# EVALUATION OF SATURATED HYDRAULIC CONDUCTIVITY (KSAT) AND SOME SOIL PROPERTIES AT AGR 305 FARM.

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**BENIN CITY**

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF SOIL SCIENCE FACULTY OF AGRICULTURE UNIVERSITY OF BENIN, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF AGRICULTURE (B. AGRIC HONS)**

**DEGREE IN SOIL SCIENCE**

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## CERTIFICATION

This is to certify that this project work was carried out by **Abigail Aimwenosa OMO-OSAGIE** in the department of soil science and land management, Faculty of Agriculture, University of Benin, Benin city, Edo State. Nigeria.

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Head of Department (HOD)

# DEDICATION

This project work is specially dedicated to God Almighty for his grace and mercy towards my education and being my help in times of need.

# ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to God Almighty, who gave me strength to complete this work, and who has been my pillar of strength and support throughout my stay in the University of Benin.

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## TABLE OF CONTENTS

Title page . . . . . . . . . . . ii

Certification. . . . . . . . . . . iii

Dedication. . . . . . . . . . . iv

Acknowledgement. . . . . . . . . . . v

Table of contents. . . . . . . . . . . vi

List of tables . . . . . . . . . . . . viii

List of figures.. . . . . . . . . . . ix

Abstract . . . . . . . . . . . x

**CHAPTER ONE**

Introduction. . . . . . . . . . . . 1

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1** Relationship between saturated hydraulic conductivity and soil losses (erosion). . . . . . . . . . 3

2.2 Relationship between saturated hydraulic conductivity and soil aggregate. 4

2.3 Relationship between saturated hydraulic conductivity and bulk density. . 5

2.4 Relationship between saturated hydraulic conductivity and soil texture. . 5

2.5 Relationship between saturated hydraulic conductivity and organic matter. 6

**CHAPTER THREE**

Materials and methods. . .. . . . . . . . 7

3.1 Experimental Site . . . . . . . . . . .. 7

3.2 Sample collection. . . . . . . . . 7

3.3 Laboratory Analysis. . . . . . . . . 8

3.3.1 Analysis for Chemical Properties. . . . . . . 8

3.3.1.2. Particle Size Analysis.. . . . . . . . 8

3.3.1.3 Textural Classification. . . . . . . . 9

3.3.1.4 Soil pH. . . . . . . . . . 9

3.3.1.5 Organic Carbon. . . . . . . . . 9

3.3.1.6 Total organic Nitrogen. . . . . . . . 9

3.3.1.7 Available Phosphorus (P). . . . . . . . 9

3.3.1.8 Cation Exchange Capacity (CEC). . . . . . . 10

3.3.1.9 Exchangeable Bases. . . . . . . . 10

3.3.1.10 Exchangeable Acidity. . . . . . . . 10

3.3.1.11 Effective Cation Exchange Capacity (ECEC). . . . . 10

3.3.1.12 Base Saturation. . . . . . . . . 10

3.3.1.13 Statistical Analysis. . . . . . . . 11

3.3.2 Analysis for Physical Properties. . . . . . . 11

3.3.2.1 Determination of Bulk Density, Porosity, and Saturated Hydraulic Conductivity. 11

3.3.2.2 Determination of Aggregate Stability and Water Holding Capacity. . . 11

**CHAPTER FOUR**

4.0 Result And Discussion. . . . . . . . . 13

**CHAPTER FIVE**

5.0 Conclusion. . . . . . . . . . 48

Reference. . . . . . . . . . . 49

## LIST OF TABLES

**Table 1:** Table showing Ksat with other soil routine parameters. . . 14

**Table 2:** Table showing Ksat and some routine parameters. . . . 15

**Table 3:** Correlation table between routine parameters and Ksat in mapping unit 1. 16

**Table 4:** Ksat vs P in Pedon 1. . . . . . . . 17

**Table 5:** Relationship between Ksat and P. . . . . . 18

**Table 6:** Ksat vs Magnesium. . . . . . . . 19

**Table 7:** Relationship between Ksat and Mg. . . . . . 20

**Table 8:** Ksat vs Potassium (K). . . . . . . 20

**Table 9:** Relationship between Ksat and potassium (K). . . . 21

**Table 10:** Ksat vs CEC . . . . . . . . 22

**Table 11:** Relationship between Ksat and CEC . . . . . 23

**Table 12:** Ksat vs Base saturation . . . . . . 23

**Table 13:** Relationship between Ksat and Base saturation (BS). . . 24

**Table 14:** Ksat vs Clay. . . . . . . . . 25

**Table 15:** Relationship between Ksat and Clay. . . . . . 26

**Table 16:** Ksat vs Bulk Density. . . . . . . . 27

**Table 17:** Relationship between Ksat and Bulk density . . . . . 28

**Table 18:** Ksat vs Sand. . . . . . . . . . 29

**Table 19:** Relationship between Ksat and Sand. . . . . . . 30

**Table 20:** Ksat vs Total porosity.. . . . . . . 31

**Table 21:** Relationship between Ksat and Total porosity. . . . . 32

**Table 22:** Ksat vs Aggregate Stability. . . . . . . . 32

**Table 4.13:** Relationship between Ksat and Aggregate Stability. . . . 33

**Table 23:** Correlation table between routine parameters and Ksat in pedon 2. . 34

**Table 24:** Ksat vs PH in Pedon 2. . . . . . . . 35

**Table 25:** Relationship between Ksat and pH. . . . . . . 36

**Table 26** Ksat vs OC in Pedon 2. . . . . . . . 36

**Table 27:** Relationship between Ksat and OC. . . . . . . 37

**Table 28** Ksat vs Total nitrogen . . . . . . . . 38

**Table 29:** Relationship between Ksat and Total nitrogen. . . . . 39

**Table 30:** Ksat vs organic matter. . . . . . . . 39

**Table 31:** Relationship between Ksat and OM . . . . . . . 40

**Table 32:** Ksat vs CEC. . . . . . . . . . 41

**Table 33:** Relationship between Ksat and CEC. . . . . . . 42

**Table 34** Ksat vs EA. . . . . . . . . . 42

**Table 35:** Relationship between Ksat and EA. . . . . . . 43

**Table 36:** Ksat vs ECEC. . . . . . . . . 44

**Table 37:** Relationship between Ksat and ECEC. . . . . . 45

**Table 38:** Ksat vs Bulk density. . . . . . . . . 46

**Table 39:** Relationship between Ksat and bulk density. . . . . 47

# LIST OF FIGURES

Fig1: Regression graph of Ksat vs. P in Pedon 1. . . . . . 18

Fig 2: Regression graph of Ksat vs. Mg in Pedon 1.. . . . . 19

Fig 3: Regression graph of Ksat vs. k in Pedon 1. . . . . . 21

Fig 4: Regression graph of Ksat vs CEC in Pedon 1.. . . . . 22

Fig 5:Regression graph of Ksat vs BS in Pedon 1. . . . . . 24

Fig 6::Regression graph of Ksat vs clay in Pedon 1. . . . . . 25

Fig 7: Regression graph of Ksat vs. Bulk density in Pedon 1. . . . 27

Fig 8: Regression graph of Ksat vs sand in Pedon 1... . . . . 29

Fig 9: Regression graph of Ksat vs Total porosity in Pedon 1.. . . . 31

Fig 10: Regression graph of Ksat vs PH in Pedon. . . . . . 35

Fig 10: Regression graph of Ksat vs. Organic carbon in Pedon 2 . . . 37

Fig11: Regression graph of Ksat vs Total nitrogen in Pedon 2. . . . 38

Fig 12: Regression graph of Ksat vs Organic matter in Pedon 2. . . . 40

Fig13: Regression graph of Ksat vs. CEC in Pedon 1. . . . . 41

Fig 14: Regression graph of Ksat vs. EA in Pedon 1.. . . . . 43

Fig 15: Regression graph of Ksat vs ECEC in Pedon 2. . . . . 44

Fig16: Regression graph of Ksat vs Bulk density in Pedon 2. . . . 46

# ABSTRACT

The saturated hydraulic conductivity in this work was determined using its relationship with other soil parameters. A soil survey process was used to determine the Ksat of two mapping unit found in the site. Each mapping unit was represented with a pedon from which soils were collected using a soil auger and core sampler. Ksat was determined in the laboratory using the constant head method, the primary objective of this study was to evaluate the relationship between saturated hydraulic conductivity and other soil routine properties of soils found at the AGR 305 Farm to see if a prediction equation could be derived and used in the determination of saturated hydraulic conductivity in soils with similar properties.

The result showed that the study site in mapping unit 1 and mapping unit 2 have parameters that correlated differently. In mapping unit 1, it was observed that phosphorus (0.736), CEC (0.879), Base saturation (0.831), clay(0.726) correlated postively while sand (-0.766), aggregate stability (-0.614) correlated negatively and was used to determine the saturated hydraulic conductivity of that mapping unit. But in mapping unit 2, ph(-0.858), organic carbon (-0.884), organic matter (-0.770), total nitrogen (-0.771) correlated negatively while bulk density (0.851) correlated positively and was used to determine the saturated hydraulic conductivity for that soil type.

# CHAPTER ONE

# INTRODUCTION

Saturated hydraulic conductivity (Ksat) is a crucial soil property that influences water movement and quality in the soil. it is a fundamental property of porous materials like soils and rocks, It’s an important soil hydraulic property that affects water flow and the transport of dissolved solutes.(Takele *et al*., 2005). It describes the rate of water flow, as it affects water infiltration, drainage, and retention, and plays a role in nutrient transformations and plant uptake. Saturated hydraulic conductivity (Ksat) is a function of particle size distribution, pore size distribution, pore continuity and configuration, and bulk density (Jabro,1992). The Ksat value is dependent on pore size distribution, especially the presence of macro pores. Soil properties like total porosity and macro-porosity have been found to positively correlate with Saturated hydraulic conductivity (Ksat).

To determine Ksat, methods such as empirical approach and experiment approach are applied (Sahu *et al*., 2016). Saturated hydraulic conductivity is solely dependent on soil texture, structure, macro pores and chemical dispersion. Soil bulk density and saturated hydraulic conductivity are inversely related. As the bulk density of the soil increases, the saturated hydraulic conductivity (Ksat) decreases. This negative correlation is due to changes in pore-size distribution and structure as bulk density increases. Higher bulk densities lead to a decrease in coarse pores and an increase in middle and fine pores, resulting in reduced hydraulic conductivity (Dorota *et al*., 2008).

Many methods can be used to conduct saturated hydraulic conductivity (Ksat). It could be done using field and laboratory methods, (Oshunsanya *et al.,* 2010). The method to be used in this study is the constant head method (Huo *et al.,* 2010). Laboratory instruments are utilized to create hydraulic conductivity curves predicting water flow in different soil types at varying water potentials. As a result, many methods have been developed over time for field and laboratory measurement for Ksat (Musa *et al*.,2018). Unsaturated hydraulic conductivity is lower than saturated values due to pore emptying during desaturation.

Agricultural decisions rely on hydraulic conductivity for irrigation rate determination, erosion prediction, nutrient leaching estimation, and landfill cover effectiveness assessment.

Studies have shown spatial and temporal variability in saturated soil hydraulic conductivity at field scales. Factors like soil sample size, land use changes, and native vegetation cover can influence the distribution patterns of saturated hydraulic conductivity values in soils (George *et al*., 2021).

The relationship between saturated hydraulic conductivity and soil properties is intricate, with soil texture, structure, macropores, and chemical dispersion playing crucial roles in determining the ease of water movement through soils.

The main objective of this study is to evaluate some saturated hydraulic conductivity properties of the soils at AGR 305 farm, faculty of agriculture university of Benin Edo state, Nigeria.

Specific objectives were to determine the:

I. Saturated hydraulic conductivity status of each mapping unit of the soils at AGR305 faculty of Agriculture.

II. Functional relationship between saturated hydraulic conductivity and the basic routine parameters of each mapping unit.

# CHAPTER TWO

# LITERATURE REVIEW

Saturated hydraulic conductivity is the ease with which pores of a saturated soil transmit water. It is the proportionality coefficient that expresses the relationship of the rate of water movement to hydraulic gradient in Darcy's Law (USDA, 2012). Saturated hydraulic conductivity which is used for soil interpretation is also known as Ksat.

Ksat is the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient (Yonggen *et al.,* 2019).Saturated hydraulic conductivity (Ksat) is a singular parameter in earth system science. Ksat not only governs the rate of flow of water under a hydraulic gradient as specified by the Darcy equation for saturated conditions, but also acts as a scaling factor in many unsaturated flow and transport applications that involve pore-size distribution models. (Yonggen *et al.,* 2019). Saturated hydraulic conductivity is dependent on soil particle distribution (Carlos *et al.,* 2018).

## 2.1 RELATIONSHIP BETWEEN SATURATED HYDRAULIC CONDUCTIVITY AND SOIL LOSSES (EROSION)

Saturated hydraulic conductivity Ksat is an essential parameter for understanding soil movement and soil hydrology (Jadczyszyn *et al.,* 2004). Soils with small values of hydraulic conductivity have low infiltration rates and during intense rains, water run-off will lead to consequent soil losses and surface transport of colloids, nutrients and microbes, which can then cause problems of eutrophication and pollution of downstream areas (Dexter *et al.,* 2004). Runoff is generally a function of rainfall intensity and soil infiltration rate and can be stimulated on agricultural land by tillage and residue management practices (Sharrat *et al.,* 2000)

## 2.2 RELATIONSHIP BETWEEN SATURATED HYDRAULIC CONDUCTIVITY AND

## SOIL AGGREGATE

Hydraulic conductivity is a key parameter which controls the movement of water and solutes through the soil profile (Hillel, 2004).

A reduction of this parameter could lead to waterlogging, reduction of the infiltration rate and soil aeration, and an increase of surface runoff and soil erosion (Kadu *et al.,* 2003, Ben-Hur, 2008). A soil's saturated hydraulic conductivity (Ksat) is strongly governed by soil structure, which affects the soil-pore geometry and quantity (Hillel, 2004).

Soil aggregation is a complex phenomenon that is a product of interactions among the soil microbial community and the mineral and organic composition, and is influenced by many factors such as the soil environment, management practices and land-use types (Seybold and Herrick 2001; Wei *et al*., 2006). Thus, aggregate stability is used as an indicator of soil structure (Six *et al.* 2000). Research has shown that Ksat is related to soil water characteristics, texture, soil structure, composition and content of soil cations, soil temperature, OM content, and land-use types (Hu *et al.,* 2005). The aggregate size distribution in the soil determines the soil bulk density and the volume and shape of the pores, which in turn affect the soil Ksat. Since there are interactions between aggregate size, OM content, and aggregate stability, it is hypothesized that these interactions would also affect the soil Ksat.

## 2.3 RELATIONSHIP BETWEEN SATURATED HYDRAULIC CONDUCTIVITY AND BULK DENSITY

Soil surface bulk density ($\rho$b) and saturated hydraulic conductivity (*K*sat) control many land-surface processes such as water flow, chemical transport and soil erosion (Hu *et al*., 2012). There's an inverse relationship between saturated hydraulic conductivity and bulk density. The larger the bulk density of the soil, the smaller the saturated hydraulic conductivity (Ksat), (Ayatt *et al.*, 2010) however, the relationship between Ksat and dry bulk density for tilled and untilled conditions is different. Ksat is lower in tilled soil than in untilled soil with the same texture at the same bulk density. (Ayatt *et al.*,2010)

## 2.4 RELATIONSHIP BETWEEN SATURATED HYDRAULIC CONDUCTIVITY AND SOIL TEXTURE

Soil texture refers to the percentage of sand, silt, and clay particles in the soil. Texture or textural class is often used for the correlation of Ksat values with other hydraulic properties of the soil e.g., water-holding capacity and drainable pore space (Asadullah *et al*., 2014). Soil texture and saturated hydraulic conductivity (Ks) are closely linked (Carlos *et al*., 2018). Soils with large soil particles have high value Ksat compared to soil with tiny soil particles. saturated hydraulic conductivity is largely influenced by the size and arrangement of soil particles and the relationship with different soil type and size. Large particle size allows easy and fast flow of water resulting in high (Ksat) value

## 2.5 RELATIONSHIP BETWEEN SATURATED HYDRAULIC CONDUCTIVITY AND ORGANIC MATTER

Organic matter used as conditioners contain an array of compounds such as proteins, fats and carbohydrates and high-molecular weight humic and fulvic acids. Organic matter is used to improve the physical and chemical properties of problem soils. The increase in the water-holding capacity and decrease in the infiltration and saturated hydraulic conductivity are more evident in coarse-textured soils than in fine-textured soils. (Demir *et al.*, 2019). In a study carried out by (Zebarth *et al.,* 1999), reported that the most important effects of organic matters on soils were the decrease in the bulk density and increase in the water-holding capacity, aggregate stability, hydraulic conductivity and permeability. Organic Matter is known to affect the hydraulic properties of the soil. It is often assumed that greater organic matter content in the soil will result in higher saturated hydraulic conductivity (Ksat). (Attila *et al.,* 2005).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 EXPERIMENTAL SITE

This study was carried out at AGR 305 farm, of the Faculty of Agriculture University of Benin, Benin city, Edo state. The area lies between latitude 06.40134• North and longitude 005.62547• East. The natural climate of the site is classified as the Humid Tropics with natural rain forest vegetation. The rainy season is bimodal with peak in July and September. There is usually a short dry break in mid-August, commonly known as "August break”. The site is situated at the rainforest belt of the humid tropics and southern ecological zone of Nigeria, with characteristic features of dry and wet seasons. The rainy season commences in April and ends in October while the dry season begins early November and ends in March.

## 3.2. SAMPLE COLLECTION

The soil used for this research was obtained from AGR 305 farm, of the faculty of agriculture university of Benin. Before the experiment, surface soil samples were collected from two profile pit, at which soils from mapping unit one (Pedon one )was taken from depth of 0-10cm, 10-35cm , 35-73cm, 73-118 and 118-200 and that of mapping unit two (pedon two) from depth of 0-20cm, 20-45cm, 45-70cm, 70-110cm, 110-195cm were randomly collected at the experimental site using soil auger and soil core sampler at different points. The samples were bulked to produce composite samples which were air dried and sieved with 2mm sieve.

## 3.3 LABORATORY ANALYSIS

### 3.3.1 ANALYSIS FOR CHEMICAL PROPERTIES

Soil samples were air-dried, grounded and passed through a 2 mm sieve and analyzed for selected physical and chemical properties following the standard operating procedure of the soil science and land management laboratory University of Benin.

#### 3.3.1.2. Particle Size Analysis.

Particle size distribution was determined by Hydrometer Method of Bouyoucos (1962), as modified by Day (1965). 51g of air-dry soil was weighed into a 250 ml beaker, 100 ml of Calgon was added and the mixture was stirred gently for few minutes before dispersing with a dispersing machine. The dispersed soil was transferred into a 1000 ml measuring cylinder and made up to mark with distilled water. The suspension was stirred thoroughly with a plunger to set the particles in motion. The first hydrometer reading was taken after 40 seconds using standard soil hydrometer with Bouyoucos scale in g/L and temperature reading was taken using thermometer. Thereafter the second hydrometer and temperature reading were taken after two hours. The particle size distribution (% sand, silt and clay) was calculated using the formula:

% Silt + % Clay = Corrected hydrometer reading/ weight of sample used × 100.

$\%\ (\text{Silt} + \%\ \text{Clay}) = 100\ [\ H_1 + 0.36\ (T_1 - 20)]\ /\ \text{wt. of soil}$

$\%\ \text{Clay} = [\ H_2 + 0.36\ (T_2 - 20)]2$

$\%\ \text{Silt} = 100 - (\%\ \text{Sand} + \%\ \text{Clay})$

Where, $H_1$ = first hydrometer reading, $H_2$ = second hydrometer reading, $T_1$ and $T_2$ = first and second temperature reading, wt. = weight.

#### 3.3.1.3 Textural Classification

Textural classification was determined using the textural triangle (soil survey staff, 2003).

#### 3.3.1.4 Soil pH

The soil pH was determined in 1:1 soil: water and 1:1 soil: KCl suspension using a glass electrode pH meter (Tan, 1996).

#### 3.3.1.5 Organic Carbon

The soil organic carbon (OC) content was determined by the wet oxidation method (walkley and Black, 1934).

#### 3.3.1.6 Total organic Nitrogen

Total organic nitrogen was computed from total organic carbon (Ibitoye, 2008).

#### 3.3.1.7 Available Phosphorus (P)

Available P was extracted by the Bray-1 solution according to methods by Bray and Kurtz (1945). The P in the extract was developed by the Sulphuric molybdate method of Murphy and Riley (1962). Acid molybdate (Reagent A) and ascorbic acid stock solutions (Reagent B) were prepared for the blue colour development procedure.

#### 3.3.1.8 Cation Exchange Capacity (CEC)

The cation capacity was determined by summation methods, where soils were treated with 1 M $NH_4OAc$ at pH 7.0 and CEC was calculated by summation of Ca, Mg, K and Na. (Udo, *et al.,* 2009).

#### 3.3.1.9 Exchangeable Bases

Exchangeable bases (Ca, Mg, Na, K) was extracted with 1 N ammonium acetate (1N $NH_4OAc$), buffered at pH 7. Na and K were read using the flame photometer while Ca and Mg were determined using the Atomic absorption spectrophotometer (AAS).

#### 3.3.1.10 Exchangeable Acidity

Exchangeable acidity was determined by extracting soils with 1 M KCl as reported by Juo (1979). The extract was titrated with 0.01 M NaOH solution until a permanent pink color end point.

#### 3.3.1.11 Effective Cation Exchange Capacity (ECEC)

The ECEC was calculated by the summation of Exchangeable bases and Exchangeable acidity.

#### 3.3.1.12 Base Saturation

Percentage base saturation was determined by the equation given below:

$$\%\ \text{Base Saturation} = \frac{\text{Total exchangeable basic cation}}{\text{ECEC}} \times 100$$

#### 3.3.1.13 Statistical Analysis

Data collected were statistically analyzed using the Genstat statistical package (12th edition).

### 3.3.2 ANALYSIS FOR PHYSICAL PROPERTIES

#### 3.3.2.1 Determination of Bulk Density, Porosity, and Saturated Hydraulic Conductivity.

Bulk density was measured with oven-dried soil core samples by the method of Grossman and Reinsch (2002) as:

........... Eq 1

Total porosity was measured with the method of Flintand Flint(2002) and calculated as:

........... Eq 2

Saturated hydraulic conductivity will be measured using the constant head soil core method (Reynolds *et al*., 2002) and calculated by rearranging Darcy's equation for constant head condition as below;

........... Eq 3

Where $V$ is the volume of water collected at steady state (cm$^3$), $L$ is the length of the soil core (cm), $A$ is the cross-sectional area (cm$^2$), $T$ is the time (h) and $H$ is the hydraulic head difference (cm).

### 3.3.2.2 Determination of Aggregate Stability and Water Holding Capacity

Aggregate stability will be measured by the mean weight diameter (MWD) of water stable aggregates using the wet-sieving method as described by Kemper and Rosenau (1986) modified by Nimmo and Perkins (2002). In this method, 50 g of 4.75 mm dry-sieved aggregates will be placed in the topmost of a nest of sieves: 2.0, 1.0, 0.5, and 0.25 mm. The aggregates will be pre-soaked by capillary in distilled water for 15 minutes and oscillated vertically in water 20 times, using 4 cm amplitude in a mechanical agitator. The remaining stable aggregates on each sieve will be oven-dried at 50$^o$C for 24 hours and weighed. The percentage of the stable aggregates on each sieve representing water stable aggregates (WSA) calculated as:

........... Eq 4

Where MR is the mass of resistant aggregates (g) and MT the total mass of wet-sieved soil (g). The mean weight diameter (MWD) of the water stable aggregates was calculated by the following equation (Hillel, 2004):

………… Eq 5

Where is the mean diameter of each size fraction, and wi is the weight of aggregates in that size range as a fraction of the dry weight of the sample analyzed. Water holding capacity of the soil was calculated as:

# CHAPTER FOUR

## 4.0 RESULT AND DISCUSSION

The results of the saturated hydraulic conductivity and its relationships to other soil parameters are discussed in this chapter according to the number of pedons (Mapping Units 1 and 2) in AGR 305 Farm Faculty of Agriculture University of Benin, Benin City.

**Table 1: table showing Ksat with other soil routine parameters**

| **Horizon depth** | **PH** | **T.N.** | **T.O.C** | **O.M.** | **AV.P** | **K** | **Ca** | **Mg** | **Na** | **CEC** | **ECEC** | **EA** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pedon1/2 | ⟶ | ⟶ | g/Kg | ⟶ | ⟶ | Mg/kg | ⟵ | ⟵ | ⟶ | Cmol/kg | ⟵ | ⟵ |
| 0-10 | 4.75 | 0.54 | 10.77 | 18.63 | 46.23 | 0.28 | 0.15 | 0.18 | 1.14 | 0.86 | 1.14 | 0.28 |
| 10-35 | 4.43 | 0.52 | 10.37 | 17.94 | 33.02 | 0.87 | 0.2 | 0.23 | 0.16 | 0.87 | 1.03 | 0.16 |
| 35-73 | 4.64 | 0.18 | 3.59 | 6.21 | 29.72 | 0.66 | 0.3 | 0.06 | 0.16 | 0.67 | 0.82 | 0.16 |
| 73-118 | 4.48 | 0.66 | 13.17 | 22.77 | 26.42 | 0.11 | 0.4 | 0.11 | 0.16 | 0.81 | 0.97 | 0.16 |
| 118-200 | 4.66 | 0.16 | 3.19 | 5.5 | 448.68 | 0.29 | 0.3 | 0.29 | 0.16 | 1.09 | 1.25 | 0.16 |
| | | | | | | | | | | | | |
| 0-20 | 4.77 | 0.11 | 2.79 | 3.79 | 47.88 | 0.77 | 0.3 | 0.09 | 0.08 | 0.77 | 0.85 | 0.08 |
| 20-45 | 4.63 | 0.08 | 1.59 | 2.76 | 75.94 | 0.53 | 0.2 | 0.57 | 0.16 | 0.53 | 0.69 | 0.16 |
| 45-70 | 4.68 | 0.16 | 3.19 | 5.52 | 79.25 | 0.62 | 0.2 | 0.53 | 0.16 | 0.62 | 0.78 | 0.16 |
| 70-110 | 4.67 | 0.13 | 2.59 | 4.49 | 231.13 | 0.51 | 0.2 | 0.04 | 0.24 | 0.51 | 0.75 | 0.24 |
| 110-195 | 4.88 | 0.22 | 4.39 | 7.59 | 110.61 | 0.60 | 0.20 | 0.10 | 1.28 | 0.60 | 1.88 | 1.28 |

**Table 2: Table showing Ksat and some routine parameters**

| Horizon Depth (cm) | Bulk Density (g/cm$^3$) | Texture (TC) | Saturated Hydraulic Conductivity (Cm/hr) | Porosity % | SAND g/kg | SILT g/kg | BS. | Aggregate Stability | Clay g/kg |
|---|---|---|---|---|---|---|---|---|---|
| 0-10 | 1.4 | LS | 22.7 | 47.1 | 0.25 | 0.23 | 75.33 | 0.56 | 0.86 |
| 10-35 | 1.47 | LS | 24.6 | 44.16 | 8.04 | 0.2 | 84.47 | 0.57 | 0.19 |
| 35-73 | 1.44 | LS | 22.1 | 45.66 | 9.32 | 0.1 | 80.54 | 0.69 | 0.21 |
| 73-118 | 1.41 | SL | 23.8 | 45.66 | 18.32 | 0.1 | 83.47 | 0.59 | 0.20 |
| 118-200 | 1.47 | SCL | 25.7 | 44.16 | 28.32 | 0.3 | 87.19 | 0.57 | 0.20 |
| | | | | | | | | | |
| 0-20 | 1.43 | LS | 22.7 | 46.12 | 11.32 | 0.2 | 90.5 | 0.63 | 0.17 |
| 20-45 | 1.44 | SCL | 25.4 | 45.6 | 24.02 | 0.1 | 76.92 | 0.61 | 0.18 |
| 45-70 | 1.41 | SCL | 22.8 | 43.1 | 23.32 | 0.2 | 79.59 | 0.63 | 0.17 |
| 70-110 | 1.47 | SCL | 25.1 | 44.6 | 23.04 | 0. 1 | 68.03 | 0.68 | 0.17 |
| 110-195 | 1.4 | SCL | 21.6 | 47.7 | 26.82 | 0.1 | 32.01 | 0.66 | 0.20 |

**Table 3: correlation table between routine parameters and Ksat in mapping unit 1**

| | Ksat(cm/hr) | p | Mg | K | CEC | BS | Sand | Silt | clay | Bulk Density | Total Porosity | Aggregate Stability | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ksat | 1 | 0.736 | 0.852 | 0.724 | 0.879 | 0.831 | -0.766 | -0.552 | 0.726 | 0.66 | -0.795 | -0.614 | 0.698 |
| P value | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |

Table 3 shows the correlation result for Pedon 1(Mapping Unit1). Correlation of saturated hydraulic conductivity with routine soil chemical and physical soil properties. It was observed that P, Mg, K, ECEC, base saturation , clay, bulk density, correlated positively while sand, silt total porosity and aggregate stability correlated negatively with Ksat. However, Mg (0.852), base saturation (0.831) had higher correlation with Ksat, which means as Ksat increases these parameters will also increase as water is being conducted when all the pores are filled with water.

**Table 4: Ksat vs P in Pedon 1**

| $K_{SAT}$ Cm/hr | P Mg/kg |
|---|---|
| 22.7 | 46.23 |
| 24.6 | 33.02 |
| 22.1 | 29.72 |
| 23.8 | 26.42 |
| 25.7 | 488.68 |

Table 4 shows that the significant soil parameter phosphorus (p) ranging from (46.23- 488.68) was used to predict the Ksat values (from 22.7-25.7).

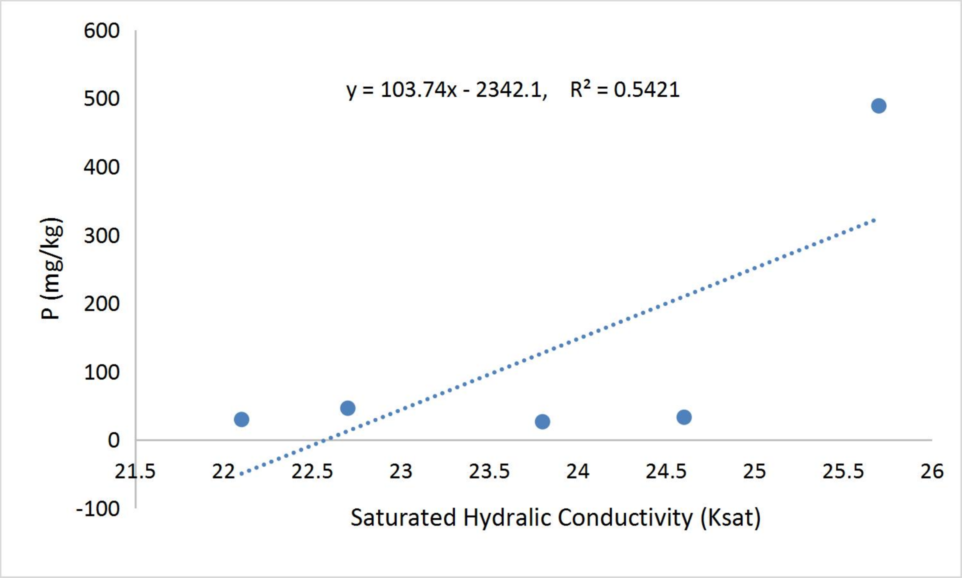

Fig1: Regression graph of Ksat vs. P in Pedon 1

**Table 5: Relationship between Ksat and P**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION CO-EFFICIENT |
|---|---|---|
| P | Y= 23.12 + 0.005X | 0.736 |

From the graph above, Phosphorus correlated positively with Ksat. This shows that P has a direct relationship with Ksat, therefore as aggregate stability increases Ksat values will also be influenced positively. This could be as a result of the role phosphorus plays in improving soil aggregate. Phosphorus plays an indirect role by improving root development and microbial growth which could have resulted in a more stable soil aggregate structure according to the observation made by (Harsh *et al*., 2006, Ohana *et al*., 2018).

**Table 6: Ksat vs Magnesium**

| KSAT<br>Cm/hr | Mg<br>Mg/kg |
|---|---|
| 22.7 | 0.18 |
| 24.6 | 0.23 |
| 22.1 | 0.06 |
| 23.8 | 0.11 |
| 25.7 | 0.29 |

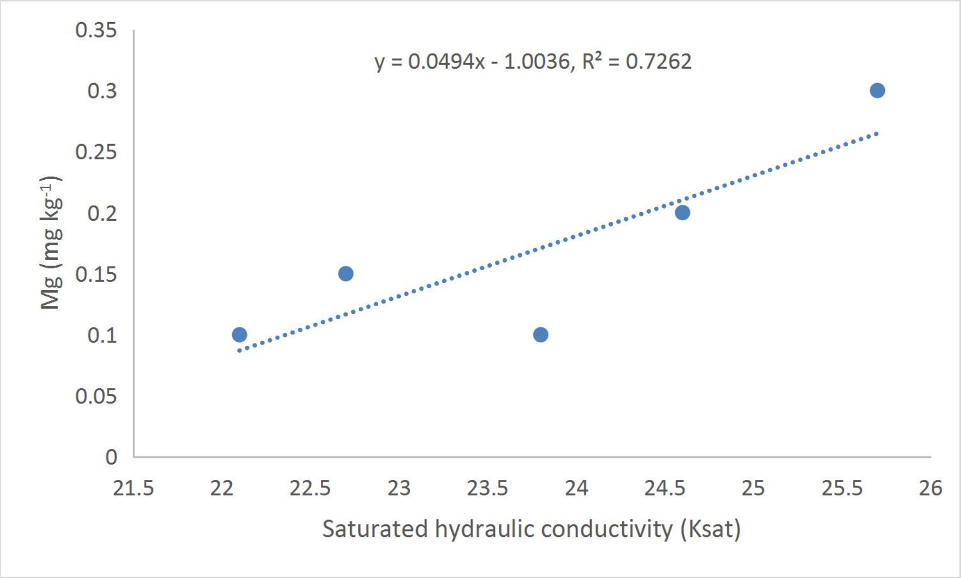

Fig 2: Regression graph of Ksat vs. Mg in Pedon 1

**Table 7: Relationship between Ksat and Mg**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION CO-EFFICIENT |
|---|---|---|
| Mg | Y= 21.27 + 14.71X | 0.852 |

The graph showed a positive correlation between Ksat and Mg and can be used to determine saturated hydraulic conductivity in areas having same soil characteristics.

An increase in magnesium level of the soil will result in an increase in saturated hydraulic conductivity.(Ohana *et al.*, 2018). and this could be related with the increase in base saturation which brings about an increase in stable aggregate.

**Table 8: Ksat vs Potassium (K)**

| $K_{SAT}$ Cm/hr | K Mg/kg |
|---|---|
| 22.7 | 0.23 |
| 24.6 | 0.23 |
| 22.1 | 0.23 |
| 23.8 | 0.06 |
| 25.7 | 0.11 |

Table 8. shows that K which is a significant parameter ranging from (0.06-1.0.23) was use for the prediction of Ksat value (ranging from 22.7-25.7).

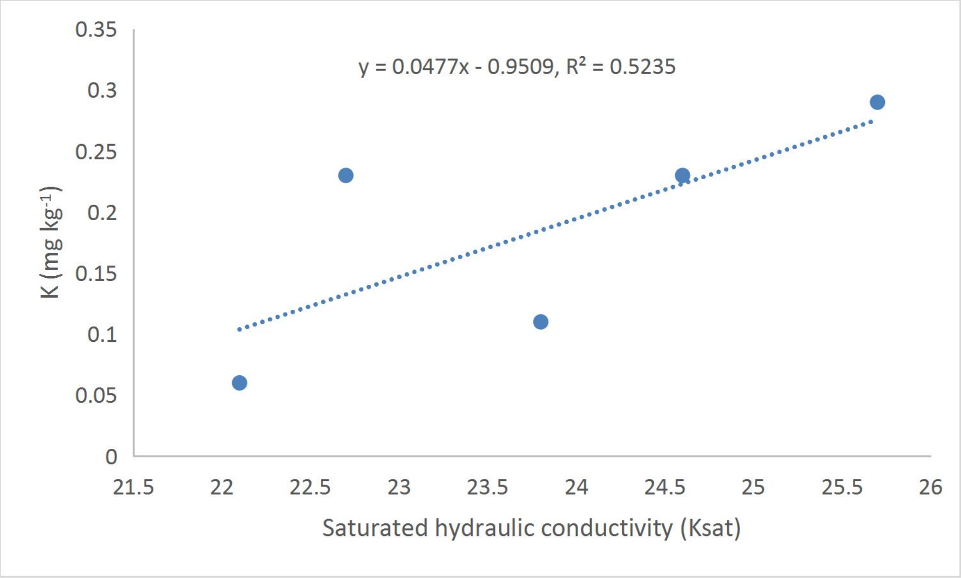

Fig3: Regression graph of Ksat vs. k in Pedon 1

**Table 9: Relationship between Ksat and potassium (K)**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION CO-EFFICIENT |
|---|---|---|
| K | Y= 21.76+ 10.96X | 0.724 |

The relationship between potassium (K) and Ksat have a postive correlation, and it can be used to determine the Ksat of soil in areas having same soil characteristics. An increase in potassium is due to an increase in the CEC and base saturation of the soil with result in more water retention and flow through soil pores (Renegasamy et al.,1998).

**Table 10: Ksat vs CEC**

| $K_{SAT}$ | CEC |
|---|---|
| Cm/hr | Cmol/kg |
| 22.7 | 0.86 |
| 24.6 | 0.87 |
| 22.1 | 0.66 |
| 23.8 | 0.81 |
| 25.7 | 1.09 |

Table 10 shows that CEC which is a significant parameter ranging from (0.81-1.09) was use for the prediction of Ksat value (ranging from 22.7-25.7).

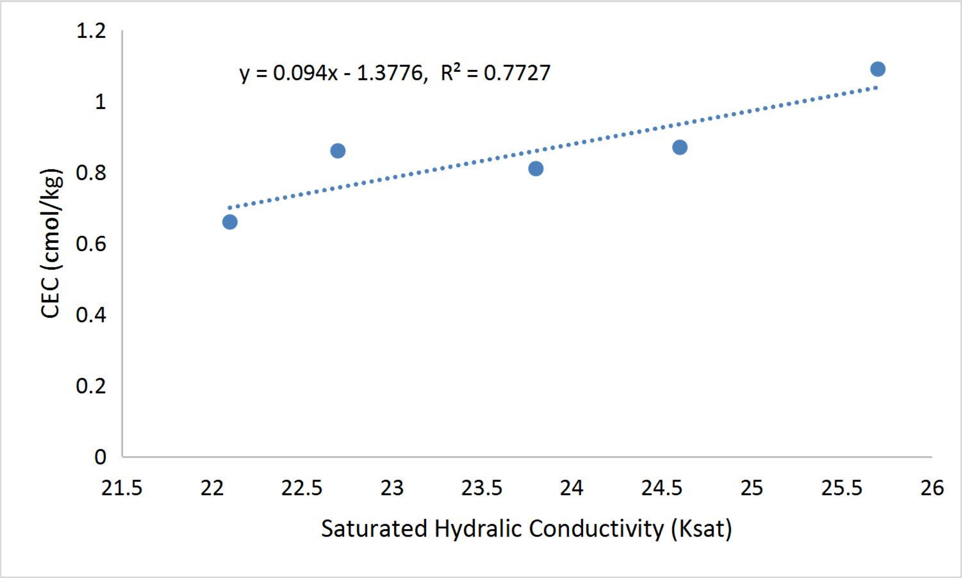

Fig 4: Regression graph of Ksat vs CEC in Pedon 1

**Table 11: Relationship between Ksat and CEC**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION CO-EFFICIENT |
|---|---|---|
| CEC | $Y = 16.72 + 8.21X$ | 0.879 |

The graph showed that CEC has a positive relationship with Ksat in soils in Pedon 1 and can be used to predict Ksat in that area. The correlation was a positively significant for CEC at ($P < 0.05$) level of probability. Indicating that an increase in CEC in the soil will result in an increase in ksat values. However, CEC can indirectly influence Ksat through its impact on soil structure and aggregation. CEC determined by the amount of clay content present in the soil. Soils with high CEC due to high clay content or high sodium levels can have lower Ksat due to the dispersive effects of sodium on soil structure (Renegasamy et al.,1998).

**Table 12: Ksat vs Base saturation**

| $K_{SAT}$ Cm/hr | BS Cmol/kg |
|---|---|
| 22.7 | 75.34 |
| 24.6 | 84.47 |
| 22.1 | 80.54 |
| 23.8 | 83.47 |
| 25.7 | 87.2 |

Table 12 shows that BS which is a significant parameter ranging from (75.34-87.2) was used for the prediction of Ksat value (ranging from 22.7-25.7).

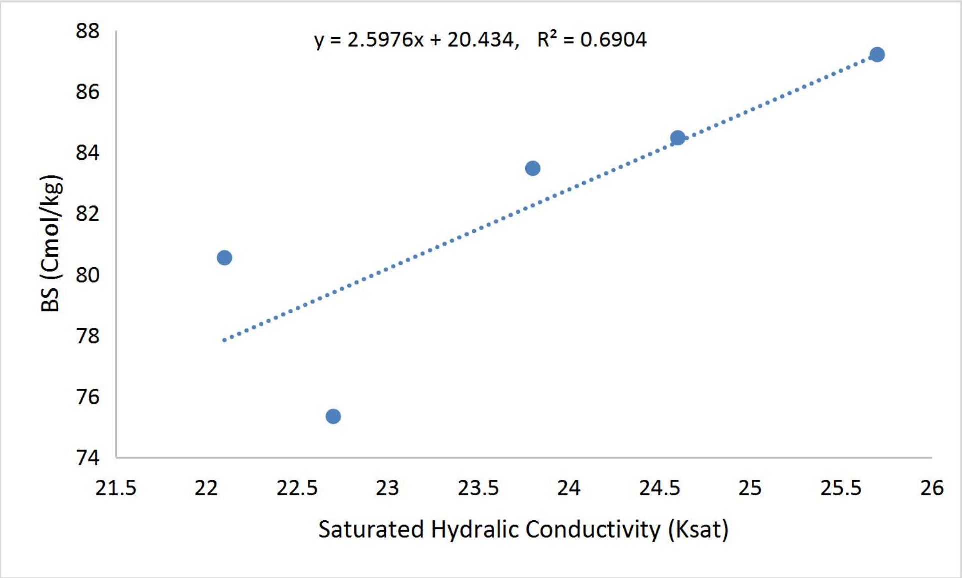

Fig 5:Regression graph of Ksat vs BS in Pedon 1

**Table 13: Relationship between Ksat and Base saturation (BS)**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION CO-EFFICIENT |
|---|---|---|
| BS | Y=1.92+0.26X | 0.831 |

The graph on Base saturation shows there is a positive correlation with Ksat in Pedon 1 and can be used to predict Ksat in this area and any other area having similar soil properties. BS represents the percentage of cation exchange sites in the soil occupied by positively charged cations (bases) like calcium (Ca++), magnesium (Mg++), and potassium (K+), (Brady et al., 2008). As reported by Tisdale *et al,* (1995) a higher base saturation indicates dominance of these bases over acidic cations like hydrogen (H+) and (AL3+). Soils with higher base saturation are often associated with a well-structured soil with good aggregation.

**Table 14: Ksat vs Clay**

| $K_{SAT}$<br>Cm/hr | Clay<br>g/kg |
|---|---|
| 22.7 | 7.04 |
| 24.6 | 8.04 |
| 22.1 | 9.32 |
| 23.8 | 18.32 |
| 25.7 | 28.32 |

Table 14 shows that clay which is a significant parameter ranging from (7.04-28.32) was used for the prediction of Ksat value (ranging from 22.7-25.7).

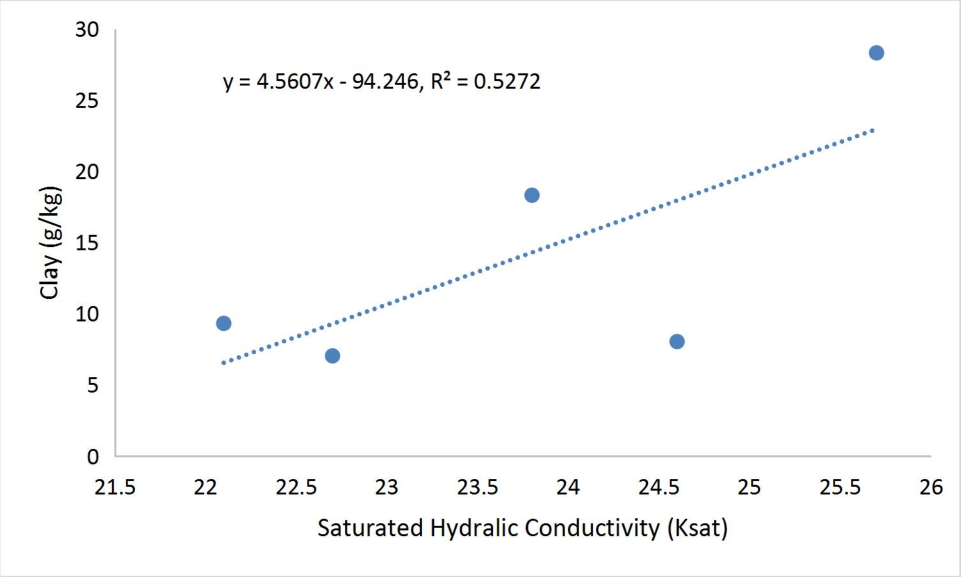

Fig 1.6::Regression graph of Ksat vs clay in Pedon 1

**Table 15: Relationship between Ksat and Clay**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Clay | $Y= 22.13 + 0.12X$ | 0.726 |

Clay correlated positively with saturated hydraulic conductivity as seen in table b. This means that as the clay particles increases saturated hydraulic conductivity is expected increase. Although, this is not the norm as saturated hydraulic conductivity is inversely related to clay content (Jury *et al*., 2004). However, there might have been a change in the structure of the soil (openings within the soil),textural differences observed at the overlying or underlying soil layer, or effect of agricultural management practices over the years could have brought about this alterations being observed in this Pedon .which would have led to water infiltrating the soil quickly despite the high clay content. The relationship between clay and Ksat is negatively correlated , which is means that as clay content increases Ksat value would decrease (Rawls *et al*., 1982).

**Table 16: Ksat vs Bulk Density**

| $K_{SAT}$ Cm/hr | Bulk Density g/cm3 |
|---|---|
| 22.7 | 1.4 |
| 24.6 | 1.47 |
| 22.1 | 1.44 |
| 23.8 | 1.41 |
| 25.7 | 1.47 |

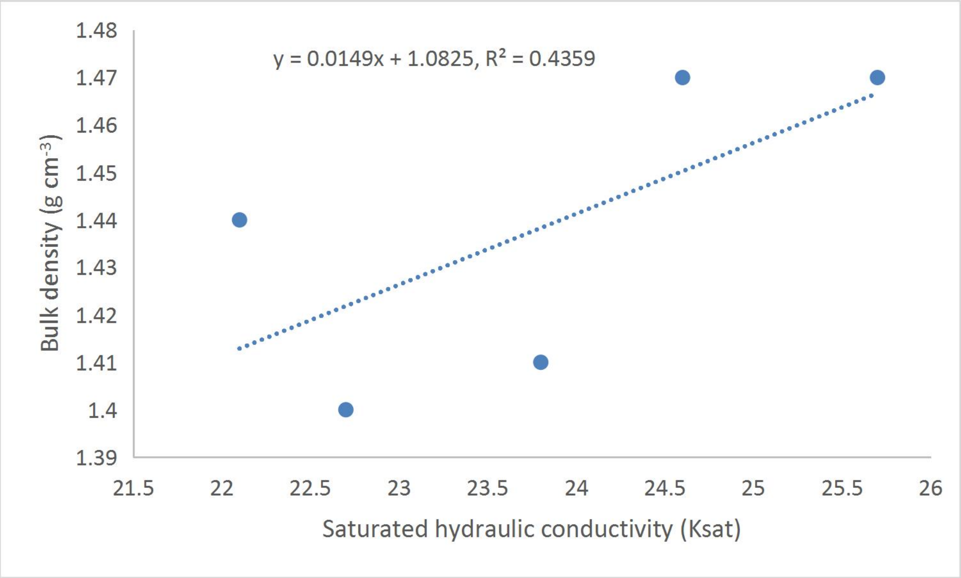

Fig 7: Regression graph of Ksat vs. Bulk density in Pedon 1

**Table 17: Relationship between Ksat and Bulk density**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Bulk Density | Y= -18.15 + 29.15X | 0.660 |

From the result it can be seen that Bulk density has high significance with Ksat and can be used to predict the Ksat in areas with same soil characteristics.

In the graph, soils with high bulk density tend to have low ksat value,  bulk density increases with compaction and soils with high bulk density have smaller pore spaces, restricting water flow and leading to lower Ksat values. (Ayatt *et a*l.,2010).

**Table 18: Ksat vs Sand**

| $K_{SAT}$<br>Cm/hr | Sand<br>g/kg |
|---|---|
| 22.7 | 86.96 |
| 24.6 | 84.96 |
| 22.1 | 84.68 |
| 23.8 | 78.68 |
| 25.7 | 69.68 |

Table 18 shows that sand which is a significant parameter ranging from (69.68-86.96) was used for the prediction of Ksat value (ranging from 22.7-25.7).

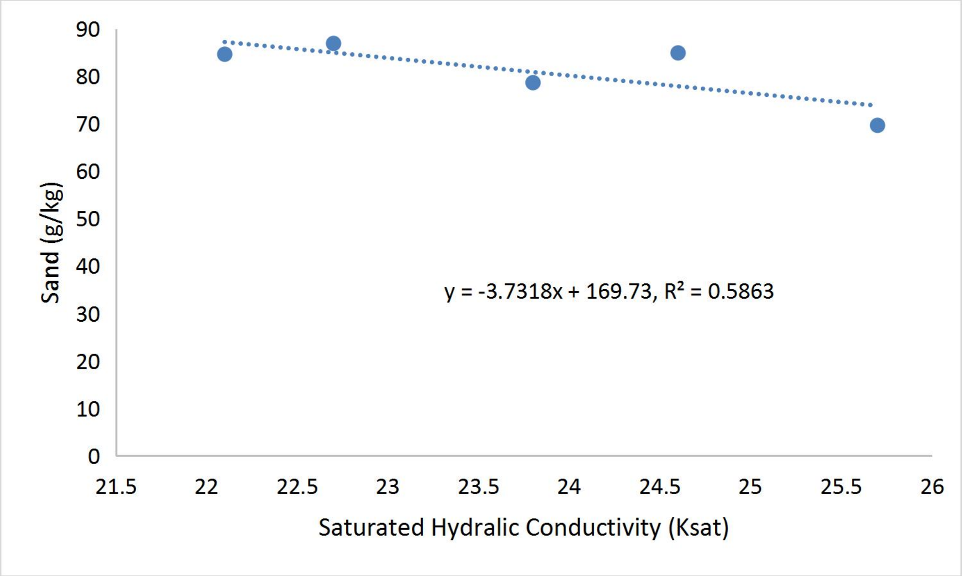

Fig 8: Regression graph of Ksat vs sand in Pedon 1.

**Table 19: Relationship between Ksat and Sand**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Sand. | Y= 36.5 + (-0.15)X | -0.766 |

Saturated hydraulic conductivity correlated negatively with sand. Although, the expectation is supposed to be a positive correlation whereby due to preponderance of macropores in the sand fraction, water is supposed to be conducted rapidly or ksat is expected to be high. However, as observed in the case of the relationship with clay the reason could be similar. As reported by (Brady *et al.,* 2008), Soils with higher clay contents generally have lower saturated hydraulic conductivity than sandy soils because of their smaller pore sizes and restricted pore continuity. Furthermore, compaction or the high bulk density could have influenced the low Ksat value. Compaction forces sand particles closer together, reducing pore size and connectivity, hindering water flow and lowering Ksat (Brady *et al.,* 2008). More so, the arrangement of sand particles can influence pore connectivity. A loose, disorganized sandy soil might have large pores between individual sand particles, but these pores might not be well connected (Brady *et al.,* 2008). This can restrict water flow and lead to a lower Ksat despite the high sand content.

**Table 20: Ksat vs Total porosity**

| $K_{SAT}$ Cm/hr | Total porosity % |
|---|---|
| 22.7 | 1.4 |
| 24.6 | 1.47 |
| 22.1 | 1.44 |
| 23.8 | 1.41 |
| 25.7 | 1.47 |

Table 20 shows that Total porosity which is a significant parameter ranging from (1.4-1.47) was used for the prediction of Ksat value (ranging from 22.7-25.7).

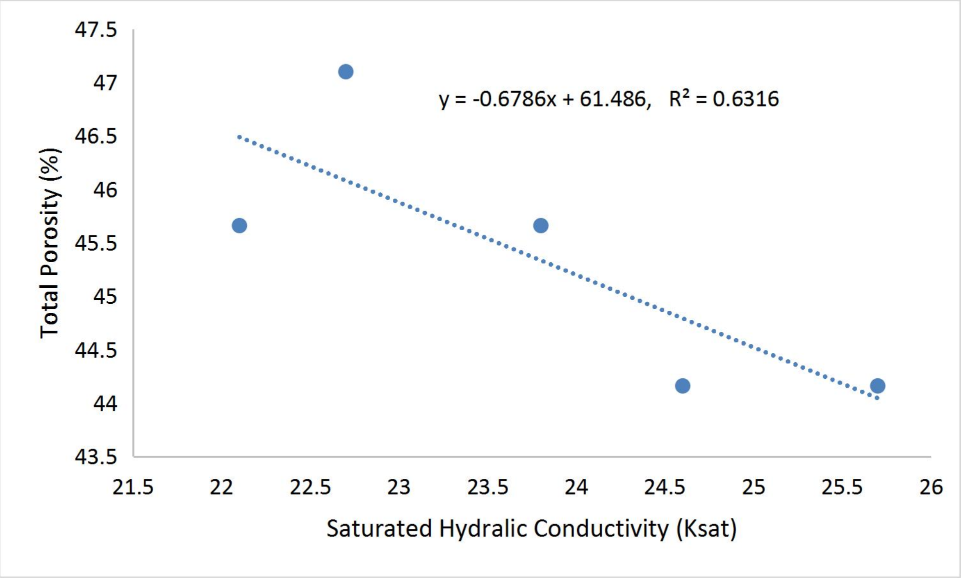

Fig 9: Regression graph of Ksat vs Total porosity in Pedon 1.

**Table 21: Relationship between Ksat and Total porosity**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Total Porosity | Y= 65.98 + (-0.93)X | -0.795 |

Total porosity correlated negatively with saturated hydraulic conductivity, which indicates that a decrease in porosity will also result in a decrease in Ksat. However a research carried out by (Ofem et al., 2021) shows, that other soil properties have a pronounced influence on soil porosity. The negative correlation with Ksat can be as a result of the positive correlation bulk density have with Ksat, the increase in bulk density affected the rate at which water flow and saturate the pores spaces of the soil .

**Table 22: Ksat vs Aggregate Stability**

| $K_{SAT}$ Cm/hr | Aggregate stability Mg/kg |
|---|---|
| 22.7 | 0.18 |
| 24.6 | 0.23 |
| 22.1 | 0.06 |
| 23.8 | 0.11 |
| 25.7 | 0.29 |

Table 22 shows that aggregate stability which is a significant parameter ranging from (0.06-0.29) was used for the prediction of Ksat value (ranging from 22.7-25.7).

**Table 4.13: Relationship between Ksat and Aggregate Stability**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Aggregate Stability | Y= 33.63 + (-16.52)X | -0.614 |

The Relationship between saturated hydraulic conductivity and aggregate stability in this analysis has been shown to be negative. That is aggregate stability correlated negatively with Ksat, implying that a decrease in aggregate stability will result in a decrease in saturated hydraulic conductivity. This could be as a reason of the increased clay content and bulk density which could disrupt the free flow of water down the soil profile. Aggregate stability is dependent on soil properties, water flow and land use type. (Hu *et al.,* 2005).

**Table 23: Correlation table between routine parameters and Ksat in pedon 2**

| | pH | O.C | T.N | O.M | CEC | EA | ECEC | Bulk Density |
|---|---|---|---|---|---|---|---|---|
| Ksat | -0.858 | -0.884 | -0.771 | -0.77 | -0.631 | -0.588 | -0.721 | 0.851 |
| P value | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |

**Table 24: Ksat vs PH in Pedon 2**

| $K_{SAT}$ Cm/hr | pH |
|---|---|
| 22.7 | 4.77 |
| 25.4 | 4.63 |
| 22.8 | 4.68 |
| 25.1 | 4.67 |
| 21.6 | 4.88 |

The table above shows that the soil parameter PH (ranging from 4.63-4.88) was used in the prediction of Ksat values (from 21.6-25.4)

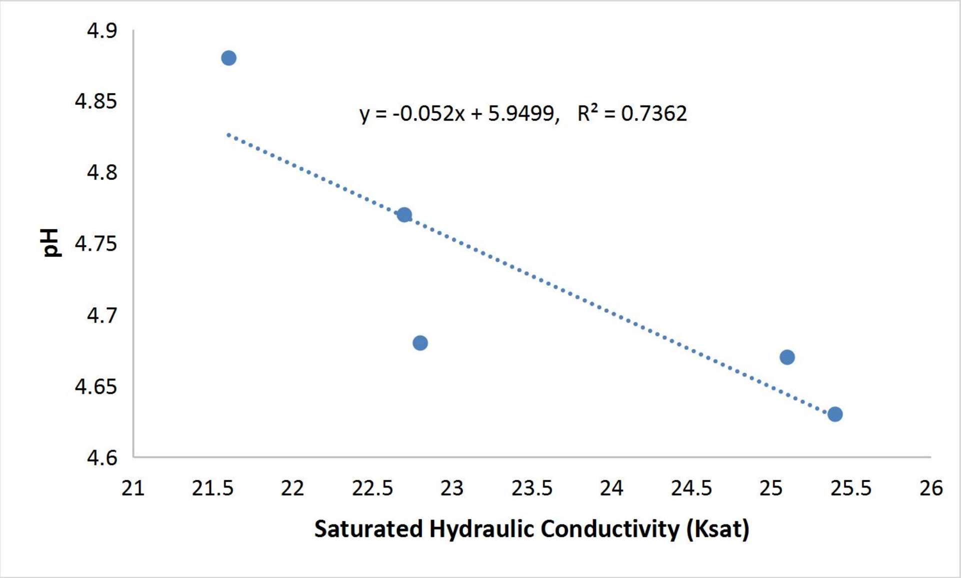

Fig 10: Regression graph of Ksat vs PH in Pedon

**Table 25: Relationship between Ksat and PH**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| PH | Y= -0.052x+ 5.9499 | -0.858 |

From the graph, it showed that pH had a negative correlation ksat and this implies that a decrease in pH will result in an increase in ksat. From the interpretation of the result it could be said that a decrease pH will result in a low pH values, which means the soil will be highly acidic, and this can cause clay dispersion and pore clogging, there by reducing Ksat.

**Table 26 Ksat vs OC in Pedon 2**

| $K_{SAT}$ Cm/hr | OC g/kg |
|---|---|
| 22.7 | 2.79 |
| 25.4 | 1.59 |
| 22.8 | 3.19 |
| 25.1 | 2.59 |
| 21.6 | 4.39 |

Table 26 shows that organic carbon (1.59-4.39) was involved in the prediction of Ksat value (21.6-25.6).

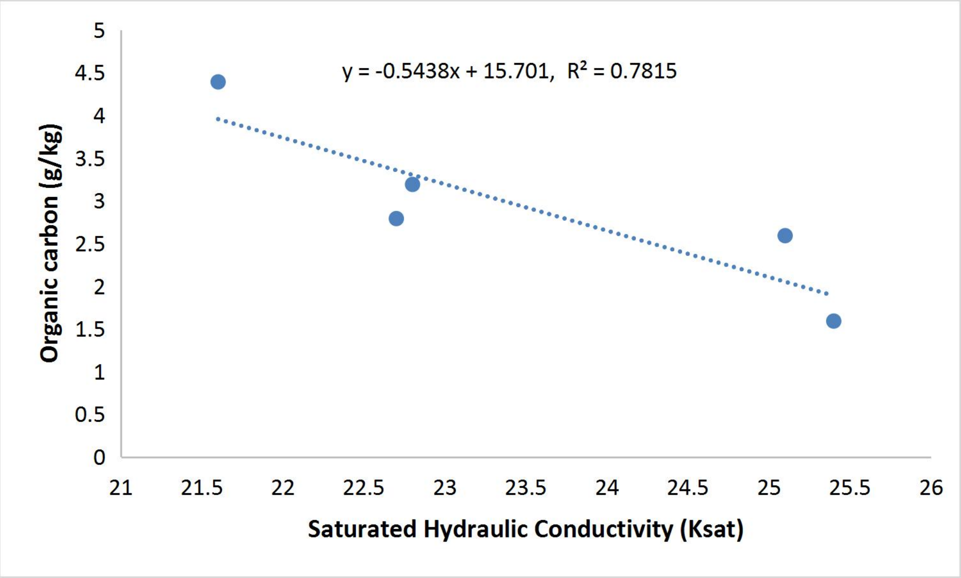

Fig 10: Regression graph of Ksat vs. Organic carbon in Pedon 2

**Table 27: Relationship between Ksat and OC**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Organic Carbon | Y= 27.70 + (-1.44) X | -0.884 |

The graph above shows O.C. having a highly negative correlation with Ksat and it can be used to determine the Ksat of this area. There is a complex relationship that exist between Ksat and organic carbon, due to the fact that a reduction in organic matter will bring about an unstable soil aggregation resulting in a negative impact on saturated hydraulic conductivity. The relationship between Ksat and organic carbon could be dependent on a positive and negative impact as seen in the case of soils high C:N ratio promoting soil aggregate stability and potentially increasing Ksat (yasen *et al.,* 2022). The opposite effect would occur for soils with low C:N ratio.

**Table 28 Ksat vs Total nitrogen**

| KSAT | TN |
|---|---|

| Cm/hr | g/kg |
|---|---|
| 22.7 | 0.11 |
| 25.4 | 0.08 |
| 22.8 | 0.16 |
| 25.1 | 0.13 |
| 21.6 | 0.22 |

The table shows that total nitrogen (0.08-0.22) was involved in the prediction of Ksat value (21.6-25.4).

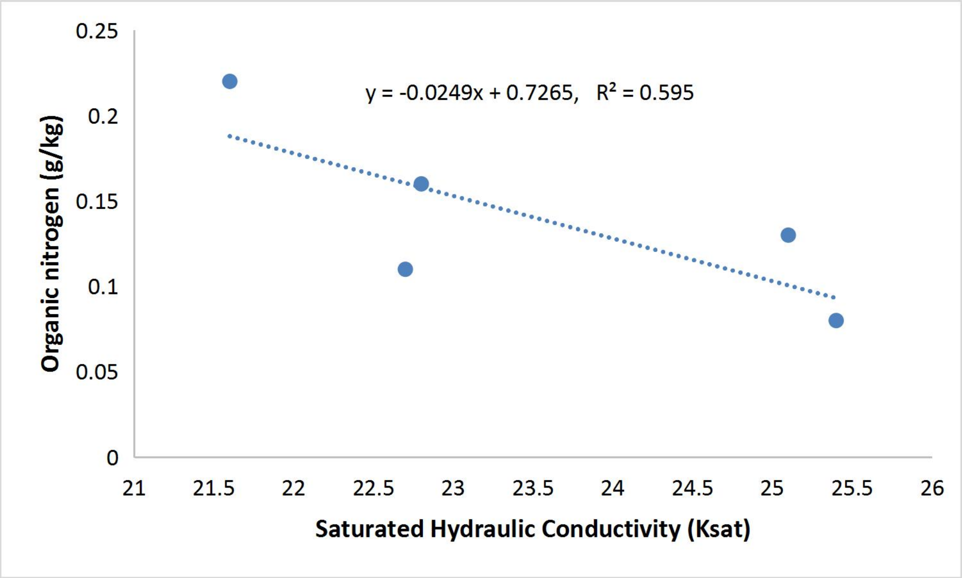

Fig11: Regression graph of Ksat vs Total nitrogen in Pedon 2

**Table 29: Relationship between Ksat and Total nitrogen**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| T. N | Y= 26.86 + (-23.85) X | -0.771 |

From the results, it can be seen that TN has a negative correlation with Ksat and is used to predict Ksat in the area. The relationship between Ksat and nitrogen showed a negative correlation, a decrease in nitrogen brought about an increase in Ksat. However, there is no direct relationship between Ksat and nitrogen. More so, an increased soil nitrogen will improve microbial activities which could lead to an improvement in soil aggregate resulting in a stable structure modifying saturated hydraulic conductivity. (Ohana *et al.,* 2018) Too much nitrogen in the soil can lead to clay dispersion which can result in formation of micro pores there by reducing Ksat.

**Table 30: Ksat vs organic matter**

| $K_{SAT}$ Cm/hr | O.M g/kg |
|---|---|
| 22.7 | 3.79 |
| 25.4 | 2.76 |
| 22.8 | 5.52 |
| 25.1 | 4.49 |
| 21.6 | 7.59 |

The table shows that Organic matter (ranging from 2.76-7.59) was involved in the prediction of Ksat value (21.6-25.4).

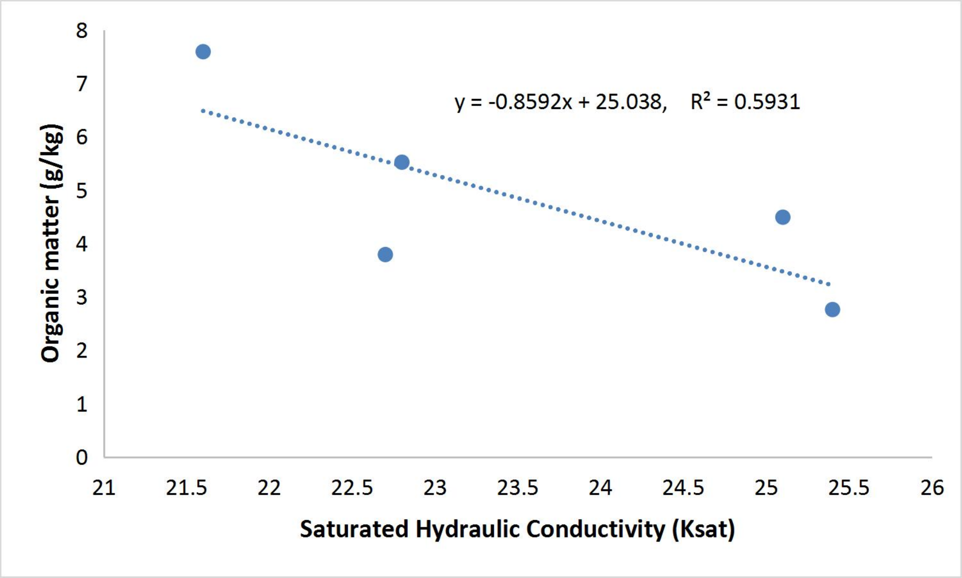

Fig 12: Regression graph of Ksat vs Organic matter in Pedon 2

**Table 31: Relationship between Ksat and OM**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Organic matter | Y= 26.85+ (-0.69) X | -0.770 |

From the results, it can be seen that OM has a negative correlation with Ksat and is used to predict Ksat in the area. Organic matter also correlated negatively with Ksat, this could be as a result of the increase in bulk density. An increase bulk density brings about a decrease in the water holding capacity, aggregate stability, saturated hydraulic conductivity and permeability as observed by (Zebarth *et al.,*1999).

**Table 32: Ksat vs CEC**

| $K_{SAT}$ Cm/hr | CEC g/kg |
|---|---|
| 22.7 | 0.77 |
| 25.4 | 0.53 |
| 22.8 | 0.62 |
| 25.1 | 0.51 |
| 21.6 | 0.60 |

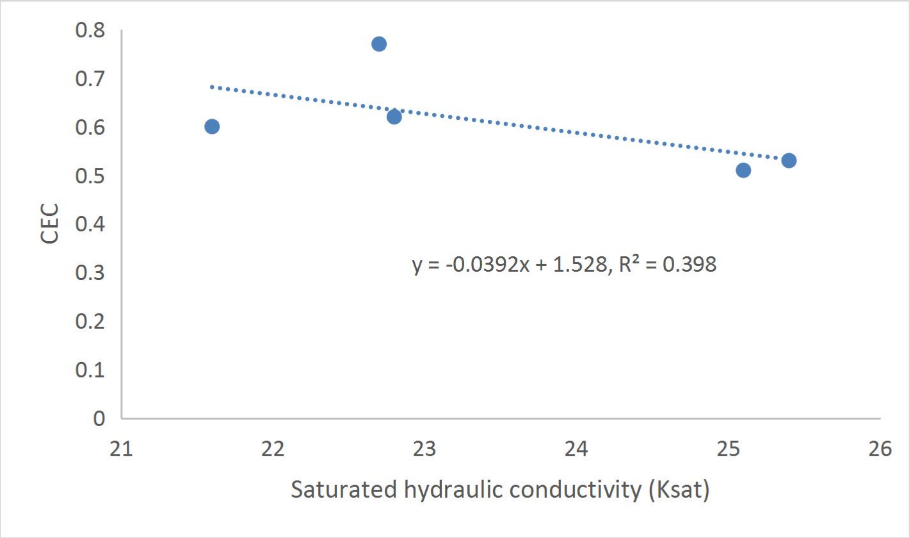

Fig13: Regression graph of Ksat vs. CEC in Pedon 1

**Table 33: Relationship between Ksat and CEC**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| CEC. | Y= 29.67+ (-10.15) X | -0.631 |

The graph showed that CEC correlated negatively with Ksat and could be used to determine Ksat in areas for soils having similar characteristics.This means that as CEC decrease, Ksat will increase. However observation by Lal and shukla, (2004)., said that CEC and saturated hydraulic conductivity are not directly related, but can be influenced by similar soil properties, such as texture and structure..

**Table 34 Ksat vs EA**

| KSAT Cm/hr | EA g/kg |
|---|---|
| 22.7 | 0.08 |
| 25.4 | 0.16 |
| 22.8 | 0.16 |
| 25.1 | 0.24 |
| 21.6 | 1.28 |

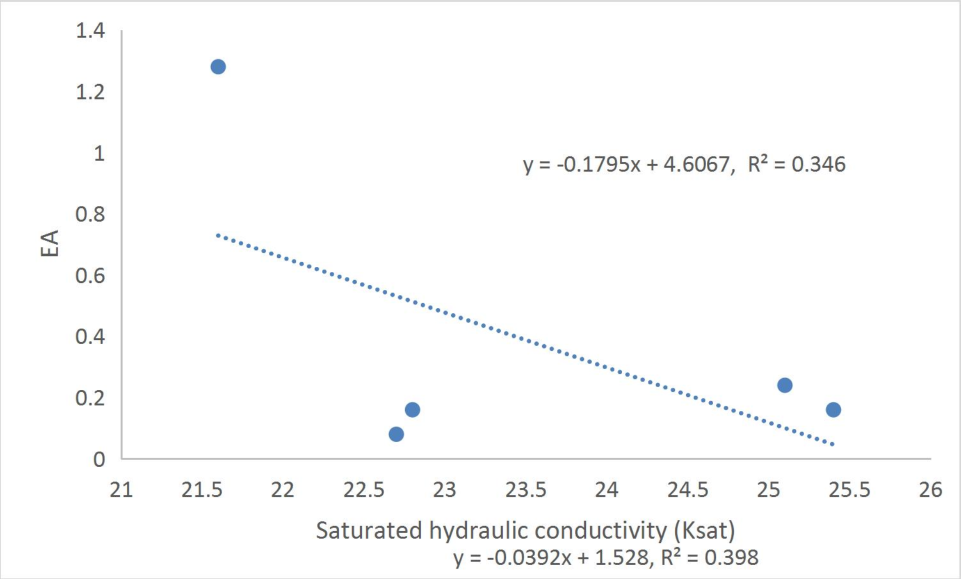

**Fig 14: Regression graph of Ksat vs. EA in Pedon 1**

**Table 35: Relationship between Ksat and EA**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| EA | Y= 24.25+ (-1.92) X | -0.588 |

**Table 36: Ksat vs ECEC**

| $K_{SAT}$<br>Cm/hr | ECEC<br>g/kg |
|---|---|
| 22.7 | 0.85 |
| 25.4 | 0.69 |
| 22.8 | 0.78 |
| 25.1 | 0.75 |
| 21.6 | 1.88 |

The table shows that ECEC (ranging from 0.69-1.88) was involved in the prediction of Ksat value (21.6-25.4).

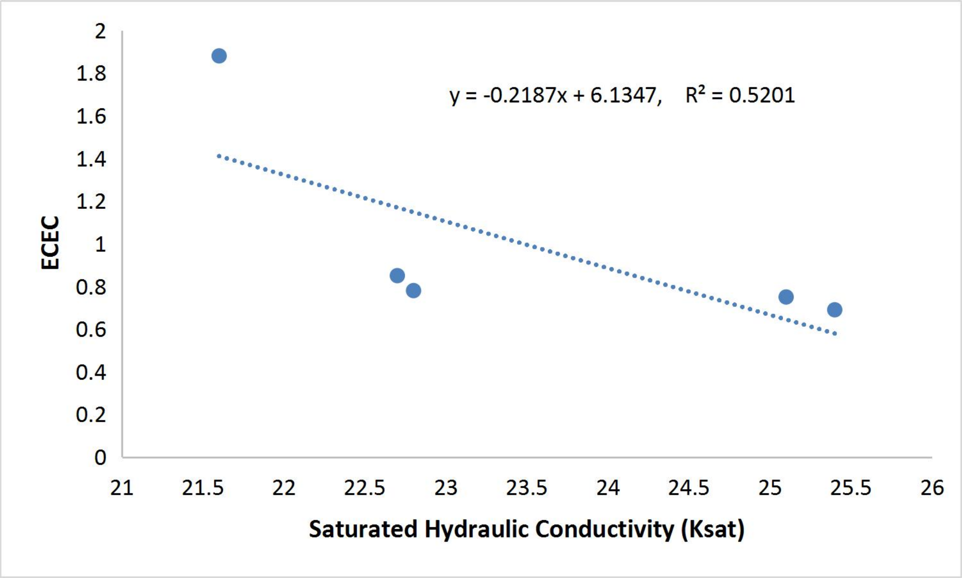

**Fig 15: Regression graph of Ksat vs ECEC in Pedon 2**

**Table 37: Relationship between Ksat and ECEC**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| ECEC | Y= 25.87+ (-2.37) X | -0.721 |

From the results, it can be seen that ECEC has a negative correlation with Ksat can be used to predict Ksat in the areas with similar soil characteristics.

ECEC refers to the ability of the soil to hold unto positively charged cations, which tends to correlate negatively with saturated hydraulic conductivity (Lal and shukla, 2004). ECEC has an indirect effect on saturated hydraulic conductivity. It is modified by soil structure and aggregate stability which in turn affect saturated hydraulic conductivity.

**Table 38: Ksat vs Bulk density**

| $K_{SAT}$ Cm/hr | Bulk density (Kg/m3) |
|---|---|
| 22.7 | 2.79 |
| 25.4 | 1.59 |
| 22.8 | 3.19 |
| 25.1 | 2.59 |
| 21.6 | 4.39 |

The table shows that Bulk density (ranging from 1.4-1.47) was involved in the prediction of Ksat value (21.6-25.4).

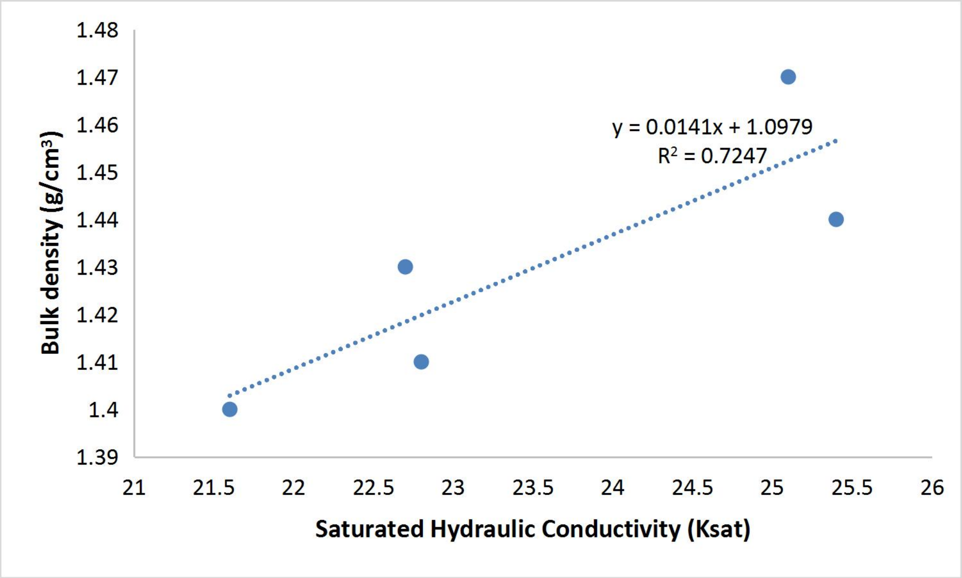

**Fig16: Regression graph of Ksat vs Bulk density in Pedon 2.**

**Table 39: Relationship between Ksat and bulk density**

| SOIL PROPERTY | REGRESSION EQUATION | CORRELATION EQUATION |
|---|---|---|
| Bulk Density | Y= (-49.88) + (51.33) X | 0.851 |

From the result it can be seen that Bulk density has high significance with Ksat and can be used to predict the Ksat in that areain the graph, soils with high bulk density tend to have low ksat value, bulk density increases with compaction and soils with high bulk density have smaller pore spaces, restricting water flow and leading to lower Ksat values. (Ayatt *et a*l., 2010).

# CHAPTER FIVE

## 5.0 CONCLUSION

Different soil routine parameters were used to account for the saturated hydraulic conductivity of the soil in the two different mapping unit (pedon 1 and 2). Result obtained from the laboratory showed that Ksat correlated with different parameters for each pedon. For mapping unit one (pedon 1) it correlated with phosphorus, magnesium, potassium,Total porosity, CEC,ECEC, base saturation,clay and sand, aggregate stability and bulk density; while for mapping unit 2 (pedon 2), it correlated with Ph, organic carbon (O.C), Total nitrogen (T.N), organic matter (O.M), ECEC, Exchangeable acidity(EA) and bulk density.

Therefore, with the corresponding prediction equations for each mapping unit and significant parameters, this study has made it relatively easy to determine the saturated hydraulic conductivity of soils anywhere with the same characteristics encountered.

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