BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIROMENTAL SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

AN ANALYSIS OF NUTRITIONAL COMPOSITION, SPECIES COMPOSITION AND DIVERSITY OF DIFFERENT PASTURES FOR ENHANCED DAIRY PRODUCTION, MASHONALAND EAST PROVINCE

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE IN ANIMAL SCIENCE

JUNE 2025

DECLARATION

I Lynnette Paridzayi Mangwanda, declare that this project hereby submitted for the Bachelor of Science Honours Degree in Animal Science and Technology at Bindura University of Science Education, is entirely my original work and affirm that it has not been submitted anywhere for the award of a degree or otherwise.

Topic: An analysis of nutritional composition, species composition and diversity of different pastures for enhanced dairy production, Mashonaland East province.

Lynnette P.Mangwanda……………………………… Date…31August 2025……..

Supervisors' declaration:

Mr T.N.C Mangwiro Date 31/08/2025

I certify that I have checked this research project and am satisfied that it conforms to the Department of Animal Sciences guidelines for Project Preparation and Presentation. I therefore authorise the student to submit this dissertation for marking.

Date…31/08/2025

Chairperson Date 07/10/25

DEDICATION

Dedicated to my family. Thanks to the Almighty.

ACKNOWLEDGEMENTS

I would like to extend special gratitude to my main supervisor Mr T.N.C Mangwiro (BUSE) and Co-supervisors Mr Pashapa (Grasslands) for their invaluable contributions making this thesis a success. Warm acknowledgements to Dr Masunda for making this thesis a success. Sincere acknowledgements to Mr Marlon Chawarika (Grasslands) for the undying support in writing of this thesis. Acknowledgements to Mr Duri for his contribution. Thumbs up to Mr Moyana and Mr Rukwava for their undying assistance during pasture sample collection, they made it happen.

ABSTRACT

An experimental study was done at Grasslands Research Station, Marondera, Zimbabwe between January and March (2025). The reason being that climate change disrupts Zimbabwe's pasture ecosystems, compromising quality, milk production, and increasing feed costs. Sustainable pasture management strategies are urgently needed to restore productivity and sustainability to the dairy industry.

The study overall objectives were to evaluate the nutritional composition of different pastures at Grasslands Research Station, four pastures were compared i.e Established combo, Monopasture, Natural combo and Silvopastures.

Species composition and nutritional content i.e. Crude Protein, Neutral Detergent Fibre, Acid Detergent Fibre, Ash and Dry Matter were determined. Species composition was done using Peter Ivy method and nutrient composition was done using proximate analysis. Results were analysed using GenStat version 18 and means were separated using Fisher's test.

There was no significant difference in nutritional composition among the four different pastures. CP $p<0.05$, ADF $p=0.013$, NDF $p=0.555$, Ash $p<0.001$

Variation in protein content means some pasture types are more suitable for pasture based dairy production than others.

The studies show that established combo pastures can enhance dairy production due to high CP content and fibre content where a balance of grasses and legumes are incorporated into the pastures

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CHAPTER 1

1:1 Introduction

The global industry is shifting towards more sustainable and environmentally friendly practices in relation to pastures. Research has shown that grazing based dairy systems can provide numerous benefits including reduced greenhouse emissions, improved biodiversity and enhanced animal welfare (Delaby *et al*., 2020). In terms of global milk production, Food and Agriculture Organization (FAO) reports world milk production reached nearly 906 million tonnes in 2020, up 2% from 2019 (FAO, 2021). The majority of milk production comes from cows, with India being the largest milk producer, accounting for 22% of global production (OECD-FAO, 2020). The global dairy industry is facing increasing pressure to improve the efficiency, sustainability, and environmental impact of dairy production systems (Gerber *et al*., 2013; IPCC, 2013). One key strategy for achieving these goals is through the adoption of diverse and resilient pasture systems that can provide high-quality feed for dairy cows while minimizing environmental degradation (Smit *et al.*, 2015; Vandermeulen *et al.*, 2016.

However, Consumers are increasingly seeking out grass-fed dairy products, driving demand for pasture-based dairy systems (OECD-FAO, 2020). Moreno, The dairy industry is vulnerable to climate change and weather variability, which can impact milk production and quality (Delaby *et al*., 2020). On the other hand, the industry is focusing on improving animal health and welfare, with many countries implementing stricter animal welfare standards (OECD-FAO, 2020). Southern Africa is characterised by a growing focus on sustainable and environmentally friendly practises. Key trends include increased adoption of rotational grazing (Muller *et al*, 2020), also growing demand for grass-fed dairy products (MPO, 2024) dairy is a significant contributor to the agricultural sector. For instance, in Zambia and Zimbabwe, dairy value chains are being developed to foster agro-processing and enhance cross-border trade (FAO, 2020). Pasture-based dairy farming is a significant sector in Southern Africa, particularly in countries like South Africa and Zimbabwe. In South Africa, pasture management is crucial for dairy farming, with a focus on planting pastures that can supply food for animals throughout the year.

Zimbabwe's dairy sector is highly competitive and has significant growth potential. The sector contributes to the country's agricultural output, which accounted for 17% of GDP in 2022 (World Bank, 2022). However, the sector faces challenges such as animal health issues, diseases, and limited financing (Moyo *et al.*, 2020). The dairy sector also provides employment opportunities, generates income, and contributes to food security. In Zimbabwe, the sector supports the livelihoods of many smallholder farmers, who rely on dairy farming as a source of income (Chitambo *et al.*, 2020).

In Zimbabwe, pasture-based dairy farming faces challenges such as limited feed resources, inadequate animal husbandry practices, and breeding limitations. Successful Pasture-Based Dairy Example in Zimbabwe is the Nharira/Lancashire Dairy Project: This project demonstrated the viability of smallholder dairy farming in Zimbabwe, with a focus on improving milk production and animal husbandry practices.

Pasture systems are a critical component of dairy production, providing a source of feed, fibre, and nutrients for dairy cows (Buxton & Fales, 1994; Frame, 2011). However, the type and management of pasture systems can have a significant impact on dairy cow productivity, environmental sustainability, and overall farm profitability (Orr et al., 2012; Michalk *et al*., 2015). Furthermore, they are a vital component of the dairy industry, providing numerous benefits including enhancing soil health, maintaining biodiversity and promoting ecosystem services (Finn *etal*, 2020). They also provide a low-cost feed option for farmers, reducing reliance on expensive concentrates. A study by Knaus, W. (2017) found that feed costs account for approximately 50-60% of total dairy production costs. However, pasture based dairy farming can be more cost effective than conventional as it reduces the need for purchased feed and inputs (McEvoy *et al*, 2018). Notably, the International Dairy Federation (IDF) (2019) reported that feed costs are the largest single expense for dairy farmers, accounting for around 40-50% of total costs. In addition to that, pasture based systems tend to have lower carbon footprints, less than 30% compared to concentrate based. This is due to the reduced need for synthetic fertilizers, pesticides and feed inputs. (O'Brien *et al*, 2020. There is also reduced greenhouse gas emissions particularly methane and nitrous oxide (McEvoy *et al*, 2019).

Pastures promote soil carbon sequestration (bio sequestration), the long-term storage of carbon that has the immediate potential to become carbon dioxide gas which plays a crucial role in limiting climate change by reducing the amount of carbon dioxide in the atmosphere. Plants absorb carbon dioxide from the air as they grow, and bind it into biomass. They also require significantly less water compared to concentrate crop production e.g. corn and soybeans. Many pasture plants are drought tolerant, reducing the need for irrigation (Herrero *et al*, 2020). Moreover, due to their deep root systems, it allows them to access water deeper in the soil profile (Finn *et al*, 2020). On another note, pasture-fed animals tend to have improved fatty acid profiles and higher levels of certain micronutrients. Milk and dairy products from cows on pasture-based farms predominantly consuming fresh grazed grass (typically classified as "grass-fed" milk) have been previously shown to possess a different nutrient profile, with potential nutritional benefits, compared with conventional milk derived from total mixed ration. Grass fed milk has been shown to contain higher levels of Alpha Linoleic Acid, a beneficial Omega 3 fatty acid, high Vitamin A and E (Dewhurst *et al*, 2020), high levels of unsaturated fatty acid and lower levels of saturated fatty acids (Butler *et al*,2019). Moreover, pasture-based production systems are considered more environmentally and animal welfare friendly by consumers, (Joubran, A, L *et al* 2021). Pasture feeding has been demonstrated to increase fat and protein contents of milks (O'Callaghan *et al*., 2016b; de la Torre *et al*., 2018; Gulati *et al.*, 2018), noting that the increase in protein and casein can modify the processing properties of milk, in particular rennet-induced gelation (O'Brien *et al*., 1999a; Amenu *et al.*, 2006). More so, there is increased farm profitability by reducing costs, improving animal health, and increasing product quality. Also, consumers are often willing to pay premium prices for products from pasture-raised animals, providing a market advantage for farmers. Indeed, Stampa *et al*, (2020) reported that there are a variety of consumer demographics willing to pay a premium price for pasture-raised attributes, even on top of an already premium organic price. Most importantly, there is literature to provide evidence that dairy feed can be expensive and that pasture-based dairy systems can offer a more cost-effective and sustainable alternative. The study of Webb, E. C., *et al,* (2015) found that pasture-based dairy systems can reduce feed costs by up to 30% compared to conventional systems. Moreover, the authors Hanson, J. C., *et al.* (2017) reported that pasture-based dairy systems can improve profitability by reducing feed costs and increasing milk production. On the other hand, a study by López, D. R., *et al.* (2018) found that pasture-based dairy systems can also improve animal welfare and reduce environmental impacts.

1.2 Objectives

1.2.1 Overall Objective

- To evaluate on the best nutritional composition between combo pastures, monoculture pastures and silvopastures

1.2.2 Specific objectives

- To determine species composition and diversity of different pastures for enhanced dairy production
- To determine nutritional parameters of the different pastures in terms of Dry matter (DM), Crude Protein (CP), Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Ash content of the different pastures for enhanced dairy production

1.3 PROBLEM STATEMENT

Climate change is disrupting pasture ecosystems in Zimbabwe, leading to shifts in species composition and diversity. This alteration compromises pasture quality, negatively impacting milk production and quality, while increasing feed costs (Mugabe *et al*., 2020). Suboptimal pasture management practices exacerbate these issues, resulting in inadequate stock feed, reduced milk yields, and decreased quality. Therefore, there is an urgent need for sustainable pasture management strategies to enhance the overall productivity and sustainability of Zimbabwe's dairy industry.

1.4 HYPOTHESES

H_0: There is no difference in species composition, diversity and nutritional quality in the different pastures

H_1: There is a difference in species composition, diversity and nutritional quality between the different pastures

1.5 JUSTIFICATION

Analysis of pasture samples in terms of ADF, NDF, CP, ASH, species composition and diversity will benefit the dairy farmer, dairy industry and the Government. Pasture-based dairying is a farming system that relies on pastures as the primary source of nutrition for dairy cattle. The nutritive value and species diversity of pastures are critical factors that influence the productivity, profitability, and sustainability of pasture-based dairy farms. This assessment reviews the existing literature on the nutritive value and species diversity of different pastures, with a focus on their implications for pasture-based dairying.

1.5.1 Nutritive Value of Pastures

Pastures have always been and will continue to be a source of forages and nutrients for dairy cattle, including heifers, dry cows, and the milking herd (D.M. Amaral-Phillips, *et al* 2014).however, Climate was found to be a key variable that determines tropical pasture nutritive values (Jayasinghe *et al*, 2022). Furthermore, the nutritive value of pastures is influenced by factors such as pasture species, stage of growth, and management practices. Research has shown that pastures with a mix of grasses and legumes tend to have higher nutritive value than those with a single species (Peri *et al.*, 2020). For example, a study by Humphreys *et al*, (2019) found that pastures with a mix of ryegrass and white clover had higher crude protein and metabolizable energy content than those with ryegrass alone.

1.5.2 Species Diversity of Pastures

Species diversity is an important aspect of pasture ecology, as it influences the stability and resilience of pasture ecosystems. Research has shown that pastures with higher species diversity tend to have better soil health, improved water quality, and increased biodiversity (Lüscher *et al.*, 2019). For example, a study by Muir *et al*. (2019) found that silvopastures with a mix of tree and pasture species had higher species diversity and better soil health than those with a single species. According to Harris *et al*, 2020, in Clover in agriculture: combined benefits for bees, environment, and farmer "Clover and other legumes host the symbiotic root bacteria Rhizobium that fix Nitrogen, reducing the need for Nitrogen fertilizer application. Grass plus clover swards are comparable to grass monocultures given medium to high inorganic Nitrogen inputs in terms of companion grass growth, livestock performance and, yield of subsequently planted crops".

1.5.3 Implications for Pasture-Based Dairying

The nutritive value and species diversity of pastures have important implications for pasture-based dairying. Pastures with high nutritive value and species diversity can support higher milk production and better animal health, while also improving the sustainability and resilience of dairy farming systems. For example, a study by Peri *et al*, (2020) found that dairy farms with pastures that had a mix of grasses and legumes had higher milk production and better profitability than those with pastures that had a single species

The dairy industry is a significant contributor to the global food system, providing essential nutrients and employment opportunities for millions of people worldwide (Gerber *et al*., 2013; FAO, 2017). However, the industry is facing increasing pressure to improve its environmental sustainability, animal welfare, and productivity (IPCC, 2013; Smit *et al*., 2015). One key strategy for achieving these goals is through the adoption of diverse and resilient pasture systems that can provide cheap, high-quality feed for dairy cows while minimizing environmental degradation. Knaus, W. (2017) found that apart from the cost of the animal, feed costs account for approximately 50-60% of total dairy production costs. The IDF (International Dairy Federation) (2019), reported that feed costs are the largest single expense for dairy farmers, accounting for around 40-50% of total costs.

1.5.4 Benefits of pasture based dairy

Webb, E. C., *et al*. (2015), found that pasture-based dairy systems can reduce feed costs by up to 30% compared to conventional systems. On another note, the authors, Hanson, J. C., *et al*. (2017), reported that pasture-based dairy systems can improve profitability by reducing feed costs and increasing milk production. Targeting niche` markets such as grass fed dairy milk, might fetch premium prices on the market. Moreover, a study by López, D. R., *et al*. (2018) found that pasture-based dairy systems can also improve animal welfare and reduce environmental impacts.

A comparative analysis of species diversity and nutritional composition of combo pastures, monoculture pastures, and silvopastures is justified for several reasons: Combo pastures and silvopastures have been shown to improve pasture productivity and nutritional quality compared to monoculture pastures (Haynes & Williams, 1993; Lüscher *et al*., 2014; Peri *et al.*, 2017). They both can provide ecosystem services such as carbon sequestration, soil conservation, and biodiversity conservation (Lauenroth *et al*., 2006; Schellberg *et al.*, 2006; Smit *et al*., 2015). More so, they can provide a more diverse and nutritious diet for dairy cows, improving their welfare and productivity (Michalk *et al.*, 2015; Peri *et al.*, 2017). Adding on to that, combo pastures and silvopastures can improve farm profitability by reducing the need for external inputs such as fertilizers and pesticides (Lüscher *et al*., 2014; Smit *et al*., 2015). Despite the potential benefits of combo pastures, monoculture pastures, and silvopastures, there is a need for further research on their species diversity and nutritional composition.

Specifically, there is a limited understanding of the species diversity of combo pastures, monoculture pastures, and silvopastures, and how this diversity impacts pasture productivity and nutritional quality. The nutritional composition of combo pastures, monoculture pastures, and silvopastures can vary significantly, depending on factors such as climate, soil type, and management practices. Also, there is a need for a comparative analysis of the species diversity and nutritional composition of combo pastures, monoculture pastures, and silvopastures to inform the development of sustainable and resilient dairy production systems. A comparative analysis of species diversity and nutritional composition of combo pastures, monoculture pastures, and silvopastures is justified due to the potential benefits of these pasture systems for dairy production. The research gap in this area highlights the need for further investigation into the species diversity and nutritional composition of these pasture systems

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, an overview of what literature says concerning combo pastures, monoculture pastures and silvopastures shall be discussed in detail. The global dairy industry is facing increasing pressure to improve the efficiency, sustainability, and environmental impact of dairy production systems (Gerber *et al*., 2013; IPCC, 2013). One key strategy for achieving these goals is through the adoption of diverse and resilient pasture systems that can provide high-quality feed for dairy cows while minimizing environmental degradation (Smit *et al.*, 2015; Vandermeulen *et al.*, 2016) Dairy production in tropical regions is often lower than in temperate regions, due to a range of factors including lower nutritive value of forage grasses and adverse climate (Thornton, P.K *et al*, 2011). Mostly tropical cattle are fed a diet that is based essentially on pasture species that generally have low nutritive value, with large seasonal variations in quantity and quality (Boval, M 2015). However, nutrient intensification through planting improved forage options (Capstaff, N.M *et al* .2018), in addition to adopting appropriate harvesting, fertilizing, and grazing practices (Paul, B.K *et al*, 2020), have substantially improved the nutritive value of tropical pastures.

Tropical pasture species predominate in tropical and subtropical climates, and are the primary feed source for grazing livestock including dairy cattle hence the need to analyse their nutritive value (Jayasinghe *et al*, 2022). On another note, improving dairy cattle nutrition through adequate feeding of quality forage, choice of appropriate herbage species and cultivars depends on the adaptability of selected species to the farm environment and the resulting balance between quantity and quality (Boga, M *et al*, 2022).

2.1.1 Types of pastures

Three types of pastures exist in dairy production are monoculture, silvopastures and combo pastures.

2.1.2 Mono Pastures

Mono pastures are composed of a single grass or legume species. They are often used in dairy production due to their simplicity and ease of management. However, they can be more susceptible to pests and diseases. Research by Lüscher *et al.* (2019) found that mono pastures of perennial ryegrass resulted in higher milk production compared to other grass species. However, the study also noted that the lack of biodiversity in mono pastures can lead to reduced soil health and increased environmental impacts. A mono pasture can be only grass e.g. Bermuda grass (*cynodon dactylon*) or only legume e.g. alfalfa (*medicago sativa*).

2.1.3 Silvopastures

Silvopastures are integrated systems that combine trees with pasture and livestock production. They offer several benefits, including; improved soil health and biodiversity, increased livestock productivity and welfare, enhanced ecosystem services, such as carbon sequestration and water cycling. A study by Peri *et al*. (2019) found that silvopastures with a mix of trees and pasture resulted in higher milk production and better animal welfare compared to traditional pasture systems. Examples of plant species found in a silvopasture, trees like egg pine trees *(pinus* spp) integrated with pastures like big bluestem (*andropogon* spp). Despite the potential benefits of combo and silvopastures, further research is necessary to fully understand their nutritive composition and species diversity. The different pasture types can have varying levels of nutrients, depending on factors like soil type, climate, and management practices (Peri *et al.*, 2020). While there is some data on the macronutrient content of combo and silvopastures, there is a lack of research on their micronutrient composition (Humphreys *et al.*, 2019). Different tree species in silvopastures can affect the nutritive composition of the pasture, but more research is needed to understand these interactions (Muir *et al.*, 2019). The complexity of Species Interactions complex interactions between multiple plant and animal species, which are not yet fully understood (Lüscher *et al.*, 2019). Different management practices, such as grazing intensity and tree pruning, can affect species diversity in combo and silvopastures, but more research is needed to optimize these practices (Peri *et al*., 2020). Legumes play a crucial role in maintaining species diversity in combo and silvopastures, but more research is needed to understand their specific contributions (Humphreys *et al.,* 2019).

This comparative analysis aims to investigate the species diversity and nutritional composition of combo pastures, monoculture pastures, and silvopastures and their impact on dairy cow productivity and environmental sustainability. The findings of this research will provide valuable insights for dairy farmers, researchers, and policymakers seeking to develop sustainable and resilient dairy production systems that can meet the demands of a growing global population while minimizing environmental degradation

2.1.4 Combo Pastures

Combo pastures are diverse mixtures of grasses and legumes that offer improved pasture productivity, nutritional quality, and soil health (Haynes & Williams, 1993; Lüscher *et al*., 2014). They can include a mix of grasses e.g. rye grass (*lollium* spp) and legumes e.g. clover (t*rifolium* spp). Studies have shown that combo pastures can provide higher yields and better nutritional quality than monoculture pastures (Orr *et al.,* 2012; Michalk *et al.,* 2015). For example, a study by Orr et al. (2012) found that a combo pasture of ryegrass and white clover produced higher yields and better nutritional quality than a monoculture pasture of ryegrass. Combo pastures combine multiple species of grasses, legumes, and other forages and have gained popularity in recent years due to their potential to improve dairy cattle productivity and farm profitability. A study by Peri *et al,* (2020) found that combo pastures with a mix of ryegrass, clover and plantain resulted in higher milk production and better pasture persistence compared to monoculture pastures. However, there is a need to assess the nutritive value, species composition, and persistence of different species in paddocks to optimize their design and management (Orr *et al*, 2012).

2.1.5 Nutritive Value of Combo Pastures

Several studies have investigated the nutritive value of combo pasture dairy paddocks. A study by Lee *et al*. (2017) found that combo pastures containing a mix of grasses and legumes had higher crude protein and energy content compared to monoculture pastures. Similarly, Wang *et al.* (2019) reported that combo pastures with a mix of grasses, legumes, and herbs had improved nutritive value and reduced fibre content, however the ability of legumes to fix Nitrogen and improve forage productivity and nutritive value makes them a vital component of temperate pastures, but reduced productivity and persistence can occur under grazing compared with mechanical harvest (C.Zegler *et al,* 2018). Sward complementarity leading to increased dry matter. They have also been found to enhance drought tolerance (Haughey *et al*., 2018, Grange *et al.*, 2021), improve soil structure and increase soil porosity compared to grass monocultures (Niklaus *et al.*, 2006, Gould *et al.*, 2016). Such findings could be due to complementary resource utilization and facilitation supported through the adoption of differing growth strategies by different functional groups or indeed individual species (Jing et al., 2017, Grace *et al.*, 2018). Production has also been observed in multispecies swards which include forage herbs along with grasses and legumes (Cranston *et al.*, 2015, Grace *et al.,* 2018, Moloney *et al*., 2020, Baker *et al*., 2023). There is also evidence to the contrary where little difference was observed in Dry Matter production between binary grass &

legume mixtures and more complex multispecies swards including these three plant functional groups (Bryant *et al.*, 2017, Grange *et al*., 2021). Baker *et al*. (2023) indicated that these differences can be subject to sward management intensity which also has a large influence on how much diverse swards can contribute to other ecosystem services and biodiversity (Hoekstra *et al.*, 2023) Grasslands comprised of grass-legume mixtures could become a substitute for nitrogen fertilizer through biological nitrogen fixation (BNF) which in turn can reduce nitrous oxide emissions directly from soils without negative impacts on productivity (Luscher *et al*, 2019) in Modelling biological nitrogen fixation and grass-legume dynamics with process based biogeochemical models of varying complexity.

Biological nitrogen fixation is the source of large annual additions of nitrogen (N) to the terrestrial biosphere. Despite the importance of manufactured fertilizers in crop production, inputs of nitrogen from biological nitrogen fixation to the terrestrial environment have been estimated to be more than double that from fertilizer inputs (Fowler *et al*., 2015; Galloway et al., 2004). There is evidence that greenhouse gas emissions from nitrogen derived from biological nitrogen fixation are lower than those associated with manufactured fertilizers, particularly as a consequence of lower nitrous oxide (N2O) emissions (Jensen *et al.*, 2012; Rochette and Janzen, 2005). The use of legumes, which purportedly provide a better synchronicity of nitrogen supply and plant nitrogen uptake and thus reduce the requirement for nitrogen fertilizer. In a meta-analysis, Jensen *et al.* (2012).

2.1.6 Species Composition of Combo Pasture Dairy Paddocks

The species composition of combo pasture dairy paddocks can vary depending on factors such as soil type, climate, and management practices. A study by Hernandez-Garay *et al*, (2015) found that combo pastures in the South eastern United States were dominated by warm-season grasses, while those in the North eastern United States were dominated by cool-season grasses. Similarly, Chapman *et al*. (2018) reported that combo pastures in New Zealand were dominated by ryegrass and white clover.

2.1.7 Monopastures

Monoculture pastures, on the other hand, consist of a single species of grass or legume and are often associated with reduced biodiversity, increased pest and disease pressure, and decreased soil health (Lauenroth *et al*., 2006; Schellberg *et al*., 2006). Studies have shown that monoculture pastures can lead to reduced pasture productivity and nutritional quality compared to combo pastures (Haynes & Williams, 1993; Lüscher *et al.*, 2014). Monoculture pastures typically consist of a single species of grass or legume thus low species diversity (Lauenroth *et al*, 2006) they have variable nutritional quality depending on the specific species and management practices (Buxton & Fales). However, they may be more prone to nutrient deficiencies, particularly if the single species is not suited to the local climate and soil conditions (Haynes & Williams, 1993).

It is well recognized that grass-based systems are fundamental to the sustainability of livestock production (Michalk *et al*., 2019, Jaramillo *et al*., 2021, Rivero *et al*., 2021).Some economically important grass species e.g. rye grass (*Lolium perenne*), whose productivity heavily depends on high nitrogen inputs(N; Suter *et al*., 2015; Grace *et al*., 2019a). Such dependence on fertilizer N challenges the sustainability of the resulting systems in that; it represents a significant direct cost to farmers (Dillon *et al*., 2021) and increases the risk of loss to the surrounding environment where it can result in loss of biodiversity, water pollution, elevated greenhouse gas emissions and air pollution (Galloway *et al*., 2008, Stark and Richards, 2008, Canfield *et al*., 2010). Legume inclusion in pastures reduces the requirement for fertilizer Nitrogen inputs and can also result in improved herbage dry matter production, weed suppression, habitat provision for pollinators, increased earthworm activity and associated soil water infiltration rates, and improved sward feed value relative to monocultures (Kemp *et al*., 2010, Finn *et al.*, 2013, Lüscher *et al*., 2014, Grace *et al.*, 2018, Cong et al., 2020, Shanel *et al.*, 2021)

Musto GA, *et al* (2023) in "Regenerative agriculture v. conservation agriculture: potential effects on soil quality, crop productivity and whole-farm economics in Mediterranean-climate regions", discussed on monoculture pastures and how they can be beneficially used in rotation with cash crops. The discussion reads; "Monoculture pastures are typically legume based, consisting of either annual medics (*Medicago* spp.), clovers (*Trifolium* spp.) or lupines (*Lupinus* spp.), which are grown in single season rotations with cash crops, or of Lucerne (*Medicago sativa*), which is grown in long phases of up to 7 years and then followed by 5–7 years of cash crops. Whereas grass based pasture phases often include oats (*Avena sativa*) or barley (*Hordeum vulgare*) that is grown during the winter growing season. These pasture phases have also further optimized the beneficial characteristics of CA, particularly via their capacity to improve weed control and break pest and disease cycles, sequester soil carbon, increase biodiversity and improve nutrient cycling (Planisich *et al*., 2021). However, the increased diversity that cover crops offer may provide superior soil quality, crop productivity and ultimately economic benefits compared to monoculture pastures. Perhaps the most significant advantage of multi-species cover crops compared to monoculture pastures is that they do not only offer temporal diversity (through a crop rotation sequence), but also offer spatial diversity".

2.1.8 Silvopastures

Silvopasture is a land management practice wherein trees, forage crops, and livestock are integrated on the same land, providing both short-term as well as long-term economic returns from the area. In silvopasture systems, trees are grown in combination with various forages and grazed by livestock. The trees provide shade for the animals and can serve as a source of browse, timber, and other non-timber forest products. Silvopastures can either be established by thinning an existing tree stand and planting forages underneath the trees or by planting trees within an existing pasture (Sanjok Poudel *et al*, 2024). Furthermore, silvopastoral systems are associations of pastures and trees in the same area (Paciullo *et al.*, 2017). They integrate trees into pasture systems, promoting ecological interactions between trees, grasses, and livestock and providing a range of ecosystem services (Peri *et al.*, 2017; Smit *et al.*, 2015). Silvopasture systems synergistically integrate trees, forage, and livestock, enhancing animal welfare, biodiversity, soil health, and overall agricultural sustainability (Sanjok Poudel *et al*, 2024).

Studies have shown that silvopastures can provide improved pasture productivity, nutritional quality, and soil health compared to monoculture pastures (Lauenroth *et al.*, 2006; Schellberg *et al*., 2006). For example, a study by Peri *et al.* (2017) found that a silvopasture system of trees and pasture produced higher yields and better nutritional quality than a monoculture pasture. Under trees, pastureland productivity generally declines, but there is a trend that the attributes of the tree such as evergreen or deciduous foliage, can determine the outcome of the effect (Silvopastures in Central America, PACA final report, 2010), López, D. R., *et al*. (2018). Environmental impact and animal welfare in pasture-based dairy systems. Journal of Dairy Science, 101(5), 3811-3823.Silvopastures have high species diversity since there will be ecological interaction between trees, grasses and livestock. They can also provide improved nutritional quality for livestock due to the diversity of plant species and the integration of trees. (Peri *et al*. 2017)

Paiva.A.G, *et al*, 2020, in “Differences in the insect fauna associated to a monopasture and a silvopasture in South eastern Brazil”, concluded that; ”Since sustainability of pastures depends upon of organisms that play important roles in maintaining ecological systems, among these the insects, measures should be taken to encourage the implementation of silvopastures on a larger scale”. It also emphasizes that combining pastures with trees creates a diversity of microclimates that increases insect diversity which contains pollinators and natural enemies. Furthermore, silvopasture has the potential to be an effective climate change mitigation and adaptation strategy. However, such potential benefits can only be realized if silvopasture is scaled up and widely adopted by farmers and landowners (Greene *et al*, 2023). In addition to that, Mulubrhan Balehegn,2017 in “Silvopasture Using Indigenous Fodder Trees and Shrubs: The Underexploited Synergy Between Climate Change Adaptation and Mitigation in the Livestock Sector” stated that; silvopastoralism contributes to climate change mitigation and adaptation in the following ways: it is more adaptive to drought, than pastures because foliage production from trees and shrubs is less affected by varying precipitation, temperature and other climatic variables thus enabling farmers to sustain livestock production even at extreme weather condition (Papanastasis *et al*. 2008); woody fodder species in a silvopastoral system increases the fertility of grazing lands there by providing suitable conditions for grasses, and improving micro-sites for grass growth (Moreno and Obrador 2007); livestock productivity is higher under a silvopastoral system compared to traditional pasture based systems, because fodder trees are of higher quality than many of the herbaceous grasses (Ibrahim *et al*. 2005), a fact that also enables reduction in the amount of enteric methane and other GHG from livestock (Williams *et al*. 2011)

A study by Mulubrhan Balehegn in “Silvopasture Using Indigenous Fodder Trees and Shrubs: The Underexploited Synergy between Climate Change Adaptation and Mitigation in the Livestock Sector”, provided an insight into the use of indigenous tree species in the agro-silvopastoral system in future local climate-change adaptation and mitigation programs. Where *Ficus thonningii*, a drought resistant multipurpose indigenous fodder tree was used as a key species in an emerging silvopastoral system. This indigenous innovation silvopastoral system enabled herders in the dryland areas of northern Ethiopia to adapt to recurrent drought, while improving their livelihoods through contribution to much sought after nutritious animal fodder, improvement of soil fertility and maintenance of ecological integrity.

2.1.9 Comparison of Nutritional Composition

Conversion of monocultural pastures to silvopastures can have important consequences on insect fauna involved in essential ecosystem functions, and the implementation of silvopastures at larger scales has the potential to benefit biodiversity conservation and ecosystem service provision at the landscape scale (Paiva.A.G, *et al*, 2020, Differences in the insect fauna associated to a monocultural pasture and a silvopasture in Southeastern Brazil.

Studies have compared the nutritional composition of combo pastures, monoculture pastures, and silvopastures. For example, a study by Michalk *et al.* (2015) found that a combo pasture of ryegrass and white clover had higher crude protein and energy content than a monoculture pasture of ryegrass. This study by Michalk et al. (2015) explores the benefits of integrating multiple pasture species to enhance livestock production and ecosystem services. The authors found that diverse pastures with multiple species can improve livestock productivity, reduce environmental degradation, and promote ecosystem services. Similarly, a study by Peri *et al*. (2017) found that a silvopasture system of trees and pasture had higher crude protein and energy content than a monoculture pasture. Combo pastures outperform monoculture pastures in terms of nutrition and production (Peri.P.L, *et al*. (2017).

Combo pastures, monoculture pastures, and silvopastures have different effects on species diversity and nutritional composition. Combo pastures and silvopastures offer improved pasture productivity, nutritional quality, and soil health compared to monoculture pastures. The choice of pasture system depends on factors such as climate, soil type, and management goals.

Further research is needed to fully understand the benefits and limitations of each pasture. Van de Meulen, J., *et al*. (2016). Nutritional composition and species diversity of pastures: A review of the current state of knowledge and future research directions. Journal of Agricultural Science, 154(5), 831-844. This study highlights the need for further research on the nutritional composition and species diversity of different pastures, citing gaps in current knowledge and understanding .The authors note that there is a lack of comprehensive data on the nutritional composition of different pasture types, particularly in tropical and subtropical regions. Also highlighting the need for further research on the relationships between species diversity, pasture productivity, and animal performance, thus indicates inadequate understanding of species diversity The authors identify a need for more research on the impacts of different pasture management practices (e.g., grazing intensity, fertilization) on nutritional composition and species diversity. Therefore gaps in knowledge on pasture management practices need to be addressed.

CHAPTER 3: METHODOLOGY

3.1 Study site

The Grasslands Research Institute in Marondera, Zimbabwe, falls under the Department of Research and Specialist Services (DR&SS) within the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development. Specifically, it's part of the division of Livestock Research, one of the four Livestock and Pasture Research Stations in Zimbabwe.

Figure 3.1 showing google map of study area showing Block 1, 2, 3, 4for Grasslands

3.2 Altitude and Climate

The research station is situated at an altitude of 1,200 meters above sea level, along the Harare-Mutare road, approximately 67 kilometres southeast of Harare. Latitude: 18.1833, Longitude: 31.5333. The area experiences a mean annual rainfall of 600 to 900 mm, with about 80% of the rainfall occurring between November and March and is found under natural farming region 2b. Grasslands falls under subtropical highlands characterized by seasonal rainfall with most precipitation occurring in summer months. The soils are predominantly acidic, with a pH of 4.5, and are deep brown, fine, and loamy.

3.3 Land Use

The research station covers an area of 2,700 hectares, which is subdivided into 300 hectares of arable land, 2,200 hectares of grazing land, and 200 hectares of woodland, roads, buildings, and wasteland. The vegetation is characterized as wooded shrub land, with dominant tree species including *Terminalia serica, Burkea africana*, and various Combretum and Acacia species.

3.4 Research Focus

The Grasslands Research Station focuses on improving livestock and pasture production in Zimbabwe, with an emphasis on sustainable research-based technologies and information dissemination. The station conducts research on dairy, beef cattle, goat, and sheep feeding and husbandry systems, as well as on pasture production and management.

3.5 Sampling procedure

The sampling procedure shall include: field sample collection, identification of the different species collected, preparation of samples for nutritional analysis to determine crude protein (CP), Crude fibre (CF) and Dry matter (DM). Five samples shall be taken in a W manner from each of the 4sites. Three different types of pastures shall be used as treatments which include: combo pasture, monoculture pasture and silvopastures.

3.6 Treatments

T1- combo pasture (natural)-intentionally created and managed pastures containing grasses, legumes and forbs

T2- monopasture- pasture dominated by a single species namely star grass

T3- silvo-pasture- agroforestry system integrating trees and pastures

T4- combo pasture (established) **(control treatment)-** naturally occurring pastures with a diverse mix of plant species including grasses, legumes, forbs and shrubs that has developed over time without human intervention or seeding.

Field sampling was conducted using quadrants measuring 1m by 1m, where five samples were collected in a W-pattern from each of the four treatments. The collected plant species were carefully identified and recorded. Following collection, the samples underwent a preparation process which involved drying, packing and labelling to ensure accurate tracking and analysis. The prepared samples were then subjected to proximate analysis, which was carried out strictly according to established protocol.

3.7 Methods

Figure 3.2 showing the W sample collection method.

Methods

To assess nutritional quality of the forages, five samples were collected from each of the four treatments. To mimic the grazing behaviour of bulk feeding, the forages within the quadrants were cut using a sickle, 2cm above the ground. The fresh weight of each sample was recorded before they were taken to the greenhouse for air drying to reduce moisture content. Once dried, the samples were oven dried at 105°c for 24hours to remove any remaining moisture. The dried samples were ground into fine powder, packed and labelled for further analysis. The prepared samples were sent to the University of Zimbabwe (UZ) Laboratory for proximate analysis to determine Crude Protein (CP), Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Ash and Dry Matter (DM) content. The data was to be analysed using GenStat version 18, employing analysis of variance (ANOVA) to determine significant differences among the treatments. Means were to be separated using Fisher's test to identify specific differences among treatments

CHAPTER 4: RESULTS

4.1 Species Composition

Table 4.1 ranking of top five most abundant species per block

Block 1 Established Combo Arena	**Block 2 star grass Monopasture**	**Block 3 Silvopasture**	**Block 4 Natural Combo Kenan's corner**
Urochloa (113)	Nutsedge (183)	Nutsedge (18)	Nutsedge (30)
Nutsedge (40)	Stargrass (812)	Stargrass (6)	Arachis (66)
Stargrass (31)	R.scabra (163)	Eragrostis (9)	H.filipendula (103)
Blackjack (10)	Casia (175)	H.filipendula (6)	Bracharia (14)
Craw's foot (4)	Sporobolus (6)	Casia (4)	Fine stem (15)

Table 4.1 shows different pasture species, only the top five in order of most dominant plant species are shown in the table above. Numbers in brackets show the actual number of plant species per block. Refer to Appendix 1 for more detail.

4.2 Established combo

In Block 1 (Established combo/Arena), Urochloa was the most dominant followed by nutsedge, star grass, blackjack, lastly Panicum with the lowest frequency. Urochloa had a higher total frequency of 113 than all the other species. Very low frequencies on all legume species were observed. *Urochloa* species have a competitive advantage over legumes due to their growth rate and ability to produce more biomass, shading out other species (Valle *et al.*, 2020). These *species* are more drought-tolerant than many legume species, allowing them to thrive in conditions where legumes may struggle (Lynch *et al.*, 2020). Moreover, they can adapt to a wide range of soils, including those with low fertility, which can give them an advantage over legumes that require more fertile soils (Ramos *et al*., 2020).

Silvopasture

In Silvopastures, nutsedge had the highest frequency followed by Stargrass, *Hyperhania filipendula*, Casia had the lowest frequency. Low frequencies of most grass species and very few legumes' species were observed with more frequency on nutsedge in the silvopasture. Nutsedges are weeds therefore have an effect on nutritional composition of pastures, impacting negatively.

The low frequency of grass species and scarcity of legumes in silvopastures can be attributed to several factors which include; shading nature of trees creating a shaded environment which limits the growth and diversity of grass and legume species (Miller *et al*, 2020). Also, silvopastures can experience soil degradation due to the trees' water and nutrient uptake, making it challenging for grasses and legumes to thrive (Jose *et al*, 2020).

4.3 Star grass monopasture

Stargrass in Block 2 had the highest frequency, followed by nutsedge, Casia, *Richardia scabra*, lastly sporobolus. Although star grass (*Cynodon nemfluensis*) was the monopasture main crop, many other grass and legume species were also present. More of Casia and nutsedge indicates poorly managed monopastures. Invasion may be primarily due to poor management of the monopasture, others being seed dispersal, dormancy. One reason is that star grass, although a dominant species, may not completely suppress the growth of other species (Crowley & McIvor, 2020).

4.4 Natural combo

Hyperhania filipendula had the highest frequency in Natural combo, followed by Arachis, Nutsedge, Fine stem lastly Bracharia. Hyperhania and Arachis species tend to have a higher frequency than other grass species in the natural combo. This indicates a slight balance between grasses and legumes. Hyperhenia and Arachis species are commonly found in natural combo pastures due to their adaptability and competitive advantages. Hyperhenia species, such as *Hyperhenia rufa*, are known to be tolerant of grazing and can thrive in disturbed areas, making them well-suited to combo pastures (O'Reagain & Turner, 2020). Arachis species, such as *Arachis pintoi*, are legumes that can fix nitrogen, making them valuable components of combo pastures. They are also relatively drought-tolerant and can compete effectively with other species (Argel *et al*., 2020).

4.5 Dry Matter Analysis

4.2 Table showing mean dry matter (%)

Treatments	Mean Dry Matter %
Block 1 Established	23.16
Block 2 Monopasture	30.04
Block 3 Silvopasture	32.07
Block 4 Natural combo	25.71

According to procedure stated in methodology, fresh weight samples were recorded before greenhouse drying to reduce moisture following oven drying. Dry weight was recorded and percentage dry matter could be calculated as shown: Dry matter (%) = dry weight\fresh weight x 100

Natural combo and established combo have higher fresh sample weights indicating an elevated amount of biomass. The established combo weights decreased rapidly maybe due to availability of succulent legumes which lost water content due to heating in oven. Combo pastures that include legumes may have higher fresh weights and lower oven dry weights compared to other types of pastures. A study published in the Journal of Agricultural Science found that combo pastures with legumes had higher fresh weights due to the increased moisture content and leafiness of the legumes (Pinto *et al.*, 2020).

Table 4.3 Table showing the ANOVA of sample weights

		Sum of Squares	df	Mean Square	F	Sig.
FRESH WEIGHT(Kg)	Between Groups	0.093	3	0.031	2.938	0.048
	Within Groups	0.347	33	0.011		
	Total	0.439	36			
DRY WEIGHT (Kg)	Between Groups	0.007	3	0.002	2.621	0.067
	Within Groups	0.028	33	0.001		
	Total	0.035	36			
OVEN DRY WEIGHT (Kg)	Between Groups	0.005	3	0.002	1.970	0.138
	Within Groups	0.026	33	0.001		
	Total	0.031	36			

Fresh weight (p = .048): This p-value is less than the typical significance level of 0.05, indicating that the observed differences in fresh weight between groups are statistically significant. One can conclude that there is a significant effect of the independent variable on fresh weight.

Oven dry weight (p = .067): This p-value is slightly above the typical significance level of 0.05, indicating that the observed differences in oven dry weight between groups are not statistically significant. However, this p-value is often considered marginally significant, suggesting that there may be a trend towards significance.

Dry weight ($p = .138$): This p-value is greater than 0.05, indicating that the observed differences in greenhouse drying weight between groups are not statistically significant. One can conclude that there is no significant effect of the independent variable on greenhouse drying weight.

4.6 Nutritional Composition

Table 4.4: Table showing Analysis of variance for nutritional composition of different pasture samples and P values

	%ADF	%NDF	%Ash	%CP
Established combo	32.88^{a}	71.11	7.63^{d}	6.54
Stargrass monopasture	35.11^{b}	72.13	5.21^{b}	4.21
silvopasture	39.42^{c}	69.27	3.15^{a}	3.39
natural combo	40.27^{d}	66.59	6.15^{c}	5.73
P Value	0.013	0.555	<0.001	0.191
LSD	2.238	1.278	4.05	1.178

4.7 Acid Detergent Fibre

There was a significant difference in ADF ($p<0.05$) content suggests that the treatment had a significant effect on the indigestible fibre fraction. This could indicate a difference in the digestibility of the feed (Van Soest & Robertson, 2020). ADF measures the indigestible component of feed i.e. cellulose and lignin content. The significant difference in ADF among different pasture samples can be attributed to variations in plant species, maturity stages, and environmental conditions.

4.8 Neutral Detergent Fibre

There was no significant difference in NDF ($p>0.05$) content suggests that the treatment did not have a significant effect on the neutral detergent fibre fraction. The no significant difference in Neutral Detergent Fibre (NDF) among different pasture samples suggests that the cell wall content and fibre composition of the pastures are relatively similar. NDF is a measure of the total fibre content in plants, including cellulose, hemicellulose, and lignin. It is an important indicator of forage quality, predicts intake by the animal as high NDF values can indicate lower digestibility and nutritional value (Van Soest, 1994). Studies have shown that NDF content can vary among different plant species and maturity stages.

4.9 Crude Protein

There was a significant difference in CP ($p<0.05$) content suggests that the treatment had a very strong effect on the protein content of the feed. This could indicate a difference in the nutritional value of the feed (Khan *et al.,* 2020). The significant difference in crude protein ($p<0.05$) among different pasture samples indicates substantial variation in the protein content of the pastures, suggesting that some pastures are more suitable for livestock production than others. Crude protein is a critical component of forage quality, as it provides essential amino acids for animal growth and production (Minson, 1990). Adding on to that, studies have shown that legume pastures tend to have higher crude protein content compared to grass pastures, due to their ability to fix atmospheric nitrogen (Unkovich *et al.*, 2020).

4.10 Ash

There was no significant difference in ash content ($p>0.05$) suggesting that the treatment did not have a significant effect on the mineral content of the feed. The non-significant difference in ash content among different pasture samples suggests that the mineral composition of the pastures is relatively similar. Ash content is a measure of the total mineral content in plants, including macro- and micro-nutrients such as potassium, calcium, and phosphorus (Jones *et al.,* 2017). The non-significant difference in ash content among pasture samples indicates that the pastures have similar mineral profiles. This finding is consistent with other studies that have reported non-significant differences in ash content among different pasture species and mixtures (Hartwig *et al*., 2019).

4.11 Crude Protein

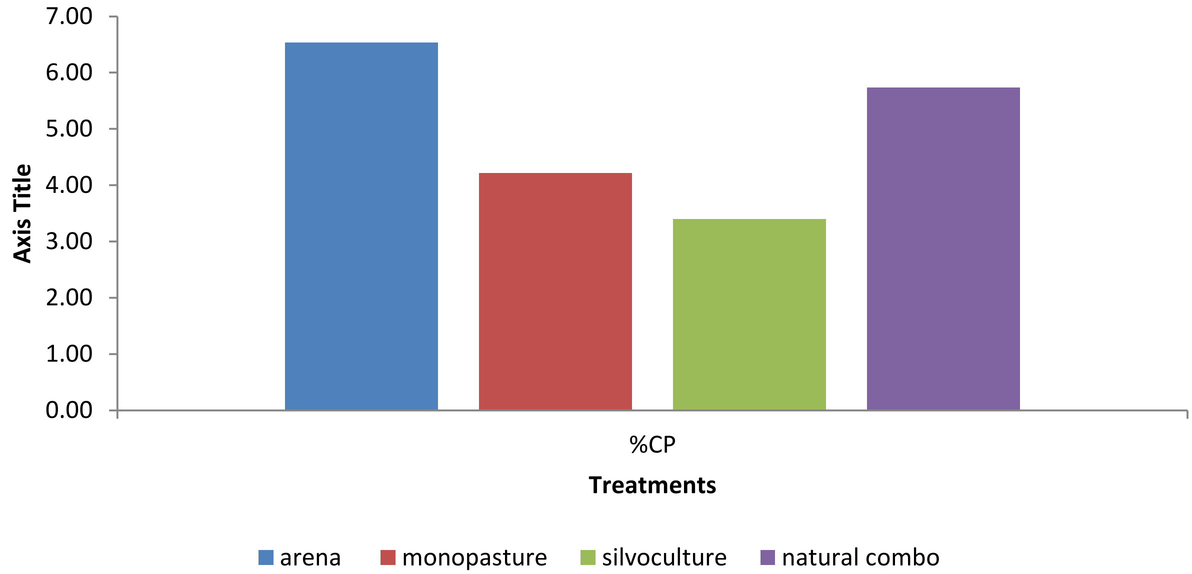

Figure 4.6 showing CP content of different pastures

Arena (established combo) had the highest CP content of 6.54% followed by Natural combo with 5.73%. Monopasture has 4.21% CP, lastly silvopasture with the least content of 3.39%.

Combo pastures seem to have higher nutritive value in terms of CP content than silvopastures and monopastures. Legume pastures typically have higher crude protein content compared to grass pastures due to several reasons which include nitrogen fixation, higher photosynthetic rates allowing them to produce more biomass (Pembleton *et al.*, 2018) and increased nutrient uptake (Unkovich *et al.*, 2020) due to extensive root system (Schofield *et al.*, 2019).

Silvopasture systems typically have a mix of trees, shrubs, and herbaceous plants, which can lead to a more diverse and complex ecosystem. However, this diversity can also result in a lower overall crude protein content compared to other pasture types. Silvopasture might have lower CP content because trees can dominate the landscape, shading out herbaceous plants and reducing their growth and CP content (Miller *et al.*, 2019),few legumes can result in lower overall CP content (Pembleton *et al.*, 2018), soil nutrient competition, including nitrogen, which is essential for CP production (Forrester *et al.*, 2018).

Natural combo pastures tend to have higher crude protein content compared to monopasture of star grass due to a diverse range of plant species, including legumes, grasses, and forbs leading to a more complex and nutrient-rich soil ecosystem, resulting in higher CP content (Pembleton *et al.*, 2018). Furthermore, they often include legumes which have the ability to fix atmospheric nitrogen, making it available to other plants in the pasture (Unkovich *et al.*, 2020).

In contrast, monopasture of star grass tends to have lower CP content due to limited plant species diversity leading to a less complex and nutrient-poor soil ecosystem. Studies have reported higher CP content in natural combo pastures compared to monopasture of star grass. For example, a study found that natural combo pastures had a CP content of 15.6%, compared to 12.3% for star grass monoculture (Rosenstock *et al*., 2019).

For more detail, refer to Appendix 2 showing forage nutritional analysis in terms of Crude Protein, ADF, NDF, Ash and Dry matter.

CHAPTER 5: DISCUSSION OF RESULTS

The study analysed the species composition, diversity, and nutritional composition of different pasture species to enhance dairy milk production. The results showed variations in species composition, diversity, and nutritional content across the different pasture types.

5.1 Species Composition and Diversity

The established combo pasture was dominated by Urochloa, while legumes like Siratro, Piata, Lucerne, and Casia were present in lower proportions. This is consistent with previous studies that reported Urochloa as a dominant species in tropical pastures (Pembleton *et al*., 2018). The low presence of legumes in the established combo pasture may be attributed to competition from the dominant Urochloa species with shading canopy and fast growth rate. The fact that they were actually established but present in low frequency indicates competitive advantage of the grass specie, urochloa.

In contrast, the natural combo pasture was dominated by Hyperhania and Arachis, indicating a more diverse species composition. This diversity can lead to a more complex and resilient ecosystem, which can provide a more stable nutritional content for dairy cattle (Hartwig *et al*., 2019). On the other hand, the silvopasture system was dominated by Nutsedge (*Cyperus rotundus)*, a common invasive species in tropical regions which is difficult to control, has rapid and perennial growth with a deep root system (Webster., 2013; Santos et al.,2016). This may indicate a need for more effective management strategies to control invasive species and promote desirable pasture species.

5.2 Nutritional Composition

The results showed significant differences in the nutritional composition of the different pasture types. The established combo pasture had the highest CP content, followed by the natural combo pasture. This is consistent with previous studies that reported higher CP content in pastures with a higher proportion of legumes (Unkovich *et al*., 2020). In contrast, the silvopasture system had the lowest CP content, which may be attributed to the dominance of nutsedge, a species known to have lower CP content. The star grass monopasture had a moderate CP content, but was invaded by other grasses and legumes, indicating a poorly managed pasture requiring a more effective management strategy.

The established combo pasture with a CP content of 6.54% is slightly below the average expected CP content of established combo pastures. According to a study by Frame and Laidlaw (2013), the average CP content of a well-managed combo pasture can range from 7% to 12%. On another note, a study by Ball *et al*. (2007) reported an average CP content of 8.5% for combo pastures in the southern United States. However, it's worth noting that CP content can vary depending on factors such as pasture management, soil type, and climate. Consequently, a study by Hartwig and Ammon (2019) found that CP content of combo pastures can range from 5.5% to 10.5%. Contrally, the CP content of the established combo pasture might be slightly below the average expected value, but it is still within the range reported in recent literature.

The ADF and NDF values also showed significant differences across the pasture types. The natural combo pasture had the highest ADF value, indicating a higher fibre content therefore low digestibility as well as palatability. In contrast, the established combo pasture had the lowest ADF value, indicating high digestibility and increased palatability.

The NDF values showed a different trend, with the established combo pasture having the highest value, indicating high potential for voluntary feed intake and gut fill. The natural combo pasture had the lowest NDF value, indicating reduced potential for voluntary feed intake with reduced digestive upsets. Research has shown that NDF content of diets has a positive relationship with rumen fill (Mertens, 1994). This means that higher NDF content can lead to increased rumen fill, which can ultimately affect voluntary feed intake (VFI). In fact, studies have demonstrated that NDF is a key factor in controlling feed intake, with higher NDF levels limiting energy intake until the rumen is emptied (Allen 2000). Moreover, the physiological factors controlled by NDF are the primary control of feed intake (Allen 2000). The relationship between NDF and VFI is further supported by research indicating that NDF content can predict maximum forage intake capacity in cattle (Sauvant *etal*; 2015). In terms of rumen fill, NDF has been shown to be a critical component, with forage NDF (fNDF) being a key determinant of rumen fill and dry matter intake (DMI) (Zebeli *etal;* 2012). Research suggests that rumen fill and NDF content of diets have a positive relationship, and that there is a variation in passage rate between high and low-quality roughages

(Zebeli *etal*; 2012). Understanding the relationship between NDF and VFI helps dairy farmers and nutritionists to make informed decisions about feed formulation and management to optimize dairy cattle productivity. The results highlight the importance of effective pasture management strategies to promote desirable pasture species and optimize nutritional content for dairy cattle and that low ADF and NDF values are a sign of higher quality pasture type capable of supporting dairy milk production (Chen, Y & Wang Y, 2022).

The ash content of the different pasture types varied significantly, with the established combo pasture having the highest ash content (7.63%) and the silvopasture having the lowest (3.15%). According to the literature, ash content in forages is an indicator of mineral content, with higher ash values indicating higher mineral levels (Ball *et al*., 2007). The ash content of the established combo pasture was within the range reported by Hartwig and Ammon (2019), who found that ash content of combo pastures can range from 6% to 9%. Contrally, the ash content of the silvopasture was lower than expected, which may indicate lower mineral levels in this pasture type. This is consistent with the findings of Peri *et al*. (2019), who reported lower ash content in silvopasture systems compared to traditional pastures. Meanwhile, the ash content of the natural combo pasture (6.15%) and monopasture (5.21%) were within the expected range for these pasture types, indicating moderate mineral levels.

CHAPTER 6: CONCLUSION AND RECOMENDATIONS

6.1 Conclusion

The study demonstrated different values for the blocks and these have different nutrient content which may affect dairy production. However, the pastures alone do not provide all the requirements of a dairy cow. On the same note, they have the best nutrients (Established and natural), meaning less supplements will be required hence reduced feed costs. Combo offer higher species diversity, nutritional quality and optimal energy levels whilst supporting high quality milk production (Frame, J., 2017). Crude protein content can be manipulated by incorporating high quality legumes into these pastures. Meanwhile, natural combo pastures remain crucial since results highlight the importance of effective pasture management strategies to promote desirable pasture species and optimize nutritional content of dairy pastures.

Combo pastures with a mix of grasses and legumes can produce higher forage yields, reducing the need for supplemental feed (Frame & Laidlaw, 2013). Also, the diversity of species in combo pastures can lead to a more balanced and nutritious forage, reducing the need for expensive concentrates (Hartwig & Ammon, 2019). Most importantly, they can provide a longer grazing season, reducing the need for stored feed and minimizing the costs associated with feed storage and handling (Pembleton *et al.*, 2018). However, management of pasture species composition through regular assessment of and implementation strategies to promote desirable species and control invasive species is crucial (Pembleton *et al*., 2018).

6.2 Recommendation

Dairy farmers should adopt combo pasture systems to improve milk yield, animal productivity and environmental sustainability. Strategic application of fertilizer to promote desirable pasture species and optimize nutritional content is recommended (Unkovich *et al*., 2020). Also monitoring pasture nutritional content by regularly testing to ensure it meets the dietary needs of dairy cattle (National Research Council, 2016). Dairy farmers should seek expert advice from pasture management specialists to develop a tailored pasture management plan that optimizes dairy cattle productivity and profitability. When designing combo pastures, it is essential to select grass species that complement legumes and minimize shading effects e.g. tall fescue (*Festuca arundinacea*), a deep-rooted, shade-tolerant grass that can coexist with legumes without competing for light (Ball *et al.*, 2007). More so, ryegrass *(Lolium* spp.), a fast-growing, fine-textured grass that can be used as a companion crop with legumes, but may require more frequent renovation (Frame & Laidlaw, 2013).

6.3 Research Gaps and Recommendations for Further Study

While this study provided valuable insights into the species composition, diversity, and nutritional content of different pasture types, there are several research gaps that warrant further investigation; firstly, this study needs to be carried out both in dry season as well as during the rainy season so that the trend in nutritional composition at varying seasonal times can be established.

Additionally, studies are required to examine the impact of different pasture types on animal performance, including milk production, weight gain, and reproductive efficiency (Kolver &Muller, 1998). In addition to that, investigating on the impact of climate change on pasture productivity and to develop strategies for mitigating these impacts (IPCC, 2013). Addressing these research gaps enables future studies to provide a more comprehensive understanding of the complex relationships between pasture type, animal performance, and environmental sustainability.

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Appendices

Appendix 1 showing species composition and their frequencies

Species	Block 1 Arena/Established Combo	Block 2 Star grass/Monopasture	Block 3 Silvopasture	Block 4 Natural Combo/Kenan's corner
Urochloa	113			
Nutsedge	40	183	18	30
Stargrass	31	812	6	4
Blackjack	10			
Craw's foot	4			
Panicum	3		1	
Arachis				66
R. scabra	3	163	1	6
A.timothy	3			
Lucerne	2			
Casia	2	175	4	2
Eragrostis	1		9	
Silverleaf	1			
Siratro	1			
Piata	1			
Sporobolus	1	6		14
A.timothy	3	3		1
A.americana		1		
Bracharia			1	14
Hyperthellia				6
H.filipendula			6	103
Fine stem			5	15
Natal redtop			2	
C.dactylon			5	

H.contortus			1	

Code	Sample ID	%ADF	%NDF	%Ash	%CP
1	Block 1 Quad 1 09/01/25 Arena	32.61	72.84	7.50	7.78
2	Block 1 Quad 2 09/01/25 Arena	32.02	62.33	8.67	5.94
3	Block 1 Quad 3 09/01/25 Arena	34.14	68.55	6.47	6.73
4	Block 1 Quad 4 09/01/25 Arena	30.72	65.72	8.79	7.14
5	Block 1 Quad 5 09/01/25 Arena	34.91	86.09	6.71	5.10
6	Block 2 Quad 1 10/01/25	35.35	74.64	5.75	3.39
7	Block 2 Quad 2 10/01/25	34.74	72.01	4.64	4.05
8	Block 2 Quad 3 10/01/25	35.74	73.29	6.15	4.30
9	Block 2 Quad 4 10/01/25	34.68	67.06	5.35	4.50
10	Block 2 Quad 5 10/01/25	35.07	73.64	4.17	4.82
11	Silvoculture Quad 1 10/01/25	42.64	60.84	4.79	6.67
12	Silvoculture Quad 2 10/01/25	38.71	74.63	4.32	3.96
13	Silvoculture Quad 3 10/01/25	38.12	68.03	2.61	1.89
14	Silvoculture Quad 4 10/01/25	41.13	73.59	2.54	2.36
15	Silvoculture Quad 5 10/01/25	36.47	69.27	3.14	5.33
16	Block 4 Quad 1 13/01/25	44.64	73.07	5.73	4.59
17	Block 4 Quad 2 13/01/25	44.67	68.84	6.51	3.46
18	Block 4 Quad 3 13/01/25	41.45	65.94	6.67	3.22
19	Block 4 Quad 4 13/01/25	29.17	68.92	5.56	6.13
20	Block 4 Quad 5 13/01/25	41.41	56.16	6.29	11.28

Appendix 2 above showing UZ Laboratory Proximate analysis results

Appendix 3 below showing ANOVA tables

GenStat 64-bit Release 14.1 (PC/Windows) 01 June 2009 06:45:08

GenStat Fourteenth Edition
GenStat Procedure Library Release PL22.1

```
   1  %CD 'C:/Users/Administrator/OneDrive/Documents'
   2  "Data taken from File: \
  -3  C:/Users/Administrator/Desktop/phd
prop/students/lynette/procimate.GSH"
   4  DELETE [REDEFINE=yes] _stitle_: TEXT _stitle_
   5  READ [PRINT=*; SETNVALUES=yes] _stitle_
   9  PRINT [IPRINT=*] _stitle_; JUST=left
```

Data imported from Excel file: C:\Users\Administrator\Desktop\phd prop\students\lynette\procimate.xlsx
on: 20-May-2009 9:41:12
taken from sheet "Sheet1", cells A2:E21

```
  10  DELETE [REDEFINE=yes] pasture_type,%ADF,%NDF,%Ash,%CP
  11  UNITS [NVALUES=*]
  12  FACTOR [MODIFY=yes; NVALUES=20; LEVELS=4; REFERENCE=1] pasture_type
  13  READ pasture_type; FREPRESENTATION=ordinal
```

Identifier	Values	Missing	Levels
pasture_type	20	0	4

```
  15  VARIATE [NVALUES=20] %ADF
  16  READ %ADF
```

Identifier	Minimum	Mean	Maximum	Values	Missing
%ADF	29.17	36.92	44.67	20	0

```
  21  VARIATE [NVALUES=20] %NDF
  22  READ %NDF
```

Identifier	Minimum	Mean	Maximum	Values	Missing
%NDF	56.16	69.77	86.09	20	0

```
  27  VARIATE [NVALUES=20] %Ash
  28  READ %Ash
```

Identifier	Minimum	Mean	Maximum	Values	Missing
%Ash	2.538	5.617	8.791	20	0

```
  33  VARIATE [NVALUES=20] %CP
  34  READ %CP
```

Identifier	Minimum	Mean	Maximum	Values	Missing
%CP	1.890	5.131	11.28	20	0

Appendix 4 showing Dry Matter (%)

Block 1 Established Combo/Arena	Quad number	Fresh weight(g)	Greenhouse weight(g)	Oven dry weight(g)	Dry matter %
	1	120	42	25	20.83
	2	140	44	30	21.43
	3	160	54	40	25
	4	160	46	35	21.87
	5	225	71	60	26.67
Block 2 Stargrass Monopasture	1	185	73	60	32.43
	2	140	50	40	28.57
	3	150	53	45	30
	4	155	55	45	29.03
	5	315	109	95	30.16
Block 3 Silvopasture	1	205	90	75	36.58
	2	45	22	10	22.22
	3	305	105	90	29.51
	4	325	134	120	36.92
	5	185	75	65	35.13
Block 4 Natural Combo	1	130	50	35	26.92
	2	325	91	75	23.08
	3	180	63	50	27.78
	4	490	160	135	27.55
	5	495	135	115	23.23