

**ASSESSMENT OF SALT BUILD UP IN AN IRRIGATION SYSTEM; A CASE STUDY
OF CHANCHAGA IRRIGATION SCHEME.**

BY

MICHEAL JACOB

MATRIC NO. 2004/18381EA

**DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.**

FEBRUARY, 2010

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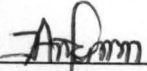
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**BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF
ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES
ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER
STATE.**

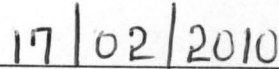
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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.



Micheal Jacob



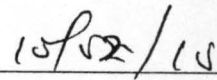
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CERTIFICATION

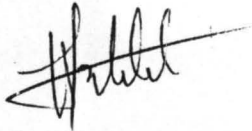
This project entitled "Assessment of Salt Build up in an Irrigation System, A Case Study of Chanchaga Irrigation Scheme. " by Micheal Jacob, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.



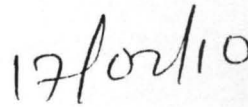
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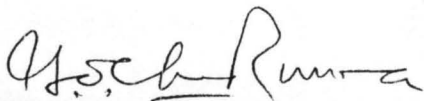
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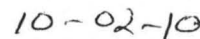
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Date

DEDICATION

This project work is dedicated to the Glory of Almighty God, who made it possible for me to conduct the project work and achieve my goal without hindrance.

AKNOWLEDGEMENTS

All praises and glory be to God almighty, besides which there is no other god, the most merciful, the creator who in his infinite mercy inspired, guided and directed me throughout the period of my studies and in carrying out this work.

I am indebted to my supervisor, Engr. P. A Idah for taken his time to go through this project, despite other academic works at his disposal. Particularly the constructive criticisms offered.

Special thanks to officer in charge of laboratory, Mohammed Jiya and other staff of Niger State water board through whom the laboratory analyses were made possible.

I owe a word of appreciation to the head of the department Dr. A.A. Balami and other staff members of the department which include; Dr. O. Chukwu, Dr. N.A. Egharevba, Dr. B.A. Alabadan, Dr. D. Adgidzi, Dr G. Agidi, Engr. P. Adeoye, Mr. M. Sadeeq, Mrs. H.I Mustapha, Mr. H. Adamu, Mrs. B. Orhevba, and Mr. S. Dauda for their contributions to my knowledge during my study.

To my father Mr. Jacob, Timothy and my mother Mrs. Jacob, Esther, I owe a million of gratitude for your love, care and supports. I also thank my brother, Moses Jacob and my beloved sisters, Hanna Jacob and Elizabeth Jacob, And to the rest of my siblings for there patience, prayers and supports.

I express immeasurable appreciations to my course mate and friends Ojukwu Henry who assisted me in organizing this work, I also appreciate Obi Samson N, Leonard Iyaji, Fadiji Samuel Tobi and the rest of my course mates too numerous to mention. May the sky be your starting point. You all made my stay in the campus a memorable one.

ABSTRACT

Salt build up in irrigation scheme is one of the major problem facing agricultural land and crop utmost growth. The objective of the project is to sustain and improve the qualities of both soil and water for agricultural purpose. The quality of surface water as well as soil were evaluated for their suitability in irrigation agriculture. River Chanchaga was sampled at the up stream, on stream, down stream and discharge point sections. Routine cations were determined using spectrophotometer while anions were determined by titration. The various chemical elements of the water and soil are well within the limits required by the Food and Agricultural Organization FAO (1994) for irrigation agriculture. The soluble salt contents of both soil and water sampled are generally low as indicated by Electrical Conductivity (EC) values. The soils are mainly loamy and are therefore highly permeable. The sodium hazard measured as sodium adsorption ratio (SAR) gives low risk of sodium alkalization (class C1-S1) with values ranging from 4.8 to 6.3 and 0.50 to 1.05 for both water and soil respectively. These results showed that the water and soil qualities are adequate for irrigated agriculture. However, if the present level of food production is to be improved on the water quality and soil need to be monitored regularly to check the concentration of certain ions, which may eventually lower the quality.

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List of Abbreviations

ESP	-	Exchangeable Sodium Percentage
SAR	-	Sodium Adsorption Ratio
CEC	-	Cations Exchange Capacity
US	-	Up Stream
ON	-	On Stream
DS	-	Down Stream
DP	-	Discharge Point
USWS	-	Up Stream Water Sample
OSWS	-	On Stream Water Sample
DSWS	-	Down Stream Water Sample
DPWS	-	Discharge Point Water Sample
EC	-	Electrical Conductivity
TDS	-	Total Dissolved Solids
Mg/l	-	Milligram per Litre
ppm	-	part per million

Mmhos/cm	-	millimhos per centimeter
μmhos/cm	-	micromhos per centimeter
Ds/m	-	Deci Siemens per meter
USDA	-	United State Department of Agricultural
FAO	-	Food and Agricultural Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

In many assessment of salt build-up in irrigation scheme and its effect on crops growths the physical, chemical and biological characteristics of water are major importance in determining whether or not water is suitable for irrigation use (Hawill, 1986). Development of soil salinity is a challenge to permanence of irrigated culture. Michael (1995) discovered that accumulation of salt in soils leads to unfavourable soil-water air relationship and decreases crop production. The origin of salinity control is frequently a major objective of irrigation management even though the primary objective of irrigation is to maintain soil metric potential in range suitable for optimum crop yield

These objectives are often closely related because salinity is almost a universal threat in areas where irrigation water typically contains significant amount of dissolved salt. In humid regions, salinity is of limited concern (Michael, 1995) because rain water is almost free of dissolved salts; thus salinity problem may occur in limited areas in hostile region subject to sea intrusion or from occurrence of brime spillage, waste disposal or excess fertilization in humid area. According to Hoffman (1994), determination of the chemical and physical properties of saline and alkaline soil serves as basis for their diagnosis, treatment and management. The important properties to be determined in the diagnosis of salt effect are the P^H , presence of soluble salts, exchangeable sodium exchange capacity and gypsum requirement.

A rapid determination of total dissolved solids can be made by measuring the electrical conductance of water. Conductance is referred rather than is reciprocal resistance, because it increases with salt content (Michael, 1995). Also drainage process or

supplementary irrigation increase in the humid regions, salinity problems similar to these in an arid region will now become prevalent. All soils and irrigation waters contain a mixture of soluble salts, some of which are not essential for plant growth. The salt concentration of soil solution is usually higher than that of applied water. The increase in salinity results on plant transpiration and soil surface evaporation, which selectively remove the water, concentrating the salt in water.

The initial source of salt in soil from weathering of rock and minerals are broken and new combinations are formed; including both secondary silicates or soluble salt. However, excessive application of soluble potassium-nitrogen fertilizer and soluble nitrate can also contribute to the degradation of soil.

The nature and extent of salt accumulation and the degree of the soil alkalinity depends on the quality of irrigation water, salt tolerance characteristics of the plant and climatic condition. Generally, soils of high texture are less salinized than those of medium and heavy texture.

1.2 Statement of the Problem

Irrigation is a means of increasing agricultural productivity for provision of food and fibre need of man. However in this task, one of the contending problems is salinity and sodicity which is harmfully affecting the irrigated land. Thus while global food and fibre needs are increasing, soil and water resources are becoming more limited and diminished in quality due to salinity and sodicity. This necessitates the investigation of salts building up in the soil.

1.3 Objectives of the Study

1. To sample soil of the study area for the purpose of soil texture analysis and determination of total salt concentration.

2. To sample the irrigation water with a view to determine the quality as it affect crop.
3. In the light of objective two above, to suggest ways of sustaining or improving the qualities of both soil and water.

1.4 Justification of the Study

One of the major problem farmers face is the presence of salt build-up in irrigation water that hinders crop growth and poor production of food, both in quality and quantity. The accumulation of salts in the soil profile depends on a balance between the amount of water and salt applied. Therefore, remedy is attained through the assessment of salt build-up in the irrigation and analysis of certain elements imposed by irrigation water and soil to the crops.

Provision of required quality of water for irrigation operation gives room for optimum yield.

1.5 Scope of the Study

The irrigated soil and irrigation water under consideration in this study is that of chanchaga local government area of Niger state, Nigeria. Analyzing the level of salt build-up in the irrigated soil in relation to the irrigating water applied to the soil. Analysis of soluble salt of Na^+ , Ca^{2+} , Mg^{2+} , K^+ , Cl^- , NO_3^{2-} and SO_4^{2-} as they affect some physical characteristics of the soil such as soil pH, soil electrical conductivity (EC) and soil textural class.

CHAPTER TWO

2.0 Literature Review

Irrigation is the application of water to the soil to increase soil moisture content for purpose of increasing yield. Rainfall is not adequate throughout the world to meet crop water requirements. Available amount is not evenly distributed throughout the year. Irrigation becomes imperative to meet the demand for food of the growing population. The quality of water effect both the soil and the crop and this can lead to increase or decrease of yield (Oyebode 1999 and Michael 1995). Water quality refers to the characteristics of a water supply that will influence its suitability for specific use, that is, how well the quality meet the need of the user. Ayers and Wescott (1985) stated that quality of water depends on certain physical, biological and chemical characteristics. The use of irrigation for crop production often leads to detrimental effect on both the soil and water quality in the environment. Therefore it is necessary that various factor involved should be studied and analyzed so that preventive measures can be taken before problematic state is reached (Mudiare and Mohammed, 1978).

Hartman *et al.* (1987) discovered that plant injury resulting from excessive soluble salts may first occur in mild chlorosis of the foliage, later progressing to a necrosis of leaf tips and margins. This type of injury is largely attributed to the mobility of soluble salts within the plant. As these salts are rapidly translocated throughout the plant, they accumulate at the leaf tips and margins. Once the salt reaches a toxic level they cause the characteristics "burn" associated with the excessive salts. This often predisposes the plant to a wide range of root diseases (phythium, fusarium etc) extreme injury may also interfere with water up take and result in excessive wilting of the plant. It is extremely important to inspect the root systems of plant on a regular basis in order to monitor the effect of soluble salts.

According to Nelson (1981), managing soluble salts involves an integrated approach to production. This includes the type of growing medium used, irrigation frequency, water quality, fertility regime and plant tolerance. Growing media should contain a substantial quantity of large pores to facilitate good drainage. Media with these characteristics are easily leached and reduces the potential for the accumulation of soluble salts of irrigation water. This medium is important to apply enough water to allow sufficient quantities to leach through the container. Approximately 15-20% more water than the soil can hold should be applied at each irrigation if the salt hazard is high. Water pressure must be adjusted to avoid overflow.

The accumulation of water-soluble salts in a soil is a factor determining its formation and properties resulting in the development of a salt-affected soil. Above a certain threshold value, salt salinity alters properties of the soil which is adverse from the point of view of their production capacity as well as the biological functions of the environment, including the decline of life support capacity, biodiversity and etc. salinization which is major in the deterioration of land, leads to a specific kind of degradation. Although numerous authors (Oldeman, 1994) treats it as one of the chemical degradation processes, as a matter of fact, its environmental effect is much wider than that of simple chemical process, example in case of soil contamination by chemicals

2.1 Nature and Extent of Salt Problems

The properties of soil are profoundly influenced by the quality of irrigation water, hydrological conditions and cultural practices. The salt problem in the irrigation area of central Nigeria plateau traversing across the areas and joining the river to discharge their content into the soil water are related to the quality of water used for irrigation (Awotunde, 1981).

Salt problem in arid and semi-arid regions having rainfall below 45cm per annum are spread over the state of Kano, Kaduna and Plateau. The field experiment performed by Awotunde, (1981), shows that out of the crops sampled, the most sensitive crop to salinity is onion. The field of this crop begins to be affected when salinity level approaches 1.2% depending on the stage of development, soil and other environmental factors. But the most tolerant crops are cotton and sugar cane. Yield can become affected when salinity approaches 7.7% since salinity can affect the yield of the most sensitive crop. The degree of suitability will vary with soil, and changing environmental conditions.

2.2 Water Logging and Soil Salinity

Salinity from irrigation can occur over time wherever irrigation occurs, since almost all water (even natural rainfall) contains some dissolved salts. When the plants use the water, the salts are left behind in the soil and eventually begin to accumulate. Since soil salinity makes it more difficult for plants to absorb soil moisture, these salts must be leached out of the plant root zone by applying additional water. This water in excess of plant needs is called the leaching fraction. Salination from irrigation water is also greatly increased by poor drainage and use of saline water for irrigating agricultural crops.

Salinity from drylands can occur when the water table is between two to three metres from the surface of the soil. The salts from the groundwater are raised by capillary action to the surface of the soil. This occurs when groundwater is saline (which is true in many areas), and is favored by land use practices allowing more rainwater to enter the aquifer than it could accommodate. For example, the clearing of trees for agriculture is a major reason for dryland salinity in some areas, since deep rooting of trees has been replaced by shallow rooting of annual crops.

Studies in land reclamation, Irrigation Research Institute Amstar, showed a rise of water table, It was observed that the salt-water problem of high water table areas is mostly governed by intensity and amount of rainfall (Uppal, 1982). The limited applicability of the various rating of soil in the water is quite reasonable on ground that the growth is not only influenced by the chemical characteristics of the irrigation water, soil types and crop species, but also the actual salt concentration wear the root zones, physical condition of the soil, fertility status, depth of water table, soil management practice and climatological conditions (Uppal, 1982).

2.2.1 Quality of Irrigation Waters

Hillal, (1994) Several schemes have been proposed as ways to evaluate irrigation waters having a ration of sodium (Na), (Ca+Mg) higher than one have been suggested as leading to alkali formation. A widely used scheme is the rating of waters according to the soluble sodium percentage $(Na-1000) / (Ca^+ Mg^+ Na)$. A diagram relates soluble-sodium percentage and salt concentration of the water to certain equilibrium exchangeable-sodium percentage values that exist when soils are continuously leached with water of specified composition. In other scheme, all water that would cause equilibrium exchangeable-sodium percentage of 15 or greater is assumed to be unsatisfactory for general use. A scheme proposed by the United State salinity laboratory has been generally approved in the western states. Sodium-adsorption-ratio value is used to separate water classes according to hazards from sodium accumulation. A logarithmic scale is used for the electrical conductivity base to establish water classes based on hazards from total salt concentration (Hillal, 1994).

A major source of salinity in the middle and western part of the riverine plain results from irrigated lands being under lined at depth by marine and lake formed sediments which contain high level of residual salts. Therefore ground water and surface water are generally

highly saline. In addition, some of the irrigation soils overlying these sediments are coarse-textured, aeolin-derived mallee soils that are very permeable. Hence unlined canals and inefficient irrigation system often lead to perched water tables forming over impervious clay layers in the sediments (Courtney and Trudgill (1982).

Research currently sponsored by the United States department of the interior, on the demineralization of saline water is of great interest to irrigation agriculture. Demineralization being investigated include vaporization procedures, methods for crystallizing salts, adsorption and diffusion phenomena, osmosis, ion exchange, precipitation electro-ion migration, streaming potentials, electrostatic and electromagnetic effects, and used of ultrasonic and ultra high frequency currents. Proposals involve the use of such low-cost energy sources as sunshine, tide and wave action to aid demineralization. At present no process appears economically feasible for treating water for irrigation (Carter, 1992).

2.2.1.1 Salinity Hazard

All soils contain some water-soluble salts. Plants absorb essential plant nutrients in form of soluble salts, but excessive accumulation on soluble salts, called **soil salinity**, suppresses plant growth (Blaylock, 1994). Saline or salt-affected soils are common in arid and semi-arid regions. Salts in the soil occur as ions (electrically charged form of atoms or compounds). Ions are released from weathering minerals in the soil. They may also be applied in irrigation water or as fertilizers, or migrate upward in the soil from the shallow groundwater. When precipitation is insufficient to leach ions from the soil profile, salts accumulate in the soil and soil salinity can result (Blaylock, 1994).

Poor drainage (the most common cause of soil salinity) and/or poor irrigation water often contribute to soil salinity. As plants absorb soil water or as water evaporates, salts from the water remain in the soil. For this reason, soil salinity will usually be greater than the

salinity of the irrigation water used. Improper irrigation management increases the risk of developing soil salinity. To prevent salt build-up, enough water must be passed through the root zone to leach salt from the soil.

The general effect of soil salinity on plants is called an **osmotic effect**. This means that salts increase the energy with which water is held in the soil. In other words, the soil must be kept wetter to supply the same amount of **plant-available water** as would be present without the salts. Plants then must increase the energy they expend to obtain water from the soil. The plant must use energy to get water that would otherwise be used for growth, flowering, or fruiting. When soil salinity exceeds a plant's tolerance, growth reductions occur. As salt concentration increases, water becomes increasingly difficult for the plant to absorb. A plant can actually die from water stress or drought in a moist soil if the salt concentration becomes high enough. Other effects on salts on plants are toxicities of specific salts and nutritional imbalances. Some elements, such as sodium, chlorine, boron, have specific toxic effects on plants. Plants sensitive to these elements may be affected at relatively low salt levels if the soil contains enough of the toxic element. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients.

The salinity of irrigation water is the sum of all the ionized dissolved salts in the water without reference to the specific ion present. It is measured by electrical conductivity, (EC) of the irrigation water since the EC is directly related to concentration of the salt (Ayers and Westcot 1994).

Salinity hazard refers to the danger that the use of irrigation water will lead to osmotic problems in the soil/plants. This hazard may be diagnosed on the basis of the EC-

value of the irrigation water. EC is the measure with which an electrical current will pass through a solution. It is the reciprocal of electrical resistivity.

Salt in soil or water reduces water availability to the crop to such an extent that yield is affected (Ayers and Westcot 1994).

2.2.1.2 Sodicity Hazard (Soil Infiltration Effect)

Salt is a natural element of soils and water. The ions responsible for salinization are: Na^+ , K^+ , Ca^{2+} , Mg^{2+} and Cl^- . As the Na^+ (sodium) predominates, soils can become sodic. Sodic soils present particular challenges because they tend to have very poor structure which limits or prevents water infiltration and drainage.

Sodicity hazard refers to dispersion problems, caused by relatively high percentage occupancy of the soil exchange complex by Na^+ which results in poor soil structure due to easy dispersion of the colloids in the soil. This hazard can be appraised on the basis of two main diagnostic parameters (Electrical Conductivity (EC) value and Sodium Adsorption Ratio (SAR) value). In general, problems are not experienced in the soil with ES-value <15% (Egharevba, 2002). Sodium adsorption ratio (SAR) is the ratio for soil extracts or and irrigation waters used to express the relative activity of sodium ions in exchange reaction with soil (Michael, 1999).

The exchangeable-sodium-percentage (ESP), the sodium-adsorption-ratio (SAR) and the adjusted SAR of the soil extract or irrigation waters are used to evaluate the exchangeable sodium status of the soil and irrigation waters (James, 1988). ESP is the degree of saturation of the soil exchange complex with sodium and may be calculated by the formula, ESP (Michael, 1999)

$$ESP = \frac{\text{Exchangeable sodium (milliequivalent per 100g)}}{\text{Cation Exchange Capacity (milliequivalent per 100g)}} \times 100$$

Cations Exchange Capacity (CEC) is the total quantity of cations which a soil can absorb by cation exchange, usually expressed in milliequivalents per 100 grams. Measured values of cation exchange capacity depend somewhat on the method used for its determination, (Michael, 1999).

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next.

An infiltration problem related to water quality occurs when the normal infiltration rate for the applied water or rainfall is appreciably reduced and water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to maintain acceptable yields. Although the infiltration rate into the soil varies widely and can be greatly influenced by the quality of the irrigation water, soil factors such as structure, degree of compaction, organic matter content and chemical make-up can also greatly influence the intake rate (Ayers and Westcot, 1994). The two most common water quality factors which influence the normal infiltration rate are the salinity of the water and its sodium content relative to the calcium and magnesium content. High salinity water will increase infiltration. A low salinity water or water with high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time, (Ayers and Westcot, 1994). The infiltration rate generally increases with increase in salinity and decreases with either decreasing salinity or increasing sodium content relative to calcium and magnesium – the sodium adsorption ratio. Therefore, two factors, salinity and SAR, must be considered together for a proper evaluation of the ultimate effect on water infiltration rate.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where Na, Ca and Mg are sodium, calcium and magnesium are in milliequivalent per litre (meq/L) from water analysis.

According to Smedema and Rycroft (1988),

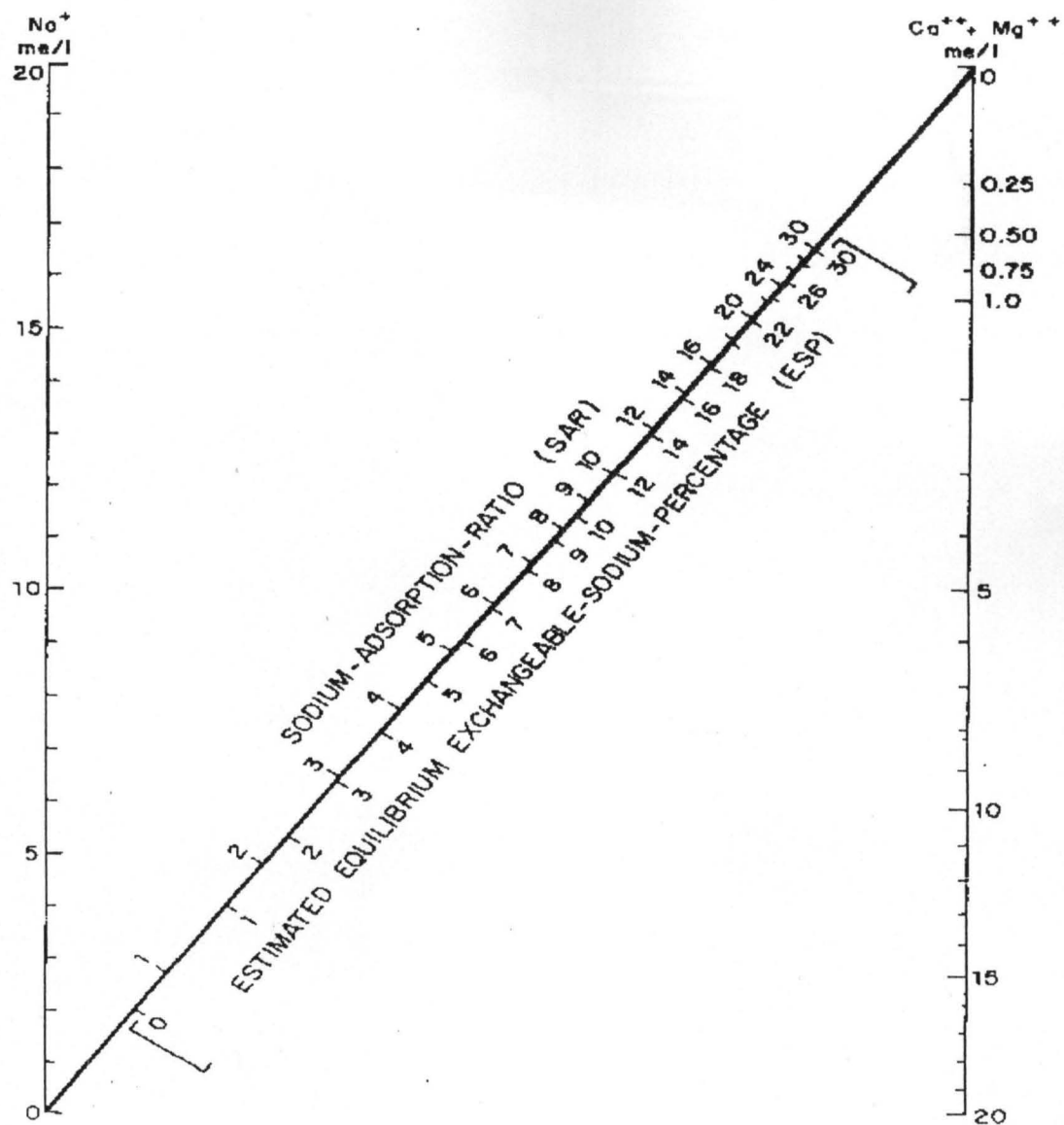
ESP can be computed by theoretical relationship

$$ESP = \frac{100(0.015SAR)}{1 + 0.015SAR}$$

However, its use is limited by many factors. An empirical relationship between ESP and SAR for soils which has reached equilibrium with the applied irrigation water is, (Landon Ed, 1991)

$$ESP = \frac{100(0.01475SAR - 0.0126)}{0.01475SAR + 0.9874}$$

This can be expressed in form of nomogram given in fig. 2.1. It determines SAR values from for irrigation water and estimates the corresponding ESP. The method is generally suitable for solution with total concentrations between about 39 and 110meq/L; outside this range other regression equations apply.



Source: US Salinity Laboratory, 1954

Figure 2.1: A Nomogram for Determining Sodium Adsorption Ratio

2.2.1.3 Toxicity Hazard

Toxicity problems occur if certain constituent (ions) in the soil or water are taken up by the plant and accumulates the concentration high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The ions of primary concern are chloride, sodium and boron.

2.2.2 Soil

2.2.2.1 What is Soil

Soil is generally referred to as the topmost part of the earth crust.

According Microsoft Encarta (2006) soil is the loose material that covers the land surface earth and support growth of plants. In general, soil is an unconsolidated, or loses, combination of inorganic and organic materials.

The Agricultural compendium (1989) viewed soil as a three dimensional body occupying the uppermost part of the earth crust, having properties different from the underlying rock material as a result of interactions between climate, living organisms (including man), parent material and relief over a period of time.

2.2.2.2 Soil Texture

The weathering processes of rock result in the formation of soil in wide range of particle sizes from stones, to gravel, to silt and to very small clay particle. Soil texture is therefore the degree of fineness or coarseness of the soil.

Forth (1990) specifically stated that, texture is the relative proportion of sand, silt, and clay in a soil. Once the percentage of sand, silt, and clay is measured, the soil may be assigned a textural class using the USDA textural triangle (Fig 2.2). Within the textural triangle are various soil textures which depend on the relative proportions of the soil fractions.

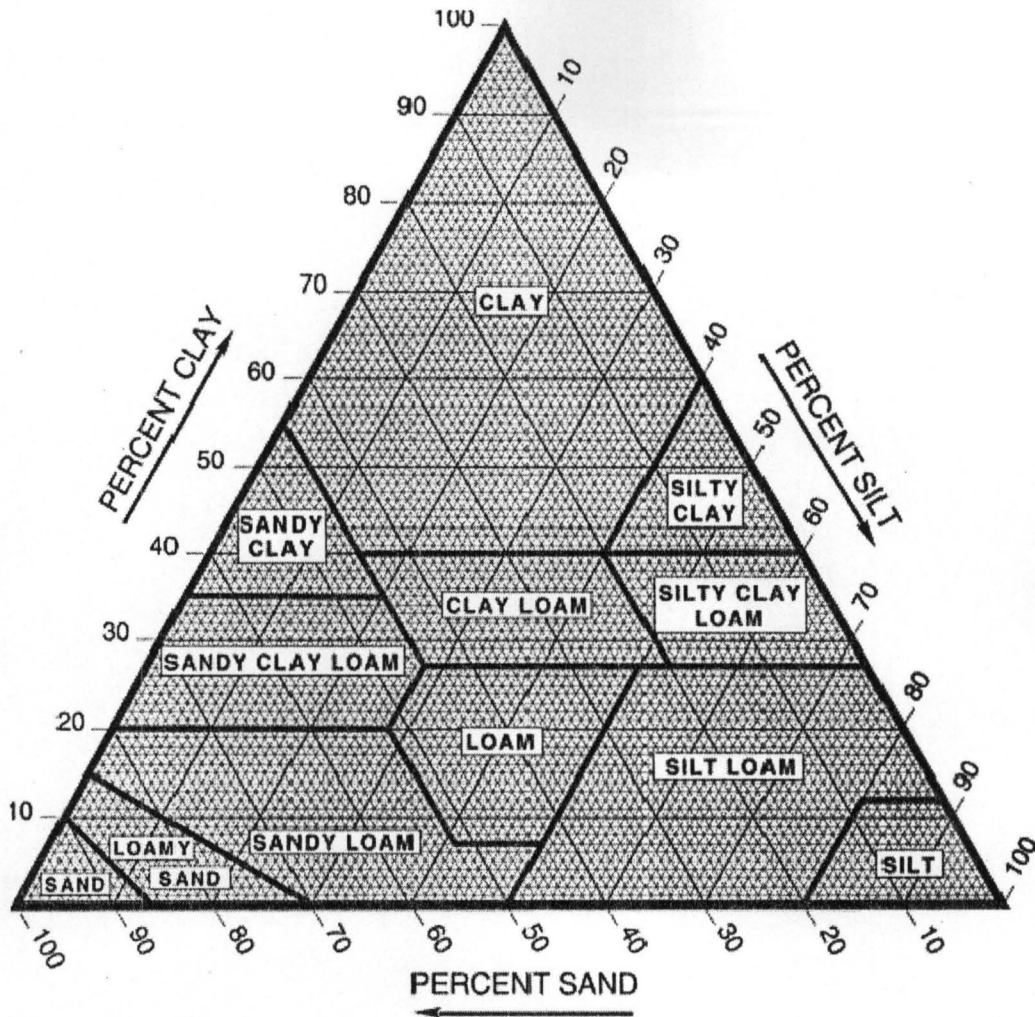


Fig 2.2: The USDA Soil Textural Triangle

2.2.2.3 The Soil Separates

Soil separates are the size groups of mineral particles less than 2 millimeters (mm) in diameter or the size groups that are smaller than gravel. Table below shows the characteristics of some soil separates, (Forth, 1990).

Table Showing Characteristics Of Soil Separate

Separate	Diameter mm^a	Diameter mm^b
Very coarse sand	2.00 – 1.00	-
Coarse sand	1.00 – 0.50	2.00 – 0.20
Medium sand	0.50 – 0.25	-
Fine sand	0.25 – 0.10	0.2 – 0.02
Very fine	0.10 – 0.05	-
Silt	0.05 – 0.002	0.02 – 0.002
Clay	Below 0.002	Below 0.002

Source: Forth, 1990

- (a) United States Department Of Agriculture
- (b) International Soil Science Society System

2.2.2.4 Soil Textural Classes

The texture of a soil is expressed with the use of class names. A loamy soil contains 7 to 27 percent clay, 28 to 50 percent silt, and between 22 and 52 percent sand. Soils in the loam class are influenced almost equally by the three separates – sand, silt, clay. For sandy soils (sand and loam sand), the properties and use of the soil are influenced mainly by the sand content of the soil. For clay (sandy clay, clay, silty clay), the properties and use of the soil are influenced mainly by high clay content (Forth, 1990).

Textural class names containing the terms ‘sand’ or ‘sandy’ are modified with the adjective very fine, fine, ‘coarse’, or ‘very coarse’, in accordance with the particle size range of the sand separate as given in USDA system.

Very coarse particles, the size of which varies between 2mm and 25mm are considered to be part of the soil mass, though not part of the fine earth, also influenced certain soil properties and, therefore if present in noticeable quantities, are noted in textural

class name by additions such as gravelly, 'cherty', 'slaty' or 'stony' (Agricultural Compendium, 1989).

2.2.2.5 Soil pH

The pH value of a soil or natural water is a measure of its alkalinity or acidity. More accurately stated, the pH is a measure of the hydrogen-ion concentration in water. Water molecules (H_2O) have a slight tendency to break down into ions, positive hydrogen ion (H^+) and negative hydroxyl ion (OH^-). In distilled water, the number of hydrogen ions formed is such that their concentration is expressed by pH of 7. (Mathematically, this is logarithm to the base of 10, of reciprocal of the hydrogen ion concentration of the water). Thus a pH 7 indicates a neutral solution neither alkaline nor acid. A pH value of 7.5 – 8.0 usually indicates the presence of carbonates of calcium and magnesium, and a pH of 8.5 or above usually indicates appreciable exchangeable sodium, (Michael, 1999).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 The Study Area

The project study area is the Chanchaga irrigation scheme, in Niger state, Niger (Fig 3.1).

Niger state is situated in north central part of the Federal Republic of Nigeria. It lies in the savanna zone of the tropics between latitude $8^{\circ}10'N$ and $11^{\circ}30'N$ and longitude $30^{\circ}30'E$.

Its climate is influence mainly by the rain-bearing South West monsoon winds from the ocean s and the dry dusty or harmattan North East winds (air masses) from the Sahara Desert. There are mainly the rainy and the dry seasons. The rainy season begins in April and ends in October and the dry season starts in October and the dry season starts in November and ends March. The mean monthly rainfall record from 1998 to 2006 ranges from 0.57mm to 215.1mm with February/March having the minimum and September having the maximum occurrence (Aminu, 2006) (Appendix A).

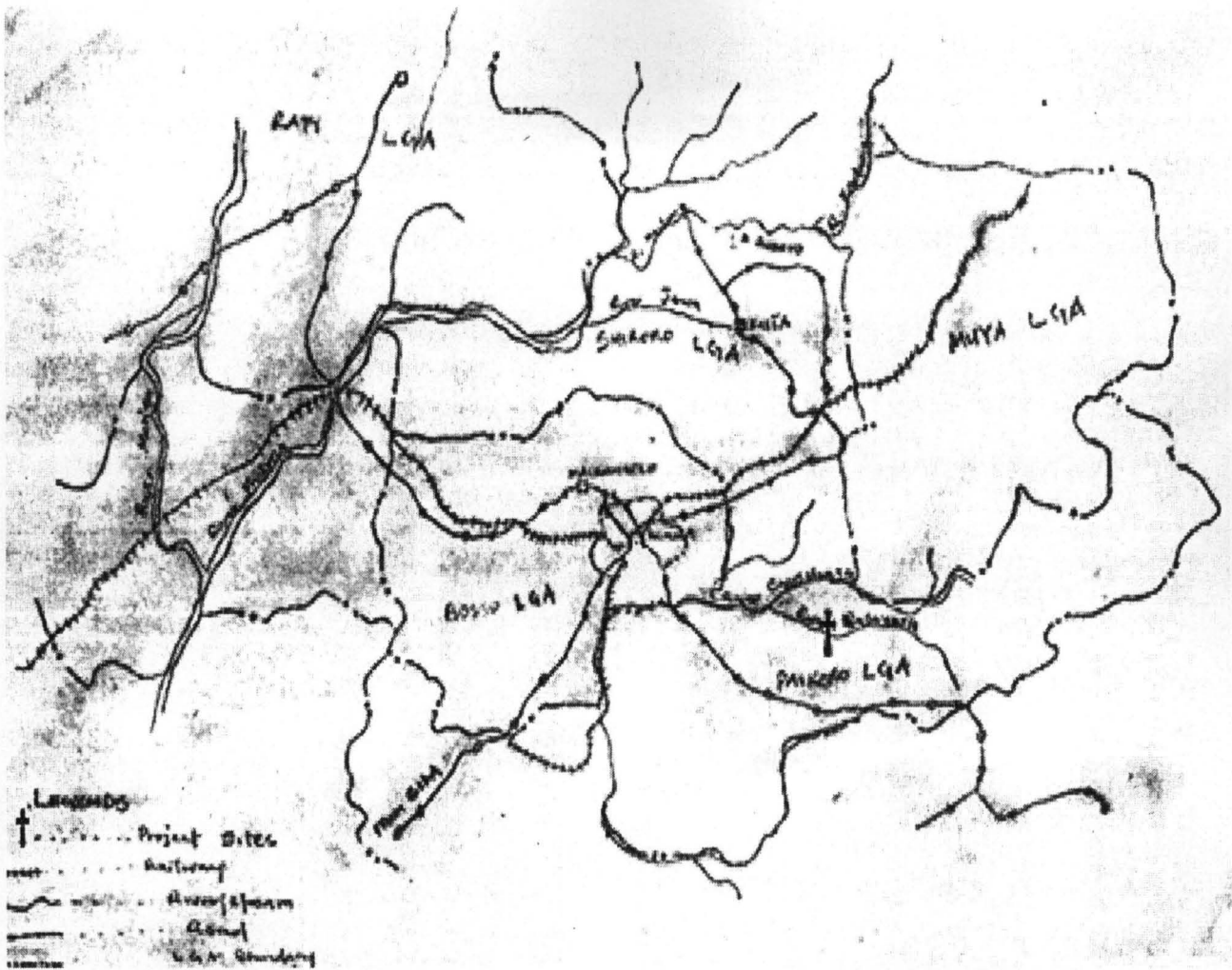


Fig.3.1: A Map Showing Project Study Area; Chanchaga Irrigation Scheme (†)

3.1.1 Chanchaga Irrigation Scheme

Chanchaga Irrigation Scheme is located at Chanchaga village at the outskirts of Minna metropolis, the capital of Niger State. River Chanchaga has been the main source of water for the irrigation scheme for dry season farming. The scheme was established in 1975 but became fully operational in the year 1978.

The scheme has a total area of twelve hectares (12ha). Out of this, wild system is adopted for eight (8ha) and four hectares (4ha) designed for gravity system using main canal and field channels (Babangida, 2001).

3.2 Water Samplings and Analyses

Water samples were obtained from different points in the running stream; Upper Stream (US), On Stream (OS), Down Stream (DS) and the Discharge Points (DP). At the point of sampling, four different plastic containers were rinsed using the stream water several times before the samples were taken. The plastic containers were filled with 1 liter of water sample taken from each point listed above and labeled accordingly.

The sampling points includes

1. Upstream of the irrigation water
2. On-stream of the irrigation water
3. Downstream of the irrigation water
4. Discharge point of the irrigation water

The upstream here refers to points on the stream course just before the scheme, On-stream refers to the points on the stream course where water is directly diverted for irrigation,

Downstream refers to points on the stream course just after the irrigation scheme, Discharge point refers to the water delivering points on the scheme from the on-stream where it diverted and put into use.

Chemical Parameters of Chanchaga Irrigation Water were determined using the standard methods. Parameters like P^H , Electrical Conductivity, Total Dissolved Solids, Chloride, Sulphate, Nitrate, Calcium, Magnesium, Potassium and Sodium were determined for water samples according to experimental procedures (see appendix B).

3.3 Soil Samplings Analyses

Soil samples were collected from different location in the scheme. Using sampling auger to the depth of 0-15cm, 15-30cm and 30-45cm at different points randomly. The surface samples were taken at 0-15cm depth and was labeled. The subsurface samples were taken at 15-30cm and 30-45cm and were also labeled. It was mixed thoroughly and all foreign matters like leaves, roots and stones etc. were removed. The auger was positioned on the soil surface vertically, in which the handle of the auger was screwed clockwise in such away that the cylindrical container was filled to the brine and was collected by a rubber container. The auger head was replaced into the toile and the same procedure was repeated until the required depths were reached. A total of 21 samples collected from this area were air dried.

Characteristics of Chanchaga Soil Samples were determined using the standard methods. Parameters like P^H , Electrical Conductivity, Sodium Adsorption Ratio, Chloride, Sulphate, Nitrate, Calcium, Magnesium, Potassium and Sodium were determined for soil samples according to experimental procedures (see appendix C).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil Texture

Results of textural analysis indicate a good soil texture both at the surface as well as the subsurface. The texture varied from plot A to plot G (i.e. cultivated land, uncultivated land and water logged area) within the scheme (Table 4.1). The surface and subsurface of Chanchaga irrigated soil are loamy and clay loam. A soil containing equal amount of sand, silt and clay is a clay loam. Soils in the loam class are influenced almost equally by all three separates – sand, silt and clay (Foth, 1990).

Increasing clay content was observed down the soil profile for all sampled plots. These characteristics would ensure adequate soil moisture retention and productivity.

The percentage sand composition of soils in this area is high, hence the permeability of the soil is therefore expected to be high and the internal drainage is also adequate. A high permeability is essential for leaching down the excessive salts or removal of sodium in alkaline soil. Therefore, this good characteristic is expected to aid cropping in this area.

Table 4.1: Results of Particle Size Analysis at Chanchaga Irrigation Scheme.

SAMPLE POINTS	SOIL DEPTH	% SAND	% SILT	% CLAY	TEXTURAL CLASS
Plot A	0-15	85.5	5.2	7.2	Loam
	15-30	78.9	10.3	9.5	Clay loam
	30-45	80.5	8.9	11.5	Clay loam
Plot B	0-15	89.2	6.1	5.5	Loam
	15-30	86.4	9.0	9.7	Clay loam
	30-45	85.2	8.5	8.4	Clay loam
Plot C	0-15	90.2	6.4	5.2	Loam
	15-30	82.4	9.2	6.9	Clay loam
	30-45	80.5	9.3	8.3	Clay loam
Plot D	0-15	91.4	4.4	3.5	Loam
	15-30	78.9	10.2	8.5	Clay loam
	30-45	90.7	4.5	3.7	Loam
Plot E	0-15	79.3	4.5	9.4	Loam
	15-30	75.3	8.9	9.2	Clay loam
	30-45	77.0	5.8	9.1	Clay loam
Plot F	0-15	79.3	10.2	4.6	Clay loam
	15-30	72.4	9.3	10.8	Clay loam
	30-45	69.5	10.2	14.2	Sandy clay
Plot G	0-15	66.3	10.5	11.5	Sandy clay
	15-30	75.6	7.6	13.7	Clay loam
	30-45	82.2	10.5	4.0	Clay loam

4.2 Water Samples Analyses & Soil Samples Analyses

The results of the water samples analyses of Chanchaga Irrigation Scheme are shown in Table 4.2a

Table 4.2a: Chemical Parameters of Chanchaga Irrigation Water

Water Quality Parameter	SAMPLING POINTS			
	USWS	OSWS	DSWS	DPWS
PH	6.8	7.2	6.8	6.5
Electrical Conductivity	9.5	10.7	11.5	13.0
Total Dissolved Solids	106.0	110.0	125.0	110.0
Chloride, Cl ⁻	23.0	29.0	25.0	30.0
Sulphate, SO ₄ ²⁻	14.5	12.0	13.8	14.8
Nitrate, NO ₃ ⁻	2.8	5.2	6.5	1.5
Calcium, Ca ²⁺	4.0	7.5	8.2	10.5
Magnesium, Mg ²⁺	1.8	4.5	3.5	7.0
Potassium, K ⁺	1.2	2.3	1.9	2.3
Sodium, Na ⁺	4.8	6.1	6.3	5.3

All parameters are in mg/l except EC in $\mu\text{mhos} / \text{cm}$ & pH unitless

Table 4.2b: Characteristics of Chanchaga Soil Samples

Sample Points	Soil Depth	P ^{II}	EC	SAR	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺
Plot A	0-15	6.80	1.80	0.065	0	11.65	1.25	16.40	2.30	0.63	1.05
	15-30	5.80	2.25	0.066	Trace	10.05	1.05	14.25	2.50	0.60	0.95
	30-45	6.40	3.50	0.054	Trace	4.00	1.75	12.35	1.75	0.45	0.60
Plot B	0-15	6.40	1.75	0.046	0	10.50	1.10	16.35	1.95	0.85	0.95
	15-30	6.40	1.55	0.040	0	9.80	1.50	16.75	3.05	0.42	0.50
	30-45	6.80	2.05	0.057	Trace	3.40	1.80	15.35	1.79	0.42	0.85
Plot C	0-15	6.30	3.55	0.066	Trace	11.00	0.95	14.70	1.75	0.40	0.80
	15-30	6.60	2.15	0.047	0	10.05	1.05	16.15	4.44	0.21	0.82
	30-45	6.40	3.35	0.052	0	11.00	0.95	16.45	5.62	0.92	0.75
Plot D	0-15	5.50	1.95	0.048	0	11.65	0.50	16.48	1.58	0.66	0.75
	15-30	6.50	1.70	0.063	0	9.70	0.50	15.55	2.35	0.20	0.80
	30-45	6.80	2.50	0.053	0	7.75	0.85	17.08	3.08	0.21	0.50
Plot E	0-15	5.50	2.85	0.055	Trace	11.25	0.25	14.30	1.45	0.40	0.82
	15-30	6.50	1.80	0.056	0	11.40	0.20	12.35	1.65	0.42	0.80
	30-45	6.80	3.05	0.050	0	11.70	0.50	11.20	1.90	0.34	0.77
Plot F	0-15	5.00	3.05	0.054	Trace	11.00	0.25	10.08	1.15	0.66	0.50
	15-30	5.00	3.35	0.047	Trace	10.52	0.50	13.62	6.23	0.21	0.75
	30-45	6.00	2.05	0.051	0	11.20	0.25	13.62	3.08	0.21	0.74
Plot G	0-15	6.40	1.50	0.085	0	11.20	0.20	9.95	2.30	0.85	0.85
	15-30	6.00	2.55	0.084	0	11.25	0.20	14.22	1.79	0.40	0.95
	30-45	6.90	2.55	0.077	0	11.00	0.95	14.25	1.90	0.41	0.95

Plot A – D = Cultivated land

Plot E and F = Uncultivated land

Plot G = Water logged area.

4.2.1 Water pH

pH is the degree or measure of the acidity or alkalinity of both soil and water. From Table 4.2a and 4.2b, it was observed that all the water and soil samples had acidic reaction with P^H ranges of 6.5 – 7.2 for water, 5.0 – 6.8 in the top soils and 5.8 – 6.9 in the sub-soils level. Thus, the P^H of this area could be considered suitable for adequate nutrient availability and could not pose problem to the plants as they seemed to be within the recommended ranges of pH 5 – 7.5 (Udo and Ogunwale, 1986).

4.2.2 Electrical Conductivity (EC) and Total Dissolved Solid (TDS)

Electrical conductivity (EC) measurements are used as indication of total quantities of soluble salts in solution. It is used in irrigation water analysis to determine the salinity of the water. Total dissolved solid (TDS) measures the concentration of dissolved solutes in irrigation water. It is also used as a measure of salinity (Aminu, 2006). Chemical quality is assessed in terms of total salt concentration or salinity by the EC and TDS in addition to other parameters. The total salt concentration or salinity of the irrigation water influences the plant osmotic activity which consequently reduces absorption of water and nutrients. The values of EC obtained for USWS, OSWS, DSWS, and DPWS are 9.5, 10.7, 11.5 and 13.0 $\mu\text{mhos/cm}$ from the Table 4.2a are within the recommended ranges of < 0.7 and > 3.0 ds/m (Ayers and Westcot, 1994). Therefore, it poses no salinity problem and the scheme water is safe for irrigation. The series of values obtained for EC at different sampling points in Table 4.2b above shows no salinity hazard on the soil and there is no restriction on the use of the soil for planting.

The total dissolved solids concentration varied 106.0 – 125.0 mg/L for water samples (table 4.2a). These values are generally considered to be low. Though the dissolved solids

may clog soil pores, coat soil surface and reduce infiltration and aeration. little of these effect were observed in the scheme. Furthermore, the salinity levels are well below the 250 $\mu\text{mhos/cm}$ level for excellent water for irrigation as indicated by US salinity laboratory staff (1984).

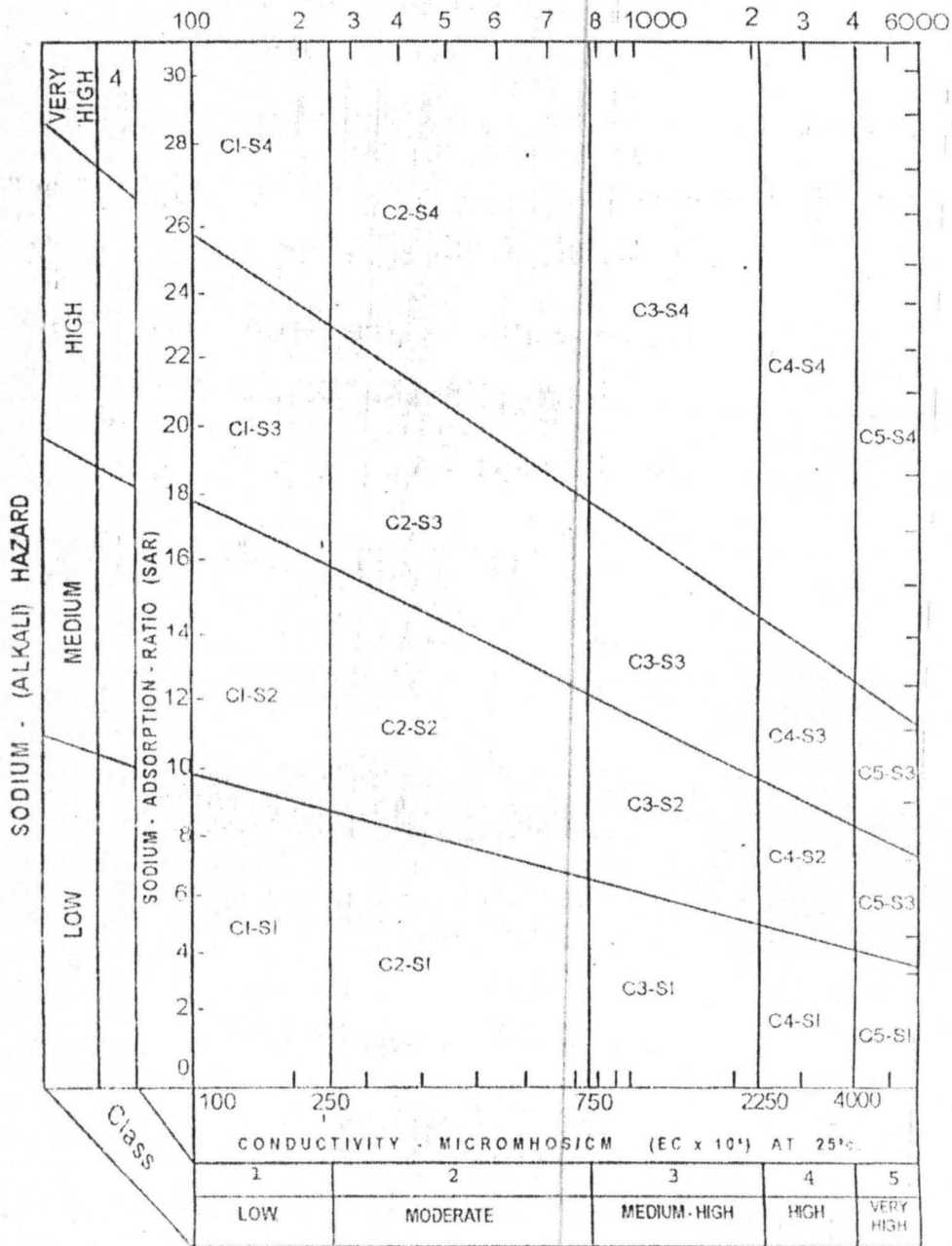


Fig 1. Classification of Quality Criteria for irrigation water (after USDA, 1984)

Source: Hillel (1994)

4.2.3 Sodium Hazard

Sodium toxicity is always assessed by Sodium Adsorption Ratio (SAR). The chemical quality as indicated by the Electrical Conductivity (EC) and Sodium Adsorption

Ration (SAR), are both within the low level as suggested by USDA (1984). The EC and SAR interact to determine the suitability of water for irrigation. From the result (Table 4.2a), the interacting effects of these parameters shows that the water is suitable for irrigation. Also, from the table 4.2b, the sample soils have low sodium values with an evaluation of less than 1.1 mg/L for all sampled points (see table 4.2b). The SAR values are generally low for all sampled soils which fall into the class of C₁-S₁ (fig 1); indicating little danger of the development of harmful level of exchangeable sodium.

4.2.4 Chloride, Sulphate and Nitrate

The chloride concentration in water ranges from 23 mg/L on USWS to 30 mg/L at DPWS, with a mean value of 26.75 mg/L (table 4.2a). These values compare with those given by FAO (1994) which are applicable under normal field conditions prevailing in most irrigated areas in arid and semi-arid regions of the world. However, chloride concentration should nil in some areas and trace in other samples plot. Therefore, the scheme soils are free from chloride toxicity (see table 4.2b).

Sulphur is a nutrient that could be assimilated in form of sulphate. Sulphate concentration could result from the geological formation and the weathering effects of the rock. From table 4.2a, the values of sulphate ranges from 12.0 mg/L to 14.8 mg/L. Also from table 4.2b, the minimum value of sulphate is 3.40 mg/L and the maximum value is 11.70 mg/L. The series of values obtained for both soil and water samples analyses of the scheme could be considered suitable for adequate nutrient availability for the plants as they seemed to be within the recommended ranges of 0-20 mg/L FAO (1994). Deficiency of sulphate in soil makes the leaves light green, but such characteristic are not found in the scheme.

Nitrate availability in water ranges from 1.5 mg/L to 6.5 mg/L (table 4.2a) and that of the soils ranges from 0.20 mg/L to 1.80 mg/L (table 4.2b) in the area sampled though they fall within FAO permissible limits (see table 4.3) but concentration is more in plot A to C which may be as a result of fertilizer application while plot D is abit moderate. Also, concentration is low in plot E and F which implies that the land still needs to be under fallow.

4.2.5 Calcium, Magnesium and Potassium

The laboratory analysis of calcium in water ranges from 10.5 mg/L at DPWS to 8.2 mg/L on DSWS (Table 4.2a). These values fall within the limit of FAO (Table 4.3). The results sampled varied from 9.95 mg/L to 17.08 mg/L (Table 4.2b). It is obvious that concentration is more in plot A – D than in plot E – G which influences the growth and strength of the plant in that areas. Calcium also serves as an important component of cell walls.

At different depth and area, the values of magnesium varied. In plot C and D, the concentration increases downward (Table 4.2b). As well, magnesium values in water also increases from USWS down to the DPWS (Table 4.2a). Though it falls within the range of FAO (see table 4.3), but at the DPWS, the concentration is higher. Magnesium is needed by plant, among other things for photosynthesis while the deficiency results to coloured spot of leaves and retardation ripening of grain and fruit.

Potassium present in water sampled is higher than soil sampled (see table 4.2a and 4.2b), it ranges from 1.2 mg/L at USWS to 2.3 mg/L at the DPWS. It is permissible and fall within limit of FAO (table 4.3). Plot B and G gave almost the same values and it is adequate for irrigation, according Scholl (1998). Potassium promotes the development of roots and

bulbs and it has a positive effect on the size of fruits and the weight of grains. Plants that have a potassium deficiency stay small and weak.

Table 4.3: Laboratory Determination Needed to Evaluate Common Irrigation Water Quality Problems.

Water Parameter	Symbol	Unit	Usual Range in Irrigation Water
Salinity			
<u>Salt Content</u>			
Electrical Conductivity	ECw	Mhos/cm	0-6
(or)			
Total Dissolved Solids	TDS	Mg/l	0-200
<u>Cations and Anions</u>			
Calcium	Ca ²⁺	Mg/l	0-800
Magnesium	Mg ²⁺	Mg/l	0-60
Sodium	Na ⁺	Mg/l	0-276
Chloride	Cl ⁻	Mg/l	0-150
Sulphate	SO ₄ ²⁻	Mg/l	0-20
<u>Nutrients</u>			
Nitrate-Nitrogen	NO ₃ N	Mg/l	0-10
Potassium	K ⁺	Mg/l	0-2
<u>Miscellaneous</u>			
Acid/Basicity	p ^H	Mg/l	0-6
Sodium Adsorption Ratio	SAR	Mg/l	0-15

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The surface water sampled at Chanchaga Irrigation Scheme of Niger State, Nigeria is of high quality for the irrigation of a variety of crops, such as rice, maize, guinea corn, sweet potatoes, sugar cane and vegetables. This assumes that the soil and the environment as well as inherent characteristics of the crops with the management of the crops are not going to include changes in the water quality when the water enters or remains in the soil for crop uses. Subsequently, this conclusion rests on the assumption that the time the samples were taken (August, 2009) was quite representative to the seasonal and annual fluctuations in the hydro-meteorological components. Following conclusions can be made;

- (i) The soluble salt content for both soil and water sampled is generally low as indicated by EC values.
- (ii) The irrigation water and salt concentration in soil shown little variation.
- (iii) The difference in the quality is of little or no significance to irrigation and crop growth.
- (iv) The salinity hazard measured as sodium absorption ratio (SAR), gave low risk of salinity and sodium alkalization.

Since the concentration of salts in the soil solution near the root zones determines the degree of adverse effects on crop growth, rather than the salt concentration of irrigation water alone, it is essential to adopt irrigation practices such that any salinity at the root zone is kept to the minimum.

5.2 Recommendations

Based on the results of this study, the following recommendations are made;

- (i) Regular sampling of water and subsequent assessment of its qualities in the light of both natural and cultural environmental changes, especially land use changes and the new waves of artificial fertilization and use of insecticides.
- (ii) It was observed by Michael (1995), that the continuous use of irrigation water with EC values greater than 750 $\mu\text{mhos/cm}$, even on loamy soils is likely to develop a saline problem if adequate drainage is not ensured. It is therefore advisable that drainage and proper leaching of salts should be observed within the drainage basin. In addition, carbonates and gypsum could be added to improve upon its quality.
- (iii) Old method of enriching the soil fertility with manure from plant or animal should be remobilized and practiced by farmers in this area. This can reduce the effect of inorganic fertilizers on ground water.

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APPENDICES

Appendix A: Climatological Data

Table A1: Monthly Rainfall (mm) in Minna from (1999 – 2008)

YEAR/MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC
1999	0.0	7.9	0.0	35.7	102.8	164.2	243.9	245.7	237.1	212.2	0.0	0.0
2000	0.3	0.0	0.0	3.6	135.9	161.0	208.8	308.5	303.0	153.4	0.0	0.0
2001	0.0	0.0	0.0	93.9	139.0	331.7	244.6	230.2	298.8	25.7	0.0	0.0
2002	0.0	0.0	5.7	98.8	42.6	201.0	143.2	226.5	260.6	180.3	0.0	0.0
2003	0.0	5.7	0.0	17.4	114.6	203.1	123.0	191.6	188.2	192.4	2.3	0.0
2004	0.0	0.0	0.0	32.2	151.9	194.9	210.3	211.4	241.5	77.6	0.0	0.0
2005	0.0	0.0	0.0	49.1	87.0	207.0	294.2	127.8	216.6	94.8	0.0	0.0
2006	11.2	0.0	TR	29.9	195.0	107.7	229.7	317.1	360.5	172.1	0.0	0.0
2007	0.0	0.0	0.4	73.1	156.6	123.9	314.0	310.1	330.1	115.1	0.0	0.0
2008	0.0	0.0	0.0	40.2	146.8	132.7	305.1	244.3	258.9	141.2	0.0	0.0

Source: NIMET, Minna

Table A2: Monthly Mean Relative Humidity (%) in Minna from (1999 – 2008)

YEAR/MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC
1999	25	30	44	42	58	66	75	-	75	66	36	30
2000	32	22	28	50	57	-	76	79	76	65	33	33
2001	23	23	39	57	61	70	76	79	73	52	32	37
2002	20	23	37	55	54	66	76	76	72	65	31	26
2003	32	32	31	49	54	71	75	78	73	66	37	23
2004	24	21	26	54	65	71	71	77	71	64	33	26
2005	20	31	36	46	61	70	76	74	71	64	33	26
2006	34	37	36	41	67	60	74	79	74	68	30	19
2007	19	25	35	50	64	71	75	80	72	66	42	29
2008	22	22	35	44	61	66	75	79	70	63	29	31

Source: NIMET, Minna

Table A3: Monthly Maximum and Minimum Temperatures (°C) in Minna from (1999 – 2008)

JAN		FEB		MARCH		APRIL		MAY		JUNE		JULY		AUG		SEPT		OCT		NOV		DEC	
Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
35.4	20.7	37.0	22.8	38.3	25.8	37.0	25.2	34.2	23.7	31.4	22.7	29.1	22.3	28.6	22.1	29.5	21.9	31.3	22.0	35.7	20.1	34.9	19.7
35.7	21.7	34.8	22.4	28.1	25.3	37.3	26.2	35.1	25.9	30.6	21.9	29.2	22.0	28.9	21.5	30.2	21.7	31.5	21.6	35.4	18.8	34.8	18.8
34.8	19.8	36.1	22.2	38.9	24.8	36.3	24.4	33.7	24.2	30.9	21.9	29.2	21.9	28.3	21.7	29.5	20.9	33.0	21.1	36.0	19.4	36.4	20.0
33.5	20.2	37.0	22.2	38.6	25.8	35.8	25.1	35.7	24.9	32.0	22.0	29.9	22.6	29.4	22.3	29.8	21.9	31.3	21.8	34.7	20.0	34.9	19.7
35.3	20.9	38.2	24.0	39.0	26.0	37.0	25.8	35.7	25.5	30.7	23.0	29.8	22.7	29.5	22.5	29.7	22.2	32.2	22.8	38.4	21.3	35.0	19.7
35.1	20.8	37.0	23.6	38.4	25.7	37.0	26.2	33.1	24.0	30.6	22.9	29.8	20.7	27.8	20.4	30.3	20.4	31.7	21.6	34.2	21.0	35.6	19.7
33.7	19.7	38.3	25.4	39.4	26.4	37.6	26.1	33.7	24.1	31.4	22.9	29.4	22.5	28.8	22.7	30.5	22.4	31.5	21.8	35.1	20.3	35.5	19.7
35.7	22.8	37.5	24.6	37.6	26.2	38.4	26.0	32.0	23.7	31.5	23.4	30.1	22.5	28.5	22.2	30.1	21.9	31.3	22.3	33.9	20.4	34.5	19.7
33.7	20.5	37.2	23.5	38.2	25.4	36.0	24.4	32.8	24.2	30.3	22.8	29.5	22.3	28.2	21.9	30.0	21.9	31.7	22.5	34.3	21.6	35.4	19.7
32.7	20.5	35.6	22.3	38.6	25.7	36.4	25.2	33.3	23.6	31.9	23.1	29.5	22.1	28.6	22.2	30.3	22.1	32.2	22.2	36.0	19.7	35.6	19.7

Source: NIMET, Minna

Appendix B : Water Samples and Analyses.

I Water pH

Methodology: the pH value of each sample was measured using the pH meter. The pH meter was first calibrated, and then its electrode and surrounding area was rinse with distilled water using the squeeze bottles and dried with soft tissue. A dry 100mL beaky deep was filled to the 50mL line with the water sample. The electrode was immersed into the water. The sample was stirred once and then the displayed value was allowed to stabilized. The value was read and recorded and the same procedure was repeated for the rest sample.

II Electrical Conductivity

A CMD 800 hydro check conductivity meter was used to determine the conductivity of made, the setting for cell constant K and sample temperature were made for specific conductivity at 25°C or at least known for absolute measurement. To view the cell constant K, μs (micro Siemens) was switched on to by key A. Then C + A (hold) – K was displayed. Making measurement, key A was switched on and cell inserted into test solution and then the reading was displayed.

III Total Dissolved Solids (TDS)

Methodology: The water sample is filtered through a standard glass fibre filter, and the filtrate is evaporated to dryness in a weighed dish and dried at 180°C. The increase in weight over that of the empty dish represents the total dissolved solids.

Materials

- Evaporating dishes: porcelain, platinum, high-silica glass (e.g Vycor), stainless steel or aluminium. Platinum or Vycor are preferable. Porcelain dishes are not

recommended owing to a tendency to lose weight. However, they may be used if the other materials are not available. Platinum dishes are not available in many laboratories owing to their high cost.

- Buchner funnel and suction flask or Millipore filtration unit
- Glass fibre filter paper, whatman GF/C, or similar
- Hot water bath

Experimental procedure: heat evaporating dish of approximate size in oven at 180°C for 1 hour. Cool in a desiccator and weigh. Measure accurately at a volume (100-500mL) of well mixed sample and pass through the filter under slight suction. Wash any remaining solid from the measuring cylinder with three successive 10mL portion of laboratory water and pass the washings through the filter. Transfer filtrates to a pre-weighed evaporating dish and evaporate to dryness on a hot water bath. If filtrate value exceeds dish capacity, add successive portions to the same dish after evaporation. dry for at least 1 hour in an oven at 180°C, cool in a desiccator and weigh. Calculate the total dissolved solids (TDC) using the same equation as in total solids.

Notes

1. Residues dried at 180°C will lose almost all mechanically included water
2. Highly mineralized water from arid and semi arid regions containing high levels of calcium, magnesium, chloride and /or sulphate content may be hygroscopic and require prolonged dried, efficient desiccation and rapid weighing. Samples high in bicarbonate may require prolonged drying at 180°C to ensure complete conversion of bicarbonate to carbonate.

For accurate work, repeat the drying, desiccating and weighing cycle as for total solids

IV Determination of Chloride

A suitable portion of the sample was diluted to 100ml. 3ml Al (OH)₃ suspension was added, mixed, left to settle, and then filtered. If sulfate, sulfide or sulfite is present, 1ml H₂O₂ is added and stirred for about 1 minute. 1ml K₂CrO₄ indicator solution is then added and titred with standard AgNO₃ titrant to a pinkish yellow end point. It is important to be consistent in end – point recognition.

V Sulphate

An excess of barium chloride (BaCl₂) is added to the sample. The barium ion reacts with the sulphate to precipitate barium sulphate crystals of uniform size:



The colloidal suspension is measured using a spectrophotometer and the sulphate concentration determined by comparison with standards. Suspended particles present in large amounts will interfere and these can be removed by filtration. Highly coloured samples may give erroneous results.

Materials

- Magnetic stirrer and bar
- Spectrophotometer and absorption cells (2 – 10cm)
- Stopwatch
- Barium chloride (BaCl₂ . 2H₂O), crystalline. Dry in an oven and pass through a sieve of 20 mesh sieve.
- Sodium chloride – hydrochloric acid reagent. Dissolve 60g NaCl in water, add 5mL concentrated HCl and dilute to 250mL.

- Glycerol – ethanol solution. Mix 100 mL glycerol with 200mL of ethanol in bottle.
- Standard sulphate solution, 100mg L^{-1} . Dissolve 147.9 mg anhydrous sodium sulphate and dilute to 1 L with water. $1\text{mL} = 0.1\text{ mg SO}_4^{2-}$.

Experimental procedure: sampling and storage. Store samples at 4°C to prevent biological reduction of SO_4^{2-} to S^{2-} . unpolluted sample can be stored at room temperature for 2-3 days. Filter through a $0.45\mu\text{m}$ membrane filter.

Analysis. Measure 100mL of sample into a 250 mL conical flask and place on a magnetic stirrer. While stirring add 20 mL of the NaCl – HCl solution and 20mL of the glycerol – alcohol solution. Add approximately 0.3g barium chloride. Stir for 2minutes exactly after adding barium chloride. Immediately pour some solution into an absorption cell and measure the absorbance at 250nm after exactly 3minutes. Prepare a series of calibration standards by pipetting aliquots of the standard sulphate solution corresponding between 0.5 and 5mg SO_4^{2-} (i.e 5-50mL) into a 100mL volumetric flask and making up to the mark with water.

Analyse in the same way as samples. Prepare sample blanks by adding all the reagents except barium chloride to 100mL of sample and measure the absorbance. Subtract from each sample reading the blank reading obtained using the same sample to compensate for sample colour and turbidity.

VI Nitrate

Methodology: Two moles of NO_3^- react with one mole of chromotropic acid to form a yellow reaction product, the absorbance of which is measured at 410nm. The method can be used to determine nitrate concentrations in the range $0.1 - 5\text{mg NO}_3^- \text{ mL}^{-1}$. It is necessary to eliminate interference by nitrate, residual chlorine and certain oxidants which yield yellow colour when they react with chromotropic acid. Interference from residual chlorine and

oxidizing agent can be eliminated by addition of sulfite. Urea eliminates nitrite interference by converting it to N_2 gas. Addition of antimony can mark up to $2000\text{mg Cl}^- \text{L}^{-1}$.

Materials:

- Spectrophotometer
- Cooling bath
- Stock nitrate solution, $100\mu\text{g NO}_3^- \text{N mL}^{-1}$. Prepare by diluting a commercially available 1000mg L^{-1} solution. Otherwise prepare as follows dry sodium nitrate (NaNO_3) in an oven at 105°C for 24hours. Dissolve 0.607g of the dried salt in water and dilute to 100mL .
- Working nitrate solution. $10\mu\text{g NO}_3^- \text{N mL}^{-1}$. Pipette 50mL of the stock solution into a 500 mL volumetric flask and make up to the mark with water.
- Sulphite – urea reagent. Dissolve 5g urea and 4g anhydrous Na_2SO_3 in water and dilute to 100mL .
- Antimony reagent. Heat 0.5g of antimony metal in 80 mL of concentrated H_2SO_4 until all the metal has dissolved. Cool the solution and cautiously add to 20mL iced water. If crystals form after standing overnight, redissolve the heating.
- Purified chromotropic acid solution (0.1%). Boil 125 mL of water in a beaker and gradually add 15 g of 4, 5-dihydroxyl-2, 7-naphthalene-disulfonic acid disodium salt, while stirring constantly. Add 5g of decolourising activated charcoal and boil the mixture for 10minute . Add water to make up for loss due to evaporation. Filter the hot solution through cotton wool. Add 5g of activated charcoal to the filtrate and boil

for 10 minutes. Remove the charcoal completely from the solution by filtering, first through cotton wool and then through filtered paper. Cool and add slowly 10 mL of concentrated H_2SO_4 . Boil the solution down to 100 mL in a beaker and stand overnight. Transfer crystals of chromotropic acid to a Buchner funnel and wash thoroughly with 95% ethyl alcohol until crystals are white. Dry the crystals in an oven at 80°C . Prepare a 0.1% solution by dissolving 100 mg of the purified chromotropic acid in 100 mL of concentrated H_2SO_4 and store in a brown bottle. This solution is stable for two weeks. If the sulphuric acid is free from nitrate impurities the solution should be colourless.

- Sulphuric acid, concentrated high purity.

Experimental procedure: (a) *storage of samples;* result form most reliable when nitrate ion is determined in fresh samples. For short term preservation of up to 1 day, samples can be stored in refrigerator at 4°C . if it is not possible to carry out the analysis promptly, samples can be preserved by adding 0.5-1.0 mL of concentrated H_2SO_4 per litre of sample and store at 4°C .

(b) *Analyses;* prepare nitrate standards in the range $0.1-5 \text{ mg NO}_3^- \text{NL}^{-1}$ by pipetting 1, 5, 10, 20, 40 and 50 mL of the working nitrate solution into a series of 100 mL volumetric flasks and making up to the mark with water. Filter the sample if significant amounts of suspended matter are present. Pipette 2 mL aliquots of samples, standards and a urea reagent to each flask. Place flasks in a tray of cool water with a temperature between $10-20^\circ\text{C}$ and add 2 mL of the antimony reagent swirl the flasks when adding to each reagent. After the flasks have stood in the bath for about 4 minute. Add 1 mL of the antimony reagent. Swirl the flasks again and allow to stand in the cooling bath for another 3 minute. Make up to the mark concentrated H_2SO_4 . stop and mix with contents by inverting them 4 times. Allow the flasks

to stand at room temperature for 45 minutes and again adjust the volume to 10 mL with concentrated H_2SO_4 . Finally, mix very gently to avoid introducing gas bubbles. Allow the flasks to stand for at least 15 minutes before measuring the absorbance at 410 nm using a 1 cm cell with water in the reference cell. Subtract the absorbance reading of the water blank from the absorbances of samples and standard. Prepare a calibration graph of net absorbance against $mg\ NO_3^- \cdot NL^{-1}$ based on the standard measured and read off directly the concentration of NO_3^- (expressed as $mg\ NL^{-1}$) in the samples.

Appendix C : Soil Samplings Analyses.

I Particle Size Analysis

Reagents: Texture dispersing reagent (Sodium Hexametaphosphate).

Equipments: Soil separation tubes (50ml plastics), soil texture stand and pipette.

Test Procedure:

- (i) Three soil separation tubes were labeled A B and C placed in a test tube rack provided.
- (ii) The soil was sieved using 2mm sieve and was added to tube A until it is even with line 15. The bottom of the tube was gentle tapped on a firm surface to pack the soil and eliminate air spaces.
- (iii) 1ml of texture dispersing reagent (Sodium Hexametaphosphate) was added to the sample tube A and water was added to line 45. It was shaken gently for 2secs and capped for 30secs.
- (iv) After this period, the cap was removed and the solution was poured in tube B and allowed to stand undisturbed for 30 minutes and tube A was returned to the rack. The remaining solution in tube B is carefully poured into tube C while B was returned to the rack.
- (v) The soil separation in tube C was allowed to stand until all the clay in suspension settles, the percentage of sand, silt and clay were determined.

$$\% \text{ Sand} = \frac{\text{Value A}}{\text{Total volume}} \times 100$$

Total volume

$$\% \text{ Sand} = \frac{\text{Value B}}{\text{Total value}} \times 100$$

Total value

$$\% \text{ Sand} = \frac{\text{Value calculated}}{\text{Total value}} \times 100$$

II Soil pH

The apparatus required in order to measure soil pH consists of:

- A pH meter with a range of 0–14 pH;
- A pipette/dispenser;
- Some beakers;
- A glass rod.

The reagents required are:

- Buffer solutions of pH 4, 7 and 9.
- Calcium chloride solution (0.01M): dissolve 14.7 g of $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ in 10 litres of water to obtain 0.01M solution.

The procedure for measuring soil pH is:

1. Calibrate the pH meter, using two buffer solutions, one should be the buffer with neutral pH (7.0) and the other should be chosen based on the range of pH in the soil. Put the buffer solutions in the beakers. Insert the electrode alternately in the beakers containing the two buffer solutions, and adjust the pH. The instrument indicating pH as per the buffers is ready to test the samples.
2. Place 10.0 g of soil sample into a 50-ml or 100-ml beaker, add 20 ml of CaCl_2 solution (use water instead of CaCl_2 solution throughout the procedure where water is used as a suspension medium).
3. Allow the soil to absorb the CaCl_2 solution without stirring, then stir thoroughly for 10 seconds using a glass rod.
4. Stir the suspension for 30 minutes, and record the pH on the calibrated pH meter.

Based on soil pH values. Acid soils need to be limed before they can be put to normal agricultural production. Alkali soils need to be treated with gypsum in order to remove the excessive content of Na.

pH range Soil reaction rating

< 4.6 Extremely acidic

4.6–5.5 Strongly acidic

5.6–6.5 Moderately acidic

6.6–6.9 Slightly acidic

7.0 Neutral

7.1–8.5 Moderately alkaline

> 8.5 Strongly alkaline

III Electrical Conductivity

The apparatus required in order to determine EC consists of:

- An EC meter;
- Some beakers (25 ml), Erlenmeyer flasks (250 ml) and pipettes;
- Filter paper.

The procedure for determining EC is:

1. Place 40 g of soil in a 250-ml Erlenmeyer flask, add 80 ml of distilled water, stopper the flask, and shake on a reciprocating shaker for 1 hour. Filter through No. 1 filter paper.
2. Wash the conductivity electrode with distilled water, and rinse with standard KCl solution.
3. Pour some KCl solution into a 25-ml beaker, and dip the electrode in the solution. Adjust the conductivity meter to read 1.412 mS/cm, corrected to 25 °C.

4. Wash the electrode, and dip it into the soil extract.
5. Record the digital display corrected to 25 °C. The EC reading is a measure of the soluble salt content in the extract

IV Nitrate by Phenoldisulphonic Acid Method

- The apparatus required using the method consists of:
- A reciprocating shaker;
- A heavy-duty hotplate;
- A spectrophotometer;
- A dispenser;
- An Erlenmeyer flask;
- Some beakers;
- A glass rod.

The reagents required are:

- Phenoldisulphonic acid (phenol 2,4-disulphonic acid): Transfer 70 ml of pure liquid phenol (carbolic acid) to an 800-ml Kjeldahl flask. Add 450 ml of concentrated H_2SO_4 while shaking. Add 225 ml of fuming H_2SO_4 (13–15 percent SO_3). Mix well. Place the Kjeldahl flask (loosely stoppered) in a beaker containing boiling water and heat for 2 hours. Store the resulting phenoldisulphonic acid [$\text{C}_6\text{H}_3\text{OH}(\text{HSO}_3)_2$] solution in a glass-stoppered bottle.
- Dilute ammonium hydroxide solution (about 7.5M NH_4OH): Mix one part NH_4OH (specific gravity 0.90) with one part H_2O .
- Copper sulphate solution (0.5M): Dissolve 125 g of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in 1 litre of distilled water.

- Silver sulphate solution (0.6 percent): Dissolve 6.0 g of Ag_2SO_4 in 1 litre of distilled water. Heat or shake well until all salt is dissolved.
- Nitrate-extracting solution: Mix 200 ml of 0.5M copper sulphate solution and 1 litre of 0.6 percent silver sulphate solution and dilute to 10 litres with water. Mix well.
- Standard nitrate solution (100 $\mu\text{g NO}_3\text{-N/ml}$, stock solution): Dissolve 0.7221 g of KNO_3 (oven dried at 105 °C) in water and dilute to 1 litre. Mix thoroughly.
- Standard nitrate solution (10 $\mu\text{g NO}_3\text{-N/ml}$, working solution): Dilute 100 ml of 100 $\mu\text{g NO}_3\text{-N/ml}$ stock solution to 1 litre with water. Mix well.
- Calcium hydroxide: AR-grade powder (free of NO_3).
- Magnesium carbonate: AR-grade powder (free of NO_3).

The procedure is:

1. Place about 5 g of soil in an Erlenmeyer flask.
2. Add 25 ml of nitrate-extracting solution.
3. Shake contents for 10 minutes.
4. Add about 0.2 g of Ca(OH)_2 and shake for 5 minutes.
5. Add about 0.5 g of MgCO_3 and shake for 10–15 minutes.
6. Allow to settle for a few minutes.
7. Filter through No. 42 filter paper.
8. Pipette 10 ml of clear filtrate into a 100-ml beaker. Evaporate to dryness on a hotplate at low heat in a fumehood (free of HNO_3 fumes). Do not continue heating beyond dryness.
9. When completely dry, cool residue, add 2 ml of phenoldisulphonic acid rapidly (from a burette having the tip cut off), covering the residue quickly. Rotate the beaker so that the reagent comes into contact with all residual salt. Allow to stand for 10–15 minutes.

10. Add 16.5 ml of cold water. Rotate the beaker to dissolve residue (or stir with a glass rod until all residue is in solution).

11. Once the beaker is cool, add 15 ml of dilute NH_4OH slowly until the solution is distinctly alkaline as indicated by the development of a stable yellow colour.

12. Add 16.5 ml of water (volume becomes 50 ml). Mix thoroughly.

13. Read the concentration of $\text{NO}_3^- \text{N}$ at 415 nm, using the standard curve.

14. Preparation of standard curve: Place 0, 2, 5, 8, and 10 ml of the $10 \mu\text{g NO}_3^-/\text{ml}$ working solution in separate 100-ml beakers, add 10 ml NO_3^- extracting solution and evaporate to dryness. Follow steps 9–13, using these standard solutions with 0, 0.4, 1.0, 1.6 and $2.0 \mu\text{g NO}_3^- \text{N/ml}$. Prepare a standard curve to be used for estimation of NO_3^- in the sample.

The calculation is:

$$\text{NO}_3^- \text{N in test soln. } \left(\frac{\mu\text{g}}{\text{ml}} \right) = \frac{\text{Vol. after colour develop. (ml)}}{\text{Vol. evaporated (ml)}} \times \frac{\text{Vol. of extracting soln. (ml)}}{\text{Wt. of oven-dried soil (g)}}$$

V Available Potassium

The apparatus required consists of:

- A multiple dispenser or automatic pipette (25 ml);
- Some flasks and beakers (100 ml);
- A flame photometer.

The reagents required are:

- Molar neutral ammonium acetate solution: Dissolve 77 g of ammonium acetate ($\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$) in 1 litre of water. Check the pH with bromothymol blue or with a pH meter. If not neutral, add either ammonium hydroxide or acetic acid as per the need in order to neutralize it to pH 7.0.

- Standard potassium solution: Dissolve 1.908 g of pure KCl in 1 litre of distilled water. This solution contains 1 mg K/ml. Take 100 ml of this solution and dilute to 1 litre with ammonium acetate solution. This gives 0.1 mg K/ml as a stock solution.
- Working potassium standard solutions: Take 0, 5, 10, 15 and 20 ml of the stock solution and dilute each volume separately to 100 ml with the molar ammonium acetate solution. These solutions contain 0, 5, 10, 15 and 20 μg K/ml, respectively.

The procedure is:

1. Preparation of the standard curve: Set up the flame photometer by atomizing 0 and 20 μg K/ml solutions alternatively to readings of 0 and 100. Atomize intermediate working standard solutions and record the readings. Plot these readings against the respective K contents and connect the points with a straight line to obtain a standard curve.

2. Extraction: Add 25 ml of the ammonium acetate extractant to a conical flask fixed in a wooden rack containing 5 g of soil sample. Shake for 5 minutes and filter.

3. Determine the potash in the filtrate with the flame photometer.

The calculation is:

$$K \left(\text{Kg/ha} \right) = \frac{A}{1000000} \times 25 \times \frac{2000000}{5}$$

Where:

A = content of k (μg) in the sample, as read from the standard curve;

Volume of the extract = 25 ml;

Weight of the soil taken = 5 g;

Weight of 1 ha of soil down to a plough depth of 22 cm is taken as 2 million kg.

VI Determination of Sodium (Na⁺), Calcium (Ca⁺) and Magnesium (Mg⁺) by Flame Emission Spectrophotometer

The reagents are:

- 5ml hydrochloric acid
- Concentrated ammonia
- Distilled water
- 1ml E.D.T.A

Procedure:

70 ml of each sample was placed in separate covers and the atomizer positioned inside them in turn. Regulated air and butane gas were passed into the chamber and ignited. Then the sample sucked in by negative pressure of the air and was burnt in the chamber to produce a characteristic flame of the metal under investigation. The corresponding filter of the metal under investigation was set in place with its wave length indicated, the intensity of the coloured flame produced was shown on the galvanometer, and calibrated from the curve each sample under investigation, the concentration of each was read accordingly.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

VII Determination of Chloride

The reagents are:

- Standard silver nitrate solution
- Sodium chloride solution
- Distilled water and sodium chloride

Procedure:

100ml of soluble sample was obtained and 1ml of potassium chromate indicator (K_2CrO_4) was added to a standard silver nitrate solution. The end point was determined with the solution turning pinkish yellow.