EFFECT OF LAND USE INTENSIFICATION ON WATER-RELATED AND OTHER SOIL PHYSICAL PROPERTIES IN ASINGE VILLAGE, TORORO DISTRICT, UGANDA.

BY

KABWEYANGIRA ELIJAH

REG. NO. 17/U/314

A SPECIAL PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL PRODUCTION IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN AGRICULTURAL LAND USE AND MANAGEMENT OF MAKERERE UNIVERSITY

JANUARY 2023

Declaration.

I Kabweyangira Elijah hereby declare that the work presented in this project report is my original work and has never been submitted by any student for degree ward, the work contained here is original unless otherwise stated.

Sign;…………………………………… Date: 17/01/2023……………………………………

Kabweyangira Elijah
Student

This project report has been submitted with my approval as an academic supervisor.

Sign…………………………………… Date 17/01/2023……………………………………

Mr. Olupot Giregon
Supervisor

Acknowledgement.

I greatly want to offer this endeavor to the Almighty God for the unfailing wisdom and strength bestowed on me till the completion of this research.

I am highly indebted to my supervisor, Dr.OlupotGiregon for his continued assistance, correction and moral support at each step of this research. It was a pleasure studying under his valuable guidance and mentorship.

I extend my sincere appreciation to my parents and siblings for their motivation, unceasing advice and courage they have given me towards the completion of this venture.

I am also grateful to my friends who have been of help directly or indirectly in finishing this research.

I specially thank Ms. AguttiGorreti, the laboratory technician at the Makerere University School of Agricultural science laboratory for their professional help, time and guidance while I conducted the research laboratory experiment.

I also extend my sincere appreciation to Dr. Godfrey Taulya for the assistance and guidance on the data analysis of the research.

Table of contents

Contents

List of tables.

List of figures.

Abstract.

There have been several land uses and management practices in the field of agriculture that have altered and led to the degradation of water related soil physical properties which has in turn largely affected food production in tropical ecosystems. This study was done to establish a deep understanding of the relationship between some of the land use intensities and the water related soil physical properties of Asinge village in the eastern region of Uganda. The emphasis was put on bulk density, porosity, saturated water conductivity, and the volumetric water content of the soil.The soil core samples were taken from different fields of land cover/land use including natural vegetation, semi-natural vegetation, sorghum monocrop, and sorghum-cow pea intercrop. The results showed that land use intensity has significant effect on buk density, porosity and water content of the soil. Bulk density increased with increase in land use intensity and was higher under cultivated soils compared to the fallowed soils. Soil total porosity and volumetric water content followed a different trend where they increased with a reduction in land use intensity and were both highest under fallowed land use compared to the cultivated land use. Soil saturated hydraulic conductivity was higher under fallowed soils compared to the cultivated soils, however there was no significant effect of land use or land cover on the saturated hydraulic conductivity of the soils.

CHAPTER ONE

1.0INTRODUCTION

1.1 Background to the study

Soil possesses many attributes that make it a unique medium for plant growth, other living organisms and life support processes on earth. These attributes are in turn determined by the physical, chemical, and bilologial properties. Of key importance are bulk density, porosity, soil structure, soil aggregation, saturated hydraulic conductivity and volumetric water content at holding capacity. These physical properties are greatly affected by different levels of intensification of land use and management systems over time forexample tillage can destroy the macropore space resulting in increased bulk density (soil compaction) which reduces the capacity of the soil to receive and transmit water.

Soil physical properties as important components of soil health influence water and nutrient movements, aeration, soil temperature, nutrient cycling, and root growth that affect crop yields and environmental quality. For example, increased bulk density due to increased soil compaction results in decreased pore volume that reduces water infiltration, increases aeration stress, lowers soil temperature and nutrient cycling, increases denitrification, losses mycorrhizal fungi, and reduces root growth. In contrast, increased soil aggregation enhances water and nutrient movements, reduces soil erosion, promotes C sequestration, favors microbial activity and abundance, and increases root growth and crop yields. Clay concentration is an important indicator of soil health that enhances the retention of soil water and nutrients. While increased soil water retention enhances crop yields, reduced water infiltration capacity of the soil results in anaerobic condition that hampers nutrient cycling and root growth, thereby reducing crop production (Upendra, 2022).

Soil physical properties are crucial in determining soil’s appropriateness for agricultural, environmental, and engineering applications. The movement of air, water, and dissolved compounds through soil, as well as circumstances impacting germination, root growth, and erosion processes, are all examples of soil physical characteristics. One of the most difficult measures in agriculture is that of soil moisture. Soil moisture is the ratio of the weight of water to the weight of solids in a particular mass of soil (Woldeyohannis, 2022).

Soilacts as a sponge to take up and retain water. Pore space in soil is the conduit that allows water to infiltrate and percolate(Plant and Soil Sciences eLibrary, 2022).

Forms of land use that promote higher rates of water infiltration are essential if the soil is to be recharged by underground reservoirs, river flow is to be controlled during droughts, and the effects of floods, runoff, and water erosion are to be mitigated (Tucci;Mendes, 2006).

A lot has been studied about how different management practices and land uses affect soil physical properties but there is limited information on how this intensification impacts on the ability of soil to receive, transmit, distribute and store water which is a function of macropore porosity, pore tortuosity, degree of aggregation, stability of soil aggregates and level of organic matter in the soil.

In light of the crucial importance of these properties, it was imperative to study the effect of land use intensification on these hydraulic and soil physical properties as a step towards improving crop yield under continuous land use.

1.2 Problem statement

Due to the many interests on land for food, water, conservation and others, so many changes are taking place whose intensification impact on soil hydraulic and physical properties is not being adequately examined.

These soils are highly heterogeneous that they exhibit high spatial and temporal variability even on a micro-scale, which calls for the establishment of location-specific physical properties for any given soil under defined sets of management (Muchelo, 2008).

With the study of the relationship between land use intensification and water-related soil physical properties in Asinge village, there could be ways to improve productivity and solve the problem of low crop yields in this place.

1.3 Objectives of the study

1.3.1 Broad Objective

To determine the effect of land use intensification on water-related and other soil physical properties in Asinge village.

1.3.2 Specific Objectives

(i) Evaluate the effect of land use intensification on soil physical properties in Asinge.

(ii) Evaluate the effect of land use intensification on soil hydraulic properties in Asinge.

(iii) Identify the soil physical properties most related with soil saturated hydraulic conductivity and volumetric water content in Asinge.

1.4 Hypothesis

(i) Less disturbed land use systems promote high porosity due to conservation of large continuous pores that are inter connected compared to intensively disturbed systems.

(ii) The less the intensity of disturbance, the higher the soil saturated hydraulic conductivity and volumetric water content.

(iii) There is a direct relationship between total porosity and soil saturated hydraulic conductivity.

(iv) The lower the intensity of disturbance, the higher the total porosity and therefore the higher the volumetric water content at holding capacity.

1.5. Scope of the study.

The study was conducted on four land uses or land cover in Asinge village, Tororo, Uganda; Natural vegetation, Semi-natural vegetation, Sorghum monocrop, and Sorghum-Cow pea intercrop.

Figure 1. Land cover under natural vegetation.

Figure 2. Land cover under semi natural vegetation.

Figure 3. Land cover under sorghum monocrop.

Figure 4. Land cover under sorghum cowpea intercrop.

CHAPTER TWO

2.0 Literature review.

2.1.0 Importance of soil physical properties.

2.1.1 Soil bulk Density.

According to Muchelo (2008), bulk density is a simple measure of soil structure and is defined as the ratio of the mass of an oven-dry soil sample (dried for 24 hours at 105ºC to constant weight) to its bulk volume. It is a temporally and spatially variable soil property that can be used as an indicator of changes in soil structure caused by agricultural management, root growth and activity of soil flora and fauna.

For practice, consider a box of undisturbed soil from the field. The box has dimensions of 2.5 cm by 10 cm by 10 cm. The volume of the box can be determined by multiplying the height of the box times its width and its depth. The wet soil in the box weighed 450 g. The dry soil weighed 375 g. Now calculate the bulk density. Your answer should be 1.5 g/cm^3. In this calculation, you did not have to use the particle density because the weight of soil in the box was already known.Each field operation compacts the soil beneath. If soils are wetter than field capacity, bulk density may increase. However, if soils are dry, bulk density is not affected much. Root growth, in general, starts to be restricted when the bulk density reaches 1.55 to 1.6 g/cm^3 and is prohibited at about 1.8 g/cm^3. Tillage can increase bulk density if it breaks down aggregates and allowssoil separates to pack more tightly. Adding organic material decreases bulk density because organic material has a lower bulk density. However, additions are typically so small in proportion to the weight of soil that they do not markedly influence bulk density except at the soil-atmosphere interface. Bulk density is also important because it tells us about the porosity of a soil (Plant and Soil Sciences eLibrary, 2022).

Bulk density is dependent on soil texture, SOM, the density of soil mineral and their packing research on porosity arrangement. Bulk density is a basic soil property that is effected by the soil properties, tillage climatic conditions and agricultural activities (Özdemir, 2022).Bulk density is an important parameter in soil management planning, structural deterioration, soil compaction level and suitability for plant root growth, soil water relationships, and applications related to fertilization, determination of nutrient status and carbon stocks (Ruehlmann &Körschens, 2009; Brahim et al., 2012), and determination of soil porosity (Lestariningsih et al., 2013).

Bulk density is a dynamic soil property, as it varies in space and time. It is affected by land and crop management practices (Çerçioğlu et al., 2019). Changes in bulk density depending on the effectiveness of the degrading and forming processes in the soil are closely related to soil organic matter content (Demir et al., 2019; Demir&Işık, 2019, 2020; Demir, 2020) and textural structure (Makovníková et al., 2017).

2.1.2 Total Soil Porosity (f)

Porosity or pore space refers to the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density. Porosity is calculated as a percentage of the soil volume. Loose, porous soils have lower bulk densities and greater porosities than tightly packed soils. Porosity varies depending on particle size and aggregation. It is greater in clayey and organic soils than in sandy soils. A large number of small particles in a volume of soil produces a large number of soil pores. Fewer large particles can occupy the same volume of soil so there are fewer pores and less porosity.Compaction decreases porosity as bulk density increases. If compaction increases bulk density from 1.3 to 1.5 g/cm^3, porosity decreases from 50 percent to 43 percent. Aggregation also decreases porosity because more large pores are present as compared to singleclay and silt particles that are associated with smaller pores.Pores of all sizes and shapes combine to make up the total porosity of a soil. Porosity, however, does not tell us anything about the size of pores (Plant and Soil Sciences eLibrary, 2022).

Porosity gives information on the water and air retention properties of soil, in volume or flow rate. In the latter case, however, just an indication of porosity is not enough, because the circulation of water (and of air) porosity depends as well on the relations among soil voids and their arrangement. The combined effect of tortuosity and connectivity of pores on soil porosity, very commonly, the general potential of water circulation in soil is revealed more by its hydraulic conductivity than by soil porosity (Muchelo, 2008).

Microporosity comprises pores with diameters of less than 30 μm and is related to soil water holding capacity. Mesoporosity (diameters between 30 and 75 μm) and macroporosity (diameters >75 μm) are linked to soil water drainage. Pores >30 μm include biopores, cracks and pores between aggregates. Biopores are important as they improve the diffusion of fluids (gas and liquid water diffusion), which affects OM decomposition. It can be added that macropores have been described as the most sensitive to management and fertilizer practices (Yu Hong et al., **2018**). Regarding pore morphology, the dominance of rounded pores corresponding to isolated vesicles has been observed in soils with low SOC (Mateo-Marín et al., **2021**).

2.1.3 Saturated hydraulic conductivity (Ks)

Soil physical properties affected by soil deformation are the ks and air permeability (kl), which show a dependency on the internal soil strength. Both the ks and unsaturated hydraulic conductivity (ku) as well as kl as a function of matric potential represent the functional quality of soil structure and pore continuity as they define the air and water fluxes within the soil. (Arthur et al., 2012).

Saturated soil hydraulic conductivity (Ks) is the most important property of a soil influencing the movement of water and solutes in the porous medium, retention of water in earthen dams, and seepage from unlined canals (Muchelo, 2008).

A detailed understanding of Ks is critical in the assessment of irrigation practices, infiltration rates, runoff, groundwater recharge rates, and drainage processes, which makes it of particular concern in forest management (MingzhouHao et al., 2019).

Understanding soil hydraulic conductivity is also essential for sound land management. Therefore, there is no single value that represents soil hydraulic conductivity because it varies in a wide range of circumstances and for all soil types, and some of the specific problems that instigated the need for this kind of study may be due to lack of suitability of the soil hydraulic conductivity and their acceptability in the study locations. Information relating to the hydraulicconductivity of the studied sites is a shortage (John Jiya Musa et al., 2021).

2.2 Impact of management practices on the hydraulic and soil physical properties

2.2.1 Tillage and soil compaction.

Tillage triggers processes that affect the soil ecosystem. It modifies many of the physical properties of soil, including bulk density, porosity and pore size distribution, water holding capacity, water content, and aggregation). Tillage also disrupts plant and animal communities that contribute to aggregation and tends to decrease soil organic matter (Noemí Mateo-Marín, 2021). No-till can generate more stable aggregates and increase soil organic carbon more than tillage does (De MoraesSá et al., **2015**; Udayakumar, Sagar, & Kumar, **2021**). In general, conservation tillage practices can increase the presence of macropores and biochannels. Soil texture and climate determine, to different extents, changes in the pore system associated with tillage (Li, Li, Cuie, & Zhang, **2020**), which means that the response of soil properties to tillage management is site specific. Besides, tractor wheelings and the weight of agricultural machinery reduce the soil-pore volume (Peng & Horn, **2008**). Strudley, Green, and Ascough II (**2008**) raise awareness of interactions between management practices, as well as some appreciation of the complexity of spatial and temporal variability. The consequences of such constraints are the inconsistent responses found in the literature, for example regarding total porosity when tillage systems are compared. The authors recommend the compilation of new data in an explicit spatiotemporal framework (Strudley et al., **2008**).

The consequences of land management and tillage, needs to be analyzed, because saturated hydraulic conductivity (ks) also depends on shear- and vibration-induced soil deformation interactions. These interactions enhance the degradation of soil properties, especially if the soil water content is high and the internal soil strength is low (Huang et al., 2021).

2.3 Impact of land cover on the hydraulic and soil physical properties.

The soil is directly or indirectly affected byit's cover growing vegetation. This means that the vegetation cover is one of the important factors in soil formation and in its current and future characteristics. Vegetation cover is significantly related to soil quality, its characteristics and the prevailing topography in it. Also, the nature and texture of soil is of great importance in the distribution and growth of vegetation, and the reason is due to the effect of soil qualities and properties on its ability to water storage by affecting its other properties. Soils cultivated with plants and trees have a high infiltration rate as a result of the increase in soil porosity and the volume of pore size distribution, and a decrease in the hydrophobic characteristics and resistance to water movement in the soil (Hussein RazzaqNayyef, 2022).

Bulk density and total porosity (TP) are significantlyaffected by land use/land cover change. The most favorable properties (low BD and high TP) are recorded for the forest land and homestead garden fields, while cultivated outfields have the highest BD (1.62 g/cm^3) and the lowest TP (0.32%), indicating soil compaction and wettability problems under intensively cultivated outfields (Belayneh et al, 2020).

In addition, pore spaces are increased by the movements of the grass roots hence increase the voids between soil particles. (Theobald et al., 2018).

Vegetation is expected to be an important factor that influences the hydraulic properties of soil by affecting its physical and chemical characteristics. Forest conversion is a major change globally, yet our understanding of its impacts on soil Ks remains incomplete. However, the prediction of forest soil Ks is complex due to multiple interactions associated with anthropological and geomorphic processes, which impact spatiotemporal Ks variations. Previous studies have found differences in Ks among deforested areas in primary forests, secondary forests, and agricultural ecosystems, and among forests, shrublands, and grasslands. Intense agricultural use can reduce Ks soils. Pasture soils have lower Ks than woodland soils (MingzhouHao. et al, 2019).

CHAPTER THREE

3.0 Materials and Methods

3.1 Location and characteristics of the study area

Asinge is a village inTororo District, Eastern Uganda and has an elevation of 1,117 metres. It is located at 0° 44' 15" N and 34° 14' 46" E, latitude and longitude respectively.Asinge is situated nearby to the villages Yobuke and Podut .

Asinge has a Tropical monsoon climate. The district's yearly temperature is 24.96ºC (76.93ºF) and it is 1.49% higher than Uganda's averages. Asinge typically receives about 324.21 millimeters (12.76 inches) of precipitation and has 329.17 rainy days (90.18% of the time) annually.

The village has a favorable climate for both crop cultivation and livestock management due to the adequate rainfall and conducive temperatures. There are only around 35 days with no rain where January is the driest month and May is the wettest month. The wet season starts around April up to November and the dry season runs from December till March.

The highest temperature is experienced during the month of February and the lowest temperature in June with average monthly sunshine hours ranging from 11 to 12 hours per month.

3.2.1 Background to the Study Procedures

A one-day reconnaissance survey was conducted to identify the fields for the study, sampling locations, mark the field boundaries where samples were to be taken from, and to test the sampling depths using an auger. The fields selected as treatment were; natural vegetation, semi-natural vegetation, sorghum garden, and cow pea-sorghum intercrop garden. Each was divided into 3 equidistant sampling locations along a linear transect.

3.2.2 Field Methods of Soil sampling

3.2.3 Core sample collection

Core soil samples were taken from each of the sampling locations at a depth of 0-0.5m using a core sampler. Soil sample collection involved driving a core fitted into a core sampler into the soil until it was completely in the soil and carefully removing the side soils to expose the core and gently plucking it off with its soil. Each core and its soil contents was labelled and wrapped tightly with white tape to prevent moisture loss in the field. The cores were then placed in a case and taken to the laboratory for analysis.

Figure 5. Soil core samples from the field brought to the laboratory.

3.3.0Determination of soil physical properties in the Laboratory

3.3.1 Saturated hydraulic conductivity (Ksat) determination

The base of each core was covered with a piece of cheesecloth and secured tightly with a rubber band. The core samples were placed upright into a large water container and the soil was left to saturate for 24 hours.

The soil cores were placed upright to remove as much air as possible from the soil pores during saturation. Care was also taken to ensure that no water entered from the top of the cores to avoid trapping air within the soil cores, which would impair flow of water through the saturated soil sample. Saturated hydraulic conductivity (Ksat) measurements were taken using the falling head methoddescribed by Klute (1986). Water was filled in a reservoir and a tube was connected to allow water to flow to the saturated core at a constant flow. As water flowed through the soil, the change of the level of water (Δb) in the reservoir was recorded at intervals ranging between 20 to 50cc. Beakers were placed under the core to collect water discharge (Q) from the core at the already determined intervals in about 8-10 runs and each was measured and recorded. The time (t) taken for each interval was also recorded.

Figure 6. The student carrying out an experiment to determine saturated hydraulic conductivity of the soil.

Darcy’s law was applied in the laboratory determination of saturated hydraulic conductivity:

$$q\max = \frac{Q}{At} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...1$$

Where;

A is cross sectional area (cm^2) of each of the core as function of diameter (D) also measured for each of the cores, Q is a volume (cm^3) of water collected in the beakers for each of the cores in a given time t(s), and qmax is the flux or discharge rate (cm/s).

$$Ksat = \frac{q \max L}{\Delta H} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where;

L is length of the column (cm) measured for each core, ΔH (cm) is the change in column of water (Δb) added to length of the column of soilandKsat is saturated hydraulic conductivity (cm/s) for each of the soil cores.

3.3.2 Determination of Bulk density and Porosity.

After determination of Ksat, the saturated cores were weighed and transferred to the oven. Samples were oven dried at 105°C for 24 hours (Blake and Hartge, 1986) and the final weight measurements were taken after the samples had been allowed to cool in the desiccators for about an hour.

The soils were emptied from the cores and empty cores plus the cheesecloth and rubber bands weighed (core weight). The weight of the soil (Ms) was calculated by subtracting the weight of the empty cores plus the cheesecloth and rubber bands from the weight of oven dry soil plus the core and its contents (Muchelo, 2008).

(i) Determination of bulk density

Bulk density (ρ_b) was determined according to Blake and Hartge (1986).

Bulk density was determined from the equation;

$$\rho_b = \frac{Ms}{Vt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. 3$$

Where: M_s is the mass of oven dry soil determined by weighing the oven dry soil after cooling inside desiccators, Vt is the total volume of soil estimated from the volume of the cores, based on the diameter (D) and height (h) of each of the cores measured (in cm). The volume of each core (Vc) was then estimated from the equation:

$$Vc = \pi \frac{D^2}{4} h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Figure 7. Soil cores placed in a dessicator for cooling after oven drying.

(ii) Determination of soil porosity (f)

Total porosity (f) was estimated as a function of bulk density (ρ_b) and particle density (ρ_s) from the relation:

$f = 1-\rho_b/\rho_s$……………………………………………………………………………………………...5

Where: ρ_s was assumed to be 2.65g/cm^3.

3.3.3 Determination of volumetric water content.

The volumetric water content (θ_v) was estimated from soil wetness (w) and bulk density ρ_b. The w was determined from the amount of water lost (Mw) in grams, at each of the suctions that the soil cores were subjected to from saturation using the equation:

$$w = \frac{Mw}{Ms}$$ ………………………………………………………………………………. 6

Where, Ms is the mass of oven dry soil.

The volumetric water content (θ_v) was then determined from the relationship:

$$\theta_v = w * \frac{\rho_b}{\rho_w}$$ ……………………………………………………………………………………7

Where: ρ_w is the density of liquid water which is approximately 1 g/cm^3 at room temperature and atmospheric pressure (Hillel, 1998).

CHAPTER FOUR

4.0 Results and Discussion

4.1 Data analysis

Descriptive statistics and a correlation matrix were generated to provide an overview of the dataset used in this study. Data were then subjected to analysis of variance. Means were separated using the Least significant difference at 95% confidence level

4.1.1 Effect of land cover on soil physical properties.

Landcover significantly affected the soil dry bulk density (F pr. = 0.009), total porosity (F pr. = 0.009), and volumetric water content at field capacity (F pr. < 0.001) but not saturated hydraulic conductivity (F pr. = 0.111). Soil dry bulk density under natural and semi-natural land cover was significantly lower than that under sorghum monocrop and sorghum + cow pea intercrop.

Table 1. Generalised ANOVAtable for water related soil physical properties under different land cover.

Source of variation	df	Bulk density	f (%)	Ks (cm/day)	θv (cm^3/cm^3)
Land cover	3	0.009	0.009	0.111	<0.001
Rep	2				
Residual	6				
Grand mean		1.54	80.46	41.78	0.3683
LSD (5%)		0.0757	111.8	6.975	0.052

However, there was no significant difference in dry bulk density under sorghum monocrop and that under sorghum + cowpea intercrop (Fig 8). Total porosity followed the opposite trend (Fig 9) while volumetric water content at field capacity followed a similar trend except that there was a significant difference in volumetric water content at field capacity between natural and semi-natural land cover types (Fig 10). There was a decreasing trend in saturated hydraulic conductivity across the land cover types. Saturated hydraulic conductivity was higher under natural and semi-natural land cover but it was not significantly different than the low values recorded under sorghum sole cropping and sorghum + cowpea intercrop system (Fig 11).

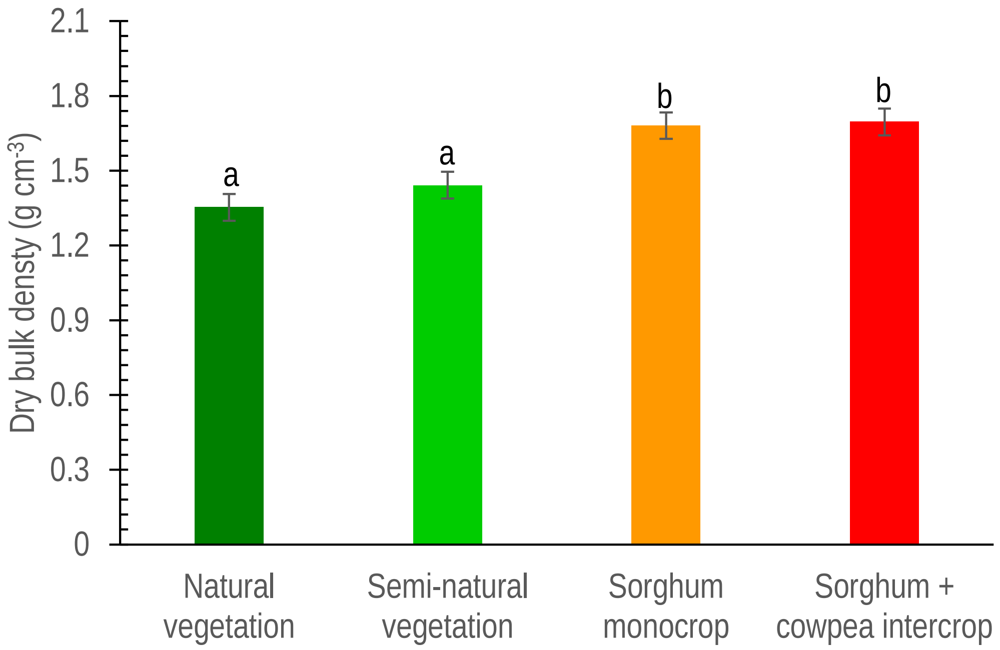

Figure 8. Effect of land cover on soil dry bulk density in Asinge, Tororo District, Uganda.

Error bars are standard error of means; Means crowned with the same lower-case letter are not significantly different at 95% confidence level

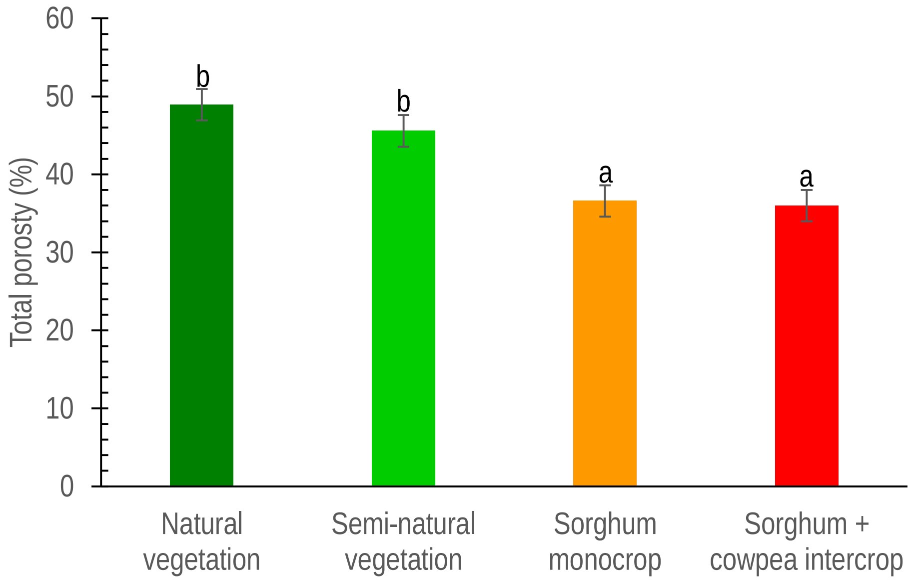

Figure 9. Effect of land cover on soil total porosity in Asinge, Tororo District, Uganda. *Error bars are standard error of means; Means crowned with the same lower-case letter are not significantly different at 95% confidence level*

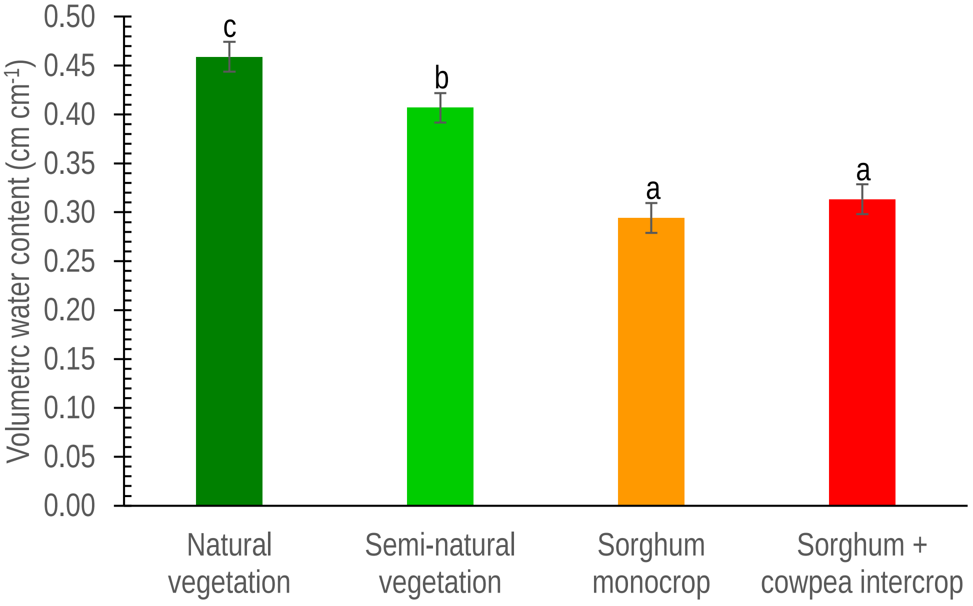

Figure 10. Effect of land cover on volumetric water content at field capacity in Asinge, Tororo District, Uganda.

Error bars are standard error of means; Means crowned with the same lower-case letter are not significantly different at 95% confidence level

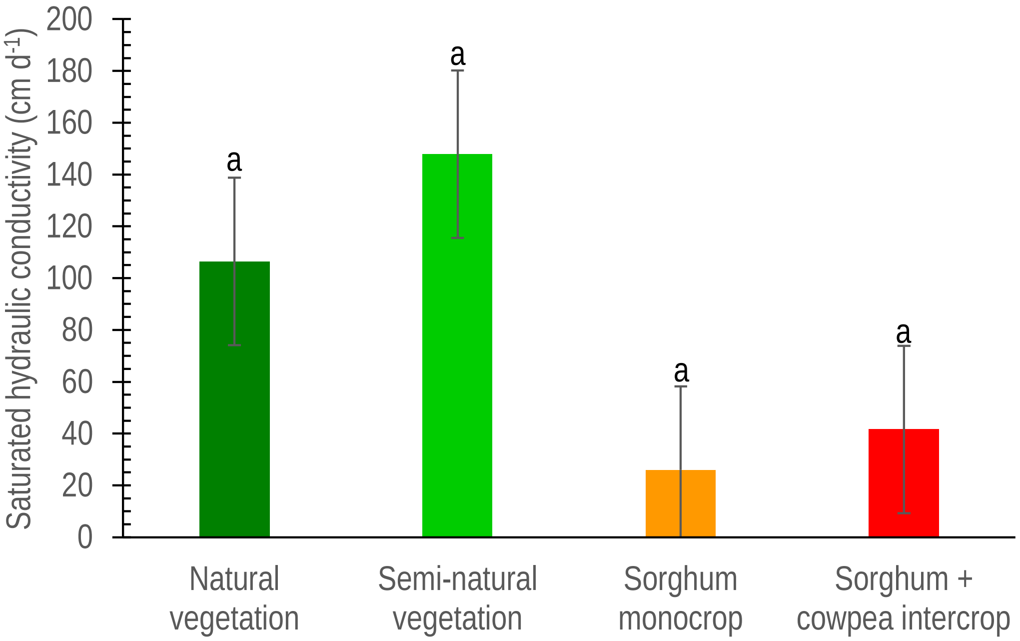

Figure 11. Effect of land cover on saturared hydraulic conductivity in Asingr, Tororo District, Uganda.

Error bars are standard error of means; Means crowned with the same lower-case letter are not significantly different at 95% confidence level

4.1.2. Descriptive statistics and correlation between soil physical properties.

The lowest soil dry bulk density of 1.205 g cm^{-3} was recorded in natural vegetation while the highest dry bulk density of 1.796 g cm^{-3} was recorded in sorghum + cowpea intercrop. The highest porosity (54.5%) was recorded in natural vegetation while the lowest value of 32.2% was recorded in sorghum + cowpea intercrop. The saturated hydraulic conductivity ranged from 11.9 cm/day in sorghum monocrop to 265.6 cm/day in semi-natural vegetation. The volumetric soil water content ranged from 0.2774 cm^{3}cm^{-3} in sorghum monocrop to 0.4968cm^{3}cm^{-3} in natural vegetation (Table 2).

Table 2. Descriptive statistics for soil physical properties in Asinge.

Statistic	Dry bulk density (g cm^{-3})	Total porosity (%)	K_{Sat} (cm/day)	Volumetric water content (cm^3 cm^{-3})
Minimum	1.21	32.2	11.9	0.28
Maximum	1.80	54.5	265.6	0.50
First Quartile	1.40	36.0	36.2	0.31
Second Quartile	1.55	41.4	57.2	0.36
Third Quartile	1.70	47.1	95.9	0.42

K_{Sat} = Saturated hydraulic conductivity; Volumetric water content was measured at (field capacity)

Dry bulk density was negatively correlated with total porosity, saturated hydraulic conductivity and volumetric watercontent at field capacity (Fig 12). Total porosity was positively correlated with saturated hydraulic conductivity and volumetric water content at saturation. However, there was no significant correlation between saturated hydraulic conductivity and volumetric water content at saturation (Fig 12).

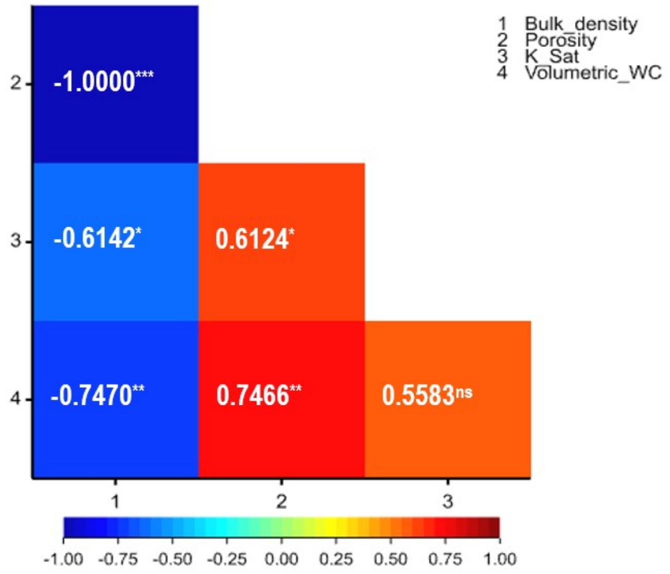

Figure 12. Correlation plot for selected soil physical properties in Asinge, Tororo District, Uganda.

Bulk_density = soil dry bulk density (g cm^{-3}); Porosity = Total porosity (%); K_Sat = Saturated hydraulic conductivity (cm d^{-1}); Volumetric_WC = Volumetric water content at field capacity (cm^3 cm^{-3}); Values in each cell represent correlation coefficients significant at either 99.9% $^{(***}$), 99.0% (**) and 95% (*) confidence limit or not significant (ns) at 95% confidence limit (^{ns})

4.1.3 Relationship between saturated hydraulic conductivity and volumetric water content.

There was a strong positive relationship between soil saturated hydraulic conductivity and volumetric water content at holding capacity where an increase in Ks showed an increase in water content in the soil. This is because increase in the Ks shows an increase in macropores which are responsible for holding water in the soil.

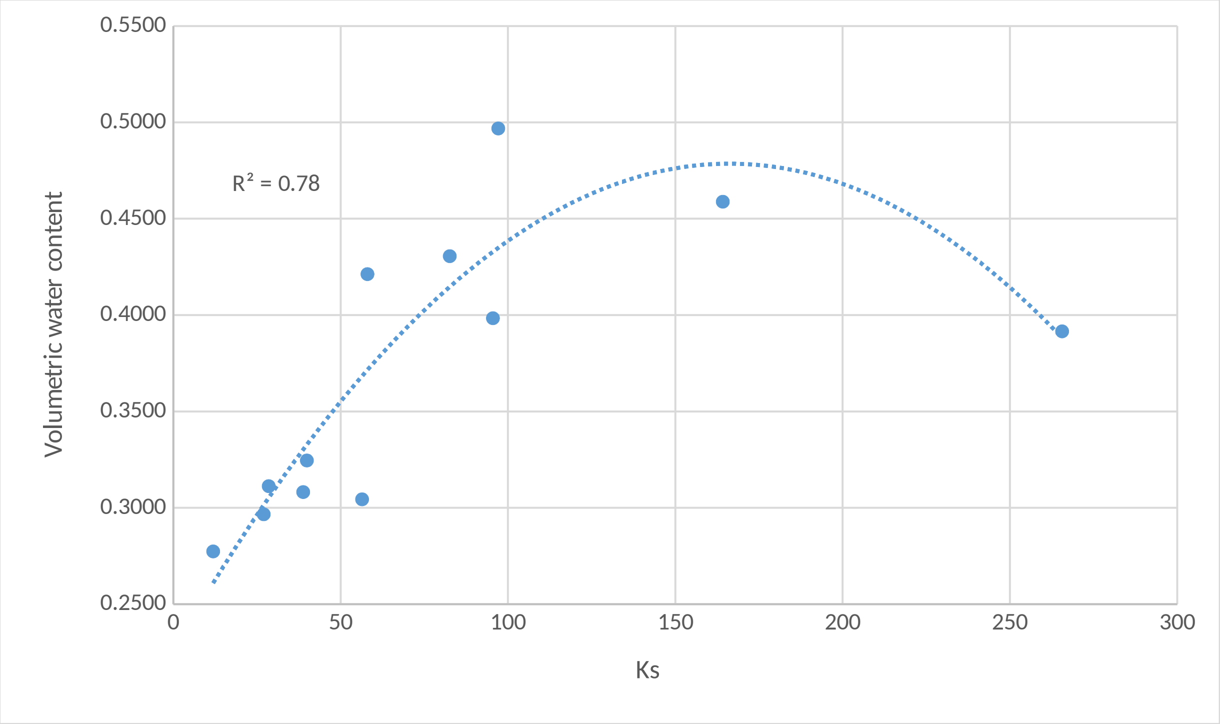

Figure 13. Relationship between saturated hydraulic conductivity and volumetric water content at holding capacity.

4.1.4 Relationship between saturated hydraulic conductivity and porosity.

There was a positive relationship between saturated hydraulic conductivity and total porosity where an increase in porosity increased the Ks of the soil. This is because an increase in total porosity implies increase in number of macropores that are responsible for receiving and transmitting water through the soil.

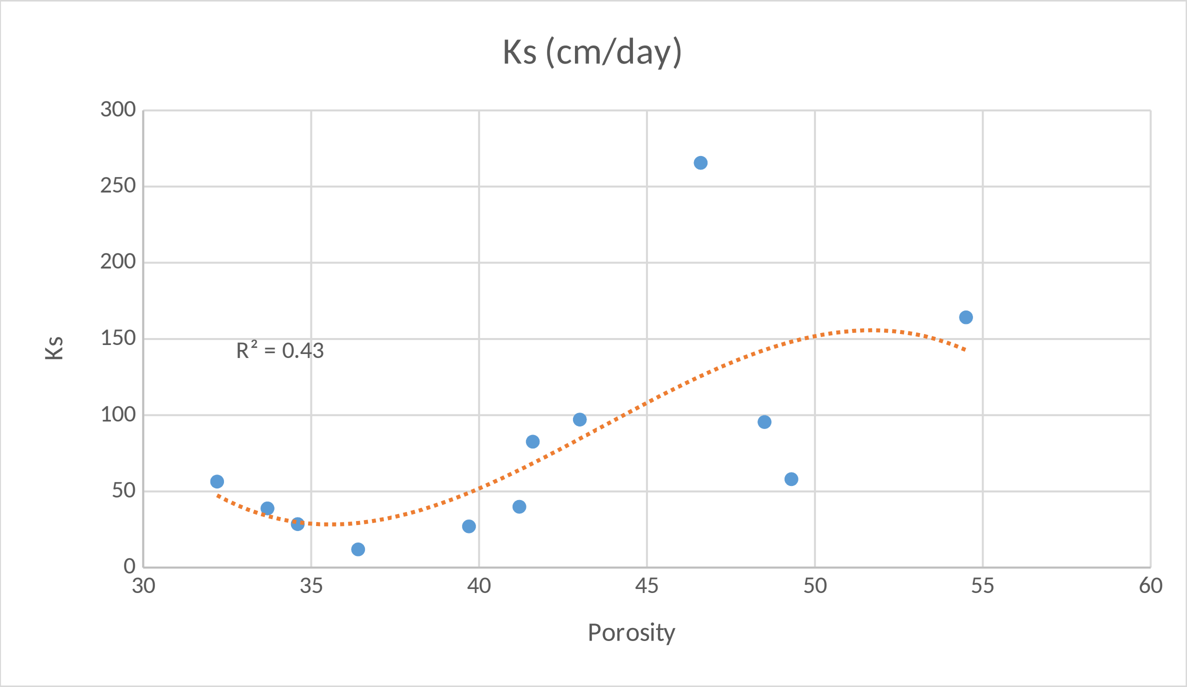

Figure 14. Relationship between saturated hydraulic conductivity and total porosity.

4.1.5 Relationship between saturated hydraulic conductivity and bulk desnity.

There was a negative relationship between saturated hydraulic conductivity and bulk density of the soil where an increase in bulk density led to a decrease in the Ks of the soil. This is because an increase in bulk density implies that the soil was compacted leading to loss of macropores responsible for receiving and transmitting water in the soil. It also implies that there was loss of organic matter responsible for aggregating soil to form good pore connectivity.

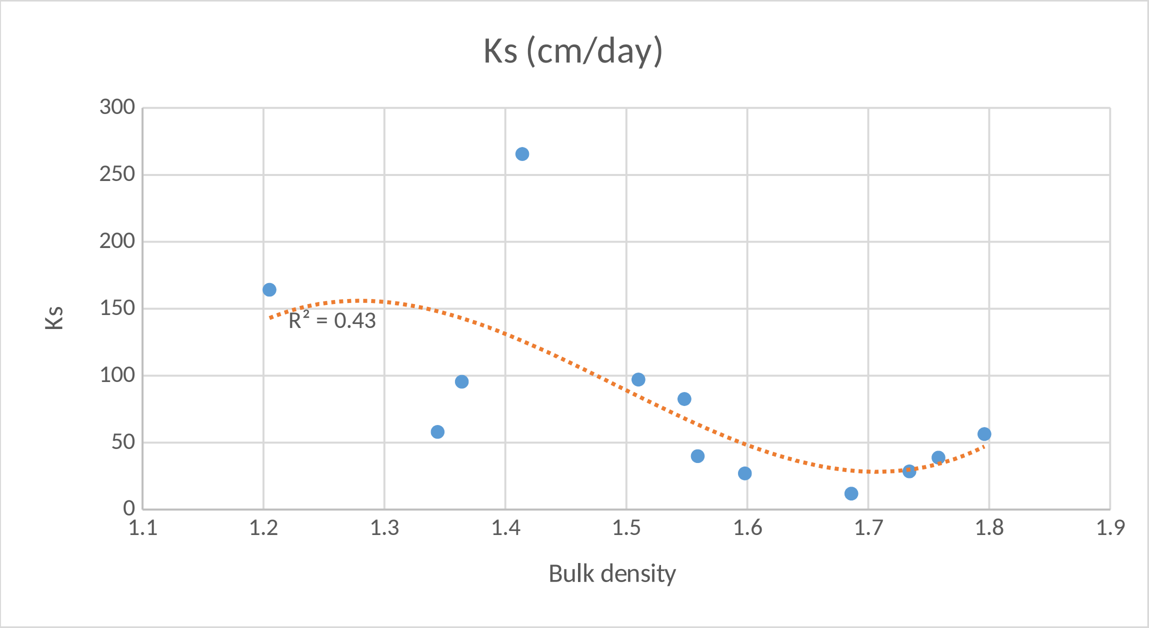

Figure 15. Relationship between saturated hydraulic conductivity and bulk density.

4.1.6 Relationship between volumetric water content and porosity.

There was positive relationship between volumetric water content at holding capacity and total porosity of the soil where an increase in porosity led to an increase in water content in the soil. This is because an increase in porosity implies there was an increase in the number of macropores responsible for holding water in the soil thus higher water conent at holding capacity.

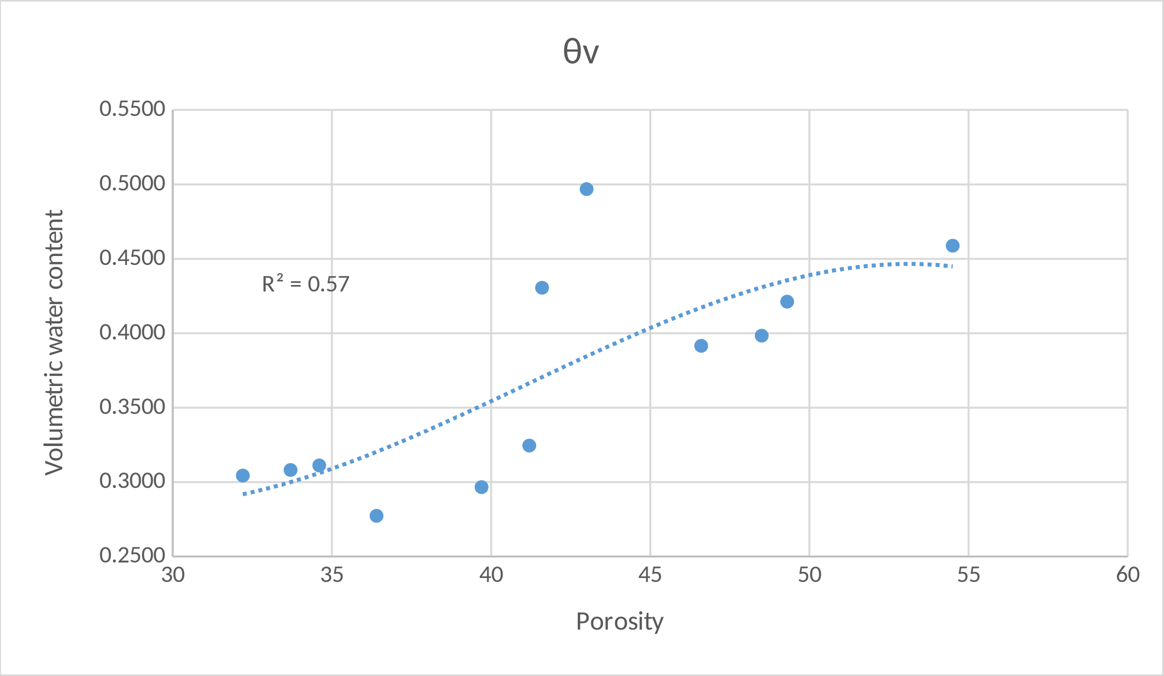

Figure 16. Relationship between volumetric water content at holding capacity and total porosity.

4.1.7 Relationship between volumetric water content and bulk density.

There was a strong negative relationship between volumetric water content at holding capacity and bulk density of the soil where an increase in bulk density showed a decrease in volumetric water content of the soil at holding capacity. This is because increased bulk density implies soil compaction which leads to reduction in macropores responsible for holding water in the soil and loss of organic carbon responsible for aggregating soil to form well connected macropores.

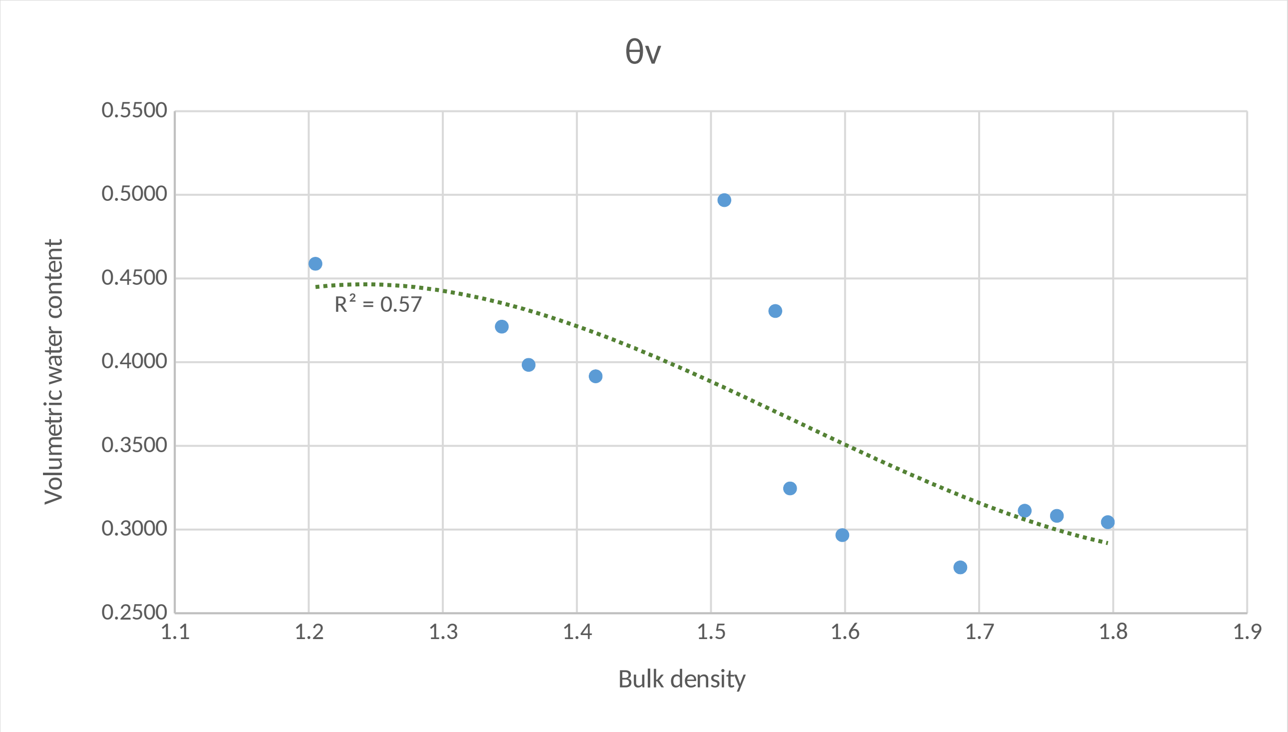

Figure 17. Relationship between volumetric water content at holding capacity and bulk density.

4.2 Discussion.

According to a report by Michael (1978), bulk density within the range of 1.0g/cm^3 to 1.6g/cm^3 is required for agricultural production. Based on the results, the bulk density reduced in the order of Sorghum-Cow pea intercrop > Sorghum monocrop >Semi-natural vegetation > Natural vegetation. This can be explained by the land use intensificationwhich was lowest under natural vegetation and highest under the sorghum-cow pea monocrop where there was soil compaction caused by the continuous tillage of the land season after season. According to Horton et al. (1988), soil compaction is considered as an increase in soil bulk density and a reduction in pore space, significantly altering water-related soil properties relative to a non-compacted condition. The reduction in pore space has a big effect on the movement of water through the soil and the amount of water available for crop use. Also root growth, in general, starts to be restricted when the bulk density reaches 1.55 to 1.6 g/cm^3 and is prohibited at about 1.8 g/cm^3(Plant and Soil Sciences eLibrary, 2022).

The low bulk densities in the natural and semi-natural blocks can be explained through the vegetation cover or land use standing for a longer time with less soil disturbance reducing natural soil erosion rates, thereby slowing down the rate of mineral surface soil removal. As a result, soils under fallow are richer in organic matter and hence lower bulk densities. According to Hughes *et al*. (2001), roots growing through soil with a bulk density of 1.2g/cm^3 may not have a high degree of branching or secondary root formation, owing to poor contact of the roots with soil. In this case, they suggested that moderate amount of compaction may be required to increase root branching and secondary root formation thus allowing roots to explore the soil more for moisture and nutrients.

The total porosity (f) values obtained were within the normal range for arable soils (30 – 60%) given by Hillel (1998).However, soil porosity increasedin the order Sorghum-Cowpea intercrop > Sorghum monocrop> Semi-natural vegetation > Natural vegetation. This difference in total porosity can also be attributed to the land use intensification by continuous destruction of soil structure through tillage done every season. The less disturbed land use systems promote high porosity due to conservation of large continuous pores that are inter connected compared to intensively disturbed systems.The soils in Asinge village being sandy soils also explains why the porosity easily reduces with land use intensification and disturbance since the soil structure is weak and easily degraded.

Saturated hydraulic conductivity (Ks) is a better index of water circulation in soil than porosity because it integrates structure, porosity, tortuosity, and connectivity of pores (Muchelo, 2008).According to the results, soil saturated hydraulic conductivity increasedin the order Sorghum monocrop>Sorghum-Cowpea intercropping > Natural vegetation > Semi-natural vegetation.This shows that the cultivated areas have their soil structure degraded by increasing land use intensification through tillage thus affecting the pore distribution, pore size, pore connectivity, tortuosity and also leading to blocked pores in the soil that are not involved in water movement through the soil.

Thevolumetric water content in the soil (at field capacity) increased with the land use intensity in the order Sorghum monocrop >Sorghum-Cowpea intercropping> Semi-natural vegetation > Natural vegetation. According to Thiago et al.(2016) the cultivated systems had higher volumes of blocked pores compared with the native forest, thus indicating that areas under cultivation have higher volume of non-functional pores, which are not available to water and gas flow. It is important to point out that the blocked porosity does not participate in the convective transport of water and air in the soil, which makes it independent of pore continuity.However, according to Ceballos *et al*. (2002)the water content values obtained in this study were much higher thanthe 0.07 cm^3/cm^3 for a sandy soil in an arid region in Spain meaning all the soils under the different land cover or land use were suitable for crop production since the crops could benefit from high water content levels for proper development.

CHAPTER FIVE

5.0 Conclusions and Recommendations.

5.1 Conclusion.

The results indicated that the land use intensification has a significant effect on the bulk density, porosity and water content in the soil.The lower the intensity of disturbance, the higher the total porosity, the higher the soil saturated hydraulic conductivity and therefore the higher the volumetric water content at holding capacity.

The soil water content is favourable for crop growth in all the land uses with the fallowed areas containing more water than the cultivated ones. The water content in the cultivated soils is likely to reduce after a long time as the porosity and bulk density keep getting degraded.

This, therefore, calls for the cultivated areas to be allowed some time for fallowing to allow the increase in organic matter together with vegetation roots rebuilding the soil structure through aggregating the soil particles. This improved soil structure will improve both the bulk density and porosity of the soil hence better soil water conductivity and higher water content in the cultivated soils.

Other management efforts and techniques may also be used like the application of manure to increase the organic matter content, conservation tillage or, reduction of mechanized operations.

However, the reduction of mechanized operations alone is insufficient to avoid soil compaction or ameliorate its effects. This necessitates the use of plant species that produce large amounts of dry matter for soil coverage and primarily have a deep and aggressive root system capable of improving the physical structure of the soil (Balbinot Junior et al., 2017).

5.2 Recommendations

The soil water properties studied have laid a foundation for understanding the effect land use intensification has soil physical propertiesand also encourage a change in management and better use of the soils in Asinge village. However, more studies are needed to understand these soils' soil moisture retention characteristics and the dynamics of soil organic carbon in soil aggregates under the different land use systems. There is also a need to understand and classify the soil texture in Asinge village.

6.0 References.

Arthur, E., Schjønning, P., Moldrup, P., and de Jonge, L. W. (2012). Soil Resistance and Resilience to Mechanical Stresses for Three Differently Managed sandy Loam Soils. Geoderma 173-174, 50–60. doi:10.1016/j.geoderma.2012.01.007.

Balbinot Junior, A. A., Franchini, J. C., Debiasi H, and Yokoyama, A. H. 2017. Contribution Of Roots And Shoots Of UrochloaSpecies To Soybean Performance In Succession.PesqAgropec Bras. 58:592-598.

BelaynehBufeboand Eyasu Elias. 2020. Effects of Land Use/Land Cover Changes on Selected Soil Physical and Chemical Properties in Shenkolla Watershed, South Central Ethiopia. https://doi.org/10.1155/2020/5145483

Blake GR, Hartge KH 1986. Bulk density. In: Klute A (Ed.). Methods of Soil Analysis, PartI. Physical and Mineralogical Methods. 2nd edn. Am. Soc. Agron., Madison, W. I. p. 363.

Brahim, N., Bernoux, M., &Gallali, T. (2012). Pedotransfer functions to estimate soil bulk density for Northern Africa: Tunisia case. Journal of Arid Environments, 81, 77-83.

Ceballos A., J. M. Fernadez, F. Satos and P.Alonso 2002. Soil water behaviour of sandy soils under semi arid conditions in the Duero Basis (Spain). Journal of Arid Environments co 51: 501-519

Çerçioğlu, M., Anderson, S. H., Udawatta, R. P., &Alagele, S. (2019). Effect of cover crop management on soil hydraulic properties. Geoderma, 343, 247-253.

De MoraesSá, J. C., Séguy, L., Tivet, F., Lal, R., Bouzinac, S., Borszowskei, P. R., Friedrich, T. (2015). Carbon depletion by plowing and its restoration by no-till cropping systems in oxisols of subtropical and tropical agro-ecoregions in Brazil. Land Degradation and Development, **26**, 531– 543.

Demir, Z. (2020). Quantifying some physical properties and organic matter of soils under different management systems in cherry orchard. Eurasian Journal of Soil Science, 9(3), 208-221.

Demir, Z., &Işık, D. (2019). Effects of cover crops on soil hydraulic properties and yield in a persimmon orchard. Bragantia, 78(4), 596-605.

Demir, Z., &Işık, D. (2020). The impact of different cover crops, mechanical cultivation and herbicide treatment on the soil quality variables and yield in apple (MalusdomesticaBorkh.) orchard with a coarse-textured soil. Journal of Agricultural Sciences, 26(4), 452-470.

Demir, Z., Tursun, N., &Işık, D. (2019). Effects of different cover crops on soil quality parameters and yield in an apricot orchard. International Journal of Agriculture and Biology, 21(2), 399-408.

Hillel, D. 1998. Environmental soil physics. Academic Press, San, Diego.

Horton, R., R.R. Allmaras, and R.M. Cruse. 1988. Tillage And Compactive Effects On Soil Hydraulic Properties And Water Flow.

Huang, X., Horn, R., and Ren, T. (2021). Deformation and Pore Water Pressure Change during Static and Cyclic Loading with Subsequent Shearing on Soils with Different Textures and Matric Potentials. *Soil Tillage Res.* 209, 104909. doi:10.1016/j.still.2020.104909.

Hughes, J. D., J. F. Moncrief., W. B. Voorhees., and J. B. Swan. 2001. Soil Compaction Causes, Effects And Control

John Jiya Musa, OtuaroEbierinAkpoebidimiyen, Pius Olufemi Olusegun Dada, Johnson KayodeAdewumi, Yahaya Usman Gupa.2021. Effect of Land Management on Soil

Hydraulic Conductivity in GidanKwano, Niger State, Nigeria. *Open Journal of Forestry*, 11, 108-116.

Klute, A., and A. Dirksen. 1986. Hydrualic conductivity and diffusivity: Laboratory methods. P. 687-734. In A. Klute (ed) Methods of soil analysis. Part 1. Agron. Monogr. No. 9 ASA and SSSA, Madison, WI.

Lestariningsih, I. D., Widianto, &Hairiah, K. 2013. Assessing soil compaction with two different methods of soil bulk density measurement in oil palm plantation soil. Procedia Environmental Sciences, 17, 172- 178.

Li, Y., Li, Z., Cuie, S., & Zhang, Q. 2020. Trade-off between soil pH, bulk density and other soil physical properties under global no-tillage agriculture. Geoderma, **361**, 114099.

Makovníková, J., Širáň M., Houšková B., Pálka B., & Jones A. 2017. Comparison of different models for predicting soil bulk density. Case study - Slovakian agricultural soils. International Agrophysics, 31(4), 491–498.

Mateo-Marín, N., Bosch-Serra, À. D., Molina, M. G., &Poch, R. M. 2021. Impacts of tillage and nutrient management on soil porosity trends in dryland agriculture. *European Journal of Soil Science*, *73*(1), e13139.

MingzhuoHao, JinchiZhang, MiaojingMeng, HanY. H. Chen, XiaopingGuo, Shenglong Liu, and LixinYe. 2019. Impacts of changes in vegetation on saturated hydraulic conductivity of soil in subtropical forests.

Muchelo, R. W. O. 2008. Characterization of soil physical properties of Makerere University Agricultural Research InstituteKabanyolo, south-central Uganda.

Nayyef, H. R. 2022. Effect of continuous cultivation and soil texture on some soil properties. GSC Advanced Research and Reviews, 13(1), 077-084.

Özdemir, N., Demir, Z., &Bülbül, E. 2022. Relationships between some soil properties and bulk density under different land use. Soil Studies, 11(2), 43-50. http://doi.org/10.21657/soilst.1218353.

Peng, X., & Horn, R. 2008. Time-dependent, anisotropic pore structure and soil strength in a 10-year period after intensive tractor wheeling under conservation and conventional tillage. Journal of Plant Nutrition and Soil Science, **171**, 936– 944.

Plant and Soil Sciences eLibrary, 2022;Soil Water | Soils - Part 2: Physical Properties of Soil and Soil Water - passel (unl.edu)

Ruehlmann, J., &Körschens, M. 2009. Calculating the effect of soil organic matter concentration on soil bulk density. Soil Science Society of America Journal, 73(3), 876-885.

Strudley, M. W., Green, T. R., & Ascough, J. C., II. 2008. Review. Tillage effects on soil hydraulic properties in space and time: State of the science. Soil and Tillage Research, **99**, 499– 512.

Theobald, B., Alexis K., Noel M., Khaldoon A. M. 2018. The Effect of Land Use Systems on Soil Properties; A case study from Rwanda. Sustainable Agriculture Research 7(2):30-40

Thiago, L. A., Arilene, F. C., Alcione, G., FreireRaimundo, N. A. J., Jaedson, C. A. M. 2016. Liquid Bovine Biofertilizer and Cultivation Effects on the Porosity of a TypicHaplocambids as a Function of Cultivation and Dose.

Tucci, C. E. M, and Mendes, C. A. 2006. Integrated environmental assessment of a watershed. Brasilia: MMA, 302 p.

Udayakumar, S., Sagar, K. L., & Kumar, S. 2021. Soil aggregates, aggregate-associated carbon and nitrogen, and water retention as influenced by short and long-term no-till systems. Soil and Tillage Research, **208**, 104885.

Upendra, B., Ciba, M., Aiswarya, A., Dev, V. V., Sreenivasulu, G., & Krishnan, K. A. (2022). Mechanisms controlling the dissolved load, chemical weathering and CO2 consumption rates of Cauvery River, South India: role of secondary soil minerals. Environmental Earth Sciences, 81(3), 1-18.

Woldeyohannis, Y. S., Hiremath, S. S., Tola, S., & Wako, A. 2022. Investigation of Soil Physiochemical Properties Effects on Soil Compaction for a Long Year Tilled Farmland. Applied and Environmental Soil Science, 2022.

Yu, X., Hong, C., Peng, G., & Lu, S. 2018. Response of pore structures to long-term fertilization by a combination of synchrotron radiation X-ray microcomputed tomography and a pore network model. European Journal of Soil Science, 69(2), 290-302.