

**PERFORMANCE EVALUATION OF SELECTED INDICES OF SOIL  
ERODIBILITY FOR IMO STATE SOILS**

**BY**

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**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL  
FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI**

**IN PARTIAL FUFILMENT OF THE REQUIREMENTS FOR THE  
AWARD OF THE DEGREE (MASTER OF ENGINEERING), M. Eng. IN  
SOIL AND WATER ENGINEERING**


**MARCH, 2023**


## CERTIFICATION


This is to certify that this research work “**Performance Evaluation of Selected Indices of Soil Erodibility for Imo State Soils**” was carried out by **NWACHUKWU, PASCHAL IFEANYI** (REG. NO. **20134872508**) in partial fulfilment of the requirements for the award of Degree of Master of Engineering in Soil and Water Engineering in the Department of Agricultural and Bioresources Engineering of the Federal University of Technology, Owerri, Imo State Nigeria.

  
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## **DEDICATION**

This work is dedicated to Chukwu Okike Abiama the God of possibilities. To my Late parents Mr. and Mrs. Alphonsus Sunday Nwachukwu.

To my wife Esther Nwamaka and wonderful son Itochukwu Mac Tetley.

To my twin sister and hubby Mr. and Mrs. Polycarp Moki and to my nephew Prince Chimeremeze Devon Moki and little niece princess Omasirichi Moki.

## ACKNOWLEDGEMENTS

My Profound appreciation goes to my Supervisor(s) Very Rev. Engr. Prof. C.N. Madubuike (Principal Supervisor) and Late Engr. Prof. J.N Maduako (Co-Supervisor) for their overwhelming attention, guidance and patience all through the period this work lasted, I am immensely grateful to them.

To all the Lecturers and staff of Agricultural and Bio-Resources Engineering Federal University of technology Owerri, I say thank you.

I want to humbly salute in a very special way the following; Engr. Prof. C.D. Okereke, Engr. Prof. G. Nwandikom, Engr. Prof. N.A.A. Okereke, Engr. Prof. Sabbas Asoegwu, Engr. Dr. Celestine Egwuonwu, Engr. Dr. K. O. Chilakpu, you all shaped me. I will not fail to remember Engr. Dr. N.R Nwakuba, Engr. Dr. Okey Okoroafor, Engr. Maxwell Chikwue my bosses.

My appreciation goes to the present Head of Department Engr. Dr. N. C. Ezeanya.

I also want to extend my appreciation to Engr. Dr. Ogechi Ikpemo for his advice and instructions that led me through the challenging times.

A big thanks to Engr. Dr. Osita Collins Chukwuezie and Engr. Kodak Emerson for their input in the success story of this work.

To my colleagues in Agricultural and Bio-Environmental Engineering Imo State Polytechnic Umuagwo-Ohaji shout out to you all.

I want to thank Technologist Inyama and Columbus for touring with me during the period of my field works and experiments.

I will not fail to mention Miss Hope Ihechi who edited my work.

Lastly to my fans, friends and well-wishers including foes I want to say that you all contributed positively in one way or the other to the success of this work God bless you abundantly.

## **TABLE OF CONTENTS**

Title page	i
Certification	ii
Dedication	iii
Acknowledgement	iv
Abstract	v
Table of Contents	vi
List of Tables	ix
List of Figures	xi
List of Plates	xii

### **CHAPTER ONE**

#### **INTRODUCTION**

1.1 Background of Study	1
1.2 Statement of Problem	4
1.3 Objectives of the Research	8
1.4 Justification	8
1.5 Scope of the Work	9

### **CHAPTER TWO**

#### **LITERATURE REVIEW**

2.1 Preview	10
2.2 Erosion Problem in Southeastern Nigeria	15

2.3 Ecological Factors and Soil Erosion	16
2.4 Land Use and Soil Erosion	17
2.5 Methods for determining indices of Soil Erodibility	18
2.5.1 Static Laboratory Tests	18
2.5.2 Static Field Tests	20
2.5.3 Dynamic Laboratory Test	20
2.5.4 Dynamic Field Test	22
<b>CHAPTER THREE</b>	
<b>MATERIALS AND METHODS</b>	
3.1a Research Approach	25
3.1b Description of the Study area	25
3.1c Rainfall Characteristics for Imo State	26
3.2 Development of Imo State Soil Map	26
3.2.1 Types of Data and Sources for development of Imo State map	27
3.2.2 Land Use Land Cover Classification of the Study Area	28
3.2.3 Image Enhancement	28
3.2.4 Image Interpretation	29
3.2.5 Digital Elevation Model	29
3.2.6 Soil Classification Map	30
3.2.7 Satellite Remote Sensing Images	31
3.2.8 Soil Erodibility factor (K)	31
3.2.9 Soil Sample Collection	34
3.3 Materials for the Field Operations and Laboratory Experiments	34
3.4 Laboratory Test	35
3.4.1 Organic Matter Content Test	35

3.4.2 Grain Size Analysis	36
3.4.3 Hydrometerfor Sieve Analysis	39
3.4.4 Moisture Content	41
3.4.5 Soil Permeability:	41
3.4.5 Soil pH	43
3.4.6 Specific Gravity	43
3.5 Rainfall Simulation	45
 <b>CHAPTER FOUR</b>	
<b>RESULTS AND DISCUSSION</b>	
4.1 Identification of Various Soil Types in Imo State	50
4.2 Rainfall intensity of the simulated rainfall	53
4.3 Soil loss and the Indices of Soil Erodibility (Clay ratio, Modified Clay ratio, water stable Aggregate, Dispersion ratio and Erosion ratio)	54
4.4 Relationship of Average Soil Loss and the Indices of Soil Erodibility.	64
 <b>CHAPTER FIVE</b>	
<b>CONCLUSION AND RECOMMENDATION</b>	
5.1 Conclusion	78
5.2 Recommendation	79
5.3 Contribution to Knowledge	79
<b>REFERENCES</b>	80
<b>APPENDIX</b>	85

## LIST OF TABLES

<b>3.1:</b>	Soil Texture Group and Locations	31
<b>3.2:</b>	Percentage area taken by each soil type	31
<b>4.0:</b>	Imo State soil group, Established Soil Group and location, Soil data Location	51
<b>4.1:</b>	Percentage of Area taken by soil type	51
<b>4.2:</b>	Soil losses, clay, modified clay, dispersion and erosion ratios of the twelve Locations	55
<b>4.3:</b>	Analysis of variance “Between Groups” and “Within groups” for the elements of simulated runs “dry, wet and saturated rainfall”.	56
<b>4.5:</b>	Results of Regression model statistics for MCR	57
<b>4.6:</b>	ANOVA of the Regression model for MCR	57
<b>4.7:</b>	Results of Regression model statistics for CR	57
<b>4.8:</b>	ANOVA of the Regression model for CR	58
<b>4.9:</b>	Results of Regression model statistics for Dispersion ratio	58
<b>4.10:</b>	ANOVA for Dispersion ratio	58
<b>4.11:</b>	Results of Regression model statistics for Erosion ratio	58
<b>4.12:</b>	ANOVA for Erosion Ratio	58
<b>4.13:</b>	Predicted and experimental values of the CR and MRC	59
<b>4.14:</b>	Predicted and experimental values of Dispersion ratio and Erosion ratio	59
<b>4.15:</b>	Organic matter content for the selected soils in Imo State	67
<b>4.16:</b>	Shear Strength Computation for Owerri	68
<b>4.17:</b>	Shear Strength Computation for Okigwe	69
<b>4.18:</b>	Shear Strength Computation for Orlu	69
<b>4.19:</b>	Soil pH for Imo State	70
<b>4.20:</b>	Coefficient of Permeability	71
<b>4.21:</b>	Specific Gravity for Owerri	72



## LIST OF FIGURES

<b>3.1:</b>	Position and Location of Study Area	26
<b>3.2:</b>	Imo State Map Showing the 27 Local Government Areas	27
<b>3.3:</b>	Digital Image Interpretation	29
<b>3.4:</b>	Soil Erodibility Map of Imo State	32
<b>4.1:</b>	Soil map of Imo state	50
<b>4.2:</b>	Graph of Rainfall depth versus duration	53
<b>4.3:</b>	Plot of Predicted and experimental Modified clay ratio	60
<b>4.4:</b>	Plot of Predicted and experimental clay ratio (CR)	60
<b>4.5:</b>	Plot of predicted DSPR and experimental DSPR	60
<b>4.6:</b>	Plot of predicted Erosion ratio and experimental Erosion ratio	61
<b>4.7:</b>	Particle size Distribution for Umuagwo Ohaji in Orlu.	62
<b>4.8:</b>	Particle size Distribution for Ezinnachi in Okigwe.	63
<b>4.9:</b>	Plot of Average soil loss and Modified Clay ratio	64
<b>4.10:</b>	Plot of Average soil loss and Clay ratio	65
<b>4.11:</b>	Plot of Average soil loss and Erosion ratio	65
<b>4.12:</b>	Plot of Average. Soil loss and Dispersion ratio	66

## LIST OF PLATES

<b>1:</b>	Devastated Farm land in Isiekenesi Ideato South L.G.A	5
<b>2:</b>	Eroded Farmland in Onicha ezinihitte Mbaise	5
<b>3:</b>	Healing Eroded Farmland in Ezinnachi Okigwe	6
<b>4:</b>	Water eroding the soil in Umuduru Okigwe L.G.A	7
<b>5:</b>	Washing away of farm land in Umuna Orlu	7
<b>6:</b>	Samples displayed in the lab for testing	37
<b>7:</b>	Sorting out the unwanted roots	37
<b>8:</b>	Oven Drying process in the Agric. and Bio-resources Engr. laboratory	38
<b>9:</b>	Soil Sampling for air drying	39
<b>10:</b>	Assembling of the soil bin	45
<b>11:</b>	Coupling of the Rainfall simulator	46

## ABSTRACT

*This work centered on evaluating the performance of some selected indices (Clay, Modified clay ratio, Water stable aggregate, Dispersion and Erosion ratios) for determining Erodibility for Imo State soils. Soil samples were collected from 12 locations in triplicate using the completely randomized design for the selected site in Imo State. Soil physical and chemical properties determined were the particle size distribution, organic matter content, dry and bulk density, permeability, porosity and void ratio, moisture content, soil p<sup>H</sup> and specific gravity. The data obtained through field and laboratory experiments were used in measuring the indices. Soil losses were obtained from the field (in-situ) using a portable rainfall simulator of 163.27mm/hr rainfall intensity. The “rainfall” was simulated under three (3) soil conditions; dry, wet and saturated. Statistical analysis using the ANOVA showed that the rainfall simulated under the conditions mentioned above were statistically significant ( $P < 0.05$ ). This suggests that any “rainfall” conditions chosen, can reliably produce soil losses for the study of soil erosion behavior. The regression model equation between the soil losses and the indices of Erodibility developed showed coefficient of correlation values for Modified clay ratio – 0.7579, Clay ratio – 0.7036, Erosion ratio – 0.7279 and Dispersion ratio – 0.7056. From comparative analysis of the selected indices, it was concluded that the Modified clay ratio, Clay ratio, Dispersion ratio and Erosion ratio had performance rating between 70% and 75% probability. These four indices performed satisfactorily thereby becoming better tools in the study of erosion. Water stable aggregate is only applicable to soils having particle size above 2mm which provides for proper evaluation of the index. Overall benefit of using this indices in assessment of soil erodibility shows the unique relationship between the primary soil textural class (sand, silt, and clay) and its percentage composition which defines the true state of any soil (easily eroded or non easily eroded).*

**Keywords:** *Modified clay ratio, clay ratio, water stable aggregate, erosion ratio, dispersion ratio, rainfall simulation, rainfall intensity*

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background of Study

Soil Erosion by water is a major threat to the social and economic lives of the people of Imo State and other parts of South-Eastern Nigeria. Soil has continued to be the most important agricultural input essential to the survival of man. Man's activities and the impending climatic changes have resulted in soil degradation such as erosion. Soil degradation by water erosion has remained a huge problem to the people in the tropics and subtropics in this present time and age.

Soil is the earth's outer layer which as such can be likened to be the earth fragile skin (Singh and khera,2008). Erosion is a naturally occurring process, it can also be man-made by excessive usage like over cropping, deforestation but the rate and effect of its impact and the level of its severity on soil and the environmental quality calls for worry. Soil erosion generally is the loosening, removal and transport of soil material from one place to another (detachment, transport and deposition). It is a universal or natural occurrence wherever there is soil and agents such as wind, water and/or ice. Soil erosion thus constitute a national hazard of which its prevention and avoidance remains paramount to national development. Soil erosion occurs in three phases, comprising the **detachment** of individual soil particles from the soil mass and their transport by erosive agents such as running water and wind (Suresh,2013).

When sufficient energy is no longer available with the erosive agent to **transport** the particles, then the third phase known as **deposition** sets in.

Soil erosion begins when the soil particles are carried by water or wind and deposited somewhere else. Soil erosion is a function of two opposing forces (the

driving force of the erosion agent and the resisting force of the soil). Different soils respond differently to the identical kinetic energy of raindrops or the shear stress exerted by moving fluid. Soil exhibit degrees of susceptibility (soil Erodibility) to the forces generated by erosion agents. Susceptibility of the soil to erosion is influenced by its physical, hydrological, chemical, biological and chemical properties as well as its profile. Soil erosion depends mainly on the Erosivity of the rainfall and Erodibility of soil. The soil Erodibility depends primarily on the physical characteristics of the soils viz., nature and amount of soil aggregates, organic matter content and particle size distribution. These physical characteristics of soils are much affected by the land use.

The soil erosion is defined as the detachment, transportation and deposition of soil particles from one place to another under influence of wind, water or gravitational forces. In the process of soil erosion, there is involvement of two forms of energy which are the potential energy and the kinetic energy.

According to Michael (2011), there is buildup of energy as well as conversion of energy when rain falls. The initial energy being developed is the potential energy: and as the water flows down the slope, there is kinetic energy whose velocity erodes the soil and causes possible detachment and transport of the soil to other areas (deposition).

The critical water velocity for the detachment, transport and deposition of soil particles is the function of particle size. The value of critical velocity increases with increase in the grain size diameter greater than 0.5mm. A greater force is required to move the larger soil particles. The fine particles (clay) are harder to get detached by the water flow because of the cohesive nature of the clay minerals (Morgan, 1996).

Suresh(2013) found that when soil mass contains mixed grain sizes, the finer particles of that soil are hindered by the coarser particles to move ahead. As a

result, the finer particles are not removed until the velocity of flow becomes sufficient enough to pick up the larger soil particles and remove them from their place.

Erosion is made up of two major processes. One is the soil, others are the external forces such as the wind, rainfall, glaciers etc. The soil always resists erosion by its various features in which the soil texture/structure, organic matter and permeability are the dominating properties. The potential susceptibility of soil to get detached is the soil Erodibility and the potential ability of external force to detach the soil particle from the soil mass is the Erosivity. So the phenomenon of soil erosion is the function of the soil Erodibility and rainfall/runoff/wind Erosivity (Renard *et al.*, 1997).

According to Boardman (2006), soil erosion as a part of soil degradation is the decline in quality and quantity of a soil, which may be a function of various processes including erosion, contamination, drainage, acidification, laterization and loss of soil structure or a combination of these.

Flowing water called sheet flow or run off offer very concentrated force to dislodge the soil particles from moving path. The raindrops falling with some velocity detach the soil particles by their kinetic energy (Michael, 2003). Generally, water erosion occurs on land with slope of about 2%. Soil moisture content, soil texture, soil permeability, soil structure, porosity, volume of voids topography e. t. c. are features and characteristics of soil used to determine the tendencies of soil to erosion (Suresh,2013).

Soil erosion depends on the Erosivity of the rain fall and the Erodibility of the soil. The extent of washing away of soil particles depends on the soil characteristics, which leads to the concept of Erodibility.

Increased demand for agriculture commodities generates incentives to convert forest and grasslands to farm fields and pastures. The transition to agriculture

from natural vegetation often cannot hold onto the soil and many of these plants, such as coffee, cotton, palm oil, soy bean and wheat, can actually increase soil's ability to maintain itself.

The menace of soil erosion goes beyond the loss of fertile land. There is also an increase in pollution, sedimentation in streams and rivers, clogging of waterways and decline in the aquatic lives and habitation. More so, degraded lands are often less able to hold water, which easily triggers flooding.

Soil susceptibility and erosion menace are overall degradation situations, the apparent lack of vegetative cover, sandy nature of soil and high rainfall regimes are consequence of geographical location (Ehirim and Ebeniro 2006).

Indices of Erodibility, as in the case of erosion prediction, are the various tools models applied in the assessment of soil Erodibility status. These can be more explained when presented as the indices of measurement in soil Erodibility. In other words, indices of Erodibility is the same as indices of measurement in soil Erodibility.

## **1.2 Statement of Problem**

The two primary types of erosion models are process-based model and empirically based models. Process-based (physically based) model mathematically describe the erosion processes of detachment, transport and deposition. The solutions of the equations describing those processes, provide estimates of soil loss and sediment yields from specified land surface areas. Erosion science is not sufficiently advanced for there to exist completely process-based models which do not include empirical aspects (Chinatu, 2007). The primary indicator, perhaps, for differentiating process-based from other types of erosion models is the use of the sediment continuity equation. Empirical models relate management and environmental factors directly to soil loss and/or sedimentary yields through statistical relationships. Current research

effort involving erosion modeling is weighted toward the development of process-based erosion models.

Several indices of soil Erodibility have been developed by soil scientist and engineers to predict the susceptibility of soil to erosion but a unified model for soil loss prediction is yet a challenge (Baja *et al.*,2014). This major setback is as result of certain limitation such as location, soil type, and climatic factors, annual as well as seasonal rainfall associated with the parameters of measurement. This brought about the emergence of various indices to measure soil Erodibility such that will satisfy the condition of a particular region or area of choice under study.

The Universal Soil Loss Equation which is an acclaimed general equation to measure soil loss is not actually universal. This is so because some factors of the equation are widely dependent on the location, soil type or class, cropping practices and conservation practices, needing further evaluation of the various indices prior to application in a particular study area (Arnold *et al.*, 1990).

In Nigeria, the eastern region is where the many cases of erosion and its devastating effects are common. Efforts are still underway to reclaim areas that have been ravaged by flood and properties worth millions washed away by erosion. Prediction tools that will help to obtain first-hand information on the extent of susceptibility of soil to erosion remain a challenge to the people of this region.

Imo State is second in rank among states that are worst hit by erosion which is orchestrated by the type of soil present in some parts of the State. The prediction tools (indices of Erodibility) suitable for the state (Imo)have been in the discus byresearchers who are working tirelessly to make erosion prediction indices available.



Plate 1: Devastated Farm land in Isiekenesi Ideato South L.G.A



Plate 2: Eroded Farmland in Onicha ezinihitte Mbaise



Plate 3: Healing Eroded Farmland in Ezinnachi Okigwe



Plate 4: Water eroding the soil in Umuduru Okigwe L.G.A



Plate 5: Washing away of farm land in Umuna Orlu

### **1.3 Objectives of the Research**

The main objective of this work is to evaluate the performance of selected indices of soil Erodibility in Imo State.

The specific objectives are to:

1. Identify the various soil types in Imo State
2. Identify selected indices for measurement of Erodibility.
3. Perform a comparative assessment of the selected indices for erosion prediction.
4. Recommend suitable indices for erosion prediction for Imo State soil.

### **1.4 Justification**

The various methods of measuring the Erodibility of soils in a given area include: direct measurement or *In-situ* test, simulated projections, algorithmic languages, indices etc. These methods and the equations guiding them have their limitations which necessitates the inclusion of a correction factor in some cases to accommodate the errors that may arise leading to a negative and unrealistic results. The wrong choice and application of one of the indices will amount to huge loss of time and available resources. Therefore, there is need for a sound performance evaluation of all the indices of soil Erodibility, Proper evaluation of the various indices of Erodibility before selection is a good start in determining the susceptibility of soil to erosion because the outcome of the result will be a working tool to achieve the specifics of soil loss determination as well as erosion projections.

The choice of a suitable model through performance evaluation will help to tackle the problems of wrong selection of indices of Erodibility thus reducing the difficulties of rigorous trial and error method associated with selection of the

best index. Consequently, the best model that is suitable will be a guide in erosion prediction in Imo State and may be extended to other states as these will reduce the challenges associated with soil erosion prediction in the eastern part of Nigeria.

### **1.5 Scope of the Work**

The scope of this research will be to evaluate the performance of different indices of Erodibility. This will be preceded by the collection of soil samples from parts of Imo State where there are different soils.

In addition, previous works as well as literatures on indices of Erodibility will be reviewed. More so, analysis of the samples will be performed and the experimental data obtained. The experimental data so obtained will be analyzed using graphical relations, Analysis of Variance (ANOVA) for statistical analysis, Regression and Correlation for determining the relationship between physiochemical properties and Erodibility. The indices that are suitable will be recommended as tools to guide in the identification and study of Erodibility for erosion predictions for Imo State soils.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Preview**

Soil is an essential input to agricultural production. In Nigeria agricultural production is important to national development. It is the source of livelihoods for majority of the populace whose daily earnings depend on Agriculture.

Agriculture land use in Nigeria often results in the degradation of natural soil fertility and reduced productivity. Soil degradation under agricultural activities or constructions sometimes brings about soil erosion, sedimentation and leaching.

Soil erosion takes place when soil particles are transported or carried off by water or wind and deposited somewhere else. Erosion commences when rain or irrigation water detaches soil particles (El-swaifi and Fowness, 1992).

Relf (2001), stated that when there is too much water on the soil surface, it fills surface depressions and begins to flow. With enough speed, this surface runoff carries away the loosed soil to different locations.

According to Nyakatawa *et al.*, (2001), soil erosion is a major environmental problem worldwide. Soil moved by erosion carries nutrients, pesticides and other harmful chemicals into rivers, streams and ground water resources. Food crops are the most affected by this development due to their shallow rooting systems (FAO, 2015).

Destruction of farmlands and crops by soil erosion creates problems for the population as the farmers cannot find suitable lands on which to cultivate their crops (FAO, 1976). Extreme fragmentation of remaining farmland may follow, which may result in man over cropping the available land, thereby reducing output unless soils fertility is enhanced.

Eroded soils are deposited in water systems leading to pollution and siltation which causes drastic reduction of water volume and quality, and eventual siltation, drying up of rivers, water reservoirs and dams. Hence, the aquatic life

is eventually eliminated (Suwit and Thinley, 2009). There is drastic reduction in land productivity for agriculture. In case of gully erosion, the land may become submerged and not useful for any purpose. However, soil erosion being a complex interaction process of many factors, most basic of which are the edaphic (soil) and rainfall factors, need to be tackled effectively.

Soil erosion is a serious environmental, economic, and social problem. It not only causes severe land degradation and soil productivity loss, but also threatens the stability and health of society in general and sustainable development of rural areas in particular. Estimating soil erosion rates and amounts began in the USA during the 1920s (Meyer, 1965; Meyer, 1958), and rapidly advanced in the 1930s following the devastating impact of the “Dust Bowl” on the American Great Plains (NCDC, 2009). Since then, soil erosion research received increasing emphasis, and Erodibility became an important parameter for estimating soil loss and implementing soil conservation practices. In recent years, soil Erodibility has also become an imperative parameter for assessing and predicting environmental impacts on surface water bodies.

Soil Erodibility is an estimate of the ability of soil to resist erosion based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved structure have a greater resistance to erosion (Ezeabisi *et al.*, 2014). In Erodibility studies and the development of erosion models, numerous publications on the effect of soil properties in erosion processes have assisted in better quantifying and defining soil Erodibility. (Idahet *et al.*, 2008).

Soil erosion depends on the Erosivity of the rainfall and Erodibility of soil. The soil Erodibility depends primarily on the physical characteristics of the soils nature and amount of soil aggregates, organic matter content and particle size

distribution. These physical characteristics of soils are much affected by the land use. Soil Erodibility can be evaluated by using runoff plots, which is quite expensive, time consuming and is not feasible at all places. It can also be estimated using nomograph developed by Wischmeier *et al.*, (1971) but it may not be applicable in many situations. Another way to estimate soil Erodibility is by using various soil Erodibility indices based on soil characteristics.

Erodibility indices like dispersion ratio, clay ratio, modified clay ratio and erosion ratio have been employed by different workers to assess the soil Erodibility. However, very little information is available on the Erodibility indices for the soils of submontaneous tract of Nigeria particularly under different land uses and in relation to runoff and soil loss (Singh and Khera, 2008).

The organic and chemical constituents of the soil are important because of their influence on stability of aggregates as well as other activities of man. Soils with less than 2% organic matter can be considered erodible (Ekwue, 1990). Most soils contain less than 15% organic content and many of the sands and sandy loams have less than 2%. Morgan (2001) suggested that soil Erodibility decreases linearly with increasing organic content over the range of 0 to 10%.

However, the Universal Soil Loss Equation (USLE) has been useful in predicting the average rate of soil loss due to water erosion from agricultural lands (Wischmeier and Smith, 1978). In the early 1990s the basic USLE was updated and computerized to create an erosion prediction tool called the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.*, 1997). The USLE/RUSLE soil loss prediction is dependent upon soil properties including texture, organic matter content and structure of the soil. The RUSLE uses the same basic factors of the USLE although some are modified and better defined (Trust and Oagile, 2013).

A soil with relatively low Erodibility factor may show signs of serious erosion, yet a soil could be highly erodible and suffer little erosion (Nyakatawa *et al.*, 2001). This is because soil erosion is a function of many factors as stated in the universal soil loss equation (USLE). These factors include rainfall factor ( $R$ ), soil Erodibility factor ( $K$ ), slope length ( $LS$ ), crop factor ( $C$ ) and control practice factor ( $P$ ). This is represented in the universal soil loss equation as (Renard *et al.*, 1997)

$$A = R K L S C P$$

2.1

The soil Erodibility factor  $K$  is a quantitative expression of the inherent susceptibility of a particular soil to erode at different rates when the other factors that affect erosion are standardized. Erodibility varies with soil textures, aggregates, stability, shear strength, soil structures, infiltration capacity, soil depth, bulk density, soil organic matter and chemical constituents (Agassi and Bradford, 1999).

Angima *et al.*, (2003) wrote that amongst the USLE factors, soil Erodibility ( $K$ ) factor is applicable to most tropical soils and was found to strongly correlate with soil loss. The Erodibility ( $K$ ) factor reflects the ease with which the soil is detached by splash during rainfall and/or by surface flow especially on sloping areas (Angima *et al.*, 2003). The two most significant and closely related soil characteristics influencing soil Erodibility are infiltration capacity and structural stability. These are largely influenced by soil texture, organic matter and soil plasticity. High infiltration capacity means that less water will be available for runoff and the surface is less likely to be ponded and more susceptible to splashing (Morgan, 1996). In particular, soils which are highly permeable have high infiltration capacities (e.g. sandy soils) and are more prone to water erosion since the soil easily allows water to penetrate and therefore easily washed away. On the other hand, stable aggregates resist the beating action of rain and thereby save soil even though runoff may occur. The factors that determine aggregate

stability include bulk density, Atterberg limits as well as texture and organic matter content of soils (Toy *et al.*, 2002).

Moreover, soils with larger sand and silt proportions are more vulnerable to water erosion due to lack of stability of soil particles (Toy *et al.*, 2002). Similarly, soils with relatively low organic matter content are very vulnerable to water erosion since organic matter increases the stability of soil (Hudson, 2009). A 36% decrease in K-factor value was observed in organic matter amended soil in respect to the control. Furthermore, the susceptibility of soil to water erosion also depends on slope length (Toy *et al.*, 2002) and is most prevalent in sloping areas (Angima *et al.*, 2003). Nanna, (1996), in their studies on 'slope length effect on soil loss for steep slopes' also reported the greater sensitive of slope effect to soil loss is due to differences in rainfall.

The depth of erosion is very often determined by the soil depth. Soils below the plough layers are often compact and less erodible. Rills will develop in areas where resistance bedrock is close to the surface if the parent material is unconsolidated such as sands and gravel (Trust and Oagile, 2013).

Soil characteristics influencing soil Erodibility are infiltration capacity and structural stability. These are largely influenced by soil texture, organic matter and soil plasticity. High infiltration capacity means that less water will be available for runoff and the surface is less likely to be ponded and more susceptible to splashing. In particular, soils which are highly permeable have high infiltration capacities (e.g. sandy soils) and are more prone to water erosion since the soil easily allows water to penetrate and therefore easily washed away. On the other hand, stable aggregates resist the beating action of rain and thereby save soil even though runoff may occur. The factors that determine aggregate stability include bulk density, Atterberg limits as well as texture and organic matter content of soils (Toy *et al.*, 2002).

## 2.2 Erosion Problem in Southeastern Nigeria

The formation of gullies has become one of the greatest environmental disasters facing many towns and villages in Southeastern Nigeria. This region is fast becoming hazardous for human habitation. Hundreds of people are directly affected every year and have to be re-located. Large areas of agricultural lands are becoming unsuitable for cultivation as erosion destroys farmlands and lowers agricultural productivity (Jim, 2010).

Erosivity and Erodibility are the factors that contribute to erosion and gully formation. Erosivity is a function of rainfall, a natural phenomenon which is outside human control and manipulation. Rainfall intensities can be high in Southeast Nigeria. Idahet *et al.*, (2008) reported that rainfalls with intensities between the range of 100 to 125 mm h<sup>-1</sup> are likely to occur more than five times a year. Storms with 25 mm/h intensity have been reported by Hudson (2009) to be erosive. Erodibility, on the other hand, is dependent on soil properties, topography, and land management.

Appropriate land management is very important in an area like Southeast Nigeria where the geotectonic, geologic, and geohydrology characteristics of the region make many areas within it susceptible to gully erosion. For example, cuestas, fractures and joints are common features in the gully-erosion-prone areas of Southeastern Nigeria and have been identified as significant factors in the formation of gully erosion (Isikwue *et al.*, 2012; Nwaimo, 2010).

The loss of soil degrades arable land and eventually renders it unproductive. As a result, there are significant per capita shortages of arable land. The effects of this erosive action are made more severe by recent and rapid population growth in the Southeastern region of Nigeria. Loss of agricultural output is one of the greatest economic costs of gully erosion (Pimentel *et al.*, 1995). Large portions of land have been destroyed in recent years in towns such as Ekwulobia and Nanka. In addition, highways are damaged, leading to numerous vehicle accidents and large displacement of residential houses (Pimentel *et al.*, 1995).

## **2.3 Ecological Factors and Soil Erosion**

Accelerated soil erosion is a symptom of ecological imbalance. It is a multi-faceted and complex process that is affected by a multitude of interacting environmental parameters (Giuliano, 2002). These include:

### **(i) Rainfall**

The high erosivity of tropical rains is obviously an important factor responsible for widespread erosion. Maximum daily rainfall of 220-430mm is often observed in many regions of tropical Africa (Biot and Lu, 1995). The high intensity of tropical rains is partly attributed to relatively large drop sizes. Rains with an energy load of  $100 \text{ J m}^{-2}$  of rain are often received at a time when the protective vegetation cover is poor (Hudson, 2009).

### **(ii) Soils**

Soils with low levels of organic matter content and those containing predominantly low-activity clays are susceptible to severe soil erosion. Alfisols, the predominant soils of the sub-humid and semiarid regions, are particularly susceptible to soil erosion. Ultisols, the soils of the humid Soudanian zone are also susceptible to erosion. Vertisols, soils of heavy texture and low permeability are particularly susceptible to severe sheet and gully erosion.

### **(iii) Landforms**

Little is known regarding the effects of slope length and profile form on runoff and erosion. The erosion processes vary considerably with landform (Hudson, 2009). For example, sheet erosion and rain

Splash occur on uncultivated slopes, sheet and rill erosion are common on cultivated slopes and undulating and rolling dissected plains, and mass

movement and gully erosion are severe on overgrazed slopes with stepped profiles.

Relf, (2001) observed that the effect of slope length is less important than slope steepness and of slope form. It is in fact difficult to relate sediment transport to a measureable slope parameter.

## **2.4 Land Use and Soil Erosion**

Every year, vast areas of forested land are being converted to arableland use in an attempt to meet the demand for food, fiber, feed, and fuel. The change in land Use and the range of cultural practices of soil and crop management used have drastic effects on erosion and sediment yield. Such Land use activities include:

### **(i) Deforestation**

Relf, (2001) also reported that the Method of deforestation had a significant effect on runoff and sediment discharge from agricultural catchment

### **(ii) Grazing**

Uncontrolled grazing is obviously an important factor determining the magnitude of soil erosion. Grazing pressure influences the vegetation cover and the water intake rate through its effect on soil compaction.

### **(iii) Fire**

Fire is an important ecological factor in tropical Africa. Fire accelerates soil erosion directly by denuding the vegetation cover and indirectly by affecting the water infiltration rate of soil (Foster *et al.*, 1997).

Bare soil surfaces are easily compacted by raindrop impact. Fire also destroys soil fauna that keep the soil porous. In spite of its ecological importance, there are few quantitative data concerning the effects of frequency and intensity of burning on soil erosion. Wischmeier *et al.*, (1971) observed that burning the crop residue increased soil erosion several fold when compared with an unburnt control.

## **2.5 Methods for determining indices of Soil Erodibility**

The indices of soil Erodibility as prescribed by Morgan (1996) show the various methods to obtain or measure the Erodibility of soil. They are divided into Static Laboratory tests, Static Field tests, Dynamic Laboratory tests and the Dynamic Field tests. These are further discussed below

### 2.5.1 Static Laboratory Tests

#### A. The Dispersion Ratio:

The dispersion ratio is the amount of silt and clay in suspension at a depth of 30 centimeters expressed in percentage of the total silt and clay as determined by mechanical analysis. This method is a useful and quick way of indicating the potential and tunneling susceptibility of soils. The dispersion percentage ratio is the ratio of the soil material <0.005mm after limited mechanical dispersion (soil dispersed during particle size distribution) without dispersants to the total material, <0.005mm, expressed as a percentage (Lutz,1934). As it is necessary to know the total soil material <0.005mm, this procedure is usually carried out in conjunction with Particle Size Analysis.

$$\text{Dispersion ratio} = \frac{\% \text{ silt} + \% \text{ clay in dispersed soil}}{\% \text{ silt} + \% \text{ clay after dispersal of soil in water}} \quad (\text{Morgan, 1996}) \quad 2.2$$

#### B. Erosion Ratio:

The erosion ratio is a measure of the dispersion ratio against the colloid content moisture equivalent ratio it is obtained using the relation:

$$\text{Erosion ratio} = \frac{\text{Dispersion ratio}}{\text{colloid content moisture equivalent ratio}} \quad (\text{Suresh,2013}) \quad 2.3$$

### C. Clay ratio:

The clay ratio is the ratio of sand, silt and clay measured in percentage. It is measure of the amount binding due to clay. It shows that clay ratio decreases with increase in depth of soil. This is interpreted to mean that the binding influence of clay hence the resistance of these soils to erosion increased with increase in depth of soil. Higher clay ratio indicates lower binding influence due to clay and therefore greater susceptibility to erosion (Ezeabasili and okoro, 2014).

The ratio is stated as follows:

$$\text{Clay ratio} = \frac{(\% \text{ Sand} + \% \text{ Silt})}{\% \text{ Clay}} \text{ (Ezeabasili and okoro, 2014) } \quad 2.4$$

### D. Surface Aggregation ratio

$$SAR = \frac{\text{Surface area of particle size } > 0.05\text{mm}}{(\% \text{ silt} + \% \text{ clay in dispersed soil}) - (\% \text{ silt} + \% \text{ clay in undispersed soil})} \quad 2.5$$

The SAR is a component whose data shows very clearly that one of the principal differences between erosive and non-erosive soils is the degree of aggregation of the finer mechanical separates into large stable granules.

### E. Instability index (Is)

The index of structural instability isa tool for analyzing the structural stability of aggregates with classification as to whether the soil issaline or alkaline revealing the existence of link between the index of Instability and soil  $p^H$ . The index may further be used to show that instability diminishes when  $p^H$  increases (Singh and Dhanya, 2011).

$$\text{Instability index} = \frac{\% \text{Silt} + \% \text{clay}}{(\% \text{ aggregate } > 0.2 \text{ mm after wet sieving}) - 0.9 (\% \text{ coarse sand})} \quad 2.6$$

## F. Pseudo-textural aggregation Index (Ipta)

This index for soil Erodibility testing and erosion measurement reveals the effect of cultivation to aggregation stabilization. Structural stability describes the ability of the soil to retain aggregation and pore space when exposed to external forces such as wind, water, cultivation/tillage (Singh and Dhanya, 2011)

$$\text{Pseudo-textural aggregation index} = \frac{MWD_w - MWD_t}{X - MWD_w} - 100 \quad 2.7$$

where  $MWD_w$  is the mean weight diameter of the wet-sieving grain size distribution (mm),  $MWD_t$  is the mean weight diameter of the primary particle grain-size distribution (mm) and  $X$  is the maximum average grain size diameter of the particles in the given grain size distribution.

### 2.5.2 Static Field Tests

#### Erodibility index:

This index method is used to measure the degree of resistance of soil to both detachment and transportation. The relationship is giving as:

$$\text{Erodibility index} = \frac{1}{\text{mean shearing resistance} \times \text{permeability of soil}} \quad 2.8$$

(Bryan, 1968)

### 2.5.3 Dynamic Laboratory Test

#### A. Water Stable Aggregates (WSA):

This is the percentage of the soil aggregate that is greater than 2 mm after wet sieving expressed as follows:

$$WSA = \% \text{ of soil aggregates } > 2.0 \text{ mm after wet sieving}$$

Or

$$WSA = \% \text{ of soil aggregates } > 0.5 \text{ mm after subjecting the soil to rain fall simulation}$$

#### B. Modified Clay ratio:

Whereas the clay ratio deals with the percentages of the sand, silt and clay, the modified clay ratio includes the percentages of the sand, silt and clay and also that of the organic matter. The latter is added such as to give a complete assessment that will give the required result about the strength composition of the soil and its level of susceptibility to erosion.

The Modified clay ratio can be estimated using the following;

$$MCR = \frac{\% \text{ sand } + \% \text{ silt}}{\% \text{ clay } + \% \text{ organic matter}} \quad (2.9)$$

(Ezeabasili and okoro, 2014)

The modified clay ratio is an improvement on the clay ratio. This is predicated upon the fact that the organic matter content of the soil is significant in determining the soil ability to resist splashing as well as disintegration of the soil particles as a result of the action of the rainfall.

### **C. Water drop Test:**

This is the percentage aggregate of soil dispersed by a pre-selected number of impacts by a standard raindrop (e.g. 5.5 mm diameter, 0.1g from height of 1m).

### **D. Simulated rainfall Test:**

Simulated rainfall test for determining soil loss describes the effect of rain drops to detach and disperse the soil. Simulated rainfall test allows generating rainfall with a known intensity and duration on an erosion plot in a controlled manner, making it possible to quantify superficial runoff and soil loss, while the same time allowing very detailed erosion predictions (Humphry *et al.*, 2002).

Humphry *et al.*, (2002) reported that simulator enhanced the study of erosion processes. The simulated rainfall makes it possible to find good correlations between soil losses measured in an erosion plot and what occurs in a watershed, Humphry *et al.*, (2002).

### **E. Erosion Index**

Erosion index shows the relationship between the degree of dispersion, the water-retaining capacity and aggregation,

$$E I = \frac{d h}{a} \text{ (Singh and Dhanya, 2011)} \quad 2.9$$

Where “d” is an index of dispersion (ratio of % particles > 0.05mm without dispersion to % particles > 0.05 mm after dispersion of the soil in (sodium chloride)); “h” is an index of water-retaining capacity (water retention of soil

relative to that of 1g of colloid); and “a” is an index of aggregate (% aggregate > 0.25 mm after subjecting the soil to water flow of 100 cm<sup>3</sup>/mm for 1hr.

#### 2.5.4 Dynamic Field Test

##### A. Erodibility index (K):

$$K = EI \quad (\text{Singh and Dhanya,2011}) \quad 2.10$$

K= mean annual soil loss per unit of EI<sub>30</sub>

*E = Total storm Energy*

*I = Rainfall intensity mm/hr or Max. 30 mins. Rainfall intensity*

The storm energy indicates the volume of rainfall and runoff, but a long slow rain may have the same E values as a shorter rain at much higher intensity. Raindrop erosion increases with rainfall intensity (Singh and Dhanya,2011).

The I<sub>30</sub> component reflects the prolonged peak rates of detachment and runoff at 30 mins. maximum rainfall. The product “term” intensity is combined in each particular storm. This term indicates how particles detachment is combined with transport capacity (Singh and Dhanya,2011).

##### B. Unit Plot Erodibility Factor

The Erodibility factor model according to Mabubuike(2006) is a model used in computing the Erodibility factor having the parameters clay content, amorphous iron oxide, soil cohesion (KNM<sup>-2</sup>), as follows:

$$(i) \quad k = 0.3362 + 0.98 \times 10^{-1} k - 8.22 \times 10^{-2} Fe + 3.6 \times 10^{-3} C + 9.0 \times 10^{-4} CL$$

#### 2.11

(Madubuike and Chukwuma, 2006)

K= Av. Annual/seasonal Erodibility factor (ton/ha)(ha.hr/MJ.mm)

Fe= amorphous iron oxide (PPM)

C= Soil Cohesion ( $\text{KNM}^{-2}$ )

CL= Clay Content (%)

OR

$$(ii) k = 1.0 \times 10^{-4} (12 - OM)M^{1.14} + 4.5 (S - 3) + 8.0 \left(\frac{P-2}{100}\right) \quad \mathbf{2.12}$$

(Madubuike and Chukwuma, 2005)

M= % Silt+% Very fine sand  $\times(100-\%$  clay), OM =% Organic matter,

S= Soil Structure class, P= Permeability class

The Erodibility factor in (ii) comprised of other soil properties namely the organic matter, the soil textural class and the silt and clay content of the soil.

Researchers have over time worked on developing the models for predicting Erodibility. According to Bryan, (1965), Bennet worked on Erodibility on lateritic soil in Cuba. The work was aimed at determining the vital role soil physical (soil texture, soil structure) properties as well as chemical composition and organic matter play in determining Erodibility. He was able to develop the relationship between erosion and some chemical composition ratio.

Bouyoucos worked around the problem of dispersion by trying to establish a more fundamental approach to solving Erodibility which culminated in the development of clay ratio.

Singh and Dhanya, (2011) reported that Erodibility is the surface aggregate ratio which is the ratio of the total surface area of particles larger than 0.05mm diameter and the quantity of aggregated silt and clay.

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Research Process**

##### **a. Research Approach**

The research approach in this study was the identification of the soil groups using Imo State Soil map. The next approach was development of a portable rainfall simulator to produce artificial rain to determine the soil loss. Experimental data, field tests were analyzed for the determination of some selected soil Erodibility indices such as the clay ratio, modified clay ratio, water stable aggregate, dispersion ratio and erosion ratio. Evaluation of the indices was performed using the amount of soil loss against the selected indices for efficiency rating. Performance of these selected indices will help ascertain their reliability for soil erosion predictions particularly for Imo State soils.

##### **b. Description of the Study area**

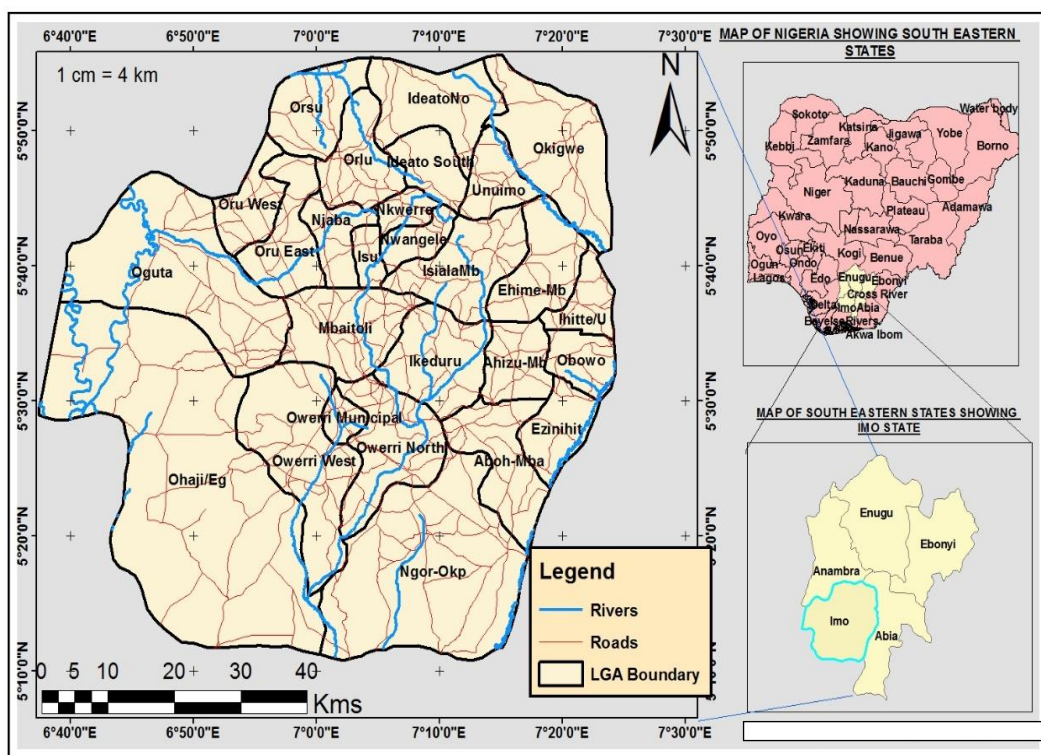
Imo state which is one of the 36 States of Nigeria and lies in the south eastern of Nigeria with Owerri as its capital is between Latitude 5° 29' North and Longitude 7° 2' East, which has a total cover area of 5,530 square kilometers and has a population of approximately 4 million (3,934,899) and density of 710/square kilometer in accordance with 2006 census (Imo State NewMap, 2016).

### c. Rainfall Characteristics for Imo State

Imo State as the study area lies in the humid tropic with high relative humidity atmospheric temperature and rainfall. The mean annual atmospheric temperature, ranges from 28°C – 31°C with February and April as the hottest months (NIMET, 2011). Mean annual rainfall range from 2500mm – 3000mm with the highest intensity between April and November (NIMET, 2011).

Figure 3.1 shows the Map of Nigeria from which the position and location of the study area was extracted.

### 3.2 Imo State Map showing locations under study



**Fig. 3.1:** Position and Location of Study Area

Source: Okorafor *et al.*, (2018)



### **3.2.2 Land Use Land Cover Classification of the Study Area**

Images were inserted into ERDAS IMAGINE 2014, ENVI 4.8 and ArcMap 10.1 interchangeably for further GIS operation (Giuliano, 2002, Gunawan *et al.*, 2013).

#### **Image Pre-Processing Techniques**

The image pre-processing techniques included image Geo-referencing, Scan line error correction, image enhancement, sub-setting, generation of false colour composites (FCC) and other composite bands.

#### **Geo-referencing of the Images**

Images were geo-referenced on ArcGIS 10.1 using ground control points (GCP's) obtained from GPS, using image to GPS techniques. Many GCP's were collected using GPS on the field. These points were distributed to ensure images are balanced on all the four axes and centralized at the center. The choice of image to GPS techniques is based on the fact that most of the data used was collected in the field using GPS and this reduced error during map composition and allowed points to fit in.

### **3.2.3 Image Enhancement**

The linear contrast stretch was used in the ERDAS IMAGINE 2014 modeling functions to increase visual discrimination amongst objects in scenes of all images for better visual perception and interpretation. Gap-fill tool in Envi 4.8 was used to clear Scan line error from images acquired from Landsat 7.

#### **Sub-setting of the Study Area**

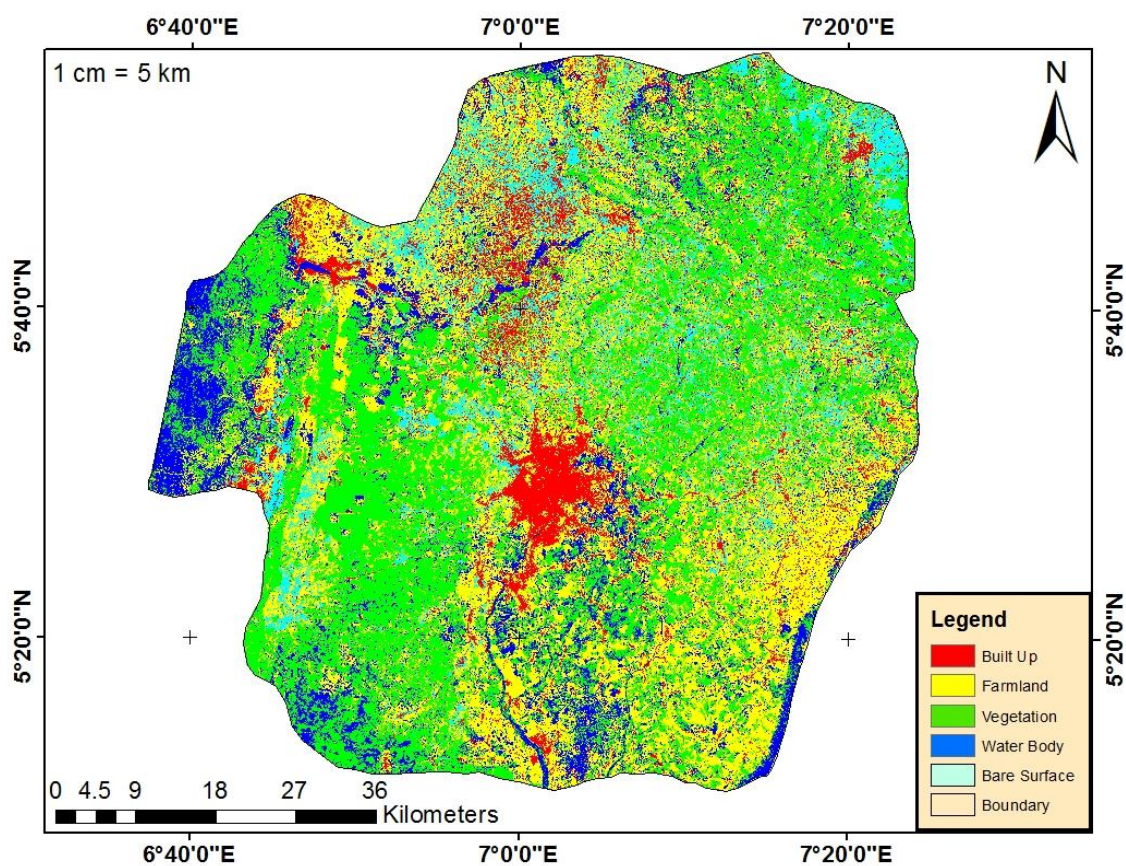
The digitized map of the study area was used to subset the satellite images obtained. This was done using ArcGIS 10.1.

### Generation of False Colour Composite (FCC)

The false colour composite of images was processed from Landsat 8, False colour composite was generated by selecting band 5, band 4 and band 3 which conforms to the Near Infrared (NIR), Red (R) and Green (G) planes respectively. Further linear stretching was performed on the FCC of the sub-scenes to enhance image quality.

### 3.2.4 Image Interpretation

Supervised classification in the maximum likelihood classifier was used.



**Fig. 3.3:** Digital Image Interpretation

Source: Okorafor *et al.*, (2018)

### **3.2.5 Digital Elevation Model**

A DEM can be used to identify different basin characteristics such as drainage area, elevation, slope length and steepness, and stream relief ratio. DEM is based on the contour lines generated from the topographic map. The purpose of this data set is to provide a single consistent elevation model for national scale mapping, GIS and Remote Sensing applications and Natural Resource Assessment.

The Topographic map was imported into ArcGIS 10.1, it was geo-referenced, then digitized with a scale of 1:100 000 to extract the contour lines and it was masked to extract the study area.

### **3.2.6 Soil Classification Map**

The primary source of Soil map for the study area is from Nigeria Geological Survey. The geological and mineral map was imported into Arc GIS 10.1. This was geo-referenced under the WGS84 Coordinate System to give it a spatial attribute and the study area and Imo State was masked from it. Soil classification were somewhat regional in the past, recent classification of the soil is done using the advance geographic mapping tool.

Old Eastern 9 soil regions:

1. Clay and Shales (Ebenebe and Umuna sandstones) – Palaeocene
2. Clayey sands and shales (Bende, Ameke and Nanka stones) – Eocene
3. Sand stones (Imo formation Inc) – Palaeocene
4. Sand stones, Limestone and coal (Upper coal measures) – Maestriclitian-Danian
5. Sands and clay (Coastal plains sands) – Plio-pleistocene
6. Sands, gravel and clay (Meander belts) – Holocene
7. Clay, sandstones, lignite and shales (Lignite formation) – Eocene

8. Sands, clay and swamps (Sombreiro Deltaic plane) – Pleistocene-Holocene
9. River Alluvium

### 3.2.7 Satellite Remote Sensing Images

The used Landsat images should be from the harmattan periods of the year 2015. The spatial resolution of the satellite images are 30metres. All images were geo-referenced under the WGS84 Coordinate System. The two satellite images used are expected to be from the same date and period. However, due to heavy cloud coverage in the Southeast region during Summer time, this requirement is difficult to fulfill. The data used in the study area are the best combination which can be found. Using the satellite remote sensing Imagery, the soil Imo State soil map was used to classify the soil according to its textural class see table 3.1.

Table 3.1: Soil Texture Group and Locations obtained from digitized soil map

<b>Soil Texture Group</b>	<b>Locations</b>
Clay and Shale	Ehime Mbanjo
Sand Stone	Ideato North
clay, sandstone, lignite and shale swamps	Ikeduru
Sand, Clay and Swamps	Oguta
Sand, gravel and clay	Ohaji Egbema
Sandstones, Limestone and Coal	Okigwe
Clay Sands and Shale	Orlu
Sands and Clay	Owerri West

Source: Okoraforet *al.*, (2018)

Table 3.2: Percentage area taken by each soil type

Soil type	Percentage coverage (%)
-----------	-------------------------

Sands, gravel and clay	1.1
Sands and clay	48.6
Sands, clays and swamps	1.8
Clays, sandstones, lignite and shales	12.2
Clayey sands and shales	20.3
Clay and shales	6.3
Sandstones	1.2
Sandstones, Lime stones and Coal	3.6
River Alluvium	4.9

Source: Okorafor *et al.*, 2018.

Table 3.2 shows the percentage coverage of the soil types obtained from soil regions in section 3.2.6. Differences in soil types shows different compositions and structure, which influence the intensity of the soil to erosion. The soil Erodibility indicates the vulnerability and susceptibility of different soil types to detachment by erosion (Nanna, 1996).

### 3.2.8 Collection of soil samples

Soil samples were collected using completely randomized design, at 20 cm depth. Three (3) replicates from each location and across (12) local areas in Imo State namely: Okwelle (Onuimo), Ezinnachi (Okigwe), Umuokanne (Orlu), Umuagwo-Ohaji, Umuna (Orlu), Mbieri (Mbaitoli), Isiekenesi (Ideato), Okwe (Onuimo), Ihiagwa (Owerri West), Obinze (Owerri West), Ugiri (Isiala Mbano), Onicha Ezinihitte Mbaise. The soils were loaded in black polythene bags for the prevention of sunlight. They were transported to the Agricultural and Bio-resources Laboratory and air dried as shown in plates 6, 7 and 9.



**Plate 6:** Samples displayed in the lab for testing



**Plate 7:** Sorting out the unwanted roots



**Plate 9:** Soil collection and Sampling

### **3.3 Materials used in the Field Operations and Laboratory Experiments:**

- Soil Augers: This was used in collecting samples
- Shovel: Used in the collection of soil sample
- Polythene Bag (black): Used for bagging of the soil sample
- Core sampler: For measurement of moisture content
- Rainfall Simulator: Artificial simulation of rainfall
- Soil bin: Used to obtain the amount of soil losses during rainfall simulation
- Oven: For soil drying
- Automated Weighing balance: Used for the weighing of soil samples
- Automated Sieve Shaker: Used for Particle size distribution
- Beakers: Used for hydrometer test

- Pitot Tube: Used for sedimentation test
- Burette: Used for hydrometer analysis
- P<sup>H</sup>scale: Used in determining the soil p<sup>H</sup>
- Stop Watch: Used for timing before taking readings

### 3.4 Laboratory Tests

#### 3.4.1 Organic Matter Content Test

This method is suitable for soils which contain little or no clay or chalky material. It is based on the procedure given in soil mechanics for road engineering (Road Research Laboratory, 1952).

##### **Apparatus:**

- Balance accurate to 0.001g
- Porcelain crucible of about 30ml capacity
- Gas burner
- Drying oven, 105-110°C and desiccators

##### **Procedure:**

Samples weighing 20g of oven dried soil(plate 8) were prepared in crucible and loaded into the desiccator. It was then cleaned, dried and weighed the crucible to 0.001g (m<sup>2</sup>). The crucible was placed in the burner applied heat. The crucible was heated to red heat over the burner taken care to avoid soil loss. We allowed the crucible to cool and then weighed it to 0.001g (m<sup>3</sup>).

**Calculation:**

Loss on ignition (percentage of organic matter)

$$= \frac{w^2 - w^3}{w^2 - w^1} \times 100\% \quad 3.1$$

$W^1$  = weight of crucible +

$W^2$  = weight of crucible + soil after oven drying

$W^3$  = weight of crucible + soil after cooling

**3.4.2 Grain Size Analysis**

This test is used to determine the percentage of different grain size contained within a soil and particle size distribution (Boyucos,1962). The distribution of different particles size reveals the engineering properties of soil. Sieve analysis involves a column of sieves with wire mesh called screen which is mounted on a sieve shaker.

**Apparatus:**

- Sedimentation cylinder ( $1000\text{cm}^3$  cylinder) or hydrometer jar
- Hydrometer (152H model preferably)
- Soil device (malt mixer)

**Procedure:**

60g of the sample was poured in to the top sieve which has the largest screen openings. Each lower sieve in the column has a smaller opening than the one above. At the base is a round pan called the receiver. Then column was then placed in a mechanical shaker for about 5-10 minutes. After shaking is completed, the material in each sieve was weighed. The weight of the sample of

each sieve is divided by the total weight to give a percentage retained on each sieve. Lastly the bottom pan and its retained fine are weighed.



**Plate 8:** Oven Drying and timing in the Agric and Bio-resources Engr. laboratory

### **3.4.3 Hydrometer(Sieve Analysis):**

#### **Test Procedure:**

The fine soil was taken from the bottom pan of the sieve set, then it was placed into a beaker and 125ml of the dispersing agent (sodium hex metaphosphate 40gl) solution was added. Then the mixture was stirred until the soil thoroughly wet, and the soil soaked for about 10mins.

After the 10 minutes, another 125ml of dispersing agent was added into the control cylinder and then it was filled with distilled water to the mark. The reading was taken at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero was recorded as a negative (-) correction and a reading between zero and sixty were recorded as a positive (+) correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (usually about +1).

The control cylinder was soaked in such a way that the contents are mixed thoroughly. Then the hydrometer and thermometer was inserted into the control cylinder and noted as zero correction and temperature respectively.

The soil slurry was transferred into a mixer by adding more distilled water until mixing cup is at least half full. Then the solution was mixed for a period of two minutes and immediately the soil slurry was transferred into the empty sedimentation cylinder. Distilled water was added up to the mark.

The open end of the cylinder was covered with a stopper and secured it with the palm of the hand. Then the cylinder was turned upside down and back upright for a period of one minute (1min). (Note that the cylinder should be inverted approximately 30 times during this period).

The cylinder was further set down and its time was recorded. The stopper was removed from the cylinder, after an elapsed time of one minute and forty seconds. The hydrometer was inserted very slowly and carefully for the first reading. (Note again; this should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing). The reading was then taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer was removed slowly and placed back into the control cylinder which was gently spined in the control cylinder to remove any particles that may have adhered to the body of the cylinder.

Then the hydrometer readings after elapsed time were taken at 2, 5, 8, 15, 30, 60 minutes and 24hours.

### 3.4.4 Moisture Content

Soil moisture determination is important in scheduling of irrigation frequency, and this helps in estimating the amount of water to be applied during each irrigation.

Gravimetric method: To determine soil moisture content by gravimetric method, the following apparatus are required.

#### Apparatus:

- Sampling tube
- Aluminum containers or cans
- Oven set at 105°C
- Weighing balance and recoding sheet
- Scale rule

#### Procedure:

Soil samples were collected using soil auger and then placed in a sample tube. Then empty cans were weighed and its weights  $w_1$  was recorded. We then placed the soil sample in a can and weigh  $w^2$  it. The soil samples were then placed in the oven for about 24hours at 105°C and after that the samples were removed from the oven so that it will cool slowly to a room temperature and its weight  $w_3$  was recorded using the formula below:

$$= \frac{w^2 - w^3}{w^3 - w^1} \times 100\% \text{ (as \% dry weight).} \quad 3.2$$

$W^2$  = Weight of container + wet soil

$W^3$  = weight of container = dry soil

$W^1$  = weight of container

### **3.4.5 Soil Permeability:**

The measurement of soil permeability in the laboratory is simple that the result may not be good representative of the actual field value because of difficulties in obtaining truly undisturbed soil sample.

#### **Apparatus:**

- Cylindrical container
- Water
- Soil sample of clay
- Stop clock
- Measuring cylinder and
- Meter rule

#### **Procedure:**

The undisturbed core or parked sample was placed in a cylindrical container with coefficient space below the soil park. The cross-sectional area (A) of the soil park or core and the length (L) and the length of the soil column was measured. The sides of the column were sealed with paraffin wax to prevent the passage of water down the size of the soil column. 30ml of water was passed through the soil and time was measured. After about 30mins the flow rate (Q) was measured to note the difference in head (H). And the permeability (K) was calculated using the DARCY'S law which states that:

$$k = \frac{Ql}{ADH} \quad 3.3$$

The experimented procedure was repeated for the same sample without determining the flow rate (Q) but other parameter. The permeability (K) was then calculated using the following formula

$$K = \frac{al}{At} \ln \frac{h_1}{h_2} \quad 3.4$$

Where:

a = cross-sectional area of stand pipe ( $cm^2$ )

A = cross-sectional area of soil sample

$h_1$  = hydraulic head across sample at the beginning of the test

$h_2$  = hydraulic head across sample at the end of the test

l = length of soil sample (cm)

t = elapsed time of test (s)

$\ln$  = logarithm to base 2.72

### 3.4.5 Soil pH

#### **Apparatus:**

- Glass-electrode pH water

#### **Procedure:**

60g of dried soil was weighed into a 50-ml beaker (note that this sample passed 2-mm sieve). 20ml of distilled water was added and allowed to stand for about 20-30mins and it was stirred occasionally with a glass-rod. Then electrodes of the pH meter were settled in suspension and its pH was measured, and immediately the stirring stopped measuring and recording were performed on it.

### 3.4.6 Specific Gravity

This test is carried out to determine the specific gravity of fine grained soil by density bottle method as per IS:2720(part III/Sec 1)-1980.

Specific gravity is the ratio of the weight in air of a given volume of material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature to the weight in air of an equal volume of distilled water at the same stated temperature

### **Apparatus**

Two density bottle of approximately 50ml capacity along with stoppers

Constant temperature water bath ( $27.0 \pm 0.2$  °c)

Vacuum desiccator

Oven capable of maintaining temperature of 105 to 110°C

Weighing balance with an accuracy of 0.001g

Spatula

### **Procedure**

The density bottle along with the stopper was dried at a temperature of 105°C to 110 °c, cooled in the desiccator and weighed to the nearest 0.001g. The sub sample which was oven dried was then transferred to the density bottle directly from the desiccator in which it was cooled. The bottles and contents together with the stopper was weighed to the nearest 0.001g). The soil was covered with air free distilled water from the glass wash bottle and leave for period of 2 to 3hrs for soaking and water to fill the bottle to about half. Entrapped air is removed by heating the density bottle on a water bath or a sand bath. The bottle was placed in a vacuum desiccator for about 1 to 2 hrs. without the stopper until there is no further loss of air. The soil is gently stored in the density bottle with a clean glass rod, carefully washing off adhering particles from the rod with

some drops of distilled water while ensuring that no more soil particles are lost. The process was repeated till no more air bubbles were observed in the soil-water mixture while noting the constant temperature in the bottle and record. The stopper and the density bottle were wiped and re-weighed. Now empty the bottle been clean thoroughly and filled the density bottle with distilled water at the same temperature. The stopper was inserted in the bottle wiped dry from outside weighed, observation for two consecutive experiments were made for the same soil (CEP, 2018).

The specific gravity was then measured and calculated using the formula below:

$$\begin{aligned} \text{Specific Gravity} &= \frac{m^2 - m^1}{(m^4 - m^1) - (m^3 - m^2)} \\ &= \frac{m^2 - m^1}{A - B} \end{aligned} \quad 3.5$$

Where:

$$m^4 - m^1 = A$$

$$m^3 - m^2 = B$$

$m^1$  = weight of density bottle

$m^2$  = weight of density + weight of the sample

$m^3$  = weight of density + dry sample + distilled water

$m^4$  = weight of density bottle + distilled water.

### 3.5 Rainfall Simulation

Simulated rainfall is artificially produced “rain” used to ascertain the amount of soil losses in erosion measurement.

For the simulation, a small plot measuring 1.5m x 1.5m that is almost bare (in-situ) selected for the setup, the soil bin 130 cm x 90cm was hit with a hammer tapping the edges to evenly insert the bin in the soil considering the nature of the land surface (tabular or sloppy). Across all the locations, the slope of the area under study varied between 0.5 – 3% this was evident with locations in okigwe based on topographic features. The rainfall simulator and soil bin was developed in the Department of Agriculture and Bio-resources laboratory FUTO(plates 10 and 11).



Plate 10: Assembling of the soil bin



Plate 11: Coupling of the Rainfall simulator

Research showed that the (Madubuike and Chukwuma,2005), worked with rainfall intensities of 30 mm/hr, 60 mm/hr and 90 mm/hr to obtain variables in soil loss which aided in categorizing the soil viz: ‘Moderately erodible’, ‘Highly erodible’ and ‘very highly erodible’ soils. The rainfall simulator and soil bin after assemblage, were test run to assess its performance and was later taken to site where the rainfall intensity was measured. The rainfall intensity obtained was maintained in the entire process of simulation across the study areas.

### 3.6 Characteristics of the rainfall Simulator

**Drop Size:** In this work the drop size or drop diameter by volume of rain was between 2-3mm through calibrations, these corresponds with the design and development of an artificial rainfall simulator as discussed by Bryan, 1968. If the drop size of rain exceeds 6 or 7 mm and at a height of 5m, it will break further before hitting the soil thereby creating differentials in the uniformity of fall (Meyer, 1958).

**Rainfall Intensity:** Rainfall intensity or rate of rainfall for the research had single value intensity of 165mm/hr although this exceeded the rainfall intensity produced by Bryan, (1968).

**Height of fall:** The height of fall was made 1.5 m according to Bryan (1968). This was made to achieve an effective “rainfall”. Raindrop size from height less than 1.5 will likely give less kinetic energy and this will reduce the terminal velocity of the simulated rainfall. This is in confirmation with the work by Bryan, (1968) whose “fall-height” was 1.66m. At this height, larger drops attained 70-75% and smaller drops up to 90% of their terminal velocities (Laws 1941), data Bryan, (1968).

**Duration for simulation:** The rainfall simulation was carried out in-situ in three (3) different soil conditions or runs they include: **Dry run**, **Wet run** and **Saturated run**. The aim is to note the differences in soil loss under separate soil conditions.

For the dry run, this was performed in the true state of the soil originally in the field (in-situ). The wet run was performed *in-situ* 6 – 10 hours after the dry run. The saturated run was carried out 1 hour after the wet run when the soil is moist and is near saturation state. In all the runs, the soil losses obtained from the field were taken to the laboratory where it was dried and weighed to measure the amount of soil loss and other parameters such as bulk density, permeability etc.

### **3.7 Determination of soil Erodibility, using the selected Indices.**

**Clay Ratio:** Clay ratio was determined by calculating the amount of sand, silt and clay in percentages as can be found in appendix 32.

**Modified clay ratio:** Modified Clay ratio is another index for determining soil Erodibility. Other than the clay ratio, the modified clay ratio in addition has the presence of organic matter. This forms the binding or cementing effect in the soil, it also increases its aggregate stability and shear strength of the soil. The determination of the modified clay can be found in the appendix.

**Water Stable aggregate:** Water stable aggregate or aggregate stability index is a useful model for determining the Erodibility status of the soil. But this is solely applicable to aggregates greater than 2mm particles after mechanical analysis of the Particle sizes (Singh and Khera, 2008).

**Dispersion ratio:** The dispersion ratio was calculated using the amount of silt and clay in suspension at a depth of 50cm expressed in percentage of the total silt and clay as determined by mechanical analysis (Singh and Dhanya, 2011).

**Erosion ratio:** The erosion ratio is the quotient obtained by dividing the dispersion ratio by the ratio of colloid content to moisture equivalent. Moisture equivalent is the percentage of water which a soil can retain in opposition to a centrifugal force 1000 times that of gravity (Singh and Dhanya, 2011).

### **3.8 Analysis of Data**

The results obtained from the simulated rainfall (weighed soil losses) using the three conditions (dry, wet and saturated) was analyzed using ANOVA (Analysis of variance) to determine the significant differences statistically if any between the 3 soil conditions. The performance of each of the four Erodibility

indices (Clay ratio, Modified clay ratio, Dispersion ratio and Erosion ratio) was then studied using Correlation and Regression analysis obtained from plot. The predicted and experimental values were used for the indices under study to produce models equations comprising the different soil conditions or runs.

### **3.9 Calculations for the indices: ‘Clay’, ‘Modified clay’, ‘Dispersion’ and ‘Erosion’ ratios**

Soil properties such as clay, sand, silt, loam etc. make up the soil textural class. The clay, sand and silt composition of any soil explains the vulnerability of any location. A combination of organic matter and these properties above describes the Erodibility status of any location. Samples of the calculations for the indices are presented below; further calculations are shown in the appendix.

#### **Clay Ratio**

$$\frac{\% sand + \% silt}{\% clay}$$

3.1

(Nwaimo, 2010)

For Locations in Okigwe

Ezinnachi

$$\frac{40 + 100}{16} = 8.75\%$$

For Locations In Owerri

Ihiagwa Owerri West

$$\frac{135 + 25}{5} = 31.6\%$$

Locations in Orlu

Isiekenesi Ideato South

$$\frac{140 + 21.7}{3.3} = 49\%$$

### Modified Clay Ratio

$$\frac{\% \text{ sand} + \% \text{ silt}}{\% \text{ clay} + \% \text{ organic matter}} \quad 3.2$$

(Nwaimo, 2010)

For locations in okigwe

Ezinnachi

$$\frac{40 + 100}{16 + 1.16} = 8.15$$

For locations in Owerri

Ihiagwa Owerri west

$$\frac{135 + 25}{5 + 2.50} = 21.33$$

For location in Orlu

Isiekenesi Ideato South

$$\frac{140 + 21.7}{3.3 + 1.55} = 8.15$$

### Dispersion ratio

$$\text{Disperion ratio} = \frac{\% \text{ silt} + \text{clay in partilce size distribution}}{\text{Total \% silt} + \text{clay} \times 100} \quad 3.3$$

(Lutz,1934)

For Locations in Owerri

Ihiagwa

$$\text{Dispersion ratio} = \frac{2}{30} = 0.066$$

**Erosion ratio**

$$\text{Erosion ratio} = \frac{\text{Dispersion ratio}}{\text{colloid content} / \text{moisture equivalent}} \quad 3.4$$

(Lutz,1934)

$$\text{colloid content} / \text{moisture equivalent} = \frac{2}{10.6} = 0.188$$

$$\text{Erosion ratio} = \frac{0.066}{0.188} = 0.351$$

For Okigwe

Ezinnachi

$$\text{Dispersion ratio} = \frac{8}{116} = 0.069$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{8}{18.2} = 0.439$$

$$\text{Erosion ratio} = \frac{0.069}{0.439} = 0.157$$

For locations in Orlu

Isieknesi Ideato South

$$\text{Dispersion ratio} = \frac{1.1}{25} = 0.044$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{1.1}{13.4} = 0.082$$

$$\text{Erosion ratio} = \frac{0.044}{0.082} = 0.536$$

# CHAPTER FOUR

## RESULTS AND DISCUSSION

### 4.1 Identification of Various Soil Types in Imo State

The soil map is shown in Figure 4.1. From the map, there are nine soil types in Imo State.

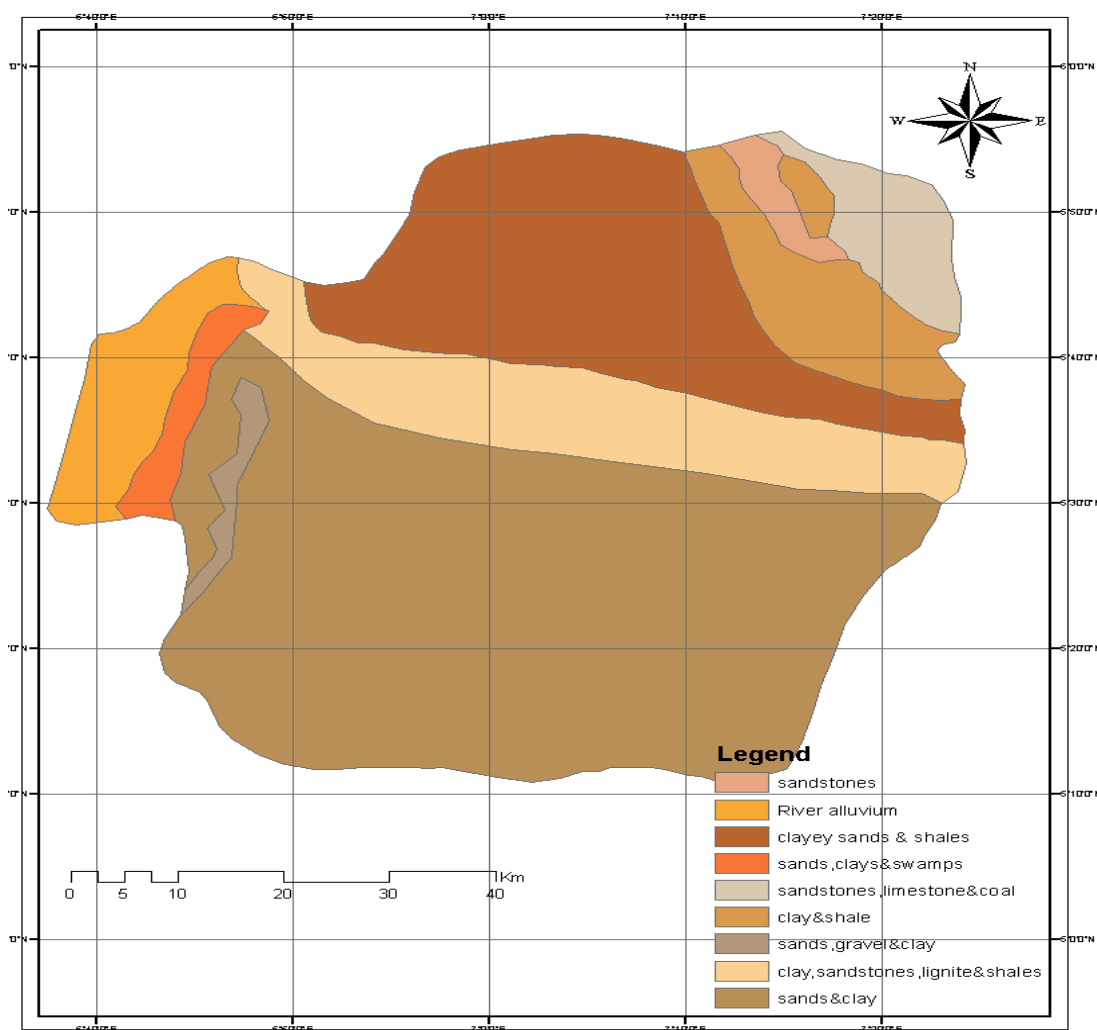


Fig. 4.1: Soil map of Imo state  
(Source: Okorafor *et al.*, 2018)

Table 4.1 Imo State soil group and locations

Imo State Soil region	Soil Group Location	Soil data Location
Clay and Shale (Ebenebe and Umuna- Palaocene	Ehime Mbanjo	Ugiri Mbanjo
Sandstone (Imo formation Inc) – Palaocene	Ideato North	Isiekenesi
Clay, Sand and Shale (Bende, Ameke, and Nanka stones)- Eocene	Orlu	Umuna Orlu
Sandstone, Lime stone and coal (Upper coal measures) – Maestriclitian-Danian	Okigwe	Okwelle, Ezinnachi, Okwe
Sands and Clay (Coastal plains Sands)- Plio-Pleistocene	Owerri West	Ihiagwa, Obinze
Sands, gravel and clay (Meander belts) – Holocene	Ohaji Egbema	Umuagwo,Umuokanne
Clay, Sandstone, Lignite and Shale	Ikeduru	Obazu Mbieri
Sands,clay and swamps (Sombreiro Deltaic Plane)- Pleistocene-Holocene	Oguta	*(a)
** (b)	** (b)	Onicha Ezinihitte

**Note:**\*(a) No location match

\*\* (b) No location match

The soil groups in Imo State, the established soil group for Imo State and the chosen locations can be found in Table 4.1 above. The data in the 1<sup>st</sup> and 2<sup>nd</sup> column formed a guide in the choice of the location with Onicha Ezinihitte not captured in all the soil groups and locations where they can be referenced to.

**Table 4.2:** Percentage of Area taken by soil type

SOIL TYPE	PERCENTAGE COVERAGE(%)
sands and clay	48.6
clay, sandstones and shales	20.3
clay sand stone, lignite and shales	12.2
clay and shale	6.3
river alluvium	4.8
sandstone, limestone and coal	3.6
sands clay and swamps	1.8
Sandstones	1.2
sand, gravel and clay	1.1

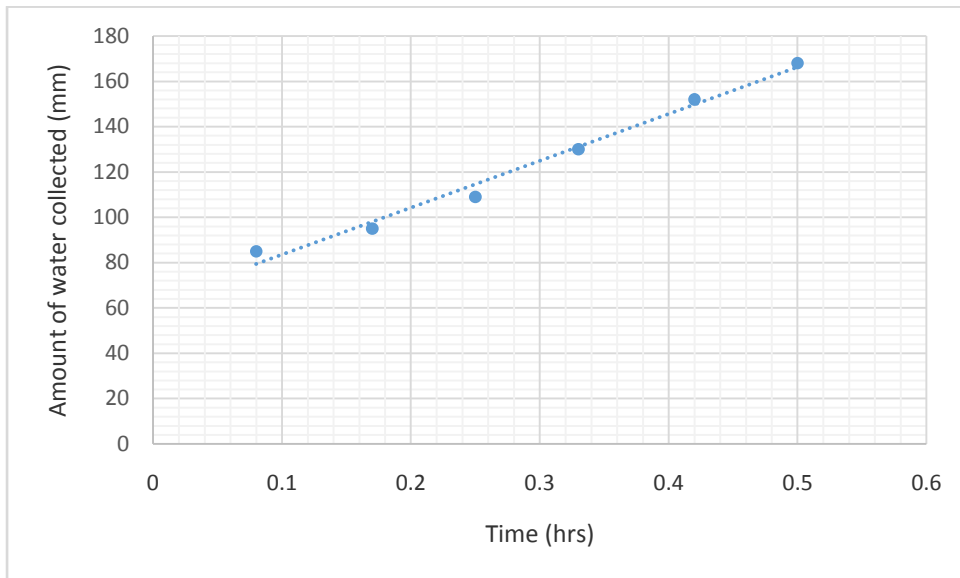
Source: Okorafor *et al.*, (2018)

Table 4.2 presents the percentage coverage of the different soil groups in Imo State. It shows the different percentage composition of the soil groups found in the study area (Imo state). According to the ranking in Table 4.2, the sand and clay has the highest value of percentage coverage at 48.6 %. It justifies the availability of this soil group in most areas and localities within Imo state (Fig. 4.1).

It is closely followed by the clayey sandstone and shales with percentage coverage of 20.3%, this soil group is mostly found within the regions of okigwe and Ideato. Another soil type that is third in the ranking is the clay, sandstones, lignite and shales which have percentage composition of 12.2. Clay and shales have 6.3 percent while river alluvium occupies 4.8 percent. Sandstones, Lime stones and coal has the percentage composition of 3.6 in the spread this clearly explain the absence of this particular soil group in some areas under study. The least in the composition is the sands, clay and swamp, sand stones, sand, gravel and clay which has the percentage composition of 1.8, 1.2 and 1.1 respectively This informs the absence of these soil types or very little presence in areas where they are found.

## 4.2 Rainfall intensity Determination

The result of rainfall intensity plot is as shown in Figure 4.2.



**Fig. 4.2:** Graph of Rainfall depth versus duration

$$\text{SLOPE} = \frac{132 - 100}{0.304 - 0.108} = \frac{32}{0.196} = 163.27 \text{ mm/hr}$$

$$\text{Rainfall intensity} = 163.27 \text{ mm/hr}$$

The intensity of rainfall result derived from the rainfall simulation was obtained by relating the amount of rainfall at various stages (depths) in (mm) against time in hours. The slope obtained was 163.27 mm/hr. This slope obtained is intensity of “rainfall” from a drop height of 1.5m. The rainfall intensity obtained and used in this study was higher than 125mm/hr Bryan (1968) and 30mm/hr, 60mm/hr and 90 mm/hr (Madubuike and Chukwuma,2005).

### **4.3 Soil loss and the Indices of Soil Erodibility (Clay ratio, Modified Clay ratio, water stable Aggregate, Dispersion ratio and Erosion ratio)**

The results of the soil losses, Clay ratio, Modified clay ratio, Dispersion ratio and Erosion ratio of the twelve Locations are shown in Table 4.2.

**Table 4.3:** Soil losses, clay, modified clay, dispersion and erosion ratios of the twelve Locations

S/N	Locations	Soil losses(tons/hc)			Indices of Erodibility (%)			
		DR	WR	SR	Modified clay ratio	clay ratio	Dispersion ratio	Erosion ratio
1	Ihiagwa, Owerri West	1.69	1.42	1.11	15.2	14.21	0.58	0.44
2	Onicha, Ezinihitte	1.86	1.64	1.48	25.55	20.14	0.65	0.48
3	Obinze, Owerri West	1.27	1.18	1.06	30.25	25.41	0.71	0.53
4	Obazu, Mbieri	1.65	1.36	0.99	35.65	30.25	0.71	0.57
5	Okwelle, Onuimo	3.5	3.09	2.59	43.11	33.62	0.73	0.65
6	Okwe, Onuimo	3.95	3.71	3.52	47.11	35.72	0.76	0.73
7	Ugiri, Isiala Mbanu	2.3	2.02	1.73	50.21	40.23	0.81	0.77
8	Ezinnachi, Okigwe	3.7	2.96	2.59	55.30	43.22	0.85	0.81
9	Isiekenesi, Ideato South	7.46	7.17	5.18	65.23	47.65	0.90	0.86
10	Umuna, Orlu	7.42	6.17	5.55	73.22	53.21	0.93	0.88
11	Umuagwo, Ohaji	7.1	6.05	5.49	77.10	55.25	0.97	0.89
12	Umuokanne, Ohaji	5.06	4.69	4.2	80.01	58.25	0.99	0.91

Key: DR:Dry Run

WR: Wet Run

SR: Saturated Run

The Analysis of Variance (Table 4.3) of the three simulated conditions of dry, wet and saturated runs indicate non-significant mean difference among their treatment means. It was observed from Table 4.3 that  $F_{\text{tabulated}} > F_{\text{calculated}}$ , and P-value was 0.54001 at 5% probability level. The non-significant means imply that soil losses obtained from the three simulated conditions as indicated by their means were not statistically significant. This means that any one of the three conditions can be applied and no clear differences amongst the three.

**Table 4.3:** Analysis of variance “Between Groups” and “Within groups” for the elements of simulated runs “dry, wet and saturated rainfall”.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F cal</i>	<i>P-value</i>	<i>F tab</i>
Between Groups	5.4848	2	2.7424	0.6278	0.54001	3.284918
Within Groups	144.15	33	4.3681			
Total	149.63	35				

The computation of the result of soil losses from the three simulated rainfall conditions Dry run (DR), Wet run (WR), Saturated run (SR) and the four selected Erodibility indices formed equations 4.1-4.4 and using regression analysis, their  $R^2$  values were obtained these equations can be used to calculate any index of choice for MCR, CR, ER and DSPR

$$\text{MCR} = 4.64\text{DR} + 6.43\text{WR} - 8.41\text{SR} \quad (R^2 = 0.7483) \quad 4.1$$

$$\text{CR} = 7.89\text{DR} + 6.97\text{WR} - 10.66\text{SR} \quad (R^2 = 0.7128) \quad 4.2$$

$$\text{DSPR} = 0.07 - 0.01\text{WR} + 0.02\text{SR} \quad (R^2 = 0.0661) \quad 4.3$$

$$\text{ER} = 0.340 + 0.088\text{DR} + 0.092\text{WR} - 0.088\text{SR} \quad (R^2 = 0.6147) \quad 4.4$$

Where MCR = modified clay ratio

CR = Clay ratio

DSPR = Dispersion ratio

ER = Erosion ratio

DR = dry run(mm)

WR = wet run (mm)

SR = saturated run (mm)

**Table 4.5:** Results of Regression model statistics for MCR

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0							
DR	4.64	15.81	0.29	0.78	-31.12	40.41	-31.12	40.41
WR	6.43	14.15	0.45	0.66	-25.59	38.45	-25.59	38.45
SR	-8.41	13.56	-0.62	0.55	-39.08	22.25	-39.08	22.25

**Table 4.6:** ANOVA of the Regression model for MCR

ANOVA					
	df	SS	MS	F	Sig. F
Regression	3	3975.4	1325.13	8.9181	0.0062
Residual	9	1337.29	148.59		
Total	12	5312.69			

**Table 4.7:** Results of Regression model statistics for CR

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0							
DR	7.89	26.00	0.30	0.77	-50.93	66.72	-50.93	66.72
WR	6.97	23.28	0.30	0.77	-45.70	59.63	-45.70	59.63
SR	-10.66	22.30	-0.48	0.64	-61.10	39.78	-61.10	39.78

**Table 4.8:** ANOVA of the Regression model for CR

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	8976.65	2992.22	7.4440	0.0106
Residual	9	3617.68	401.96		
Total	12	12594.33			

**Table 4.9:** Results of Regression model statistics for Dispersion ratio

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0.07	0.00	17.96	0.00	0.06	0.08	0.06	0.08
DR	0.00	0.01	-0.53	0.61	-0.02	0.02	-0.02	0.02
WR	-0.01	0.01	-1.39	0.20	-0.03	0.01	-0.03	0.01
SR	0.02	0.01	2.17	0.06	0.00	0.03	0.00	0.03

**Table 4.10:** ANOVA for Dispersion ratio

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	0.00058	0.00019	4.25384	0.04508
Residual	8	0.00036	0.00005		
Total	11	0.00094			

**Table 4.11:** Results of Regression model statistics for Erosion ratio

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0.340	0.247	1.377	0.206	-0.229	0.909	-0.229	0.909
DR	0.088	0.553	0.159	0.878	-1.187	1.363	-1.187	1.363
WR	0.020	0.493	0.040	0.969	-1.118	1.157	-1.118	1.157
SR	-0.088	0.471	-0.187	0.857	-1.175	0.999	-1.175	0.999

**Table 4.12:** ANOVA For Erosion Ratio

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	0.101566	0.033855	0.188857	0.901051
Residual	8	1.434108	0.179264		
Total	11	1.535674			

The regression model was used to generate predicted and experimental values of Modified clay ratio(MCR), Clay ratio(CR), Dispersion ratio (DR) and Erosion ratio(ER)values from the experimental values shown in Table 4.13 and Table 4.14.

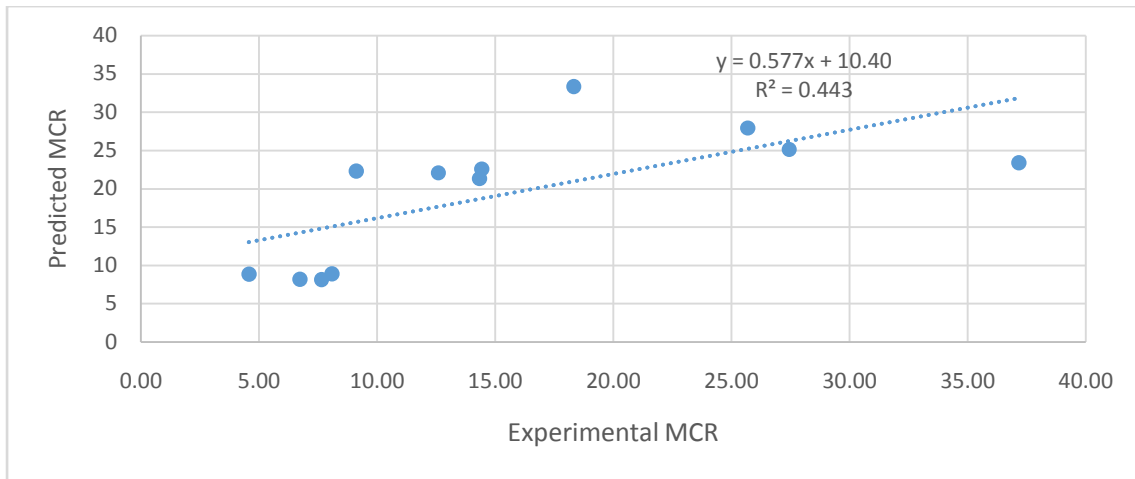
**Table 4.13:** Predicted and experimental values of the CR and MRC

<b>Locations</b>	<b>Predicted CR</b>	<b>Experimental CR</b>	<b>Predicted MRC</b>	<b>Experimented MRC</b>
Ihiagwa, Owerri west	11.40	8.55	7.64	8.15
Onicha, Ezinihitte	10.33	8.75	6.73	8.2
Obinze, Owerri West	6.95	9.34	4.57	8.87
Obazu, Mbieri	11.95	9.43	8.08	8.92
Okwelle, Onuimo	21.55	31.6	14.33	21.33
Okwe, Onuimo	19.50	31.86	12.59	22.08
Ugiri, Isiala Mbano	13.79	31.98	9.12	22.32
Ezinnachi, Okigwe	22.22	32	14.43	22.58
Isiekenesi, Ideato South	53.62	33.2	37.17	23.39
Umuna Orlu Umuagwo,	42.39	48.04	27.44	25.13
Ohaji Umuokanne,	39.67	48.96	25.69	27.93
Ohaji	27.84	49	18.32	33.34

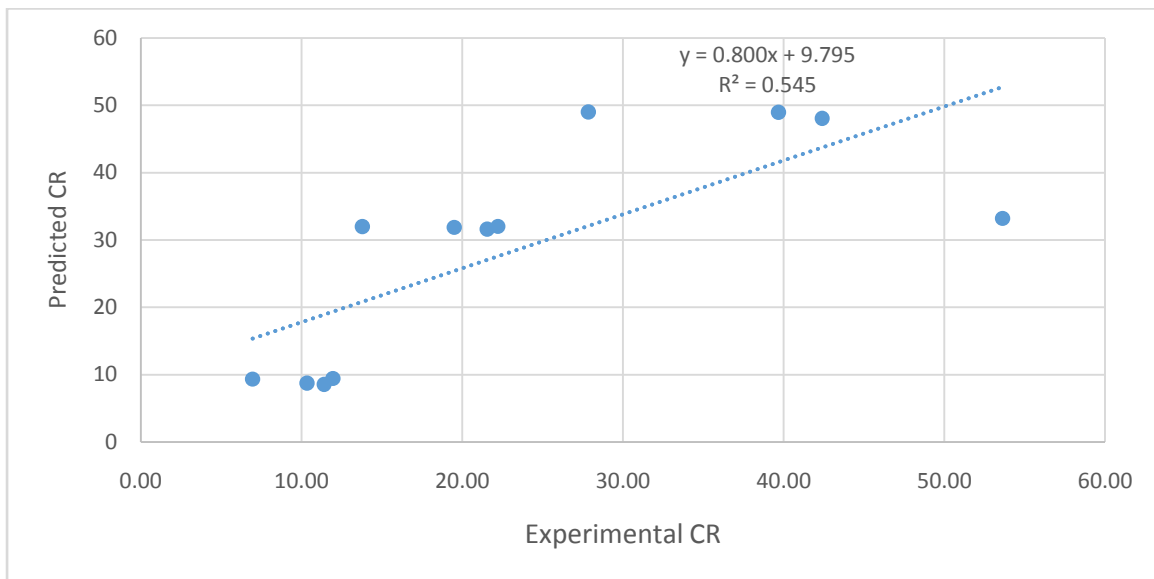
**Table 4.14** Predicted and experimental values of Dispersion ratio and Erosion ratio

Locations	Predicted DSPR	Experimental DSPR	Predicted ER	Experimental DR
Ihiagwa, Owerri west	11.40	8.55	7.64	8.15
Onicha, Ezinihitte	10.33	8.75	6.73	8.15
Obinze, Owerri West	6.95	9.34	4.57	8.87
Obazu, Mbieri	11.95	9.43	8.08	8.92
Okwelle, Onuimo	21.55	31.6	14.33	21.33
Okwe, Onuimo	19.50	31.86	12.59	22.08
Ugiri	13.79	31.98	9.12	22.32
Ezinnachi	22.22	32	14.43	22.38
Isiekenesi	53.62	33.2	37.17	23.39
Umuna, Orlu	4.39	48.04	27.44	25.13
Umuagwo, Ohaji	39.67	48.96	25.69	27.93
Umuokanne, Ohaji	27.84	49	18.32	33.34

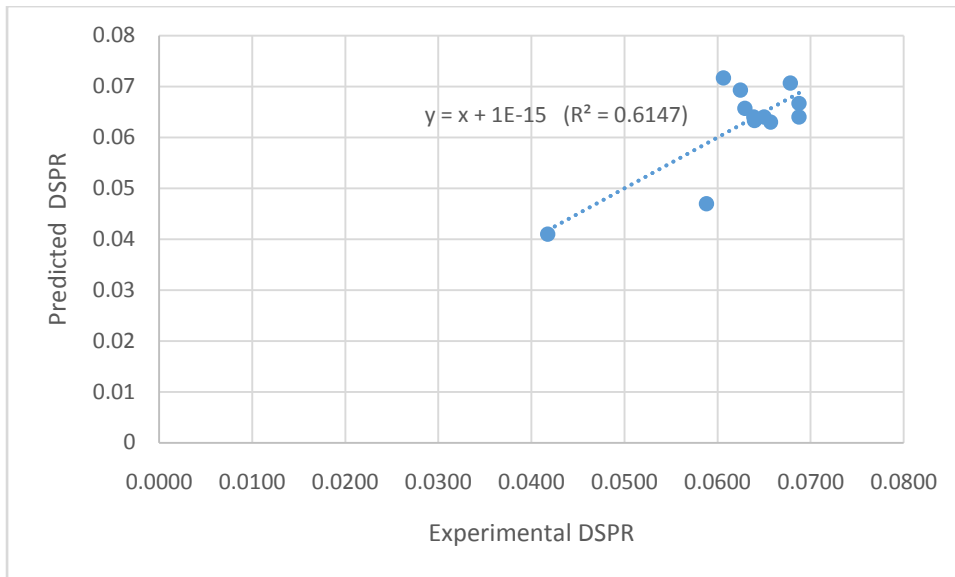
The model was validated using the plot of predicted and experimental for Modified clay and Clay ratio, Dispersion ratio as well as Erosion ratio shown in Figures 4.3,4.4,4.5 and 4.6 respectively. The R-square values are 0.4435, 0.5454,0.6147 and 0.3363. It implies that using either dry or wet or saturated rainfall (simulated) data, the Modified Clay ratio, Clay ratio, Dispersion ratio and Erosion ratio of Imo State can be predicted up to 4.4%, 5.5%, 6.1% and 3.4% performance respectively.



**Fig. 4.3:** Plot of Predicted and experimental Modified clay ratio

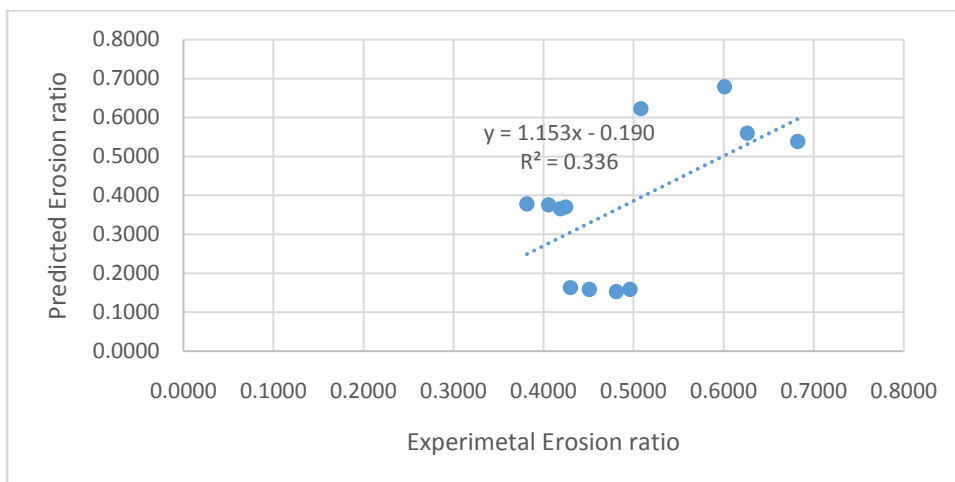


**Fig. 4.4:** Plot of Predicted and experimental clay ratio (CR)



**Figure 4.5:** Plot of predicted DSPR and experimental DSPR

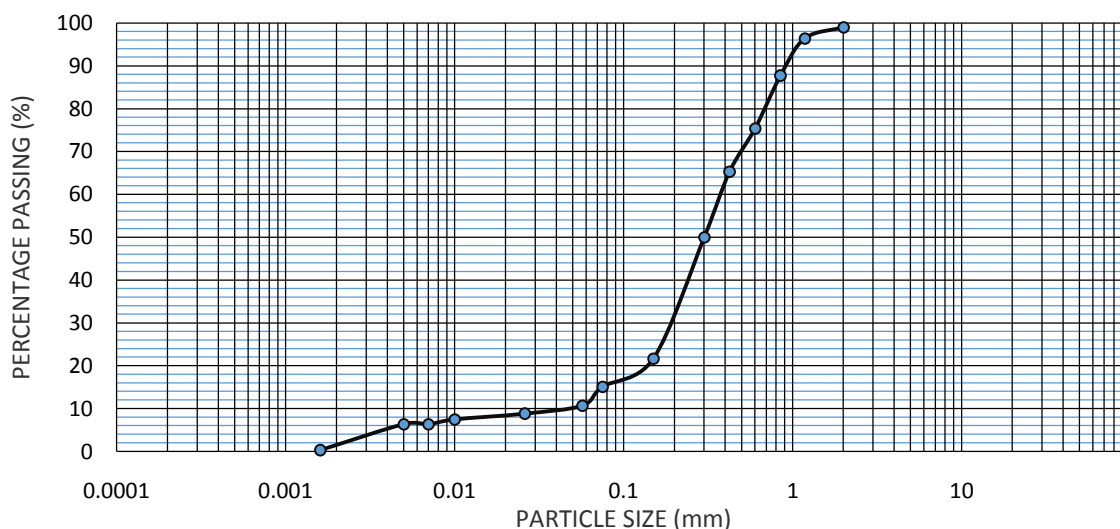
The cluster of plots as seen in fig.4.5 was attributed to slim variations in both experimental and predicted values for the Dispersion ratio index.



**Figure 4.6:** Plot of predicted Erosion ratio and experimental Erosion ratio

#### 4.4 Particle size Distribution

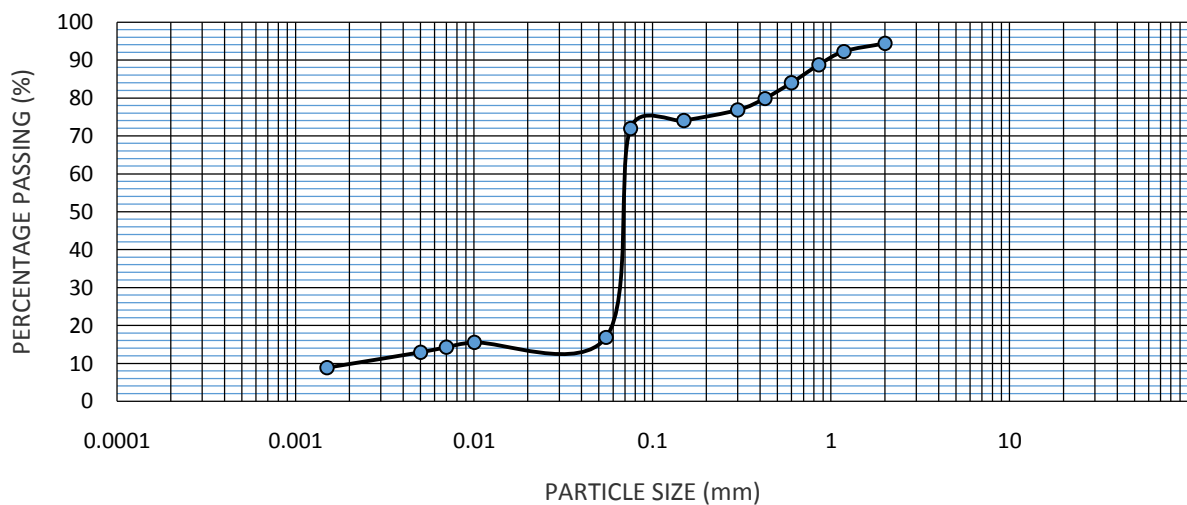
The results of the particle size analysis (grain size) for Umuagwo in Orlu, Ezinnachi in Okigwe, and Onicha Ezinihitte in Owerri are shown in Figures 4.4 to 4.6. From the data obtained in the grain size distribution analysis as found in appendix 5 to 12 covering all the locations under study, it is interesting to note that the soil sizes were all below the 2mm sieve size pan, this is further showed in figure 4.4. Also within 0.08mm to 2mm sieve size; there was higher percentage of particle passage which represents about 80 % and 20% from 0.07 to 0.003mm sieve. It implies that, 80% mass of the soil fall between sand and fine gravel while less than 20% of the soil are silt with no clay present. The same was observed for the three other locations in Orlu namely Umuna, Umuokanne and Isiekenesi as shown in Appendix.



CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

**Fig.4.7:** Particle size Distribution for Umuagwo Ohaji in Orlu.

In figure 4.7, all the particles were less than the 2mm sieve size pan. It was also observed that there was a gradual decrease in particle passage from 0.075mm to 2mm sieve size which is about 20 per cent while there is a high passage of particle 0.065mm to 0.08mm representing 52 per cent particle passing. Between 0.0014mm – 0.01mm sieve were fairly uniform representing 18 per cent of the soil. The implication is that 20 per cent of the soil was mainly medium sand and fine gravel from the chat, 52 per cent of the soil was fine sand whereas 18 per cent was made of silt. With these result it can be deduced that the soil in these areas are prone to erosion when there is heavy rainfall with high intensity. The observation is in agreement with Isikwue *et al*,2012. Other locations in Okigwe such as Okwelle, Okwe and Ugiri share similar pattern in particle distributions as shown in Appendix.



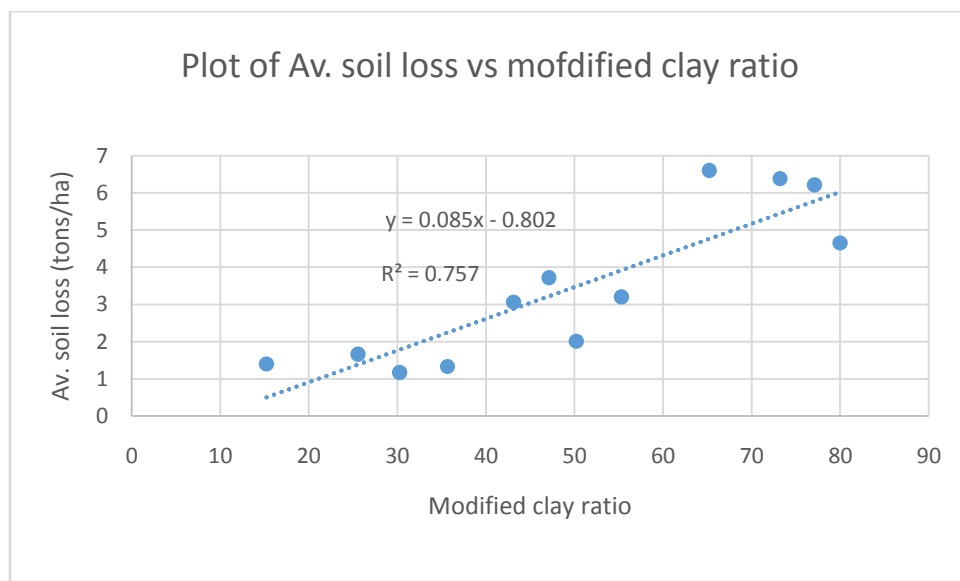
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

**Fig.4.8:** Particle size Distribution for Ezinnachi in Okigwe.

From the plot of 4.8 and other locations shown appendix in okigwe, a change can be seen in the particle size distribution curve. This indicates the different geographical /soil textural information's when compared with other regions.

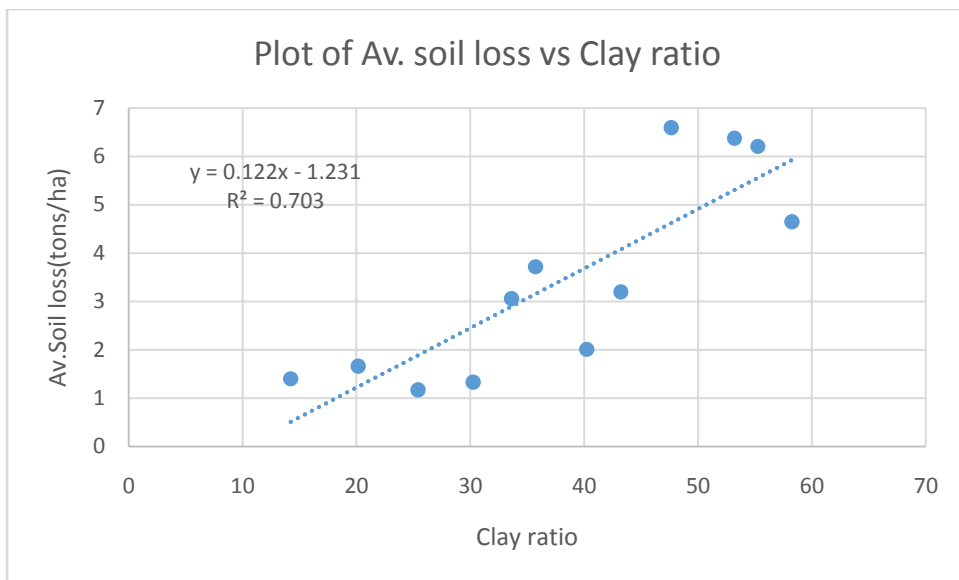
Results obtained from the determination of water stable aggregate (soil aggregates > 2 mm) showed that from all the locations, the percentage weight from water stable aggregate were below 2mm sieve pan that is <2mm which suggest that a reduction in the resistance of soil aggregates increases the vulnerability of the soil to erosion. Aggregate stability is important because it governs the ease with which large aggregates above the erosion threshold may be broken down to small aggregates or separates which are vulnerable to erosion (Isikwue *et al.* 2012).

#### 4.4 Relationship of Average Soil Loss and the Indices of Soil Erodibility.



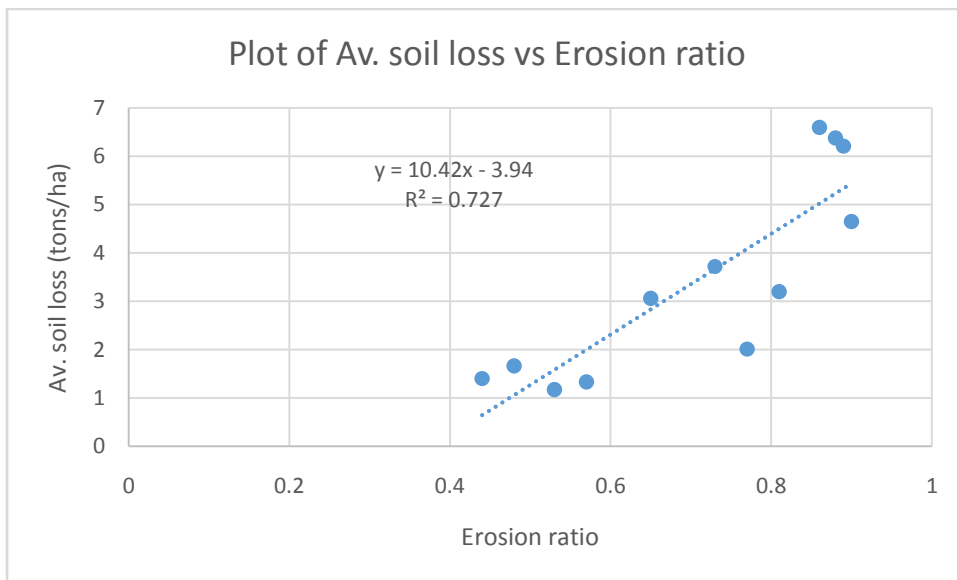
**Fig.4.9: Plot of Average soil loss and Modified Clay ratio**

The plot above in fig.4.9 shows the plot of average soil loss against Modified clay ratio. From the plot, it was observed that the  $R^2$  value is 0.7579 which represent a performance probability of 75%. This describes performance rating of the model as good.



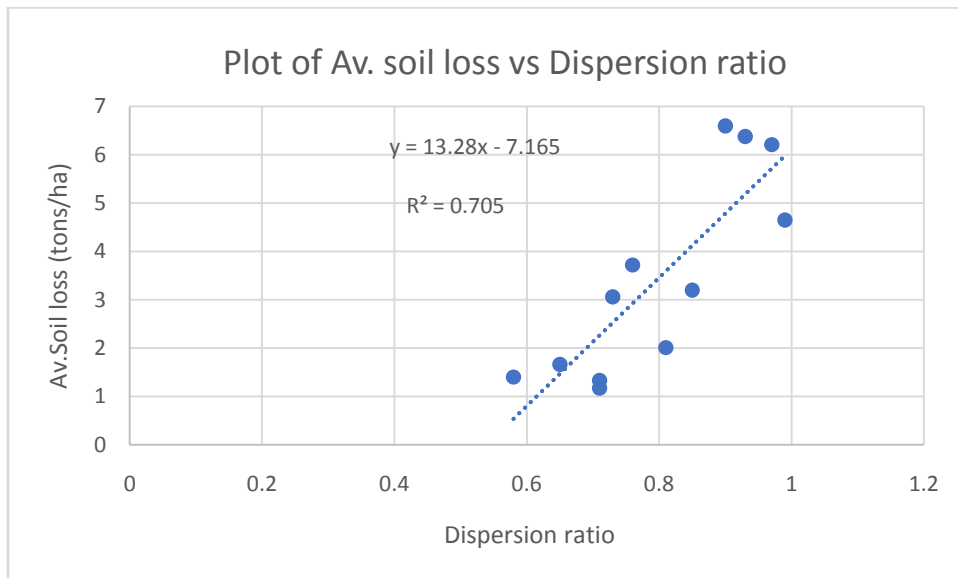
**Fig.4.10: Plot of Average soil loss and Clay ratio**

The plot above in fig.4.10 show the plot of average soil loss against the Clay ratio. The plot revealed an  $R^2$  value of 0.7036 which describes a performance probability rate of 70%. This further describe the action of this index as high performing and is rated with the Modified clay ratio good.



**Fig.4.11: Plot of Average soil loss and Erosion ratio**

The plot above in fig 4.11 shows the relationship between the average soil loss and the erosion ratio. The plot showed  $R^2$  value of 0.7279 which represents a performance probability of 72%. The index performance was rated good. Having same average performance with the Clay and Modified clay ratios.



**Fig 4.12: Plot of Average. Soil loss and Dispersion ratio**

Figure 4.12 shows the relationship between average soil loss and the Dispersion ratio. The plot shows a negative trend with an  $R^2$  value of 0.7056 which represents a performance probability of 70%. This also is acceptable due to its average performance same as the other indices.

Summary: The  $R^2$  values for the indices of measuring Erodibility all have average performance between 70 - 75 per cent. This entails that the indices are all reliable tool for the evaluation studies on erosion in Imo State.

**Table 4.15:** Organic matter content for the selected soils in Imo State

S/N	Soil data Location	Average Values (%)	Standard Deviation from Average
1	Ihiagwa Owerri West	2.50	0.090
2	Onicha Ezinihitte	2.40	0.040
3	Obinze, Owerri west	1.84	0.098
4	Obazu, Mbieri	2.35	0.050
5	Okwelle, Onuimo	0.71	0.046
6	Okwe, Onuimo	0.77	0.020
7	Ugiri, Mbanu	1.04	0.040
8	Ezinnachi, Okigwe	1.16	0.020
9	Isiekenesi Ideato South	1.55	0.140
10	Umuna, Orlu	1.34	0.120
11	Umuagwo Ohaji	3.95	0.065
12	Umuokanne Ohaji	2.24	0.220

From table 4.15 above, Umuagwo Ohaji from findings, had the high values of organic matter content of the soil with an average value of 3.9. Ihiagwa owerri west and Onicha Ezinihitte with average values of 2.50 and 2.40 respectively. Okwelle and Okwe in Onuimo has the lowest values 0.71 and 0.77. The implication is that soil in Okwelle and Okwe in Onuimo are more vulnerable to erosion attacks than those at Ihiagwa owerri west and Onicha Ezinihitte. The shear strength of soils in Owerri, Okigwe and Orlu are shown in Tables 4.16 to 4.18.

**Table 4.16:** Shear Strength Computation for Owerri

SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_{n+}$ (KN/m <sup>2</sup> )	$\tau$ (KN/m <sup>2</sup> )
Ihiagwa, Owerri West	4	24	177.8	83.2
Onicha, Ezinihitte	3	25	177.8	85.9
Obinze, Owerri West	4	25	177.8	86.9
Obazu, Mbieri	5	25	177.8	87.9

Table 4.16 shows that the shear strength values of Owerri and environs. The Table showed that Obazu, Mbieri has the high shear strength value of 87.9 (KN/m<sup>2</sup>) from the group this was followed by Obinze, Owerri west 86.9 (KN/m<sup>2</sup>), Onicha, Ezinihitte 85.9 (KN/m<sup>2</sup>) and Ihiagwa, Owerri west 83.2 (KN/m<sup>2</sup>) respectively.

**Table 4.17:** Shear Strength Computation for Okigwe

SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_n$ (KN/m <sup>2</sup> )	$\tau$ KN/m <sup>2</sup>
Okwelle, Onuimo	9	26	177.8	95.7
Okwe, Onuimo	10	24	177.8	89.2
Ugiri Isiala Mbanjo	8	24	177.8	87.2
Ezinnachi, Okigwe	8	25	177.8	90.9

Table 4.17 also shows the shear strength of the locations in Okigwe. Okwelle has high shear strength value of 95.7KN/m<sup>2</sup>, this is followed by Ezinnachi with shear strength value of 90.9 KN/m<sup>2</sup>. Ugiri and Okwe had shear strength values behind Okigwe and Ezinnachi (87.2 KN/m<sup>2</sup> and 89.2 KN/m<sup>2</sup>) respectively.

**Table 4.18:** Shear Strength Computation for Orlu

SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_n$ (KN/m <sup>2</sup> )	$\tau$ KN/m <sup>2</sup>
Isiekenesi, Ideato South	6	22	177.8	77.8
Umuna, Orlu	6	24	177.8	85.2
Umugwo, Ohaji	5	24	177.8	84.2
Umuokanne, Ohaji	5	22	177.8	76.8

Results from Table 4.18 showed that Umuna orlu has shear strength value of 85.2 KN/m<sup>2</sup>, it was followed by Umuagwo 84.2 KN/m<sup>2</sup>. Isiekenesi and Umuokanne had shear strength values of 76.8 KN/m<sup>2</sup> and 77.8 KN/m<sup>2</sup> respectively.

Other shear stress results are found in appendix as computed with the shear strength to produce plot of normal stresses.

**Table 4.19:** Soil pH for Imo State

S/N	LOCATIONS	Average	Standard Deviation
1	Ihiagwa, Owerri West	8.01	0.01
2	Ezinnachi, Okigwe	6.47	0.25
3	Obinze, Owerri West	7.98	0.07
4	Obazu, Mbieri	8.02	0.01
5	Okwelle, Onuimo	6.48	0.10
6	Okwe, Onuimo	6.75	0.06
7	Ugiri, Isiala Mbano	6.64	0.02
8	Onicha, Ezinihitte	8.04	0.02
9	Isiekenesi, Ideato South	8.56	0.07
10	Umuna, Orlu	8.60	0.08
11	Umuagwo, Ohaji	8.43	0.15
12	Umuokanne, Ohaji	8.43	0.10

Table 4.19, showed the result of the  $p^H$  values which describes the acidic, sodic or alkaline properties of the soil. From the table above locations in Okigwe and environs showed slightly acidic whose values were Ezinnachi (6.47), Okwelle (6.8), Ugiri (6.64) and Okwe (6.75). This could be as a result of the soil textural class. Obinze had  $P^H$  of 7.98 which fall within the neutral scale. Mbieri, Umuagwo, Umuna, Umuokanne and Isiekenesi have values of  $P^H$  8.02, 8.43, 8.60, 8.43 and 8.56 respectively. This results showed that the soils are relatively alkaline. Soil properties such as textural classification could be likened to the possibility of the variations.

**Table 4.20: Coefficient of Permeability**

S/N	Location	D <sub>10</sub> (mm)	D <sub>10</sub> <sup>2</sup> (mm) <sup>2</sup>	K(cm/s)
1	Ihiagwa, Owerri West	0.0300	0.000900	9.0 x 10 <sup>-4</sup>
2	Onicha, Ezinihitte	0.0300	0.000900	9.0 x 10 <sup>-4</sup>
3	Obinze, Owerri West	0.0360	0.012960	1.296 x 10 <sup>-2</sup>
4	Obazu, Mbieri	0.0300	0.000900	9.0 x 10 <sup>-4</sup>
5	Okwelle, Onuimo	0.0025	0.000625	6.25 x 10 <sup>-4</sup>
6	Okwe, Onuimo	0.0023	0.000529	5.29 x 10 <sup>-4</sup>
7	Ugiri, Isiala Mbano	0.0025	0.000625	6.25 x 10 <sup>-4</sup>
8	Ezinnachi, Okigwe	0.0020	0.000400	4.0 x 10 <sup>-4</sup>
9	Isiekenesi, Ideato South	0.0450	0.002025	2.025 x 10 <sup>-3</sup>
10	Umuna, Orlu	0.0400	0.001600	1.6 x 10 <sup>-3</sup>
11	Umuagwo, Ohaji	0.0500	0.002500	2.5 x 10 <sup>-3</sup>
12	Umuokanne, Ohaji	0.0450	0.002025	2.205 x 10 <sup>-3</sup>

The coefficient of permeability for the locations ranged between 1.296 x 10<sup>-2</sup>/s - 9.0 x 10<sup>-4</sup> cm/s as indicated in Table 4.20. These results showed that Obinze had the high permeability coefficient of 1.296 x 10<sup>-2</sup>/s while Onicha and Ihiagwa had low permeability coefficient of 9.0 x 10<sup>-4</sup> in ranking.

**Table 4.21:** Specific Gravity for Owerri

Locations	Ihiagwa, Owerri west	Onicha, Ezinihitte	Obinze Owerri west	Obazu, Mbieri
$G_L$	1.000	1.000	1.000	1.000
$G_s$	2.63	2.70	2.65	2.75

Table 4.21 above shows the specific gravity of locations under study in Owerri. The values ranged from 2.63 -2.78 across the locations. Onicha from findings conforms with the standard specific gravity of 2.7 as revealed by Isikwue *et al.*, 2012. Others are Mbieri with specific gravity of 2.78, Obinze 2.65 and Ihiagwa 2.63 respectively.

**Table 4.22:** Bulk and Dry Unit Weight ( $\rho_b$  &  $\rho_d$ ) for Owerri

Locations	Ihiagwa, Owerri west	Onicha, Ezinihitte	Obinze, Owerri west	Obazu, Mbieri
Bulk unit wt. ( $\rho_b$ ) $Mg/m^3$	1.63	1.50	1.57	1.58
Dry unit wt. ( $\rho_d$ ) ( $Mg/m^3$ )	1.47	1.35	1.42	1.42
Dry unit wt. ( $\rho_d$ ) ( $KN/m^3$ )	14.7	13.5	14.2	14.2

Table 4.22 shows the Bulk and Dry Unit weight of the soil in Owerri environs.

From the Table above, Ihiagwa has the highest values of bulk unit weight and dry unit weight  $1.63 Mg/m^3$  and  $14.7 KN/m^3$  respectively. Mbieri ( $1.58 Mg/m^3$ ,  $14.2 KN/m^3$ ), Obinze ( $1.57 Mg/m^3$ ,  $14.2 KN/m^3$ ) and Onicha ezinihitte ( $1.50 Mg/m^3$ ,  $13.5 KN/m^3$ ) bulk unit weight and dry unit weight varied across the locations.

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Conclusion

This study was set up to evaluate the performance of some selected indices which are used in the measurement of soil Erodibility for Imo State soils.

The following conclusion were made

- i. The Correlation/Regression analysis of the soil losses against the selected indices, the Modified clay, Clay, Erosion and Dispersion ratios have performance ratings of 0.7579, 0.7036, 0.7279 and 0.7056 respectively. This suggests that with further data modification and widened experiments, the performance of the indices will be enhanced especially for Imo State and environs.
- ii. All the selected indices with the exception of the water stable aggregate can be reliably used to predict erosion status of soils of Imo State.
- iii. Water stable aggregate condition for application as an index could not be determined due to aggregate sizes of the soil (below 2mm) sieve size. For soils to be analyzed using the index, the particle size of the aggregate should be above 2mm as described in section 2.5.3.
- iv. Regression model equations for determining the suitable index were developed using inputs such as the rainfall conditions from the simulated rainfall under different (wet, dry and saturated) conditions.

## **5.2 Recommendations**

It is recommended that the information and data produced on the Clay ratio, Modified clay ratio, Water stable aggregate, Dispersion ratio and Erosion ratio be put to use and developed for further studies. Also, it is recommended that the research be extended to other parts of the state to have a broader spectrum information and data for the development of the models in erosion prediction for Imo State soils in particular, and south eastern Nigeria in general.

## **5.3 Contribution to Knowledge**

1. Application of indices of Erodibility in the study of erosion has brought about a shift in paradigm. This is because the indices take a wider coverage of all the components responsible for causing erosion such include clay, sand, silt, organic matter, and equivalent moisture composition.
2. The result of the experimental, analysis shows that Clay, Modified Clay, Dispersion and Erosion ratios are reliable indices for the study of soil Erodibility in Imo State, while water stable aggregate is specifically for agricultural soil having particle size above 2mm.
3. These selected indices can produce more precise results when they could be merged into a concise erosion prediction model.

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## APPENDIX

### SAMPLE: Orlu 1

#### GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER SEDIMENTATION TEST METHOD)

##### 1) Wet Sieving

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 51.1g

Therefore, mass lost to washing (mass of fines) = 8.9g

Percentage (%) of fines = 14.8%

##### 2) Dry sieving of Residue, Mass = 51.1g

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	0.6	59.4	99.0
1.180	1.6	57.8	96.4
0.850	5.2	52.6	87.7
0.600	7.4	45.2	75.4
0.425	6.1	39.2	65.3
0.300	9.2	30.0	50.0
0.150	17.0	13.0	21.7
0.075	4.0	9.1	15.1
Pan	0.2	8.9	-

##### 3) Hydrometer Readings on Filtrate

###### Data:

Initial Mass of Sample, M,	=	60g
Test Temperature	=	23.5°C
Meniscus Correction ( $C_m$ )	=	+0.5
Temperature Correction ( $M_t$ )	=	+1.0
Dispersant Correction (x)	=	3.5

**SAMPLE: Orlu 2**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 51.8g

Therefore, mass lost to washing (mass of fines) = 8.2g

Percentage (%) of fines = 13.7%

**2) Dry sieving of Residue, Mass = 51.8g**

<b>Sieve Size (mm)</b>	<b>Mass Retained (g)</b>	<b>Mass Passing (g)</b>	<b>Percentage Passing (%)</b>
2.000	0.8	59.2	98.7
1.180	2.2	57.0	95.0
0.850	5.2	51.8	86.4
0.600	8.8	43.0	71.7
0.425	6.7	36.3	60.5
0.300	9.8	26.5	44.2
0.150	14.7	11.8	19.7
0.075	3.5	8.3	13.9
Pan	0.1	8.7	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample,  $M$ , = 60g

Test Temperature = 23.5°C

Meniscus Correction ( $C_m$ ) = +0.5

Temperature Correction ( $M_t$ ) = +1.0

**SAMPLE: Orlu 3**

**GRAIN SIZE DISTRIBUTION ANALYSIS ((HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g  
Weight of sample after washing and drying = 58.1g  
Therefore, mass lost to washing (mass of fines) =9.9g  
Percentage (%) of fines= 16.5%

**2) Dry sieving of Residue, Mass = 58.1g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	0.7	59.3	98.8
1.180	1.6	57.7	96.1
0.850	5.3	52.4	87.3
0.600	7.9	44.5	74.1
0.425	7.0	37.4	62.4
0.300	9.5	28.0	46.6
0.150	14.1	13.8	23.0
0.075	3.7	10.1	16.8
Pan	0.2	9.9	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M, = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Orlu 4**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g  
Weight of sample after washing and drying = 50.8g  
Therefore, mass lost to washing (mass of fines) = 9.2g  
Percentage (%) of fines = 15.3%

**2) Dry sieving of Residue, Mass = 50.8g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	7.8	59.2	98.7
1.180	17.4	57.5	95.8
0.850	49.8	52.5	87.5
0.600	7.6	44.9	74.8
0.425	6.7	38.7	64.5
0.300	9.8	28.9	48.2
0.150	15.3	13.6	22.7
0.075	5.0	9.4	15.6
Pan	0.2	9.2	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M, = 60g  
Test Temperature = 23.5°C  
Meniscus Correction (C<sub>m</sub>) = +0.5  
Temperature Correction (M<sub>t</sub>) = +1.0  
Dispersant Correction (x) = 3.5

**SAMPLE: Okigwe 1**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 16.9g

Therefore, mass lost to washing (mass of fines) = 43.1g

Percentage (%) of fines = 71.8%

**2) Dry sieving of Residue, Mass = 16.9g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	3.4	56.6	94.4
1.180	1.3	55.4	92.3
0.850	2.7	53.2	88.7
0.600	2.8	50.4	84.0
0.425	2.5	47.9	79.9
0.300	1.9	46.1	76.8
0.150	1.7	44.4	74.0
0.075	1.3	43.1	71.9
Pan	0.0	43.1	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M, = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Okigwe 2**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 17.5g

Therefore, mass lost to washing (mass of fines) = 42.5g

Percentage (%) of fines = 17.5%

**2) Dry sieving of Residue, Mass = 48.7g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	3.7	56.3	93.8
1.180	1.6	54.7	91.1
0.850	2.5	52.2	87.0
0.600	2.4	49.8	83.0
0.425	2.3	47.5	79.2
0.300	1.7	45.8	76.3
0.150	1.7	44.0	73.4
0.075	1.4	42.6	71.0
Pan	0.0	42.5	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M, = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Okigwe 3**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 16.4g

Therefore, mass lost to washing (mass of fines) = 43.6g

Percentage (%) of fines = 72.7.4%

**2) Dry sieving of Residue, Mass = 16.4g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	3.8	56.2	93.7
1.180	1.8	54.4	90.7
0.850	2.6	51.8	86.4
0.600	2.3	49.6	82.6
0.425	1.9	47.7	79.5
0.300	1.7	46.0	76.7
0.150	1.1	44.9	74.9
0.075	1.3	43.6	72.7
Pan	0.0	43.6	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M <sub>i</sub>	=	60g
Test Temperature	=	23.5°C
Meniscus Correction (C <sub>m</sub> )	=	+0.5
Temperature Correction (M <sub>t</sub> )	=	+1.0
Dispersant Correction (x)	=	3.5

**SAMPLE: Okigwe 4**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 17.2g

Therefore, mass lost to washing (mass of fines) = 42.8g

Percentage (%) of fines = 71.3%

**2) Dry sieving of Residue, Mass = 17.2g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	4.0	56.0	93.3
1.180	1.2	54.8	91.3
0.850	2.3	52.5	87.5
0.600	2.2	50.3	83.9
0.425	2.5	47.9	79.8
0.300	1.7	46.1	76.9
0.150	1.5	44.6	74.4
0.075	2.4	42.8	71.4
Pan	0.0	42.8	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample,  $M$ , = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Owerri 1**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 47.6g

Therefore, mass lost to washing (mass of fines) = 12.4g

Percentage (%) of fines = 20.0%

**2) Dry sieving of Residue, Mass = 47.6g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	1.1	58.9	98.2
1.180	3.3	55.6	92.7
0.850	4.7	50.9	84.9
0.600	7.0	43.9	73.2
0.425	5.6	38.3	63.9
0.300	9.7	28.6	47.7
0.150	10.7	17.9	29.9
0.075	5.3	12.7	21.1
Pan	0.2	12.5	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample,  $M$ , = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Owerri 2**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 48.7g

Therefore, mass lost to washing (mass of fines) = 11.3g

Percentage (%) of fines = 18.8%

**2) Dry sieving of Residue, Mass = 48.7g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	1.1	58.9	98.1
1.180	3.6	55.3	92.1
0.850	6.7	50.3	83.9
0.600	6.8	43.6	72.6
0.425	6.1	37.5	62.5
0.300	9.3	28.2	47.0
0.150	11.6	16.6	27.7
0.075	5.2	11.5	19.1
Pan	0.2	11.6	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample,  $M_i$  = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

**SAMPLE: Owerri 3**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g

Weight of sample after washing and drying = 48.4g

Therefore, mass lost to washing (mass of fines) = 11.6g

Percentage (%) of fines = 19.4%

**2) Dry sieving of Residue, Mass = 48.4g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	0.8	59.2	98.6
1.180	3.2	56.0	93.3
0.850	4.6	51.4	85.7
0.600	6.7	44.7	74.5
0.425	5.7	39.0	65.0
0.300	9.7	29.3	48.9
0.150	12.9	16.4	27.4
0.075	4.7	11.8	19.6
Pan	1	11.7	-

**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample, M, = 60g

Test Temperature = 23.5°C

Meniscus Correction ( $C_m$ ) = +0.5

Temperature Correction ( $M_t$ ) = +1.0

Dispersant Correction (x) = 3.5

**SAMPLE: Owerri 4**

**GRAIN SIZE DISTRIBUTION ANALYSIS (HYDROMETER  
SEDIMENTATION TEST METHOD)**

**1) Wet Sieving**

Weight of sample before washing and drying = 60g  
Weight of sample after washing and drying = 49.2g  
Therefore, mass lost to washing (mass of fines) = 10.8g  
Percentage (%) of fines = 18.0%

**2) Dry sieving of Residue, Mass = 49.2g**

Sieve Size (mm)	Mass Retained (g)	Mass Passing (g)	Percentage Passing (%)
2.000	7.8	59.2	98.7
1.180	3.4	55.9	93.1
0.850	4.7	51.2	85.3
0.600	6.9	44.3	73.8
0.425	5.9	38.4	64.0
0.300	9.4	29.0	48.3
0.150	13.1	15.8	26.4
0.075	4.9	11.0	18.3
Pan	0.2	10.8	-

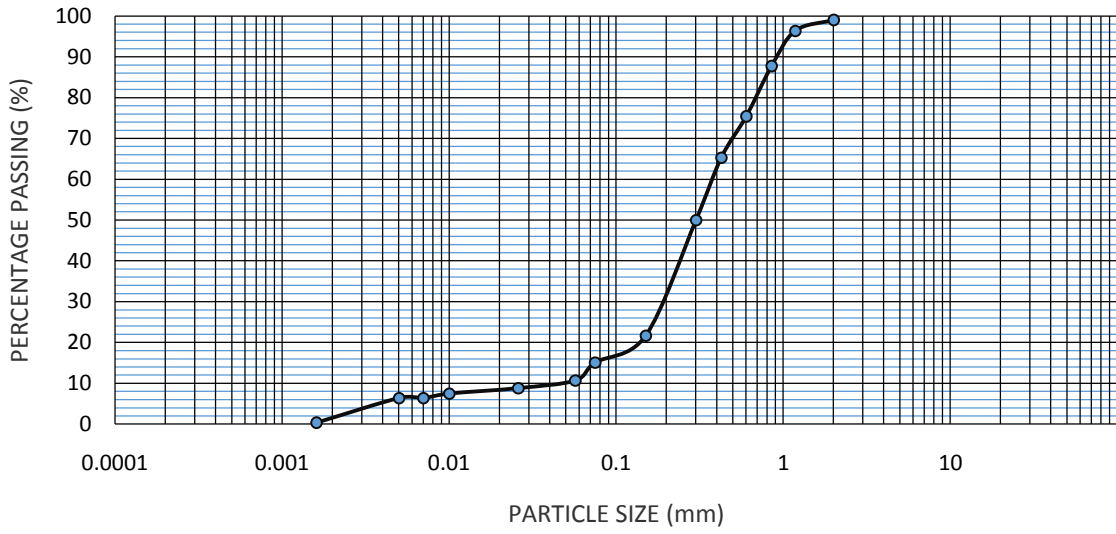
**3) Hydrometer Readings on Filtrate**

**Data:**

Initial Mass of Sample,  $M_i$  = 60g  
Test Temperature = 23.5°C  
Meniscus Correction ( $C_m$ ) = +0.5  
Temperature Correction ( $M_t$ ) = +1.0  
Dispersant Correction ( $x$ ) = 3.5

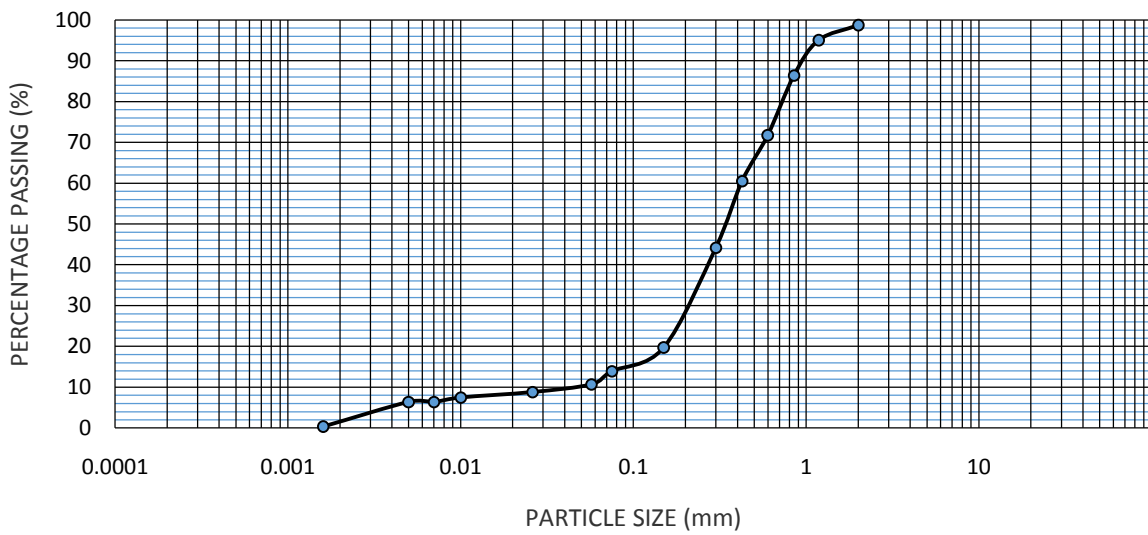
## GRAIN SIZE ANALYSIS GRAPH

ORLU 1- UMUAGWO-OHAJI



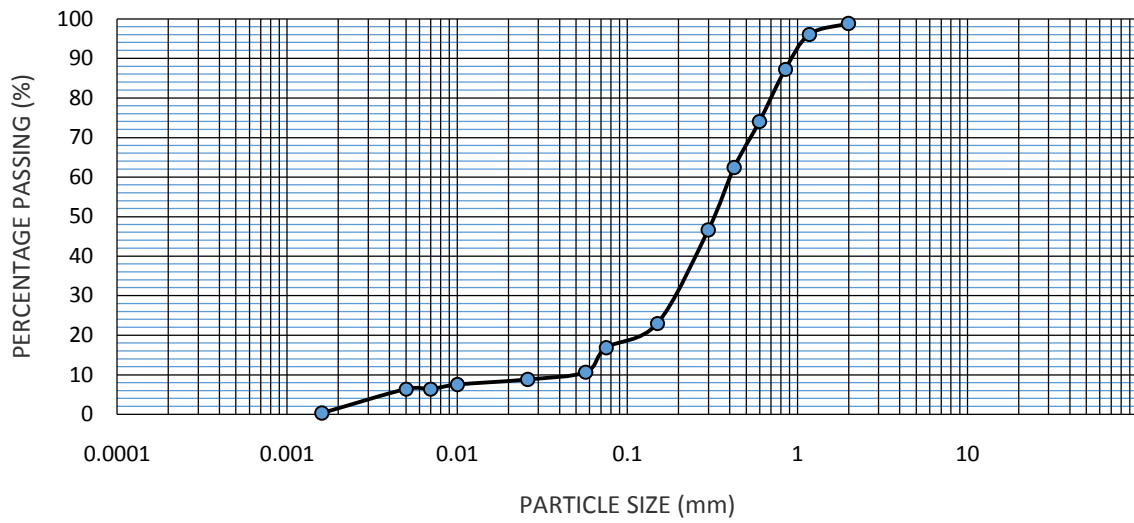
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

ORLU 2-UMUNA



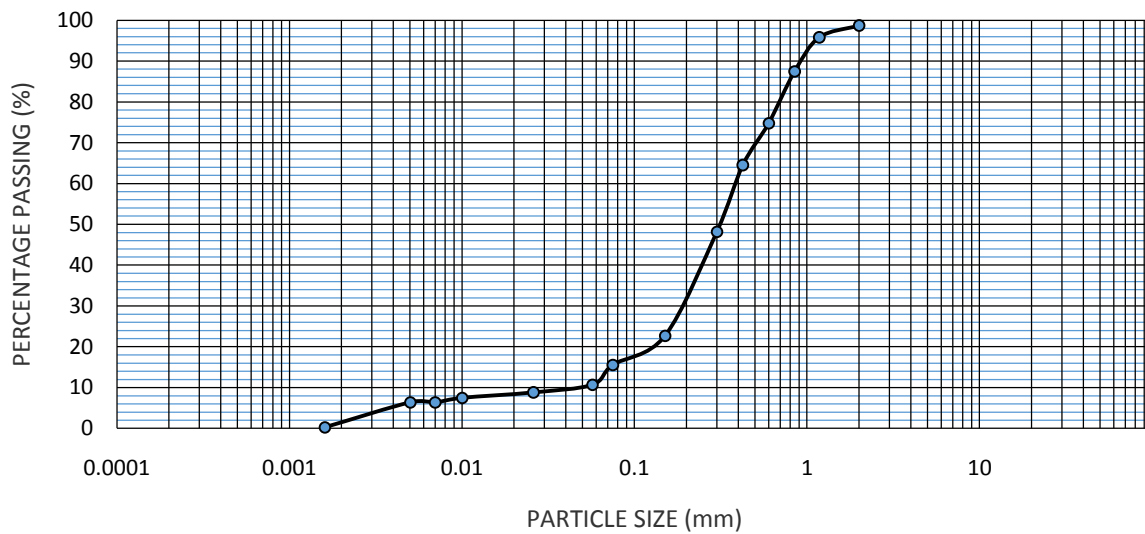
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

ORLU 3-UMUOKANNE



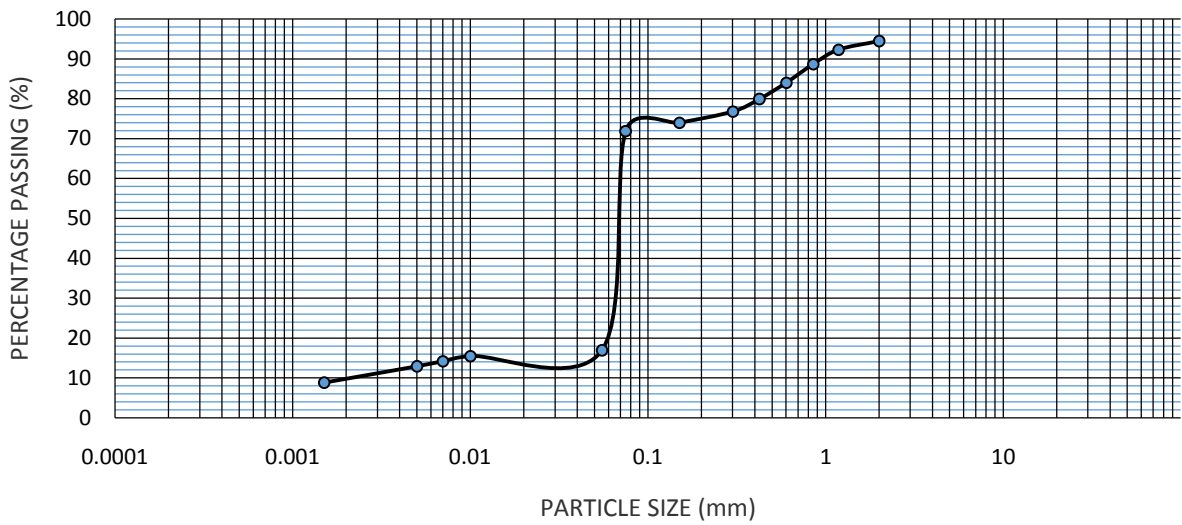
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

ORLU 4-ISIEKENESI IDEATO SOUTH



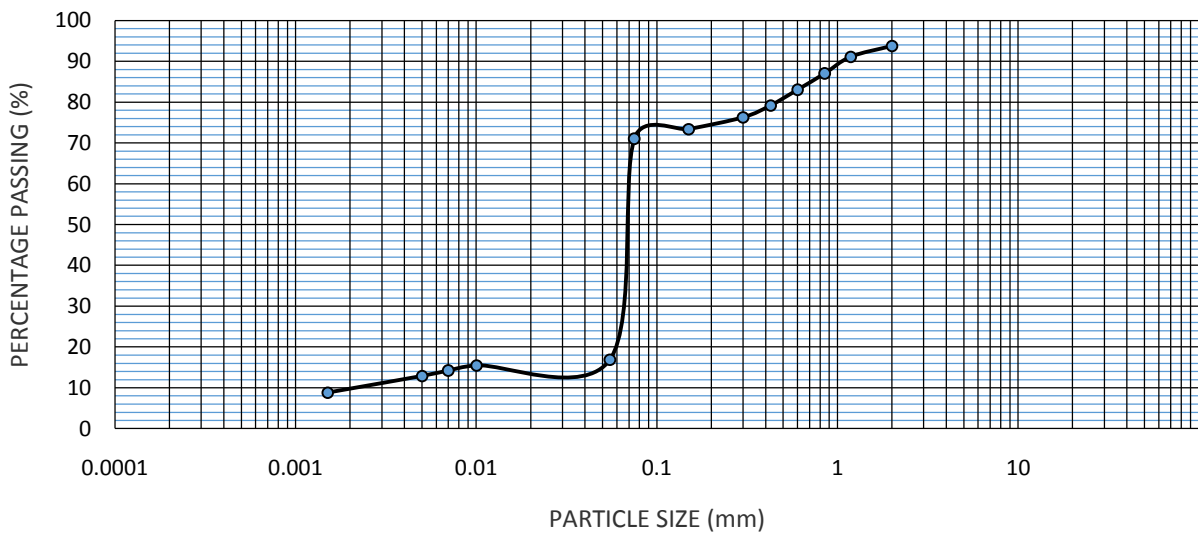
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OKIGWE 1-EZINNACHI OKIGWE



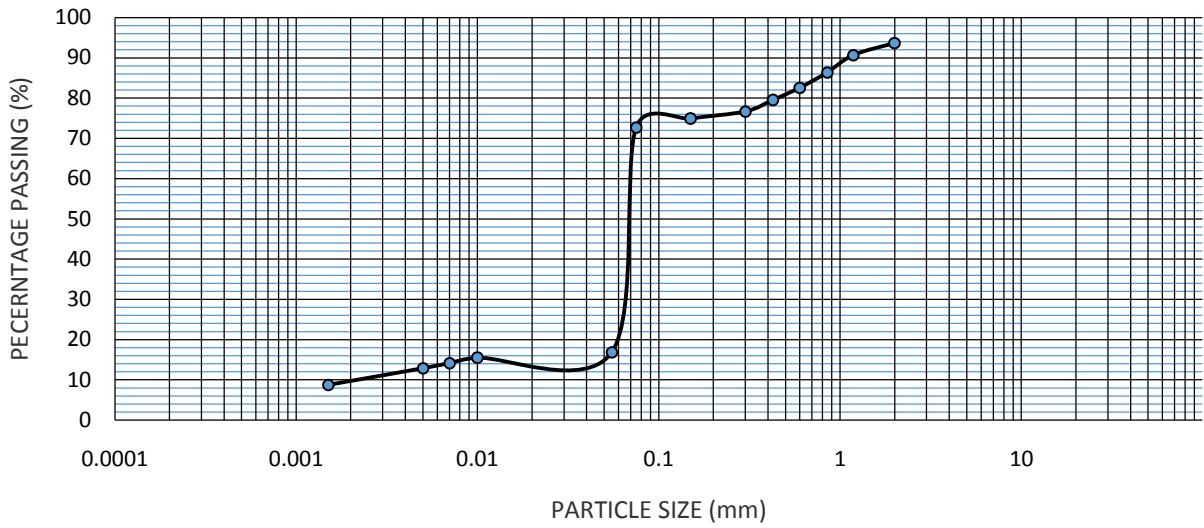
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OKIGWE 2-OKWELLE ONUIMO



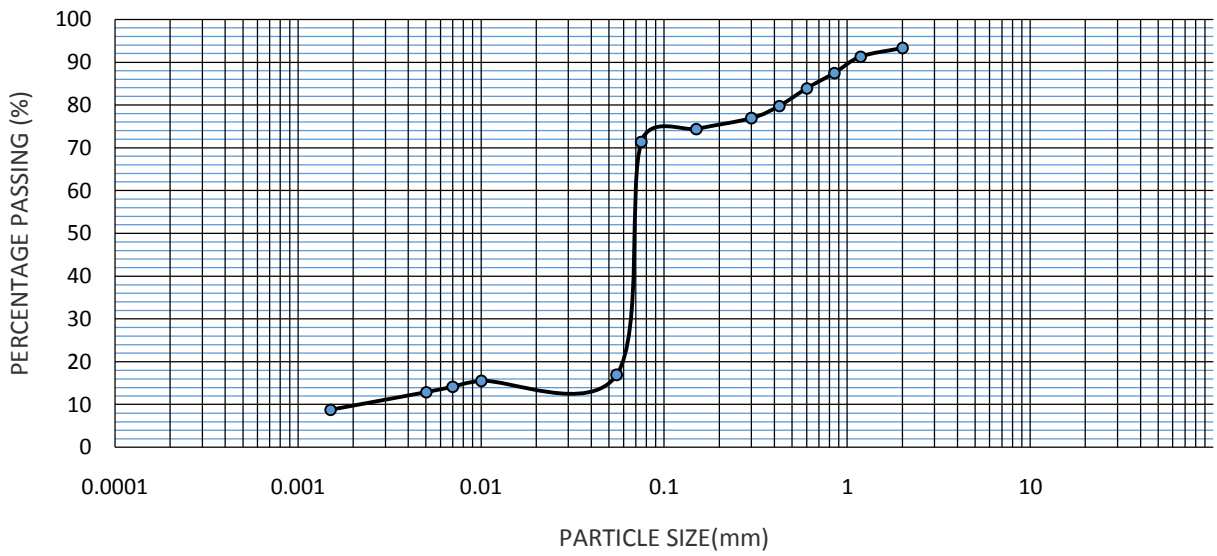
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OKIGWE 3-UGIRI ISIALA MBANO



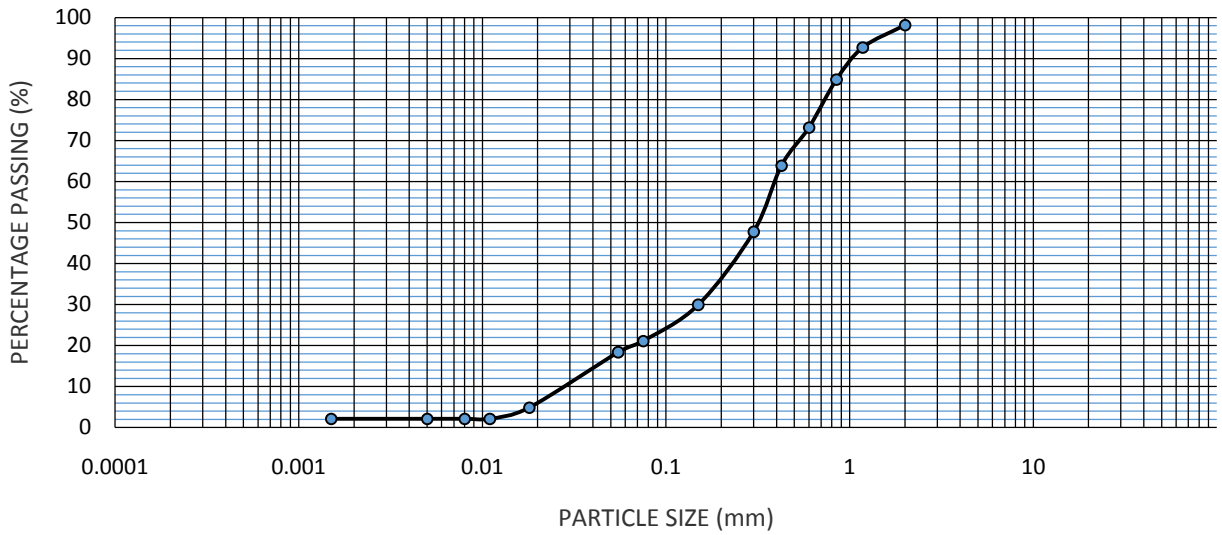
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OKIGWE 4- OKWE



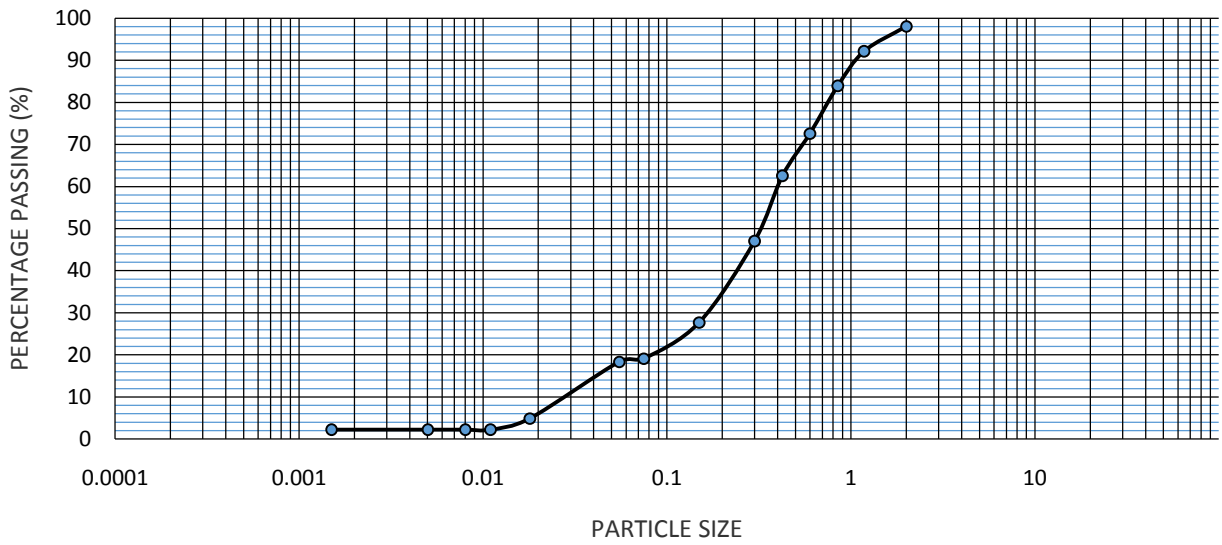
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OWERRI 1-ONICHA EZINIHITE



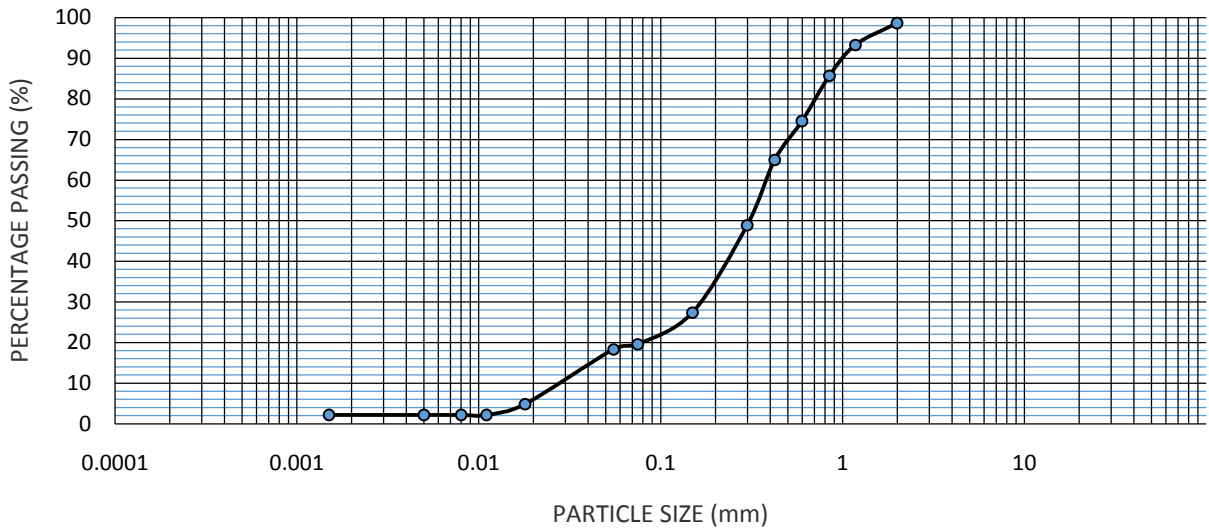
CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OWERRI 2 IHIAGWA

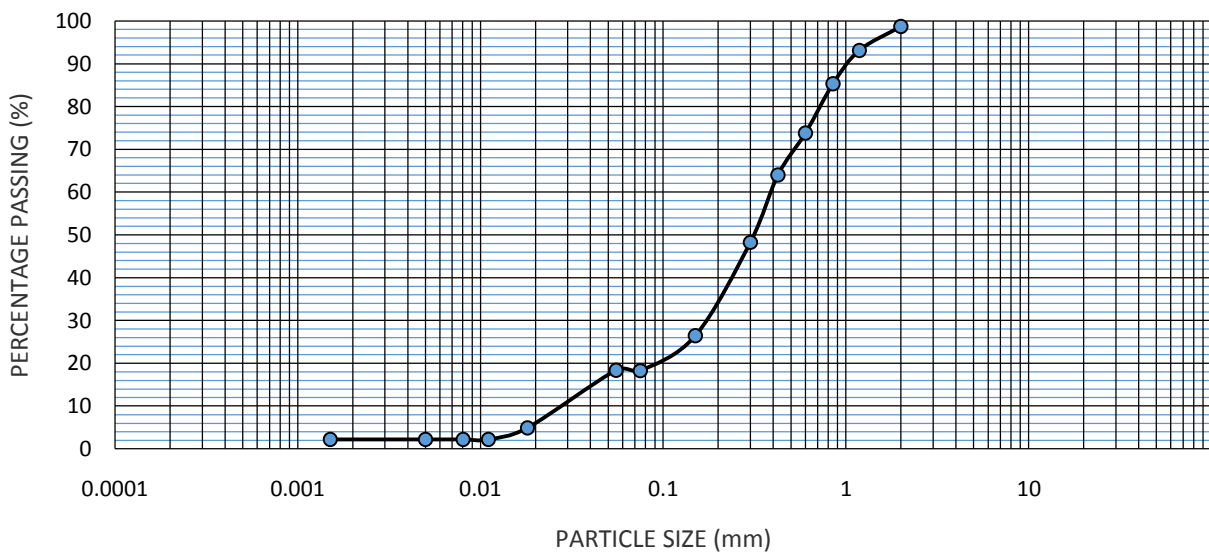


CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

OWERRI 3- OBINZE

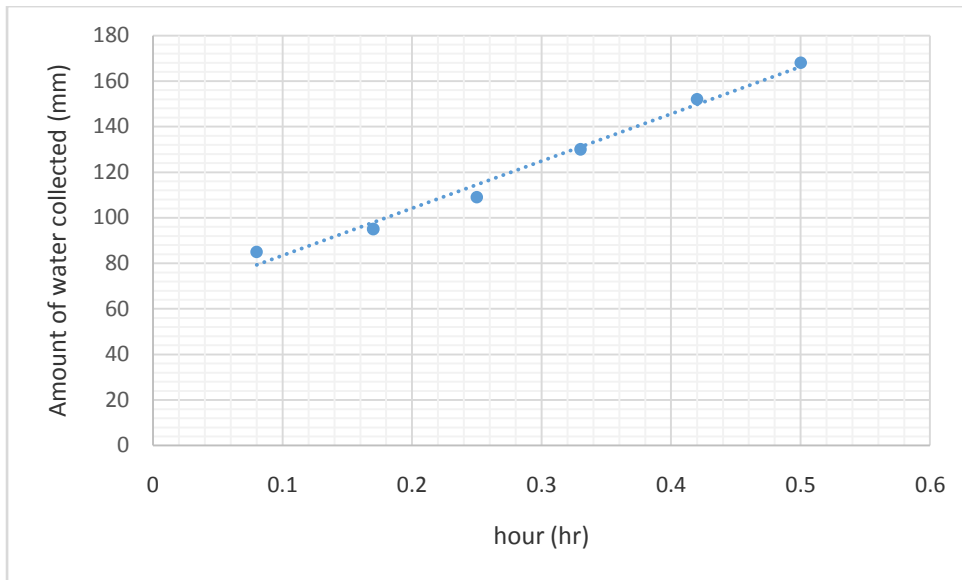


CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			



CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

Measurement of Rainfall Intensity Using a Rainfall Simulator (Rainulator)



$$\text{SLOPE} = \frac{132-100}{0.304-0.108} = \frac{32}{0.196} = 163.27 \text{ mm/hr}$$

Rainfall intensity = 163.27 mm/hr

Organic matter content for the selected soils in Imo State

S/N	LOCATION	AVERAGE	STANDARD DEV.
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1	Ezinnachi Okigwe	1.16	0.020
2	Okwelle Onuimo	0.71	0.046
3	Ugiri Mbano	1.04	0.040
4	Okwe Onuimo	0.77	0.020
5	Onicha Ezinihitte Mbaise	2.40	0.040
6	Ihiagwa Owerri West	2.50	0.090
7	Mbieri Mbaitolu	2.35	0.050
8	Obinze Owerri West	1.84	0.098
9	Umuagwo Ohaji	3.95	0.065
10	Umuna Orlu	1.34	0.120
11	Umuokanne Ohaji	2.24	0.220
12	Isiekenesi Ideato South	1.55	0.140

#### Normal Stress ( $\sigma$ ) Computation

(1) Load (Kg)	(2) Load (KN) (1) $\div$ 100	(3) Area (m <sup>2</sup> )	(4) (KN/m <sup>2</sup> ) (2) $\div$ (3)
24	0.24	0.0036	66.7
44	0.44	0.0036	122.2
64	0.64	0.0036	177.8

#### Shear Stress ( $\tau$ ) Computation for Owerri

(1) Sample	(2) Load (Kg)	(3) Max. H.R	(4) (3) x 0.002 (mm)	(5) (4 x 0.88) (KN)	(6) (5) ÷ A (KN/m <sup>2</sup> )
Onicha, Ezinihite Mbaise	24	76	0.152	0.134	37.2
	44	145	0.290	0.255	70.9
	64	200	0.400	0.352	97.8
Ihiagwa, Owerri West	24	70	0.140	0.123	34.2
	44	142	0.284	0.227	63.1
	64	193	0.386	0.340	94.4
Obinze, Owerri West	24	73	0.146	0.128	35.7
	44	145	0.290	0.260	70.9
	64	201	0.404	0.354	98.3
Mbieri, Mbaitolu	24	78	0.148	0.130	36.2
	44	151	0.302	0.266	73.8
	64	196	0.392	0.350	95.8

Shear Stress ( $\tau$ ) Computation for Okigwe

(1) Sample	(2) Load (Kg)	(3) Max. H.R	(4) (3) x 0.002 (mm)	(5) (4 x 0.88) (KN)	(6) (5) ÷ A (KN/m <sup>2</sup> )
Okwelle, Onuimo	24	80	0.160	0.408	39.1
	44	171	0.342	0.301	83.6
	64	212	0.424	0.373	103.6
Ezinnachi, Okigwe	24	83	0.166	0.146	40.6
	44	173	0.346	0.305	84.6
	64	215	0.430	0.378	105.0
Okwe, Onuimo	24	82	0.164	0.144	40.1
	44	176	0.352	0.310	86.0
	64	220	0.792	0.700	193.6
Ugiri, Isiala Mbano	24	80	0.160	0.141	39.1
	44	173	0.346	0.305	84.6
	64	212	0.424	0.373	103.6

Shear Stress ( $\tau$ ) Computation for Orlu

(1) Sample	(2) Load (Kg)	(3) Max. H.R	(4) (3) x 0.002 (mm)	(5) (4 x 0.88) (KN)	(6) (5) ÷ A (KN/m <sup>2</sup> )
Umuagwo, Ohaji	24	76	0.152	0.134	37.2
	44	150	0.300	0.264	73.3
	64	198	0.393	0.349	96.8
Umuna, Orlu	24	78	0.156	0.137	38.1
	44	153	0.306	0.269	74.8
	64	202	0.404	0.356	98.8
Umuokanne, Ohaji	24	80	0.164	0.141	39.1
	44	205	0.410	0.278	77.2
	64	211	0.410	0.370	102.7
Isiekenesi, Ideato South	24	82	0.164	0.144	40.1
	44	205	0.410	0.361	100.2
	64	211	0.422	0.371	103.2

### Shear Strength Computation for Owerri

SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_n$ (KN/m <sup>2</sup> )	$\tau$ KN/m <sup>2</sup>
Onicha, Ezinihite	3	25	177.8	85.9
Ihiagwa, Owerri West	4	24	177.8	83.2
Obinze, Owerri West	4	25	177.8	86.9
Mbieri, Mbaitoli	5	25	177.8	87.9

Shear Strength Computation for Okigwe

SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_n$ (KN/m <sup>2</sup> )	$\tau$ KN/m <sup>2</sup>
Ezinnachi, Okigwe	8	25	177.8	90.9
Okwelle, Onuimo	9	26	177.8	95.7
Ugiri Isiala Mbano	8	24	177.8	87.2
Okwe, Onuimo	10	24	177.8	89.2

Shear Strength Computation for Orlu

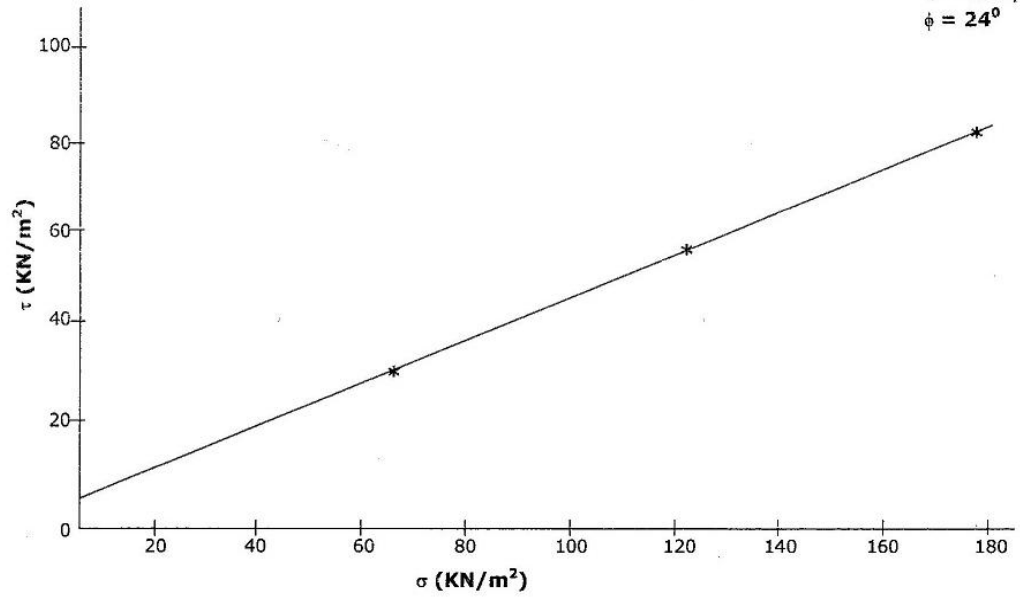
SAMPLE	C (KN/m <sup>2</sup> )	$\phi^{(0)}$	$\sigma_n$ (KN/m <sup>2</sup> )	$\tau$ KN/m <sup>2</sup>
Umugwo, Ohaji	5	24	177.8	84.2
Umuna, Orlu	6	24	177.8	85.2
Umuokanne, Ohaji	5	22	177.8	76.8
Isiekenesi, Ideato South	6	22	177.8	77.8

UMUAGWO  
OHAJI

### Shear Stress Vs Normal Stress Curve

SAMPLE: Orlu 1

$C = 5 \text{ KN/m}^2$   
 $\phi = 24^\circ$

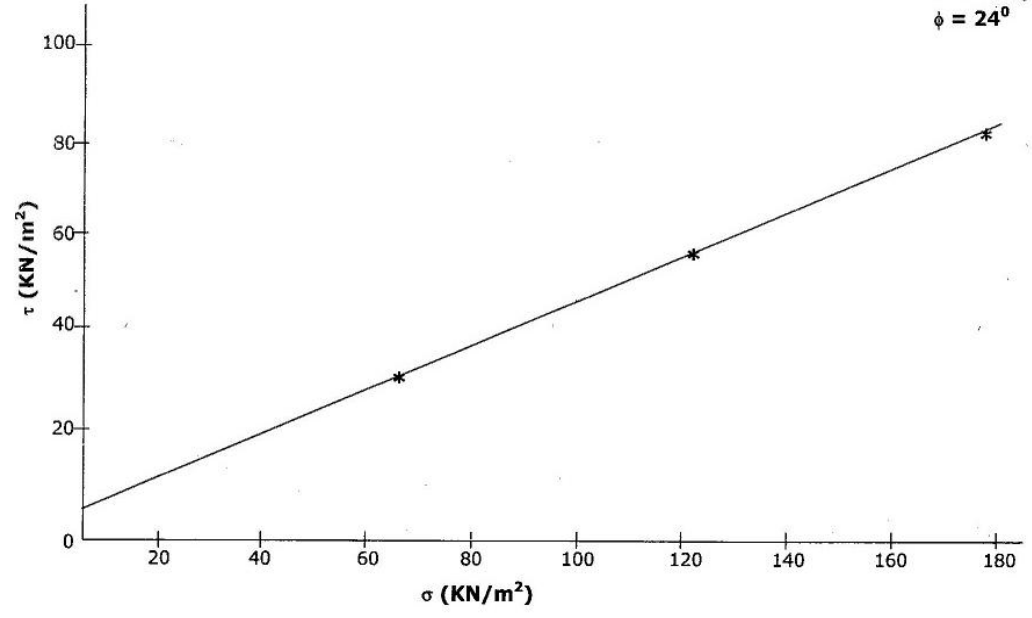


UMUNA ORLU

### Shear Stress Vs Normal Stress Curve

SAMPLE: Orlu 2

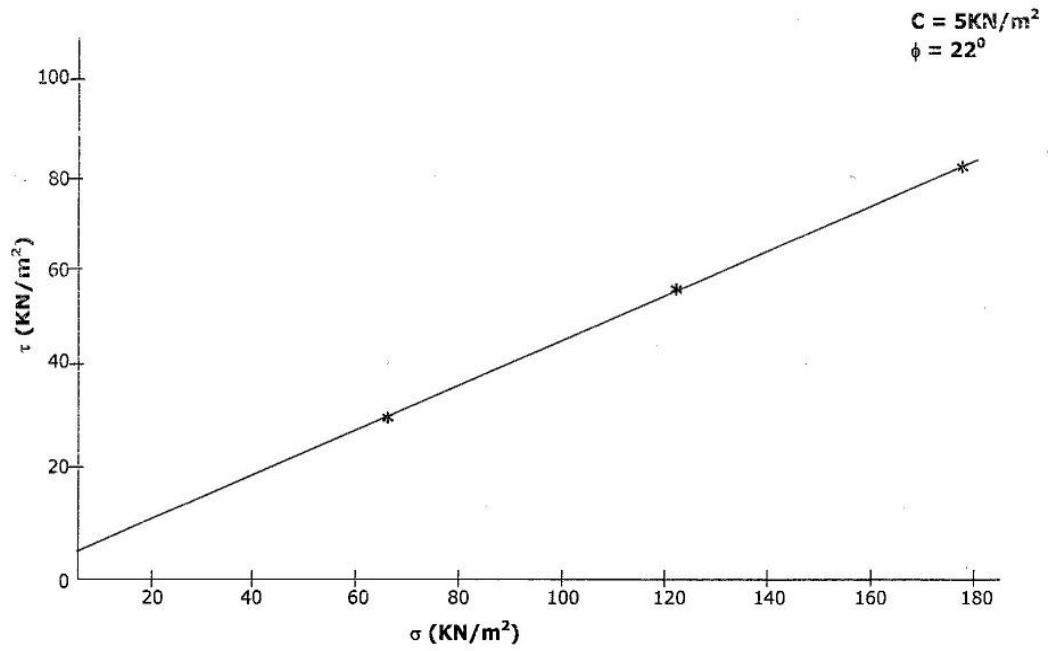
$C = 6 \text{ KN/m}^2$   
 $\phi = 24^\circ$



UMUOKANNE  
OHAJI

### Shear Stress Vs Normal Stress Curve

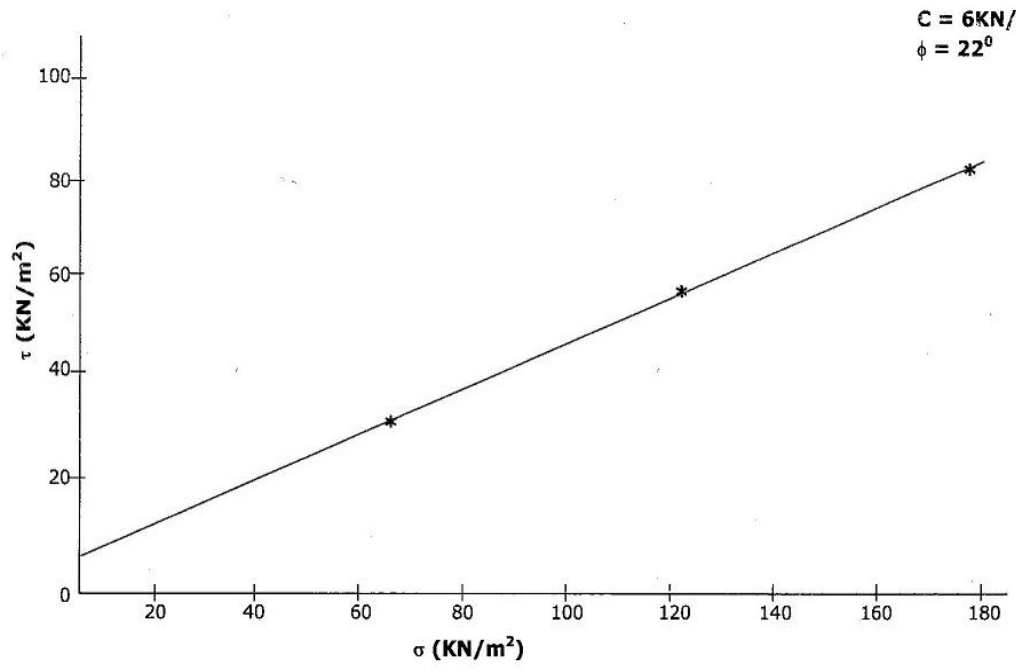
SAMPLE: Orlu 3



ISIKENESI  
IDEATO SOUTH

### Shear Stress Vs Normal Stress Curve

SAMPLE: Orlu 4

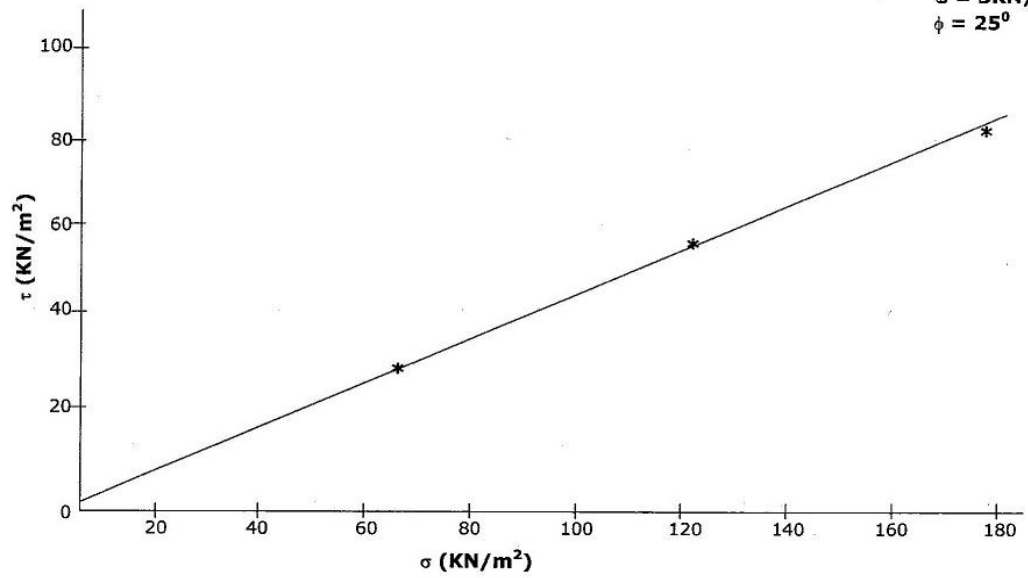


DNICHA EZINIHITTE  
MBAISE

Shear Stress Vs Normal Stress Curve

SAMPLE: Owerri 1

$c = 3\text{KN/m}^2$   
 $\phi = 25^\circ$

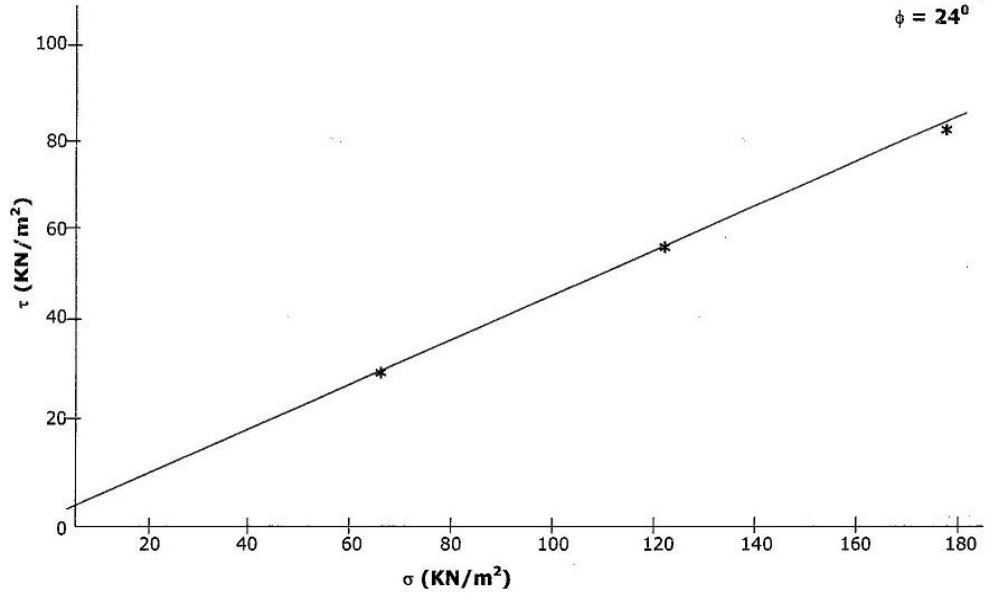


HIGWA OWERRI  
WEST

Shear Stress Vs Normal Stress Curve

SAMPLE: Owerri 2

$C = 4 \text{ KN/m}^2$   
 $\phi = 24^\circ$

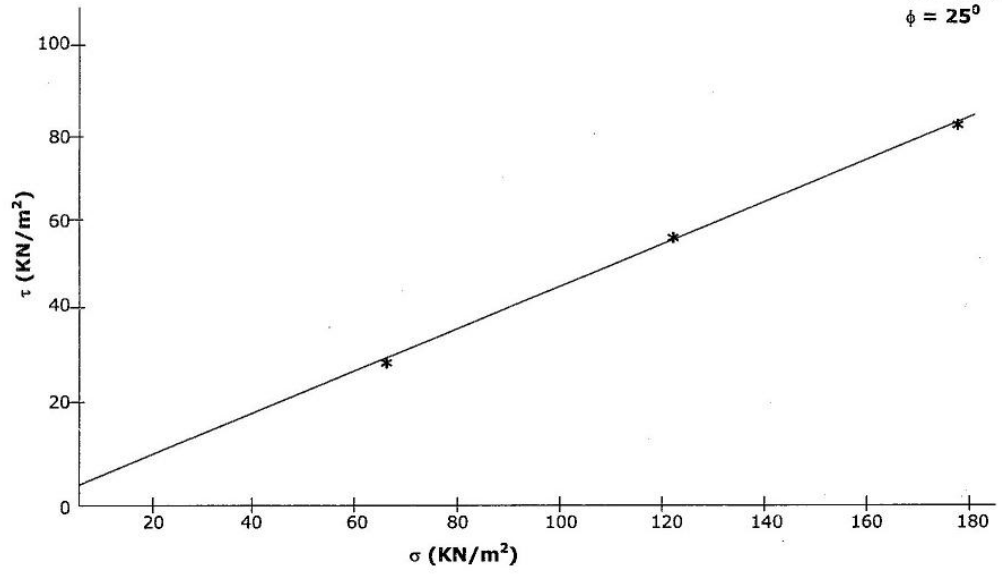


OBINE OWERRI  
WEST

### Shear Stress Vs Normal Stress Curve

SAMPLE: Owerri 3

$C = 4 \text{ KN/m}^2$   
 $\phi = 25^\circ$

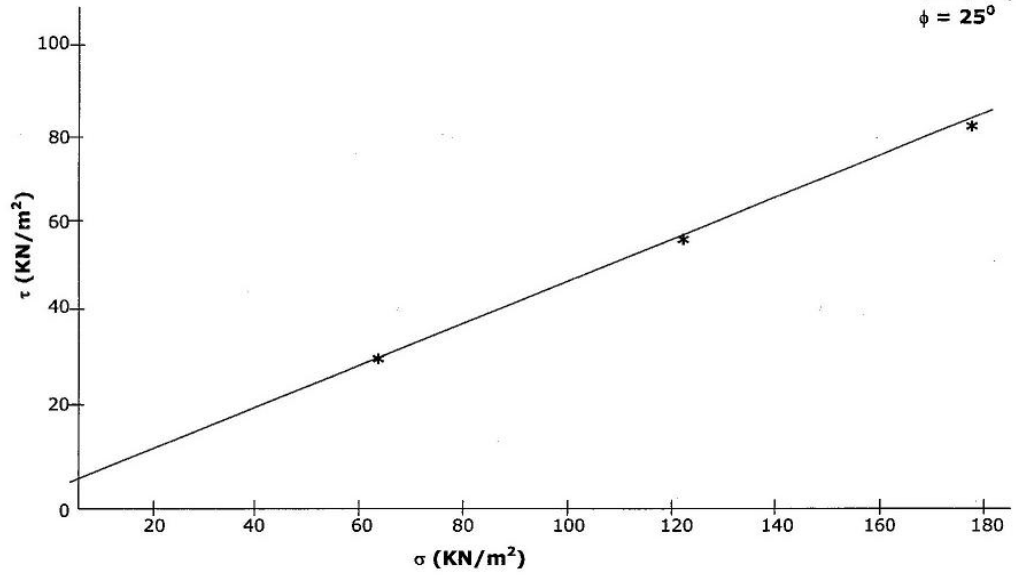


MBIERI  
MBAITOLI

### Shear Stress Vs Normal Stress Curve

SAMPLE: Owerri 4

$C = 5 \text{ KN/m}^2$   
 $\phi = 25^\circ$

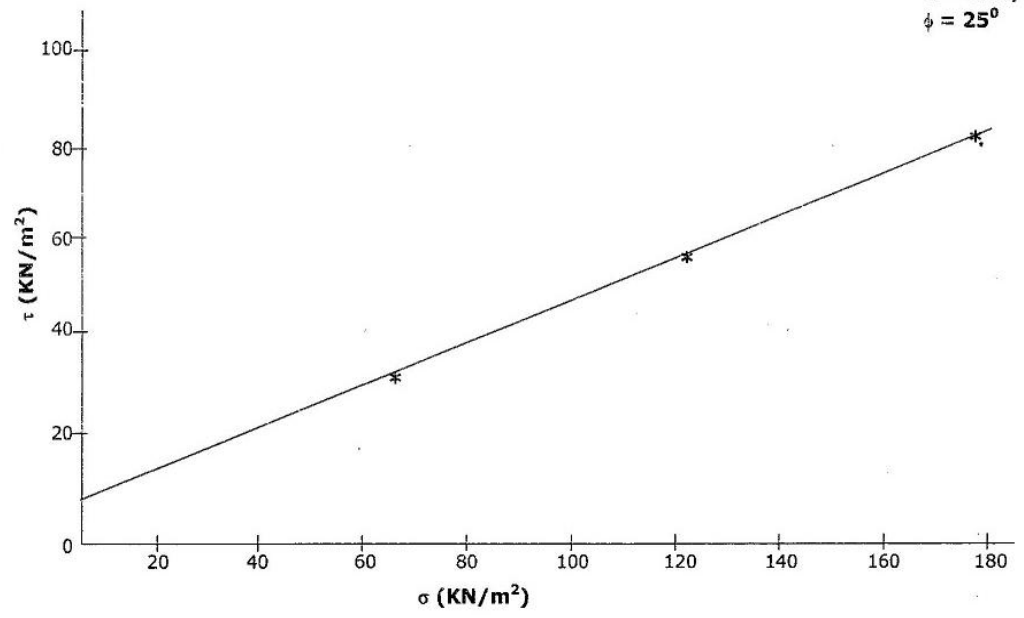


EZINMACHI  
OKIGWE

### Shear Stress Vs Normal Stress Curve

SAMPLE: Okigwe 1

$C = 8 \text{ KN/m}^2$   
 $\phi = 25^\circ$

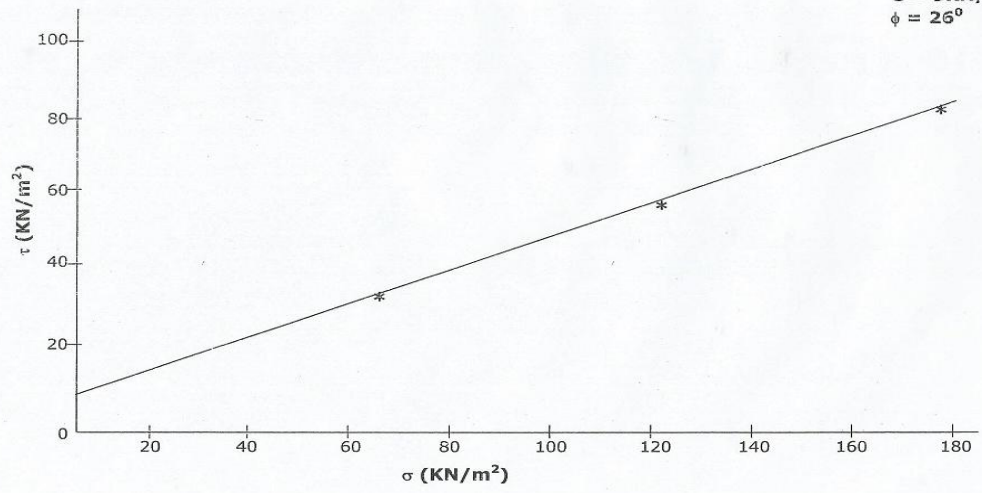


Shear Stress Vs Normal Stress Curve

OKWELLE  
ONUIMO

SAMPLE: Okigwe 2

$c = 9 \text{KN/m}^2$   
 $\phi = 26^\circ$

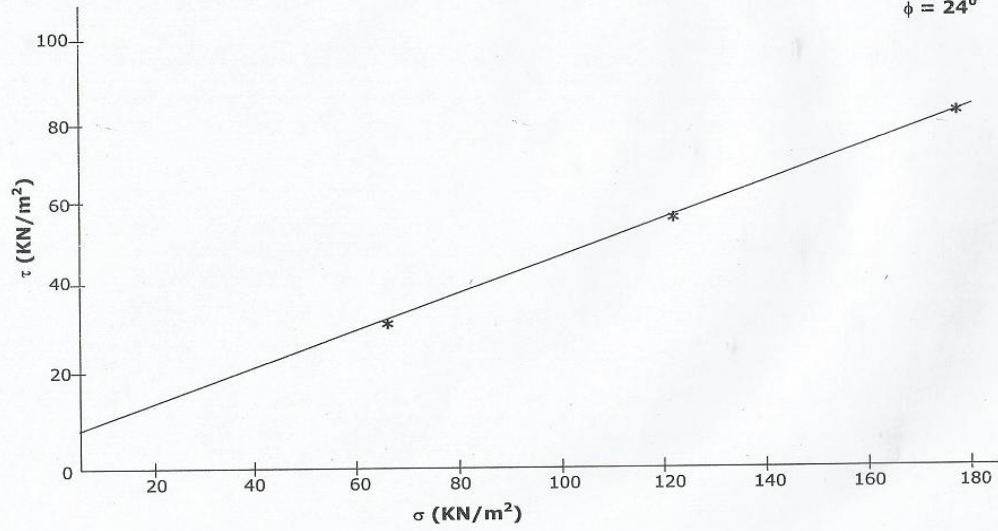


Shear Stress Vs Normal Stress Curve

UGIRI  
ISIA'LA. MBANO

SAMPLE: Okigwe 3

$C = 8 \text{ KN/m}^2$   
 $\phi = 24^\circ$

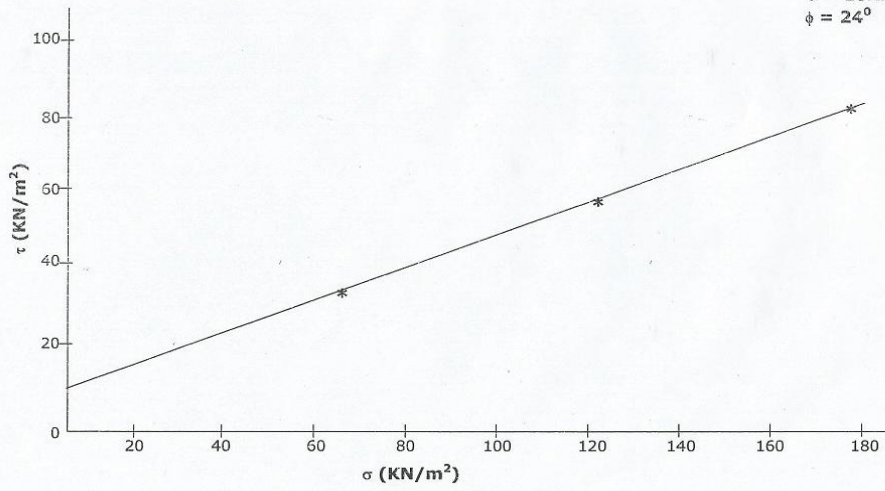


Shear Stress Vs Normal Stress Curve

OKWE  
ONUIMO

SAMPLE: Okigwe 4

$c = 10 \text{KN/m}^2$   
 $\phi = 24^\circ$



Computation for Porosity (n) for Imo State

S/N	LOCATION	AVERAGE	STANDARD DEVIATION
1	Onicha Ezinihitte Mbaise	0.232	No Deviation
2	Ihiagwa Owerri West	0.220	0.0015
3	Obinze Owerri West	0.212	0.0015
4	Mbieri Mbaitolu	0.239	0.0003
5	Ezinnachi Okigwe	0.393	0.0770
6	Okwelle Onuimo	0.327	0.0002
7	Ugiri Isiala Mbano	0.359	0.0003
8	Okwe Onuimo	0.326	0.003
9	Umuagwo Ohaji	0.266	0.0002
10	Umuokanne Ohaji	0.282	0.0001
11	Umuna Orlu	0.270	0.0002
12	Isiekenesi Ideato South	0.253	0.001

Computation for Void Ratio (e) for Imo State

S/N	LOCATION	AVERAGE	STANDARD DEVIATION
1	Onicha Ezinihitte Mbaise	0.302	0.0002
2	Ihiagwa Owerri West	0.281	No Deviation
3	Obinze Owerri West	0.271	0.0002
4	Mbieri Mbaitolu	0.314	No Deviation
5	Ezinnachi Okigwe	0.534	0.0015
6	Okwelle Onuimo	0.486	0.0002
7	Ugiri Isiala Mbano	0.561	0.0002
8	Okwe Onuimo	0.514	0.0002
9	Umuagwo Ohaji	0.362	0.0002
10	Umuokanne Ohaji	0.392	No Deviation
11	Umuna Orlu	0.370	0.0002
12	Isiekenesi Ideato South	0.373	0.0002

Natural Moisture Content for Okigwe

SAMPLE OKIGWE	Ezinnachi	Okwelle	Ugiri	Okwe
Can identification No.	31	42	23	27
Wt. of wet soil + can(g)	61.3	61.8	58.1	61.2
Wt. of dry Soil + Can (g)	54.8	55.5	52.0	54.8
Wt. of can (g)	19.1	19.5	20.1	20.2
Wt. of dry soil (g)	35.7	36.0	31.9	34.6
Wt. of water (g)	6.5	6.3	6.1	6.0
Water content, w, (%)	18.2	17.5	19.1	18.5

#### Natural Moisture Content for Orlu

SAMPLE (Locations) ORLU	Umuagwo	Ideato south	Umuokanne	Umuna
Can identification No.	17	22	23	32
Wt. of wet soil + Can (g)	57.8	65.0	60.3	57.1
Wt. of dry Soil + Can (g)	52.4	59.7	55.1	51.6
Wt. of can (g)	15.4	20.1	19.2	16.7
Wt. of dry soil (g)	37.0	39.6	35.9	37.0
Wt. of water (g)	5.4	5.3	5.2	5.5
Water content, w (%)	14.6	13.4	14.5	15.8

#### Natural Moisture for content for Owerri

SAMPLE (Locations) OWERRI	Onicha Ezinihite	Ihiagwa Ohaji	Obinze Owerri west	Mbieri Mbaitolu
Can identification No.	10	11	16	17
Wt. of wet soil + can (g)	42.7	47.3	45.7	50.2
Wt. of dry Soil + Can (g)	40.1	44.6	42.9	47.1
Wt. of can (g)	15.8	19.2	18.5	20.1
Wt. of dry soil (g)	24.3	25.4	24.4	27.0
Wt. of water (g)	2.6	2.7	2.8	3.1
Water content, w (%)	10.7	10.6	11.5	11.5

Bulk and Dry Unit Weight ( $\rho_b$  &  $\rho_d$ ) for Owerri

Locations	Onicha Ezinihite	Ihiagwa	Obinze	Mbieri
Wt. of Ring + Sample (g)	262.7	276.2	271.1	272.1
Wt. of Ring (g)	115.30	116.30	116.90	116.9
Wt. of Sample (g)	147.4	159.9	154.2	152.2
Volume of sample $\text{cm}^3$	98.2	98.2	98.2	98.2
Bulk unit wt. ( $\rho_b$ ) $\text{Mg/m}^3$	1.50	1.63	1.57	1.58
Dry unit wt. ( $\rho_b$ ) ( $\text{Mg/m}^3$ )	1.35	1.47	1.42	1.42
Dry unit wt. ( $\rho_b$ ) ( $\text{KN/m}^3$ )	13.5	14.7	14.2	14.2

Bulk and Dry Unit Weight ( $\rho_b$  &  $\rho_d$ ) for Okigwe

Locations	Ezinnachi	Okwelle	Okwe	Ugiri
Wt. of Ring + Sample (g)	286.1	287.4	287.3	288.1
Wt. of Ring (g)	116.3	116.3	116.3	116.3
Wt. of Sample (g)	169.8	171.1	171.0	171.8
Volume of sample cm <sup>3</sup>	98.2	98.2	98.2	98.2
Bulk unit wt.( $\rho_b$ ) Mg/m <sup>3</sup>	1.73	1.74	1.74	1.75
Dry unit wt. ( $\rho_b$ ) (Mg/m <sup>3</sup> )	1.46	1.48	1.46	1.48
Dry unit wt. ( $\rho_b$ ) (KN/m <sup>3</sup> )	14.6	14.8	14.6	14.8

Bulk and Dry Unit Weight ( $\rho_b$  &  $\rho_d$ ) for Orlu

Locations	Umuagwo	Umuna	Umuokanne	Isiekenesi
Wt. of Ring + Sample (g)	291.6	294.0	293.7	292.1
Wt. of Ring (g)	116.3	116.3	116.3	116.3
Wt. of Sample (g)	175.3	177.7	177.4	175.8
Volume of sample cm <sup>3</sup>	98.2	98.2	98.2	98.2
Bulk unit wt.( $\rho_b$ ) Mg/m <sup>3</sup>	1.79	1.81	1.81	1.79
Dry unit wt. ( $\rho_b$ ) (Mg/m <sup>3</sup> )	1.56	1.56	1.58	1.58
Dry unit wt. ( $\rho_b$ ) (KN/m <sup>3</sup> )	15.6	15.6	15.8	15.8

Specific Gravity for Owerri

Locations	Onicha Ezinihite	Ihiagwa	Obinze	Mbieri
M1 (g)	115.7	115.7	115.7	115.7
M2 (g)	125.7	125.7	125.7	125.7
M3 (g)	370.0	369.9	369.8	370.1
M4 (g)	363.7	363.7	363.7	363.7
G <sub>L</sub>	1.000	1.000	1.000	1.000
G <sub>S</sub>	2.70	2.63	2.65	2.78

Specific Gravity for Okigwe

Locations	Onicha Ezinihite	Ihiagwa	Obinze	Mbieri
M1	115.7	115.7	115.7	115.7
M2	125.7	125.7	125.7	125.7
M3	370.3	370.1	370.3	370.1
M4	363.7	363.7	363.7	363.7
G <sub>L</sub>	1.000	1.000	1.000	1.000
G <sub>S</sub>	2.94	2.78	2.94	2.78

Specific Gravity for Orlu

Locations	Isiekenesi	Umuokanne	Umuna	Umuagwo
M1	116.2	105.9	107.6	116.2
M2	146.2	135.9	137.6	146.2
M3	382.8	371.9	374.8	383.0
M4	364.9	354.0	356.6	364.9
G <sub>L</sub>	1.000	1.000	1.000	1.000
G <sub>S</sub>	2.48	2.48	2.54	2.52

#### Soil pH for Imo State

S/N	LOCATIONS	Average	Standard Deviation
1	Onicha Ezinihitte Mbaise	8.04	0.02
2	Ihiagwa Oerri West	8.01	0.01
3	Obinze Owerri West	7.98	0.07
4	Mbieri Mbaitolu	8.02	0.01
5	Ezinnachi Okigwe	6.47	0.25
6	Okwelle Onuimo	6.48	0.10
7	Ugiri Isiala Mbano	6.64	0.02
8	Okwe Onuimo	6.75	0.06
9	Umuagwo Ohaji	8.43	0.15
10	Umuna Orlu	8.60	0.08
11	Umuokanne Ohaji	8.43	0.10
12	Isiekenesi Ideato South	8.56	0.07

Coefficient of Permeability

S/N	Location	D <sub>10</sub> (mm)	D <sub>10</sub> <sup>2</sup> (mm) <sup>2</sup>	K(cm/s)
1	Ezinachi Okigwe	0.002	0.000004	4.0 x 10 <sup>-4</sup>
2	Okwelle Onuimo	0.0025	0.00000625	6.25 x 10 <sup>-4</sup>
3	Ugiri Isiala Mbano	0.0025	0.00000625	6.25 x 10 <sup>-4</sup>
4	Okwe Onuimo	0.0023	0.00000529	5.29 x 10 <sup>-4</sup>
5	Umuagwo Ohaji	0.05	0.0025	2.5 x 10 <sup>-1</sup>
6	Umuna Orlu	0.04	0.0016	1.6 x 10 <sup>-2</sup>
7	Umuokanne Ohaji	0.045	0.002025	2.205 x 10 <sup>-1</sup>
8	Isiekenesi Ideato South	0.045	0.002025	2.025 x 10 <sup>-1</sup>
9	Onicha Ezinitte Mabise	0.03	0.0009	9.0 x 10 <sup>-2</sup>
10	Ihiagwa Owerri West	0.03	0.0009	9.0 x 10 <sup>-2</sup>
11	Obinze Owerri West	0.036	0.001296	1.296 x 10 <sup>-1</sup>
12	Mbieri Mbaitoli	0.03	0.0009	9.0 x 10 <sup>-2</sup>

**SOIL LOSS COMPUTATION (Tons/ha)**

S/N	LOCATION	Dry run (Tons/ha)	Wet run (Tons/ha)	Saturated run (Tons/ha)
1	IHIAGWA	1.69	1.42	1.11
2	ONICHA EZINIHITE	1.86	1.64	1.48
3	OBINZE	1.27	1.18	1.06
4	MBIERI	1.65	1.36	0.99
5	OKWELLE	3.5	3.09	2.59
6	OKWE	3.95	3.71	3.52
7	UGIRI ISIALA MBANO	2.30	2.02	1.73
8	EZINNACHI	3.70	2.96	2.59
9	ISIEKENESI	7.46	7.17	5.18
10	UMUNA ORLU	7.42	6.17	5.55
11	UMUAGWO OHAJI	7.10	6.05	5.49
12	UMUOKANNE	5.06	4.69	4.20

## **CALCULATIONS FOR THE COMPOSTION SOIL AGGREGATES:**

For Okigwe 1 (Ezinnachi)

### **CLAY**

$$\frac{0.1}{60} \times 100 = 16\%$$

Percentage of clay = 16%

### **SILT**

$$\frac{60}{60} \times 100 = 100\%$$

Percentage of silt = 100%

### **SAND**

$$\frac{24}{60} \times 100 = 40\%$$

Percentage of sand = 40%

For Okigwe 2 (Okwelle)

### **CLAY**

$$\text{Point 1: } \frac{9}{60} \times 100 = 15\%$$

Percentage of clay = 15%

### **SILT**

$$\frac{61}{60} \times 100 = 101\%$$

Percentage of silt = 101%

### **SAND**

$$\frac{25}{60} \times 100 = 41.6\%$$

Percentage of sand = 41.6%

For Okigwe 3 (Ugiri Mbano)

### **CLAY**

$$\frac{10}{60} \times 100 = 16.6\%$$

Percentage of clay = 16.6%

### **SILT**

$$\frac{60}{60} \times 100 = 100\%$$

Percentage of silt = 100%

### **SAND**

$$\text{Point 1: } \frac{34}{60} \times 100 = 56.6\%$$

Percentage of sand = 56.6%

For Okigwe 4 (Okwe)

### **CLAY**

$$\frac{10}{60} \times 100 = 16.6\%$$

Percentage of clay = 16.6%

**SILT**

$$\frac{60}{60} \times 100 = 100\%$$

Percentage of silt = 100%

**SAND**

$$\frac{33}{60} \times 100 = 55\%$$

Percentage of sand = 55%

For Orlu 1 (Umuagwo Ohaji)

**CLAY**

$$\frac{2}{60} \times 100 = 3.3\%$$

Percentage of clay = 3.3%

**SILT**

$$\frac{11}{60} \times 100 = 18.3\%$$

Percentage of silt = 18.3%

**SAND**

$$\frac{86}{60} \times 100 = 143.3\%$$

Percentage of sand = 143.3%

For Orlu 2 (Umuna Orlu)

**CLAY**

$$\frac{3}{60} \times 100 = 5\%$$

Percentage of clay = 5%

**SILT**

$$\frac{14}{60} \times 100 = 23.3\%$$

Percentage of silt = 23.3%

**SAND**

$$\frac{82}{60} \times 100 = 136\%$$

Percentage of sand = 136%

For Orlu 3 (Umuokanne Ohaji)

**CLAY**

$$\frac{3}{60} \times 100 = 5\%$$

Percentage of clay = 5%

**SILT**

$$\frac{11}{60} \times 100 = 18.3\%$$

Percentage of silt = 18.3%

**SAND**

$$\frac{85}{60} \times 100 = 141.6\%$$

Percentage of sand = 141.6%

For Orlu 4 (Isiekenesi Ideato South)

**CLAY**

$$\frac{2}{60} \times 100 = 3.3 \%$$

Percentage of clay = 3.3 %

**SILT**

$$\frac{13}{60} \times 100 = 21.7 \%$$

Percentage of silt = 21.7 %

**SAND**

$$\frac{84}{60} \times 100 = 140 \%$$

Percentage of sand = 140%

FOR OWERRI

Owerri 1 (Ihiagwa)

**CLAY**

$$\frac{3}{60} \times 100 = 5\%$$

Percentage of clay = 5 %

**SILT**

$$\frac{15}{60} \times 100 = 25 \%$$

Percentage of silt = 25%

**SAND**

$$\frac{80}{60} \times 100 = 133 \%$$

Percentage of sand = 133%

For Owerri 2 (Onicha Ezinihitte)

**CLAY**

$$\frac{2}{60} \times 100 = 3.3 \%$$

Percentage of clay = 3.33 %

**SILT**

$$\frac{15}{60} \times 100 = 25 \%$$

Percentage of silt = 25 %

**SAND**

$$\frac{81}{60} \times 100 = 135 \%$$

Percentage of sand = 135%

For Owerri 3 (Obinze)

**CLAY**

$$\frac{3}{60} \times 100 = 5 \%$$

Percentage of clay = 5 %

**SILT**

$$\frac{15}{60} \times 100 = 25 \%$$

Percentage of silt = 25 %

**SAND**

$$\frac{81}{60} \times 100 = 135 \%$$

Percentage of sand = 135%

For Owerri 4 (Mbieri)

**CLAY**

$$\frac{3}{60} \times 100 = 5 \%$$

Percentage of clay = 5%

**SILT**

$$\frac{15}{60} \times 100 = 25 \%$$

Percentage of silt = 25 %

**SAND**

$$\frac{81}{60} \times 100 = 135 \%$$

Percentage of sand = 141%

## CALCULATIONS FOR THE INDICES CONTD.

### CLAY RATIO

$$\frac{\% \text{ sand} + \% \text{ silt}}{\% \text{ clay}}$$

For Locations in Okigwe

Ezinnachi

$$\frac{40 + 100}{16} = 8.75$$

Okwelle

$$\frac{41 + 101}{16.6} = 8.55$$

Ugiri Mbano

$$\frac{56.6 + 100}{16.6} = 9.34$$

Okwe

$$\frac{55 + 100}{16.6} = 9.34$$

For Locations in Orlu

Umuagwo Ohaji

$$\frac{143.3 + 18.3}{3.3} = 48.96$$

Umuna Ohaji

$$\frac{136 + 23.3}{5} = 31.86$$

Umuokanne Ohaji

$$\frac{141.6 + 18.3}{5} = 31.98$$

Isiekenesi Ideato South

$$\frac{140 + 21.7}{3.3} = 49$$

For Locations in Owerri

Ihiagwa Owerri West

$$\frac{135 + 25}{5} = 31.6$$

Onicha Ezinihitte

$$\frac{135 + 25}{3.33} = 48.04$$

Obinze Owerri West

$$\frac{135 + 25}{5} = 32$$

Obazu Mbieri

$$\frac{141 + 25}{5} = 33.2$$

## MODIFIED CLAY RATIO

$$\frac{\% \text{ sand} + \% \text{ silt}}{\% \text{ clay} + \% \text{ organic matter}}$$

For Locations in Okigwe

Ezinnachi

$$\frac{40 + 100}{16 + 1.16} = 8.15$$

Okwelle

$$\frac{41 + 101}{16.6 + 0.71} = 8.20$$

Ugiri Isiala Mbanjo

$$\frac{56.6 + 100}{16.6 + 1.04} = 8.87$$

Okwe

$$\frac{55 + 100}{16.6 + 0.77} = 8.92$$

For Locations in Orlu

Umuagwo Ohaji

$$\frac{143.3 + 18.3}{3.3 + 3.94} = 22.32$$

Umuna Orlu

$$\frac{136 + 23.3}{5 + 1.34} = 25.13$$

Umuokanne Ohaji

$$\frac{141.6 + 18.3}{5 + 2.24} = 33.34$$

Isiekenesi Ideato South

$$\frac{140 + 21.7}{3.3 + 1.55} = 8.15$$

For Locations in Owerri

Ihiagwa Owerri west

$$\frac{135 + 25}{5 + 2.50} = 21.33$$

Onicha Ezinihitte Mbaise

$$\frac{135 + 25}{3.33 + 2.40} = 27.92$$

Obinze Owerri West

$$\frac{135 + 25}{5 + 1.84} = 23.39$$

Obazu mbieri

$$\frac{141 + 25}{5 + 2.35} = 22.58$$

$$\text{Disperion ratio} = \frac{\% \text{silt} + \text{clay in partilce sie distribution}}{\text{Total \% silt} + \text{clay} \times 100}$$

$$\text{Erosion ratio} = \frac{\text{Dispersion ratio}}{\text{colloid content}/\text{moisture equivalent}}$$

1) For Ihiagwa

$$\text{Dispersion ratio} = \frac{2}{30} = 0.066$$

$$\text{colloid content}/\text{moisture equivalent} = \frac{2}{10.6} = 0.188$$

$$\text{Erosion ratio} = \frac{0.066}{0.188} = 0.351$$

2) For Onicha Ezinihitte

$$\text{Dispersion ratio} = \frac{2}{28.3} = 0.071$$

$$\text{colloid content}/\text{moisture equivalent} = \frac{2}{10.7} = 0.187$$

$$\text{Erosion ratio} = \frac{0.071}{0.187} = 0.376$$

3) For Obinze

$$\text{Dispersion ratio} = \frac{2}{30} = 0.066$$

$$\text{colloid content}/\text{moisture equivalent} = \frac{2}{11.5} = 0.174$$

$$\text{Erosion ratio} = \frac{0.066}{0.174} = 0.379$$

4) For OBAZU MBIERI

$$\text{Dispersion ratio} = \frac{2}{30} = 0.066$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{2}{11.7} = 0.171$$

$$\text{Erosion ratio} = \frac{0.066}{0.171} = 0.385$$

5) For OKWELLE ONUIMO

$$\text{Dispersion ratio} = \frac{8}{115} = 0.069$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{8}{17.5} = 0.457$$

$$\text{Erosion ratio} = \frac{0.069}{0.457} = 0.153$$

6) For OKWE ONUIMO

$$\text{Dispersion ratio} = \frac{8}{116.6} = 0.068$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{8}{18.5} = 0.432$$

$$\text{Erosion ratio} = \frac{0.068}{0.432} = 0.157$$

7) For UGIRI ISIALA MBANO

$$\text{Dispersion ratio} = \frac{8}{115.4} = 0.065$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{8}{19.1} = 0.419$$

$$\text{Erosion ratio} = \frac{0.065}{0.419} = 0.162$$

8) For Ezinnachi Okigwe

$$\text{Dispersion ratio} = \frac{8}{116} = 0.069$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{8}{18.2} = 0.439$$

$$\text{Erosion ratio} = \frac{0.069}{0.439} = 0.157$$

9) For Isiekenesi Ideato South

$$\text{Dispersion ratio} = \frac{1.1}{25} = 0.044$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{1.1}{13.4} = 0.082$$

$$\text{Erosion ratio} = \frac{0.044}{0.082} = 0.536$$

10) For UMUNA ORLU

$$\text{Dispersion ratio} = \frac{1.4}{28.3} = 0.049$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{1.4}{15.8} = 0.088$$

$$\text{Erosion ratio} = \frac{0.049}{0.088} = 0.556$$

11) For UMAGWO OHAJI

$$\text{Dispersion ratio} = \frac{1.6}{21.6} = 0.074$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{1.6}{14.6} = 0.109$$

$$\text{Erosion ratio} = \frac{0.074}{0.109} = 0.678$$

12) For UMUOKANNE OHAJI

$$\text{Dispersion ratio} = \frac{1.55}{23.3} = 0.066$$

$$\text{colloid content} / \text{moisture equivalent} = \frac{1.55}{14.5} = 0.106$$

$$\text{Erosion ratio} = \frac{0.066}{0.106} = 0.622$$