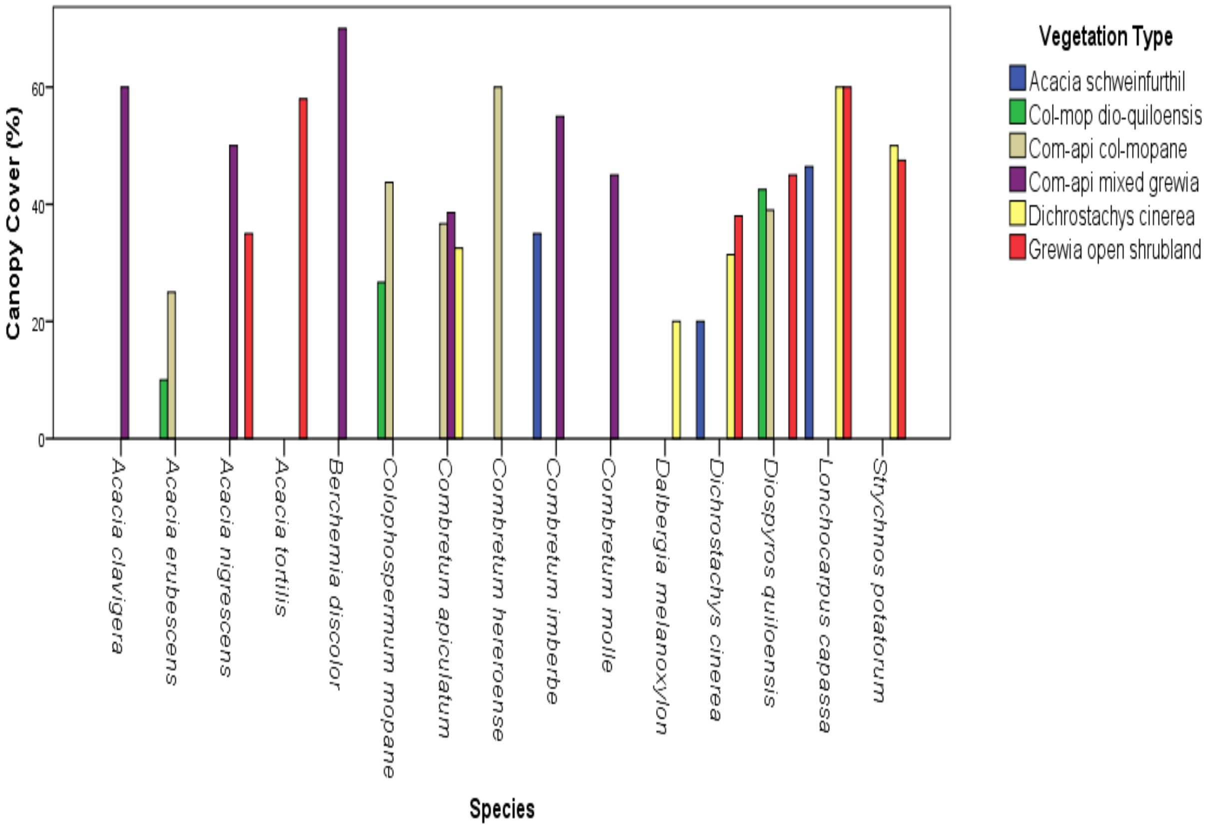

Figure 3: Canopy cover of different tree species across different vegetation types

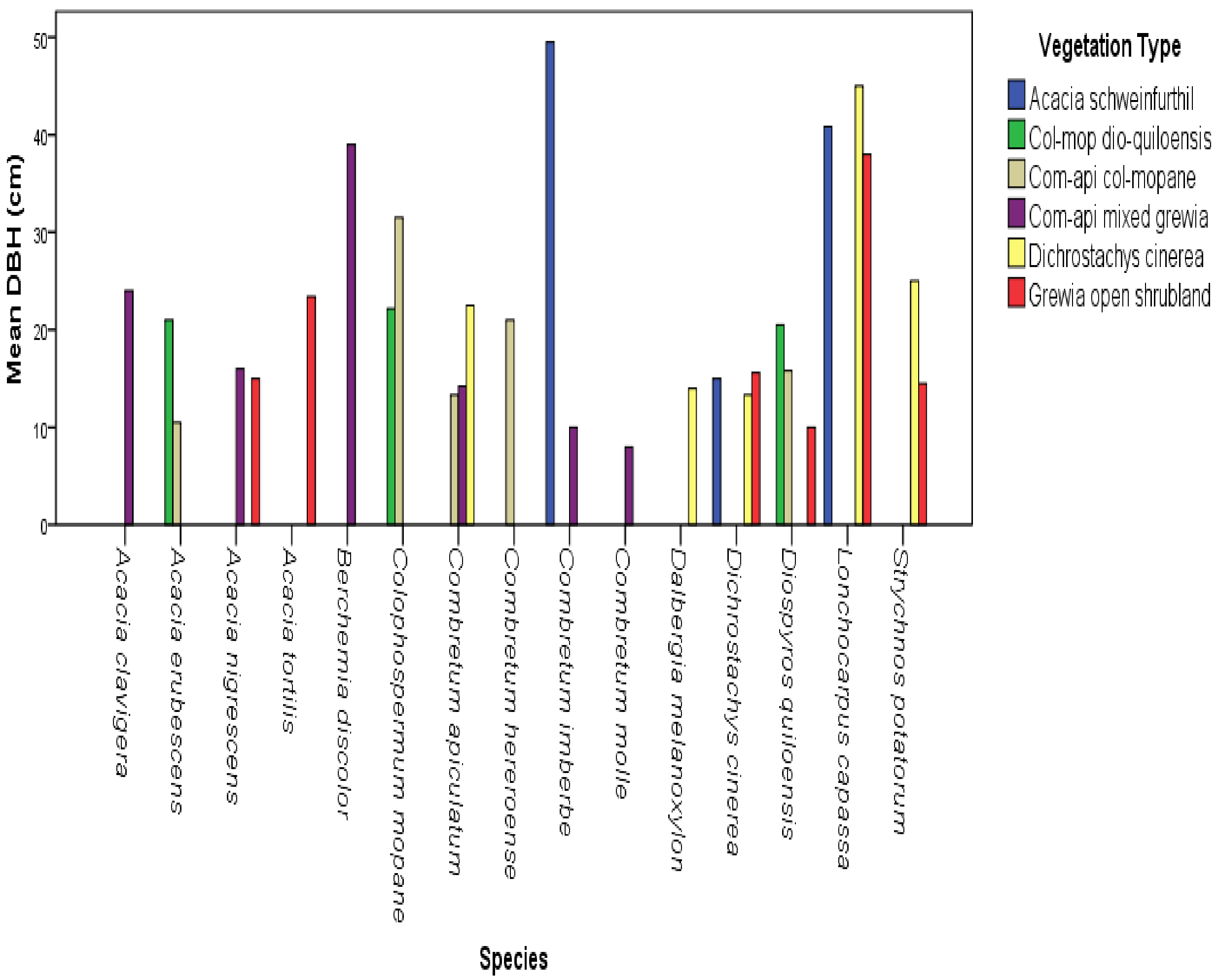

Figure 4: Mean DBH of different tree species across different vegetation types

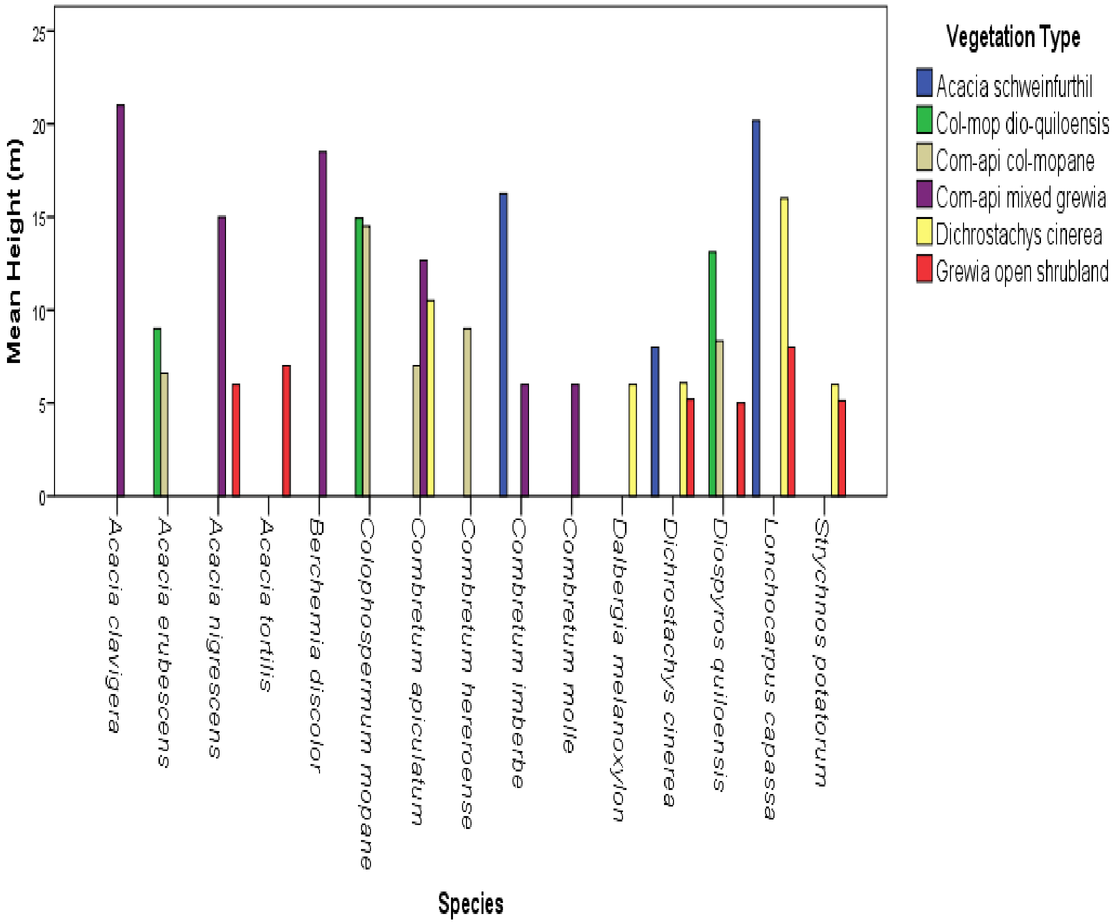

Figure 5: Mean height across different vegetation types

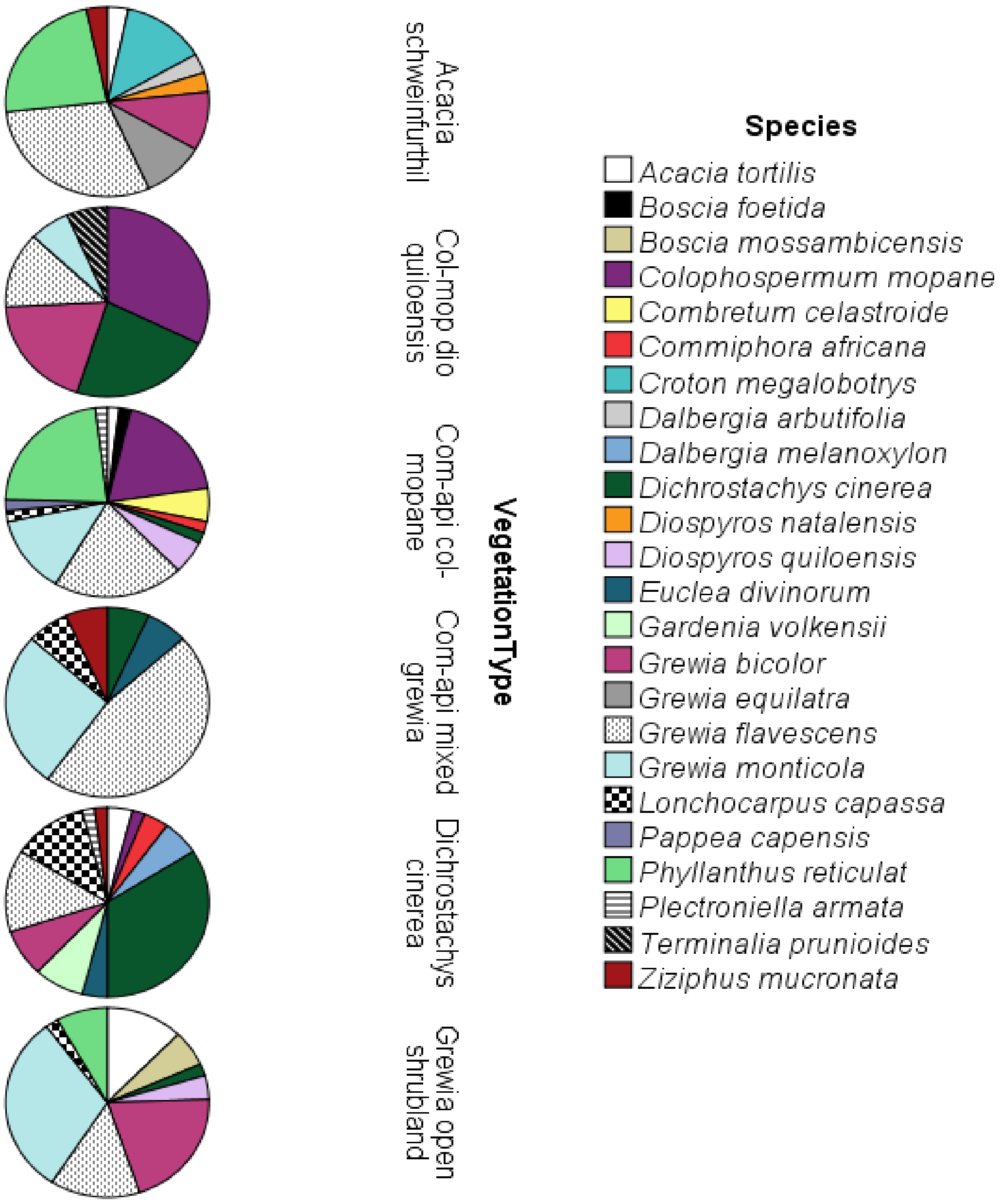

Figure 6: Shrub species composition across different vegetation types

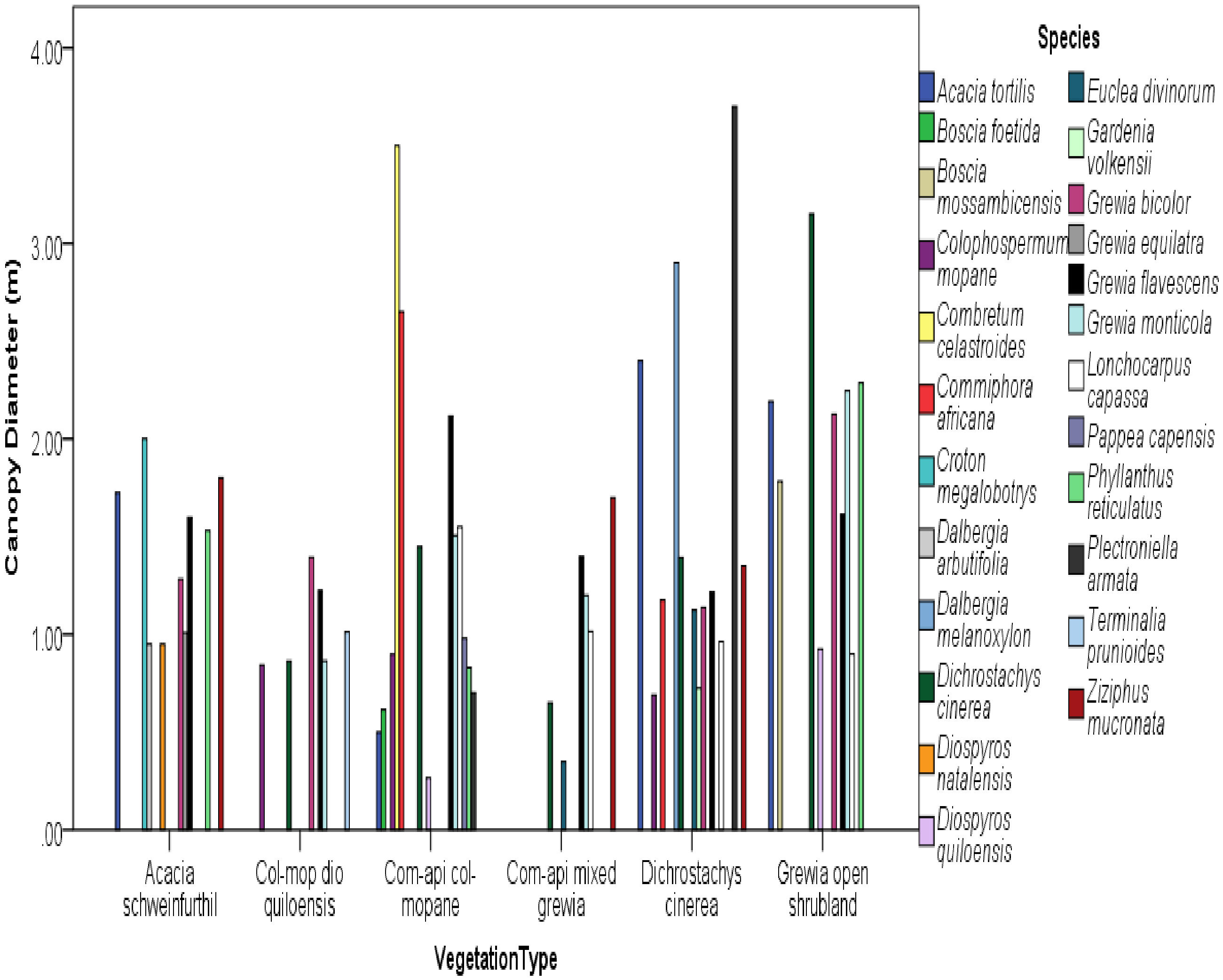

Figure 7: Canopy diameter of different shrub species across different vegetation types

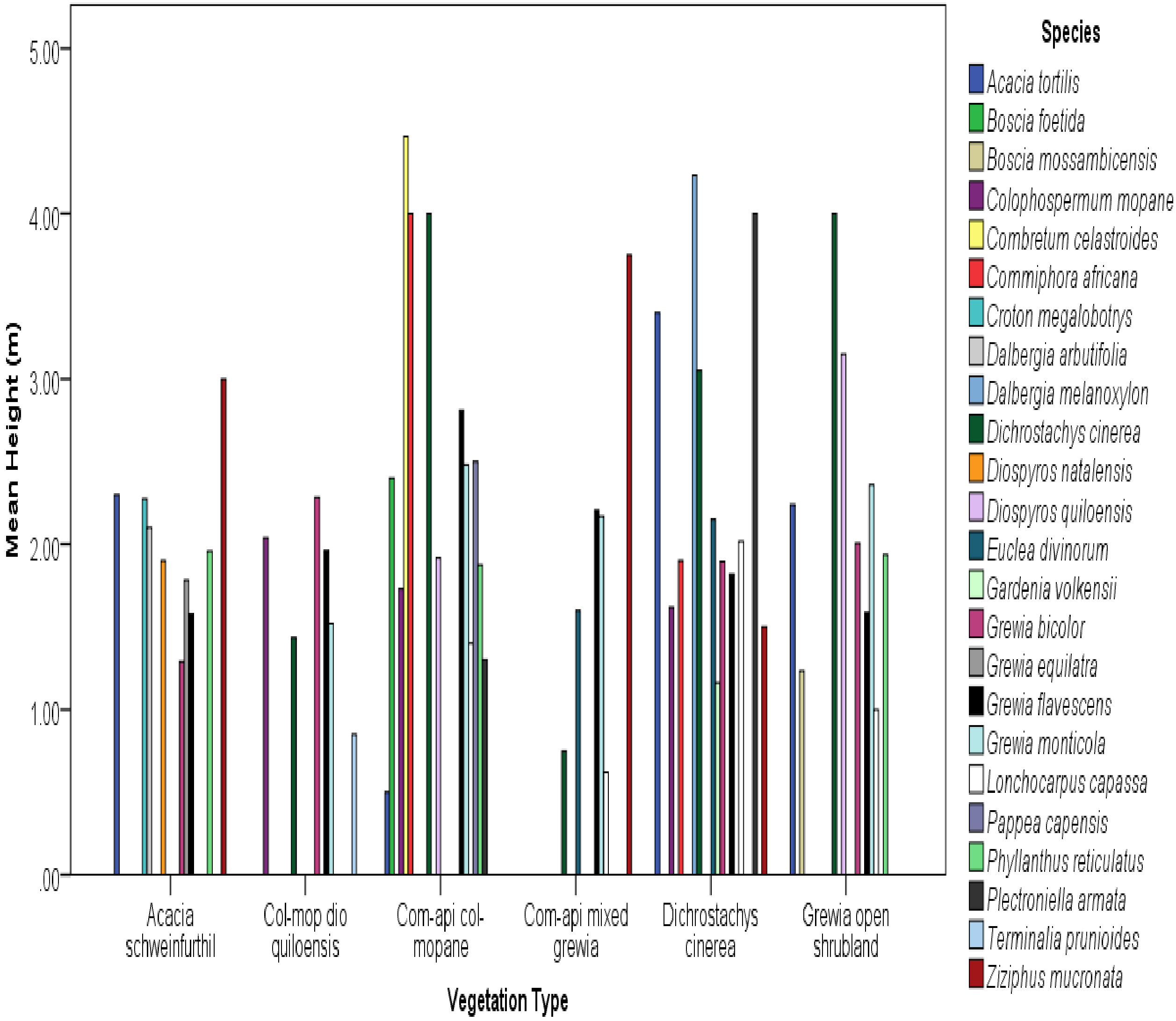

Figure 8: Mean height of different shrub species across different vegetation types

4.2 Influence of Vegetation Type on Study Variables

4.2.1 Height

Grasses in *Acacia schweinfurthil* vegetation type were notably taller than those in *Grewia* open shrub land (Fig 4.2.1a). Results showed marginal significant differences in height between transects under tree canopies and in open vegetation types (Fig 9).

There were no differences in height of forbs across different vegetation types. However, forb species (*Crinum walteri*, *Kalanchoe lanceolata*) in the *Dichrostachys cinerea* vegetation type were notably taller than those in other vegetation types (Fig 10).

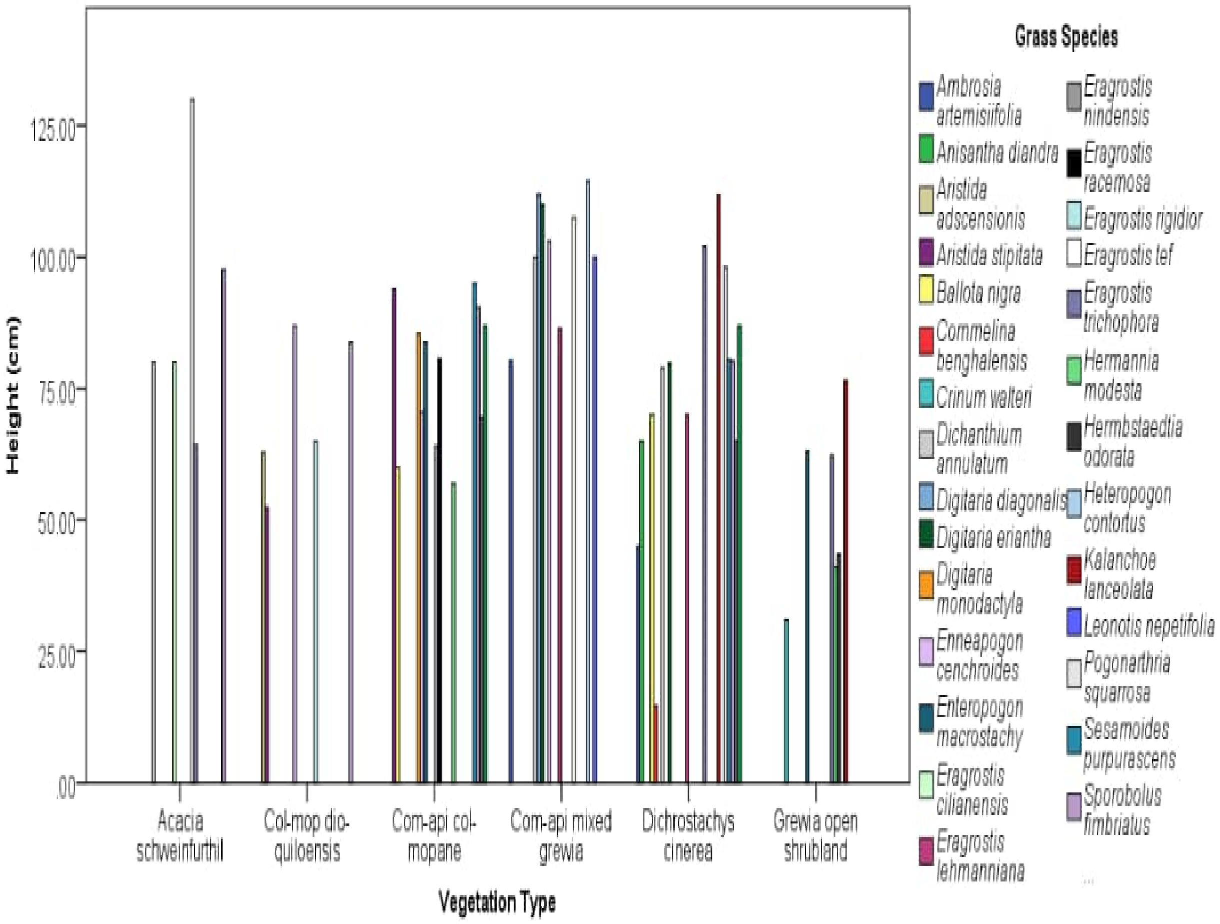

Figure 9: Height of different grasses across different vegetation types

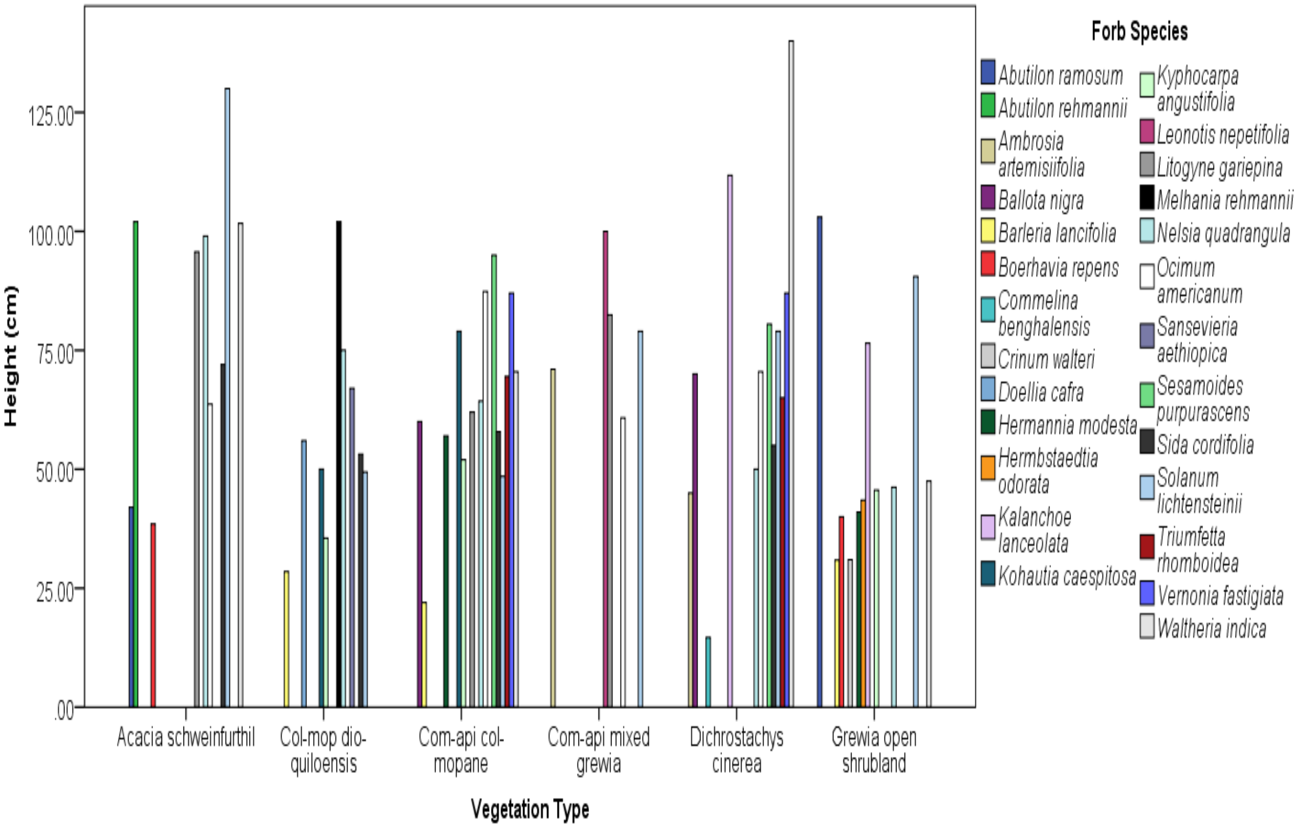

Figure 10: Height of different forbs across different vegetation types

4.2.2 Pinnacle Height

Pinnacle height for grasses showed differences (Fig 11), with *Aristida stipitata* in the *Combretum_apiculatum- Colophospermum_mopane* vegetation type having the tallest pinnacle.

Pinnacle height of forbs showed differences across different vegetation types (Fig 12).

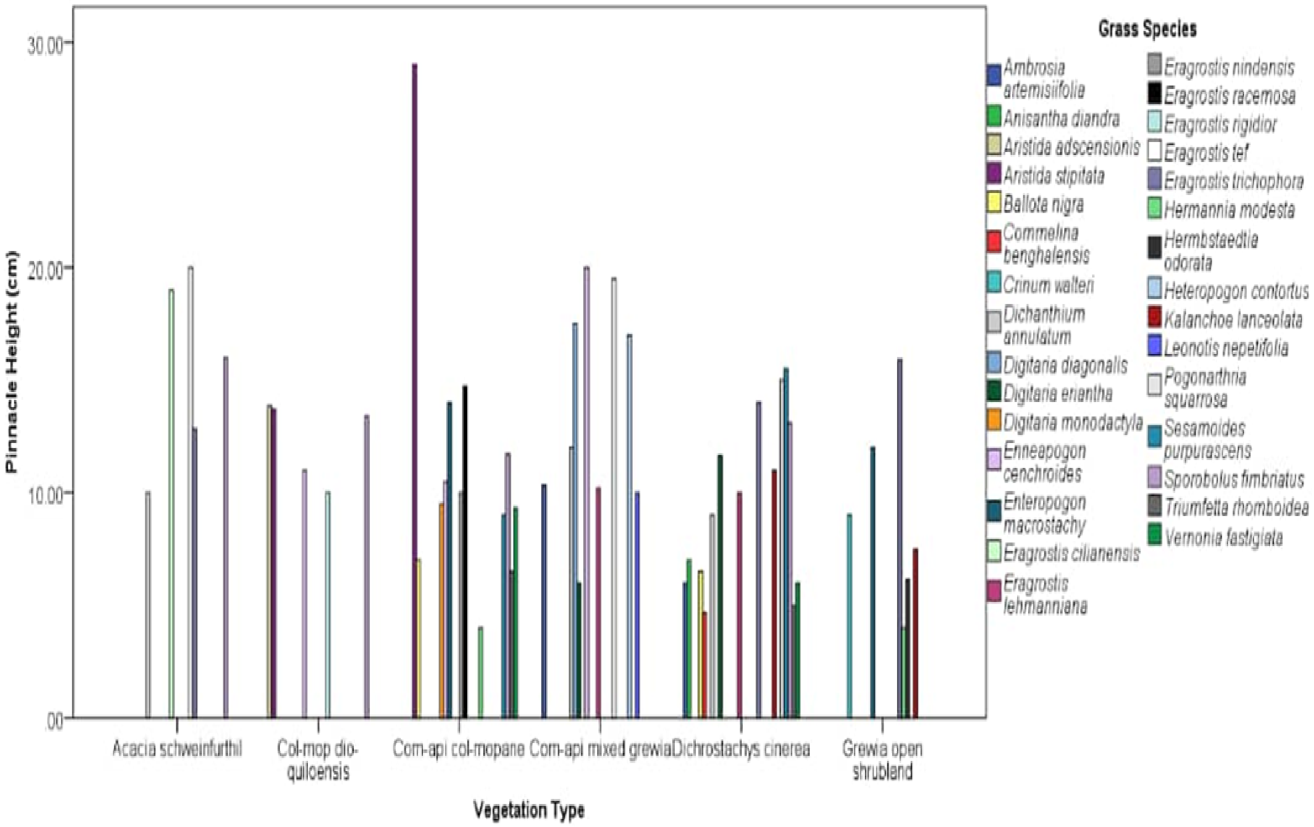

Figure 11: Pinnacle height of grasses in different vegetation types

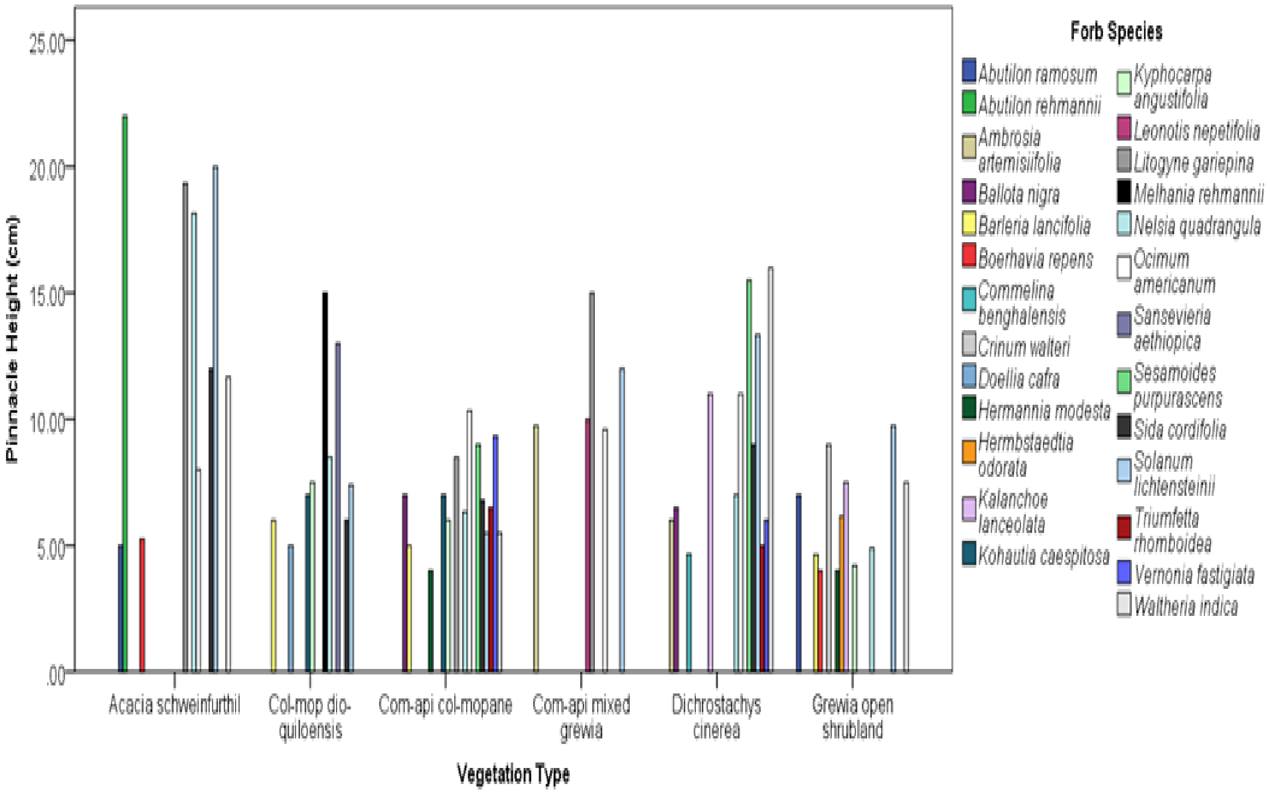

Figure 12: Pinnacle height of forbs across different vegetation types

4.2.3 Internode Length

For grasses, internode length showed differences in different vegetation types (Fig 4.2.3a). Grasses in the *Acacia schweinfurthil* vegetation type had longer internode length than those in the *Grewia* open shrub land (Fig 13).

Internode length of forb species showed differences in different vegetation types (Fig 14).

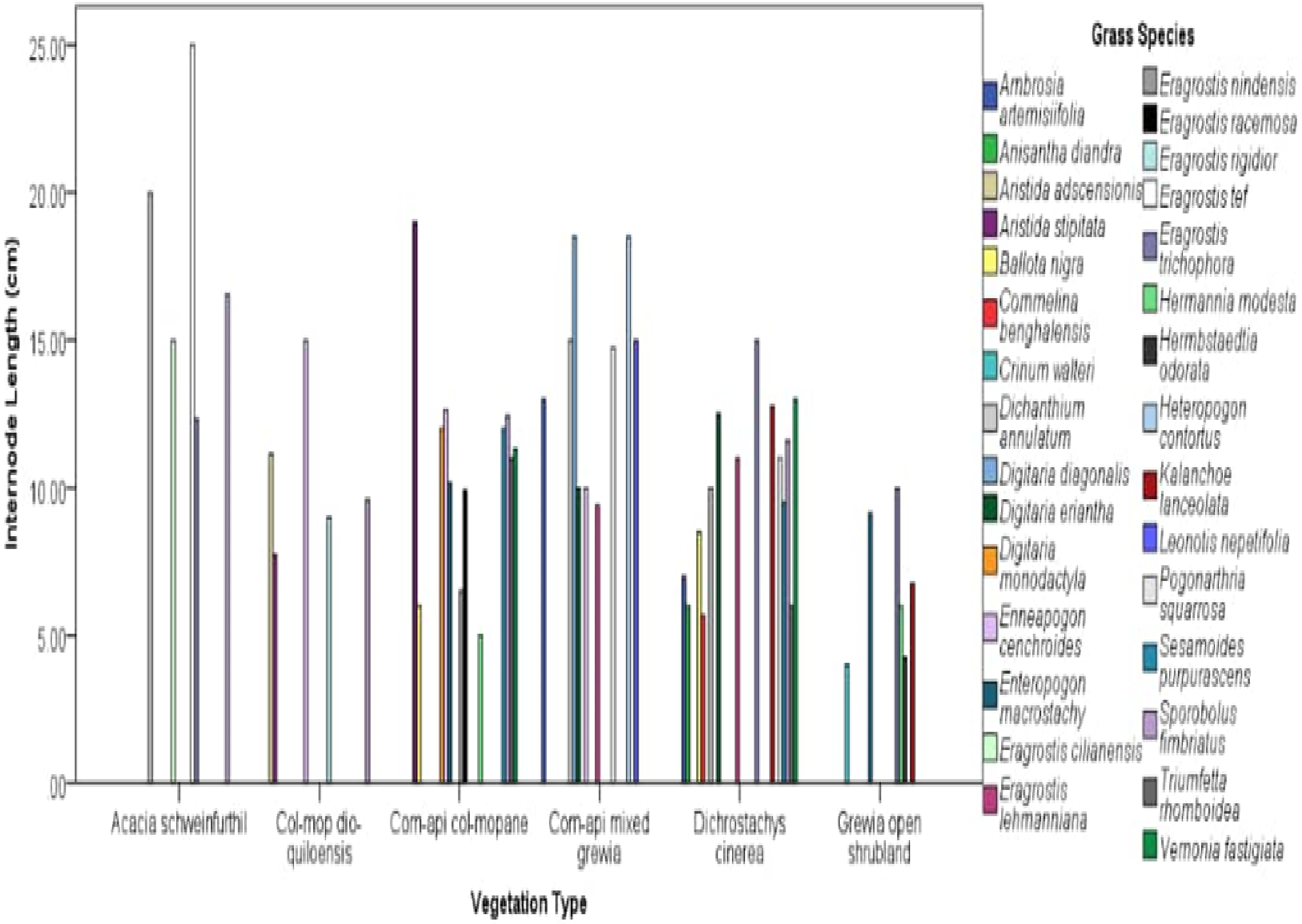

Figure 13: Internode length of grasses in different vegetation types

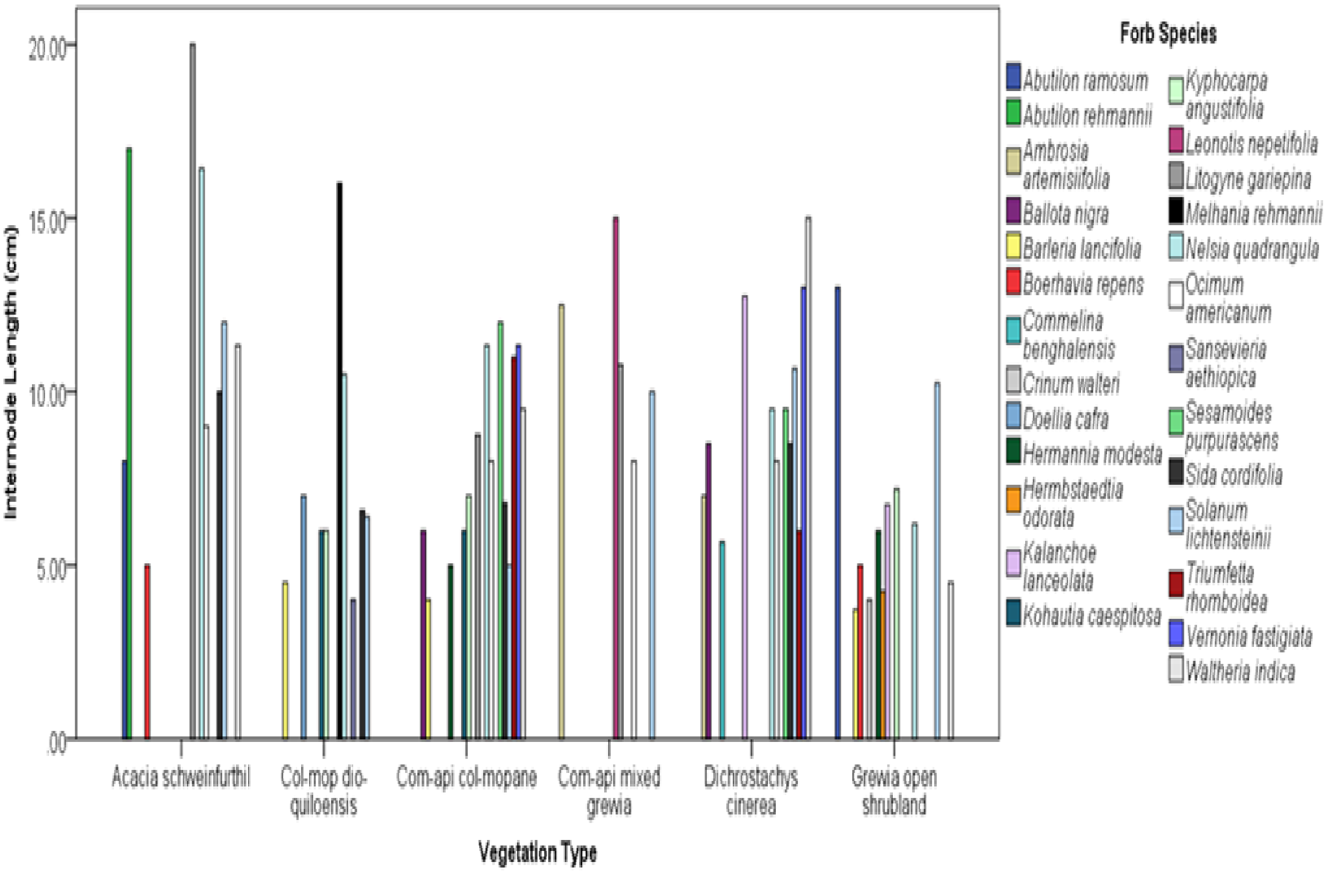

Figure 14: Internode length of forbs in different vegetation types

4.2.4 Leaf Area

There were differences in leaf area of both grasses (Fig 15) and forbs (Fig 16) in different vegetation types.

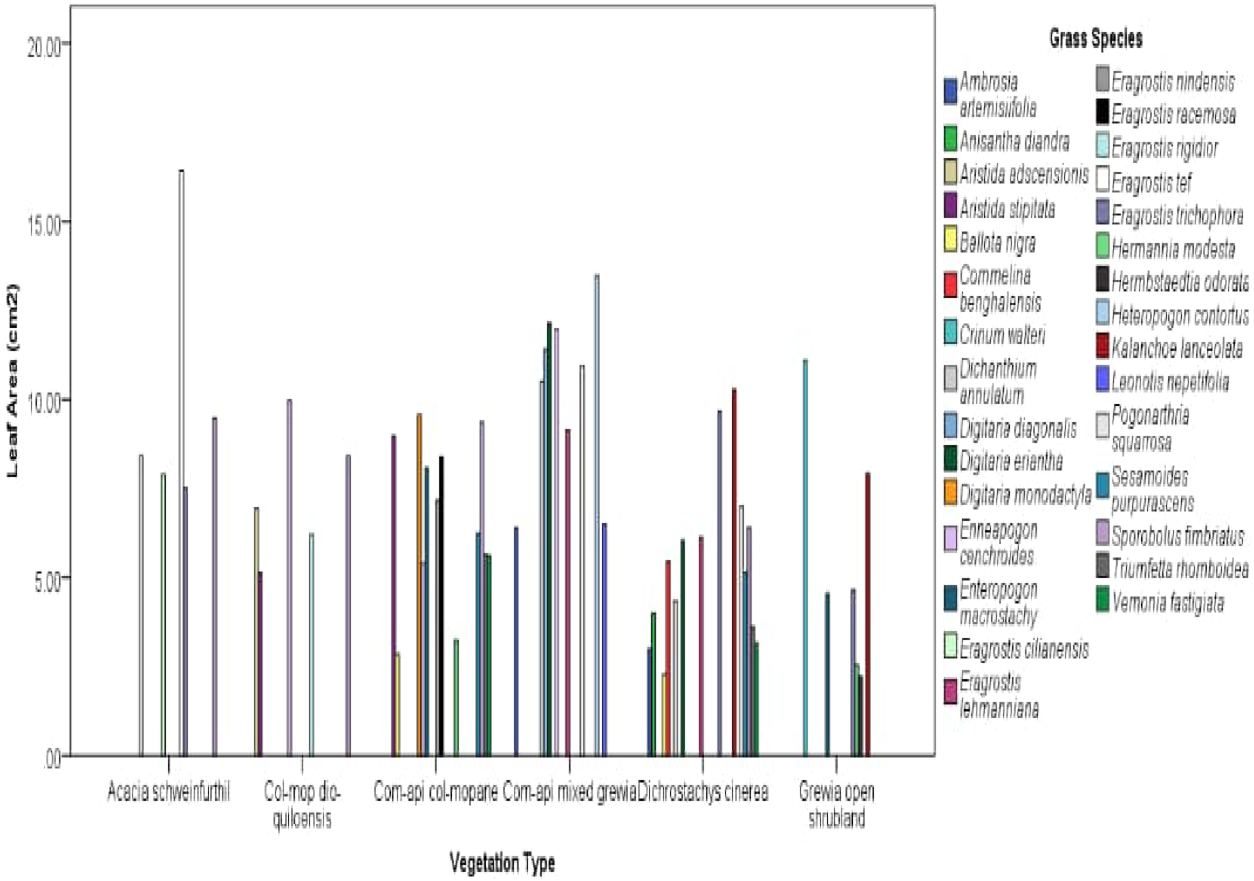

Figure 15: Leaf area of grasses in different vegetation types

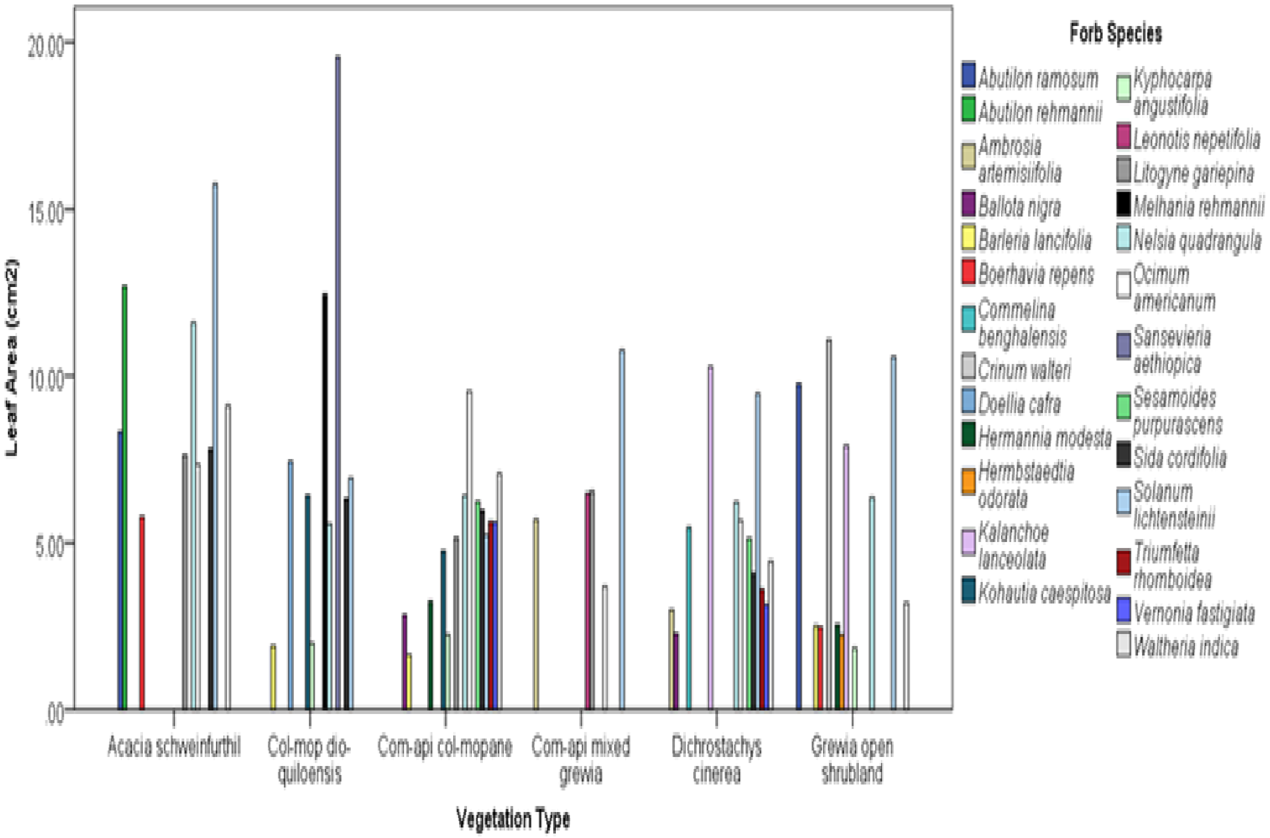

Figure 16: Leaf area of forbs in different vegetation types

4.2.5 Leaf Thickness

There were no differences in leaf thickness of grass species. However, individual grasses (*Crinum walteri* and *Kalanchoe lanceolata)* in the *Grewia* open shrub land exhibited higher leaf thickness than others (Fig 17).

There were significant differences in leaf thickness of forbs (Fig 18).

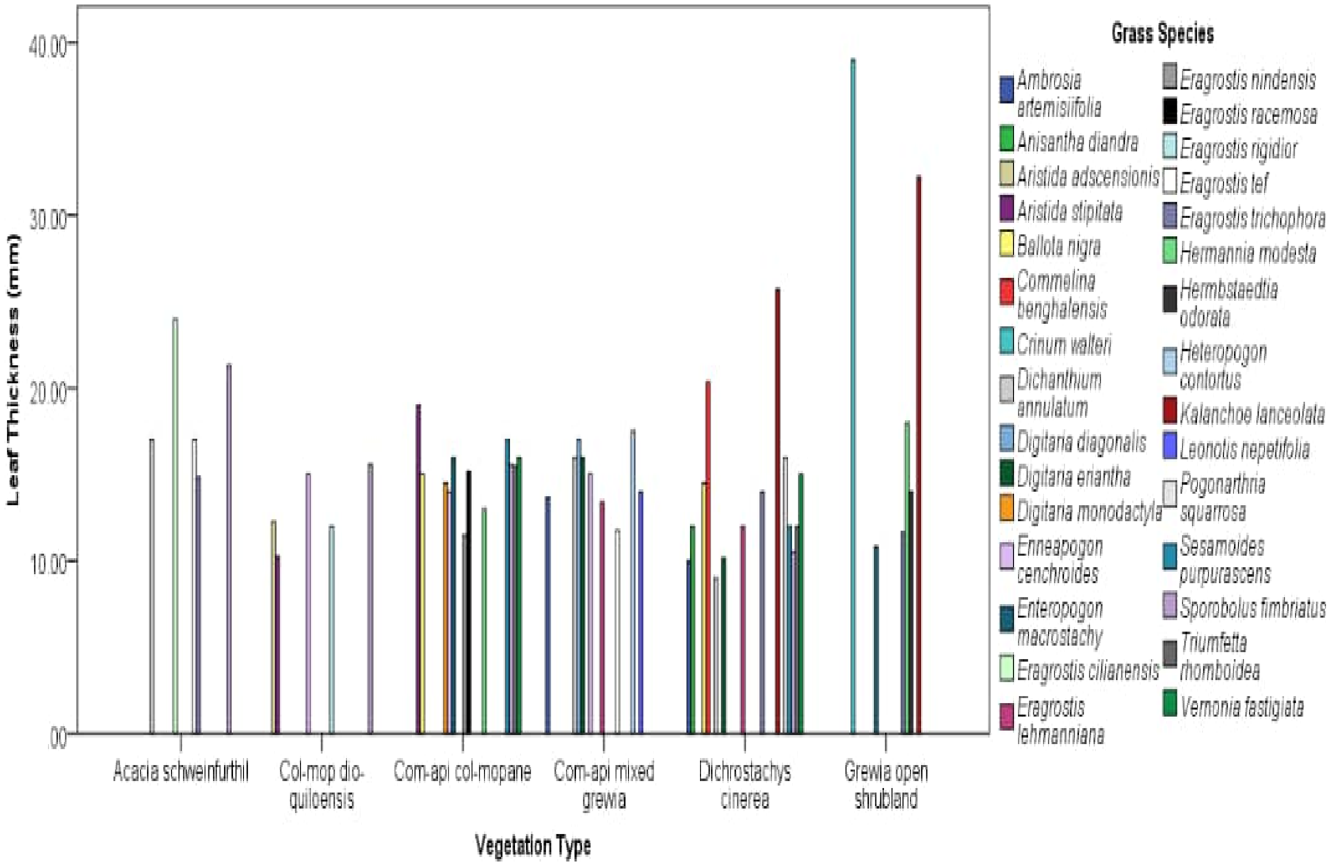

Figure 17: Leaf thickness of grasses in different vegetation types

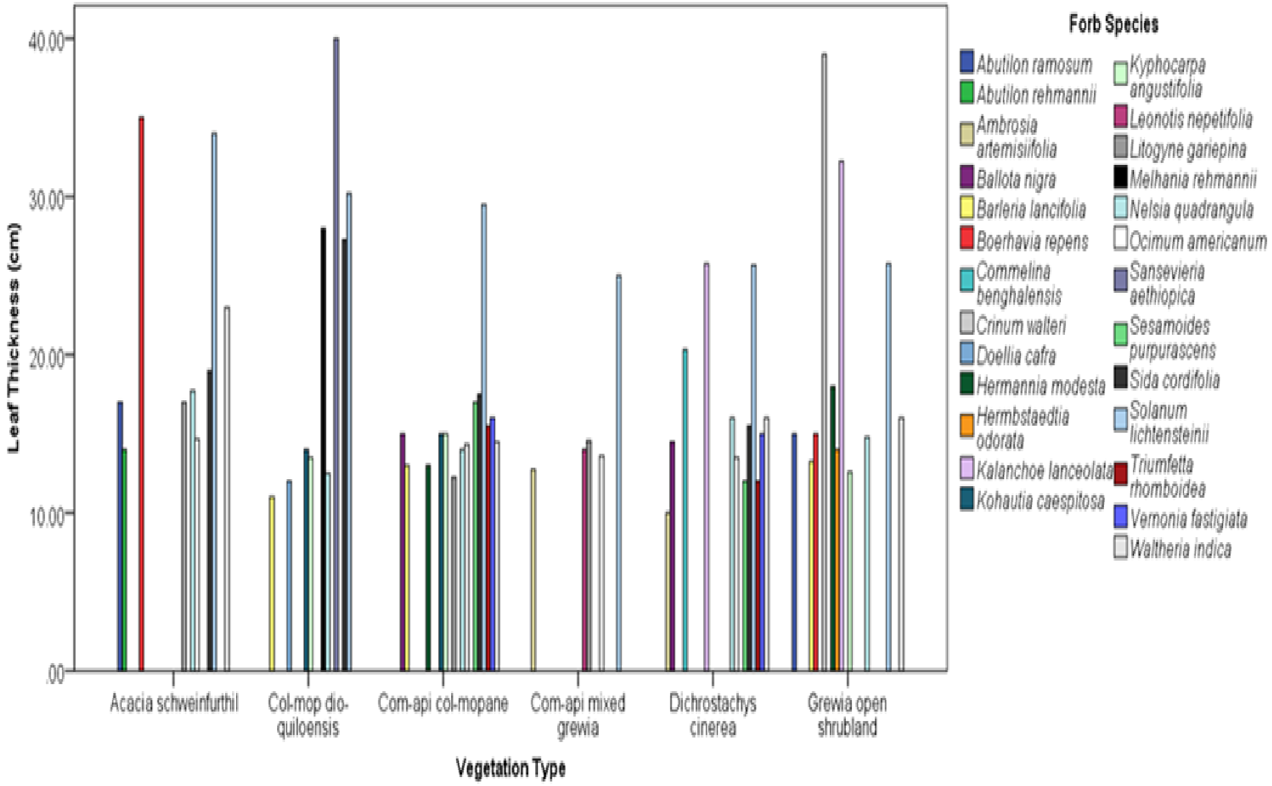

Figure 18: Leaf thickness of forbs in different vegetation types

4.2.6 Aerial Cover

For grasses, aerial cover was higher in *Dichrostachys cinerea* than in other vegetation types (Fig 19), and lower in *Colophospermum_mopane-Diospyros_quiloensis*.

For forbs, aerial cover showed significant differences in different vegetation types (Fig 20).

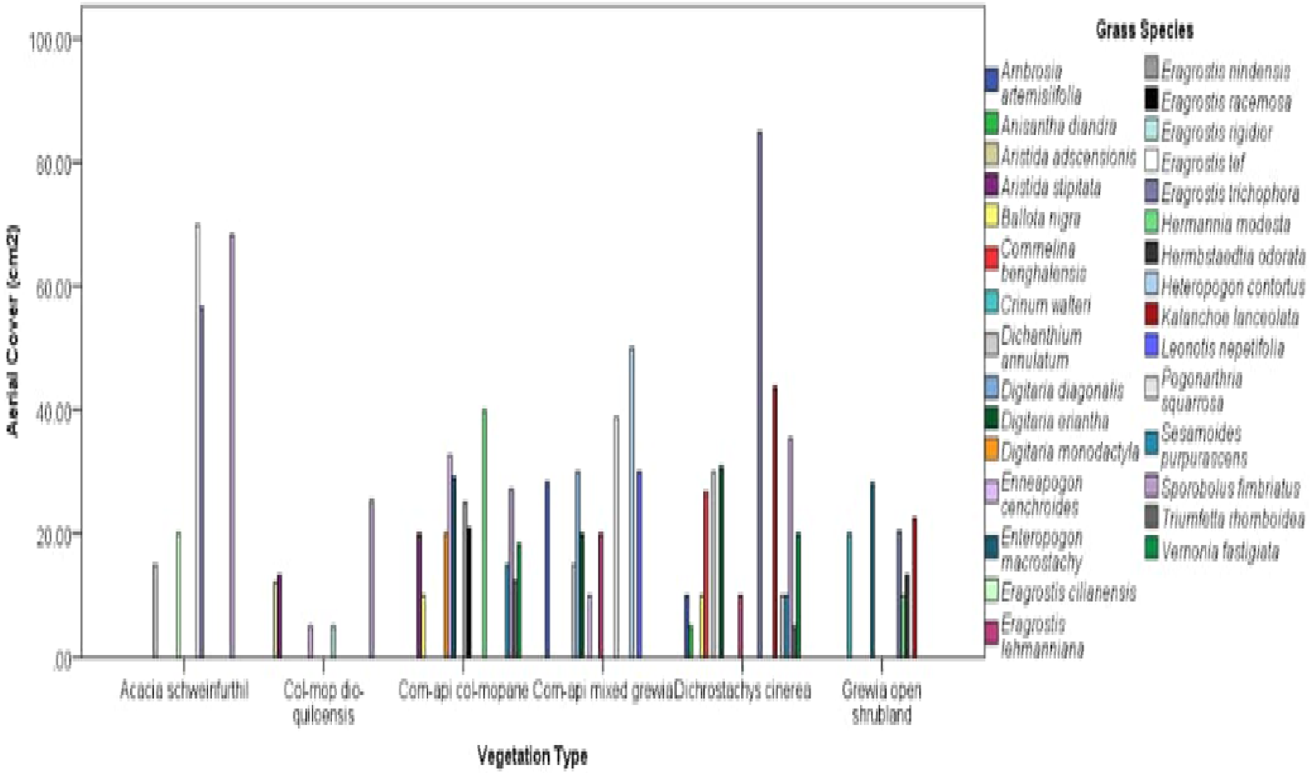

Figure 19: Aerial cover of grasses in different vegetation types

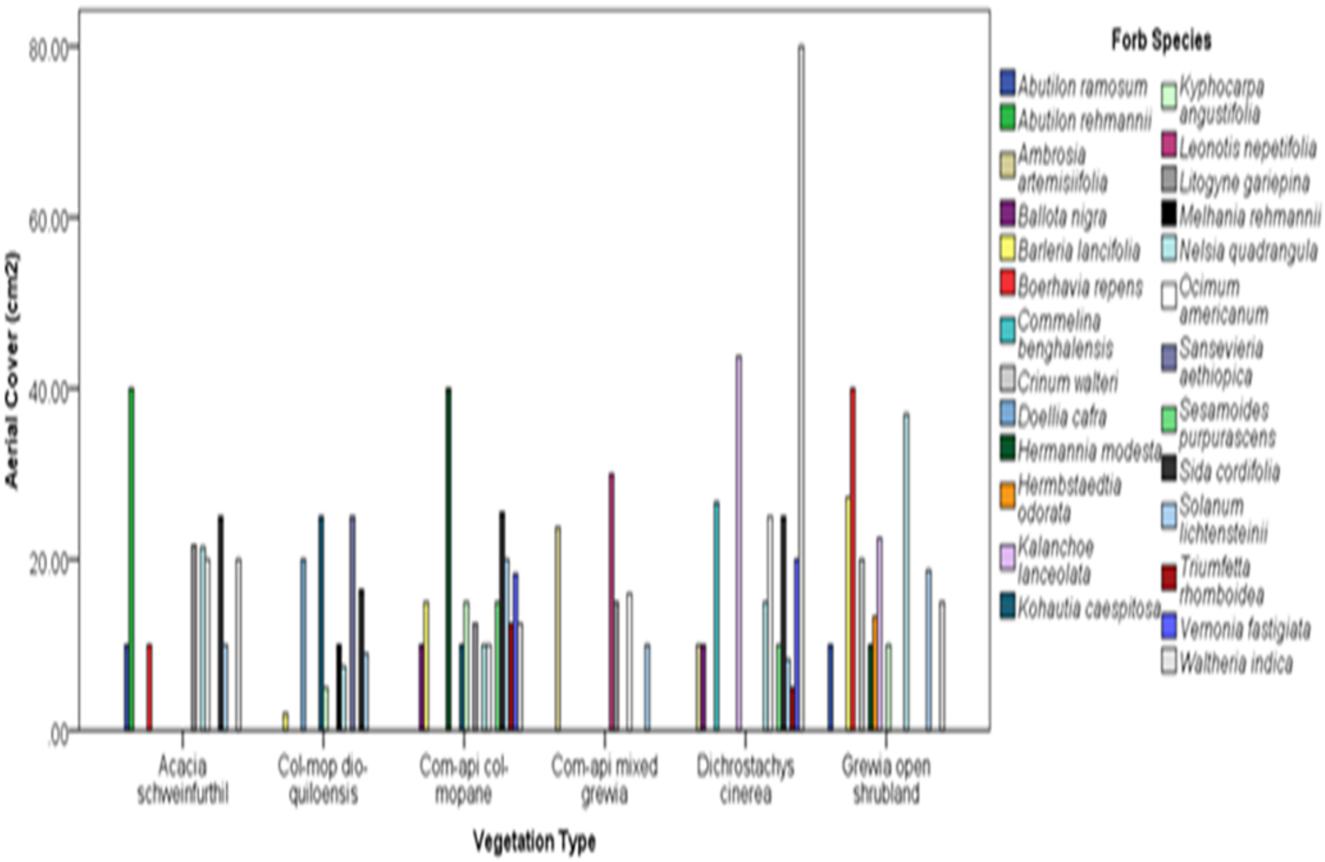

Figure 20: Aerial cover of different forb species in different vegetation types

4.2.7 Basal Cover

For grasses, basal cover was higher in the *Dichrostachys cinerea* vegetation type and lower in the *Colophospermum_mopane-Diospyros_quiloensis* (Fig 21).

For forbs, basal cover showed significant differences in vegetation types (Fig 22).

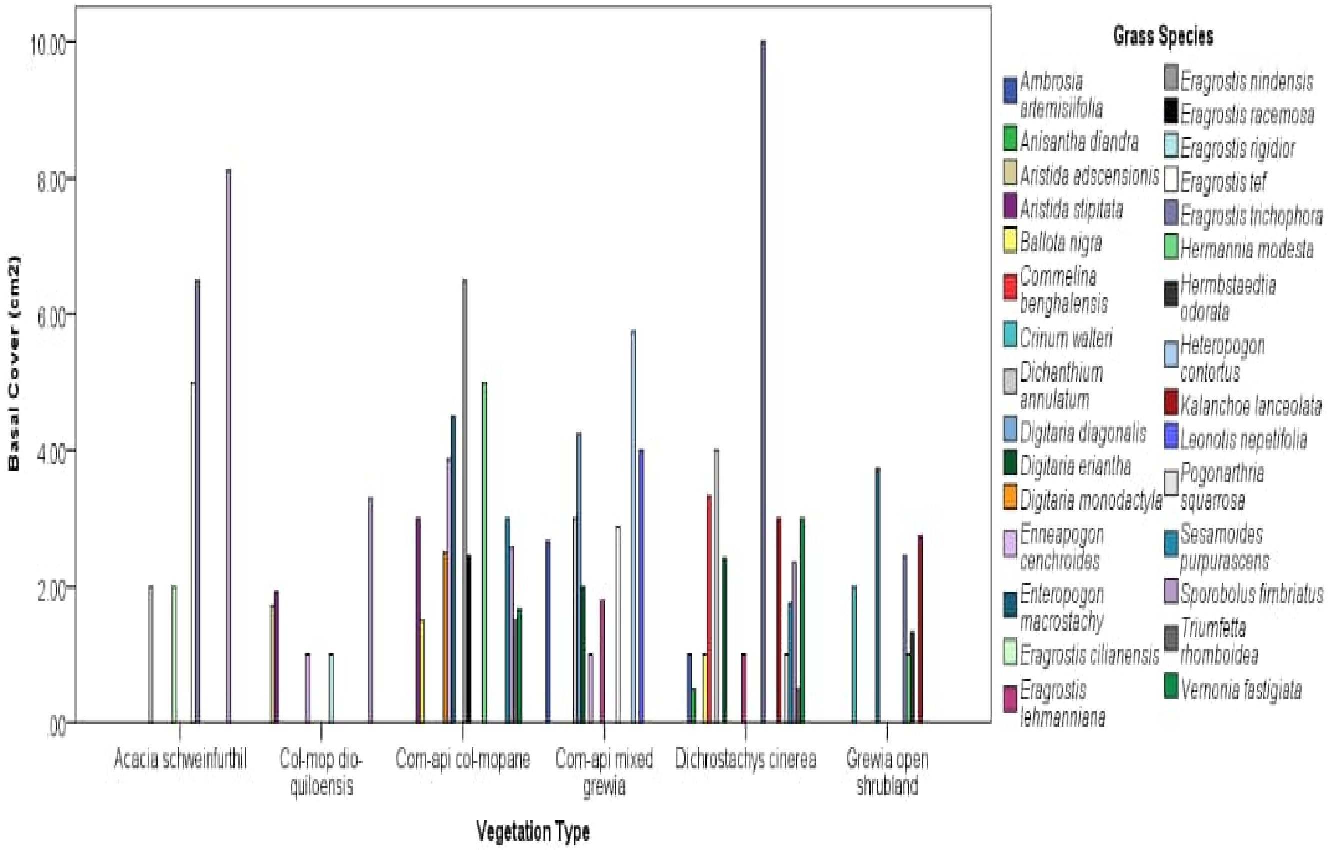

Figure 21: Basal cover of grasses in different vegetation types

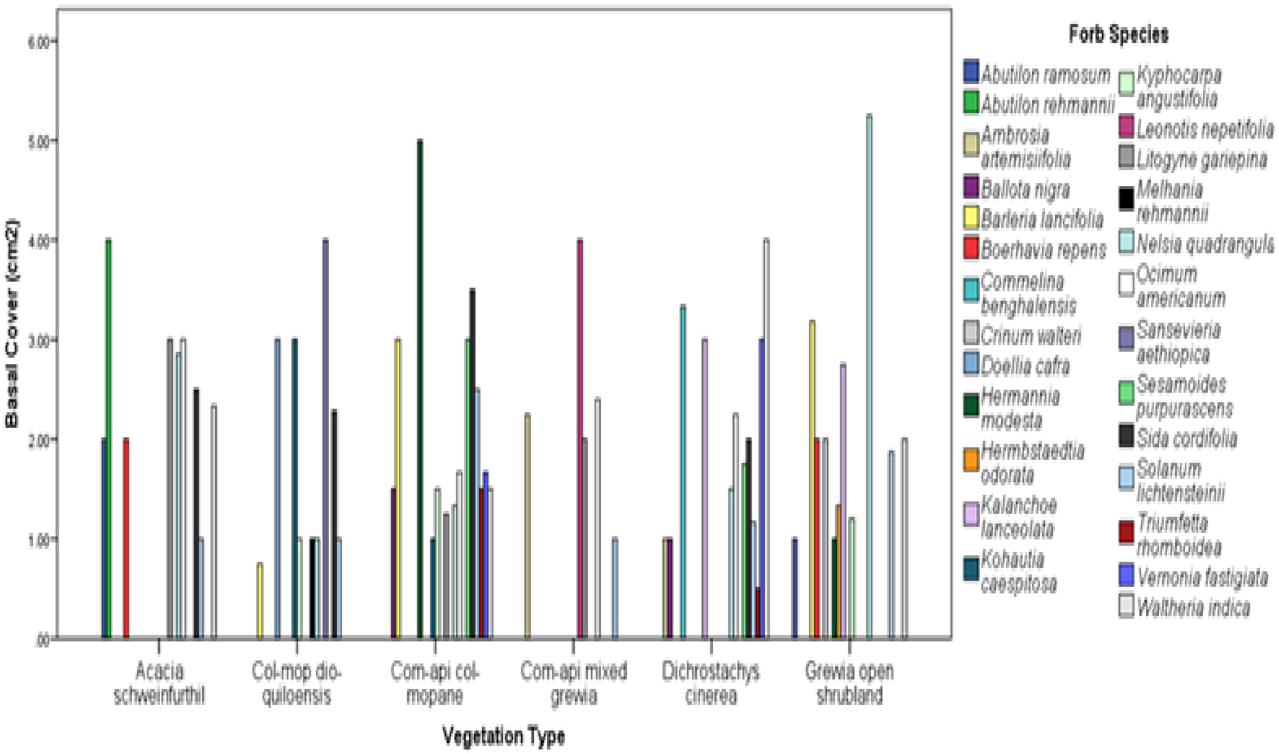

Figure 22: Basal cover of forbs in different vegetation types

CHAPTER 5: DISCUSSION

5.1 Species Diversity

The findings of the study were in line with the prediction, that vegetation type is likely to influence the taxonomic diversity and functional traits of grasses and forbs. The findings demonstrated that these vegetation types received an uneven distribution of resources such as nutrients, sunlight and water, hence differences in composition, structure and diversity of woody plants (trees and shrubs). The low Shannon tree diversity indices show that certain tree species can surpass others in their ability to compete for essential resources such as light, water, and nutrients. According to Ruger *et al*., (2011) all plant species tend to exhibit faster growth rates in areas where light availability is the greatest.

All vegetation types showed very low shrub species diversity suggesting that the distribution and clustering of juvenile shrubs in relation to adult plants may be driven by a nurse-protégé dynamic (Callaway, 1995). In this nurse-protégé model, the adult plants (trees) act as nurse plants that create a favourable environment for the growth and establishment of the juvenile protégé plants (shrubs) (Callaway, 1995). This facilitation likely occurs through the nurse plants providing things like shade, shelter, and potentially even nitrogen fixation, which helps the protégé juveniles to germinate and thrive successfully.

The same interactions also explain the low diversities recorded for grasses. As stated above, different vegetation types create different microclimates (Stoutjesdijk and Barkman, 2015) that accommodate the growth of different species. This can be due to differences in soil nutrient concentrations and competitive interactions. Similar findings were recorded in the central highlands of Madagascar where Tapia woodland grass species showed higher species richness and phylogenetic diversity compared to grassland due to heterogeneity in tree cover (Solofondranohatra *et al*., 2018).

All vegetation types also showed very low forb species diversity. The similarity in forb species diversity within these vegetation types can be attributed to the surrounding environmental conditions. Specific environmental factors like extreme temperatures, restricted water availability, soils lacking in nutrients, or high salinity can create difficult circumstances for numerous forb species.

5.2 Growth Parameters

Grasses in *Acacia schweinfurthil* vegetation type were much taller than those in *Grewia* open shrub land. *Acacia schweinfurthil* is close to the river, and therefore there is adequate water to facilitate the growth of grasses. Cao *et al*., (2012) explained that the maximum height of grasses is determined by roots. The findings of this study showed significant differences in grasses under tree canopies and open vegetation types because tree canopies have the ability to change the microclimate beneath them by lessening temperature fluctuations, increasing humidity and decreasing wind speed (Gilbert, 2000). These modified environmental conditions can favour the growth of certain species that are adapted to such microclimates, resulting in taller grasses compared to open areas.

The characteristics of grasses and forbs, such as height, pinnacle height, internode length, leaf area, leaf thickness, aerial cover, and basal cover, are influenced by the type of vegetation they grow in. This is because different plant species have inherent genetic traits and growth patterns that give them advantages in certain vegetation types. For instance, the grass species *Aristida stipitata* may outcompete other grasses in the same environment.

The length of internodes in grasses and forbs is related to the availability of light. In dense vegetation with limited light, like *Acacia schweinfurthii*, these plants tend to have longer internodes as they compete to access sunlight. Conversely, in more open vegetation types like *Grewia* open shrub land, grasses and forbs exhibit shorter internodes since light is more readily available. Similar to this finding, von Oheimb and Härdtle, (2009) reported that canopy openness increases the proportion of light demanding species and species richness and diversity as well.

Similarly, the leaf area of grasses and forbs varies across different vegetation types, likely due to their adaptations to factors such as sunlight, moisture, and nutrient levels. Additionally, forbs in habitats with high herbivory pressure may develop thicker leaves as a defense mechanism. Taboada *et al*., (2011) demonstrated that heavy grazing and the associated trampling effect can have several detrimental impacts on the environment. Specifically, they found that heavy grazing increases soil temperature and compaction, while also decreasing water infiltration and overall water availability. These environmental changes ultimately led to a decline in plant community composition, above-ground biomass, leaf area, and light interception.

The aerial and basal cover of grasses and forbs is influenced by their competitive interactions with other plant species. Open vegetation types like *Dichrostachys cinerea* provide conditions that favour grass growth, while the closed canopy of *Colophospermum_mopane-Diospyros_quiloensis* restricts light and reduces grass cover. Other studies confirmed our result indicating that canopy closure, was the important factors influencing understory vegetation composition.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study provides evidence that taxonomic diversity and functional traits of both grasses and forbs change with different vegetation types. It also provides evidence that grasses and forbs adopt different ecological strategies in response to different vegetation types. Vegetation types with specific structural and environmental characteristics select for particular functional traits and strategies. It was observed that, in more open vegetation types, grasses and forbs had traits that enable efficient resource acquisition and rapid growth (higher leaf area), while in denser vegetation types, they exhibited traits for shade tolerance or greater resource conservation (reduced leaf area). These observed patterns likely arise from variations in environmental conditions, resource availability, and competitive interactions associated with the distinct vegetation types.

This study provides a reference baseline for monitoring changes in grasses and forbs structure which is of vital importance to the ecology of Chishakwe Safari. While the vegetation type present can be an important factor in shaping the characteristics of semi-arid environments, other factors like herbivory may play a more significant role in structuring the functional traits and diversity of grasses and forb

6.2 Recommendations

It is recommended that ecologists and conservationists should recognize the specific vegetation types that support high diversity and unique functional traits, and prioritize the protection of these habitats to maintain overall ecosystem health and resilience. Further research is recommended to enhance our understanding of the relationship between vegetation type, taxonomic diversity, and functional traits. This can include investigating additional vegetation types, extending the study area, or exploring other factors that influence grass and forb communities.

References

André T C Dias 1, Eveline J Krab, Janine Mariën, Martin Zimmer, Johannes H C Cornelissen, Jacintha Ellers, David A Wardle, Matty P Berg .(2013). Traits underpinning desiccation resistance explain distribution patterns of terrestrial isopods. Oecologia 172, 667–677

Andrew Siefert, Catherine Ravenscroft, David Althoff, Juan C. Alvarez-Yépiz, Benjamin E. Carter, Kelsey L. Glennon, J. Mason Heberling, In Su Jo, Alyssa Pontes, Amy Sauer, Adam Willis, Jason D. Fridley (2012). Scale dependence of vegetation-environment relationships: a meta-analysis of multivariate data. Journal of Vegetation Science, 23, 942–951. https://doi.org/10.1111/j.1654-1103.2012.01401.x

Angela T. Moles, David I. Warton, Laura Warman, Nathan G. Swenson, Shawn W. Laffan, Amy E. Zanne, Andy Pitman, Frank A. Hemmings, Michelle R. Leishman. (2009). Global patterns in plant height. Journal of Ecology, 97, 923-932

Ballantyne M, Pickering CM. 2015. Shrub facilitation is an important driver of alpine plant community diversity and functional composition. Biodiversity and Conservation 24: 1859-1875

Bram Van Wyk. (2000). Field Guide to trees of Southern Africa

Brian J. McGill, Brian J. Enquist, Evan Weiher, Mark Westoby. (2006). Rebuilding community ecology from functional traits. Trends Ecol Evol 21, 178-185.

Bulleri F, Bruno JF, Silliman BR, Stachowicz JJ. 2016. Facilitation and the niche: implications for coexistence, range shifts and ecosystem functioning. Functional Ecology 30: 70-78

Butterfield BJ, Callaway RM. 2013. A functional comparative approach to facilitation and its context dependence. Functional Ecology 27: 907-917

C Mashapa (2018). Human Livelihoods and Sustainable Conservation: Herbivory and Anthropogenic Impacts on Woody Vegetation and Ecosystem Goods in Save Valley, Southeastern Lowveld of Zimbabwe

Callaway, R.M., (1995). Positive interactions among plants. The Botanical Review, 61(4), pp.306-349.

Cao KF, Yang SJ, Zhang YJ, Brodribb TJ. The maximum height of grasses is determined by roots. Ecol Lett. 2012 Jul; 15(7): 666-672. doi:10.1111/j.1461-0248.2012.01783x. Epub 2012 Apr 11. PMID: 22489611.

Cernansky, R. (2017). The biodiversity revolution. Nature 546, 22–24 Christian Schöb, Bradley

Cyrille Violle, Marie-Laure Navas, Denis Vile, Elena Kazakou, Claire Fortunel, Irène Hummel, Eric Garnier (2007). Let the concept of trait be functional! https://doi.org/10.1111/j.0030-1299.2007.15559.xCitations: 3,004

Cyrille Violle, Peter B. Reinch, Stephen W. Pacala, Jens Kattge (2014). The emergence and promise of functional biogeography.

Dainese M, Leps J, de Bello F (2015). Different effects of elevation, habitat fragmentation and grazing management on the functional, phylogenetic, and taxonomic structure of mountain grassland. Perspect Plant Ecol Evol Syst 17: 44-53

Dana Michalcová, Milan Chytrý, Vilém Pechanec, Ondřej Hájek, Jan W. Jongepier, Jiří Danihelka, Vít Grulich, Kateřina Šumberová, Zdenka Preislerová, Anne Ghisla, Giovanni Bacaro & David Zelený (2014). High plant diversity of grasslands in a landscape context: a comparison of contrasting regions in Central Europe. Folia Geobotanica 49: 117-135

David Tilman, Forest Isbell, Jane M. Cowles (2014). Biodiversity and ecosystem functioning. Annual review of Ecology, Evolution and Systematics. Vol 45: 471-493

Dengler, J., Biurrun, I., Boch, S., Dembicz, I. and Török, P. (2020b) Grasslands of the Palaearctic biogeographic realm: introduction and synthesis. In: M.I. Goldstein and D.A. DellaSala (Eds.) Encyclopedia of the World's biomes (pp. 617–637). Oxford: Elsevier.

E. Kathryn Morris, Tancredi Caruso, Francois Buscot, Markus Fischer, Christine Hancock, Tanja S. Maier, Torsten Meiners, Caroline Muller, Elisabeth Obermaier8, Daniel Prati7, Stephanie A. Socher7, Ilja Sonnemann1, Nicole Waschke , Tesfaye Wubet, Susanne Wurst1 & Matthias C.Rillig (2014). Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. Department of Biology, Xavier University, 3800 Victory Parkway

Edwin Lebrija-Trejos, Eduardo A. Perez-Garcia, Jorge A. Meave, Frans Bongers, Lourens Poorter (2010). Functional traits and environmental filtering drive community assembly in a species-rich tropical system. Ecology Vol 91

Fabio Carvalho, Kerry A Brown, Martyn P Waller, Onja H Razafindratsima, Arnoud Boom, (2020). Changes in functional, phylogenetic and taxonomic diversities of lowland fens under different vegetation and disturbance levels. Plant Ecology 221: 441-457

Forest Isbell, Dylan Craven, John Connolly, Michel Loreau, Bernhard Schmid, Carl Beierkuhnlein, T. Martijn Bezemer, Catherine Bonin, Helge Bruelheide, Enrica de Luca, Anne Ebeling, John N. Griffin, Qinfeng Guo, Yann Hautier, Andy Hector, Anke Jentsch, Jürgen Kreyling, Vojtěch Lanta, Pete Manning, Sebastian T. Meyer, Akira S. Mori, Shahid Naeem, Pascal A. Niklaus, H. Wayne Polley, Peter B. Reich, Christiane Roscher, Eric W. Seabloom, Melinda D. Smith, Madhav P. Thakur, David Tilman, Benjamin F. Tracy, Wim H. van der Putten, Jasper van Ruijven, Alexandra Weigelt, Wolfgang W. Weisser, Brian Wilsey & Nico Eisenhauer. Biodiversity increases the resistance of ecosystem productivity to climate extremes. Nature 526, 574–577 (2015). https://doi.org/10.1038/nature15374

Francesco de Bello, Sandra Lavorel, Sandra Díaz, Richard Harrington, Johannes H. C. Cornelissen, Richard D. Bardgett, Matty P. Berg, Pablo Cipriotti, Christian K. Feld, Daniel Hering, Pedro Martins da Silva, Simon G. Potts, Leonard Sandin, Jose Paulo Sousa, Jonathan Storkey, David A. Wardle & Paula A. Harrison. (2010). Towards an assessment of multiple ecosystem processes and services via functional traits. Biodivers. Conserv. 19, 2873–2893

Frank Sterck, Lars Markesteijn, Feike Schiveng, Lourens Poorter (2011). Functional traits determine trade-offs and niches in a tropical forest community. 108(51): 20627-20632

Frits Van Oudtshoorn (2002). Guide to grasses of Southern Africa

Garnier, E, Marie-Laure Navas, Karl Grigulis. (2016). Plant Functional Diversity. Organism traits, community structure, and ecosystem properties, Oxford University Press

Gary W. Luck, Andrew Carter, Lisa Smallbone., 2013. Changes in bird functional diversity across multiple land uses: interpretations of functional redundancy depend on functional group identity. PLoS ONE, 8 (2013), p. e6371

Gilbert Aussenac, 2000. Interactions between forest stands and microclimate: Eco physiological aspects and consequences for silviculture. Ann. For. Sci., 57 3 (2000) 287-301. DOI: https://doi.org/10.1051/forest:2000119

J. Bastow Wilson, Robert K. Peet, Jürgen Dengler, Meelis Pärtel. (2012) Plant species richness: the world records. Journal of Vegetation Science, 23, 796–802.

J. Butterfield, Francisco I. Pugnaire (2012). Foundation species influence trait-based community assembly. New Phytologist 196: 824-834

J. G. Guerra, F. Cabello, C. Fernandez-Quintanilla, J. M. Pena, J. Dorado. (2022). How weed management influence plant community composition, taxonomic diversity and crop yield? A long-term study in a Mediterranean vineyard. Agriculture, Ecosystems and Environment 326

Jan Lepš, Maria Májeková, Alena Vítová, Jiří Doležal, Francesco de Bello. (2018). Stabilizing effects in temporal fluctuations: management, traits, and species richness in high-diversity communities. Ecology 99, 360–371

Jan Lepš. (2013). Diversity and ecosystem function. In Vegetation Ecology. 2nd edn. (van der Maarel, E. and Franklin, J., eds), pp. 308–346, Wiley, Oxford

Jennifer L. Funk, Julie E. Larson, Gregory M. Ames, Bradley J. Butterfield, Jeannine Cavender-Bares, Jennifer Firn, Daniel C. Laughlin, Ariana E. Sutton-Grier, Laura Williams, Justin Wright. (2017). Revisiting the Holy Grail: using plant functional traits to understand ecological processes. Biological 579 Reviews 92, 1156-1173

Jeremy W Fox (2005). Interpreting the ‘selection effect’ of biodiversity on ecosystem function. Ecology Letters 8(8), 846-856

Jiang, Zhang and Wang. (2007). Effects of different components of diversity on productivity in artificial plant communities. Ecological Research, 22, 629-634.

Jiri Dolezal , Miroslav Dvorsky , Martin Kopecky, Jan Altman, Ondrej Mudrak 1, Katerina Capkova, Klara Rehakova, Martin Macek, Pierre Liancourt (2019). Functionally distinct assembly of vascular plants colonizing alpine cushions suggests their vulnerability to climate change. Annals of Botany 123: 569-578

JM Levine, J HilleRisLambers. (2009). The importance of niches for the maintenance of species diversity. Nature 461, 254-257.

Knapp, S., Winter, M., & Klotz, S. (2017). Increasing species richness but decreasing phylogenetic richness and divergence over a 320year period of urbanization. Journal of Applied Ecology, 54(4), 1152–1160.

L. Watson, M. J. Dallwitz, A. J. Gibbs, and R. J. Pankhurst. Automated taxonomic descriptions.Prospects in systematics 36, 297-304, 1988

Liu, J., Zhang, X., Song, F., Zhou, S., Cadotte, M.W. and Bradshaw, C.J., 2015. Explaining maximum variation in productivity requires phylogenetic diversity and single functional traits. Ecology, 96(1), pp.176-183.

M. P. Veldhuis, E. S. Kihwele, J. P. G. M. Cromsigt, J. O. Ogutu, J. G. C. Hopcraft, N. Owen-Smith, H. Olff. (2019). Large herbivore assemblages in a changing climate: Incorporating water dependence and thermoregulation. Ecol. Lett. 22, 1536–1546

Marc W Cadotte (2017). Functional traits explain ecosystem function through opposing mechanisms. Ecology Letters 20(8), 989-996

Maria Májeková, Francesco de Bello, Jiří Doležal, Jan Lepš. (2014). Plant functional traits as determinants of population stability. Ecology 95, 2369–2374

Mariya A. Polyakova, Iwona Dembicz, Thomas Becker, Ute Becker, Olga N. Demina, Nikolai Ermakov, Goffredo Filibeck, Riccardo Guarino, Monika Janišová, Renaud Jaunatre, Łukasz Kozub, Manuel J. Steinbauer, Kohei Suzuki & Jürgen Dengler. (2016) Scale-and taxon-dependent patterns of plant diversity in steppes of Khakassia, South Siberia (Russia). Biodiversity and Conservation, 25, 2251–2273.

Nadja Rüger, Uta Berger, Stephen P. Hubbell, Ghislain Vieilledent, Richard Condit (2011). Growth strategies of tropical tree species: disentangling light and size effects. PLoS One, 6(9), p.e25330

Nancy B. Grimm , Stanley H. Faeth, Nancy E. Golubiewski, Charles L. Redman, Jianguo Wu, Xuemei Bai and John M. Briggs (2008). Global Change and the Ecology of Cities. Science, 664 319(5864), 756–760. https://doi.org/10.1126/science.1150195

Nathan J. B. Kraft, Oscar Godoy, and Jonathan M. Levine. (2015). Plant functional traits and the multidimensional nature of species coexistence. Proc. Natl. Acad. Sci. U. S. A. 112, 797–802

Olden, J.D., Poff, N.L., Douglas, M.R., Douglas, M.E. and Fausch, K.D., 2004. Ecological and evolutionary consequences of biotic homogenization. Trends in ecology & evolution, 19(1), pp.18-24.

P. A. Lindsey, S. S. Romañach, H. T. Davies-Mostert (2009). The importance of conservancies for enhancing the value of game ranch land for large mammal conservation in southern Africa. Journal of Zoology, 277(2), 99–105.

Pakeman RJ (2011). Functional diversity indices reveal the impacts of land use intensification on plant community assembly. J Ecol 99:1143-1151

Peter B. Reich. (2014). The world-wide ‘fast-slow’ plant economics spectrum: a traits 610 manifesto. Journal of Ecology 102, 275-301.

Pole, A. (2006). ‘Management plan for the Save Valley Conservancy’.

S. Diaz, J.G. Hodgson, K. Thompson, M. Cabido, J.H.C. Cornelissen, A. Jalili, G. Montserrat-Martí, J.P. Grime, F. Zarrinkamar, Y. Asri, S.R. Band, S. Basconcelo, P. Castro-Díez, G. Funes, B. Hamzehee, M. Khoshnevi, N. Pérez-Harguindeguy, M.C. Pérez-Rontomé, F.A. Shirvany, F. Vendramini, S. Yazdani, R. Abbas-Azimi, A. Bogaard, S. Boustani, M. Charles, M. Dehghan, L. de Torres-Espuny, V. Falczuk, J. Guerrero-Campo, A. Hynd, G. Jones, E. Kowsary, F. Kazemi-Saeed, M. Maestro-Martínez, A. Romo-Díez, S. Shaw, B. Siavash, P. Villar-Salvador, M.R. Zak (2004). The plant traits that drive ecosystems: evidence from three continents. J. Veg. Sci. 15, 295–304

S. Diaz, M. Cabido (2011). Vive la difference: plant functional diversity matters to ecosystem processes. Trenas Ecol Evol 16:645-655

Sandra Diaz, JG Hodgson, K Thompson, M Cabido, Johannes HC Cornelissen, A Jalili, G Montserrat-Martí, JP Grime, Fvcx Zarrinkamar, Y Asri, SR Band, S Basconcelo, P Castro‐Díez, G Funes, B Hamzehee, M Khoshnevi, N Pérez‐Harguindeguy, MC Pérez‐Rontomé, FA Shirvany, F Vendramini, S Yazdani, R Abbas‐Azimi, A Bogaard, S Boustani, M Charles, M Dehghan, L de Torres‐Espuny, V Falczuk, J Guerrero‐Campo, A Hynd, G Jones, E Kowsary, F Kazemi‐Saeed, M Maestro‐Martínez, A Romo‐Díez, S Shaw, B Siavash, P Villar-Salvador, MR Zak. The plant traits that drive ecosystems: evidence from three continents Journal of vegetation science 15 (3), 295-304, 2004

Sandra Lavorel, Jonathan Storkey, Richard D. Bardgett, Francesco de Bello, Matty P. Berg, Xavier Le Roux, Marco Moretti, Christian Mulder, Robin J. Pakeman, Sandra Díaz, Richard Harrington. (2013). A novel framework for linking functional diversity of plants with other trophic levels for the quantification of ecosystem services. J. Veg. Sci. 24, 942–948

Santiago Soliveres, Fons van der Plas, Peter Manning, Daniel Prati, Martin M. Gossner, Swen C. Renner, Fabian Alt, Hartmut Arndt, Vanessa Baumgartner, Julia Binkenstein, Klaus Birkhofer, Stefan Blaser, Nico Blüthgen, Steffen Boch, Stefan Böhm, Carmen Börschig, Francois Buscot, Tim Diekötter, Johannes Heinze, Norbert Hölzel, Kirsten Jung, Valentin H. Klaus, Till Kleinebecker, Sandra Klemmer, Jochen Krauss, Markus Lange, E. Kathryn Morris, Jörg Müller, Yvonne Oelmann, Jörg Overmann, Esther Pašalić, Matthias C. Rillig, H. Martin Schaefer, Michael Schloter, Barbara Schmitt, Ingo Schöning, Marion Schrumpf, Johannes Sikorski, Stephanie A. Socher, Emily F. Solly, Ilja Sonnemann, Elisabeth Sorkau, Juliane Steckel, Ingolf Steffan-Dewenter, Barbara Stempfhuber, Marco Tschapka, Manfred Türke, Paul C. Venter, Christiane N. Weiner, Wolfgang W. Weisser, Michael Werner, Catrin Westphal, Wolfgang Wilcke, Volkmar Wolters, Tesfaye Wubet, Susanne Wurst, Markus Fischer & Eric Allan (2016). Biodiversity at multiple trophic levels is needed for ecosystem multifunctionality. Nature, 536, 456–459.

Stefan Karlowsky, Angela Augusti, Johannes Ingrisch, Roland Hasibeder, Markus Lange, Sandra Lavorel, Michael Bahn, Gerd Gleixner.(2018). Land use in mountain grasslands alters drought response and recovery of carbon allocation and plant-microbial interactions. J. Ecol. 106, 1230–1243

Stoutjesdijk, P.H. and Barkman, J.J., 2015. Microclimate, vegetation & fauna. Brill.

Taboada, M. A., Rubio, G., & Chaneton, E. J. (2011). Grazing impacts on soil physical, chemical and ecological properties in forage production systems. In: Jerry, L.H. & Thomas, J.S. Soil management: Building a stable base for agriculture (pp. 301-320). Washington, USA: American Society of Agronomy and Soil Science.

Tom H. Oliver, Matthew S. Heard, Nick J.B. Isaac, David B. Roy, Deborah Procter, Felix Eigenbrod, Rob Freckleton,Andy Hector, C. David L. Orme, Owen L. Petchey, Vânia Proença, David Raffaelli, K. Blake Suttle, Georgina M. Mace, Berta Martín-López,Ben A. Woodcock, James M. Bullock. (2015). Biodiversity and resilience of ecosystem functions. Trends Ecol. Evol. 30, 673–684

Valério D. Pillar, Carolina C. Blanco, Sandra C. Müller, Enio E. Sosinski, Fernando Joner, Leandro D. S. Duarte (2013). Functional redundancy and stability in plant communities. J Veg Sci 24:963-974

von Oheimb, G. and W. Härdtle. 2009. Selection harvest in temperate deciduous forest: impact on herb layer richness and composition. *Biodivers. Conserv.* 18: 271-287.

Yann Hautier, Pascal A Niklaus, Andy Hector (2009). Competition for light causes plant biodiversity loss after eutrophication. Science 324 (5927), 636-638

NYATHI MIRACULOUS B202502B.docx

ORIGINALITY REPORT

15%	13%	11%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	link.springer.com Internet Source	3%
2	scholar.ufs.ac.za Internet Source	2%
3	dx.doi.org Internet Source	2%
4	academic.oup.com Internet Source	1%
5	www.zora.uzh.ch Internet Source	1%
6	Gubsch, M., N. Buchmann, B. Schmid, E.-D. Schulze, A. Lipowsky, and C. Roscher. "Differential effects of plant diversity on functional trait variation of grass species", Annals of Botany, 2011. Publication	1%
7	onlinelibrary.wiley.com Internet Source	1%

8	Barbier, S.. "Influence of tree species on understory vegetation diversity and mechanisms involved-A critical review for temperate and boreal forests", Forest Ecology and Management, 20080115 Publication	1 %
9	elibrary.buse.ac.zw:8080 Internet Source	1 %
10	cyberleninka.org Internet Source	1 %
11	ecologicalprocesses.springeropen.com Internet Source	1 %
12	Marcos B. Carlucci, Pedro H. S. Brancalion, Ricardo R. Rodrigues, Rafael Loyola, Marcus V. Cianciaruso. "Functional traits and ecosystem services in ecological restoration", Restoration Ecology, 2020 Publication	1 %
13	iproject.com.ng Internet Source	1 %

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		