BINDURA UNIVERSITY OF SCIENCE EDUCATION

CROP SCIENCE DEPARTMENT

A COMPARATIVE STUDY OF THE RELATIONSHIP BETWEEN SOIL MANAGEMENT PRACTICE AND CROP PRODUCTIVITY UNDER DIFFERENT SOIL TYPES

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCES

DEDICATION

I dedicate this work with love and gratitude to my caring parents who are responsible for all my academic requirements.

DECLARATION

I Prosper Matsiya declares that this research project is a result of my original work and has not been presented somewhere for any degree or any institute. All other supplementary sources of information have been acknowledged by means of references.

CERTIFICATION OF THE DISSERTATION

Bindura University of Science Education

Department of Crop Science

The undersigned certify that they have read and recommend to the Bindura University to accept a dissertation entitled: A COMPARATIVE STUDY OF THE RELATIONSHIP BETWEEN SOIL MANAGEMENTPRACTICE AND CROP PRODUCTIVITY UNDER DIFFERENT SOIL TYPES.

Submitted by

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In partial fulfilment of the requirements for the Bachelor of Science Honors Degree in Agriculture.

SUPERVISOR..

DATE ....

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ABSTRACT

Maize is a staple crop in Zimbabwe, and optimizing its productivity under different soil conditions is vital for sustainable food security. Information on the interaction between soil management practices and soil types is essential for enhancing maize yield. A field experiment was conducted at [insert farm name/location] in Zimbabwe to assess the effects of three soil management practices—conventional tillage, zero tillage, and cover cropping—on maize productivity under three contrasting soil types: sandy, loam, and clay. The trial was laid out in a Randomized Complete Block Design (RCBD) with three replicates, totaling 27 plots. The parameters measured included grain yield, dry stalk weight, cob diameter, number of grains per cob, leaf area index (LAI), harvest index, and soil pH. Data were analyzed using Analysis of Variance (ANOVA) in GenStat at a 5% significance level. Both soil type and management practice had significant effects on most parameters. The highest grain yield (e.g., X kg/plot) was recorded on loam soils under cover cropping, while the lowest was observed on sandy soils under conventional tillage. Cover cropping and zero tillage notably improved soil pH and maize performance across all soil types. No significant interaction effects were found for most parameters except [e.g., LAI or pH if applicable]. Overall, cover cropping on loam soil emerged as the most effective strategy for maximizing maize productivity. These results underscore the need for site-specific soil management strategies to enhance crop yields and promote sustainable agriculture in Zimbabwe.

Contents

CHAPTER 1

1.1Introduction

Soil management practices are integral to the sustainability of agricultural systems, significantly influencing both crop productivity and environmental health. As the global population continues to rise, projected to reach around 9.7 billion by 2050 (United Nations, 2019), ensuring a reliable food supply becomes an increasingly complex challenge. Agricultural productivity is fundamentally linked to soil quality, as soil provides essential nutrients, water, and structural support for crop growth. However, with growing concerns about climate change, soil erosion, and land degradation, it is becoming more critical to understand how various soil management practices impact crop yields. Effective soil management is crucial for maintaining soil fertility, improving agricultural output, and promoting sustainable environmental practices (Bationo et al., 2021).

The connection between soil management and crop productivity is complex and multifaceted. Different soil management techniques, such as tillage, crop rotation, fertilization strategies, and organic matter application, interact with the soil's physical, chemical, and biological properties, which in turn affect crop performance. For instance, tillage is commonly used to break up compacted soil, control weeds, and improve aeration. However, excessive tillage can result in soil degradation, erosion, organic matter loss, and reduced water retention (Mbah et al., 2023). On the other hand, conservation tillage, which minimizes soil disturbance, can enhance soil structure, promote better water infiltration, and maintain organic carbon levels, ultimately leading to improved crop yields (Zhao et al., 2023).

In addition to tillage practices, cover cropping is considered an effective strategy for improving soil health and increasing maize productivity, particularly under Zimbabwean soil conditions.

In addition to tillage practices, cover cropping is considered an effective strategy for improving soil health and increasing maize productivity particularly under Zimbabwean soil conditions (Rusinamhodzi et al., 2012; Thierfelder & Wall, 2010; Vanlauwe et al., 2011; Zhao et al., 2023). Cover crops planted during the off-season help reduce soil erosion, enhance organic matter content and promote nutrient cycling all of which benefits subsequent maize crops. In the context of Zimbabwe, where soil degradation and nutrient depletion are common challenges, the adoption of cover cropping has shown long-term benefits, including improved soil carbon storage and increased maize yields, making it a vital component of sustainable agricultural systems (Zhao et al., 2023).

Conventional tillage remains one of the most widely adopted soil management practices in global agriculture, particularly in regions where mechanized farming is dominant. It involves the mechanical turning and breaking up of soil, typically through plowing, harrowing, and other forms of soil disturbance aimed at creating favorable seedbeds, managing weeds, and incorporating crop residues (Lal, 2004). While conventional tillage can temporarily enhance soil aeration and improve short-term crop productivity, its long-term implications on soil health and sustainability are increasingly under scrutiny. Studies have shown that repeated tillage can lead to soil structure degradation, organic matter loss, and increased vulnerability to erosion and nutrient leaching (Montgomery, 2007; Mbah et al., 2023). The effects of conventional tillage vary significantly across different soil types. For instance, in sandy soils, the practice may exacerbate nutrient depletion and surface runoff while in clay soils it can contribute to compaction and reduced infiltration capacity (Brady & Weil, 2017). These outcomes highlight the importance of evaluating conventional tillage not as a one-size-fits-all strategy but within the context of specific soil characteristics.

Soil fertility and appropriate agronomic management practices are essential for enhancing maize productivity, particularly in smallholder farming systems where resource constraints limit the use of synthetic inputs. Among the critical soil chemical properties, soil pH plays a fundamental role in regulating nutrient availability, microbial activity, and root development. Consequently, understanding the influence of soil pH under different soil management strategies is vital for optimizing maize yields in diverse and variable soil environments (Brady & Weil, 2016; Zingore et al., 2007; Fageria & Baligar, 2008; Vanlauwe et al., 2011).It is crucial to examine how conventional tillage influences crop productivity across various soil types aiming to identify both the benefits and limitations of the practice in different agroecological settings.

Crucially, the effectiveness of soil management practices is not uniform across different soil types, which vary in texture, structure, drainage, nutrient-holding capacity, and organic matter content. For example, sandy soils typically have low water and nutrient retention capacities requiring more frequent fertilization and organic matter amendments to support productive agriculture (Lal, 2015). In contrast clay soils may have higher fertility but are prone to waterlogging and compaction, influencing the suitability of certain tillage and irrigation methods (Brady & Weil, 2017). Loamy soils, considered ideal for most crops, often respond well to integrated soil fertility management strategies (Vanlauwe et al., 2010). Understanding these variations is key to tailoring soil management approaches that are both efficient and sustainable within specific agroecological contexts.

This research provides valuable insights into how soil-specific management practices can be optimized to increase crop yields while promoting soil conservation. This is important as the world faces growing challenges related to food security, environmental sustainability and the impacts of climate change. Understanding the dynamics of soil management across varying soil types is important for ensuring that agricultural systems remain productive, resilient, and environmentally responsible in the face of these challenges.

1.2 Research problem

Despite the growing body of research on soil management, significant gaps remain in understanding the specific mechanisms through which soil type interacts with management practices to influence crop productivity. While many studies focus on individual practices or specific crop species, few have comprehensively examined how combinations of management practices across the same agroecological contexts and different soil types affect long-term crop performance (Mbah et al., 2023; Vanlauwe et al., 2010).In particular soil pH plays a fundamental role in regulating nutrient availability and microbial activity, both of which are critical for crop growth. Understanding how soil pH interacts with different management practices can inform targeted soil amendment strategies and optimize maize productivity. Addressing these gaps is essential for developing effective, location-specific soil management approaches that enhance crop yields while maintaining soil health.

1.3 Justification

Understanding the impact of soil management practices on crop productivity is essential for optimizing agricultural yields, particularly given the variability in soil types across different regions. Although various management practices have shown positive effects on crop performance, their effectiveness is often contingent upon specific soil characteristics which remain insufficiently understood. This study is therefore significant both theoretically and practically. Theoretically, it seeks to deepen our understanding of the complex interactions between soil type, soil pH, and management practices thereby addressing critical gaps in current agricultural research. Practically the findings will inform the development of tailored location-specific soil management strategies that can enhance crop productivity while maintaining soil health. This is especially important in the context of climate change which adds layers of environmental variability and stress on agricultural systems. Ultimately this research offers valuable insights for farmers, agronomists and policymakers aiming to improve food security and sustainable land use by optimizing soil management under the same agroecological conditions.

1.4 Aim

To investigate how zero tillage, conventional tillage and cover cropping influence maize productivity across sand, clay and loam soil in Zimbabwe

1.5 Specific Objectives

1. To evaluate the influence of soil ph on maize yield under different soil management practice across contrasting soil type.

2. To investigate how different soil management practices under different soil types influence maize growth and development.

1.6 Hypothesis

a) H_0: There is no significant influence of various soil management practices on maize productivity across sand, clay and loam soil in Zimbabwe

H_1: There is significant impact of the influence of various soil management practices maize productivity across sand, clay and loam soil in Zimbabwe

b) H_0: There is no significant relationship on the influence of soil ph on maize yield under different soil management practice across contrasting soil type.

H_1: There is significant relationship on the influence of soil ph on maize yield under different soil management practice across contrasting soil type.

c) $H_{0:}$ There is no significant difference on soil management practices under different soil types on influence on maize growth and development.

$H_{1:}$ There is significant difference on soil management practices under different soil types on influence on maize growth and development.

CHAPTER 2: Literature Review

2.1 History of maize

Maize (*Zea mays* L.) holds historical and economic significance in Zimbabwe, serving as a staple food crop and a key component of the country's agricultural landscape. The origins of maize cultivation in Zimbabwe can be traced back to the pre-colonial era, although the crop gained prominence after the introduction of improved varieties and agricultural practices in the late 20th century (Nyanga et al., 2021). Historically, maize was not only a food source but also a central component of cultural practices among various ethnic groups (Makanda et al., 2020).

The relationship between soil management practices and agronomic factors such as maize yield is central to optimizing productivity, especially in areas with diverse soil types. Among the key soil management practices are zero tillage, cover cropping, and conventional tillage, each of which has distinct effects on soil properties and crop performance. Recent studies have examined these practices in relation to different soil types, highlighting their potential benefits and challenges for maize production

2.2 Zero Tillage and Soil Productivity

Zero tillage (ZT), also known as no-till, maintains soil structure by eliminating ploughing and is recognized for its ability to enhance soil aggregation, organic carbon, and moisture retention—especially under irregular rainfall patterns and in erosion-prone landscapes (Cooper et al., 2021; Chauhan et al., 2023). Meta-analyses confirm ZT increases maize yields across diverse environments by reducing soil compaction and preserving moisture (Ghimire et al., 2023; Vogel, 1993). In tropical Africa, ZT combined with mulching significantly improves crop performance in semi-arid zones (Thierfelder & Wall, 2010; Munodawafa, 2012). Long-term studies show ZT enhances labile and stable soil organic carbon (SOC) fractions within macro- and micro-aggregates, underpinning improved carbon sequestration and soil structural stability (Cooper et al., 2021; Kravchenko & Robertson, 2011).

2.2.2 Cover Cropping and Soil Fertility

Cover cropping ameliorates soil health by increasing nutrient inputs, protecting against erosion, and promoting microbial activity. Meta-analysis indicates that cover crops in maize systems increase SOC by an average of 7.3% (Glab et al., 2023), and may sequester over 175 million Mg of CO_2-equivalent annually (Afzal et al., 2020). Leguminous cover crops notably improve nitrogen content, enhancing maize yield and reducing fertilizer dependency (Mobasser et al., 2014; Zhang et al., 2021). Furthermore, in tropical areas, cover crop integration enhances microbial diversity and drought resilience—attributes vital for Zimbabwean soils (Sainju et al., 2003; Blanco-Canqui et al., 2011).

2.2.3 Conventional Tillage and Soil Management

While conventional tillage supports immediate agronomic needs such as weed control and seedbed preparation, its long-term impact on soil health is problematic. Studies show tillage disrupts aggregates, reduces soil organic matter, increases runoff in clay soils and diminishes soil microbial diversity (Chakraborty et al., 2023; Liu et al., 2022). Comparative research in Nigeria and Zimbabwe reveals that conservation techniques like minimum tillage and mulching outperform conventional tillage in preserving soil moisture and yield (Ahaneku & Onwualu, 2007; Mupangwa et al., 2007).

2.2.4 Soil Type and Its Interaction with Tillage Practices

Soil texture influences the efficacy of tillage systems. Conservation tillage excels in clay and loam soils, improving maize yield via moisture retention (Zhao et al., 2024; Vogel, 1993). In contrast, sandy soils may initially benefit from conventional tillage for seedbed structure, though gains fade over time (Thierfelder et al., 2015). Conservation agriculture strategies such as tied ridges significantly minimize erosion in Zimbabwe's sandy zones (Munodawafa, 2012).

2.2.5 Integrated Approach: ZT, Cover Cropping, and Fertilization

Combining ZT, cover crops, and organic/ammonium fertilizers creates synergistic improvements in soil health and maize productivity (Yang et al., 2022). Intercropping strategies with legumes improve nutrient cycling, microbial biomass, and yield stability across agro-ecological zones (Fan et al., 2019; Ablimit et al., 2022). The FAO highlights this integrated conservation agriculture model for its benefits in yield generation and soil service sustainability (FAO, 2007).

2.2.6 Soil Organic Carbon and Biophysical Impacts of Conservation Agriculture

SOC accumulation under conservation practices is well-documented. Field studies in Zimbabwe show that mulching with residues enhances topsoil SOC under ZT conditions, though deeper layers (>30 cm) show limited change (Nyamangara et al., 2024). Meta-analyses across Mediterranean and subtropical climates report SOC increase of ~12% in conservation systems (Tadiello et al., 2023). No-till systems with residue return increase SOC by 14%, while residue return alone yields 24% gains (Zhang et al., 2024). Ecology studies show ZT boosts microbial mass and enzyme activity, reinforcing nutrient cycles (Frontiers, 2023).

2.2.7 Soil Biological Activity and Aggregate Stability

Conservation tillage has been proven to sustain microbial health. Research in the Indo-Gangetic Plains notes a 23–30% rise in microbial biomass and enzyme activities under ZT with residue retention (Frontiers, 2023). Meta-analysis of no-till globally indicates it enhances the proportion of large macroaggregates by 49.5%, a key structure for water infiltration and erosion resistance (Global meta-analysis, 2023; Tadiello et al., 2023).

2.2.8 Environmental Benefits: Carbon Sequestration and GHG Emissions

Conservation agriculture benefits extend into climate regulation—SOC increases while N_2O emissions decrease by up to 70% in no-till systems (Zhang et al., 2024; No-till farming, 2024). Globally, no-till could sequester between one-quarter and one-third of total annual anthropogenic CO_2, with combined residue incorporation further enhancing sequestration (Regenerative agriculture, 2024).

Chapter 3

3.0 Methodology

3.1 Research Site

This study was conducted at Reeds Farm located in Chanaka area of Bindura, Mashonaland Central Province, Zimbabwe (16.51° S, 31.30° E). The site lies at an altitude of approximately 1150 meters above sea level and receives annual rainfall ranging from 700 mm to 1000 mm with average temperatures between 25°C and 30°C. The region exhibits diverse soil types, primarily sandy, loamy and clay soils, making it ideal for assessing the interaction between soil types and management practices.

Bindura is a semi-arid agroecological region where agriculture is the main livelihood activity**.** The dominant crops grown in the area include maize, cotton, groundnuts, tobacco, and soybeans, typically cultivated under both rainfed and small-scale irrigation systems. Livestock rearing, particularly of cattle, goats, and poultry, is also an important component of the farming systems in the region.

Weed pressure is a common challenge for local farmers. Common weed species in the area include *Striga asiatica* **(witchweed)**, *Bidens pilosa* **(blackjack)**, *Cyperus rotundus* **(nutgrass)**, and *Amaranthus spp***.** These weeds compete with crops for water and nutrients and are especially problematic in maize production systems where soil fertility is low or tillage is limited.

3.2 Experimental Design

This research adopted a quantitative research design using a 2-factorial Randomized Complete Block Design (RCBD) to investigate the influence of three different soil management practices on maize productivity across three major soil types.

3.2.2Treatments and Factors

Two main factors were considered:

(A) Soil Management Practices with 3 levels which are conventional Tillage (C), Zero Tillage (Z) and cover Cropping (C).
(B) Soil Types with 3 levels which are sandy soil, loam soil and clay Soil

Each combination of these two factors was tested, resulting in a total of 9 treatment combinations as shown by the table below:

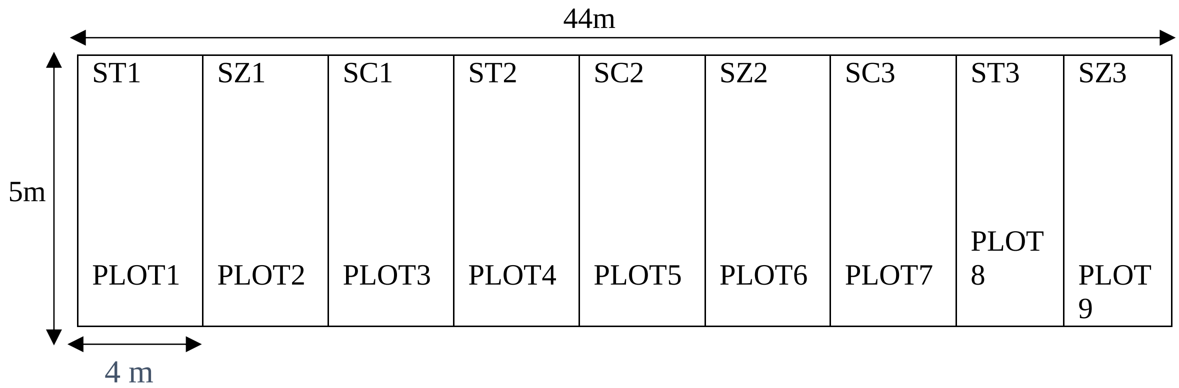
Table3.1: Treatments of the study

Soil type	Tillage practice	Code	Treatment
Sand	Conventional tillage	ST	T1
Sand	Zero tillage	SZ	T2
Sand	Cover Cropping	SC	T3
Loam	Conventional tillage	LT	T4
Loam	Zero tillage	LZ	T5
Loam	Cover Cropping	LC	T6
Clay	Conventional tillage	CT	T7
Clay	Zero tillage	CZ	T8
Clay	Cover Cropping	CC	T9

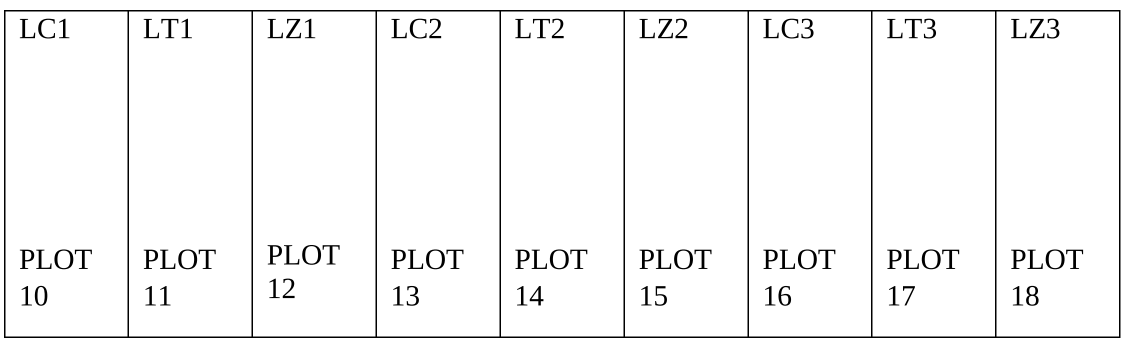
Field plan

RCBD of 9 treatments replicated 3 times

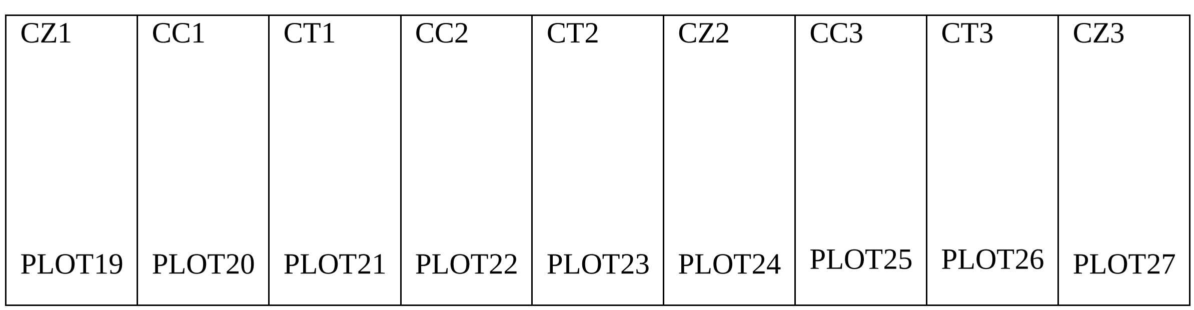
sand



loam



clay



These treatments were applied across three distinct soil types, sand, loam, and clay, with each combination replicated three times, giving a total of 27 plots (3 soil types × 3 practices × 3 replicates).

To establish the blocks, a pre-experimental soil survey was carried out across the experimental field using both laboratory and field-based methods. Soil texture was determined using the hydrometer method on composite samples, and physical characteristics such as structure, drainage, and colour were observed. These assessments allowed the classification of three distinct soil zones, sandy, loam and clay, all located within the same farm but spatially separated enough to maintain distinct soil profiles.

Each soil type was treated as a block in the RCBD and within each block, the three soil management treatments were randomly assigned and replicated three times. The plots were laid out with dimensions of 5 m × 4 m and 1-meter buffer zones were maintained between plots to reduce cross-treatment contamination

3.3Materials and Method

3.3.1Agronomic Practices

Prior to treatment application, composited soil samples were collected from each plot and tested to confirm soil type classification (sandy, loamy, or clay) following AOAC (1990). The field was planted with maize of variety SC 649 (medium maturity) at a rate of 25kg per hectare. The crop was planted on 4 November 2024.An inter-row spacing of 90cm and intra row of 25cm was used in every plot. Planting was done by manual method which is the hand method. Compound D was used as a basal fertilizer at a rate of 300kg/h during planting. Under zero tillage, the soil was left undisturbed, and maize was planted directly into the residue of the previous crop. Before maize planting, under cover cropping the cover crop (grass) were terminated by tilling in the cover crops as green manure. In conventional tillage, the land was plowed and disked, to create a fine tilth in compacted soil before planting.

3.3.2 Fertilizer Application

After planting when the plant was about 10-20cm (8-10leaves), we applied top dressing (ammonium nitrate) at a rate of 200kg/hectare. The split application method was used so as to reduce leaching and maximise efficient nutrient uptake.

3.3.3Weed, Pest, and Disease

The experimental site was kept weed free throughout the growing season to reduce risk of diseases through use of herbicides and hand hoeing. Most weeds were killed at planting where pre-emergency herbicide was applied Rescue and glyphosate at a rate of 2kg/hectare Integrated pest management (IPM) strategies were implemented including monitoring pest populations and using biological pest controls.

3.4Data collection

The following parameters were determined dry maize stalk weight, maize grain yield, number of grains per cob, Leaf area index, soil ph. and dry cob diameter. The performance of each management technique was measured on each of the following parameters Leaf area index (LAI) at 8weeks after emergency, soil ph and yield components. LAI was determined using a Delta-T leaf area meter which was the AM350 model

Parameter	**Description**
Dry maize stalk weight	After harvesting dry stalks from each block under each treatment was weighed on a mechanical scale
Maize grain yield	After shelling of cobs from each block under each treatment, a digital scale was used to measure weight and calculate yield
Number of grains per cob	The number of grains was counted and their means were calculated
Leaf area index	A delta-T leaf area meter was used to measure LAI
Soil ph	Soil pH was measured using the potentiometric method as described by AOAC (1990). Ten grams of air-dried soil were mixed with 25 ml of distilled water (1:2.5 ratio), stirred and allowed to stand for 30 minutes. The pH was then read using a calibrated digital pH meter.
Dry cob diameter	At harvest 15 dry cobs were selected and recorded cob diameter using a tape measure
Maize harvest index	Maize harvest index was calculated using data from maize grain yield and stalk weight using the following model Harvest index =maize grain yield /total biomass net

3.4.2Soil sampling

Soils were sampled before planting of maize (SC 649) in all the blocks and were also sampled prior to harvest. Samples were collected at 0-25cm depth by collecting 5cores per block. The five samples were mixed to obtain one composite per plot.500g of soil were weighed from each sample and examined at the lab. This soil was assessed for soil ph using the AOAC (1990) and texture.

3.4Statistical Analyses

All data were subjected to statistical analysis using GenStat 8th Edition. A two-way Analysis of Variance (ANOVA) was conducted to evaluate the effects of soil management practices and soil types on maize yield and related variables and their interaction on all measured traits. Where significant treatment effects were observed, Least Significant Difference (LSD) tests at the 5% significance level were used to separate treatment means.

CHAPTER 4: RESULTS

The objectives of the experiment were to investigate how zero tillage, conventional tillage and cover cropping influence maize productivity across sand, clay and loam soil in Zimbabwe.

4.1 Effects of soil types and management practice on Cob diameter

Both soil type and soil management practice significantly influenced cob diameter ($p<0.001$), while the interaction effect between the two was not statistically significant ($p=0.196$). Specifically loam soils showed large cobs consistently as shown by figure 4.1 below.

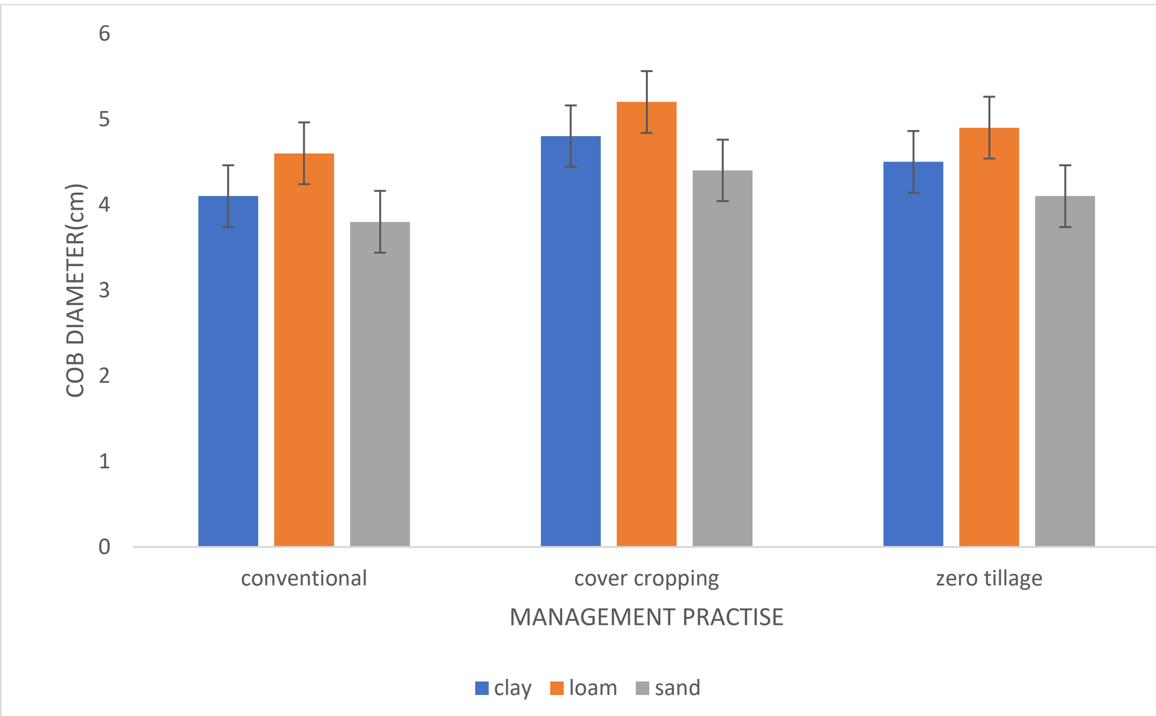


Figure 4.1 Effects of soil management practice and soil type on cob diameter

4.2Effects of soil types and management practice on maize grain yield

Significant main effects were found for management practice ($p < 0.001$) and soil type ($p < 0.001$), as well as a significant interaction ($p = 0.007$). Grain yield was highest in loam soils and under cover cropping, cover cropping consistently outperformed other practices in all soil types as shown in figure4.2:

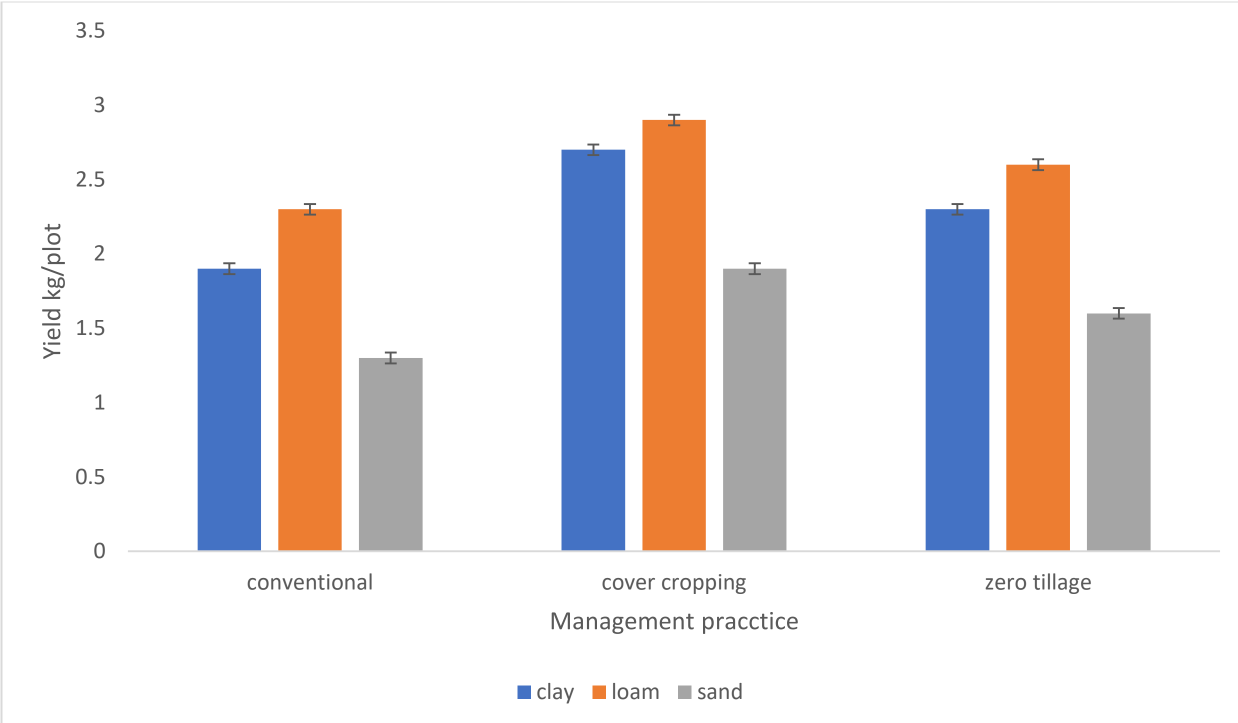


Figure 4.2: Effects of soil management practice and soil type on maize yield

4.3Effects of soil types and management practice on dry stalk weight

Results (Figure4.3) show significant effects from both soil type and practice ($p < 0.001$), with no significant interaction ($p = 0.196$). Clay and loam soils supported higher biomass accumulation than sandy soils. Among practices, cover cropping promoted greater stalk development.

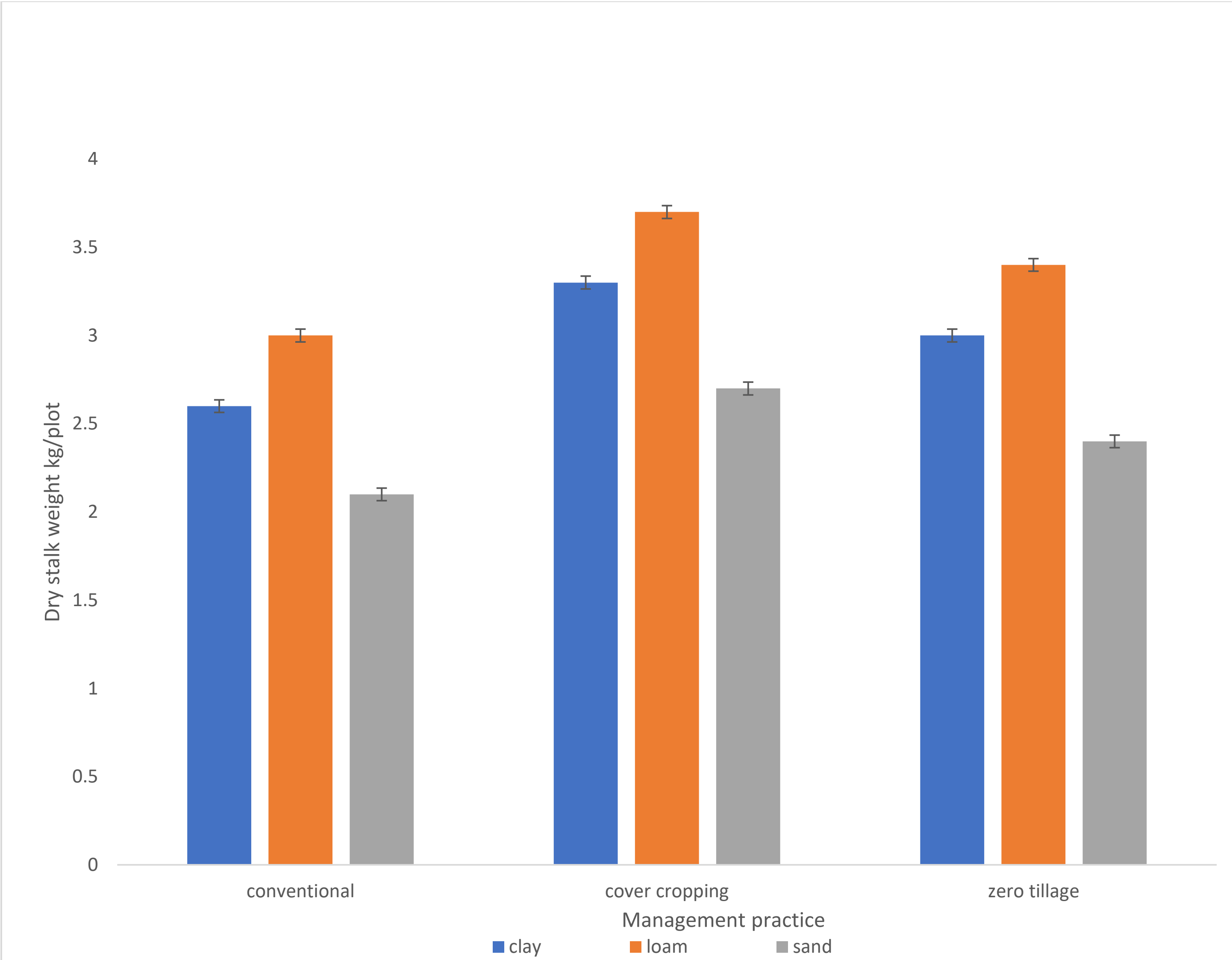


Figure4.3: Effects of soil types and management practice on dry stalk weight

4.4Effects of soil types and management practice on grains per cob

As shown in (figure4.4), both soil and practice significantly affected grain number ($p < 0.001$), with an interaction effect ($p<0.009$). The highest grain count was recorded under cover cropping in loam soils, while sandy soils under conventional tillage yielded the lowest.

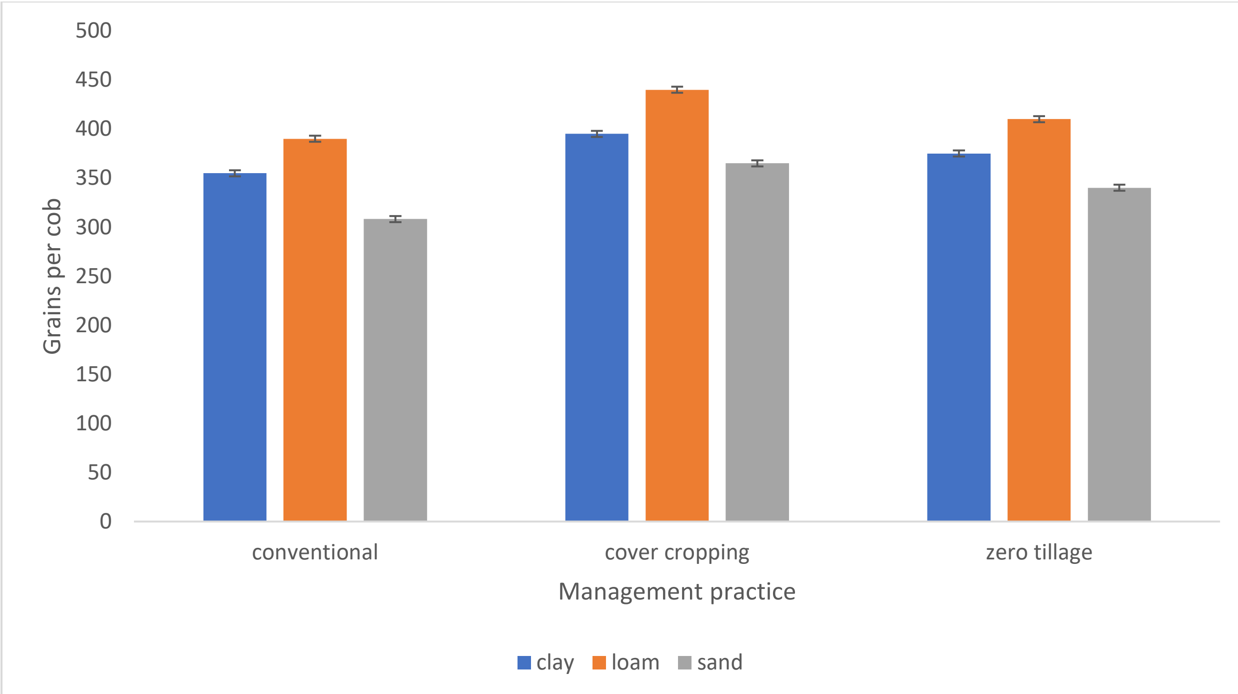


Figure4.4: Effects of soil types and management practice on grains per cob

4.5Effects of soil types and management practice on leaf area index

Figure 4.5 indicates significant effects of both soil type ($p<0.001$) and practice($p<0.001$), with no interaction. LAI was highest under cover cropping in loam soils, consistent with better moisture retention and nutrient availability.

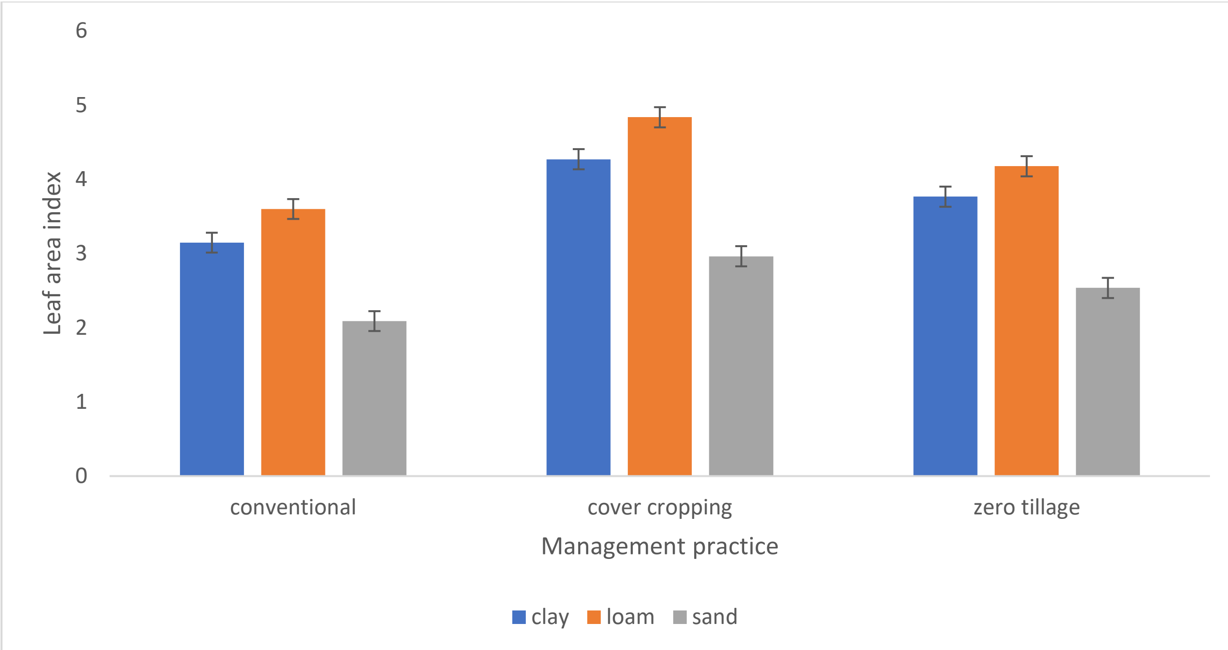


Figure4.5: Effects of soil types and management practice on leaf area index

4.6 Effects of soil types and management practice on soil ph.

Soil type and management practice showed significant effect both on soil ph. ($p<0.001$) and interaction was also statistically significant ($p<0.022$) . Soil ph. was lowest in sandy soils consistently.

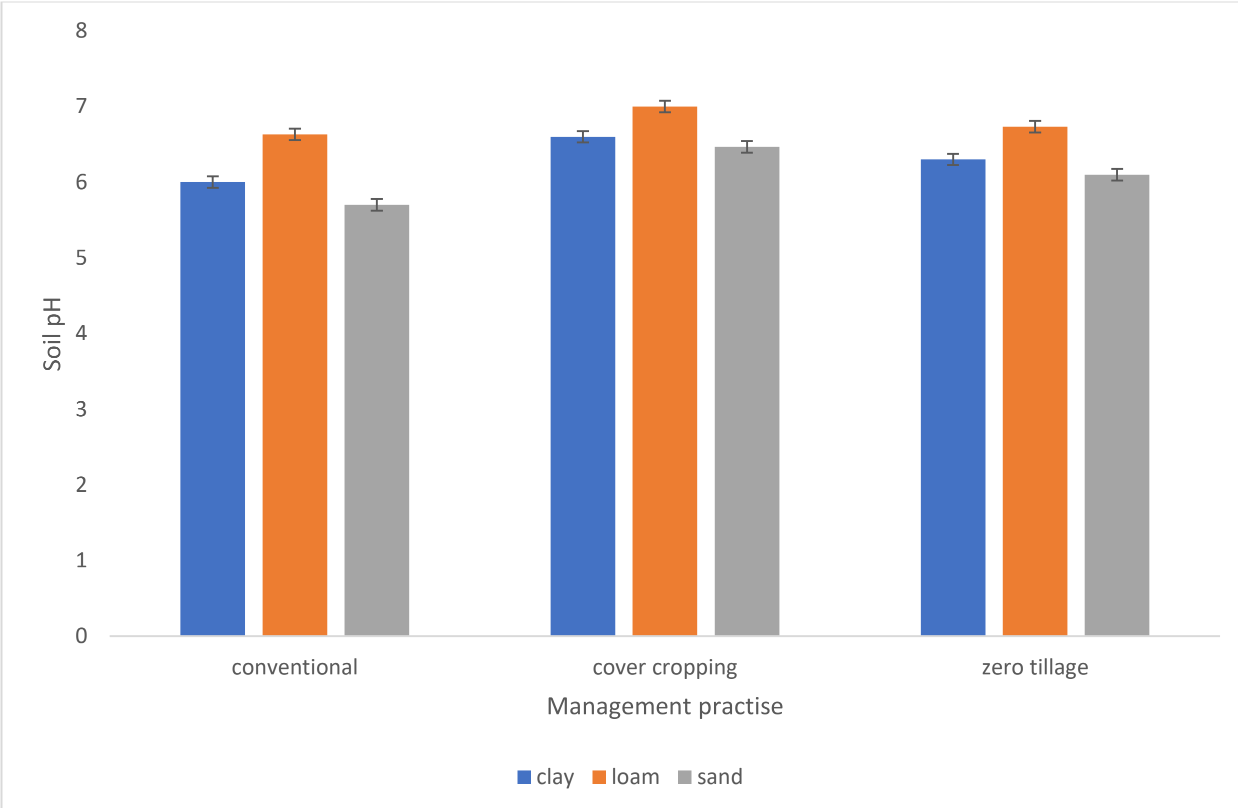


Figure4.6: Effects of soil types and management practice on soil ph

4.7Effects of soil types and management practice on harvest index

The two-way ANOVA revealed highly significant main effects for both soil type and management practice ($p<0.001$), while the interaction effect was statistically significant ($p=0.002$). Cover cropping improved HI across all soil types as demonstrated by figure 4.7 below.

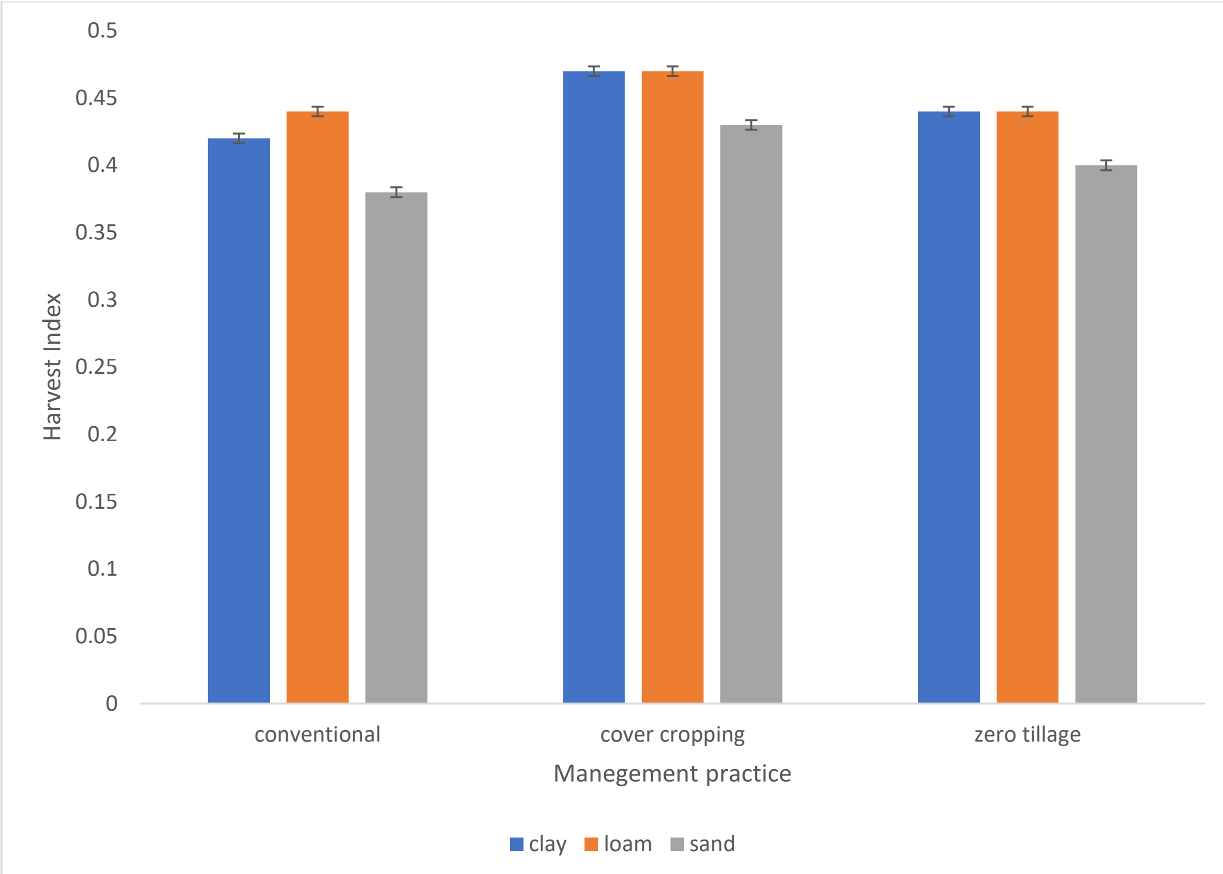


Figure4.7: Effects of soil types and management practice on harvest index

Chapter5: Discussions

5.1 Soil ph.

Cover cropping elevated soil pH, most notably in loam soils. Soil pH is a critical determinant of nutrient availability and microbial activity (Brady & Weil, 2017). Acidic conditions in sandy soils can reduce cation exchange capacity, leading to nutrient leaching and poor plant growth (Fageria & Baligar, 2008). The application of organic matter, such as manure, introduces buffering capacity and enhances biological activity, thus improving pH stability (Palm et al., 2001). This supports the importance of using organic inputs in sandy soils in Zimbabwe, where soil acidification is common due to over-cultivation and limited liming.

5.2 Grain yield

Grain yield was significantly affected by both soil type and management practice. Loam soils consistently outperformed clay and sandy soils. Zero tillage and cover cropping incorporation increased yield. Yield increases in loam soils are attributed to favorable soil structure and water-holding capacity (Tittonell et al., 2005). Conservation agriculture practices enhance soil organic matter, reduce erosion, and maintain soil moisture—factors that directly influence maize yield (Thierfelder & Wall, 2010).

5.3Dry maize stalk weight

Stalk weight significantly increased under loam and clay soils, especially with cover cropping. Sandy soils recorded the lowest biomass. Biomass accumulation is influenced by nutrient availability and water retention (Lal, 2006). Organic amendments improve root development and nutrient cycling, leading to greater vegetative mass (Vanlauwe et al., 2011).

5.4 Grains per cob

This trait responded positively to loam soils and cover cropping. Fewer grains per cob were observed under conventional tillage on sandy soils. Grain number per cob reflects the plant's reproductive efficiency and is sensitive to stress during silking and pollination (Bänziger et al., 2006). Poor soil fertility and drought stress, common in sandy soils limits kernel development (Rusinamhodzi et al., 2012).

5.5Cob diameter

Cob diameter was greatest in loam soils under cover cropping treatments. Cob growth is influenced by assimilate supply during grain filling, depending on photosynthetic area and root access to nutrients (Mueller & Vyn, 2001). Smaller cobs in sandy soils indicate nutrient or moisture constraints.

5.6Harvest Index

Harvest index values were higher in loam soils and under cover cropping and zero tillage. HI reflects the balance between economic yield and total biomass. Conservation practices optimize this ratio (Cassman et al., 2003). Lower HI in sandy soils under conventional tillage suggests a trade-off toward vegetative growth or stress-induced grain abortion.

5.7Leaf area index

LAI was highest in cover cropping and loam soil and lowest in acidic sandy soils. LAI is a proxy for photosynthetic capacity (Monteith, 1977). High LAI under improved management suggests better light interception. Soil acidity impairs root uptake of nutrients, limiting leaf development (Fageria et al., 2010).

CHAPTER 6: RECOMENDATIOS

6.1 Introduction

This study investigated the influence of soil management practices and soil type on maize productivity in Zimbabwe focusing on seven key agronomic traits. Loam soils consistently supported higher maize productivity with cover cropping producing the most beneficial results. Sandy soils performed poorly under conventional tillage, particularly for traits such as grain yield, leaf area index and soil ph. These findings highlight the need for tailored soil management practices specific to soil type in order to enhance maize productivity.

6.2 Recommendations

1.Farmers should prioritize the adoption of sustainable soil management practices, particularly Cover Cropping and Zero Tillage, to improve soil health and crop productivity. These practices can lead to enhanced soil structure, increased organic matter, and better moisture retention.

2Implementing a routine soil testing program is essential for monitoring soil pH and other health indicators. This allows farmers to make informed decisions regarding amendments and management practices tailored to their specific soil conditions

3.Policymakers should create incentives for farmers to adopt sustainable practices. This could include financial support, subsidies for organic inputs, and resources for training programs that focus on sustainable agriculture.

4.Future research should focus on long-term studies that examine the sustained impact of different soil management practices on soil health, crop productivity, and ecosystem services. This can provide valuable insights into the durability of these practices over time.

5.Researchers should explore the integration of precision agriculture technologies with sustainable practices. This can include the use of remote sensing, soil moisture sensors, and data analytics to optimize soil management strategies.

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APPENDECIES

GenStat Release 17.1 (PC/Windows 8) 23 May 2013 21:57:05
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GenStat Seventeenth Edition
GenStat Procedure Library Release PL25.1

```
   1  SET [WORKINGDIRECTORY='C:/Users/hi/Documents']
   2  "Data taken from file: '\
  -3  C:/Users/hi/Desktop/xool/Maize_Data_with_LAI_Updated.xlsx'"
   4  DELETE [REDEFINE=yes] _stitle_: TEXT _stitle_
   5  READ [PRINT=*; SETNVALUES=yes] _stitle_
   9  PRINT [IPRINT=*] _stitle_; JUST=left
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Data imported from Excel file: C:\Users\hi\Desktop\xool\Maize_Data_with_LAI_Updated.xlsx
on: 23-May-2013 21:57:24
taken from sheet "Sheet1", cells A2:J28

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  10  DELETE [REDEFINE=yes] Soil_Type,Practice,Rep,Dry_Stalk_Wt_kg_plot,\
  11
Grain_Yield_kg_plot,Grains_Cob,Cob_Diameter_cm,Harvest_Index,Leaf_Area_Index\
  12  ,pH
  13  UNITS [NVALUES=*]
  14  FACTOR [MODIFY=no; NVALUES=27; LEVELS=3;
LABELS=!t('Clay','Loam','Sandy')\
  15  ; REFERENCE=1] Soil_Type
  16  READ Soil_Type; FREPRESENTATION=ordinal
```

Identifier	Values	Missing	Levels
Soil_Type	27	0	3

```
  18  FACTOR [MODIFY=no; NVALUES=27; LEVELS=3; LABELS=!t('Conventional',\
  19  'Cover Cropping','Zero Tillage'); REFERENCE=1] Practice
  20  READ Practice; FREPRESENTATION=ordinal
```

Identifier	Values	Missing	Levels
Practice	27	0	3

```
  22  FACTOR [MODIFY=no; NVALUES=27; LEVELS=3; LABELS=*; REFERENCE=1] Rep
  23  READ Rep; FREPRESENTATION=ordinal
```

Identifier	Values	Missing	Levels
Rep	27	0	3

```
  25  VARIATE [NVALUES=27] Dry_Stalk_Wt_kg_plot
  26  READ Dry_Stalk_Wt_kg_plot
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Dry_Stalk_Wt_kg_plot	2.000	2.911	3.800	27	0

```
  29  VARIATE [NVALUES=27] Grain_Yield_kg_plot
  30  READ Grain_Yield_kg_plot
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Grain_Yield_kg_plot	1.200	2.167	3.000	27	0

```
  33  VARIATE [NVALUES=27] Grains_Cob
  34  READ Grains_Cob
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Grains_Cob	300.0	375.4	450.0	27	0

```
  37  VARIATE [NVALUES=27] Cob_Diameter_cm
  38  READ Cob_Diameter_cm
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Cob_Diameter_cm	3.700	4.489	5.300	27	0

```
  41  VARIATE [NVALUES=27] Harvest_Index
  42  READ Harvest_Index
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Harvest_Index	0.3700	0.4322	0.4800	27	0

```
  45  VARIATE [NVALUES=27] Leaf_Area_Index
  46  READ Leaf_Area_Index
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Leaf_Area_Index	1.920	3.487	5.130	27	0

```
  49  VARIATE [NVALUES=27] pH
  50  READ pH
```

Identifier	Minimum	Mean	Maximum	Values	Missing
pH	5.600	6.393	7.100	27	0

```
  53
  54  %PostMessage 1129; 0; 100001 "Sheet Update Completed"
  55  "Two-way design in randomized blocks"
  56  DELETE [REDEFINE=yes] _ibalance
  57  A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
  58   BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
  59   EXIT=_ibalance] Cob_Diameter_cm; SAVE=_a2save
```

Analysis of variance

Variate: Cob_Diameter_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.148889	0.074444	38.29	
Rep.*Units* stratum					
Practice	2	1.806667	0.903333	464.57	<.001
Soil_Type	2	2.886667	1.443333	742.29	<.001
Practice.Soil_Type	4	0.013333	0.003333	1.71	0.196
Residual	16	0.031111	0.001944		
Total	26	4.886667			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	0.0778	s.e.	0.0339
Rep 1 *units* 2	0.0778	s.e.	0.0339
Rep 2 *units* 1	-0.0778	s.e.	0.0339
Rep 2 *units* 2	-0.0778	s.e.	0.0339

Tables of means

Variate: Cob_Diameter_cm

Grand mean 4.4889

Practice	Conventional	Cover Cropping	Zero Tillage
	4.1667	4.8000	4.5000

Soil_Type	Clay	Loam	Sandy
	4.4667	4.9000	4.1000

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		4.1000	4.6000	3.8000
Cover Cropping		4.8000	5.2000	4.4000
Zero Tillage		4.5000	4.9000	4.1000

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3

d.f.	16	16	16
s.e.d.	0.02079	0.02079	0.03600

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.04407	0.04407	0.07633

Stratum standard errors and coefficients of variation

Variate: Cob_Diameter_cm

Stratum	d.f.	s.e.	cv%
Rep	2	0.09095	2.0
Rep.*Units*	16	0.04410	1.0

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	3.800	3.722	0.07778
2	2	3.700	3.778	-0.07778
3	3	3.900	3.900	0.00000
4	1	4.100	4.022	0.07778
5	2	4.000	4.078	-0.07778
6	3	4.200	4.200	0.00000
7	1	4.300	4.322	-0.02222
8	2	4.400	4.378	0.02222
9	3	4.500	4.500	0.00000
10	1	4.500	4.522	-0.02222
11	2	4.600	4.578	0.02222
12	3	4.700	4.700	0.00000
13	1	4.800	4.822	-0.02222
14	2	4.900	4.878	0.02222
15	3	5.000	5.000	0.00000
16	1	5.100	5.122	-0.02222
17	2	5.200	5.178	0.02222
18	3	5.300	5.300	0.00000
19	1	4.000	4.022	-0.02222
20	2	4.100	4.078	0.02222
21	3	4.200	4.200	0.00000
22	1	4.400	4.422	-0.02222
23	2	4.500	4.478	0.02222
24	3	4.600	4.600	0.00000
25	1	4.700	4.722	-0.02222
26	2	4.800	4.778	0.02222
27	3	4.900	4.900	0.00000

```
  60  SET [IN=*]
  66  "Two-way design in randomized blocks"
  67  DELETE [REDEFINE=yes] _ibalance
  68  A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
  69   BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
  70   EXIT=_ibalance] Dry_Stalk_Wt_kg_plot; SAVE=_a2save
```

Analysis of variance

Variate: Dry_Stalk_Wt_kg_plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.148889	0.074444	38.29	
Rep.*Units* stratum					
Practice	2	2.006667	1.003333	516.00	<.001
Soil_Type	2	4.246667	2.123333	1092.00	<.001
Practice.Soil_Type	4	0.013333	0.003333	1.71	0.196
Residual	16	0.031111	0.001944		
Total	26	6.446667			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	0.0778	s.e.	0.0339
Rep 1 *units* 2	0.0778	s.e.	0.0339
Rep 2 *units* 1	-0.0778	s.e.	0.0339
Rep 2 *units* 2	-0.0778	s.e.	0.0339

Tables of means

Variate: Dry_Stalk_Wt_kg_plot

Grand mean 2.9111

Practice	Conventional	Cover Cropping	Zero Tillage
	2.5667	3.2333	2.9333

Soil_Type	Clay	Loam	Sandy
	2.9667	3.3667	2.4000

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		2.6000	3.0000	2.1000
Cover Cropping		3.3000	3.7000	2.7000
Zero Tillage		3.0000	3.4000	2.4000

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3

d.f.	16	16	16
s.e.d.	0.02079	0.02079	0.03600

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.04407	0.04407	0.07633

Stratum standard errors and coefficients of variation

Variate: Dry_Stalk_Wt_kg_plot

Stratum	d.f.	s.e.	cv%
Rep	2	0.09095	3.1
Rep.*Units*	16	0.04410	1.5

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	2.100	2.022	0.07778
2	2	2.000	2.078	-0.07778
3	3	2.200	2.200	0.00000
4	1	2.400	2.322	0.07778
5	2	2.300	2.378	-0.07778
6	3	2.500	2.500	0.00000
7	1	2.600	2.622	-0.02222
8	2	2.700	2.678	0.02222
9	3	2.800	2.800	0.00000
10	1	2.900	2.922	-0.02222
11	2	3.000	2.978	0.02222
12	3	3.100	3.100	0.00000
13	1	3.300	3.322	-0.02222
14	2	3.400	3.378	0.02222
15	3	3.500	3.500	0.00000
16	1	3.600	3.622	-0.02222
17	2	3.700	3.678	0.02222
18	3	3.800	3.800	0.00000
19	1	2.500	2.522	-0.02222
20	2	2.600	2.578	0.02222
21	3	2.700	2.700	0.00000
22	1	2.900	2.922	-0.02222
23	2	3.000	2.978	0.02222
24	3	3.100	3.100	0.00000
25	1	3.200	3.222	-0.02222
26	2	3.300	3.278	0.02222
27	3	3.400	3.400	0.00000

```
SET [IN=*]
"Two-way design in randomized blocks"
DELETE [REDEFINE=yes] _ibalance
A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
 BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
 EXIT=_ibalance] Grain_Yield_kg_plot; SAVE=_a2save
```

Analysis of variance

Variate: Grain_Yield_kg_plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.148889	0.074444	38.29	
Rep.*Units* stratum					
Practice	2	2.000000	1.000000	514.29	<.001
Soil_Type	2	4.740000	2.370000	1218.86	<.001
Practice.Soil_Type	4	0.040000	0.010000	5.14	0.007
Residual	16	0.031111	0.001944		
Total	26	6.960000			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	0.0778	s.e.	0.0339
Rep 1 *units* 2	0.0778	s.e.	0.0339
Rep 2 *units* 1	-0.0778	s.e.	0.0339
Rep 2 *units* 2	-0.0778	s.e.	0.0339

Tables of means

Variate: Grain_Yield_kg_plot

Grand mean 2.1667

Practice	Conventional	Cover Cropping	Zero Tillage
	1.8333	2.5000	2.1667

Soil_Type	Clay	Loam	Sandy
	2.3000	2.6000	1.6000

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		1.9000	2.3000	1.3000
Cover Cropping		2.7000	2.9000	1.9000
Zero Tillage		2.3000	2.6000	1.6000

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3

d.f.	16	16	16
s.e.d.	0.02079	0.02079	0.03600

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.04407	0.04407	0.07633

Stratum standard errors and coefficients of variation

Variate: Grain_Yield_kg_plot

Stratum	d.f.	s.e.	cv%
Rep	2	0.09095	4.2
Rep.*Units*	16	0.04410	2.0

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	1.300	1.222	0.07778
2	2	1.200	1.278	-0.07778
3	3	1.400	1.400	0.00000
4	1	1.600	1.522	0.07778
5	2	1.500	1.578	-0.07778
6	3	1.700	1.700	0.00000
7	1	1.800	1.822	-0.02222
8	2	1.900	1.878	0.02222
9	3	2.000	2.000	0.00000
10	1	2.200	2.222	-0.02222
11	2	2.300	2.278	0.02222
12	3	2.400	2.400	0.00000
13	1	2.500	2.522	-0.02222
14	2	2.600	2.578	0.02222
15	3	2.700	2.700	0.00000
16	1	2.800	2.822	-0.02222
17	2	2.900	2.878	0.02222
18	3	3.000	3.000	0.00000
19	1	1.800	1.822	-0.02222
20	2	1.900	1.878	0.02222
21	3	2.000	2.000	0.00000
22	1	2.200	2.222	-0.02222
23	2	2.300	2.278	0.02222
24	3	2.400	2.400	0.00000
25	1	2.600	2.622	-0.02222
26	2	2.700	2.678	0.02222
27	3	2.800	2.800	0.00000

```
SET [IN=*]
"Two-way design in randomized blocks"
DELETE [REDEFINE=yes] _ibalance
A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
 BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
 EXIT=_ibalance] Grains_Cob; SAVE=_a2save
```

Analysis of variance

Variate: Grains_Cob

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	585.19	292.59	20.22	
Rep.*Units* stratum					
Practice	2	10757.41	5378.70	371.78	<.001
Soil_Type	2	25690.74	12845.37	887.87	<.001
Practice.Soil_Type	4	281.48	70.37	4.86	0.009
Residual	16	231.48	14.47		
Total	26	37546.30			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	6.48	s.e.	2.93
Rep 2 *units* 1	-6.85	s.e.	2.93

Tables of means

Variate: Grains_Cob

Grand mean 375.37

Practice	Conventional	Cover Cropping	Zero Tillage
	351.11	400.00	375.00

Soil_Type	Clay	Loam	Sandy
	375.00	413.33	337.78

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		355.00	390.00	308.33
Cover Cropping		395.00	440.00	365.00
Zero Tillage		375.00	410.00	340.00

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
s.e.d.	1.793	1.793	3.106

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	3.801	3.801	6.584

Stratum standard errors and coefficients of variation

Variate: Grains_Cob

Stratum	d.f.	s.e.	cv%
Rep	2	5.702	1.5
Rep.*Units*	16	3.804	1.0

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	310.0	303.5	6.481
2	2	300.0	306.9	-6.852
3	3	315.0	314.6	0.370
4	1	340.0	335.2	4.815
5	2	335.0	338.5	-3.519
6	3	345.0	346.3	-1.296
7	1	360.0	360.2	-0.185
8	2	365.0	363.5	1.481
9	3	370.0	371.3	-1.296
10	1	385.0	385.2	-0.185
11	2	390.0	388.5	1.481
12	3	395.0	396.3	-1.296
13	1	400.0	405.2	-5.185
14	2	410.0	408.5	1.481
15	3	420.0	416.3	3.704
16	1	430.0	435.2	-5.185
17	2	440.0	438.5	1.481
18	3	450.0	446.3	3.704
19	1	350.0	350.2	-0.185
20	2	355.0	353.5	1.481
21	3	360.0	361.3	-1.296
22	1	370.0	370.2	-0.185
23	2	375.0	373.5	1.481
24	3	380.0	381.3	-1.296
25	1	390.0	390.2	-0.185
26	2	395.0	393.5	1.481
27	3	400.0	401.3	-1.296

```
SET [IN=*]
"Two-way design in randomized blocks"
DELETE [REDEFINE=yes] _ibalance
A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
 BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
 EXIT=_ibalance] Harvest_Index; SAVE=_a2save
```

Analysis of variance

Variate: Harvest_Index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00148889	0.00074444	38.29	
Rep.*Units* stratum					
Practice	2	0.00886667	0.00443333	228.00	<.001
Soil_Type	2	0.01146667	0.00573333	294.86	<.001
Practice.Soil_Type	4	0.00053333	0.00013333	6.86	0.002
Residual	16	0.00031111	0.00001944		
Total	26	0.02266667			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	0.00778	s.e.	0.00339
Rep 1 *units* 2	0.00778	s.e.	0.00339
Rep 2 *units* 1	-0.00778	s.e.	0.00339
Rep 2 *units* 2	-0.00778	s.e.	0.00339

Tables of means

Variate: Harvest_Index

Grand mean 0.43222

Practice	Conventional	Cover Cropping	Zero Tillage
	0.41333	0.45667	0.42667

Soil_Type	Clay	Loam	Sandy
	0.44333	0.45000	0.40333

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		0.42000	0.44000	0.38000
Cover Cropping		0.47000	0.47000	0.43000
Zero Tillage		0.44000	0.44000	0.40000

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3

d.f.	16	16	16
s.e.d.	0.002079	0.002079	0.003600

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.004407	0.004407	0.007633

Stratum standard errors and coefficients of variation

Variate: Harvest_Index

Stratum	d.f.	s.e.	cv%
Rep	2	0.009095	2.1
Rep.*Units*	16	0.004410	1.0

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	0.3800	0.3722	0.007778
2	2	0.3700	0.3778	-0.007778
3	3	0.3900	0.3900	0.000000
4	1	0.4000	0.3922	0.007778
5	2	0.3900	0.3978	-0.007778
6	3	0.4100	0.4100	0.000000
7	1	0.4200	0.4222	-0.002222
8	2	0.4300	0.4278	0.002222
9	3	0.4400	0.4400	0.000000
10	1	0.4300	0.4322	-0.002222
11	2	0.4400	0.4378	0.002222
12	3	0.4500	0.4500	0.000000
13	1	0.4300	0.4322	-0.002222
14	2	0.4400	0.4378	0.002222
15	3	0.4500	0.4500	0.000000
16	1	0.4600	0.4622	-0.002222
17	2	0.4700	0.4678	0.002222
18	3	0.4800	0.4800	0.000000
19	1	0.4100	0.4122	-0.002222
20	2	0.4200	0.4178	0.002222
21	3	0.4300	0.4300	0.000000
22	1	0.4300	0.4322	-0.002222
23	2	0.4400	0.4378	0.002222
24	3	0.4500	0.4500	0.000000
25	1	0.4600	0.4622	-0.002222
26	2	0.4700	0.4678	0.002222
27	3	0.4800	0.4800	0.000000

```
SET [IN=*]
"Two-way design in randomized blocks"
DELETE [REDEFINE=yes] _ibalance
A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
 BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
 EXIT=_ibalance] Leaf_Area_Index; SAVE=_a2save
```

Analysis of variance

Variate: Leaf_Area_Index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.06459	0.53229	19.38	
Rep.*Units* stratum					
Practice	2	5.22770	2.61385	95.18	<.001
Soil_Type	2	13.39694	6.69847	243.91	<.001
Practice.Soil_Type	4	0.11368	0.02842	1.03	0.420
Residual	16	0.43941	0.02746		
Total	26	20.24232			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Area_Index

Grand mean 3.487

Practice	Conventional	Cover Cropping	Zero Tillage
	2.946	4.023	3.493

Soil_Type	Clay	Loam	Sandy
	3.728	4.204	2.530

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		3.147	3.600	2.090
Cover Cropping		4.270	4.837	2.963
Zero Tillage		3.767	4.177	2.537

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
s.e.d.	0.0781	0.0781	0.1353

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice

			Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.1656	0.1656	0.2868

Stratum standard errors and coefficients of variation

Variate: Leaf_Area_Index

Stratum	d.f.	s.e.	cv%
Rep	2	0.2432	7.0
Rep.*Units*	16	0.1657	4.8

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	1.920	1.884	0.0363
2	2	2.070	2.028	0.0419
3	3	2.280	2.358	-0.0781
4	1	2.330	2.330	-0.0004
5	2	2.310	2.475	-0.1648
6	3	2.970	2.805	0.1652
7	1	2.520	2.757	-0.2370
8	2	2.980	2.901	0.0785
9	3	3.390	3.231	0.1585
10	1	3.390	3.394	-0.0037
11	2	3.580	3.538	0.0419
12	3	3.830	3.868	-0.0381
13	1	4.220	3.970	0.2496
14	2	4.060	4.115	-0.0548
15	3	4.250	4.445	-0.1948
16	1	4.410	4.630	-0.2204
17	2	4.970	4.775	0.1952
18	3	5.130	5.105	0.0252
19	1	3.030	2.940	0.0896
20	2	3.100	3.085	0.0152
21	3	3.310	3.415	-0.1048
22	1	3.740	3.560	0.1796
23	2	3.540	3.705	-0.1648
24	3	4.020	4.035	-0.0148
25	1	3.970	4.064	-0.0937
26	2	4.220	4.208	0.0119
27	3	4.620	4.538	0.0819

```
 115  SET [IN=*]
 121  "Two-way design in randomized blocks"
 122  DELETE [REDEFINE=yes] _ibalance
 123  A2WAY [PRINT=aovtable,information,means,residuals,%cv;
TREATMENTS=Practice,Soil_Type;\
 124   BLOCKS=Rep; FACTORIAL=2; FPROB=yes; PSE=diff,lsd,alllsd; LSDLEVEL=5;
PLOT=*; COMBINATIONS=present;\
 125   EXIT=_ibalance] pH; SAVE=_a2save
```

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.082963	0.041481	4.84	
Rep.*Units* stratum					
Practice	2	1.505185	0.752593	87.87	<.001
Soil_Type	2	2.320741	1.160370	135.48	<.001
Practice.Soil_Type	4	0.132593	0.033148	3.87	0.022
Residual	16	0.137037	0.008565		
Total	26	4.178519			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Rep 1 *units* 1	0.159	s.e.	0.071
Rep 1 *units* 5	-0.174	s.e.	0.071
Rep 3 *units* 1	-0.174	s.e.	0.071

Tables of means

Variate: pH

Grand mean 6.393

Practice	Conventional	Cover Cropping	Zero Tillage
	6.111	6.689	6.378

Soil_Type	Clay	Loam	Sandy`
	6.300	6.789	6.089

Practice	Soil_Type	Clay	Loam	Sandy
Conventional		6.000	6.633	5.700
Cover Cropping		6.600	7.000	6.467
Zero Tillage		6.300	6.733	6.100

Standard errors of differences of means

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16

s.e.d.	0.0436	0.0436	0.0756

Least significant differences of means (5% level)

Table	Practice	Soil_Type	Practice Soil_Type
rep.	9	9	3
d.f.	16	16	16
l.s.d.	0.0925	0.0925	0.1602

Stratum standard errors and coefficients of variation

Variate: pH

Stratum	d.f.	s.e.	cv%
Rep	2	0.0679	1.1
Rep.*Units*	16	0.0925	1.4

Residuals and fitted values

Unit	Block	Response	Fitted value	Residual
1	1	5.800	5.641	0.15926
2	2	5.700	5.685	0.01481
3	3	5.600	5.774	-0.17407
4	1	6.100	6.041	0.05926
5	2	6.000	6.085	-0.08519
6	3	6.200	6.174	0.02593
7	1	6.500	6.407	0.09259
8	2	6.400	6.452	-0.05185
9	3	6.500	6.541	-0.04074
10	1	6.600	6.574	0.02593
11	2	6.600	6.619	-0.01852
12	3	6.700	6.707	-0.00741
13	1	6.500	6.674	-0.17407
14	2	6.800	6.719	0.08148
15	3	6.900	6.807	0.09259
16	1	6.900	6.941	-0.04074
17	2	7.000	6.985	0.01481
18	3	7.100	7.074	0.02593
19	1	5.900	5.941	-0.04074
20	2	6.000	5.985	0.01481
21	3	6.100	6.074	0.02593
22	1	6.200	6.241	-0.04074
23	2	6.300	6.285	0.01481
24	3	6.400	6.374	0.02593
25	1	6.500	6.541	-0.04074
26	2	6.600	6.585	0.01481
27	3	6.700	6.674	0.02593

```
126  SET [IN=*]
```