# EVALUATION OF IRRIGATION WATER QUALITY AND ASSESSMENT OF SALTS IN IRRIGATED LANDS OF CHANCHAGA, GUSORO AND SOJE IRRIGATION SCHEMES

**BY**


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## DECLARATION

I hereby declare that this project 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 Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

.................................... 20/11/2006 ..............................

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**CERTIFICATION**

This project entitled " Evaluation of Irrigation Water Quality and Assessment of Salts in Irrigated Lands" by Ibrahim, Aminu meets the regulations governing the award of 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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## DEDICATION

This project is dedicated to my late Mum, Maymunah Yousuf ,the vehicle through whom Allah sent me to this world for the education legacy she left behind for me and to all those who consider knowledge as their loss property and therefore acquire it wherever they found it.

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## ABSTRACT

Good irrigation water quality and non salty soils are essential for sustainability of irrigation project and improved agricultural productivity. This project deals with the evaluation of irrigation water quality and assessment of salts in irrigated lands of Chanchaga, Gusoro and Soje Irrigation Schemes of Niger State, Nigeria. Water samples were taken from upstream, on scheme and downstream of the irrigation water sources. Soil samples were also taken both at surface (0-15cm) and subsurface (15-60cm) levels of irrigated and non-irrigated soils of the schemes. These samples were analyzed for their salts contents. Statistical analyses focused on the variability in the water quality along the stream courses and correlations of salts concentrations of irrigated soils and non irrigated soils. These show that the waters are not significantly different along the stream courses at 5% levels of significance; rather they have *p*-values (smallest pre-set levels of significance) of 0.9852, 0.9729 and 0.9401 for Chanchaga, Gusoro and Soje Irrigation waters respectively. At the surface level of the soils, the irrigated soils correlated well with the non-irrigated soils with $R^2$ values of 0.9553, 0.8747 and 0.8951 for Chanchaga, Gusoro and Soje soils respectively. At the sub-surface level, the $R^2$ values are 0.5691, 0.1027 and 0.8503 for Chanchaga, Gusoro and Soje soils respectively. Variability between salts concentration of irrigated and non irrigated soils and between irrigated surface and subsurface soils were depicted with the aid of charts. The schemes' waters are safe for irrigation and the irrigated soils are non saline and non sodic.

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## ABBREVIATIONS

| | | |
|---|---|---|
| CUWS | – | Chanchga Upstream Water Sample |
| COWS | – | Chanchga On scheme Water Sample |
| CDWS | – | Chanchga Downstream Water Sample |
| GUWS | – | Gusoro Upstream Water Sample |
| GOWS | – | Gusoro On scheme Water Sample |
| GDWS | – | Gusoro Downstream Water Sample |
| SUWS | – | Soje Upstream Water Sample |
| SOWS | – | Soje On scheme Water Sample |
| SDWS | – | Soje Downstream Water Sample |
| CISFS | - | Chanchaga Irrigated Surface Soil Sample |
| CISBS | - | Chanchaga Irrigated Sub-Surface Soil Sample |
| CNISFS | - | Chanchaga Non-Irrigated Surface Soil Sample |
| CNISBS | - | Chanchaga Non-Irrigated Sub-Surface Soil Sample |
| GISFS | - | Gusoro Irrigated Surface Soil Sample |
| GISBS | - | Gusoro Irrigated Sub-Surface Soil Sample |
| GNISFS | - | Gusoro Non-Irrigated Surface Soil Sample |
| GNISBS | - | Gusoro Non-Irrigated Sub-Surface Soil Sample |
| SISFS | - | Soje Irrigated Surface Soil Sample |
| SISBS | - | Soje Irrigated Sub -Surface Soil Sample |
| SNISFS | - | Soje Non-Irrigated Surface Soil Sample |
| SNISBS | - | Soje Non- Irrigated Sub-Surface Soil Sample |
| NSMW | – | Niger State Ministry of Works |
| FAO | - | Food and Agriculture Organization |
| WHO | - | World Health Organization |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| $EC_W$ | - | Electrical Conductivity of irrigation water |
| $EC_e$ | - | Electrical Conductivity of saturated soil extract |
| TDS | - | Total Dissolved Solid |
| SAR | - | Sodium Absorption Ratio |
| DO | - | Dissolved Oxygen |
| N | - | Nitrogen |
| $Ca^{2+}$ | - | Calcium |
| $Mg^{2+}$ | - | Magnesium |
| $Mn^{2+}$ | - | Manganese |
| $Cu^{2+}$ | - | Copper |
| $Fe^{2+}$ | - | Iron |
| $K^+$ | - | Potassium |
| $Na^+$ | - | Sodium |
| $Cl^-$ | - | Chloride |
| $SO_4^{2-}$ | - | Sulphate |
| $CO_3^{2-}$ | - | Carbonate |
| $HCO_3^-$ | - | Bicarbonate |
| $CaSO_4.2H_2O$ | - | Gypsum |
| pH | - | Potential Hydrogen |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Preamble

The need to match productivity with the increasing world's population has given rise to the increasing demand of man, for provision of food and fibre needs, which is one of the primary objectives of agriculture.

This development has lead to the adoption of irrigation practice on large scales. This artificial application of water to soil for the purpose of crop production in order to supplement water available from rainfall and the contribution to soil moisture from ground water is helping to meet the needed increase in arable land for growth in crop production.

However, the irony of the situation is that, in an attempt to solve a problem, we end up creating a problem. We are now faced with the problem of gradual salt build-up in our irrigated land. This perhaps, as noted by Smedema and Rycroft (1988) is due to man's activities especially by incorrect irrigation practices. Michael (1999) observed that excessive irrigation and poor water management are the chief causes of water logging and salt build-up.

Rhoades *et al.* (1992) stated that large and increasing proportions of the word's irrigated land are deleteriously been affected by water logging and excessive salinity. While the exact area affected is not known it is estimated that approximately 25 percent of the world's irrigated land is damaged by salinization. Some claim that up to 50 percent of the word's irrigated land may be affected by salt. Certainly no continent is free from salt affected soils.

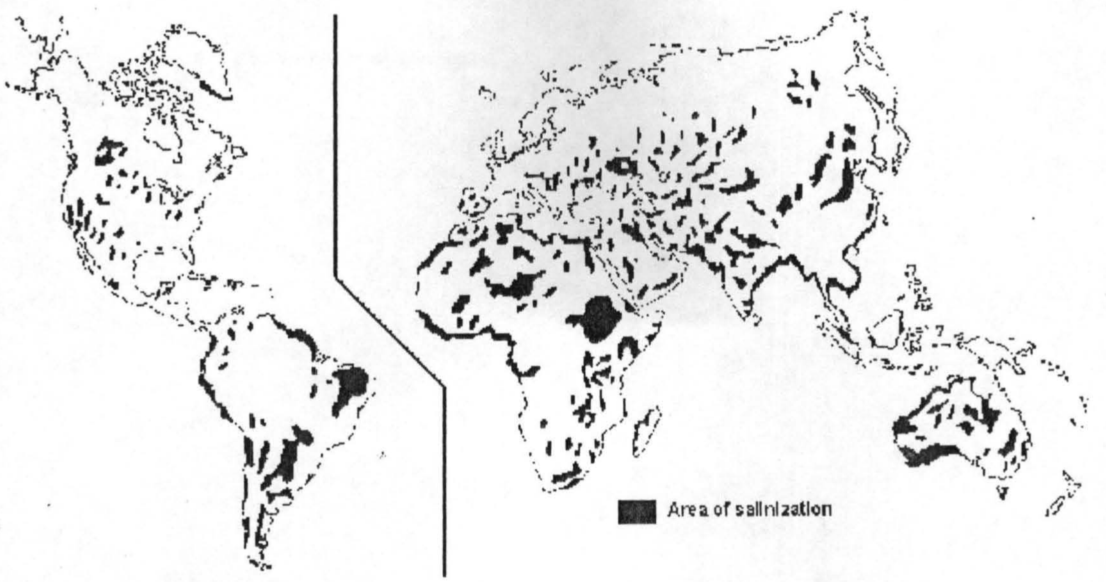



Fig. 1.1 Global distribution of salt-affected soils

Source: Rhoades *et al.*, 1992

All irrigation water irrespective of its source contains salts. Therefore the vulnerability of irrigated lands to water logging and salinization is not too surprising and should be sufficiently recognized.

The critical challenge facing most of the irrigated land is to halt and reverse the present development of salt build-up. To act appropriately, assessment of the salts in the irrigated lands and irrigation water quality evaluation become imperative.

## 1.2 Statement of the Problem

Irrigation is a means of increasing agricultural productivity for provision of food and fibre needs 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 salinity and sodicity. This necessitates the evaluation of irrigation water quality and investigation of salts building up in the soil.

## 1.3 Objectives

The purpose of this study includes;

1. To determine the quality of water use for irrigation in Chanchaga, Gusoro and Soje Irrigation Schemes.
2. To determine the salt contents of the irrigated soils of Chanchaga, Gusoro and Soje Irrigation Schemes.
3. To assess the impact of water use on salts build-up in the soil and the environment.

## 1.4 Research Questions

The research question includes;

i. What is quality of the irrigation water?

ii. Is the water 'good' enough for irrigation?

iii. What are the properties of the irrigated soils?

iv. What are the properties of the non irrigated soils?

v. What are the salt concentrations?

vi. What are the effects of the salt concentrations on the soils and plants?

vii. What are the effects of the irrigation system on the environment?

## 1.5 Research Hypotheses

These include;

i. The irrigation water contains salts.

ii. All soils contain salts.

iii. The higher the salts content of the irrigation water the higher the salt build-up.

iv. Leaching affects the rate of salt build-up in the root zone.

v. Water table depth affects the salts build-up in the root zone.

## 1.6 Justification

The rationale for undertaking this project is to be able to solve problem with optimum use of available land and water resources. Adequate knowledge of the salt build-up in the soil is needed for appropriate soil reclamation and salinity management measures adoption. The knowledge of salts build-up helps in the selection of the types of crops to be grown on any salt affected soil.

Finally, there is increasing need to conserve water, to utilize it more efficiently and to protect its quality, and at the same time, there is increasing need to protect soil resources.

## 1.7 Scope of the study

The irrigated soils and irrigation water under consideration in this study are those of Soje Irrigation Scheme of Minna Local Government Area, Chanchaga Irrigation Scheme of Chanchaga Local Government Area and Gusoro Irrigation Scheme in Shirroro Local Area all in Niger state, Nigeria. Furthermore, at Soje Irrigation Scheme, investigation was only limited to the wastewater and the soils irrigated with the wastewater.

The study is limited to salt concentrations in the wet season of these sites.

# CHAPTER TWO

## REVIEW OF RELATED LITERATURE

The application of water to soil whether in the form of rainfall or irrigation carries with it salts. When the soil is in equilibrium that rate of addition of salt is equal to the rate of loss (Raine *et al.,* 2005). Salts continue to accumulate in soils of irrigated areas where greater amounts are brought in than are removed. Irrigation waters contain from 0.5 to 30 kilograms of salt per cubic meter of water. Some irrigation farmers apply only a depth of 50cm of water per season; others where the summers are long and hot, apply up to 200cm of water or more. Where drainage is not provided, the irrigation water may add as much as 3 to 25 or more tons of salt each to a hectare of land (Hansen *et al.,* 1979).

Rhoades *et al.* (1992) reported that typical irrigation waters may contain from 0.1 to 4kg of salts per $m^3$ and are generally applied at annual rates of 1.0 to 1.5m. Thus, from 1 to 60 metrics tones of salt per hectare may be added to irrigated soils annually.

The salt build-up is one of the challenges facing irrigated agriculture. Plants growths are impaired by excessive accumulation of salts in the root zone and consequently, decrease in agricultural productivity.

Foth (1990) noted that, today crop production is reduced on 50% of world's irrigated land as a result of salinity or drainage problem. The accumulation of salts around the root system prevents the circulation of air and water into the plant root. Therefore, plants become unable to get sufficient amount of water and air for their survival and satisfactory growth. Thus, crop production ultimately gets reduced (Suresh, 2002)

This decline in agricultural productivity courtesy of irrigation Salinization has given birth to several questions. Included in these questions are: what is the quality of the irrigation waters? How 'good' is it for irrigation? How does soil properties changes consequent on concentration and precipitation of salts? What are the effects of the accumulated salt on plant growth and yields?

This makes this research worth while with particular references to Gusoro, Chanchaga and Soje irrigated lands. Michael (1999) stated:

*"In order to predict the success of irrigation in a particular situation, it is essential to have adequate information on the quality of irrigation water, its effect on the physical and chemical properties of soil, water transmission characteristic and salt build-up."*

## 2.1 Irrigation & Irrigation Process

Irrigation is the artificial watering of crops in areas with insufficient rainfall in order to ensure a good crop development. Rainfall can be insufficient during certain periods of the year or all year round (Agricultural Compendium, 1989). Essentially, irrigation is the artificial application of water to soil to supplement the water available from precipitations and the contribution to soil moisture from ground water, for the purpose of crop productions.

Egharevba (2002) noted that, irrigation process can be explained in two ways:

(a) Distribution to water in the field after reserving them and transporting them

(b) Use of the input water in the most economical and efficient way in the agricultural system.

Irrigation systems can be divided into:

(a) Open systems-gravitational flow (surface irrigation systems)

The surface system includes the flooding, basins, borders and furrow methods.

(b) Closed systems-Pressurized flow (Sprinkler and Drip irrigation system).

Drip is also called Trickle or Micro-irrigation System.

Other methods which might not fit directly into these categories are sub irrigation and low-energy precision application (LEPA) systems.

## 2.2 Sources of Irrigation Waters

The source of water for irrigation is very important in any irrigation project as the success of the irrigation largely depends on the source of its water. James (1988) observed that, *"the suitability of a water source for irrigation depends on several factors including legal constraints, the quality of the water (i.e., the amount and identity of suspended and dissolved materials in the water) as well as the ability of the source to supply the total irrigation requirement and seasonally varying irrigation requirement year after year."*

Irrigation water is obtainable from ground water and surface water sources.

### 2.2.1 Groundwater Sources

Groundwater is water that occupies voids within rocks and the soil. Subsurface material constraining groundwater may be divided into zones of saturation and aeration. Voids within the zone of saturation are completely filled with water, while the zone of aeration consists of voids occupied partially by water and particularly by air. Because only the zone of saturation contains drainable water, groundwater for irrigation comes from the zone of saturation (and not from zone of aeration). Portion of the zone of saturation, that yields significant quantity of water is called an aquifer, (James, 1988).

The irrigation potential of groundwater depends on hydro geological conditions such as: the presence and depth of exploitable aquifers, the available groundwater reserve, and the natural or artificial recharging conditions, (Agricultural Compendium, 1989).

#### 2.2.1.2 Wells

A water well is a hole or shaft, usually vertical excavated in the earth for bringing groundwater to the surface, (Todd, 1980). An irrigation well is a conduit that conveys water from an aquifer to the ground surface (drainage wells convey water to an aquifer), (James, 1988).

#### 2.2.1.2 Springs

A spring is a concentrated discharge of groundwater appearing at the ground surface as flowing water. Springs may be the result of non-gravitational forces such as those associated with volcanic rocks and deep fractures in the earth's crust. Such springs often discharge water that is highly mineralized and has elevated temperatures (e.g. hot springs and warm springs). Other major springs are the result of gravitational forces (James, 1988)

The use of groundwater for irrigation poses especial problems because this water in particular may contain a considerable salt load (Smedema and Rycroft, 1988).

### 2.2.2 Surface Sources

Schwab (1993) observed that surface water exist in natural basins and stream channels while Linsley *et al.* (1988) stated that the stream channel serves as the meeting place of water from surface runoff, interflow, groundwater and municipal and industrial discharge.

The surface sources of water use for irrigation projects include streams/rivers, reservoirs, lakes and waste waters.

#### 2.2.2.1 Streams/Rivers

Flowing streams or rivers are important sources of irrigation water. The water quality characteristics of streams are determine by the inflows to the stream, the amount of turbulence, interactions between water and the channel rocks and soils, and interactions at the air- water interface (Linsely *et al.,* 1988).

The water use for irrigation is withdrawn directly in the case where the streams or rivers are large enough to meet irrigation demand through both wet and dry seasons. However, Schwab (1993) stated that on many streams and rivers, flow fluctuates widely from season to season and from year to year. Furthermore, peak demands from major rivers occur at season of minimum flow and in fact require that as much of the annual as flow as possible be conserved and diverted for beneficial use.

Such streams require the construction of storage reservoir for it to be useful for irrigation project.

These reservoirs as stated by James (1988) regulate the stream so that the natural flow is adjusted to meet, as nearly as possible, the rate of demand (i.e. storage reservoirs store water during periods of high flow for use during periods of inadequate flow). Smedema and Rycroft (1988) noted that rivers often have higher salt content during the low flow season than during the flood season, while salt conditions may also vary along the course of a river.

#### 2.2.2.2 Reservoirs

Artificial reservoirs are constructed by closing off the river valley at a suitable site by a dam. The dam is equipped with a spillway to evacuate excess floodwater. Water for irrigation is released through an intake tower and conveyed to the area by a main canal, or to a diversion dam via the riverbed, (Agricultural Compendium, 1989).

#### 2.2.2.3 Lake

A lake is a large body of water surrounded by land. Lakes are another surface source of water for irrigation. Gravity diversion and pumping plants are use to withdraw water as with streams. There are often legal barriers to the use of lakes for irrigation, such as prior water levels and recreational rights (James, 1988).

The lake is a land-locked sink with no outflow but a continued inflow from rivers discharging into it. These rivers carry varying quantities of salt. The main river flowing into Lake Chad is Chari River. The salinity level of the lake is dependent on the river Chari discharges, Ayers and Westcot (1994).

#### 2.2.2.4 Wastewater

Sewage, industrial and agricultural wastewaters are increasingly being used for irrigation projects this is normally re-sorted to in areas where there is no availability of other sources of water.

Ayers and Westcot (1994) noted that rising demands for good quality water for domestic and industrial uses in countries with highly developed economies have created the necessity to re-use wastewater. They argued that agriculture is the major user of water and can accept low quality water than domestic and industrial users. It is therefore inevitable that there will be a growing tendency to look toward irrigated agriculture for solution to the overall effluent disposal problem. They cautioned that because wastewater contains impurities, careful consideration must be given to the possible long-term effects on soils and plants from salinity, sodicity, nutrients and trace elements that occur normally manageable if associated problems with these impurities are understood and allowances made for them.

## 2.3 Origin of Salts in Irrigation Waters

It is said that all irrigation waters contain salts. What then is the origin of the salts in irrigation water?

Michael (1999) stated that the weathering of parent material of soil or rocks is the primary source of salts in irrigation water.

The environment, movement and source of irrigation water determine its type of salt and concentration. The groundwater saline can result from seawater intrusion and upcoming. Rhoades *et al.* (1992) noted that in coastal regions, surface water sources can become saline due to tidal influence of the sea.

Ayers and Westcot (1994) remarked that salts are present in irrigation water in relatively but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used.

## 2.4 Irrigation Water Quality Evaluation

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics. In irrigation water evaluation, emphases are placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important, (Ayers and Westcot, 1994).

The quality of irrigation water is judged by the amount of suspended and dissolved materials it contains. Suspended materials include eroded soil particles, seeds, leaves and other debris. The most common cations (positively charged ions) dissolved in irrigation water are calcium, magnesium, sodium, and potassium. Bicarbonate, sulphate, and chloride are the most common anions (negatively charged ions). Other solutes, nitrates, carbonates, and trace elements such as boron are occasionally present, (James, 1988). Furthermore he noted that dissolved materials in irrigation water are described by the total concentration of ions (without reference to the specific ions) and by the identity and concentration of the specific ions present. Crop yield can be reduced significantly when the total concentration of ions dissolved in the irrigation water usually called the salinity of irrigation water is high enough. High amounts of exchangeable sodium can cause soil particle dispersion that reduces soil structure and restricts air and water movement into and within the soil. Sodium, chloride, boron, and other ions are toxic to many plants when present in sufficient concentrations.

Smedema and Rycroft (1988) stated that the salinization/ sodification hazards posed by irrigation water can be readily predicted on the basis of the amount and types of salts contained in the water. Irrigation development should not therefore be undertaken without prior analysis and appraisal of the water to be used for irrigation. He distinguished three different hazards which include:

- Salinity hazard
- Sodicity hazard
- Toxicity hazard

### 2.4.1 Salinity Hazard

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

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

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

### 2.4.2 Sodicity hazard (Soil Infiltration Effect)

This 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 (EC-Value and SAR-Value). In general problems are not experienced in soil with ES-Values <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 soil extracts or irrigation waters are used to evaluate the exchangeable sodium status of 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)

$$\mathrm{ESP} = \frac{\text{Exchangeable sodium (milliequivalent per 100 gm)}}{\text{Cation - exchange capacity(millieqivalent per 100)}} \times 100$$

Cation exchange capacity (CEC) is the total quantity cations which a soil can absorb by cation exchange, usually expressed as milliequivalents per 100 grams. Measured values of the 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 of water into 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. The two most common water quality factors which influence the normal infiltration rate are the salinity of 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

rate generally increases with increasing salinity and decreases with either decreasing salinity or increasing sodium content relative to calcium and magnesium - the sodium adsorption ratio. Therefore, the two factors, salinity and SAR, must be considered together for a proper evaluation of the ultimate effect on water infiltration rate.

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

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 the theoretical relationship

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

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)

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

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

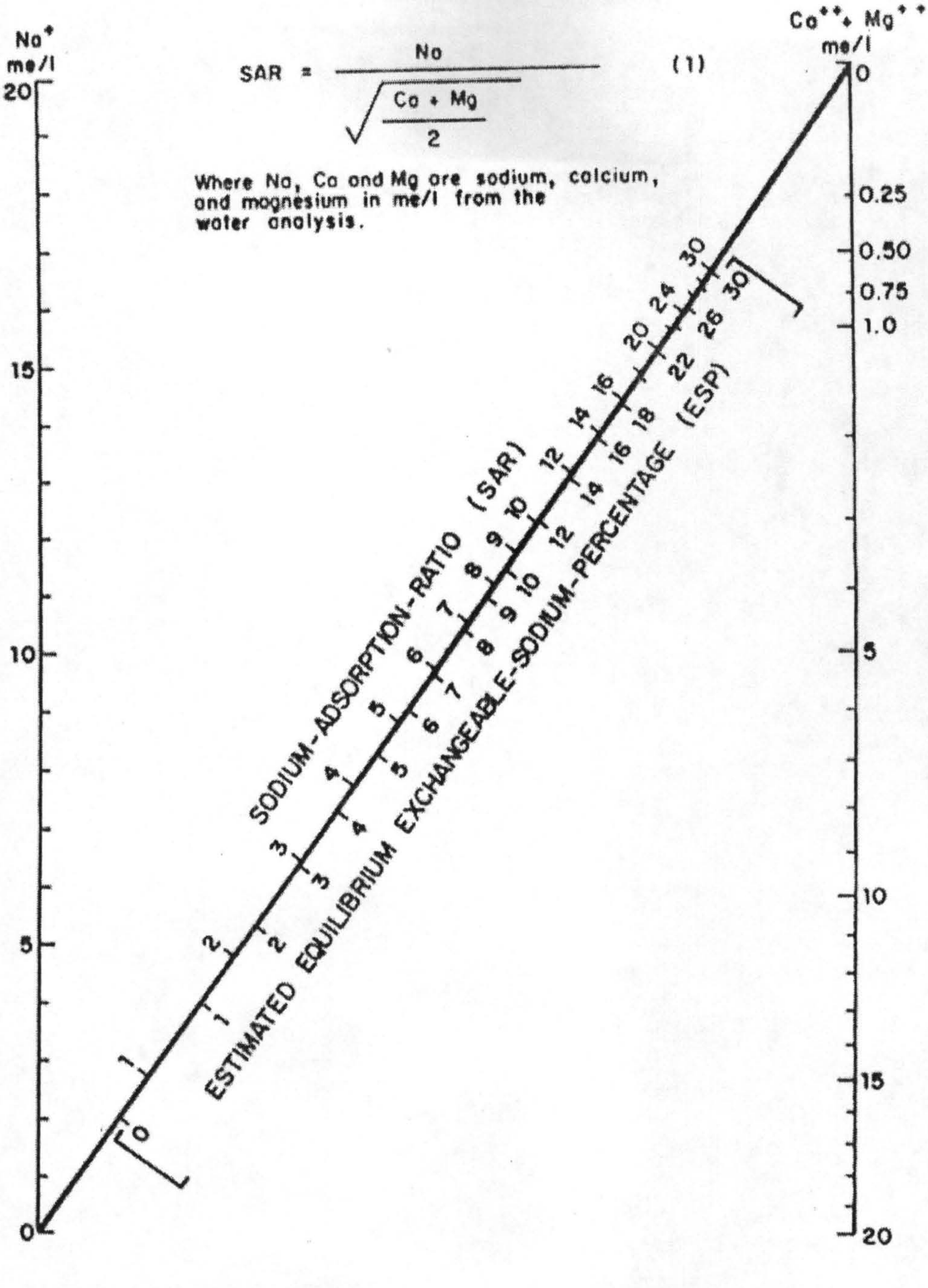



Fig.2. 1 Nomogram for determining the SAR value of irrigation water and for estimating the corresponding ESP value of a soil that is at equilibrium with the water.

Source: Ayers and Westcot , 1994.

### 2.4.3 Toxicity hazard

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations 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.

### 2.4.4 Classification of Saline Waters

Saline water may be classified as given in table 2.1. The classification is given in terms of total salt concentration, which is the major, quality factor generally limiting the use of saline waters for crop production

Table 2.1 Classification of saline waters

| Water class | Electrical conductivity dS/m | Salt concentration mg/l | Type of water |
|---|---|---|---|
| Non-saline | <0.7 | <500 | Drinking and irrigation water |
| Slightly saline | 0.7-2 | 500-1 500 | Irrigation |
| Moderately saline | 2-10 | 1 500-7 000 | Primary drainage water and groundwater |
| Highly saline | 10-25 | 7000-15000 | Secondary drainage water and groundwater |
| Very highly saline | 25-45 | 15 000-35 000 | Very saline groundwater |
| Brine | >45 | >45 000 | Seawater |

Source: Rhoades *et al*., 1992.

### 2.4.4 Irrigation Water Quality Guidelines

Guidelines for evaluation of water quality for irrigation are given in table 2.2. They emphasize the long-term influence of water quality on crop production, soil conditions and farm management. The guidelines are practical and have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, groundwater, drainage water, sewage effluent and wastewater, (Ayers and Westcot , 1994)

Table 2.2 Guidelines for Interpretations of Water Quality for Irrigation

| Potential Irrigation Problem | Units | Degree of Restriction on Use | | |
|---|---|---|---|---|
| | | None | Slight to Moderate | Severe |
| **Salinity** *(affects crop water availability)*[1] | | | | |
| **$EC_w$** | dS/m | < 0.7 | 0.7 – 3.0 | > 3.0 |
| (or) | | | | |
| **TDS** | mg/l | < 450 | 450 – 2000 | > 2000 |
| **Infiltration** *(affects infiltration rate of water into the soil. Evaluate using $EC_w$ and SAR together)* | | | | |
| **SAR** = 0 – 3 **And $EC_w$** = | | > 0.7 | 0.7 – 0.2 | < 0.2 |
| = 3 – 6 = | | > 1.2 | 1.2 – 0.3 | < 0.3 |
| = 6 – 12 = | | > 1.9 | 1.9 – 0.5 | < 0.5 |
| = 12 – 20 = | | > 2.9 | 2.9 – 1.3 | < 1.3 |
| = 20 – 40 = | | > 5.0 | 5.0 – 2.9 | < 2.9 |
| **Specific Ion Toxicity** *(affects sensitive crops)* | | | | |
| **Sodium (Na)** | | | | |
| surface irrigation | SAR | < 3 | 3 – 9 | > 9 |
| sprinkler irrigation | me/l | < 3 | > 3 | |
| **Chloride (Cl)** | | | | |
| surface irrigation | me/l | < 4 | 4 – 10 | > 10 |
| sprinkler irrigation | me/l | < 3 | > 3 | |
| **Boron (B)** | mg/l | < 0.7 | 0.7 – 3.0 | > 3.0 |
| **Trace Elements** (see Table 21) | | | | |
| **Miscellaneous Effects** *(affects susceptible crops)* | | | | |
| **Nitrogen ($NO_3$ - N)** | mg/l | < 5 | 5 – 30 | > 30 |
| **Bicarbonate ($HCO_3$)** | | | | |
| *(overhead sprinkling only)* | me/l | < 1.5 | 1.5 – 8.5 | > 8.5 |
| pH | | **Normal Range 6.5 – 8.4** | | |

Source: Ayers and Westcot, 1994

[1] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equiva-lent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

Table 2.3 Laboratory Determinations Needed To Evaluate Common Irrigation Water Quality Problems

| Water parameter | Symbol | Unit[1] | Usual range in irrigation water | |
|---|---|---|---|---|
| **SALINITY** | | | | |
| Salt Content | | | | |
| Electrical Conductivity | $EC_w$ | dS/m | 0 – 3 | dS/m |
| (or) | | | | |
| Total Dissolved Solids | TDS | Mg/l | 0 – 2000 | mg/l |
| Cations and Anions | | | | |
| Calcium | $Ca^{2+}$ | Meq/l | 0 – 20 | me/l |
| Magnesium | $Mg^{2+}$ | Meq/l | 0 – 5 | me/l |
| Sodium | $Na^{+}$ | Meq/l | 0 – 40 | me/l |
| Carbonate | $CO^{2-}_3$ | Meq/l | 0 – .1 | me/l |
| Bicarbonate | $HCO_3^-$ | Meq/l | 0 – 10 | me/l |
| Chloride | $Cl^-$ | Meq/l | 0 – 30 | me/l |
| Sulphate | $SO_4^{2-}$ | Meq/l | 0 – 20 | me/l |
| **NUTRIENTS**[2] | | | | |
| Nitrate-Nitrogen | $NO_3$-N | mg/l | 0 – 10 | mg/l |
| Ammonium-Nitrogen | $NH_4$-N | mg/l | 0 – 5 | mg/l |
| Phosphate-Phosphorus | $PO_4$-P | mg/l | 0 – 2 | mg/l |
| Potassium | $K^+$ | mg/l | 0 – 2 | mg/l |
| **MISCELLANEOUS** | | | | |
| Boron | B | mg/l | 0 – 2 | mg/l |
| Acid/Basicity | pH | 1–14 | 6.0 – 8.5 | |
| Sodium Adsorption Ratio[3] | SAR | (meq/l), | 0 – 15 | |

Source: Ayers and Westcot, 1994

[1] dS/m = deciSiemen/metre in S.I. units (equivalent to 1 mmho/cm = 1 millimmho/centi-metre)

Mg/l = milligram per litre ≃ parts per million (ppm).

Me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 millimol/litre adjusted for electron charge.

[2] $NO_3$ -N means the laboratory will analyse for $NO_3$ but will report the $NO_3$ in terms of chemically equivalent nitrogen. Similarly, for $NH_4$-N, the laboratory will analyse for $NH_4$ but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalent elemental nitrogen. The same reporting method is used for phosphorus

## 2.5 Soil

### 2.5.1 What is Soil?

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

According to Microsoft Encarta (2006) soil is the loose material that covers the land surface Earth and supports the growth of plants. In generally, 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 differing from the underlying rock material as a result of interactions between climate, living organisms (including man), parent material and relief over periods of time.

### 2.5.2 Soil Texture

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

Foth (1990) specifically stated that, texture is the relative proportions of sand, silt, and clay in a soil.

### 2.5.3 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 2.4 shows the characteristics of some soil separates, (Foth, 1990).

• 6 I/O channels for additional devices such as extensometers, micrometers, calipers, balance etc.

• High stiffness loading frames with solid specialized steel crossheads and rigid extruded support columns with T-slots for accessory mounting.

• Overload, overtravel and impact protection.

• Telescopic covers giving additional protection for ballscrews against dust and testing debris.

• Extensive range of grips and fixtures for tension, compression, flexural, shear, peel and product testing etc.

• A wide range of contacting and non-contacting extensometers is available including laser and video models.

**3.3.2.1 Test Procedure**

The height of the samples were measured so has to be imputed in the machine this been the first process. Then the shape of the samples were determined but was not among the default shape of the machine, none was used to signify its non determination. Afterward, the samples were separated into fresh yellow tiger nut, dried yellow tiger nut, dried brown tiger nut. The first sample were put into the loader, the start button on the universal testing machine was pressed and it automatically applied force, which are recorded on the display until the sample cannot withstand any further increase in the force applied. The result obtained was used to automatically compute the table and graph for each respective sample of fresh yellow tiger nut. This process was repeated for the dried yellow and dried brown tiger nut, result obtained was computed.

**Table2.4 Characteristics of Soil Separates**

| 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 | 0.25-010 | 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: Foth, 1990

(a) United States Department of Agriculture System

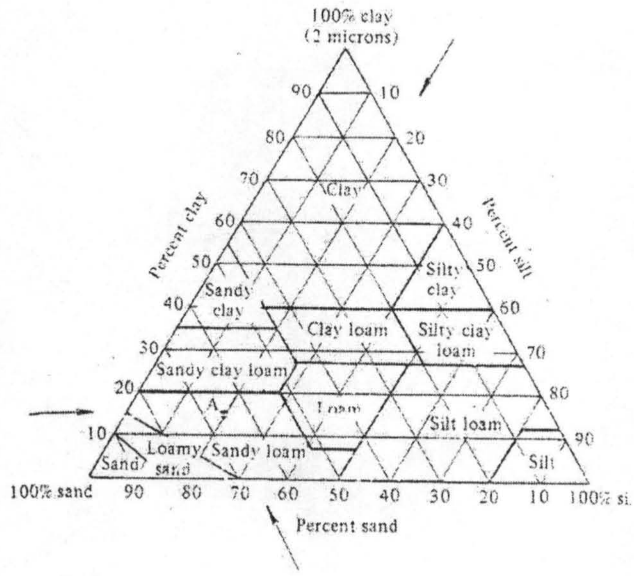
(b) International Soil Science Society System

### 2.5.4 Soil Textural Classes

The texture of a soil is expressed with the use of class names, as shown in figure 2.2. The sum of the percentages of sand, silt and clay at any point in the triangle is 100. Point A represents a soil containing 15 percent clay, 65 percent sand, and 20 percent silt, resulting in a textural class name of sandy loam. A soil containing equal amounts of sand, silt and clay is a clay loam. The area outlined by the bold lines in the triangle defines a given class. For example, a loam 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 all three separates – sand, silt and clay. For sandy soils (sand and loamy 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 he soil are influenced mainly by high clay content (Foth, 1990)

Textural class names containing the term "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 25cm are considered to be part of the soil mass, though not part of the fine earth, also influence certain soil properties and, therefore if present in noticeable quantities, the are noted in textural class name by additions such as gravelly, 'cherty', 'slaty' or 'stony' (Agricultural Compendium, 1989).




Source: Foth,1990

Fig. 2.2 The textural triangle showing the limits of sand, silt and clay contents of the various texture classes

### 2.5.5 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 a 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 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).

## 2.6 Irrigation Salinization

Soil salinization generally refers to the development of non-salty soil into a salty soil, and especially to the development of a non-saline soil into a saline soil. It involves an increase of soluble salt content of the soil, resulting in an increase of the salt concentration of the soil solution, (Smedema and Rycroft, 1988)

Soil salinity may be primary or secondary. Primary or Residual salinity is that which is directly related to parent material of the soil. The high salt content in this case came from the rocks as they weather into soil. The secondary salinity is the accumulation of salt in the root zone from outside source. Rhoades *et al.* (1992) observed that while salt-affected soils occur extensively under natural conditions, the salt problems of greatest importance to agriculture arise when previously productive cultivated soil becomes salinized as a result of irrigation (so-called secondary salinization).

### 2.6.1 Classification of Salty Soils

The system developed by the US salinity laboratory (Riverside, California) is most commonly used for the classification of salty soils.

The diagnostic parameters in this system are the EC-Value (indicative of the osmotic problem) and the ESP- Value (indicative of the dispersion problem), (Smedema and Rycroft, 1988).The table is shown below.

Table 2.5 USDA Classification of Salt-affected soils

| Soil | ECe ($mScm^{-1}$) | ESP | pH | Description |
|---|---|---|---|---|
| Saline soil | > 4 | <15 | Usually <85 | Non-sodic soils containing sufficient soluble salts to interfere with growth of most crops. |
| Saline Sodic soils | >4 | <15 | Usually <8.5 | Soil with sufficient exchangeable sodium to interfere with growth of most plants, and containing appreciable quantities of soluble salts. |
| Sodic soils | <4 | >15 | Usually >8.5 | Soil with sufficient exchangeable sodium to interfere with growth of most plants, but without appreciable quantities of soluble salts. |

Source: Landon (Ed.), 1991

Note: Although fairly widely accepted, the values for ECe, ESP and pH should be regarded as indicative rather then as fixed critical values. The effects of increases ESP, for example, gradually worsen rather than rapidly change soil conditions as a value of 15 is reached. Local experience should be compared with measured values wherever this is possible. The presence of gypsum, in particular, in a soil can mitigate the effects of high ESP Values.

### 2.6.2 Climate and Salt build-up

The major saline regions of the world are generally found in semi-arid and arid and relatively low-lying poorly drained lands. This is the result of the mobilization of large quantities of salts by excessive irrigation and leaching and the subsequent accumulation of the salt in localized areas with restricted drainage,(Rhoades *et al.,* 1992).

Arid-region soils contain relatively large amounts of soluble salts. The heavy annual rainfalls of humid regions cause water to percolate through the soil and carry to the streams, rivers, and oceans large amounts of soluble minerals substances. The scanty rains of arid regions do not penetrate the virgin arid soils deeply enough to cause appreciable percolation, (Hansen *et al.*, 1979)

Scenarios were set up in What if to provide an example of projected effects of different rainfall and climate effects on profile salt changes over a year. Root zone salinity was found to increase most under dry conditions (table 2.6) where grapes are grown in

Loxton on a soil with root zone salinity of 1 dS/m, applying 1100mm of irrigation water with a salinity of 0.8 dS/m would increase root zone salinity to 2.3dS/m in wet year and 3.7 dS/m in a dry year. Applying the same strategy in the Riverina would increase root zone salinity to 1.8dS/m in an average year while if the strategy was supplied in the relatively high rainfall area of south – eastern Queensland the root zone salinity would decrease to 0.4dS/m.

Where no irrigation is applied to grapes grown in south – eastern Queensland, it would be expected that root zone salinity would increase to 1.2dS/m. However, where cotton is grown in the same area without irrigation there would be no significant change in root zone salinity. Adding irrigation with high quality water (0.2dS/m) effectively results in net leaching of salt and so the root zone salinity will decline. If mildly salty water (0.8dS/m) is used for irrigation then with the same rainfall and irrigation amounts salinity level in the root zone would increase by 0.1dS/m (Raine *et al.*, 2005)

### 2.6.3 Causes and Processes of Salt Build–Up.

a) The major causes for the build –up of salt in an irrigated area include;
b) Use of saline water for irrigation
c) Deposition of salts on soil surface from high sub-soil water table
d) Water logging and poor drainage conditions
e) Seepage from the canals
f) Arid climate
g) Back-water flow or diffusion of sea water in coastal areas.
h) Under – irrigation.

Table 2.6 Effect of climate on root zone salinity of a fast infiltration loam with a starting root zone salinity of 1dS/m[a]

| **Crop** | **Location** | **Rainfall during season(mm)** | **Total annual rainfall(mm)** | **Irrigation water applied(mm)** | **Change in root zone salinity after one year(dS/m)** |
|---|---|---|---|---|---|
| Grape | Loxton(dry year) | 88 | 93 | 1100 [b] | 2.7 |
| | Loxton(wet year) | 79 | 198 | 1100 [b] | 1.3 |
| | S.E Qld | 223 | 418 | 1100 [b] | 0.8 |
| | S.E Qld | 523 | 719 | 1100 [b] | -0.6 |
| | S.E Qld | 523 | 719 | 0 | 0.2 |
| Cotton | S.E Qld | 491 | 777 | 0 | 0 [d] |
| | S.E Qld | 491 | 777 | 300 [c] | -0.4 |
| | S.E Qld | 491 | 777 | 300 [b] | 0.1 |

Source: Raine *et al.,* 2005

[a] Watertable depth =2.2m below surface with water quality =5.0dS/m

[b] Irrigation water quality =0.8dS/m

[c] Irrigation water quality =0.2dS/m; note 300mmof irrigation required to achieved fully irrigated yield

[d] note yield is estimated to be 28% lower than a fully irrigated yield

problem before irrigation, and its extent, and management practices during irrigation are equally important factors.

How do these process results in salt build–up? Two main ways through which these processes result in salt build up are:

(i) Direct salinization by irrigation due to inadequate leaching

(ii) Capillary salinization: salinization from groundwater

Direct salinization by irrigation results, if there is inadequate leaching. All irrigation waters contain salt which are brought into the root zone during irrigation. After irrigation, the water is lost by the process of evapotranspiration leaving the salt content behind in the root zone as the salt uptake by crops is small. These salts accumulate unless there is adequate leaching by deep percolation. Inadequate leaching is cause by poor drainage conditions, and climate, under-irrigation and use of saline water.

The capillary salinisation as explained by Smedema and Rycroft (1988) is thus

*"Evaporation of (Saline) groundwater from the soil is a common cause of soil salinisation. The groundwater may evaporate directly from the water-table when the latter occurs within the evaporation zone, or it may be drawn from deeper down as the evaporation itself will create a gradient for upward capillary flow from the water-table into the evaporation zone. As the water evaporates the salts remain behind in the evaporation zone"*

### 2.6.4 Chemistry of Salty Soil

The main process occurring in soils when irrigating with poor quality waters are (i) ion exchange between cations in irrigation water and those present on the soil exchange complex. (ii) dissolution and precipitation of $CaCO_3$ (iii) weathering of minerals (iv) hydration and dehydration of the soil as a result of fluctuation in soil moisture (v) leaching down of ions (vi) upward movement of ions through capillary activity and (vii) mineral nutritional characteristics of the crop grown.

The clay particles have a certain charge deficit which is balanced by the charge of the adsorbed cation taken from the soil solution. An order of replaceabilily of any ion present on the soil can be expressed as

$NH_4^+ > Mg2^+ > Ca^{2+} > K^+ > Na^+$

A clay particle with sodium and calcium ions attached tends to hydrolyze. When a sodium ion is exchanged for a hydrolyze ion, and the sodium ions combines with a molecule of water, sodium hydroxide (NaOH) is formed.

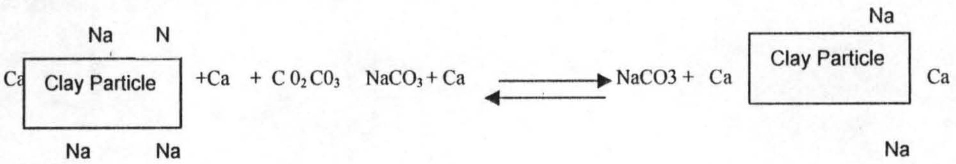
Ca [ Clay ] Na + H20 ⟶ NaOH + H [ Clay Particle ] Ca

When carbon dioxide ($CO_2$) is present in the soil air, it readily reacts with the water to form hydrogen carbonate ($H_2C0_3$). However, the sodium hydroxide (NaOH) reacts readily with the hydrogen carbonate ($H_2C0_3$) to form sodium carbonate ($Na_2C0_3$).

$$H_2\,C0_3 + 2\,NaoH \rightleftharpoons Na_2\,C0_3 + 2H_2O$$

The $Na_2CO_3$ is gradually removed with extensive leaching, and the soil is left with hydrogen ions having replaced sodium ions. This increase of hydrogen ions is reflected in a lower pH (pH being a reciprocal index of hydrogen ions concentration).

Where soils contain calcium carbonate ($CaC0_3$) or gypsum, calcium is dissolved into the soil solution. This available calcium is exchanged for sodium during the leaching process to obtain a normal soil.




**2.6.5 Salt Balance**

The relationship between the quantity of soluble salts brought into an area by the irrigation water and the quantity removed from the area by the drainage water is called the salt balance of the area. Therefore, in an irrigation area, a favourable salt balance a condition wherein the output of salts equals or exceeds the input-must be maintained if irrigated agriculture is to be permanent. The salt balance in soil is influenced by the quantity and quality of irrigation water and the affectivities of leaching and drainage, (Michael, 1999). Any imbalance that would lead to excessive salt in the soil has adverse effect on the soil, crop growth and crop yield.

The salt balance of soils is expressed by the following relationship, (Michael, 1999):

$$ViCi + Sm - Sp - Sc = 0$$

Vi =Volume of irrigation water

Ci =Amount of dissolved from soil minerals

Vd = Volume of drainage water

Ca = Salt content of drainage water

Sp = The amount of salt precipitated over the soil surface

Sc = Amount of salt removed by crop

An equation expressing for a root zone under irrigation reads, (Smedema and Rycroft, 1988):

$$I.C + R.C_r + G.C_g = PC_p + DS$$

I = irrigation water entering root zone

R = rainfall entering the root zone

Cr = salt concentration of the rainfall

G = capillary flow for groundwater into root zone

$G_p$ = salt concentration of the groundwater

P = deep percolation from the root zone

$C_p$ = salt concentration of the water of de-percolation

DS = change in salt content of soil solution in the root zone

Cg = salt concentration of groundwater

### 2.6.6 Leaching Requirement

The fraction of the irrigation water that must be leached through the rootzone to control soil salinity is termed the leaching requirement.

Assuming that the salt balance is in equilibrium, mathematically, LR (Michael, 1999):

$$LR = \frac{D_d}{D_i} = \frac{EG}{E_{cd}}$$

LR = leaching requirement, expressed as a ratio or per cent

$D_d$ = depth of drainage water

$D_i$ = depth of irrigation water

EG = electrical conductivity of irrigation water

$E_{cd}$ = electrical conductivity of drainage water.

### 2.7.1 Environmental Impact of Irrigation

The impact of irrigation system on the environment and immediate and surrounding communities are both positive and negative. The positive effects include provision and development of social economic infrastructure. The negative impacts include health, salinity, alkalinity and rising water table hazards, (Adeniran, 2004). There are at least four major environmentally-related potential hazards associated with irrigation in general and with use of more saline waters in particular. They are: **loss in soil productivity** due to salinity and water logging, **pollution of associated water resources** with salts and toxicants by drainage, **damage to the associated ecosystems** and **increased risk to public health** resulting from water pollution and water logging, (Rhoades *et al.*, 1992). On irrigated lands salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. The accumulation of salts in soils can lead to irreversible damage to soil structure essential for irrigation and crop production. Effects are most extreme in clays soil where the presence of sodium can bring about soil structural collapse. This makes growing condition very poor, makes soils very difficult to work on and prevent reclamation by leaching using standard techniques, (FAO, 1995)

## 2.8 Other Works

Related work has been carried out on the Chanchaga Irrigation Scheme, (Babangida, 2001). He determine the surface and ground water quality and concluded that the water from the River Chanchaga and ground water are save for irrigation at dry season farming. Also, Aboubakar in 2000 worked on Soil Salinity and Water logging due to Irrigation and Drainage Problem. He observed that the surface water supply is of satisfactory for irrigation purpose and that the project area is not subject to any problem of salinity. Furthermore, he observed that the area is far from being water logged because of the absence of excess water. No salt related work has been carried out on Soje and Gusoro Irrigation Scheme.

This project aims at evaluating the irrigation water quality, soil salt contents and environmental impacts of the schemes on the areas. This is inline with FAO (1995) suggestion: *'It is important that all evaluation regarding irrigation water quality is linked to the evaluation of the soil to be irrigated. Low quality irrigation waters might be hazardous on heavy, clayey soils, while the same water could be used satisfactorily on sandy and/ or permeable soils.*

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Study Areas

The project study areas under investigation were the Chanchaga Irrigation Scheme, Soje irrigation Scheme, and Gusoro Irrigation Scheme, all in Niger State, Nigeria (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 $8^0\ 10'$ N and $11^0\ 30'$ N and longitude $3^0 30'$ E and $7^0\ 30'$ E

Its climate is influence mainly by the rain- bearing South West monsoon winds from the oceans 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 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 (Appendix A)

### 3.1.1 Chanchaga Irrigation Scheme

Chanchaga Irrigation Scheme is located at chanchaga village at the outskirt 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 become fully operational in the year 1978.

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

### 3.1.2 Gusoro/Awulo Irrigation Scheme

The Gusoro Irrigation Scheme is located in Gusoro village of Shiroro Local Government of Niger State.

The irrigation system is a surface irrigation system using canals and pressure pipes. River Kaduna is the source of water for the scheme. NPC (1998) noted that, north of the Niger-Benue trough, all the major rivers rise from the Jos Plateau, which is known as the hydrological centre of Nigeria. The rivers include the Sokoto, Kaduna and Gongola, all of which drain into the Niger-Benue system and the Yobe River System which drain into Lake Chad.

Amodou (2000) reported that Gusoro irrigation Scheme was evolved by the Upper River Basin Development Authority to take advantage of the discharge from the Shiroro Dam at 18 Km from Shiroro Hydroeletric Dam with a net area of 220 ha.

### 3.1.3 Soje Irrigation Scheme

The Soje Irrigation Scheme is located in Soje, few kilometers from the Minna Railway Station. The source of water is the wastewaters from Minna Township. The water flow through unlined channels and the farmers took advantage of its continuous flow for irrigation. Stream Morris Rafisanyi flows into the wastewater towards the downstream. Therefore one part of the farm is been irrigated using only Morris Rafisanyi Stream while the other part of the scheme is irrigated using the waste water. The investigation was limited to the latter part of the scheme. The scheme, from enquiring, is a private arrangement of the farmers and it's about 7.5 ha.

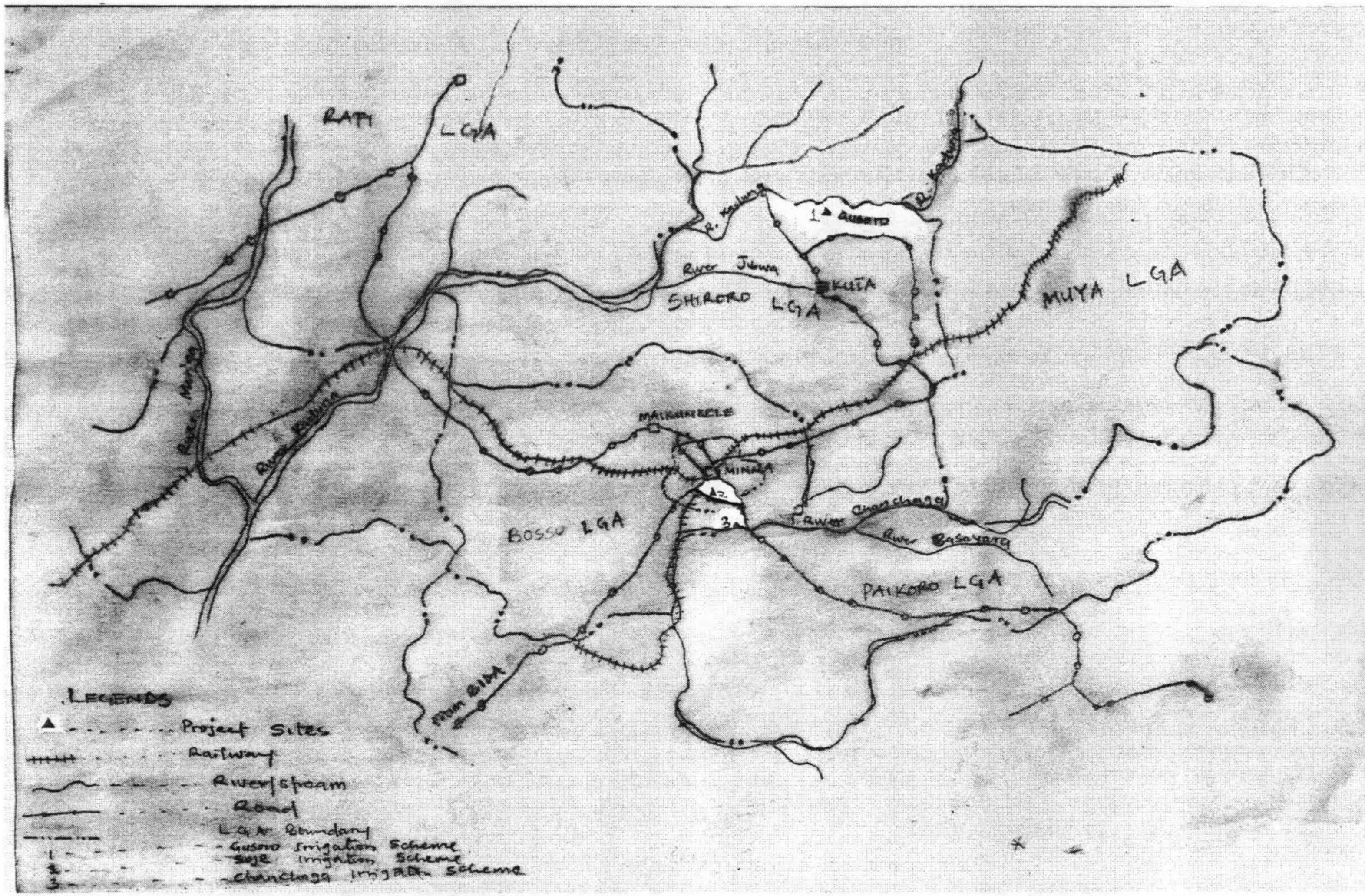


FIG. 3.1: AN ABRIDGE MAP OF NIGER STATE SHOWING THE THREE PROJECTS SITES.

### 3.2 Water Samplings and Analyses

Water samples were collected using 1.5 litres plastic containers. All the containers were initially washed using detergent and properly rinsed. At the point of sampling, the containers were also rinsed using the stream water several times before the samples were taken.

Samples were taken from the three irrigation schemes.

The sampling points were section into:

1. Upstream of the irrigation water
2. On scheme of the irrigation water
3. Downstream of the irrigation water

The upstream here refers to points on the stream course just before the scheme. On scheme 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 (see fig. 3.2a, 3.2b and 3.2c).

The samples were collected by dipping the container into the stream, at different spots to get a composite sample. After collection, the container is closed and labeled before moving to another sampling point. See list of symbols for labeling. All samples were collected mid-June, 2006.

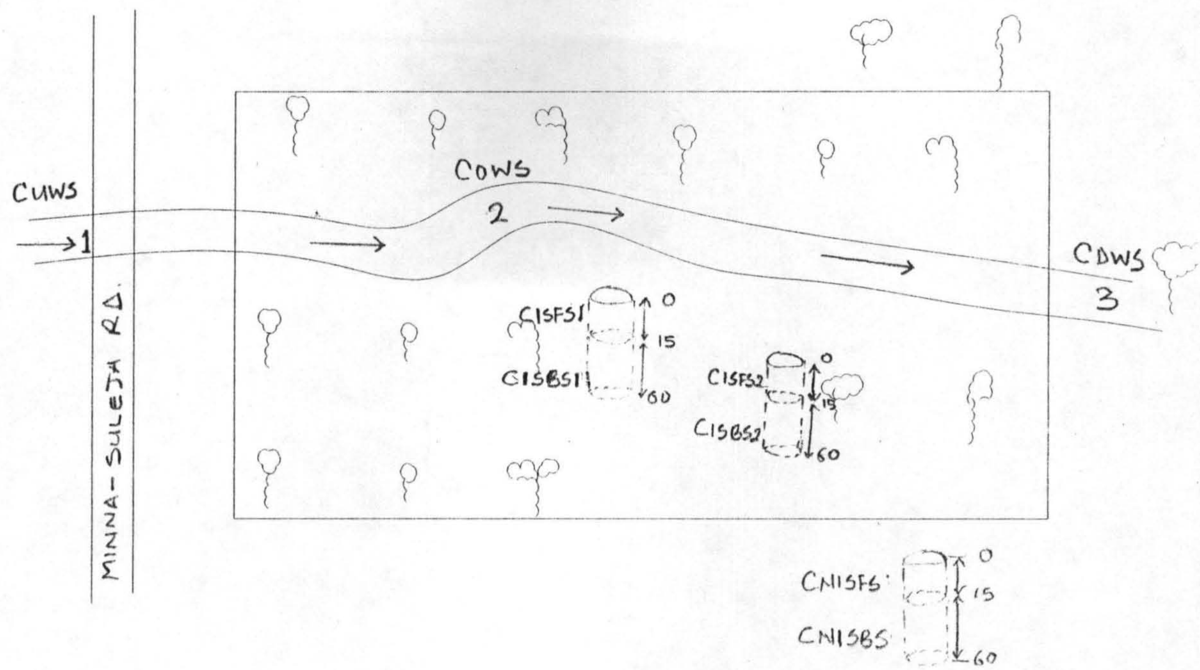



Fig.3.1a Sketch of Sampling Points at Chanchaga Irrigation Scheme

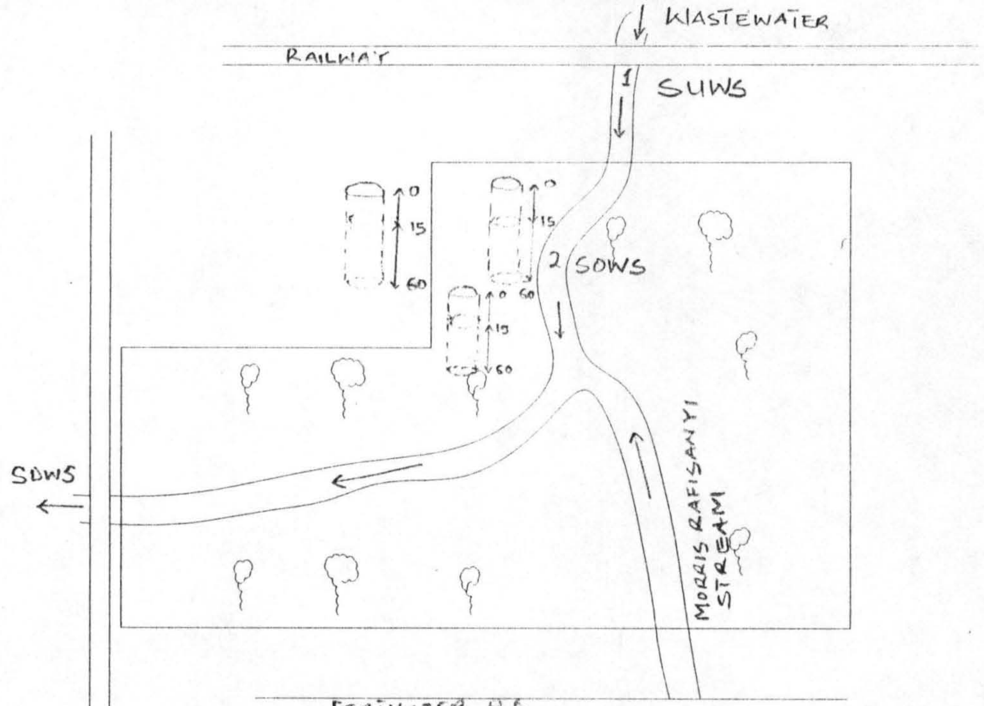



Fig. 3.1b Sketch of Sampling Points at Soje Irrigation Scheme

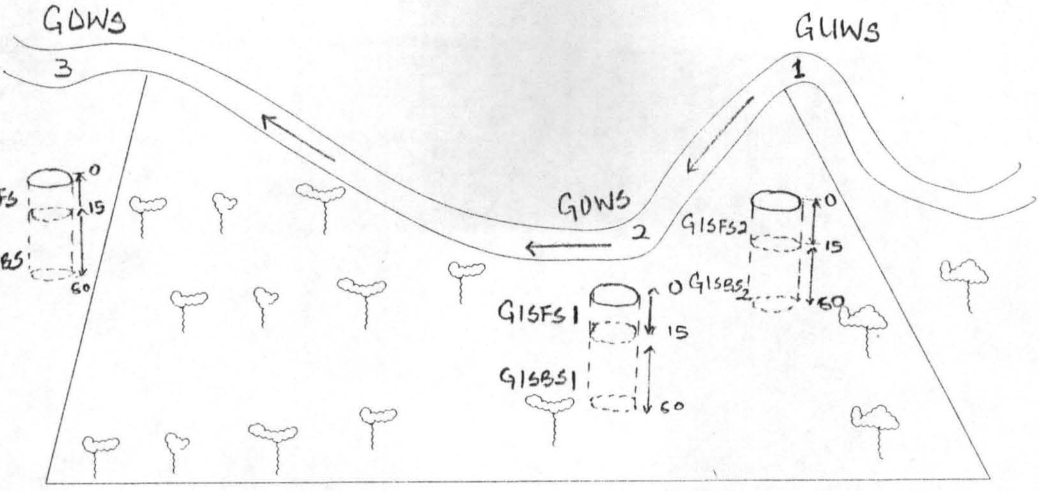



Fig.3.1c Sketch of sampling points at Gusoro Irrigation Scheme

The irrigation waters were analyzed for physical and chemical parameters.

The physical parameters analyzed include;

a) Total dissolve solids

b) Temperature

The chemical parameters include;

pH, electrical conductivity, total hardness – EDTA, dissolved oxygen, chloride, sulphate, nitrate, iron, magnesium, sodium, potassium, calcium, copper, manganese, chlorine and boron.

The analyses were carried out using the Atomic Absorption Spectrometer (AAS), pH meter, Wagtech D.P.D (diethyl-P-phnylene & diememine) Chlorine Method and dissolved oxygen test kit (appendix).

### 3.3 Soil Samplings and Analyses

Two sampling points were randomly selected on site since the two points form one population. The distance between the two points was approximately 3 to 4 metres apart. The third sampling point was selected from outside the irrigated area. Farmers were asked to confirm that the third sampling point was truly a non irrigated area. Surface litters were separated and discarded from sampling points.

A carbon steel, one long, 10cm diameter soil auger was used for the sampling. The auger was position vertically (at an angle of $90^0$ ) on the soil surface. The handle was turned clockwise for some revolutions until the cylinder was full. It was lifted from the hole and the cylinder content emptied into a rubber container. The auger head was replaced into the hole and the procedure repeated until the required depths were reached. Samples were taken from both surface and sub surface depths. The surface samples were taken at 0-15cm depth and was labelled. The subsurface samples were taken at 15-60cm and labelled. The samples were labelled before taking the next sampling point.

The same procedure was used for sampling the soils in the three irrigation schemes under investigation.

The soil samples before being sent to the laboratory for analysis were treated by drying. The samples were spread out and air dried at room temperature for three days. At least 450g of each sample was sent. Analyses were carried out using glass electrode-pH meter, Bouyoucos methods for Particle size analysis, Macro-kjeldahl method, Electrical conductivity meter and atomic absorption spectrometer (Appendix I)

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.1 Water Samples Analyses

The results of the water samples analyses are shown in Table 4 .1a, 4.1b and 4. 1c for Chanchaga, Gusoro and Sȯje Irrigation shemes respectively

Table 4.1a Physical and Chemical Parameters of Chanchaga Irrigation Water

| Water Quality Parameters | CUWS | COWS | CDWS |
|---|---|---|---|
| Temperature | 28.2 | 27 | 28 |
| pH | 6.4 | 7 | 6.9 |
| Electrical Conductivity,µmhos/cm | 10.5 | 11.8 | 12 |
| Total Dissolved Solids | 106 | 110 | 130 |
| Total Hardness-EDTA($MgCaCO_3$) | 56 | 50 | 42 |
| Dissolved Oxygen | 6.3 | 4 | 3.2 |
| Chloride,$Cl^-$ | 25 | 28 | 27 |
| Sulphate,$SO_4^+$ | 15.7 | 14 | 14.8 |
| Calcium,$Ca^{2+}$ | 3.5 | 8 | 8.3 |
| Iron,$Fe^{2+}$ | 0.1 | 0.3 | 0.22 |
| Magnesium,$Mg^{2+}$ | 1.6 | 4.1 | 3.6 |
| Phosphate,$PO^{4-}$ | 0.9 | 4 | 5.61 |
| Nitrate,$NO_3^-$ | 1.5 | 4.6 | 6.2 |
| Sodium,$Na^+$ | 4.8 | 5.3 | 6 |
| Potassium,$K^+$ | 1.8 | 2.81 | 2.6 |
| Copper,$Cu^{2+}$ | 0.4 | 0.21 | 0.2 |
| Manganese,$Mn^+$ | 0.04 | 0.04 | 0.05 |
| Chlorine,Cl | 1.8 | 2.71 | 3.1 |
| Boron,B | 0 | 0 | 0 |
| Calculated: | | | |
| $SAR^c$ | 0.53324649 | 0.379693 | 0.43769 |
| $ESP^d$ | -0.4757138 | -0.704887 | -0.61821 |

[a] All parameters arc in mg/l except otherwise stated

[b] Unitless

[c] calculated in $(meq/l)^{1/2}$ , [d] Expressed as %

Table 4.1b Physical and Chemical Parameters of Gusoro Irrigation Water

| Water Quality Parameter [a] | GUW | GOWS | GDWS |
|---|---|---|---|
| Temperature($^0$ C) | 26.8 | 30.5 | 27 |
| pH [b] | 6.7 | 6.8 | 7.1 |
| Electrical Conductivity,µmmhos/cm | 23 | 21 | 20 |
| Total Dissolved Solids | 34 | 41 | 39 |
| Total Hardness EDTA($MgCaCO_3$) | 13.2 | 11.8 | 12 |
| Dissolved Oxygen | 2.5 | 3.1 | 3 |
| Chloride,$Cl^-$ | 2.4 | 2.44 | 2.4 |
| Sulphate,$SO_4^+$ | 21 | 23 | 24 |
| Calcium,$Ca^{2+}$ | 5.2 | 5.5 | 5.8 |
| Iron,$Fe^{2+}$ | 0.13 | 0.1 | 0.2 |
| Magnesium,$Mg^{2+}$ | 0.21 | 1.2 | 0.4 |
| Phosphate, $PO_4^-$ | 2.1 | 4.7 | 3.8 |
| Nitrate,$NO_3^-$ | 13.7 | 13.8 | 14 |
| Sodium,$Na^+$ | 0.34 | 0.54 | 0.67 |
| Potassium,$K^+$ | 1.3 | 1.8 | 1.6 |
| Copper,$Cu^{2+}$ | 1 | 1.1 | 1.2 |
| Manganese,$Mn^+$ | 1.2 | 2.3 | 2.4 |
| Chlorine,Cl | 0 | 0.2 | 0 |
| Boron,B | 0 | 0 | 0 |
| Calculated: | | | |
| SAR | 0.039738 | 0.05435 | 0.072561 |
| ESP | -1.21599 | -1.1939 | -1.16642 |

[a] All parameters are in mg/l except otherwise stated

[b] Unitless

[c] calculated in $(meq/l)^{1/2}$ , [d] Expressed as %

### 4.1.1 Electical Conductiveties ($EC_W$), Total Dissolved Solid (TDS) and Sodium Absorption Ratio (SAR)

Electrical conductivity (EC) measurements are used as indication of total quantities of soluble salts in solution. It is use in irrigation water analysis to determine the salinity of the water. Total dissolved solid measure the concentration of dissolved solutes in irrigation water. It is also used as a measure of salinity.

Table 4.1c Physical and Chemical Parameters of Soje Irrigation Water

| Water Quality Parameters [a] | SUWS | SOWS | SDWS |
|---|---|---|---|
| Temperature,( $^{0}C$) | 30.5 | 30 | 31 |
| pH [b] | 7.3 | 7.2 | 6.4 |
| Electrical Conductivity,(μmmhos/cm) | 74 | 65 | 86 |
| Total Dissolved Solids | 108 | 110 | 156 |
| Total Hardness-EDTA($MgCaCO_3$) | 203 | 215 | 237 |
| Dissolved Oxygen | 1.5 | 1.9 | 2.6 |
| Chloride,$Cl^-$ | 96 | 110 | 126 |
| Sulphate,$SO_4^+$ | 35 | 43 | 27 |
| Calcium,$Ca^{2+}$ | 23 | 28 | 25 |
| Iron,$Fe^{2+}$ | 0.23 | 0.1 | 0.22 |
| Magnesium,$Mg^{2+}$ | 2.1 | 2.6 | 2.4 |
| Phosphate,$PO_4^-$ | 2.5 | 5.8 | 4.1 |
| Nitrate,$NO_3^-$ | 12.3 | 23.6 | 16.9 |
| Sodium,$Na^+$ | 4.3 | 6.2 | 4.8 |
| Potassium,$K^+$ | 11.4 | 13.3 | 12.2 |
| Copper,$Cu^{2+}$ | 1.9 | 1.6 | 1.3 |
| Manganese,$Mn^+$ | 0.3 | 0.2 | 0.44 |
| Chlorine,Cl | 5.8 | 3.2 | 4.8 |
| Boron,$B^+$ | 1.6 | 1.5 | 1.66 |
| **Calculated:** | | | |
| SAR | 0.23008 | 0.300334 | 0.245521 |
| ESP | -0.92919 | -0.82374 | -0.90599 |

[a] All parameters are in mg/l except otherwise stated
[b] Unitless
[c] calculated in $(meq/l)^{1/2}$ , [d] Expressed as %

The EC values obtained for COWS, CUWS and CDWS are 10.5, 118 and 12 μmmhos/cm receptively. These values when compared to the guidelines (see table 2.2) are within the given range of < 0.7 dS/m. It therefore poses no salinity problem and there is no restriction on the use of the water for irrigation. The result of that of Gusoro ranges from 20 to 23 μmmhos/cm while that of Soje ranges from 30 to 31 μmhos/cm, therefore, the schemes waters are safe for irrigation.

The Total Dissolve Solids (TDS) can also be use to evaluate salinty hazards. The values of TDS obtained for the schemes are below the 450mg/l limit. Hence by the guidelines (Fig. 2.2) , the water will not cause salinity problem and there is no degree of restriction on the use of the schemes waters for irrigation.

Potential infiltration problem is evaluated using EC and SAR. The SAR values for the three schemes are ≤ 0.53. When we compare the SAR values and ECw of the schemes to the guidelines (Fig. 2.2), it will be observed that the SAR values are within the range 0-3 while the ECW values are < 0.2 dS/m. The schemes waters therefore have a potential of causing infiltration problem and a severe degree of restriction on its use. This is because as explained by Ayers and Westcot(1994) low salinity water (less than 0.5 dS/m and especially below 0.2 dS/m) is corrosive and tend to leach surface soils free of soluble minerals and salts especially calcium, thus reducing their strong stabilizing influence on soil aggregates and soil structure. Without salts and without calcium, the soil disperses and the dispersed finer soil particles fill many of the smaller pore space sealing the surface and greatly reducing the rate at which water infiltrates the soil surface.

Therefore, the low salinity of the three irrigation waters with SAR values ≤ 0.53 is of concern because severe problem of infiltration is expected in a long time to come.

### 4.1.2 Temperature and pH

The temperature is an important parameter because of its effects on other water quality parameters (Babangida, 2001). Schwab *et al.* (1993) observed that irrigation may be use for cooling, particularly when germination occurs under high temperatures. These underscore the importance of irrigation water temperature. The highest temperature of 31°C was recorded from SDWS. Therefore, the schemes water temperature most likely would not cause harm to the plants and soil.

The pH is a measure of the acidity or alkalinity of the water. Most of the pH values obtained would pose no danger to plants or soil. When compare to the guidelines (Fig 2.2), there are within the allowable range of 6.5-8.4. However, the pH for CUWS, 6.4, is slightly acidic. Probably due to self-purification; this pH raises to 7 and 6.9 for COWS and CDWS respectively, which are within the allowable range. SDWS was slightly acidic; this acidic value, however, does not restrict the use of the Soje water for irrigation. This is because; it is the downstream value and not that of on scheme, where the water is diverted for irrigation. This however, calls for close monitoring of the scheme pH values to ensure that they do not become too acidic to the level that would pose problem to the plants.

### 4.1.3 Sodium, Chloride and Boron

These three are the most common elements known for specific ion toxicity. Specific ion toxicity is when certain elements become more concentrated in the irrigation water that it causes a decline in crop growth. They all effect sensitive crops (see Appendix C)

Boron is absent in both Chanchaga and Gusoro irrgation water. However it is present in the upstream, on scheme and downstream of the Soje irrigation water. The presence of Boron in the Soje irrigation water could be attributed to its source. The part of the water of the scheme, which the research work is considering, is essentially waste water from Minna Township. Therefore, household detergents may be the source of the boron in the irrigation water; its values are 1.6, 1.5 and 1.66 mg/l for SUWS, SOWS and SUWS respectively. These values when compare to the guideline (Fig. 2.2)) are within the range of 0.7-3.0 mg/l. Hence there is slight to moderate restriction on the use of the water for irrigation. The absence of Boron in the Chanchaga scheme confirms the result reported by Babangida (2001).

Sodium toxicity is evaluated using SAR. All the values of SAR for the three schemes are < 3.0; hence there is no restriction to the use of the schemes water in terms of Na-toxicity problem.

Also there is no restriction to the use of the three schemes water with respect to chloride-toxicity problem, this is because their values are <4.00mg/l.

Comparing the chloride values of the three schemes, those of Soje are reasonably above those of Chanchaga while those of Gusoro are low. This perhaps is because that of Soje is waste water; hence domestic waste many have been responsible for the high value of the chloride.

### 4.1.4 Calcium, Magnesium and potassium.

Potassium is a plant nutrient necessary for plant morphological development. The concentration of potassium is higher in the Soje irrigation water than is in Chachaga and Gusoro irrigation water. This may be because the Soje water is waste water.

Calcium and Magnesium are nutrient elements for tissue formation. The ratio of Ca: mg in all the three schemes are greater than 1, this according to Ayers and Westcot (1994) would not increase potential effect of sodium. The lower the ratio is less than 1, the more damaging is SAR.

### 4.1.5 Chlorine and Trace Elements

Chlorine is absent in the Gusoro water except GOWS that it appeared though little,0.2mg/l. It is higher in the Soje water than the Chanchaga water. The presence of chlorine in the Soje is due to the domestic waste while that of Chanchaga could be attributed to the activities of Niger State Water Board. The chlorine values for both schemes are within the range of 1.0-5.0 and according to Ayers and Westcot (1994) there should be slight to moderate restriction on the use of such water for irrigation. This however, is applicable to overhead sprinkling only. Therefore, there should be no restriction on its use at Soje and Chanchaga schemes since it is surface irrigation that is being practiced.

Among trace elements, iron, manganese, molybdenum and zinc are essential for plant growth in small quantities.The maximum recommended concentrations of trace element in irrigation water are given in Appendix D.

Manganese is 0.3mg/l and 0.44mg/l in the upstream and downstream respectively of the Soje scheme, which are higher than recommended limit but it is at the limit, 0.2mg/l on the scheme water. It is higher than recommended limit at the Gusoro water while it is lower than the maximum recommended limit in the Chanchaga scheme. Therefore, Chanchaga is safe; Soje has the potential of being at risk while Gusoro is at risk of its toxicity to plants. However this may not really be effective since the soil as we shall see in subsequent section is not too acidic. Copper reduces from 0.4mg/l which is above maximum recommended limit in the upstream of Chanchaga water to the maximum recommended limit of 0.2mg/l in the downstream while it is above maximum recommended limit in both Soje and Gusoro waters. These would be toxic to a number of plants.

All the three schemes are safe for use in terms of iron concentration since their concentrations (table 4.1a, 4.1band4.1c) are far below the maximum recommended limit of 5.0mg/l.

### 4.1.6 Total Hardness and Dissolved Oxygen

The hardness of water is characterized by its ability to form lather with soap. The value of total hardness of Soje ranges from 203mg/l to237mg/l, it is therefore hard, this is probably due to waste therein. Gusoro is softer than Chanchaga.

Dissolve oxygen (DO) essentially is needed for sustainability of the bio-organisms in water. DO is highest at 6.3mg/l in Chanchaga water, it is low as 2.4mg/l in Gusoro and lowest at 1.5mg/l at Soje upstream. This increases to 2.6mg/l in the downstream due to wastewater mingling with fresh Stream Rafisanyi. The lower level of DO in the upstream is due to smell of waste water.

### 4.1.7 Statical Analysis (Analysis of variance, ANOVA)

The concentrations of the parameters vary from upstream to downstream. This is illustrated in Fig.4.1a, 4.1b and 4.1c.

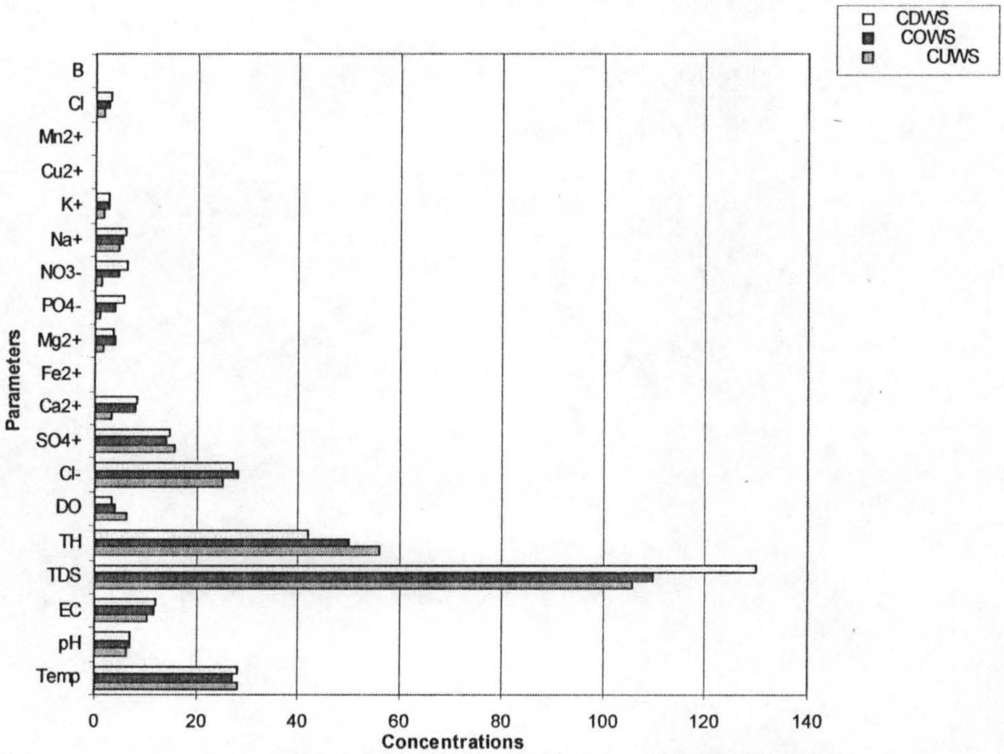



**Fig.4.1a Chart showing the Parameters values for Upsteram, Onscheme and Downstream of Chanchaga**

The charts indicate that total dissolve solid is the only parameter that clearly increases from 106mg/l upstream to 130mg/l in the Chanchaga Scheme. At Gusoro, total dissolve solid only increases from 34mg/l at upstream to 41mg/l on the Scheme and this reduces to 39mg/l downstream. For Soje, total dissolved solid increases from 108mg/l to156mg/l while total hardness increases from 203mg/l to 237mg/l from upstream to downstream.

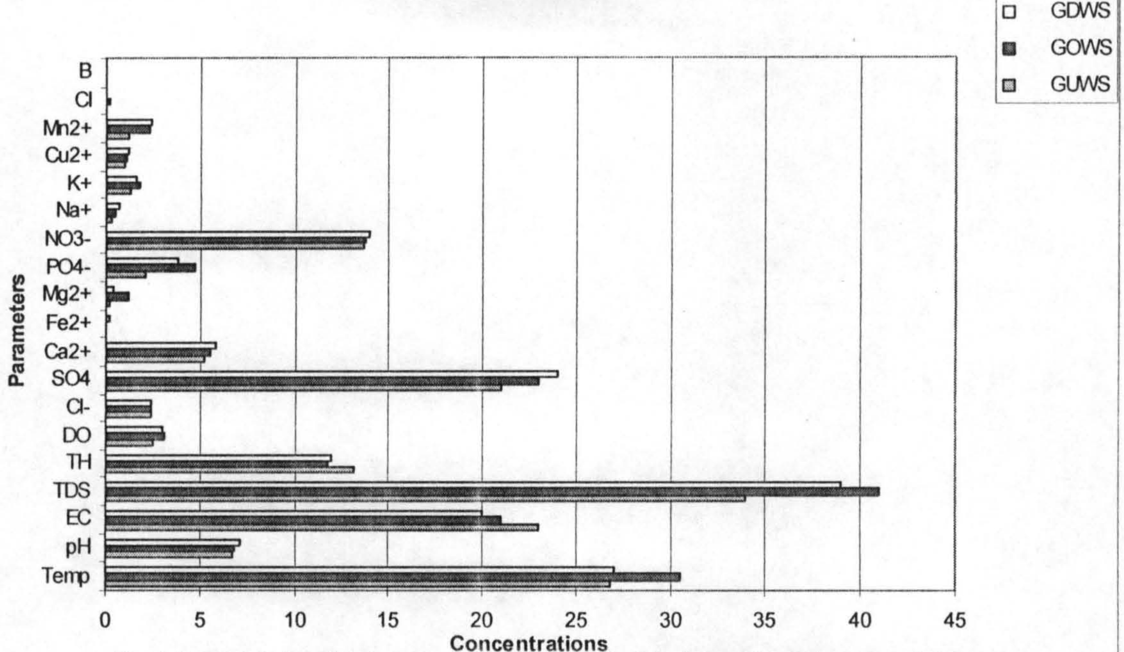



**Fig. 4.1b Chart showing parameters values in the Upstream, Onscheme and down stream of Gusoro**

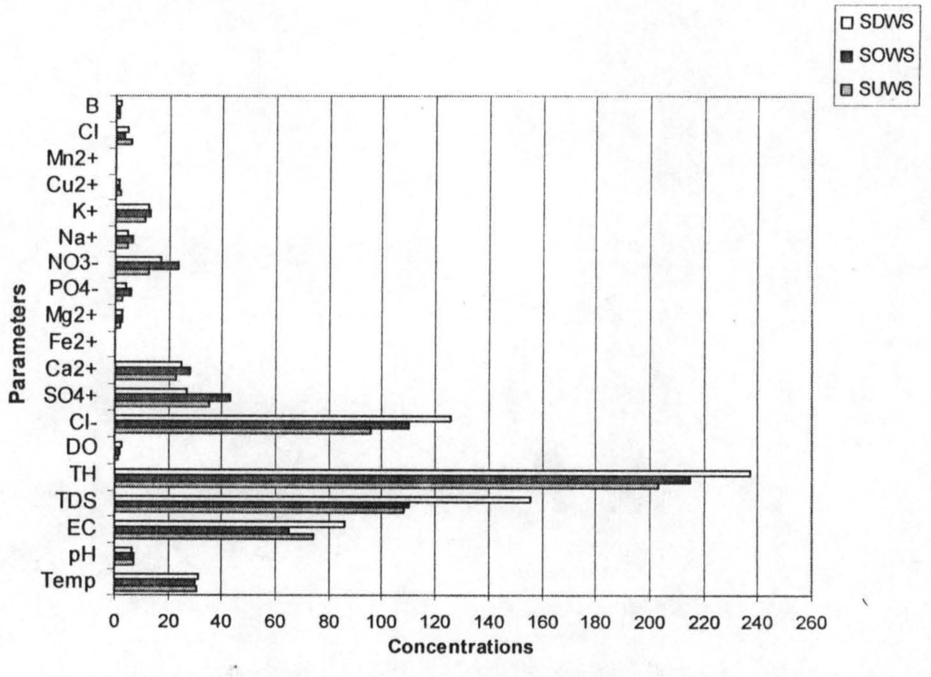



**Fig.4.1cChart showing Parameters Values at UPstream,On shemes, and Downstream of Soje**

These variability of the parameters from upstream to downstream subjected to analysis of variances (Appendix E) show that the observed variability in the values of parameters as shown in the Fig 4.1a, 4.1b and 4.1c are not significantly different at 0.05 (5%) level. The null hypothesis can not be rejected at 0.05 levels and therefore certainly can not be rejected at 0.01 level of significant i.e. all treatments are statistically identical. For Chanchaga Irrigation Scheme, the computed F is 0.01488 and the *p*-value is 0.9852. Thus the smallest pre-set level of significance is equal to 0.9852; therefore the null hypothesis would not be rejected at 0.05 and 0.01.

The *p*-values for Gusoro and Soje are 0.9729 and 0.9401 respectively, which are the smallest pre-set levels of significance. Therefore, the null hypotheses can neither be rejected at 0.05 nor at 0.01 levels of significance.

### 4.1.8 Environmental Impact on Downstream

Since variability along irrigation water course is not significantly different, it can be concluded that there is no significant difference in the concentrations of the parameters due to irrigation. Moreover none of the increased parameter exceeded the standard by WHO in appendix F, there is no environmental pollution impact on the downstream. This seems to suggest that runoff from the irrigated area to the stream or return of drains to the stream has not made tremendous negative impacts on the downstream. This is contrary to the case of Colorado River water whose concentration increased consequent on deep percolation of the concentrated drainage water and return of such waters to surface waters thus causing the increase in downstream salinity (pollution)

## 4.2 Soil Sample Analyses

The results of the soil sample analysis are shown in Table 4.2a, 4.2b and 4.2c for Chanchaga, Gusoro and Soje Irrigation Schemes respectively.

### 4.2.1 Electrical Conducivities (EC) Exchangeable Sodium Percentage and pH

The schemes ECe are all less than 4 mmhos/cm. The calculated ESP in table 4.2a, 4.2b and 4.2c are all less than 15 %. Therefore, neither the surface nor the subsurface could be said to be saline. The soils are non – saline and non – sodic (see table 2.3).The schemes ECe values when compare to the crop tolerance ECe values in Appendix F is expected to give 100% yield. No osmotic problem is expected to be cause by the soil concentrations, because according Smedema & Rycroft (1988), ECe of 0-2mmhos/cm has negligible effect on all crops on Schofield scale.

The soils are fine texture soil as we shall see in subsequent subsection, therefore using ESP limit of 10% for fine texture soil (in accordance with Smadema & Rycroft, 1988) no dispersion problem is anticipated since the ESP of the schemes are less that 10%, therefore water logging resulting from the general deterioration of the drainage characteristic of the soil is not expected

The pH (see table 4,2a, 4.2b and 4.2c) of surface and subsurface of Soje and Gusoro are very slightly acidic. The surface of Chanchaga is very slightly acidic while the subsurface is slightly acidic. These pHs are suitable for most commercial crops since they are within the range of 6.3-7.5 given in the Book Tropical Soil Manual (1991). The pH will not pose the problem of unavailability of nutrients to plants

### 4.2.2 Nitrates and Nitrogen

Nitrates are the main forms of nitrogen use by plants. The nitrates are generally higher in the surface of the schemes than in the subsurface. This perhaps, is due to fertilizer application by the farmers.

The Nitrogens of both surface (2.2%) and subsurface (1.7%) of Soje irrigated area are very high. The surface of Gusoro (1.26%) is very high while the subsurface (0.91%) is also high. The nitrogen of Chanchaga irrigated area is medium (0.39%) for surface while it is

Table 4.2a Characteristics of Chanchaga Soil Samples

| Sample Location | Depth (cm) | pH | ECe | SAR | ESP | Na | K | Ca | Mg | N | $SO_4$ | $PO_4$ | $NO_3$ | Cl | Textural Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CISFS | 0 -15 | 6.80 | 1.70 | 0.066 | -1.18 | 1.08 | 0.63 | 16.35 | 2.30 | 0.39 | 11.65 | 3.20 | 1.10 | 10.09 | Loam |
| CISBS | 15-60 | 6.40 | 3.35 | 0.046 | -1.21 | 0.66 | 0.40 | 12.30 | 1.75 | 0.23 | 3.40 | 2.20 | 1.80 | 7.75 | Clay loam |
| CNISFS | 0 -15 | 7.00 | 1.20 | 0.055 | -1.19 | 0.82 | 0.42 | 14.30 | 1.40 | 0.14 | 11.20 | 1.20 | 0.20 | 5.81 | Clay loam |
| CNISBS | 15-60 | 6.90 | 1.40 | 0.056 | -1.19 | 0.77 | 0.34 | 11.20 | 1.92 | 0.11 | 11.70 | 1.40 | 0.50 | 5.83 | Sandy clay loam |

Table 4.2b Characteristics of Gusoro Soil Samples

| Sample Location | Depth (cm) | pH | ECe | SAR | ESP | Na | K | Ca | Mg | N | $SO_4$ | $PO_4$ | $NO_3$ | Cl | Textural Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GISFS | 0 -15 | 6.8 | 2.25 | 0.05 | -1.19 | 0.79 | 0.76 | 5.00 | 6.32 | 1.26 | 24.00 | 4.80 | 0.92 | 3.80 | Sandy clay |
| GISBS | 15-60 | 6.5 | 2.10 | 0.06 | -1.18 | 0.70 | 0.56 | 6.25 | 2.17 | 0.91 | 2.77 | 5.15 | 0.17 | 1.76 | Clay |
| GNISFS | 0 -15 | 7.2 | 2.70 | 0.08 | -1.16 | 0.62 | 0.51 | 1.28 | 2.16 | 1.06 | 13.70 | 6.30 | 0.22 | 1.66 | Sandy clay |
| GNISBS | 15-60 | 7.0 | 1.80 | 0.06 | -1.19 | 0.45 | 0.22 | 1.52 | 1.74 | 0.69 | 15.60 | 5.80 | 0.11 | 1.53 | Sandy clay |

Table 4. 2c Characteristics of Soje Soil Samples

| Sample Location | Depth (cm) | pH | ECe | SAR | ESP | Na | K | Ca | Mg | N | $SO_4$ | $PO_4$ | $NO_3$ | Cl | Textural Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SISFS | 0 -15 | 6.8 | 7.30 | 0.10 | -1.14 | 2.5 | 0.44 | 41.5 | 5.0 | 2.2 | 88 | 1.6 | 28.0 | 43.3 | Clay |
| SISBS | 15-60 | 6.5 | 6.85 | 0.19 | -0.99 | 5.0 | 0.50 | 31.1 | 13.1 | 1.7 | 73 | 4.3 | 8.3 | 33.9 | Clay |
| SNISFS | 0 -15 | 7.0 | 3.4 | 0.05 | -1.20 | 1.2 | 0.28 | 27.0 | 11.1 | 0.9 | 45 | 3.9 | 13.9 | 12.5 | Clay loam |
| SNISBS | 15-60 | 6.9 | 4.10 | 0.07 | -1.16 | 1.8 | 0.02 | 27.5 | 10.8 | 1.6 | 37 | 2.6 | 12.8 | 12.9 | Silty clay loam |

Table 4.3 Broad Ratings of Nitrogen Measurements

| N Content Kjeldahl Method ( % of soil Weight) | Rating |
|---|---|
| > 1.0 | very high |
| 0.5 -10 | high |
| 6.2 - 0.5 | Medium |
| 0.1 – 0.2 | low |
| < 0.1 | very low |

Source Landon (Ed), 1991

Low (0.23%) for subsurface (table 4.2 shows the rating). Nitrogen rich fertilizer application in Soje and Gusoro should only be if a specific crop so desired

### 4.2.3 Calcium, (Ca) Magnesium (Mg), Potassium (k) and Sodium (Na)

The calcium and magnesium of the surface soil of Soje are 4.15 mg/l and 5mg/l respectively while that of Chanchaga are 16.35mg/l and 2.3mg/l respectively. These gave Ca:Mg ratio greater than 5:1; this by Landon (1991) may make Mg increasingly unavailable to plants with increasingly Ca. This ratio is above the 3:1-4:1 ratio, the approximate optimum range for most crops. Although soils can remain fertile over a very wide range of Ca: Mg ratio.

The Ca: Mg for Gusoro irrigated area is less than 1. This may slightly reduce Ca availability to plants.

The K:Mg ratio in the schemes are less than 1, which is within the recommended range for field crops, vegetables and sugar beet given in the Booker Tropical Soil Manual.

Sodium toxicity to plant is evaluated using the ESP since the ESP is < 15% no Na toxicity problem is expected.

### 4.2.3 Sulphate, Phosphate and Chloride

Surphur is a necessary plant nutrients which is assimilated in sulphate form by plants. The sulphate of the Chanchaga irrigated soil surface is 11.65mg/l which reduced to 3.4mg/l in the subsurface. That of Gusoro is higher at the surface, 24mg/l and reduced to a lower level of 2.77mg/l. The sulphate of Soje is highest. It was 88mg/l at the surface and reduced to 73.1mg/l at the subsurface. The high concentration of Sulphate in the Soje is probably due to the irrigation of the land with wastewater.

The Phosphate of the Soje and Gusoro are higher at the surface soil than the subsurface while that of Chachanga is lower at the surface than at the subsurface.

Excess uptake of $Cl^-$ affects sensitive crops like various kinds of berries, many fruit trees. Some orange and grape spp. Damage may be expected when the $Cl^-$ concentration in the saturation extract exceeds 10meq/L or when the leaves contains >0.3-0.5% $Cl^-$ (dry weight basis),(Smedema and Rycroft, 1988). The results show that $Cl^-$ is 1.22 meq/L at the surface and 0.95meq/l at the subsurface of Soje irrigated soil, is less than that 0.11meq/L at surface and subsurface of Gusoro irrigated soil and ≤ 0.22 meq/L at the surface and subsurface of the Chanchaga irrigated soil. Therefore, the schemes soils are free from chloride toxicity.

### 4.2.5 Textural Class

The classes for the soil samples are shown in table 4.2a, 4.2b, and 4.2c.The surface and subsurface of the Soje irrigated soil are clay. Clay soil has capacity of retaining water after irrigation and rainfall because of its micro pores. This is of no concern since the irrigation water is not saline.

The surface of Gusoro irrigated area is sandy clay while the subsurface is clay and according to Foth (1990), for clays (sandy clay, clay, and silty clay), the properties and use of the soil are influenced mainly by the high clay content.

The surface and subsurface of Chanchaga irrigated soil are loam and clay loam respectively. According to Foth (1990), a soil containing equal amounts 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.

### 4.2.6 Variability between Surface and Sub surface soils

The charts in fig. 4.2c, 4.2f and 4.2i for irrigated surface and subsurface soils of Chanchaga, Gusoro and Soje respectively show that there is disparity between surface and subsurface soils. However, it does not follow specific order. For Chanchaga irrigated soils (fig. 4.2c), while nitrogen, sodium potassium calcium, magnesium, sulphate decrease with depth, only nitrate and electrical conductivity increase with depth. For Gusoro (fig. 4.2f), only calcium and phosphate increase with depth, others decrease with depth. The higher concentration of salts in the surface is perhaps due to evaporation of irrigated water leaving the salt components on the soil surface. Sodium, potassium, magnesium and phosphate increase with depth while nitrogen, calcium, sulphate, chloride and nitrate decrease with depth in Soje irrigated soils.

It can therefore be concluded that salts varies spatially within the soil profile. This perhaps is due to soil water movement within the soil profile; it carries the salt along as it moves through the soil and due evaporation the concentrations of some salts are higher in the surface soils.

### 4.2.7 Comparisms of Irrigated and Non irrigated Soil

Comparisms of the salts parameters of irrigated and non irrigated soils are depicted using line charts in figures 4.2. Those of Chanchaga scheme show that the concentration of salts is relatively higher in the irrigated surface area than the non irrigated surface area, (fig. 4.2b). This is due to gradual build of salt on the irrigated soil courtesy of the irrigation water. Adequate leaching by rainfall and irrigation water application may explain why the build up is not too much to adversely affect plants. However there is gradual salinization (pollution) of the irrigated soil. This is one of the negative impacts of the water (irrigation) on the soil (environment) Also; the subsurface salts of the irrigated soil are relatively higher except for sulphate that is higher in the non-irrigated subsurface, (fig.4.2a).

For Gusoro, the salts in the surface of the irrigated soils are relatively higher except phosphate that is higher in the non irrigated surface, (fig.4.2d). Also, the salts relatively higher in the irrigated subsurface but sulphates and phosphates are higher in the subsurface of the non irrigated soil,(fig.4.2e). Perhaps, salinity of the soils is primary (i.e.

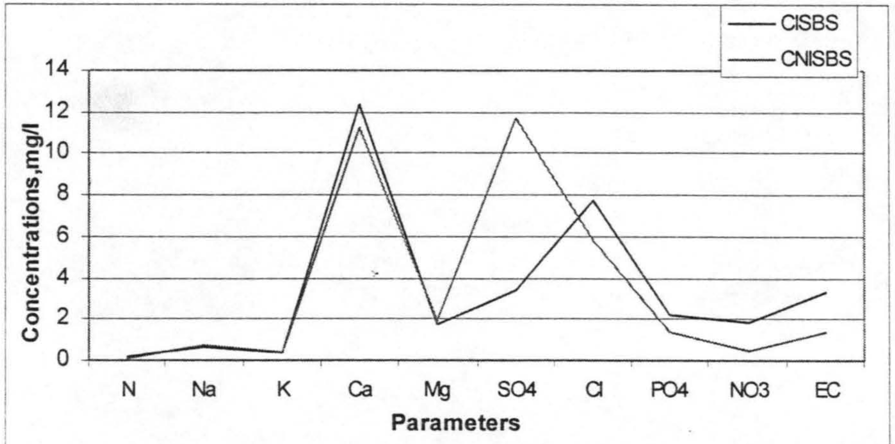


fig.4.2aChanchaga irrigated and Nonirrigated Subsurface soils

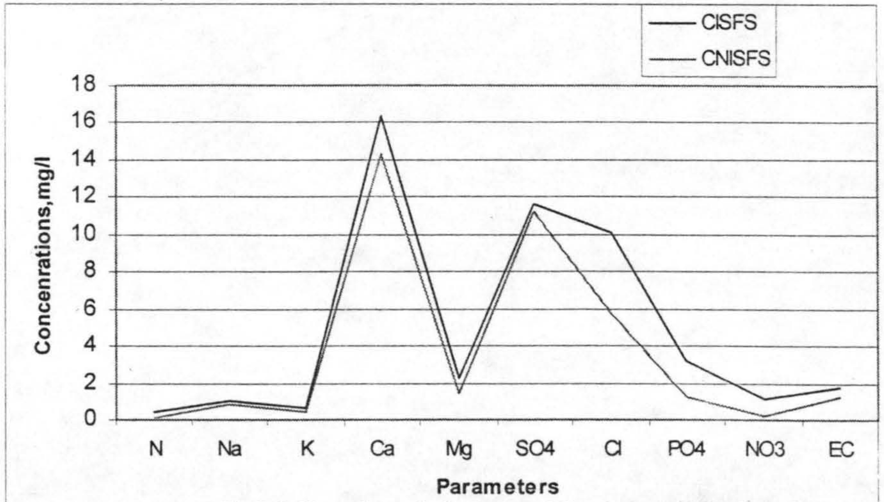


Fig4.2bChanchaga Irrigated and Non irrigated Surface Soils

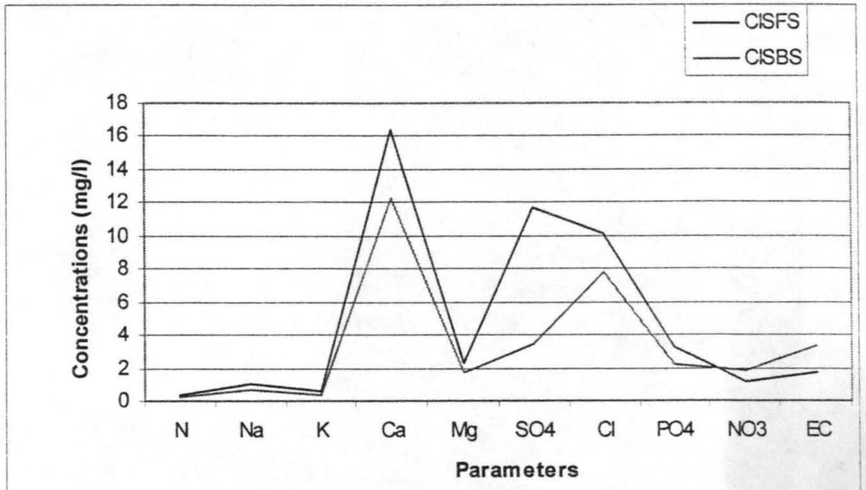


Fig4.2cChanchaga irrgated Surface and Subsurface Soils

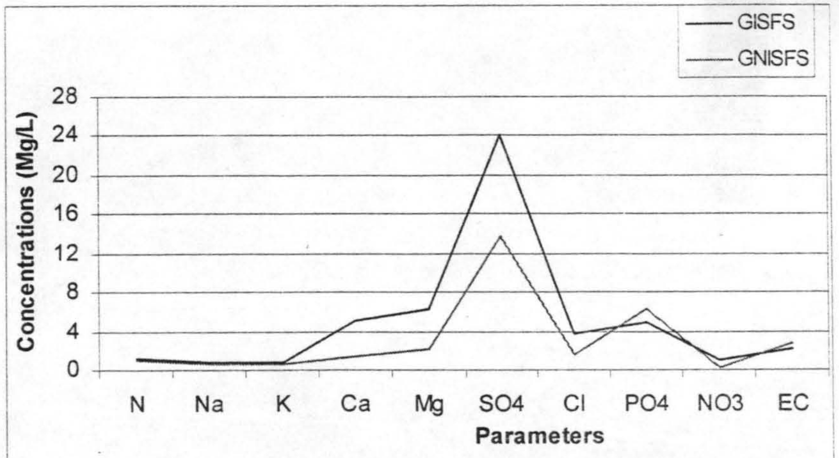


Fig.4.2d Gusoro irrigated and Non irrigated Surface Soils

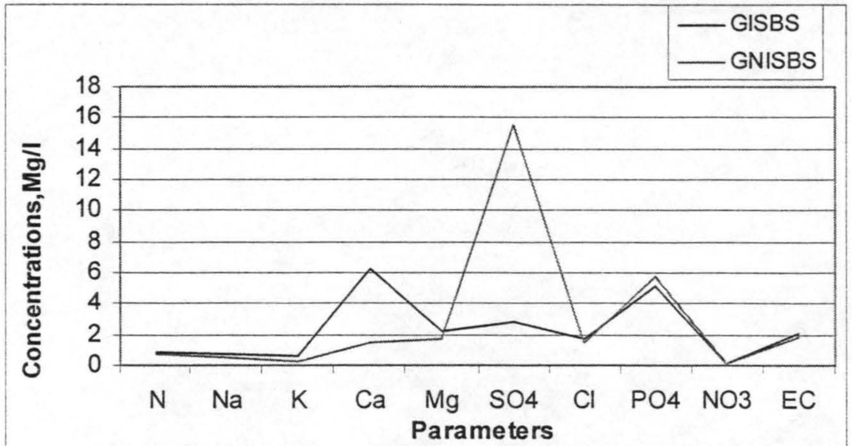


Fig.4.2e Gusoro irrigated and Non irrigated Sub surface Soils

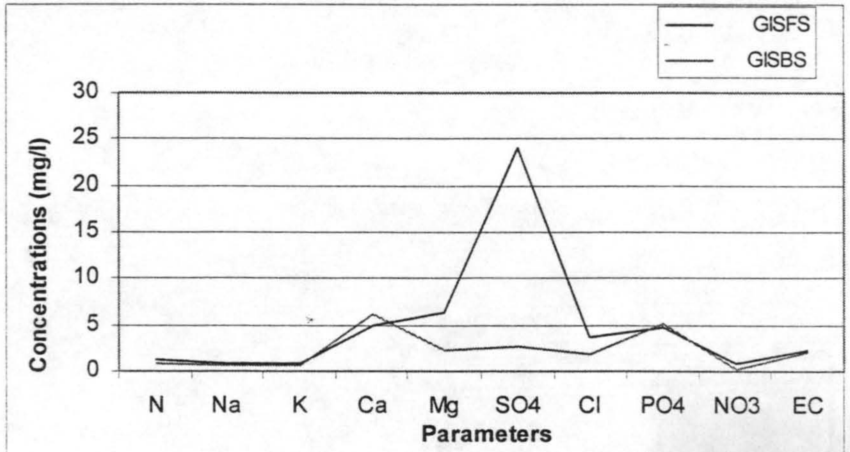


Fig4.2f Gusoro irrigated Surface and Subsurface Soils

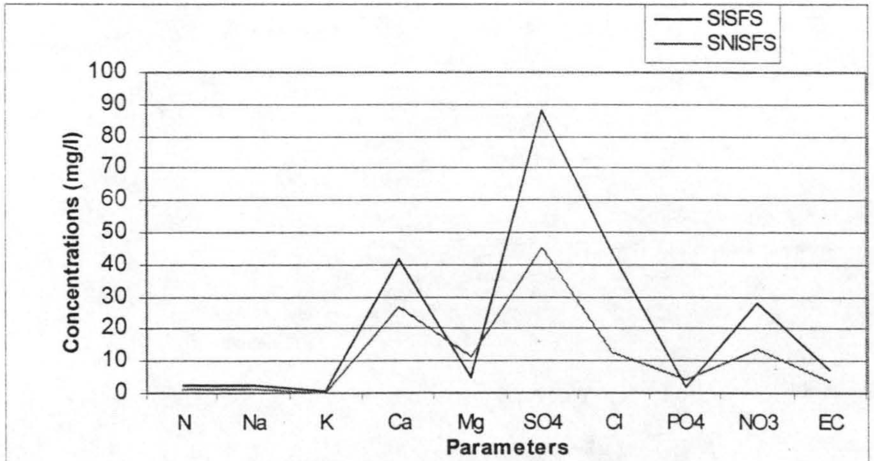


Fig.4.2g Soje Irrigated and Non irrigated Surface Soils

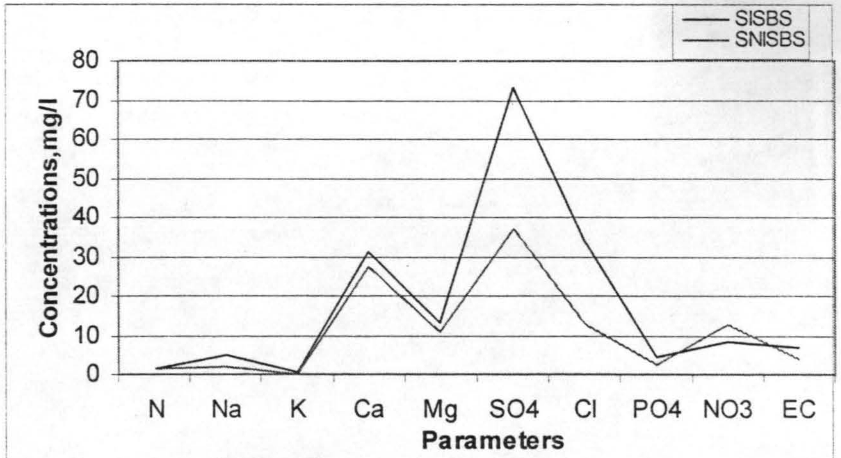


Fig.4.2h Soje irrigated and non irrigated subsurface soils

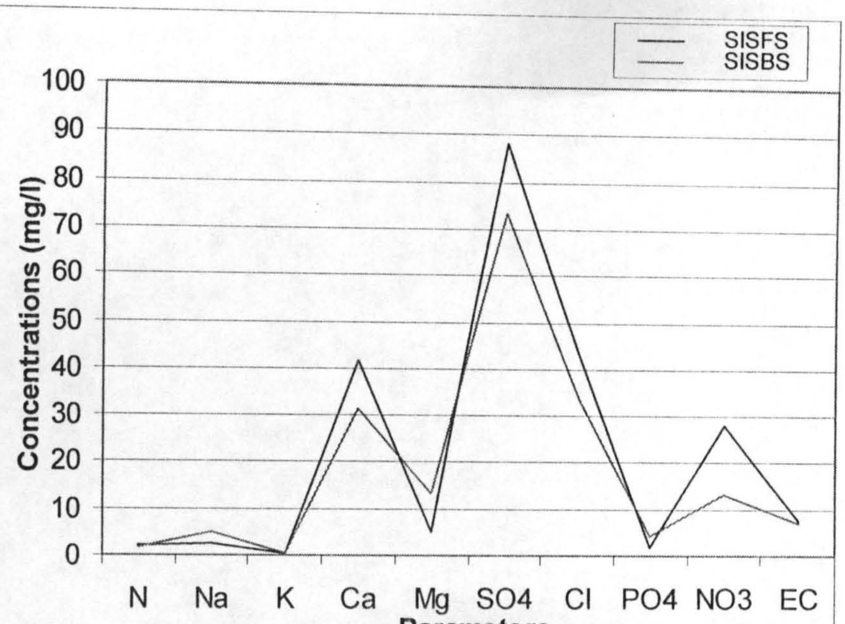


**Fig.4.2i Soje irrigated Surface and Subsurface Soils**

Note : all parametes are in mg/l except EC which is in μmhos/cm

salinity from parent materials) and due to irrigation the salts in the irrigated soil slightly increased while low salinity of the irrigation water may have diluted the sulphate and phosphate irrigated soils. Similarly, in Soje, the salts of the irrigated surface are relatively higher, with the exception of magnesium and phosphate that are higher in the non irrigated soils, (fig.4.2g). And likewise, with the exception of nitrate, the salts in the irrigated subsurface soil are relatively higher, (fig. 4.2h).

**4.2.7.1 Correlation Coefficients, R and coefficient of Determination $R^2$**

Table 4.4 shows the correlation coefficients of the irrigated and non irrigated soil.

CISFS and CNISFS has a very high, positive linear correlation of 0.9774 while that of CISBS and CNISBS is 0.7544, which is also a good, positive linear association. Thus, both surface and subsurface of Chanchaga irrigated and non irrigated soils have good, positive linear correlation. This implies that they vary linearly in the same way.

Similarly, GISFS and GNISFS have a good correlation of 0.9352 whilst that of GISBS and GNISBS is 0.3205, which is a poor, positive linear relationship. Thus, while the surfaces of Gusoro irrigated and non irrigated soils have a good association, the sub surfaces have a poor, positive linear relationship, which implies that GISBS and GNISBS do not vary in the same way. SISFS & SNISFS and SISBS & SNISBS have high positive, linear correlation coefficients of 0.9461 and 0.9221 respectively. Thus both the surfaces and sub surfaces of Soje have good, positive linear relationship.

Table 4.4 Correlation Coefficients, R, of the Irrigated and Non-irrigated Soils.

| | CNISFS | CNISBS | GNISFS | GNISBS | SNISFS | SNISBS |
|---|---|---|---|---|---|---|
| CISFS | 0.9774 | – | – | – | – | – |
| CISBS | – | 0.7544 | – | – | – | – |
| GISFS | – | – | 0.9352 | – | – | – |
| GISBS | – | – | – | 0.3205 | – | – |
| SISFS | – | – | – | – | 0.9461 | – |
| SISBS | – | – | – | – | – | 0.9221 |

The scattered diagrams of the irrigated and non irrigated soils are shown in figures 4.3. The coefficient of determination, $R^2$ for CISFS and CNISFS is 0.9553. Thus 95.53% of the total variation is explained by the regression equation, $y = 1.0883x + 0.8547$ i.e. 95.53 % of the total variation in Chanchaga irrigated surface soils is explained in terms of the variable of the non irrigated surface soil. Likewise, for the subsurface soils (CISBS and CNISBS), $R^2$ is 0.5691 while the regression equation is $y = 0.6426x + 1.1231$, (fig.4.3a and fig.4.3b).

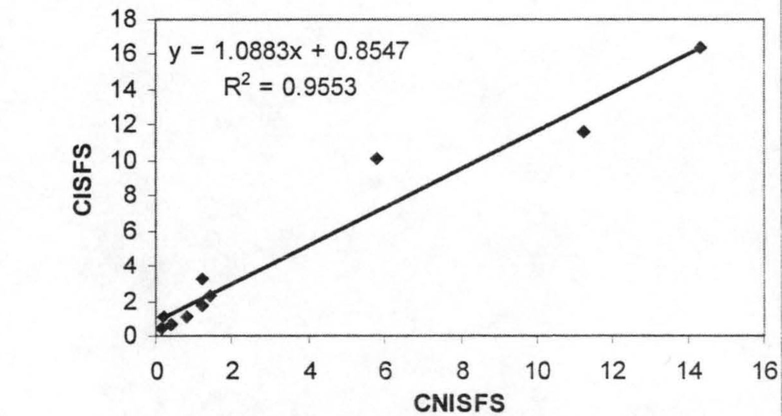


Fig4.3a Scatter Diagram showing the Correlation of Chanchaga Irrigated and Non irrigated Surface Soils

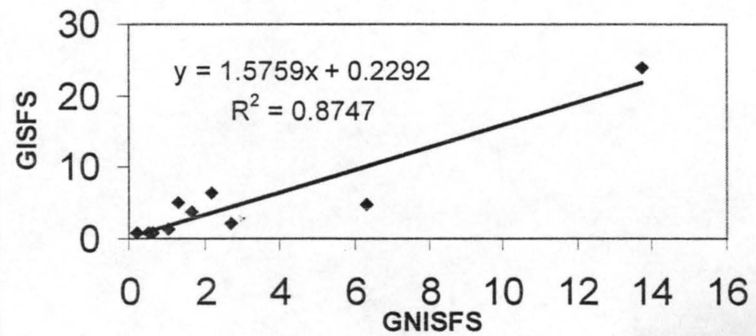


Fig.4.3c Scatter Diagram showing the Correlation of Gusoro Irrigated and Non irrigated Surface Soils

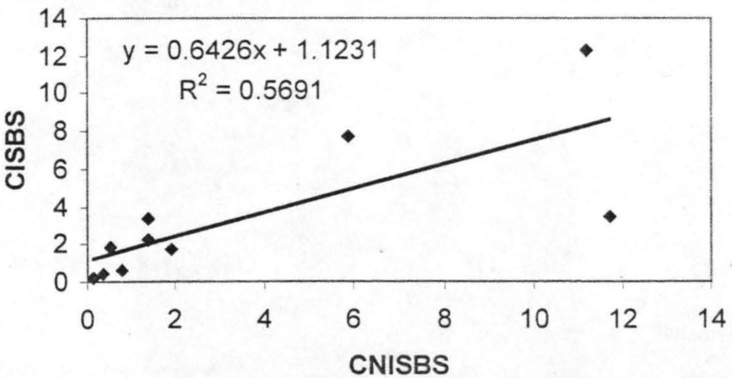


Fig.4.3b Scatter Diagram showing the Correlation of Chanchaga Irrigated and Non irrigated Subsurface Soils

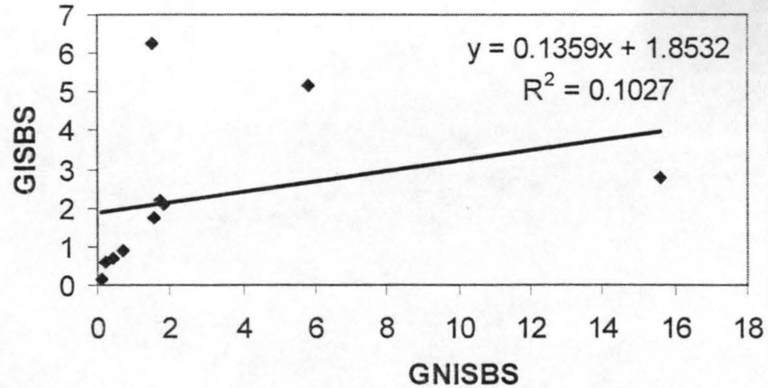


Fig.4.3d Scatter Diagram showing the correlation of Gusoro Irrigated and Non irrigated Subsurface Soils

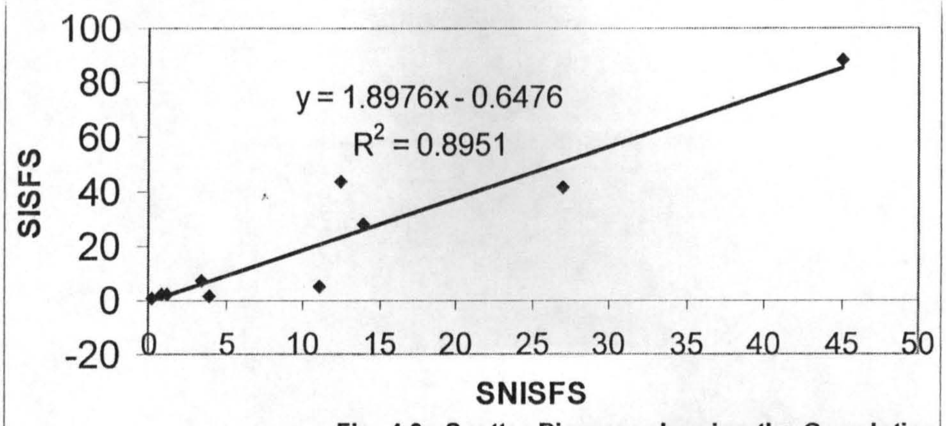



**Fig 4.3e Scatter Diagram showing the Correlation of Soje Irrigated and Non irrigatd Surface Soils**

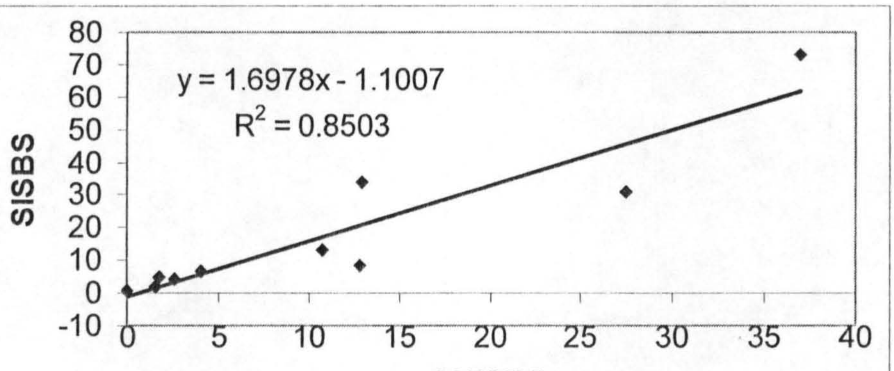



**Fig.4.3fScatter Diagram showing the Correlation of Soje Irrigated and Non irrigated Subsurface Soils**

Similarly, $R^2$ for GISFS and GNISFS is 0.8747 while the regression equation is $y = 1.5759x + 0.2292$ . Thus, 87.47% of the total variation in the Gusoro irrigated surface soil is explained in terms of the variable of the non irrigated surface soil by the regression equation. For the subsurface soils (GISBS and GNISBS), $R^2$ is 0.1027 while the regression equation is $y = 0.1359x + 1.8532$, (fig.4.3c and fig.4.3d). Only 10.27% of the total variation is explained, therefore, there is virtually no linear correlation, thus the linear regression is not a good fit for the relationship between GISBS and GNISBS.

$R^2$ for SISFS and SNISFS is 0.8951 with the regression equation, $y = 1.8976x - 0.6476$ thus 89.51% of the variation is explained by the equation. While $R^2$ for SISBS and SNISBS is 0.8503 with the regression equation $y = 1.6978x - 1.007$, this implies that 85.03% of the variation is explained by the regression fit.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

Irrigation water quality, irrigated and non irrigated soils of Chanchaga, Gusoro and Soje Irrigation Schemes of Niger State, Nigeria were analyzed. The results were compared to guidelines for interpretation of water quality and relevant literatures. Statistical analyses focused on the variability of the water quality along the stream course and correlation of salts concentration between irrigated and non irrigated soils. Variability between salts concentrations of irrigated and non irrigated soils and between irrigated surface and subsurface soils were observed with the aid of chart. These led to the following conclusions:

A. The irrigation water for the schemes

I. Pose no salinity hazard

II. Pose no specific ion toxicity of sodium, chlorine and boron problems

III. Has no salinity environmental pollution downstream

IV. Has potential infiltration problem (sodicity hazard) owing to low salinities of $< 0.2$dS/m with low SAR values of $\leq 0.53$

B. The schemes irrigated soils

I. Are non saline and non sodic

II. Salinities vary spatially from the surface (0-15cm) to the subsurface (15-60cm) in the wet season in which this study took place.

III. Salts vary spatially within the soil profile. This perhaps is due to soil water movement within the soil profile; it carries the salts along as it moves through the soil and due evaporation the concentrations of some salts are higher in the surface soils.

IV. Salts in the irrigated areas are relatively higher except in cases where phosphate and sulphate are higher in the Gusoro non irrigated subsurface soil while phosphate is higher in the surface of the non irrigated soil, nitrate is higher in the non irrigated subsurface of Soje while magnesium is higher in the non irrigated soils of Soje.

## 5.2 Observations

During the study the following observations were made on the schemes

a. A very small area of the total land area is been irrigated

b. The drainage system of Gusoro and Chanchaga Irrigation system have broken down.

c. The Soje Irrigation Scheme was not designed

## 5.3 Recommendations

Appropriate design of the Soje irrigation scheme should be carried out and relevant agency should coordinate the scheme to avoid improper irrigation and proper maintenance the scheme. The Chanchaga and Gusoro scheme should be revitalized so that more of the land could be put into cultivation to enhance more food production.

Regular check of the irrigation water and soil pH should be carried out as any abnormality in the pH calls for further investigation of the scheme.

Further investigation of the impact of the irrigation on the environment should be carried focusing on possible contamination of the ground water, rise in water table and health hazards.

The potential infiltration problem can be avoided by the application of gypsum either to the irrigation water or on the irrigated land. This would raise the salinity to counter the effect of the corrosiveness of the rather too low water salinity. It is more economical to apply the gypsums to the soil.

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APPENDIX A: CLIMATOLOGICAL DATA

TABLE A1: Total Monthly Rainfall (mm) (1998 – 2006)

| YEAR | JAN | FEB | MARCH | APPRIL | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1998** | 0.0 | 0.0 | 0.0 | 0.0 | 121.2 | 221.0 | 155.1 | 243.0 | 201.9 | 212.6 | 0.0 | 0.0 |
| **1999** | 0.0 | 0.0 | 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 | 203.0 | 123.0 | 191.6 | 188.2 | 192.4 | 2.3 | 0.0 |
| **2004** | 0.0 | 0.0 | 0.0 | 32.2 | 151.4 | 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 | | | | | |
| TOTAL | 11.2 | 5.7 | 5.7 | 360.6 | 1089.5 | 1791.5 | 1852.8 | 1977.4 | 2151 | 1264 | 8.4 | 0.00 |
| MEAN | 1.12 | 0.57 | 0.57 | 36.06 | 108.95 | 179.15 | 185.28 | 197.74 | 215.1 | 126.4 | 0.84 | 0.00 |

TableA2: Mean Monthly Temperature (°C)

| YEAR | JAN | FEB | MARCH | APPRIL | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1998** | 34.7 | 38.8 | 38.5 | 38.4 | 33.7 | 31.4 | 29.5 | 28.6 | 29.9 | 31.9 | 36.3 | 35.5 |
| **1999** | 35.4 | 37.0 | 38.3 | 37.0 | 34.2 | 31.4 | 29.1 | 28.6 | 29.5 | 31.3 | 35.7 | 34.4 |
| **2000** | 35.7 | 34.5 | 38.1 | 37.3 | 35.1 | 30.6 | 29.2 | 28.9 | 30.2 | 31.5 | 35.4 | 34.8 |
| **2001** | 34.8 | 36.1 | 38.9 | 36.3 | 33.7 | 30.9 | 29.2 | 28.3 | 29.5 | 33.0 | 36.0 | 36.4 |
| **2002** | 33.5 | 37.0 | 38.6 | 35.8 | 35.7 | 32.0 | 29.9 | 29.4 | 29.8 | 31.3 | 34.7 | 34.9 |
| **2003** | 35.3 | 38.2 | 39.0 | 37.0 | 35.7 | 30.7 | 29.8 | 29.5 | 29.7 | 32.2 | 35.4 | 35.0 |
| **2004** | 35.1 | 37.0 | 38.4 | 37.0 | 33.1 | 31.0 | 29.8 | 27.8 | 30.3 | 31.7 | 34.2 | 35.0 |
| **2005** | 33.7 | 38.3 | 39.4 | 37.6 | 33.7 | 31.4 | 29.4 | 28.8 | 30.5 | 31.5 | 35.1 | 35.0 |
| **2006** | 35.7 | 37.5 | 37.6 | 38.4 | 32.0 | 31.5 | 30.1 | | | | | |
| TOTAL | 313.9 | 334.4 | 346.8 | 334.8 | 342.6 | 280.9 | 266 | 260.1 | 270.2 | 286.1 | 317.7 | 316 |
| MEAN | 31.39 | 33.44 | 34.68 | 33.48 | 34.26 | 28.09 | 26.60 | 26.01 | 27.02 | 28.61 | 31.77 | 31.60 |

Source: Meteorological Station, Minna Airport.

APPENDIX B: MAPS OF PROJECTS AREAS

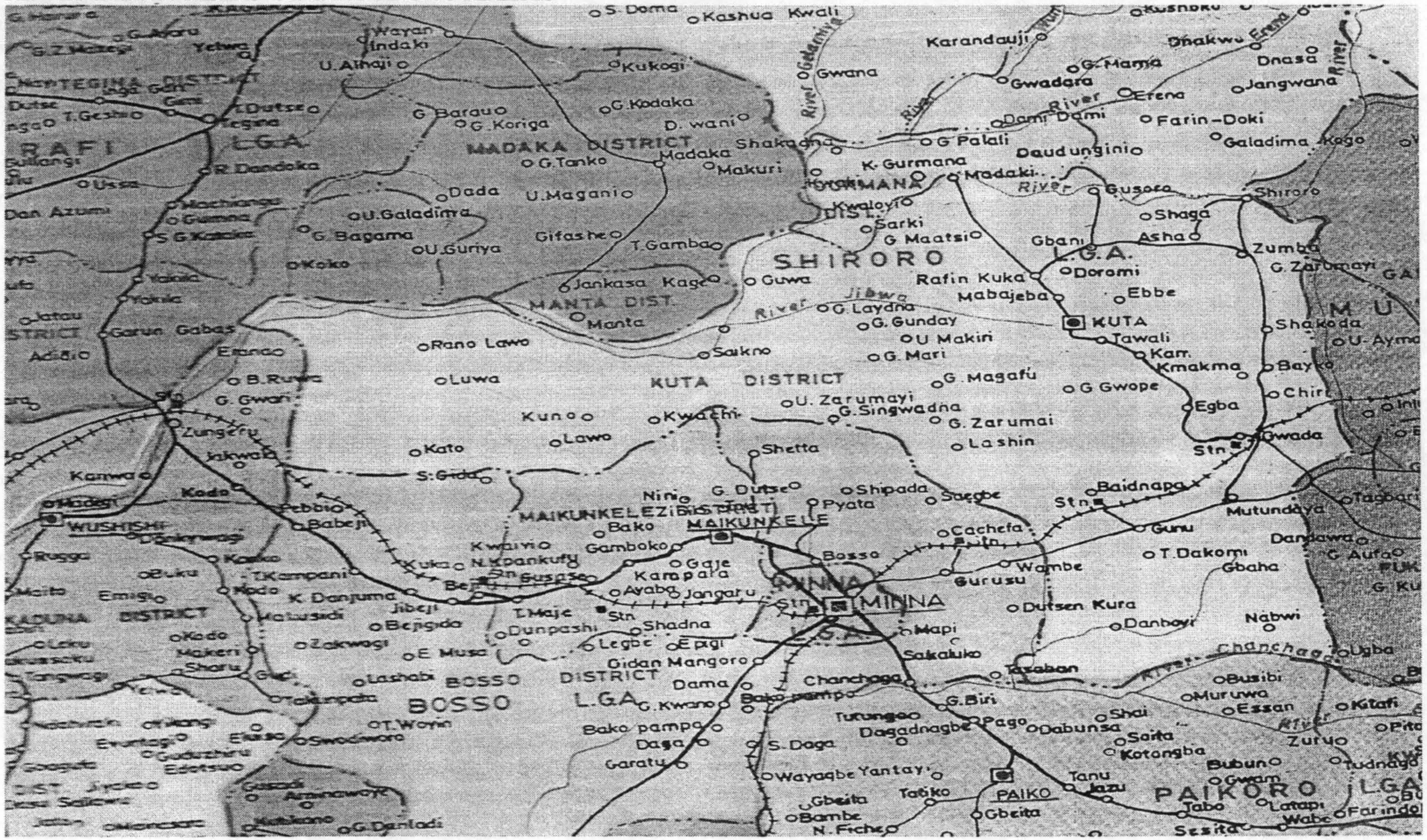


FIG. B1: AN EXTRACTED MAP OF NIGER STATE SHOWING PROJECTS LOCATIONS

Source: NSMW

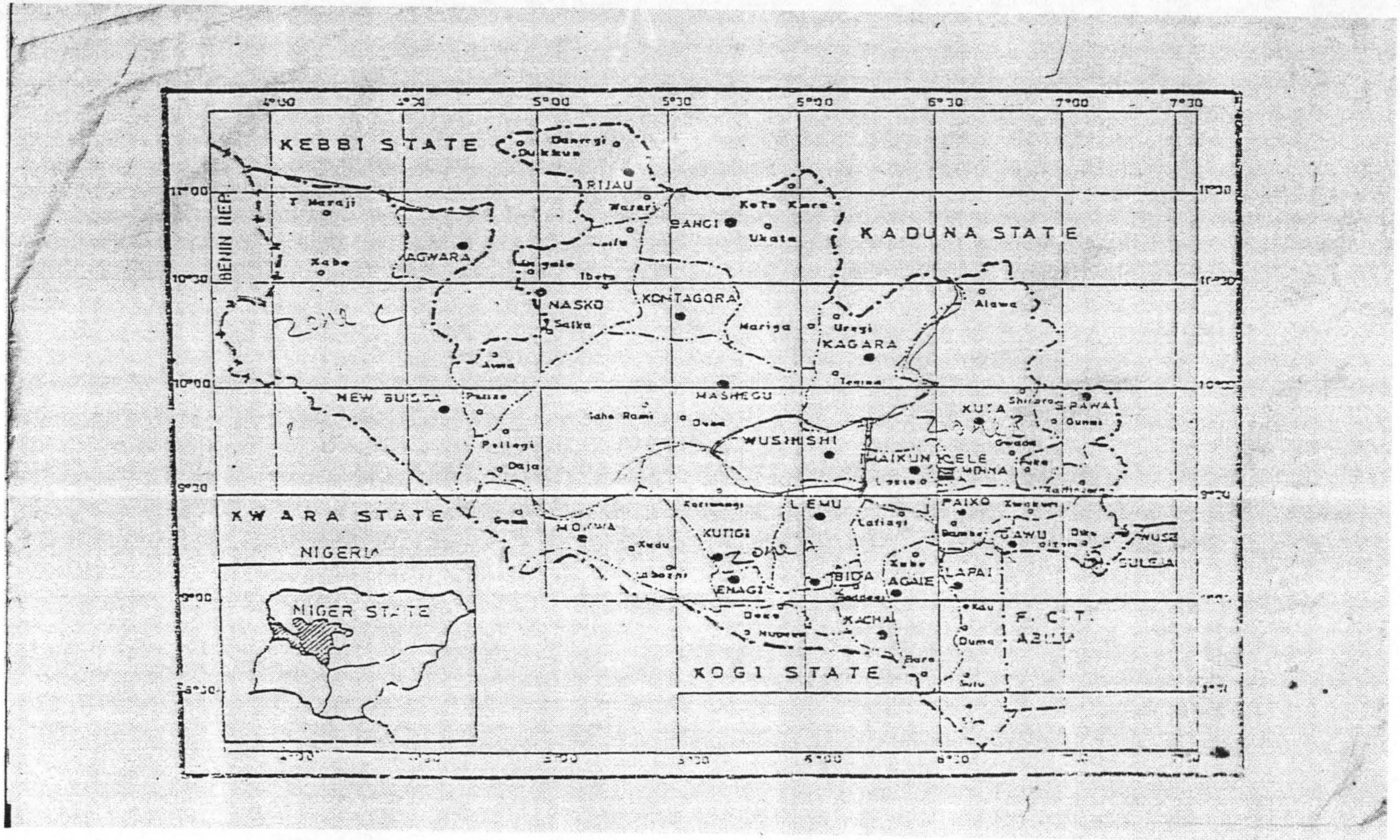


**FIG.B3: A MAP SHOWING THE LOCATION OF NIGER SATE IN NIGERIA**

SOURE:NSMW

## APPENDIX C: RELATIVE SALTS TOLERANCE OF AGRICULTURAL CROPS

| | |
|---|---|
| **TOLERANT** | |
| Fibre, Seed and Sugar Crops | |
| Barley | *Hordeum vulgare* |
| Cotton | *Gossypium hirsutum* |
| Jojoba | *Simmondsia chinensis* |
| Sugarbeet | *Beta vulgaris* |
| Grasses and Forage Crops | |
| Alkali grass, Nuttall | *Puccinellia airoides* |
| Alkali sacaton | *Sporobolus airoides* |
| Bermuda grass | *Cynodon dactylon* |
| Kallar grass | *Diplachne fusca* |
| Saltgrass, desert | *Distichlis stricta* |
| Wheatgrass, fairway crested | *Agropyron cristatum* |
| Wheatgrass, tall | *Agropyron elongatum* |
| Wildrye, Altai | *Elymus angustus* |
| Wildrye, Russian | *Elymus junceus* |
| Vegetable Crops | |
| Asparagus | *Asparagus officinalis* |
| Fruit and Nut Crops | |
| Date palm | *Phoenix dactylifera* |
| | |
| **MODERATELY TOLERANT** | |
| Fibre, Seed and Sugar Crops | |
| Cowpea | *Vigna unguiculata* |
| Oats | *Avena sativa* |
| Rye | *Secale cereale* |
| Safflower | *Carthamus tinctorius* |
| Sorghum | *Sorghum bicolor* |
| Soybean | *Glycine max* |
| Triticale | *X Triticosecale* |
| Wheat | *Triticum aestivum* |
| Wheat, Durum | *Triticum turgidum* |
| Grasses and Forage Crops | |
| Barley (forage) | *Hordeum vulgare* |
| Brome, mountain | *Bromus marginatus* |
| Canary grass, reed | *Phalaris arundinacea* |
| Clover, Hubam | *Melilotus alba* |
| Clover, sweet | *Melilotus* |
| Fescue, meadow | *Festuca pratensis* |
| Fescue, tall | *Festuca elatior* |
| Harding grass | *Phalaris tuberosa* |
| Panic grass, blue | *Panicum antidotale* |
| Rape | *Brassica napus* |
| Rescue grass | *Bromus unioloides* |
| Rhodes grass | *Chloris gayana* |
| Ryegrass, Italian | *Lolium italicum multiflorum* |
| Ryegrass, perennial | *Lolium perenne* |
| Sudan grass | *Sorghum sudanense* |
| Trefoil, narrowleaf | *Lotus corniculatus* |
| Birdsfoot | *tenuifolium* |
| Trefoil, broadleaf | *Lotus corniculatus* |
| Birdsfoot | *arvenis* |
| Wheat (forage) | *Triticum aestivum* |

APPENDIX C: Cont'd

| | |
|---|---|
| standard crested | |
| Wheatgrass, intermediate | *Agropyron intermedium* |
| Wheatgrass, slender | *Agropyron trachycaulum* |
| Wheatgrass, western | *Agropyron smithii* |
| Wildrye, beardless | *Elymus triticoides* |
| Wildrye, Canadian | *Elymus canadeneis* |
| Vegetable Crops | |
| Artichoke | *Helianthus tuberosus* |
| Beet, red | *Beta vulgaris* |
| Squash, zucchini | *Cucurbita pepo melopepo* |
| Fruit and Nut Crops | |
| Fig | *Ficus carica* |
| Jujube | *Ziziphus jujuba* |
| Olive | *Olea europaea* |
| Papaya | *Carica papaya* |
| Pineapple | *Ananas comosus* |
| Pomegranate | *Punica granatum* |
| **MODERATELY SENSITIVE** | |
| Fibre, Seed and Sugar Crops | |
| Broadbean | *Vicia faba* |
| Castorbean | *Ricinus communis* |
| Maize | *Zea mays* |
| Flax | *Linum usitatissimum* |
| Millet, foxtail | *Setaria italica* |
| Groundnut/Peanut | *Arachis hypogaea* |
| Rice, paddy | *Oryza sativa* |
| Sugarcane | *Saccharum officinarum* |
| Sunflower | *Helianthus annuus* |
| Grasses and Forage Crops | |
| Alfalfa | *Medicago sativa* |
| Bentgrass | *Agrostis stolonifera palustris* |
| Bluestem, Angleton | *Dichanthium aristatum* |
| Brome, smooth | *Bromus inermis* |
| Buffelgrass | *Cenchrus ciliaris* |
| Burnet | *Poterium sanguisorba* |
| Clover, alsike | *Trifolium hydridum* |
| Clover, Berseem | *Trifolium alexandrinum* |
| Clover, ladino | *Trifolium repens* |
| Clover, red | *Trifolium pratense* |
| Clover, strawberry | *Trifolium fragiferum* |
| Clover, white Dutch | *Trifolium repens* |
| Corn (forage) (maize) | *Zea mays* |
| Cowpea (forage) | *Vigna unguiculata* |
| Dallis grass | *Paspalum dilatatum* |
| Foxtail, meadow | *Alopecurus pratensis* |
| Grama, blue | *Bouteloua gracilis* |
| Lovegrass | *Eragrostis sp.* |
| Milkvetch, Cicer | *Astragalus cicer* |
| Oatgrass, tall | *Arrhenatherum Danthonia,* |
| Oats (forage) | *Avena sativa* |
| Orchard grass | *Dactylis glomerata* |
| Rye (forage) | *Secale cereale* |
| Sesbania | *Sesbania exaltata* |

APPENDIX C: Cont'd

| | |
|---|---|
| Sphaerophysa | *Sphaerophysa salsula* |
| Timothy | *Phleum pretense* |
| Trefoil, big | *Lotus uliginosus* |
| Vetch, common | *Vicia angustifolia* |
| <u>Vegetable Crops</u> | |
| Broccoli | *Brassica oleracea botrytis* |
| Brussels sprouts | *B. oleracea gemmifera* |
| Cabbage | *B. oleracea capitata* |
| Cauliflower | *B. oleracea botrytis* |
| Celery | *Apium graveolens* |
| Corn, sweet | *Zea mays* |
| Cucumber | *Cucumis sativus* |
| Eggplant | *Solanum melongena esculentum* |
| Kale | *Brassica oleracea acephala* |
| Kohlrabi | *B. oleracea gongylode* |
| Lettuce | *Latuca sativa* |
| Muskmelon | *Cucumis melo* |
| Pepper | *Capsicum annuum* |
| Potato | *Solanum tuberosum* |
| Pumpkin | *Cucurbita peop pepo* |
| Radish | *Raphanus sativus* |
| Spinach | *Spinacia oleracea* |
| Squash, scallop | *Cucurbita pepo melopepo* |
| Sweet potato | *Ipomoea batatas* |
| Tomato | *Lycopersicon lycopersicum* |
| Turnip | *Brassica rapa* |
| Watermelon | *Citrullus lanatus* |
| <u>Fruit and Nut Crops</u> | |
| Grape | *Vitis sp.* |
| **SENSITIVE** | |
| <u>Fibre, Seed and Sugar Crops</u> | |
| Bean | *Phaseolus vulgaris* |
| Guayule | *Parthenium argentatum* |
| Sesame | *Sesamum indicum* |
| <u>Vegetable Crops</u> | |
| Bean | *Phaseolus vulgaris* |
| Carrot | *Daucus carota* |
| Okra | *Abelmoschus esculentus* |
| Onion | *Allium cepa* |
| Parsnip | *Pastinaca sativa* |
| <u>Fruit and Nut Crops</u> | |
| Almond | *Prunus dulcis* |
| Apple | *Malus sylvestris* |
| Apricot | *Prunus armeniaca* |
| Avocado | *Persea americana* |
| Blackberry | *Rubus sp.* |
| Boysenberry | *Rubus ursinus* |
| Cherimoya | *Annona cherimola* |
| Cherry, sweet | *Prunus avium* |
| Cherry, sand | *Prunus besseyi* |
| Currant | *Ribes sp.* |
| Gooseberry | *Ribes sp.* |
| Grapefruit | *Citrus paradisi* |

APPENDIX C: Cont'd

| | |
|---|---|
| Lime | *Citrus aurantiifolia* |
| Loquat | *Eriobotrya japonica* |
| Mango | *Mangifera indica* |
| Orange | *Citrus sinensis* |
| Passion fruit | *Passiflora edulis* |
| Peach | *Prunus persica* |
| Pear | *Pyrus communis* |
| Persimmon | *Diospyros virginiana* |
| Plum: Prume | *Prunus domestica* |
| Pummelo | *Citrus maxima* |
| Raspberry | *Rubus idaeus* |
| Rose apple | *Syzygium jambos* |
| Sapote, white | *Casimiroa edulis* |
| Strawberry | *Fragaria sp.* |
| Tangerine | *Citrus reticulata* |

SOURCE: Ayers and Westcot, 1994

[1] These data serve only as a guide to the relative tolerance among crops. Absolute tolerances vary with climate, soil conditions and cultural practices.

## APPENDIX D: RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATER

| Element | Recommended Concentration (mg/l) | Maximum | Remarks |
|---|---|---|---|
| Al(aluminium) | 5.0 | | Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity. |
| As (arsenic) | 0.10 | | Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice. |
| Be (beryllium) | 0.10 | | Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans. |
| Cd (cadmium) | 0.01 | | Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans. |
| Co (cobalt) | 0.05 | | Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils. |
| Cr (chromium) | 0.10 | | Not generally recognized as an essential growth element. Con-servative limits recommended due to lack of knowledge on its toxicity to plants. |
| Cu (copper) | 0.20 | | Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions. |
| F (fluoride) | 1.0 | | Inactivated by neutral and alkaline soils. |
| Fe (iron) | 5.0 | | Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings. |
| Li (lithium) | 2.5 | | Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron. |
| Mn (manganese) | 0.20 | | Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils. |
| Mo (molybdenum) | 0.01 | | Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum. |
| Ni (nickel) | 0.20 | | Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH. |
| Pd (lead) | 5.0 | | Can inhibit plant cell growth at very high concentrations. |
| Se (selenium) | 0.02 | | Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations. |
| Sn (tin) | | | |
| Ti (titanium) | ---- | | Effectively excluded by plants; specific tolerance unknown. |
| W (tungsten) | | | |
| V (vanadium) | 0.10 | | Toxic to many plants at relatively low concentrations. |
| Zn (zinc) | 2.0 | | Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils. |

SOURCE: Ayers and Westcot, 1994

[1] The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 $m^3$ per hectare per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 $m^3$ per hectare per year. The values given are for water used on a continuous basis at one site.

## APPENDIX E: ANALYSIS OF VARIANCE FOR THE IRRIGATION WATERS

The *analysis of variance* (ANOVA) was developed by Fisher, R A as a technique use to test the significance of differences between three or more sampling means or, equivalently, to test the null hypothesis that the sample means are all equal(drawn from populations with the same mean).It makes use of the F distribution. In a *single (or one) factor experiment,* measurements ( or observation) are obtained for *a* independent groups of samples, where the number of measurements in each group is *b*, (Spiegel and Stephen,2000).

### TABLE E1: ANOVA FOR CHANCHAGA IRRIGATION WATER

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| CUWS | 19 | 270.54 | 14.23895 | 690.277 |
| COWS | 19 | 283.87 | 14.94053 | 690.7505 |
| CDWS | 19 | 299.78 | 15.77789 | 892.9009 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 22.5578 | 2 | 11.2789 | 0.01488 | 0.985234 | 3.168246 |
| Within Groups | 40930.71 | 54 | 757.9761 | | | |
| Total | 40953.27 | 56 | | | | |

Hypothesis:

$Ho = \mu 1 = \mu 2 = \mu 3$ i.e. there is no significant difference.

H1= the μ's are not equal i.e. there is significant difference.

$\alpha = 0.05$

Test statistic, F= MSt /Mse

Decision rule: Reject Ho if F ≥ Fcrit otherwise Ho is not rejected

Since F= 0.0148 < than Fcrit = 3.1682, Ho is not rejected

## TABLE E2: ANOVA FOR GUSORO IRRIGATION WATER

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| GUWS | 19 | 154.78 | 8.146316 | 113.2189 |
| GOWS | 19 | 170.88 | 8.993684 | 138.8752 |
| GDWS | 19 | 164.57 | 8.661579 | 125.7902 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 6.927547 | 2 | 3.463774 | 0.027499 | 0.97289 | 3.168246 |
| Within Groups | 6801.917 | 54 | 125.9614 | | | |
| | | | | | | |
| Total | 6808.845 | 56 | | | | |

Hypothesis:

Ho=μ1=μ2=μ3 i.e. there is no significant difference.

H1= the μ's are not equal i.e. there is significant difference.

α= 0.05

Test statistic, F= MSt /Mse

Decision rule: Reject Ho if F ≥ Fcrit, otherwise Ho is not rejected

Since F= 0.0275 < than Fcrit = 3.1682, Ho is not rejected

## TABLE E3:ANOVA FOR SOJE IRRIGATION WATER

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| SUWS | 19 | 620.73 | 32.67 | 2798.661 |
| SOWS | 19 | 668.2 | 35.16842 | 3087.039 |
| SDWS | 19 | 745.82 | 39.25368 | 4298.407 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 419.7504 | 2 | 209.8752 | 0.061824 | 0.940114 | 3.168246 |
| Within Groups | 183313.9 | 54 | 3394.702 | | | |
| | | | | | | |
| Total | 183733.7 | 56 | | | | |

Hypothesis:

Ho=μ1=μ2=μ3 i.e. there is no significant difference.

H1= the μ's are not equal i.e. there is significant difference.

α= 0.05

Test statistic, F= MSt /Mse

Decision rule: Reject Ho if F ≥ Fcrit otherwise Ho is not rejected

Since F= 0.0618 < than Fcrit = 3.1682, Ho is not rejected

## APPENDIX F: World Health Organization Standards for (2004)

| Substances or Characteristics | Unit | Symbols | WHO |
|---|---|---|---|
| Nickel | mg/l | Ni | N/A |
| Nitrates | mg/l | $NO_3$ | 10 |
| Copper | mg/l | Cu | 1.0 |
| Iron | mg/l | Fe | 0.30 |
| Magnesium | mg/l | Mg | 30 |
| Nitrite | mg/l | $NO_2$ | 1 |
| Sulphate | mg/l | $SO_4$ | 250 |
| Total dissolve solids | mg/l | TDS | 500 |
| Conductivity | µs/cm | | N/A |
| Total hardness as $CaCO_3$ | mg/l | | 500 |
| Odour | | | Inoffensive |
| Suspended solids | mg/l | SS | N/A |
| Turbidity | FTU | | 5 |
| $P^H$ | | | 6.5-8.5 |
| Biochemical Oxygen Demand | mg/l | BOD | 0 |
| Dissolved Oxygen | mg/l | DO | 5 |
| Chemical Oxygen Demand | mg/l | COD | N/A |

**FTU = Formazin Turbidity Unit**

**PtCo = Platinum Cobolt**

**N/A = Not Available**

## APPENDIX G: CROP TOLERANCE AND YIELD POTENTIAL OF SELECTED CROPS AS INFLUENCED BY IRRIGATION WATER SALINITY ($EC_w$) OR SOIL SALINITY ($EC_e$)[1]

| | YIELD POTENTIAL[2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| FIELD CROPS | 100% | | 90% | | 75% | | 50% | | 0% "maximum"[3] | |
| | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ | $EC_e$ | $EC_w$ |
| **Barley** *(Hordeum vulgare)*[4] | 8.0 | 5.3 | 10 | 6.7 | 13 | 8.7 | 18 | 12 | 28 | 19 |
| **Cotton** *(Gossypium hirsutum)* | 7.7 | 5.1 | 9.6 | 6.4 | 13 | 8.4 | 17 | 12 | 27 | 18 |
| **Sugarbeet** *(Beta vulgaris)*[5] | 7.0 | 4.7 | 8.7 | 5.8 | 11 | 7.5 | 15 | 10 | 24 | 16 |
| **Sorghum** *(Sorghum bicolor)* | 6.8 | 4.5 | 7.4 | 5.0 | 8.4 | 5.6 | 9.9 | 6.7 | 13 | 8.7 |
| **Wheat** *(Triticum aestivum)*[4,6] | 6.0 | 4.0 | 7.4 | 4.9 | 9.5 | 6.3 | 13 | 8.7 | 20 | 13 |
| **Wheat, durum** *(Triticum turgidum)* | 5.7 | 3.8 | 7.6 | 5.0 | 10 | 6.9 | 15 | 10 | 24 | 16 |
| **Soybean** *(Glycine max)* | 5.0 | 3.3 | 5.5 | 3.7 | 6.3 | 4.2 | 7.5 | 5.0 | 10 | 6.7 |
| **Cowpea** *(Vigna unguiculata)* | 4.9 | 3.3 | 5.7 | 3.8 | 7.0 | 4.7 | 9.1 | 6.0 | 13 | 8.8 |
| **Groundnut (Peanut)** *(Arachis hypogaea)* | 3.2 | 2.1 | 3.5 | 2.4 | 4.1 | 2.7 | 4.9 | 3.3 | 6.6 | 4.4 |
| **Rice (paddy)** *(Oriza sativa)* | 3.0 | 2.0 | 3.8 | 2.6 | 5.1 | 3.4 | 7.2 | 4.8 | 11 | 7.6 |
| **Sugarcane** *(Saccharum officinarum)* | 1.7 | 1.1 | 3.4 | 2.3 | 5.9 | 4.0 | 10 | 6.8 | 19 | 12 |
| **Corn (maize)** *(Zea mays)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Flax** *(Linum usitatissimum)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Broadbean** *(Vicia faba)* | 1.5 | 1.1 | 2.6 | 1.8 | 4.2 | 2.0 | 6.8 | 4.5 | 12 | 8.0 |
| **Bean** *(Phaseolus vulgaris)* | 1.0 | 0.7 | 1.5 | 1.0 | 2.3 | 1.5 | 3.6 | 2.4 | 6.3 | 4.2 |
| **VEGETABLE CROPS** | | | | | | | | | | |
| **Squash, zucchini (courgette)** *(Cucurbita pepo melopepo)* | 4.7 | 3.1 | 5.8 | 3.8 | 7.4 | 4.9 | 10 | 6.7 | 15 | 10 |
| **Beet, red** *(Beta vulgaris)*[5] | 4.0 | 2.7 | 5.1 | 3.4 | 6.8 | 4.5 | 9.6 | 6.4 | 15 | 10 |
| **Squash, scallop** *(Cucurbita pepo melopepo)* | 3.2 | 2.1 | 3.8 | 2.6 | 4.8 | 3.2 | 6.3 | 4.2 | 9.4 | 6.3 |
| **Broccoli** *(Brassica oleracea botrytis)* | 2.8 | 1.9 | 3.9 | 2.6 | 5.5 | 3.7 | 8.2 | 5.5 | 14 | 9.1 |
| **Tomato** *(Lycopersicon esculentum)* | 2.5 | 1.7 | 3.5 | 2.3 | 5.0 | 3.4 | 7.6 | 5.0 | 13 | 8.4 |
| **Cucumber** *(Cucumis sativus)* | 2.5 | 1.7 | 3.3 | 2.2 | 4.4 | 2.9 | 6.3 | 4.2 | 10 | 6.8 |
| **Spinach** *(Spinacia oleracea)* | 2.0 | 1.3 | 3.3 | 2.2 | 5.3 | 3.5 | 8.6 | 5.7 | 15 | 10 |
| **Celery** *(Apium graveolens)* | 1.8 | 1.2 | 3.4 | 2.3 | 5.8 | 3.9 | 9.9 | 6.6 | 18 | 12 |
| **Cabbage** *(Brassica oleracea capitata)* | 1.8 | 1.2 | 2.8 | 1.9 | 4.4 | 2.9 | 7.0 | 4.6 | 12 | 8.1 |
| **Potato** *(Solanum tuberosum)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Corn, sweet (maize)** *(Zea mays)* | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10 | 6.7 |
| **Sweet potato** *(Ipomoea batatas)* | 1.5 | 1.0 | 2.4 | 1.6 | 3.8 | 2.5 | 6.0 | 4.0 | 11 | 7.1 |
| **Pepper** *(Capsicum annuum)* | 1.5 | 1.0 | 2.2 | 1.5 | 3.3 | 2.2 | 5.1 | 3.4 | 8.6 | 5.8 |
| **Lettuce** *(Lactuca sativa)* | 1.3 | 0.9 | 2.1 | 1.4 | 3.2 | 2.1 | 5.1 | 3.4 | 9.0 | 6.0 |
| **Radish** *(Raphanus sativus)* | 1.2 | 0.8 | 2.0 | 1.3 | 3.1 | 2.1 | 5.0 | 3.4 | 8.9 | 5.9 |
| **Onion** *(Allium cepa)* | 1.2 | 0.8 | 1.8 | 1.2 | 2.8 | 1.8 | 4.3 | 2.9 | 7.4 | 5.0 |
| **Carrot** *(Daucus carota)* | 1.0 | 0.7 | 1.7 | 1.1 | 2.8 | 1.9 | 4.6 | 3.0 | 8.1 | 5.4 |
| **Bean** *(Phaseolus vulgaris)* | 1.0 | 0.7 | 1.5 | 1.0 | 2.3 | 1.5 | 3.6 | 2.4 | 6.3 | 4.2 |
| **Turnip** *(Brassica rapa)* | 0.9 | 0.6 | 2.0 | 1.3 | 3.7 | 2.5 | 6.5 | 4.3 | 12 | 8.0 |
| **Wheatgrass, tall** *(Agropyron elongatum)* | 7.5 | 5.0 | 9.9 | 6.6 | 13 | 9.0 | 19 | 13 | 31 | 21 |
| **Wheatgrass, fairway crested** *(Agropyron cristatum)* | 7.5 | 5.0 | 9.0 | 6.0 | 11 | 7.4 | 15 | 9.8 | 22 | 15 |

APPENDIX G: Cont'd

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Barley (forage)** *(Hordeum vulgare)*[4] | 6.0 | 4.0 | 7.4 | 4.9 | 9.5 | 6.4 | 13 | 8.7 | 20 | 13 |
| **Ryegrass, perennial** *(Lolium perenne)* | 5.6 | 3.7 | 6.9 | 4.6 | 8.9 | 5.9 | 12 | 8.1 | 19 | 13 |
| **Trefoil, narrowleaf birdsfoot**[8] *(Lotus corniculatus tenuifolium)* | 5.0 | 3.3 | 6.0 | 4.0 | 7.5 | 5.0 | 10 | 6.7 | 15 | 10 |
| **Harding grass** *(Phalaris tuberosa)* | 4.6 | 3.1 | 5.9 | 3.9 | 7.9 | 5.3 | 11 | 7.4 | 18 | 12 |
| **Fescue, tall** *(Festuca elatior)* | 3.9 | 2.6 | 5.5 | 3.6 | 7.8 | 5.2 | 12 | 7.8 | 20 | 13 |
| **Wheatgrass, standard crested** *(Agropyron sibiricum)* | 3.5 | 2.3 | 6.0 | 4.0 | 9.8 | 6.5 | 16 | 11 | 28 | 19 |
| **Vetch, common** *(Vicia angustifolia)* | 3.0 | 2.0 | 3.9 | 2.6 | 5.3 | 3.5 | 7.6 | 5.0 | 12 | 8.1 |
| **Sudan grass** *(Sorghum sudanense)* | 2.8 | 1.9 | 5.1 | 3.4 | 8.6 | 5.7 | 14 | 9.6 | 26 | 17 |
| **Wildrye, beardless** *(Elymus triticoides)* | 2.7 | 1.8 | 4.4 | 2.9 | 6.9 | 4.6 | 11 | 7.4 | 19 | 13 |
| **Cowpea (forage)** *(Vigna unguiculata)* | 2.5 | 1.7 | 3.4 | 2.3 | 4.8 | 3.2 | 7.1 | 4.8 | 12 | 7.8 |
| **Trefoil, big** *(Lotus uliginosus)* | 2.3 | 1.5 | 2.8 | 1.9 | 3.6 | 2.4 | 4.9 | 3.3 | 7.6 | 5.0 |
| **Sesbania** *(Sesbania exaltata)* | 2.3 | 1.5 | 3.7 | 2.5 | 5.9 | 3.9 | 9.4 | 6.3 | 17 | 11 |
| **Sphaerophysa** *(Sphaerophysa salsula)* | 2.2 | 1.5 | 3.6 | 2.4 | 5.8 | 3.8 | 9.3 | 6.2 | 16 | 11 |
| **Alfalfa** *(Medicago sativa)* | 2.0 | 1.3 | 3.4 | 2.2 | 5.4 | 3.6 | 8.8 | 5.9 | 16 | 10 |
| **Lovegrass** *(Eragrostis sp.)*[9] | 2.0 | 1.3 | 3.2 | 2.1 | 5.0 | 3.3 | 8.0 | 5.3 | 14 | 9.3 |
| **Corn (forage) (maize)** *(Zea mays)* | 1.8 | 1.2 | 3.2 | 2.1 | 5.2 | 3.5 | 8.6 | 5.7 | 15 | 10 |
| **Clover, berseem** *(Trifolium alexandrinum)* | 1.5 | 1.0 | 3.2 | 2.2 | 5.9 | 3.9 | 10 | 6.8 | 19 | 13 |
| **Orchard grass** *(Dactylis glomerata)* | 1.5 | 1.0 | 3.1 | 2.1 | 5.5 | 3.7 | 9.6 | 6.4 | 18 | 12 |
| **Foxtail, meadow** *(Alopecurus pratensis)* | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.5 | 12 | 7.9 |
| **Clover, red** *(Trifolium pratense)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, alsike** *(Trifolium hybridum)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, ladino** *(Trifolium repens)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **Clover, strawberry** *(Trifolium fragiferum)* | 1.5 | 1.0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 9.8 | 6.6 |
| **FRUIT CROPS**[10] | | | | | | | | | | |
| **Date palm** *(phoenix dactylifera)* | 4.0 | 2.7 | 6.8 | 4.5 | 11 | 7.3 | 18 | 12 | 32 | 21 |
| **Grapefruit** *(Citrus paradisi)*[11] | 1.8 | 1.2 | 2.4 | 1.6 | 3.4 | 2.2 | 4.9 | 3.3 | 8.0 | 5.4 |
| **Orange** *(Citrus sinensis)* | 1.7 | 1.1 | 2.3 | 1.6 | 3.3 | 2.2 | 4.8 | 3.2 | 8.0 | 5.3 |
| **Peach** *(Prunus persica)* | 1.7 | 1.1 | 2.2 | 1.5 | 2.9 | 1.9 | 4.1 | 2.7 | 6.5 | 4.3 |
| **Apricot** *(Prunus armeniaca)*[11] | 1.6 | 1.1 | 2.0 | 1.3 | 2.6 | 1.8 | 3.7 | 2.5 | 5.8 | 3.8 |
| **Grape** *(Vitus sp.)*[11] | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.5 | 12 | 7.9 |
| **Almond** *(Prunus dulcis)*[11] | 1.5 | 1.0 | 2.0 | 1.4 | 2.8 | 1.9 | 4.1 | 2.8 | 6.8 | 4.5 |
| **Plum, prune** *(Prunus domestica)*[11] | 1.5 | 1.0 | 2.1 | 1.4 | 2.9 | 1.9 | 4.3 | 2.9 | 7.1 | 4.7 |
| **Blackberry** *(Rubus sp.)* | 1.5 | 1.0 | 2.0 | 1.3 | 2.6 | 1.8 | 3.8 | 2.5 | 6.0 | 4.0 |
| **Boysenberry** *(Rubus ursinus)* | 1.5 | 1.0 | 2.0 | 1.3 | 2.6 | 1.8 | 3.8 | 2.5 | 6.0 | 4.0 |
| **Strawberry** *(Fragaria sp.)* | 1.0 | 0.7 | 1.3 | 0.9 | 1.8 | 1.2 | 2.5 | 1.7 | 4 | 2.7 |

SOURCE: Ayers and Westcot, 1994

[1] These data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2 dS/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

[2] ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in deciSiemens per metre (dS/m) at 25°C. ECw means electrical conductivity of the irrigation water in deciSiemens per metre (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15–20 percent leaching fraction and a 40-30-20-10 percent water use pattern for the upper to lower quarters of the root zone. These assumptions were used in developing the guidelines in Table 1.

[3] The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

[4] Barley and wheat are less tolerant during germination and seeding stage; ECe should not exceed 4–5 dS/m in the upper soil during this period.

[5] Beets are more sensitive during germination; ECe should not exceed 3 dS/m in the seeding area for garden beets and sugar beets.

[6] Semi-dwarf, short cultivars may be less tolerant.

[7] Tolerance given is an average of several varieties; Suwannee and Coastal Bermuda grass are about 20 percent more tolerant, while Common and Greenfield Bermuda grass are about 20percent less tolerant.

[8] Broadleaf Birds foot Trefoil seems less tolerant than Narrow leaf Birds foot Trefoil.

[9] Tolerance given is an average for Boer, Wilman, Sand and Weeping Love grass; Lehman Love grass seems about 50 percent more tolerant.

[10] These data are applicable when rootstocks are used that do not accumulate $Na^+$ and $Cl^-$ rapidly or when these ions do not predominate in the soil. If either ions do, refer to the toxicity discussion in Section 4.

[11] Tolerance evaluation is based on tree growth and not on yield.

## APPENDIX H: SOIL SAMPLES RESULTS AS RECORDED FROM THE LABORATORY AND THE CALCULATED SAR AND ESP.

TABLE H1: SOIL SAMPLE ANALYSES OF CHANCHAGA IRRIGATION SCHEME

| | Concentration mg/l | | | | | |
|---|---|---|---|---|---|---|
| PARAMETERS | CISFS1 | CISBS1 | CISFS2 | CISBS2 | CNISFS | CNISBS |
| N | 0.32 | 0.25 | 0.46 | 0.21 | 0.14 | 0.11 |
| Na | 0.75 | 0.64 | 1.4 | 0.67 | 0.82 | 0.77 |
| K | 0.67 | 0.35 | 0.58 | 0.44 | 0.42 | 0.34 |
| Ca | 15.9 | 12.8 | 16.8 | 11.8 | 14.3 | 11.2 |
| Mg | 2.2 | 1.8 | 2.4 | 1.7 | 1.4 | 1.92 |
| $SO_4$ | 12.6 | 3.6 | 10.7 | 3.2 | 11.2 | 11.7 |
| Cl | 9.67 | 7.9 | 10.5 | 7.6 | 5.81 | 5.83 |
| $PO_4$ | 2.6 | 2.6 | 3.8 | 1.8 | 1.2 | 1.4 |
| $NO_3$ | 0.7 | 2.1 | 1.5 | 1.5 | 0.2 | 0.5 |
| EC | 1.9 | 3.6 | 1.5 | 3.1 | 1.2 | 1.4 |
| pH | 6.7 | 6.4 | 6.9 | 6.4 | 7 | 6.9 |
| Silt | 38 | 23 | 40 | 29 | 32 | 23 |
| Sand | 42 | 45 | 45 | 51 | 41 | 54 |
| Clay | 20 | 32 | 15 | 30 | 27 | 23 |

TABLE H2: SOIL SAMPLES ANALYSES OF GUSORO IRRIGATION SCHEME

| | Concentration,mg/l | | | | | |
|---|---|---|---|---|---|---|
| Soil Parameter | GISFS1 | GISBS1 | GISFS2 | GISBS2 | GNISFS | GNISBS |
| N | 1.3 | 0.87 | 1.22 | 0.94 | 1.06 | 0.69 |
| Na | 0.81 | 0.73 | 0.76 | 0.67 | 0.62 | 0.45 |
| K | 0.81 | 0.54 | 0.74 | 0.61 | 0.51 | 0.22 |
| Ca | 4.8 | 6.8 | 5.2 | 5.7 | 1.28 | 1.52 |
| Mg | 7.23 | 2.22 | 5.4 | 2.11 | 2.16 | 1.74 |
| $SO_4$ | 23 | 2.43 | 25 | 3.1 | 13.7 | 15.6 |
| Cl | 3.7 | 1.71 | 3.9 | 1.8 | 1.66 | 1.53 |
| $PO_4$ | 3.8 | 5.6 | 5.8 | 4.7 | 6.3 | 5.8 |
| $NO_3$ | 0.23 | 0.12 | 1.6 | 0.22 | 0.22 | 0.11 |
| EC | 1.8 | 2.1 | 2.7 | 2.1 | 2.7 | 1.8 |
| pH | 6.8 | 6.7 | 6.8 | 6.3 | 7.2 | 7 |
| Silt | 17 | 12 | 14 | 15 | 13 | 16 |
| Sand | 54 | 45 | 51 | 39 | 64 | 46 |
| Clay | 29 | 43 | 35 | 46 | 23 | 38 |

TABLEH3: SOIL SAMPLES ANALYSES OF SOJE IRRGATION SCHEME

| | Concentration,mg/l | | | | | |
|---|---|---|---|---|---|---|
| PARAMETERS | SIFS1 | SIBS1 | SIFS2 | SIBS2 | SNISFS | SNISBS |
| N | 2.3 | 1.5 | 2.1 | 1.8 | 0.9 | 1.6 |
| Na | 3.5 | 5.7 | 1.5 | 4.3 | 1.2 | 1.8 |
| K | 0.26 | 0.4 | 0.61 | 0.6 | 0.28 | 0.02 |
| Ca | 45 | 31.2 | 38 | 31 | 27 | 27.5 |
| Mg | 4.7 | 12.4 | 5.3 | 13.8 | 11.1 | 10.8 |
| $SO_4$ | 142 | 57.2 | 34 | 89 | 45 | 37 |
| Cl | 46.3 | 32.1 | 40.2 | 35.6 | 12.5 | 12.9 |
| $PO_4$ | 1.3 | 4.7 | 1.8 | 3.8 | 3.9 | 2.6 |
| $NO_3$ | 31.3 | 13.6 | 24.6 | 12.9 | 13.9 | 12.8 |
| EC | 6.8 | 6.5 | 7.8 | 7.2 | 3.4 | 4.1 |
| pH | 6.8 | 6.6 | 6.8 | 6.4 | 7 | 6.9 |
| Silt | 19 | 15 | 31 | 17 | 45 | 59 |
| Sand | 50 | 34 | 8 | 33 | 22 | 12 |
| Clay | 31 | 51 | 61 | 50 | 33 | 29 |

TABLE H4: WATER SAMPLES ANALYSES OF CHANCHAGA IRRIGATION SCHEME

| | Concentration, mg/l | | |
|---|---|---|---|
| Water Quality Parameter | CUWS | COWS | CDWS |
| Temperature | 28.2 | 27 | 28 |
| $pH^a$ | 6.4 | 7 | 6.9 |
| Electrical Conductivity,µmhos/cm | 10.5 | 11.8 | 12 |
| Total Dissolved Solids | 106 | 110 | 130 |
| Total Hardness-EDTA($MgCaCO_3$) | 56 | 50 | 42 |
| Dissolved Oxygen | 6.3 | 4 | 3.2 |
| Chloride,$Cl^-$ | 25 | 28 | 27 |
| Sulphate,$SO_4^+$ | 15.7 | 14 | 14.8 |
| Calcium,$Ca^{2+}$ | 3.5 | 8 | 8.3 |
| Iron,$Fe^{2+}$ | 0.1 | 0.3 | 0.22 |
| Magnesium,$Mg^{2+}$ | 1.6 | 4.1 | 3.6 |
| Phosphate,PO4- | 0.9 | 4 | 5.61 |
| Nitrate,$NO_3^-$ | 1.5 | 4.6 | 6.2 |
| Sodium,$Na^+$ | 4.8 | 5.3 | 6 |
| Potassium,$K^+$ | 1.8 | 2.81 | 2.6 |
| Copper,$Cu^{2+}$ | 0.4 | 0.21 | 0.2 |
| Manganese,$Mn^+$ | 0.04 | 0.04 | 0.05 |
| Chlorine,Cl | 1.8 | 2.71 | 3.1 |
| Boron,B | 0 | 0 | 0 |

WATER SAMPLES ANALYSES OF GUSORO IRRIGATION SCHEME

| Water Quality Parameter | Concentration, mg/l GUWS | GOWS | GDWS |
|---|---|---|---|
| Temperature | 26.8 | 30.5 | 27 |
| pH | 6.7 | 6.8 | 7.1 |
| Electrical Conductivity,µmhos/cm | 23 | 21 | 20 |
| Total Dissolved Solids | 34 | 41 | 39 |
| Total Hardness-EDTA($MgCaCO_3$) | 13.2 | 11.8 | 12 |
| Dissolved Oxygen | 2.5 | 3.1 | 3 |
| Chloride,$Cl^-$ | 2.4 | 2.44 | 2.4 |
| Sulphate,$SO_4^+$ | 21 | 23 | 24 |
| Calcium,$Ca^{2+}$ | 5.2 | 5.5 | 5.8 |
| Iron,$Fe^{2+}$ | 0.13 | 0.1 | 0.2 |
| Magnesium,$Mg^{2+}$ | 0.21 | 1.2 | 0.4 |
| Phosphate, PO4- | 2.1 | 4.7 | 3.8 |
| Nitrate,$NO_3^-$ | 13.7 | 13.8 | 14 |
| Sodium,$Na^+$ | 0.34 | 0.54 | 0.67 |
| Potassium,$K^+$ | 1.3 | 1.8 | 1.6 |
| Copper,$Cu^{2+}$ | 1 | 1.1 | 1.2 |
| Manganese,$Mn^+$ | 1.2 | 2.3 | 2.4 |
| Chlorine,Cl | 0 | 0.2 | 0 |
| Boron,B | 0 | 0 | 0 |

TABLE H6: WATER SAMPLES ANALYSES OF SOJE IRRIGATION SCHEME

| Water Quality Parameter | Concentrations,mg/l SUWS | SOWS | SDWS |
|---|---|---|---|
| Temperature | 30.5 | 30 | 31 |
| pH | 7.3 | 7.2 | 6.4 |
| Electrical Conductivity | 74 | 65 | 86 |
| Total Dissolved Solids | 108 | 110 | 156 |
| Total Hardness-EDTA($MgCaCO_3$) | 203 | 215 | 237 |
| Dissolved Oxygen | 1.5 | 1.9 | 2.6 |
| Chloride,$Cl^-$ | 96 | 110 | 126 |
| Sulphate,$SO_4^+$ | 35 | 43 | 27 |
| Calcium,$Ca^{2+}$ | 23 | 28 | 25 |
| Iron,$Fe^{2+}$ | 0.23 | 0.1 | 0.22 |
| Magnesium,$Mg^{2+}$ | 2.1 | 2.6 | 2.4 |
| Phosphate,$PO_4^-$ | 2.5 | 5.8 | 4.1 |
| Nitrate,$NO_3^-$ | 12.3 | 23.6 | 16.9 |
| Sodium,$Na^+$ | 4.3 | 6.2 | 4.8 |
| Potassium,$K^+$ | 11.4 | 13.3 | 12.2 |
| Copper,$Cu^{2+}$ | 1.9 | 1.6 | 1.3 |
| Manganese,$Mn^+$ | 0.3 | 0.2 | 0.44 |
| Chlorine,Cl | 5.8 | 3.2 | 4.8 |
| Boron,B | 1.6 | 1.5 | 1.66 |

## Calculations of SAR and ESP

$$\text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad 1$$

$$\text{ESP} = \frac{100(0.01475SAR - 0.0126)}{0.01475SAR + 0.9874} \qquad 2$$

$Na^+$, $Mg^{2+}$ and $Ca^{2+}$ are in millieqivalents

$$milliequivalent = \frac{milligramme / Litre(mg / L)}{Equivalent \ Weight}$$

$$Equivalent Weight = \frac{Atomic Weight}{Valency}$$

Atomic weight of $Na^{+,}$ $Mg^{2+}$ and $Ca^{2+}$ are 23, 24.30 and 40 respectively.

Equivalent weight of $Na^+ = \frac{23}{1} = 23$ ; $Mg^{2+} = \frac{24.30}{2} = 12.15$; $Ca^{2+} = \frac{40.08}{2} = 20.04$

For SUWS,

$Na^{+,}$ $Mg^{2+}$ and $Ca^{2+}$ are 4.3 mg/L, 2.1mg/L and 23 mg/L respectively.

$Na^+ \frac{4.3}{23} = 0.1870 meq / L$ ; $Mg^{2+} \frac{2.1}{12.15} = 0.1728 meq / L$; $Ca^{2+} \frac{23}{20.04} = 1.1477 mq / L$

$$SAR = \frac{0.1870}{\sqrt{\frac{1.1477 + 0.1728}{2}}}$$
$$= 0.2301$$

$$\therefore ESP = \frac{100(0.01475 * 0.2301 - 0.0126)}{0.01475 * 0.2301 - 0.9875}$$
$$= -0.9292$$

## APPENDIX I: LABORATORY ANALYSES PROCEDURES

### The Atomic Absorption Spectrophomerter (AAS)

This is an electronic device that is used to determine the concentration of many parameters in a water sample. The spectrophotometer was connected to a power source. It then requested for an input data and after the data was supplied it then requested for a sample. A small volume of the sample was poured through a hole on the device. The device analyzed the sample and the concentration of each parameter was displayed on the screen and was recorded accordingly.. The time it took for each parameter analysis varied, for example nitrate analysis took about 15 minutes. The spectrophotometer was used to determine the concentrations of the following parameters in the water sample, $K^+$, $Fe^{2+}$, $Na^+$, $Ca^{2+}$, $Mg2^+$, $SO42^-$, $PO^-_4$, $Cl^-$, total hardness.

### pH

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 rinsed with distilled water using the squeeze bottles and dried with soft tissue. A dry 100ml beaker 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 stabillised.The value was read and recorded and the same procedure was repeated for the rest samples.

### Dissolved Oxygen Test

The dissolved oxygen content of each water sample was measured using the dissolved oxygen test kit.

### Wagtech Chlorine Test.

The Wagtech D.P.D (diethyl-P-phnylene & diemine) chlorine method whose reagent is in tablet form was used to measure chlorine. Free chlorine reacted with DPD in buffered solution to produce buffered solution producing a pink colouration.The intensity of the colour is proportional to the free chlorine concentration. This was measured by Wegtech photometer. Subsequent addition of excess potassium iodide induced a further reaction with combined chlorine present. The colour intensity would then be proportional to the total chlorine concentration was also measured using Wagtech photometer. The combined chlorine was obtained by subtracting the free chlorine residual result from the total chlorine

**Soil pH Determination.**

The apparatus used was the Glass – electrode pH meter and the reagent is distilled water. 20g of air dried soil was weighed into a 50ml beaker.20ml of distilled water was added and allowed to stand for 30 minutes, this was stirred occasionally with glass rod.

The electrode of the pH meter was inserted into the partly settled suspension and measurement was taken. The suspension was not stirred during the measurement. The pH measured was recorded as pH (1:2.5 soil/water rations)

**Particle Size Analysis (Bouyoucos methods)**

Particle size (or mechanical analysis) is the determination of the percentage sand, silt and clay, particles in the soil. The Bouyoucos method is also known as the hydrometer method. The principle used is based on the fact that particles suspended in water settle differently depending on the amount of surface per unit volume. The apparatus used were;

1) Multi mix machine with baffled milk shape cups
2) Glass (Bouyoucos) cylinders approximately of 1 liter capacity.
3) Special hydrometer.
4) Sodium hexametaphosphate, dispersing agent (calgon) $Na_3(PO_3)_6$

51g of the air dried fine textured soil was placed in the baffled cup. The cup was half filled with distilled water and 50ml of neutral Sodium hexametaphosphate was added.

The cup was stirred until the soil aggregate were broken down (6 minute for sand, 10 minute for lithely heavy sandy loams and 15 minutes for other soils.

The suspension was transferred to Bouyoucos cylinder and filled to the lower mark with distilled water while the hydrometer was in suspension.

The percentage sand was then determined thus:

The hydrometer was removed and the suspension was shaked vigorously. The cylinder was then placed on the desk for the time recorded. At the end of 20 seconds, the hydrometer was carefully inserted and read at the end of 40 seconds. This was recorded on the data sheet. The hydrometer was removed from the suspension for reading of the temperature of suspension. For each degree above 67°F, 0.2 units were added to the recorded reading to get the corrected hydrometer readings. For degree less than 67°F, 0.2 units were subtracted to the recorded readings to get the corrected hydrometer readings. (In the centigrade scale, 0.3 units will be added or subtracted for above 20°C and below 20°C respectively.

The hydrometer was calibrated so that the corrected readings gave the grams of soil material in suspention.The sands settled to the bottom cylinder within 40 seconds, therefore the 40 second hydrometer reading actually gave the amount of silt, and clay in suspension.

The weight of sand in the sample was obtained by subtracting the corrected hydrometer reading from the total weight of the sample. The percentage sand was weight of sand divided by the weight of sample multiply by 100.

The percentage clay in the sample was then determined thus:

The suspension was shaked and the readings taken at the end of 2 hours. The hydrometer was inserted just before the reading was taken. The temperature of the suspension was taken and used to correct the hydrometer reading as described above.

At the end of two hours, the silt in addition to the sand has settled out of suspension. The corrected hydrometer reading then represented the grams of clay in the sample. The percentage clay was calculated by dividing this weight by the weight of the samples and multiplying by 100.

The percentage silt in the sample was calculated by difference.

100 – (Clay & sand).

**Nitrogen Determination**

The total nitrogen in a soil sample was determined by regular Macro-Kjeldahl method.

**Electrical conductivity**

Saturated extract of the soil was prepared by addition of distilled water to the soil samples. The exact electrical conductivity was measured using the electrical conductivity meter.