Investigating maize-rotation and legume intercropping systems' resilience to moisture stress in Zimbabwe

A dissertation submitted in partial fulfilment of the requirements for the Master of Science Degree in Food Security and Sustainable Agriculture (Production)

Bindura University of Science Education

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DECLARATION

I hereby declare that the research project entitled "**Investigating maize- legume rotations and intercropping systems' resilience to moisture stress in Zimbabwe**" submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension. It is a record of original work done by myself under the guidance and supervision of Mr Gotosa and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

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DEDICATION

I dedicate this project to my husband, Tapfumaneyi Joseph Shawatu, my dearest daughter Tiana Irikidzai Shawatu and to all smallholder farmers in Zimbabwe**.**

ACKNOWLEDGEMENTS

I would like to thank my supervisors Mr Gotosa and Dr C. Thierfielder for their thoughtful guidance, support, patience, and timely help from the onset of my study up to the end. I also want to extend my gratitude to International Maize and Wheat Improvement Centre (CIMMYT) Zimbabwe, for its support and the provision of all the funds for my project to be successful. Again, my gratitude goes to my husband for his assistance and patience and the rest of my family and friends for all the support they have given me during this research.

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ABSTRACT

As the effects of climate change are being experienced world over, there is need to engage in sustainable intensification cropping systems. Southern Africa has been experiencing low rainfall and dry spells. These have impacted smallholder farmers the most as they rely on rain fed agriculture. Intercropping and crop rotations are part of the sustainable intensification. These have enabled increased maize grain yield. This research looked at impacts of intercropping and rotations. The research was carried out at University of Zimbabwe (UZ) farm (17.73° S, 31.02 E) and Domboshava Training Centre (DTC) ($17^{0}36'$ S,$31^{0}26$ E) and research during the 2019/20 season. The experiment had five treatments (maize sole, maize pigeon pea intercropping, and maize after pigeon pea, maize cowpea intercropping and maize after cowpea). Water infiltration, soil biota, maize grain and stover yield data was collected. Partial land equivalent ratio was calculated using grain and stover yield. Analysis of variance was done using R version 3.6.0. Both maize grain and stover was significant at both sites. Site had a significant difference at (P<0.000), treat at (p<0.000), and sub treat at (p<0.000). Partial Land Equivalent ratio had a significant difference between site and sub treat (p<0.010) grain partial land equivalent ratio. Stover showed a significant difference on site at p<0.006) and on treatments (p<0.002). There was no significant difference in water infiltration in all treatments (p<0.27). On the soil macro organism, there was no significant difference except for site (p<0.008). The results showed that intercropping can increase grain and stover yields and also it is better to practise intercropping than sole crops as intercropping treatments had values more than 1. However, the results showed that infiltration as well as macro organism density was high in maize pigeon pea intercrops. What was the main recommendation?

Keywords: Partial land equivalent ratio, Intercropping, Soil biota, Maize grain and stover yields, Water infiltration.

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LIST OF ACRONYMS AND ABBREVIATIONS

AN	Ammonium Nitrate
ANOVA	Analysis of Variance
BNF	Biological Nitrogen Fixation
C	Carbon
CA	Conservation Agriculture
COVID-19	CoronaVirus Disease 2019
DTC	Domboshava Training Centre
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GMCC	Green Manure Cover Crops
GoZ	Government of Zimbabwe
Ha	Hectare
Hr	Hour
K	Potassium
LSD	Least Significant Differences
N	Nitrogen
NH4+	Ammonium Nitrate
NO3-	Nitrate
NR	Natural Region
P	Phosphorous
PLER	Partial Land Equivalent Ratio
SHF	Smallholder Farmer
SSA	Sub-Saharan Africa
UZ	University of Zimbabwe

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CHAPTER 1

INTRODUCTION

1.1 Background to the study

The world's population is projected to have increased to 9 billion people and 2.5 billion in Africa by 2050 (Opele, 2019). This means that there is a need to increase the current food production levels, especially maize by about 60%, since it is a staple food crop in most African countries and an essential raw material as well as livestock feed.

Smallholder farmers are involved more in food crops production particularly maize for their subsistence and also sell the excess for additional income (Wise, 2013). According to the African Smallholder Farmers Group (ASFG), around 7% of the World population are smallholder farmers and they produce at least 80% of the food consumed in Africa and Asia. Smallholder farmers are characterised by small land holdings and availability of water is a major setback to productivity (Opele, 2019).

Studies have shown that the African continent will continue to have increased water stress and therefore decreased yields as most rely on rain fed agriculture (Chitongo, 2019 and World Bank Group, 2017). Increased water stress and desertification will sum up to increased food insecurity as yields are expected to decrease by more than 50% as a result of climate change. In most countries in sub-Saharan Africa, smallholder farmers make up the greater part of the farming population (Chitongo, 2019)

Agriculture is the backbone of Zimbabwe's economy and according to the Food and Agriculture Organisation (FAO) year?, it contributes approximately 17% to Zimbabwe's Gross Domestic Product (GDP). It is the main source of livelihood for both the rural and urban populace. Like any other sector, it has not been spared by the effects of climate change. Its performance is key in determining the rural livelihood resilience and the level of poverty (FAO, 2016).

Just as in most developing countries, smallholder farmers in Zimbabwe are located in the marginal areas which are usually characterised by infertile sandy soils, poor road network and unavailability of water for supplementary irrigation among other things. Since they rely on rainwater for production with little or no inputs at all, it leaves them to produce enough for their immediate needs and very little surplus for sale.

There is increasing concern that climate change will affect food security in Africa. Temperature increase is quite significant with no significant change in rainfall thus affecting productivity. Rurinda et al., (2014) recommended the need to change cropping systems in order to reduce the effects of climate change. Intercropping is one system which can be used to address the issue of water loss and thus increasing productivity (Bashagaluke et al., 2018).

Zimbabwe lies in a semi-arid region and this means that it does not get any better for any ordinary smallholder farmer who relies on rain fed agriculture. Records show that just like any other country in Sub-Saharan Africa (SSA), the environment has already started to exhibit signs of climate change (Brown et al., 2012). This ranges from unreliable low rainfall to rapid temperature variations.

Since the rainfall pattern has changed both in amount received and distribution and also with temperatures continuing to rise, there is need to conserve the little moisture in the ground to enhance productivity (Pauley, 2017). Research has been done on the possibility of practicing intercropping as a climate change mitigation strategy. Results revealed better yield of the main crop which in most instances is a staple like maize. There is also increased nutrient composition, and better soil conservation and management (Himanen et al., 2016).

Apart from water retention, intercropping aides in reducing proliferation of pests and ultimately increase biodiversity as there is reduced use of pesticides which destroy soil microorganisms and pollination agents (Pauley, 2017)

Conservation Agriculture and the Zimbabwean context

The Government of Zimbabwe (GoZ) working with development agencies in the country are going to greater lengths in trying to come up with technologies to increase agricultural productivity. According to the Farming for the Future cited in 'Edwards et al., n.d ', the national yield stands at less than 0.5MT/Ha. This is evidently low albeit the time they take working the land.

It has been over a decade since the concept of Conservation Agriculture (CA) has been introduced in the country but still the concept hasn't been fully adopted. According to the (FAO, 2019) only 5% of the maize growing areas are making use of the technology. This clearly shows the need to sensitise farmers more on the benefits of (CA). Due to it being labour intensive, most farmers are demoralised to try it in succeeding seasons after they try it.

Researchers also suggest that the reason why communities have failed to take up CA is that Non-Governmental Organisations give them inputs for the free. Once the development partners move out from the communities, farmers immediately go back to their conventional methods of farming (FAO, 2019).

The GoZ is confident that the slow adoption of CA by farmers will be escalated by the use of the new 'Pfumvudza' concept (Edwards et al., n.d). The concept still uses the principles of CA but concentrating their resources on a smaller piece of land. Farmers will be able to provide supplementary irrigation thus increasing productivity and ultimately food security.

1.2 Problem Statement

Climate change has affected agricultural productivity the world over and smallholder farmers are hit the hardest. Smallholder farmers are usually cash and inputs constrained. Most are situated in marginal areas, where the soils are infertile and have low nutrient content especially nitrogen (Aamali., 2019). In SSA there are also problems of prolonged intra seasonal dry spells that cause moisture scarcity in sandy areas leading to droughts. Farmers are often faced with a difficult decision to make between using crop residue as animal feed or mulching under conservation agriculture (CA). CA is a package of agronomic management practices which are; minimum soil disturbance, permanent soil cover and crop management systems such as rotations and intercropping (Thierfelder et al., 2013). Since it is not a single technology, there is need to implement it holistically if one is to reap the total benefits. In some documented cases, farmers often leave out the mulch as they feel the process of gathering leaves and crop residue is too labor demanding (FAO, 2019). This has detrimental effects on crop productivity as there is reduced moisture retention.

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1.3 Objectives

1.3.1 Main Objective

The objective of the study was to determine the effects of intercropping maize with cowpea and pigeon pea on maize productivity, water infiltration and soil biota in smallholder farming systems under conservation agriculture (CA) in Zimbabwe

1.3.2 Specific Objectives

The specific objectives were:

a. To determine the effects of intercropping maize with cowpea and pigeon pea on maize productivity
b. To determine the effects of rotating maize with cowpea and pigeon pea on maize productivity
c. To evaluate the effects of intercropping and rotating maize with cowpea and pigeon pea on water infiltration.
d. To determine the effects of maize-legume intercropping and rotation systems under CA on soil macro fauna activity
e. To evaluate the effects of intercropping legumes (cowpea/pigeon pea) on maize grain yield, stover production and Land Equivalent Ratio

1.4 Hypothesis

- Legume intercropping systems retain soil moisture than sole crops.
- Intercropping maize and pigeon pea has positive effects on soil macro organisms than cowpea.
- Intercropping systems have different species diversity, evenness, and density

1.5 Justification

Knowing the suitable Green manure cover crops (GMCC) to intercrop with maize will help in optimizing maize production for the smallholder farmers at an affordable cost. Furthermore, smallholder farmers can also benefit from GMCC legume intercrops by earning extra income through selling these legume seeds for example velvet beans. They can even get extra food and feed for their livestock from the stover they get from the legumes. GMCCs help reduce the farmers' costs as they have the potential to improve soil fertility, reduce erosion and control weeds. All this reduces the production cost to the farmer. The use of legumes such as pigeon pea and cowpea in conservation agriculture (CA) have been reported to be viable and affordable alternative sustainable intensified ways of maize production which increase maize production. As cited in the problem statement, farmers are often faced with a difficult decision to make on whether to use crop residue as mulch or feed for the animals. Hence the incorporation of legumes such as mucuna and lablab which will help to serve the purpose of the crop residue.

1.6 Outline of the thesis

This thesis was written in a paper format. This section is a layout of the whole document.

Chapter 1 General introduction

Chapter 2 literature review

Chapter 3 General methodology

Chapter 4 Water infiltration and Soil biota (Manuscript 1)

Chapter 5 Maize grain and Stover yield (Manuscript 2)

Chapter 6 Summary, conclusions and recommendations

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is broken down into the important elements of this study which are Conservation Agriculture, Factors affecting productivity, Cropping systems, Soil microorganisms, Land Equivalent Ratio and the Conceptual framework.

2.2 Definition of Key Terms

2.2.1 Conservation Agriculture

According to Kassam et al. (2018), FAO defines Conservation Agriculture (CA) as an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. Conservation Agriculture has three main principles which if linked to good practical application can yield good results. The three principles are minimal soil disturbance where direct planting of seeds is done into untilled soil or broadcasting causing minimum soil disturbance. The other principles are maintenance of a permanent soil mulch cover on the ground surface and crop rotation (diversification of crop species). However, for these principles to be efficient there is need to combine with appropriate agronomic practices, proper planting dates, weeding in time, nutrient management, pest control to mention a few (Giller et al., 2009).

2.2.2 Crop Rotation

Crop rotation is the practice of growing two or more dissimilar types of crops in the same space in a sequence (Mutua., 2014). Smallholder farmers should plant several crops in rotation or as intercrops. Crop rotations should include legumes, deep-rooted crops and high-residue crops. Crop rotations have many benefits to the soil as well as to the farmer.

2.2.3 Intercropping

Intercropping is a farming practice involving two or more crop species, or genotypes, growing together and coexisting for a time (Brooker *et al*., 2014). It is a system which can be used even in low input agricultural systems (Dai *et al*., 2019).

2.2.4 Land Equivalent Ratio

Land equivalent ratio (LER) is an index which is used to measure land productivity in an intercropping system versus a sole cropping one. It is often used as an indicator to determine the efficacy of intercropping (Brintha and Seran, 2009). LER is defined as the relative area required by sole crops to produce the same yield as intercrops (Mead and Willey, 1980) or is the ratio of land required by sole crop to produce the same yield as that of intercrop. A LER value higher than 1.0 indicates that intercropping uses the land more efficiently than the comparative sole systems under the given management (Ropholo et al., 2019). The partial land Equivalent ratio is calculated according to equation 1 as:

$$pLER = \frac{la}{lb} \qquad \text{(Equation 1)}$$

Where:

$pLER$ = Partial Land Equivalent Ratio

la = Yields for maize in the intercropping system

lb = Yields for sole maize crops (Nassary et al., 2020)

2.3 Factors affecting productivity

Food production in Africa, dominated by the smallholder sector has been increasing at a very slow rate despite the need to produce at least 50% more food to cater for the projected 2.5 billion population by 2050 (Godfray et al., 2010). This drawback is a result of several factors such as inadequate access to draught power and limited land (Zingore et al., 2007); poor soil nutrient quality (Mtambanaengwe et al., 2007). Maize yields remain low ranging from less than 1.5/ha to 2t/ha (Shieferaw et al, 2011) in the smallholder farming sector.

2.3.1 Soil Fertility

Soil fertility is another constraint to the production of the staple maize crop in Africa (Bhattacharyya et al., 2013). Most smallholder farmers do not afford to buy fertilisers or manure to supplement and improve the soil quality. Increase in land use intensity is also contributing to nutrient depletion among smallholder farmers (Drechsel et al., 2001) and this has threatened food production.

The soils on which smallholder farmers rely on have been extensively cropped with cereals and are depleted of nutrients such as nitrogen and phosphorus which are the major nutrients required in maize production. However, the use of mineral fertiliser by smallholder farmers has been identified as an option to achieve higher yields and also to increase land productivity (Nkoma, 2016). This can improve the nutrient balance of the soil which may lead to increase in crop yield. Unfortunately, the use of mineral fertilizers in the smallholder farming system to replenish these depleted nutrients is limited due to their prohibitive costs (Grabowski, 2011). This has resulted in declining crop yield and increase in poverty (Kamhabwa, 2014). Low amounts of nitrogenous fertilizers (about 35kg N ha^{-1}) are usually applied as top dressing. To add on, smallholder farmers do not afford irrigation and hence they depend on rainwater. However, there are changes in seasonal rainfall amounts and the rainfall will be erratic but received in a short space of time, leading moisture stress from the dry spells resulting in low crop yields.

With these projections there is a need therefore to find ways to increase food security especially at household level going up. Farmers should adopt farming methods that call for sustainable intensification and also preserves moisture leading to an increase in food production. Conservation agriculture is one option by which smallholder farmers can increase maize production as well as livestock feed. It has basically three main principles which are crop rotations, minimum soil disturbance and use of mulching.

2.3.2 Crop rotations

Rotating crops can improve soil structure as some crops especially legumes such as pigeon pea have strong deep roots which can penetrate deep into the soil breaking hard pans, and can tap moisture and nutrients from deep in the soil (Margenot *et al*., 2017). Others have shallow roots and tap nutrients near the soil surface and also bind the soil together. Another benefit is that when leguminous crops are part of the rotation, they fix nitrogen into the soil and their stover adds nitrogen through decomposition.

Crop rotation also helps in control of some weeds, pests and diseases. Planting of the same crop season after season may encourage certain weeds, insects and diseases to thrive. Planting different crops season after season breaks their life cycle and prevents them from multiplying(Giller et al., 2009). It is therefore of importance to include rotations on smallholder farming as this can help to curb the problem of moisture and also weed management meaning there will not be much need to use pesticides.

2.3.3 Intercropping

Intercropping can contribute to higher production as well as high nutrient availability, effective management of weeds and pests. Intercropping can improve soil quality and soil phyto availability due to species complementarity (Lopes *et al*., 2016). This type of farming can improve land use efficiency as it requires a small piece of land to yield the same quantities of monoculture crop grains. (Martin-Guay *et al.*, 2018). Farmers usually intercrop leguminous crops versus non- leguminous crops Legumes host symbiotic rhizobia bacteria in their root nodules, which perform biological nitrogen fixation. Intercropping allows competition between legumes and other crops for soil nutrients, which potentially limits the nutrient supply for the legumes and thus triggers the symbiotic bacteria to quickly engage in Biological Nitrogen Fixation (Fung *et al*., 2019). According to Yong *et al*., (2015) Nitrogen which has been fixed by legumes is available in excess and the surplus is accessible to other crops in intercropping systems. This leads to the same yields of non-legume crops and can be maintained with less fertilizer input than their monoculture counterparts, leading to an enhancement in nitrogen-use efficiency (Fung et al., 2019).

One of the attractive strategies for increasing productivity per unit area in smallholder farming systems is intercropping maize with legumes (green manure cover crops, GMCCs) especially in low input production systems and high risk environments (Mucheru-Muna *et al*., 2010). According to Belel *et al*. (2014), integrating legumes in CA is one of the viable ways of optimizing sustainable agricultural production systems per unit land area. Thierfelder et al. (2013) points out that smallholder farmers may start to include GMCCs in their cropping system and these should be legumes which contribute to food security while at the same time adding nitrogen to the cropping system. These can be incorporated as relay crops or intercrops. Legumes, especially green manure cover crops are primarily used as soil amendments, a nitrogen (N) source through biological nitrogen fixation (BNF), P retention (Margenot *et al.,* 2017) and a carbon (C) source. This is important in areas with sandy soils that are prone to leaching as ammonium ions (NH_4^+) adsorb to the negatively charged soil particles and organic matter in contrast to NO_3^- which reduces leaching (Snyder, 2016). Furthermore, GMCCs add soil organic matter and increase soil microbial stover and soil carbon which in turn improves soil structure.

2.3.4 Use of mulching

Mulch is used with the aim of having a protective layer on the soil surface. This can be done using live or dead legume such as lablab, mucuna, pigeon pea and cowpea or maize residues. In the absence of legume mulch, small holder farmers can use dead vegetative material, mainly from agroforestry tree species. Covering the soil reduces its chances of being eroded by moving water or wind, conserves soil moisture, reduces weed growth, increases the rate of water infiltration into the soil while reducing the same from evaporation. To add on mulch also increases the soil fertility and the organic matter content of the soil. When leguminous cover crops such as lablab and pigeon pea are used, they add nitrogen to the soil. Increases soil moisture by allowing more water to sink into the ground and reduces evaporation. Stimulates development of plant roots, which in turn improves soil structure.

2.3.5 Soil macro organisms

Soil macro organisms play a particularly important role in decomposing organic matter and cycling nutrients. They enhance biodegradation and humification of organic residues in several ways which include breaking down of organic residues and increasing surface area for microbial activity. They also play a significant role in soil aggregation and porosity as a consequence of their burrowing and mixing activities. This in turn improves the soil aeration and moisture. Soil macro organisms are responsible for producing enzymes which break down complex bio-molecules into simple compounds to form humus. To add on they improve the soil environment for microbial growth and soil-plant interactions. Termites and earthworms that play a major role in moving, mixing and aerating the soil.

2.4 Conceptual/theoretical framework

This section looks at the Conceptual framework which is the logic behind the study in question. Dickson et al., (2018) defines it as the critical path of a research which gives it its firmness and credibility. The Conceptual framework showcases a scientific synthesis of the insights from different literature in order to try and understand the subject matter. Put simply, it is the researcher's understanding of how variables in the study relate to each other (Regional, 2015). Having interacted with different literature, the researcher's understanding and interaction of the variables under study are represented in the form of a diagram as shown in Figure 1.

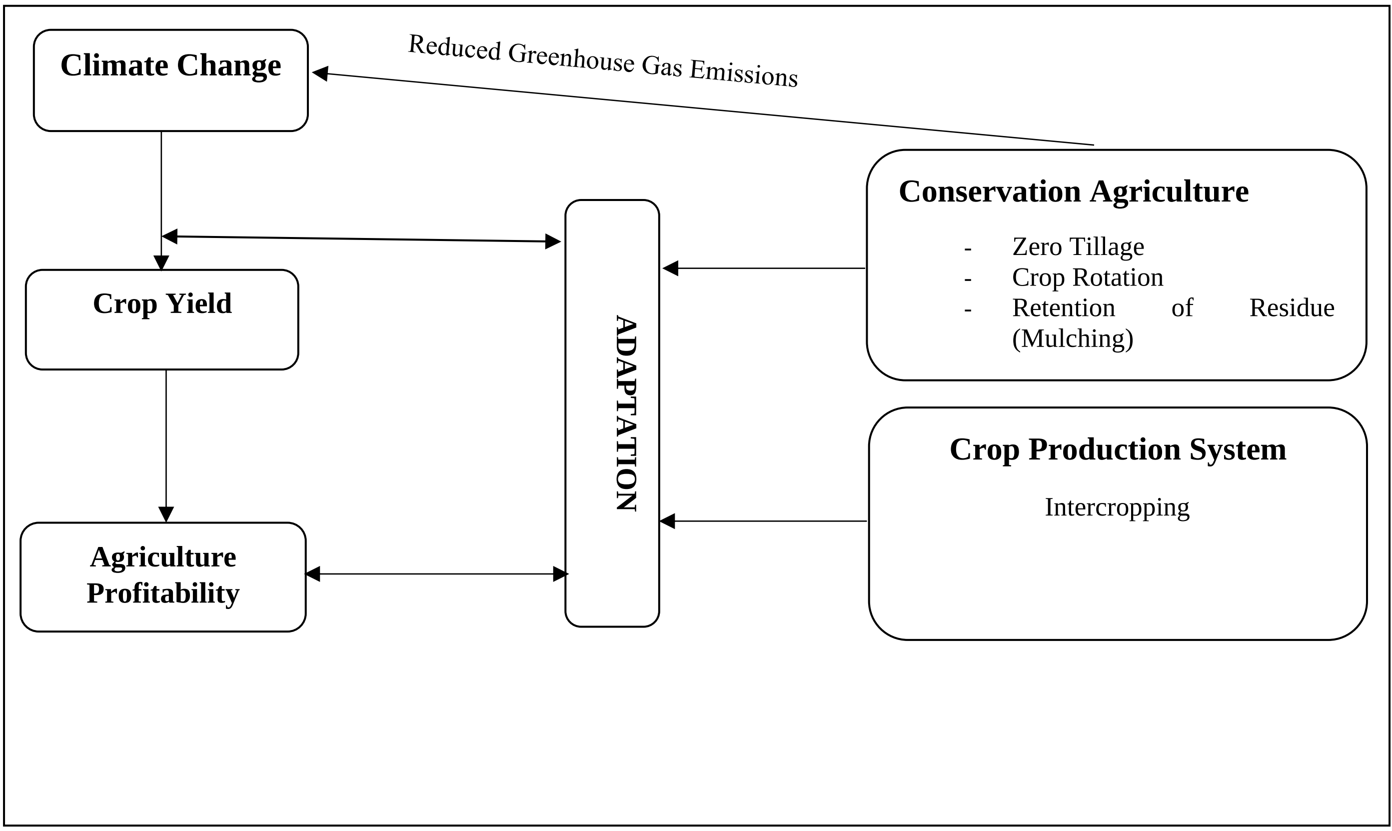

Figure2. 1: Conceptual Framework

Source: Adopted from Climate Volatility and Change in Central Asia: Economic Impacts and Adaptation (Braun and Heckelei, 2013)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will start off by looking at the description of the study areas. It will go on to give the research design process in detail together with the description of the different treatments under study. Later sections of the chapter will look at the methods used for data collection and analysis. Lastly, the researcher will give the ethical considerations observed whilst undertaking this study.

3.2 Brief description of study area/sites

The study was conducted at the University of Zimbabwe (UZ) farm and Domboshava Training Centre (DTC).

The University of Zimbabwe (UZ) farm is in Teviot dale, Mazoe District. It is located (17.73° S, 31.02 E) approximately 12.5km North of Harare along Mazowe road with an altitude of 1503 masl. It falls in NR 2a and receives an average annual rainfall of 826 mm. The soils at the farm classified as Chromic Luvisols or fersiallitic (40-60% of clay) (Nyamapfene, 1991);

Domboshava Training Centre is located 27 km North-East of Harare in Goromonzi District, Mashonaland East Province at latitude 17^{0}36’ S and longitude 31^{0}26 ‘ E with an altitude of 1560 m.a.s.l. The soils at DTC are granitic sands (<5% clay); moderately deep (100 cm) and classified as *Arenosol*s or Paraferralitics (Jones et al., 2013). Domboshawa Training Centre is in agro ecological region IIa which is predominated by intensive and semi-intensive farming. The area receives an annual average rainfall of 750-1000 mm and daily temperatures range from 15-20ºC.

3.3 Research Design and treatment description

A Split plot design was used, replicated four times with five treatments. All treatments were under CA.

Main Treatments

MS-sole maize s*ole cropping*

MPI- Maize and pigeon pea *Intercropping*

MPR- Maize after pigeon pea *rotation*

MCI- Maize and cowpea I*ntercropping*

MCR-maize after cowpea rotation

Sub Treatments

a) Unfertilised control

b) Application of 150kg/ha Compound D (7:14:7)

3.4 Plot Management

3.4.1 Land preparation and residue management

The experiment was conducted in the 2019/2020 cropping season. The trials had a gross plot size of 12m × 8m for the main treatments. Net plot of sub- treatment was 5m × 3.6m. Maize variety of PGS 63 was sown in all plots at a spacing of 90cm between rows and 50cm between planting stations within rows with 3 seeds per planting station which were thinned to 2. Compound D was used as basal fertiliser dressing at 150kg ha^{-1}. This was only applied to maize only during planting. Top dressing (Ammonium Nitrate) was applied only to maize plots, at a rate of 150kg ha^{-1}. All maize seeds were planted on the same day. Pigeon pea was planted in the same rows with maize at a spacing of 90cm × 50cm and 90cm × 25cm for sole cropping. Cowpea was planted in between maize rows 90cm × 25cm for intercropping and 45cm× 25cm for sole cropping. All legumes were sown with 3 seeds per hole which were thinned to one plant per station.

Weed control was done by hand weeding 2-3 times during the cropping season when weeds were about 5-10cm in height. Planting stations were holed out using hand hoes. Crop residues were retained wherever possible and aimed at a minimum residue retention rate of 2.5-3t/ha. In all intercrops, sole maize with a plant population of 44 444 plants/ ha was used as a control in each block.

3.5 Data collection methods

3.5.1 Soil macro organisms

To determine the number of soil macro fauna under each treatment, soil monoliths measuring 25cm ×25cm ×30 cm deep were used. The soils were extracted from 0-10 cm, 10-20 cm and 20-30 cm layers. Samples from the monoliths were hand-sorted for macro fauna, (beetle spider, earthworms and termites) assessment (Nhamo 2009). Numbers of organisms found were recorded according to each depth. Thmacro organism data was collected once for the season 2019/2020.

3.5.2. Water infiltration

Water infiltration was measured using the time to pond method (Ngwira et al., 2012; Verhulst et al., 2011). Firstly, the watering can was calibrated to determine the exact values of water to be poured. This was done by pouring known volumes (5000ml) of water into the can and recording the water level. Measurements were then taken at two positions per plot. A metal wire ring of 50 cm diameter was placed on the soil surface and water irrigated in the middle of the ring using a rose nozzle. The wire ring was placed over the soil, with the planting row located within the wire diameter so as not to impede water to flow out of the area. The initial water level was indicted within the watering (5000mls). Water was then poured from a height of 75 cm into the centre of the ring under a stable angle. Ponding was considered, when water was flowing out of the ring and the time taken to attain this was taken to be the time-to-pond with the assistance of a stop watch. The time taken and the final water level in the watering can was recorded (Govaerts et al., 2006). The results were reported in mm hr^{-1}

3.5.3 4 Maize grain and stover yield

Maize grain and stover were harvested for yield determination from the net plot measuring 5m x 3.5 m stover Maize grain and stover was harvested with 4 rows within each plot in all the treatments. The number of plants and cobs per net plot were recorded. The fresh cobs and stover were weighed and recorded. A sub-sample comprising five cobs in all treatments were taken and the fresh weight cobs will be recorded. Stover sub-sample of approximately 500 g was taken and its fresh weight was measured. The stover and cob sub-samples were oven dried at 75^{o}C for 72 hours and the dry weight was recorded. The grain weight was recorded after shelling for each plot. Grain moisture was recorded using a Dickey-john mini GAC® moisture tester meter and grain weight was adjusted to 12.5% moisture content.

3.6 Data analysis methods and calculations

The data was subjected to Analysis of Variance (ANOVA) to compare the treatment effects on biota, soil moisture grain and stover yields of maize and GMCCs using R version 3.6.0. Where the treatment means were significantly different, the least significant difference (LSD) test at 0.05 probability level separated them.

Equation 1: Partial/ Relative Land Equivalent Ratio (PLER)

The Land Equivalent ratio was calculated according to equation 1 as:

$$pLER = \frac{la}{lb} \qquad \text{(Equation 1)}$$

Where:

$pLER$ = Partial Land Equivalent Ratio

la = Yields for maize in the intercropping system

lb = Yields for sole maize crops (Nassary et al., 2020)

3.7 ETHICAL CONSIDERATIONS

This research study was undertaken in the most acceptable manner. The researcher carried the research taking into account the ethical considerations expected and acceptable for a good study.

Respect for the Environment

The manner in which this research study was conducted shows the researcher's respect for the environment. All chemicals used in this study are environment friendly.

Respect for Intellectual property

The researcher acknowledged fully all work done by other researchers. All cited sources were referenced correctly and using the department's recommended referencing style.

Honesty

The research was carried out in total honesty. There was no bias in the manner in which data was collected and presentation of facts. Data was collected according to the steps laid out in the research design. Findings were presented without alteration to suit the researcher's expectations.

Carefulness

The researcher was careful not to leave room for error. All data collected was cross checked and clearly labelled.

3.7 SUMMARY

The experiment was conducted at two sites which are the University of Zimbabwe farm and Domboshava Training center. The two sites have clay soils and sandy soils respectively. The experiment consisted of five treatments with two sub treatments which were unfertilised and fertilised. These treatments were replicated four times and a split plot design was used.

Data was collected for water infiltration, soil macro organism, maize and stover yield. Soil macro organisms were collected using a soil monolith at 0-30cm depth to determine the biota activity in different treatments. Water infiltration was collected using time to pond method and the results were reported in mm/hr. Grain and stover yield was determined by collecting a subsample of 5 cobs which were oven dried and then shelled. Stover had subsamples of 500g which were oven dried and weighed. The partial land equivalent ratio was calculated using the yield data. All data was subjected to Anova at ($p<0.005$) to compare the treatment effects using R version 3.6.0. Where the treatment means were significantly different, they were separated using the least significant differences (LSD) test.

CHAPTER 4

Title?

Abstract

Climate change is being experienced in most parts of the world. It has resulted in low rainfall and dry spells. These weather conditions has resulted in smallholder farmers suffering the most as they rely on rainfed agriculture. Intercropping has been advocated by many researchers as positive results have been noticed. This practice not only conserve soil moisture but also protects the soil from erosion as well as increase macro organism activity in the soil. The research was carried out at University of Zimbabwe (UZ) farm and Domboshava Training Centre (DTC) and research during the 2019/20 season. The experiment had five treatments (maize sole, maize pigeon pea intercropping, maize after pigeon pea, maize cowpea intercropping and maize after cowpea). Water infiltration and soil biota data was collected. All data was subjected to Analysis of variance (ANOVA) used to R version 3.6.0.There was no significant difference in water infiltration in all treatments (p >0.27). with respects to soil macro organisms, site was the only factor with significant difference (p<0.008). However the results showed that infiltration as well as macro organism density was high in maize pigeon pea.

Keywords: macro organisms, water infiltration, intercropping

Maize-legume rotation and intercropping effects on water infiltration and soil biota under conservation agriculture on sandy and clay soils in humid.

4.1 Introduction

In moisture stress areas and arid, crop failure is usually associated with moisture stress due to water scarcity. There is high moisture loss from the soil due to high temperatures in those areas (Ayele, 2020). Intercropping is a better way of reducing the effects of climate change being adopted by many farmers, smallholder farmers included. In areas with fragmented land and cropping systems with limited external inputs, intercropping is one of the ways to attain sustainable development as more crops can be grown on a small piece of land.

The most common type of intercropping is that of cereals and legumes. Many studies have been undertaken to assess the impact of intercropping and have shown the incredible benefits of this kind of crop production system especially to areas which receive little rainfall. These studies show that due to their broad leaves, legumes like mucuna and jack bean provide a vegetation cover which reduces evaporation unlike in bare soils and fields with a sole crop (source?). According to Lemlem,, (2013), Different studies have shown that cover crops such as mucuna, common vetch and lablab can help in retaining soil moisture. Their cover nature allows them to conserve more moisture and also prevent soil erosion therefore the importance of intercropping systems. Legumes such as cowpea and pigeon pea could significantly reduce soil moisture stress and increase soil productivity as compared to sole maize cropping (Janeth et al., 2014).

4.2 Materials and Methods

4.2.1 Description of the site

The experiment was conducted for one year at University of Zimbabwe farm and Domboshava. The University of Zimbabwe farm is geographically located with the ranges of farm 17.73° S, 31.02 E with an elevation of 1503 m.a.s.l. It is found on the 12.5 km peg from Harare the capital city of Zimbabwe. It falls under Natural Region (NR) 2a with soils 40-60% of clay. The site soils are classified as Chromic Luvisols (Nyamapfene, 1991). The study site has a bi-modal rainfall pattern with shorter rainy season from March-May and longest rainy season from August-November. The area receives an average annual rainfall of 826 mm.

Domboshava Training Centre is located 27 km North-East of Harare in Goromonzi District, Mashonaland East Province at latitude $17^{0}36'$ S and longitude $31^{0}26$ ' E with an altitude of 1560 m.a.s.l. The soils at DTC are granitic sands (<5% clay); moderately deep (100 cm) and classified as *Arenosol*s or Paraferralitics (Jones et al., 2013). Domboshawa Training Centre is in agro ecological region IIa which is predominated by intensive and semi-intensive farming. The area receives an annual average rainfall of 750-1000 mm and daily temperatures range from 15-20ºC.

4.2.2 Research Design

The experiment was laid in a split plot design with five treatments replicated four times. The treatments were: sole Maize - cropping (MS), Maize – pigeon pea intercropping (MPI), Maize after pigeon pea rotation (MPR), Maize –cowpea intercropping (MCI) and Maize after cowpea rotation (MCR). The experiment field was prepared by hand using a hole. The plot sizes were 12m x 8m. In all treatments maize was planted at a recommended spacing of 90cm × 50cm. Pigeon pea was planted in the same rows with maize at a spacing of 90cm × 50cm and 90cm × 25cm for sole cropping. Cowpea was planted in between maize rows 90cm × 25cm for intercropping and 45cm× 25cm for sole cropping. All legumes were sown with 3 seeds per hole which were thinned to one per plant station. Basal fertiliser of Compound D (7:14:7) was applied to maize only at rate of 150kgha. Top dressing of Ammonium Nitrate was later applied in two equal splits at the 4^{th} week and 7^{th} week maize only after planting. It was applied at a rate of 150kg/ha. All agronomic practises such as weeding, pest control was done in the experiment according to maize and legume recommendations as described in Chapter 3.

4.2.3 Water infiltration measurement

Water infiltration was measured using the time to pond method (Ngwira et al., 2012; Verhulst et al., 2011). Firstly, the watering can was calibrated to determine the exact values of water to be poured. This was done by pouring known volumes (5000ml) of water into the can and recording the water level. Measurements were then taken at two positions per plot. A metal wire ring of 50 cm diameter was placed on the soil surface and water irrigated in the middle of the ring using a rose nozzle. The wire ring was placed over the soil, with the planting row located within the wire diameter so as not to impede water to flow out of the area. The initial water level was indicted within the watering (5000mls). Water was then poured from a height of 75 cm into the centre of the ring under a stable angle. Ponding was considered, when water was flowing out of the ring and the time taken to attain this was taken to be the time-to-pond with the assistance of a stop watch. The time taken and the final water level in the watering can was recorded (Govaerts et al., 2006). The results were reported in mm hr^{-1}

Soil biota

To determine the number of soil organisms under each treatment, soil monoliths measuring 25cm ×25cm ×30 cm deep were used. The soils were extracted from 0-10 cm, 10-20 cm and 20-30 cm layers.Samples from the monoliths were hand-sorted for macro fauna, (beetle spider, earthworms and termites) assessment (Nhamo 2009). Numbers of organisms found were recorded according to each depth. The soil macro organism data was collected once for the season 2019/2020.

4.2.4 Data analysis

The data was subjected to Analysis of Variance (ANOVA) to compare the treatment means on biota and water infiltration stover using R version 3.6.0. Where the treatment means are significantly different, they were separated using the least significant differences (LSD) test at p= 0.05.

4.2.5 Challenges encountered during data collect

Transport was one of the major setbacks in terms of collecting data as the research was conducted in two different sites. The researcher failed to collect time to pond data in Domboshava because of the pandemic which had hit the country. For this reason, the researcher could not go on with infiltration analysis for the Domboshava site and left only to rely with the UZ farm site which could be accessed better.

4.3 Results and Discussion

4.3.1 Infiltration on different treatments

The results showed that there was no significant difference on infiltration in all treatments ($P>0.05$) Fig.3. However, maize pigeon pea intercrop (MPI) showed the highest rate of infiltration amongst all treatments whereas maize sole showed the least rate of infiltration. This can be attributed to the fact that in sole maize there was less macro organism activity unlike in intercrops which had more vegetative cover from the leaves of legumes (pigeon pea and cowpea) on top of the mulch. The vegetative cover and mulch increased biota activity which led to increased soil disturbance resulting in increased infiltration Thierfelder et al., (2012). Again, the increased infiltration can be explained by reduced runoff as a result of intercropping with the legume. This is similar to the findings by Ajayi (2016) which showed that intercropping promotes earthworm population which protects the bare soil and makes soil water content higher. There was no significant difference between plots due to the fact all the plots were under conservation agriculture which meant there was presence of mulch in all plots. However, it was only the degree of infiltration which was different owing to the different amount of vegetative cover in the plots.

Figure 2: Infiltration

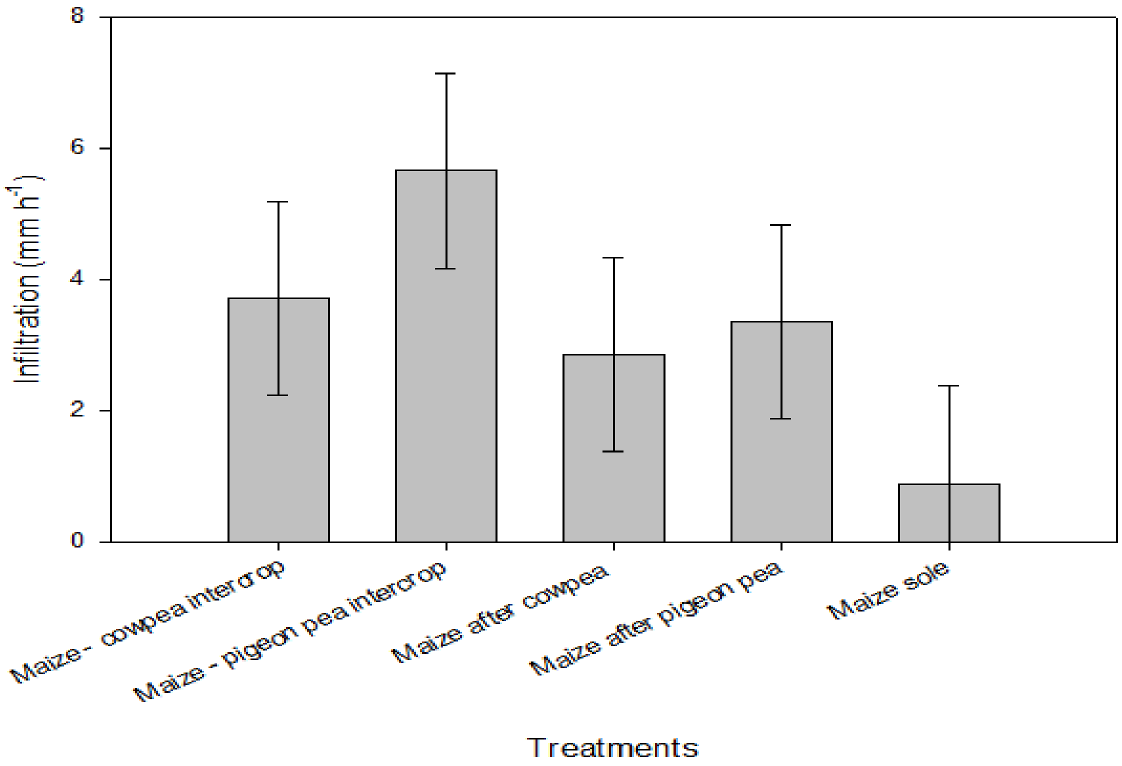

Figure 3: Effects of infiltration on different treatments

4.3.2 Soil density

On the soil macro organism, site had a significant difference at ($p<0.008$). This can be attributed to the fact that the two sites have got different soil types. University of Zimbabwe farm has clay soils and Domboshava training centre has sandy soils.

There was no significant difference in the cropping systems (MS, MPI, MPR, MCI and MCR). However, a significant number of microorganisms were found in the treatment which had maize and pigeon pea interaction. Maize and cowpea treatments showed low density numbers of macro organisms. This is because cowpea is a fast growing legume and it is a short season legume compared to pigeon pea, which is late maturing hence giving macro-organisms ample time to multiply and decompose the vegetative matter This means that the cowpea leaves and mulch quickly decompose and once they decompose micro-organisms move away deep down the soil profile which is more than 30cm deep. Pigeon pea on the other hand, it's a long seasoned legume and it takes about three quarters of the season in the field, therefore with this the legume continues to drop leaves and the macro organism reactions continue to take place hence higher density in pigeon pea plots. Another reason is that pigeon pea residues take a long time to decompose because of the thickness whereas cowpea has got thin stems which quickly decompose (Bationo and Ntare, 2000).

Discussion needs to be compared go findings done by other researchers on similar studies

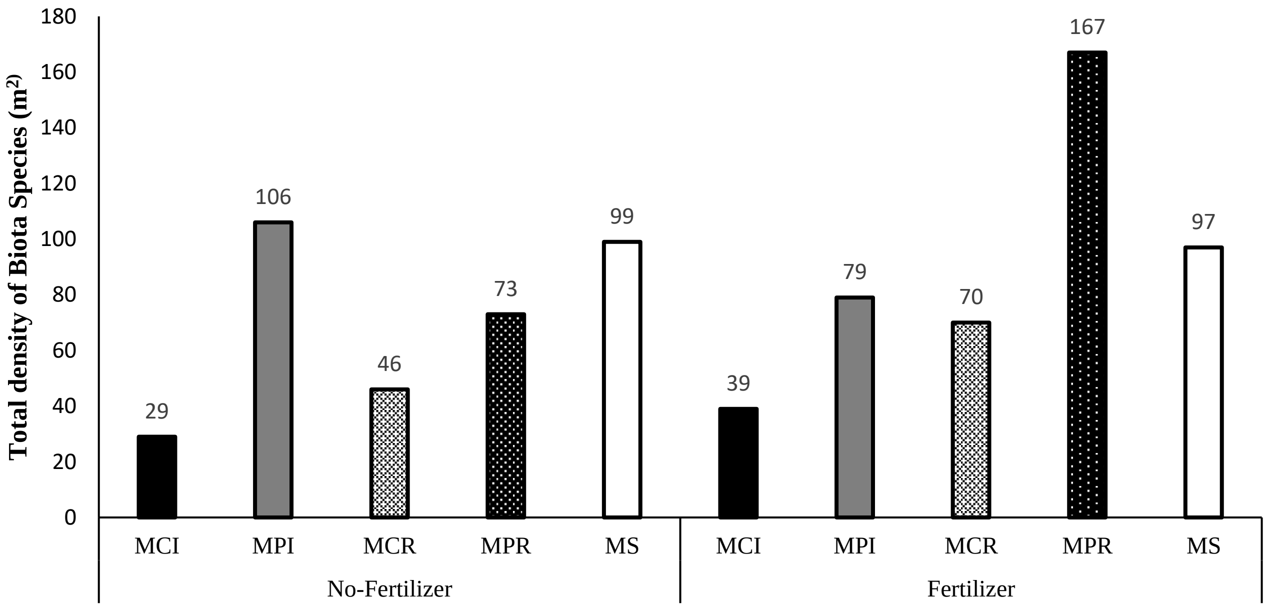

Figure 4: Total density of biota species.

4.4 Recommendations

Based on the results of this study, smallholder farmers are encouraged to practice intercropping as this will promote macro organism activity leading to high rate of decomposition. When decomposition occurs, it will promote water infiltration and reduce soil erosion thereby making use of the little moisture they would have received. To add on, smallholder farmers can integrate into intercropping farming especially with pigeon pea as it is a long season legume therefore the soul will be protected from erosion of wind as well as water.

4.5 Conclusion

The results showed positive effects on treatments with legumes than sole cropping therefore it shows that interaction of cereal and legume yield positive results whether in intercropping or rotation systems.

CHAPTER 5

RESULTS

Effects of intercropping and rotating maize with cowpea and pigeon pea on maize grain yield, stover yield and Land Equivalent Ratio.

Abstract

Different technologies to increase maize (grain) production under rain fed systems are needed, considering the low grain yield in small-scale farming sector in Zimbabwe. Intercropping and crop rotations are part of the sustainable intensification strategies. These have enabled increased maize grain yield. This research examined the impact of maize-legume intercropping and rotation on maize grain yield, stover yields and land equivalent ratio. The study was carried out at the University of Zimbabwe (UZ) farm (17.73° S, 31.02 E) and Domboshava Training Centre (DTC) ($17^0$36’ S,$31^0$26 E). The trial had five treatments (maize sole, maize pigeon pea intercropping, maize after pigeon pea, maize cowpea intercropping and maize after cowpea). Partial land equivalent ratio was calculated using grain and stover yields. Analysis of variance was done to compare treatments using R version 3.6.0. Both maize grain and stover was significant at both sites. Site had a significant difference at

($P<0.000$), treat at ($p<0.000$), and sub treat at ($p<0.000$) with F-Values of 358.881, 39.025, 66.672 respectively.Partial Land Equivalent ratios was a significant difference between site and sub treat ($p<0.010$) grain partial land equivalent ratio. Stover yield showed a significant difference on site $p<0.006$) and on treatments (MS, MPI, MPR, MCI, MCR) ($p<0.002$).The results showed that intercropping can increase grain and stover yields and also it is better to practise intercropping than sole crops as intercropping treatments had values more than 1 on pLER.

Keywords: Intercropping, Partial land equivalent ratio, water infiltration, soil biota, maize grain and stover yields.

5.1 Introduction

Most smallholder farmers in Southern Africa rely on maize production for their means of survival. However due to changes in climate, Southern Africa has not been spared on the issues of receiving little rainfall, high temperature and increase in heat waves. These weather changes have resulted in drought in most parts of Africa. Studies have been conducted across the globe and in Africa per ser and have shown that the practice of conservation agriculture can help in reducing food shortages. Farmers can practise intercropping as well as crop rotations. These practices help in fighting pests and diseases as well increase in weed suppression. Intercropping reduces soil erosion as most of the legumes like mucuna form a dense bush which protects the soil from water and wind erosion. Smallholder farmers are encouraged to incorporate green manure cover crops in their fields as these help in reducing moisture loss due to their cover nature. Legumes also play a role in biological nitrogen fixation which is an essential nutrient to maize. For those farmers which cannot afford fertilisers they can make use of these legumes thereby increase in maize yields. Integrating legumes such as green manure cover crops (GMCCs) with maize is an advantage to smallholder farmers who practice mixed farming because some GMCCs like pigeon pea and cowpea are rich in protein and these can be used as food for humans and or feed for livestock (Maasdorp and Titterton, 1997).

5.2 Material and Methods

5.2.1 Description of study area

The study was conducted at two sites which are the University of Zimbabwe (UZ) farm and Domboshava Training Centre (DTC) which is a Centre for agricultural training and research.

The University of Zimbabwe (UZ) farm is in Teviot dale, Mazoe District. It is located approximately 12.5km North of Harare along Mazowe road. It falls in Natural Region 2a on soil with 40-60% of clay. The UZ farm (17.73° S, 31.02 E) at an altitude of 1503 m asl has soils classified as Chromic Luvisols (Nyamapfene, 1991) and receives an average annual rainfall of 826 mm.

Domboshava Training Centre is located 27 km North-East of Harare in Goromonzi District, Mashonaland East Province at latitude (17^{0}36' S,31^{0}26 ' E) with an altitude of 1560 m.a.s.l. The soils at DTC are granitic sands (<5% clay); moderately deep (100 cm) and classified as *Arenosol*s or Paraferralitics (Jones et al., 2013). Domboshawa Training Centre is in agro ecological region IIa which is predominated by intensive and semi-intensive farming. The area receives an annual average rainfall of 750-1000 mm and daily temperatures range from 15-20ºC.

5.2.2 Research Design

The experiment was laid in a split plot design with five treatments which were replicated four times. The treatments were (MS) Maize - sole cropping, (MPI) Maize – pigeon pea intercropping, (MPR) Maize after pigeon pea rotation, (MCI) Maize –cowpea intercropping and (MCR) Maize after cowpea rotation.

The experiment field was prepared using a hand hoe. The plot size was 12m * 8m. In all treatments, maize was planted at a recommended spacing of 90cm × 50cm. Pigeon pea was planted in the same rows with maize at a spacing of 90cm × 50cm and 90cm × 25cm for sole cropping. Cowpea was planted in between maize rows 90cm × 25cm for intercropping and 45cm× 25cm for sole cropping.

All legumes were sown with 3 seeds per hole which were later on thinned to remain with one per plant station. Basal fertiliser of Compound D (7:14:7) was applied to maize only at a rate of 150kgha. Top dressing of Ammonium Nitrate was later applied in two equal splits at the 4th week and 7th week maize only after planting. It was applied at a rate of 150kg/ha. All agronomic practises such as weeding, pest control were done in the experiment according to maize and legume recommendations.

5.2.3 Data collection procedure

5.2.3.1 Maize grain and stover

Maize grain and stover were harvested for yield determination from the net plot of 4rows at a distance of 5 m in all the treatments. The number of plants and cobs per net plot were recorded. The fresh cobs and stover were weighed and recorded. A sub-sample comprising 5 cobs in all treatments were taken and the fresh weight cobs will be recorded. Stover sub-sample of approximately 500 g was taken and its fresh weight was measured. The stover and cob sub-samples were oven dried at 75°C for 72 hours and the dry weight was recorded. The grain weight was recorded after shelling for each plot. Grain moisture was recorded using a Dickey-john mini GAC® moisture tester meter and grain weight was adjusted to 12.5% moisture content.

5.2.3.2 Partial Land Equivalent ratio

Partial/ Relative Land Equivalent Ratio (LER)

The Land Equivalent ratio was calculated according to equation 1 as:

$$pLER = \frac{la}{lb} \qquad \text{(Equation 1)}$$

Where:

$pLER$ = Partial Land Equivalent Ratio

la = Yields for maize in the intercropping system

lb = Yields for sole maize crops (Nassary et al., 2020)

5.2.4 Data analysis procedure

The data was subjected to Analysis of Variance (ANOVA) to compare the treatment effects on biota, soil moisture grain and stover yields of maize and GMCCs using R version 3.6.0. Where the treatment means are significantly different, they were separated using the least significant differences (LSD) test at 0.05 probability level

5.3 Results

5.3.1 Maize grain yield results and Discussion

The results showed that there was a significant difference on site ($P<0.000$), cropping systems ($p<0.000$), and subtreat ($p<0.000$). Sub treatment and treatment had a significant difference also at ($p<0.010$). Site+ treatment + sub treatment had a significant difference ($p<0.001$).

Fig.5, shows that maize after pigeon pea (MPR) had the highest yields ranging about 5000kg/ha and maize sole showed the least grain yields of less than 2500kg/ha. This shows that rotations, cereals and legumes have a lot of benefits as far as yield and water retention is concerned. This may be because there was no competition for nutrients and water than in plots with intercrops. Nutrients are washed down through the soil profile by the vertical movement of water. Another reason is that since pigeon pea is a deep rooted legume, it is able to access nutrients that had been washed down the soil profile hence giving benefit to that maize in the intercrop whereas cowpea and maize are shallow rooted crops hence low yields than maize pigeon pea plot. Again, upon plant death and decomposition, nitrogen is released to the top soil layers.

These results show the importance or rather benefits of practising intercropping because these legumes can also be used to supplement food at household level. According to Snapp et al., (2010) pigeon peas are eaten green as a snack, dry as a paste, and as relish. In most parts of southern Africa, cowpea leaves are used to make a vegetable relish and the grain is used similarly to pigeon peas. This means that legumes provide a cheap source of protein, no matter how they are prepared and consumed. Again, upon plant death and decomposition, nitrogen is released to the top soil layers so that crops like maize will be able to utilise the nitrogen

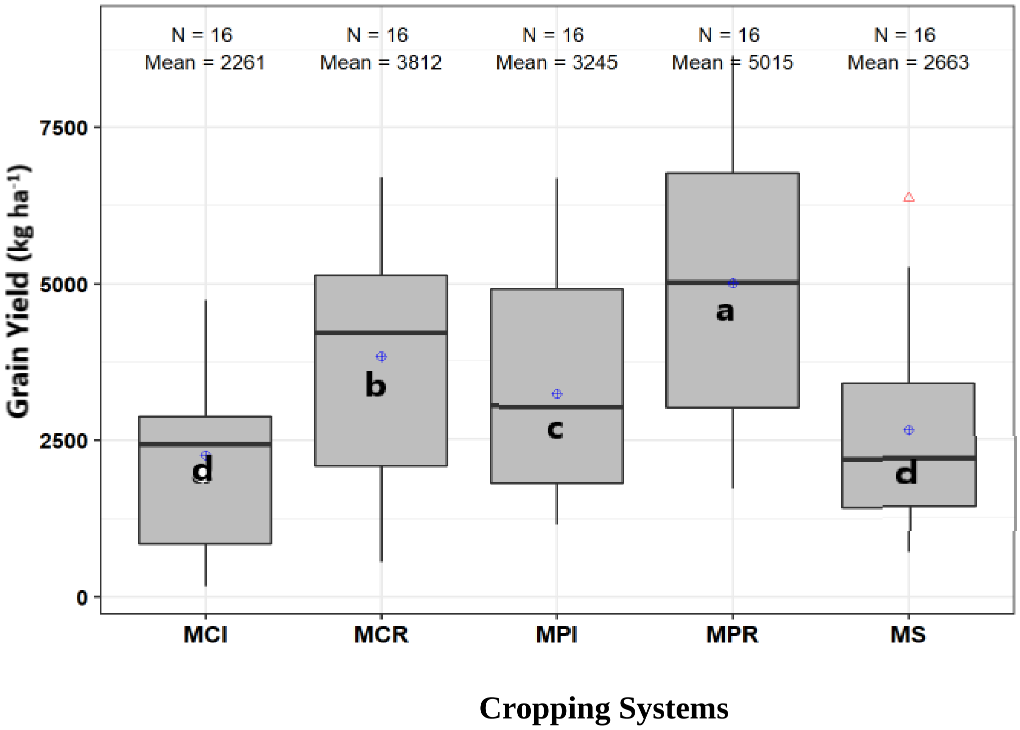

Figure 5.1 Box plot of Maize grain yields in kgha^{-1}

Figure 6 , Domboshava had a lower grain yield than the University of Zimbabwe which has got clay soils. At UZ farm maize pigeon pea rotation showed the highest yields of 6000kg/ha. This is because sand soils which are found at Domboshava tend to leach more than clay soils (UZ) hence the leaching will lead to downward movement of nutrients into the soil profile.

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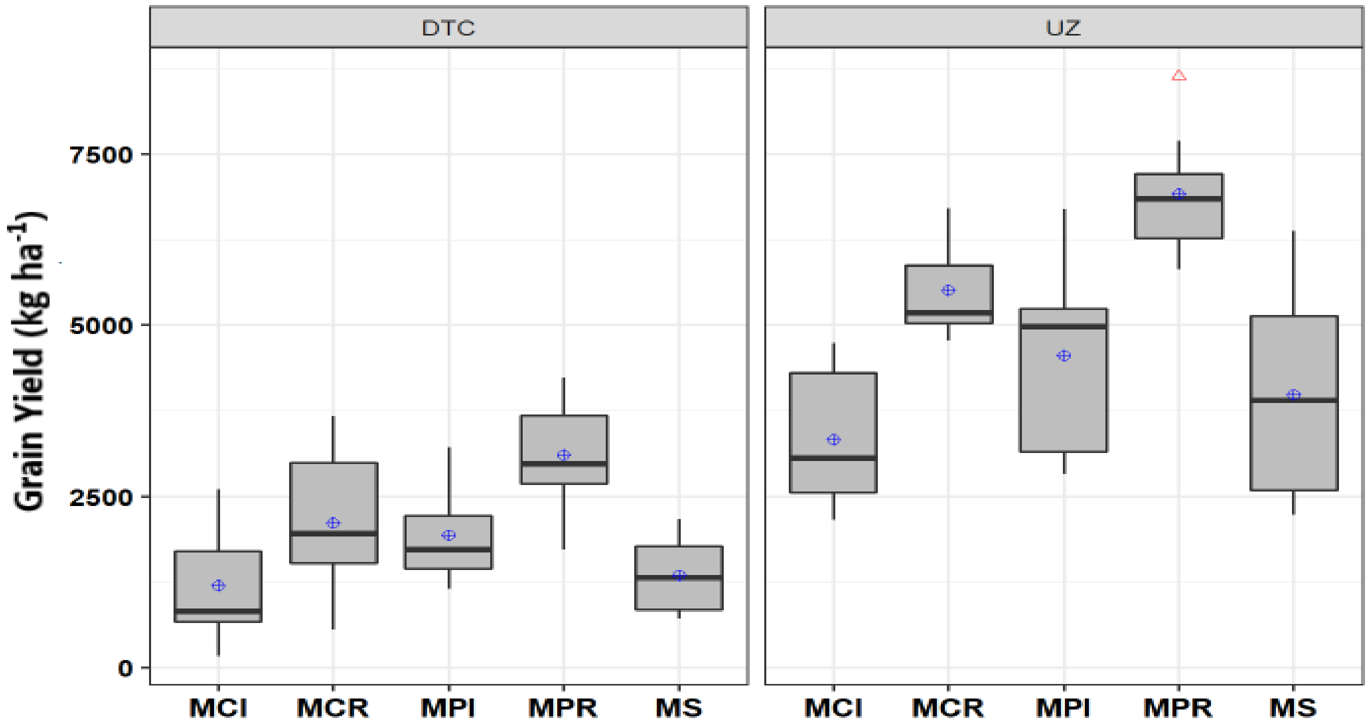

CROPPING SYSTEMS

Figure 6: Box plots showing differences in grain yield at UZ and DTC.

Fig. 7 shows that cropping systems that had fertiliser recorded higher yields compared to cropping systems that were unfertilised. Addition of fertiliser helped in boosting nitrogen in the soil especially in areas at Domboshava which has sand soil and have low nitrogen hence this boast in grain yield.

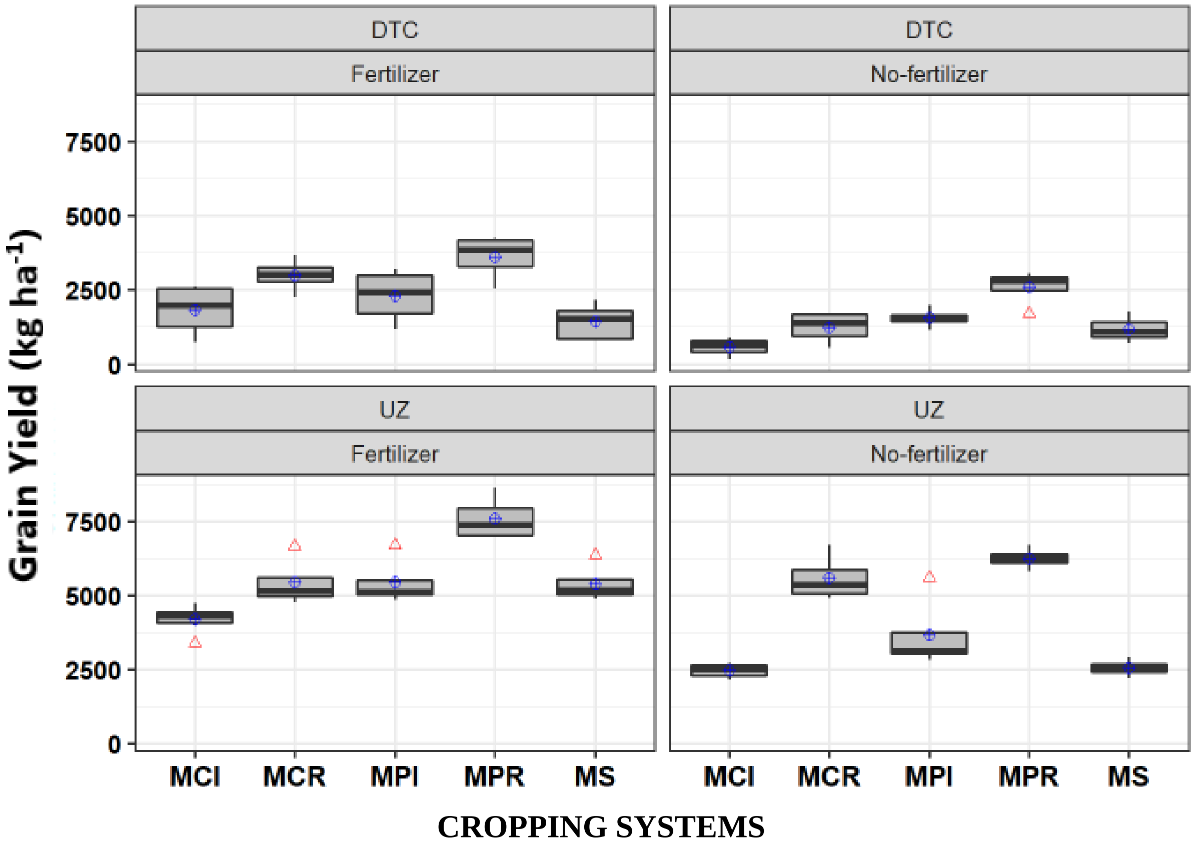

Figure 7: Box plots showing subtreat effect on different cropping systems and sites.

5.3.2. Stover Yield

The table ?? below shows that there was a significant difference on site ($p<0.000$), treatments ($p<0.005$) and sub treatment ($p<0.046$).This shows that different soil types play a role in terms of stover yields. More stover was recorded at University of Zimbabwe farm than at Domboshava.

The Figure 8 shows that maize after pigeon pea (MPR) had the highest stover yields of about 3523kg/ha with maize cowpea (MCI) intercrop being the lowest which was below 2500kg/ha. These results can be attributed to the fact that pigeon pea is a long seasoned legume and pigeon pea has got thicker stacks than that of cowpea therefore resulting in highest stover than other plots. The results show the importance of legumes as their stover can improve soil fertility through nitrogen fixation and litter decomposition.

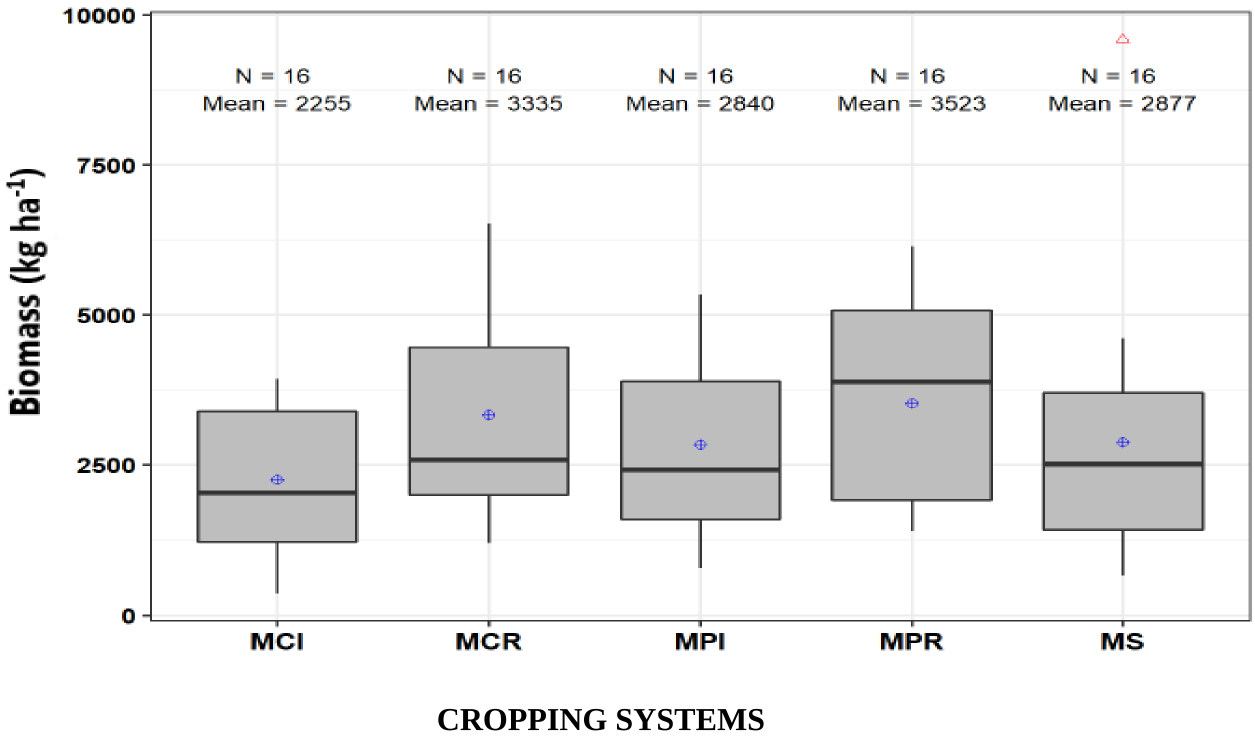

Figure 8: Box plots showing stover yields in kgha^{-1}

University of Zimbabwe had more stover than in Domboshava with the highest treatment maize after cowpea as shown in *Figure* ***8***. The highest stover was about 4000kg/ha and the least recorded in maize sole crop and Maize cowpea intercrop. At Domboshava, maize after cowpea had the highest stover although it was less than that of University of Zimbabwe

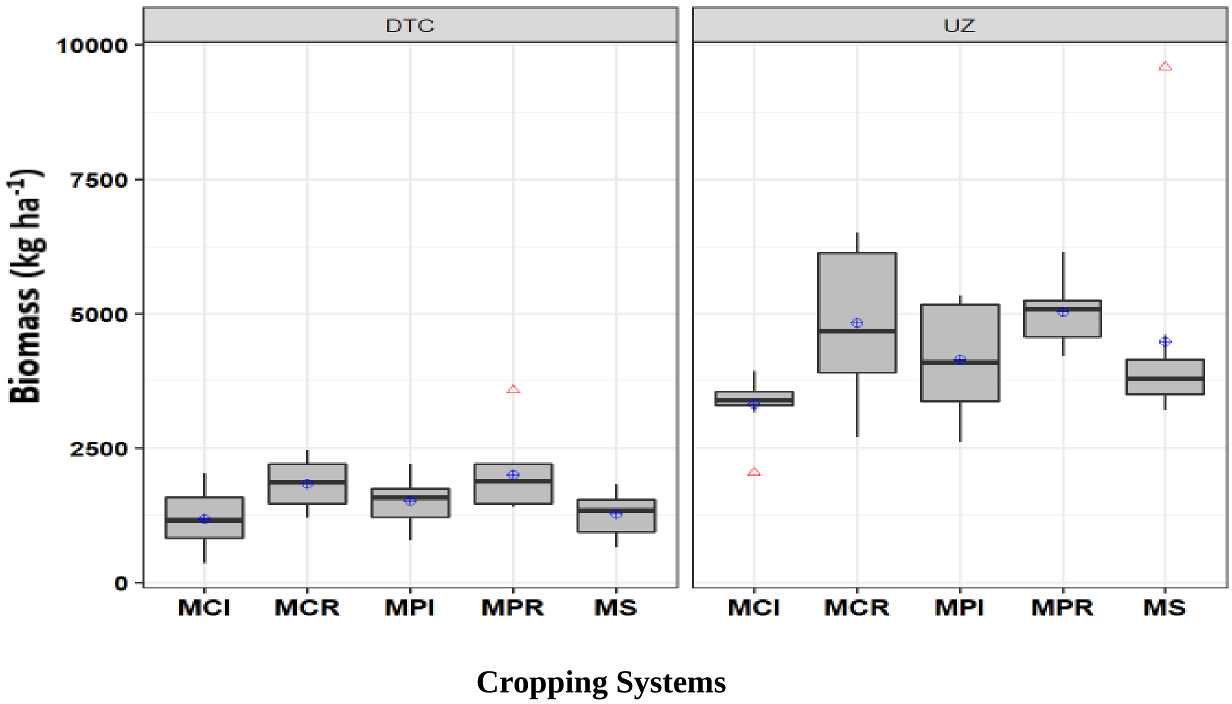

Figure 9 Box plots showing stover yield at different sites in different cropping systems:

In terms of Subtreat the results showed that there was significant difference (p<0.046) as shown in **Error! Reference source not found.**. Highest stover was recorded in fertilised plots at DTC than plots without fertiliser. However the opposite was recorded at University of Zimbabwe farm. Plots without fertiliser recorded the higher stover yields than those fertilised. This could be attributed to the fact that UZ has better soils (Clay) than DTC (Sandy), and application of fertiliser to sandy soils often give positive results. As for the case with clay soils, they have a good nutrient retention capacity and as such the soils might end up being too concentrated which may lower productivity. Maize after cowpea however recorded the highest yields at both sites. University of Zimbabwe farm of about 3523kg/ha and Domboshava had about 3420kg/ha with maize sole being the lowest at all sites.

In terms of Fertiliser and no fertiliser, the results showed that there was significant difference amongst sub treatments (p<0.046) as shown in **Error! Reference source not found.**. Highest stover was recorded in fertilised plots at DTC than plots without fertiliser. However the opposite was recorded at University of Zimbabwe farm. Plots without fertiliser recorded the highest stover yields than with fertiliser. Maize after cowpea however recorded the highest yields at both sites. University of Zimbabwe farm of about 3523kg/ha and Domboshava had about 3420kg/ha with maize sole being the lowest at all sites.

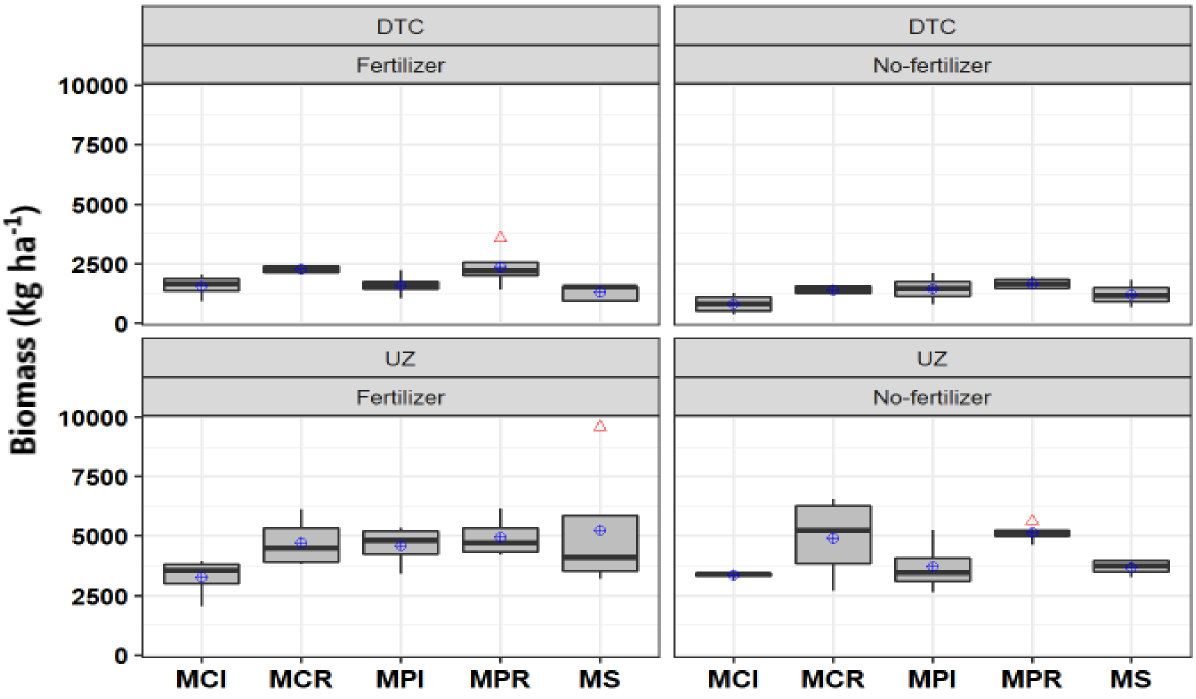

Figure 10: Box plots showing Stover Yields for UZ and DTC

5.3.3 Partial Land Equivalent Ratio Results and Discussion

Results **Error! Reference source not found.** indicated that there was significant difference between site and sub treat (p<0.010) grain partial land equivalent ratio. Stover (**Error! Reference source not found.**) showed a significant difference on site p<0.006) and on treatments (p<0.002).

Figure 11 shows that the partial land equivalent ratio was high in maize after pigeon pea, maize pigeon pea intercrop and maize after cowpea which are more than 1. Maize cowpea intercrop had less than 1 on both sites. This showed that it is better to grow maize and cowpea as sole crops than intercrops. However in the case of pigeon pea it showed that intercropping is better than maize and pigeon pea alone. At Domboshava it shows that intercropping is about 60% better than sole cropping and more than 200% when rotating maize and pigeon pea at both sites. University of Zimbabwe farm shows that maize intercropping is better than sole cropping with about 80% better than sole cropping.

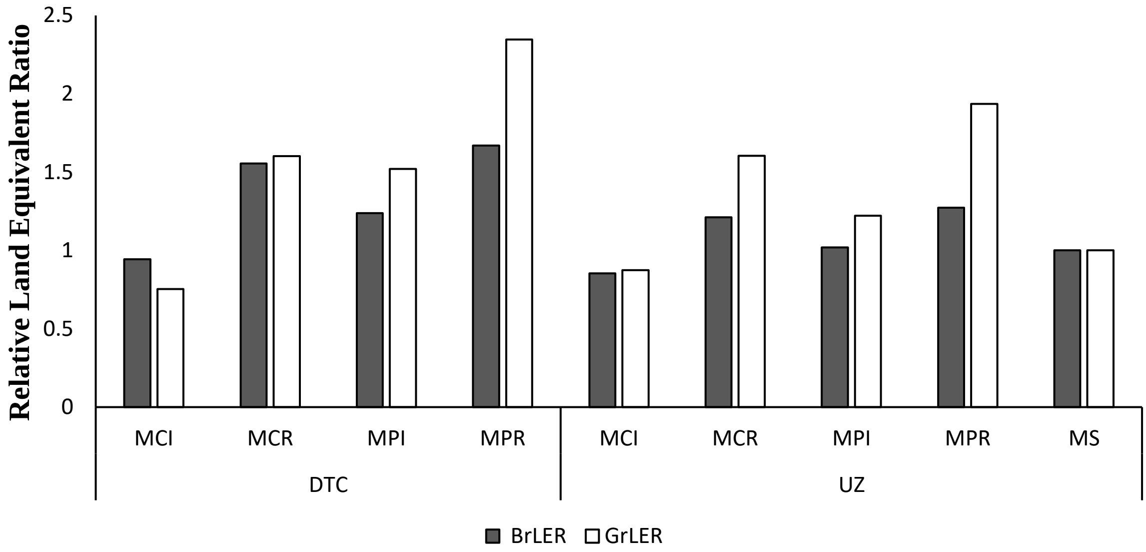

Figure 11: Partial Land Equivalent Ratio – Stover and Grain

5.4 Recommendations

The results show that smallholder farmers can engage into intercropping farming systems as it gives higher yields than those they were getting from sole cropping of maize on their small pieces of land. There is also a greater chance of getting more mulch from the legumes which they can use as residues in the next growing season. This will help to conserve the little moisture they have especially in areas with sand soils.

5.5 Conclusion

Based on the results, it is advisable to practice intercropping with pigeon pea as it increases maize yields. Pigeon peas can be sold thus generating extra income which they can use to buy inputs among other essential needs.

Comments

The Discussion part is lacking as it is combined with the results, you therefore presented more of the results and less of the discussion

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter showcases the summary, the conclusions and recommendations from the study.

6.2 Research summary

This research looked at the various Crop production systems i.e. Crop rotation, mono cropping and intercropping systems that farmers use so as to come up with the one that yields the best results.

Five treatments were used in the study which were maize sole maize/ cowpea intercropping, maize/ pigeon pea intercropping, maize after cowpea and maize after pigeon pea. These two legumes were used as these legumes are easily accessible and edible. The research showed that maize and pigeon pea intercropping system conserves more moisture compared to maize cowpea and other treatments. There is also high biota activity in intercropping systems than in other treatments. Land equivalent ratio was also calculated and it showed that intercropping systems are better as compared to sole cropping of maize. This is evidenced by high yields in intercropping systems for both maize grain and stover yields in both sites. alone as these yield. Research studies have shown positive results from practising sustainable intensification agriculture like intercropping and practice of rotations. These practises will thereby help smallholder farmers as most of the maize production comes from smallholder farmers.

6.3 Conclusions

It has been noted in preceding chapters that both intercropping and rotations gave higher yields with the latter being giving the highest. For intercropping, the best combination was Maize and pigeon and the same can also be rotated yielding the same results.

6.4 Policy implication and recommendations

In line with climate change, governments should aim to strengthen policies on climate smart agriculture. It is one of the few win-win free technologies available to smallholder farmers (Edwards et al., n.d). As shown in earlier sections of this research, there is a need to sensitize farmers on the benefits of a holistic approach when it comes to CA as opposed to using one technology without cooperating the other two.

As evident in previous chapters, there is a need to lay out a clear path or simply put an exit strategy for when development agencies move out of communities. It has been noted that most projects fail as soon as the development agencies move out. There is a need for a sense of ownership by communities so as to ensure that there is continuity.

6.5 Areas for further research

Since the GoZ has taken CA to the next level by introducing the 'pfumvudza' concept in the bid to increase agricultural productivity, the researcher feels it can be a possible area of further research. Given that the adoption of CA is fairly low, there will be a gap in literature to assess the effects of the new concept.

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