EFFECTS OF COW DUNG MANURE ON SOME PHYSICAL AND CHEMICAL PROPERTIES ON SALINE - SODIC SOILS

IN KIBOKO

MAKUENI DISTRICT

(Kenya)

BY

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A thesis submitted on partial fulfilment of the requirements for the degree of

Master of Science in Soil Science

Faculty of Agriculture

University of Nairobi

1998

DECLARATION

This thesis is my original work and has not been presented for degree in any other University.

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This thesis has been submitted for examination with my approval as the university supervisor.

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DEDICATION

This work is dedicated to

My Father Osman Ali and my mother Fatima Humida.

They gave themselves for my excellence in life.

AKNOWLEDGMENT

First of all thanks to Alla for guiding me through this work, be all glory for ever and ever.

My deepest appreciation is extended to the AAS for granting me a full scholarship for this work and to the University coordinator.

My special gratitude goes to my supervisor Mr S.M. Kinyali for the guidance, through discussion and constructive ideas and support during the research work and writing up of this thesis.

I am particularly thankful to Mr. Geoffrey Kironchi through his advice, cooperation and interest. I am greatly indebted to the technical staff of the department of Soil Science and Agricultural Engineering. Notably is the contribution of Mr. S.K. Tirop in the fieldwork, Miss P.N. Nduhiu for her cooperation and assistance in all aspects of chemical analysis and Mr. Muliro for his continuous assistance while I was using the Agricultural Engineering Laboratory.

My special thanks to university of Gezira for giving me a study leave.

I wish to acknowledge the farmers (Joel Mbondo and Albert Kyambo in Kiboko) who allowed me to use their farms to conduct the experiments.

Finally I would like to thank all those who may not be listed but contributed in any way to the completion of this thesis.

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ABBREVIATIONS AND SYMBOLS

BSP	Base saturation percent
C	Clay
%C	Carbon percent
CEC	Cation exchange capacity
CL	Clay loam
cm	Centimetre
dS/m	Decisiemens per metre
EC	Electrical conductivity
Ed(s)	Editors
ESP	Exchangeable sodium percent
FAO	Food and agriculture organization
FC	Field capacity
g	Gram
g/cm^3	Gram per cubic centimetre
ha	Hectare
hr	Hour
kg	Kilogram
Pa	Pascals
K_{sat}	Saturated hydraulic conductivity
me/L	Milliequivalent per litre

mg/L	Milligram per litre
ml	Millilitre
mm	millimetre
%N	Nitrogen percent
Pb	Bulk density
SAR	Sodium adsorption ratio

ABSTRACT

The effect of cow dung manure on some physical and chemical properties of saline-sodic soils in Kiboko, Makueni district were examined. Two soil types, namely, chromo- haplic Lixisols for site 1 and mollic and sodic Solonchaks for site 2 were selected in two different farms. Within each farm, 15 plots each measuring 5 x 5 m were treated with different levels of cow dung manure (0, 10, 20, 30 and 40 tonnes/ha) in three replicates. After 18 weeks of application of cow dung manure, soil samples were taken from the top two horizons for physical and chemical analysis. In addition, water samples used for irrigation were analyzed to determine their chemical characteristics and their suitability for irrigation.

At site 1, there was little evidence of improving the physical and chemical properties of the soil ,notably, bulk density, antecedent moisture content, organic carbon, soil pH, EC, CEC, % total N, ESP and SAR when compared with the control. However, after the application of 40 tonnes /ha there was significant difference in aggregate stability ($P \leq 0.05$) among the treatments and the two top horizons when compared with the control. Similarly K_{sat} significantly improved ($P \leq 0.05$) after the application of 20 and 40 tonnes ha^{-1} The highest final infiltration rate was obtained from the plots which received 20 tonnes /ha of cow dung manure. This was significantly different ($P \leq 0.01$) from the control.

At site 2, there were significant improvements in aggregate stability, infiltration rate and available water. In the two top horizons, aggregates stability improved with increasing rate of cow dung manure. There were significant differences in aggregate stability among the treatments ($p \leq 0.01$) when compared with the control. After the application of 30 tonnes/ha the

final infiltration rate were significantly different ($p \leq 0.05$) from the control, while other physical and chemical parameters improved slightly.

The irrigation water from the boreholes in the two sites fall under very high saline class (EC= 4.08 and 5.10 dSm^{-1} at 25°c for site 1 and 2 respectively) and low to medium sodium hazard (SAR_{adj}=15.27 and 11.92 for site 1 and 2 respectively). The Kiboko river, which was also used in site 2, falls under medium saline class (EC= 2.04dSm^{-1} at 25°c) and low sodium hazard (SAR_{adj} =3.92).

CHAPTER ONE

1.0 INTRODUCTION

Agricultural production in the arid and semi arid regions of the world is limited by poor water resources, limited rainfall and the detrimental effects associated with an excess of soluble salts, constrained to a localized area or sometimes extending over the whole basin (Gupta *et al.*, 1990). Due to limited rainfall in these areas, irrigation is required for crop production.

Extension of irrigation to the arid regions, however, usually has led to an increase in the area affected by shallow water tables and intensified and expanded the hazard of salinity (Gupta and Abrol, 1991). Arable land is continuously going out of production at approximately 5-7 million hectares per year due to soil degradation (FAO, 1983). On irrigated lands, salinization is the major cause of land being lost to production. Szabolcz (1991) estimated that salinity and sodicity affected 10% of the world land. It is estimated that in Africa, 47 countries will be critically short of land for agriculture production by the year 2000, and in the African region there are estimated to be 43.6 million hectares of salt affected land (Dudal and Purnell, 1986). Saline conditions severely limit the choice of crop, adversely affect crop germination and yield and can make soil difficult to work (Dougherty and Hall, 1995).

Apart from irrigated areas, salinity is also experienced under dry land rainfed conditions. Dry land salinity has caused severe management problems in Australia, in the Great Plains region of North America, in the Canadian prairies of Manitoba, Saskatchewan and Alberta and North and South Dakota. Dry land salinity is also extensive in South Africa, Iran, Afghanistan, Thailand, India and other countries (Abrol and Sandhu., 1988).

About 83% of Kenya's land area is semi arid to very arid (Braun and Mungai, 1981; Muchena and Van der pouw, 1981 and Government of Kenya, 1986), yet about 10, 031,200 hectares of the total area are salt affected. Salt affected soils in Kenya are wide spread. They are commonly found in Mandera, Turkana, Taita-Taveta, Kajiado (Amboseli area) and Baringo districts (Muchena, 1985). Salt problem has been experienced in a majority of irrigation schemes in Kenya (Worthington, 1976). This has led to some of the land being abandoned. For example, the Naivasha vegetable farm and Mwea rice station were abandoned due to salinity problem; while Block C in Tavita was abandoned due to salinity, sodicity, silting of the drains and variation of ground water table (Wakindiki, 1993).

Control of the salinity and alkalinity regime in the root zone is one of the main problems of irrigation in arid and semi arid areas. Development of irrigation in arid and semi arid lands requires permanent control of salinity and alkalinity in soils and irrigation water since the development of soil salinity and alkalinity is a challenge to the prominence of irrigated agriculture.

The present need for more food and fiber entails reclamation and development of new land resources. Apart from an increase in the agricultural inputs necessary for greater production, scarcity of land has resulted in a tendency to moving into arid and semi arid lands where irrigation is required. Irrigation is one way of improving the total volume of reliability of agricultural production by managing water for the.

Irrigation is necessary for successful farming in the marginal arid and semi arid zones. Irrigation of the marginal areas of Kibwezi and the TARDA pilot irrigation project are practical examples of the expansion of agricultural land in Kenya. Extensive areas of the marginal land under irrigation have, however, gone out of cultivation due to salinity and/or alkalinity.

The control of salinity and alkalinity is therefore essential for operation of successful farming. It involves both reclamation of salt affected soils and or improving of other soils (Kouda, 1961). Reclamation can be done through

1. Leaching salts from the root zone if the water for irrigation is non-saline
2. Application of a chemical compound such as gypsum and polymers
3. Applications of organic materials such as crop residues, filtermud or organic manure.

Leaching requires extra water and arrangement for drainage, while use of chemicals is expensive. But use of organic materials is relatively cheap and has an added advantage of soil structure and fertility improvement. Despite the salinity/sodicity problems cited above, use of organic matter has not been popular among farmers in attempt to alleviate the problem. Therefore, the aim of this study was to solve problems of salinity and/or alkalinity at Kiboko area using organic matter (cow dung manure) as the amendment.

1.1 Justification

In the past two decades, most research work has been focused on the chemical amelioration of saline-sodic soil. Less research has been carried out and there is scarce literature on improvement of the poor physical properties of such soils. Therefore this study aims at investigating the following:

1. To evaluate of the effectiveness of animal manure amendments in improving the soil structure and hydraulic properties of soils.

3. To give the farmer the confidence of using the animal manure which is readily available and cheap, and

4. To act as the basis of initiating a large field trail on long-term effects of the farmyard manure on saline-sodic soils.

1.2 Objectives

The objectives of this research are to determine the following:

1. The effect of cow dung manure on some physical properties of saline-sodic soil
2. The effect of cow dung manure on some chemical properties of saline-sodic soil
3. The chemical characteristics of irrigation water from two sources(The Kiboko river and Well) used for irrigation.

1.3 Hypotheses

The above objectives were formulated to test the following hypotheses:

1. The chemical characteristics of the water for the two sources are the same.
2. Different levels of cow dung manure have the same effect on some physical properties of each soil in the two farms under study.
3. Different levels of cow dung manure have the same effects on some chemical properties of each soil under this study.

CHAPTER TWO

2.0 LITRETURE REVIEW

2.1 Introduction

Salinity and sodicidy are considered separately from other chemical properties because of their common occurrence in arid and semi arid regions and special problems they cause in soil and water management (Landon, 1991). Salt affected soils are widely distributed over the world (Table 1) in arid and semi arid regions where annual evaporation exceeds precipitation (Rowell, 1994). Irrigation is required for crop growth in these areas although it may itself induce salinization and/or alkalization unless salts are removed regularly.

2.2 Characterization of salt affected soil

Salt accumulate in some surface soils of arid and semi arid regions because there is insufficient rainfall to flush them from the upper soil layer. The salts are primarily chlorides and sullphates of calcium, magnesium.Sodium and potassium. The source of these salts is the weathering rock and mineral, rainfall, ground water and irrigation. Once deposited or released in soil, the salts are brought to or near the surface by upward moving water, which then evaporate, leaving the salt behind (Brady, 1990).

Table 1: Comparative distribution of areas of saline and sodic soils on several continents (10^3 km^2)

Continent	Saline	Sodic	Saline/sodic ratio
North America[1/]	81.6	95.6	0.85
South America[1/]	694.1	595.7	1.17
Africa[1/]	534.9	2690.5	0.78
Asia[1/]	1949.2	1218.6	1.60
Australia[2/]	86.3	1997.0	0.04

Source: [1/] Northcote and Skene (1974)
[2/] Gupta and Abrol (1990)

Research has shown that the detrimental effects on plant stem not only from the high salt contents, but also from the level of sodium in soil, especially in relation to levels of calcium and magnesium. This situation has led to the development of techniques to measure three primary soil properties that, along with soil pH, can be used to characterize salt affected soils (Brady, 1990; Gupta and Abrol, 1990).

2.2.1 Salinity

The salt concentration of the soil is estimated by methods based on the ability of the salt in the soil solution to conduct electricity. Laboratory measurements of electrical conductivity (EC) of the soil solution extracted from a saturated sample of soil give an indication of the salt levels (dS/m) (Brady, 1990; Gupta and Abrol, 1990 and Rowell, 1994).

At the field level, using various kinds of salinity sensors such as porous matrix sensor and four electron probes can also make salinity measurements. The salinity is commonly expressed in terms of the electrical conductivity (EC) which is measured in decisiemens per metre (dS/m) (Brady, 1990; Rowell, 1994).

2.2.2 Sodicity

Two means are used to characterize the sodium status of soils. The exchange sodium percentage (ESP) identifies the degree to which the exchangeable complex is saturated with sodium. This is calculated as follows:

$$ESP = \frac{\text{Exchangeable sodium}}{\text{Cation exchange capacity}} \times 100 \quad \text{...} (1)$$

ESP levels of 15-yield pH values of 8.5 and above. The ESP is complemented by a second more easily measured characteristic, the sodium adsorption ratio (SAR), which gives information on the comparative concentrations of Na^+, Ca^{2+} and Mg^{2+} in the soil solution. SAR is calculated as follows:

$$SAR = Na^+ / 0.5\sqrt{(Ca^{2+} + Mg^{2+})} \quad \text{..} (2)$$

Where;

$[Na^+]$ = Concentration of sodium in the soil solution (cmol/kg)

$[Ca^{2+}]$ = Concentration of calcium in the soil solution (cmol/kg)

$[Mg^{2+}]$ = Concentration of magnesium in the soil solution (cmol/kg l)

SAR of a soil extract takes into consideration that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions.

Using the three indices (EC, ESP and SAR) and soil pH, salt affected soils are classified as saline, saline-sodic and sodic (Table 2).

Table 2: Properties of normal soils compared to saline, Saline-sodic and sodic soils

Soil	Common pH	EC (dS/m)	SAR
Normal	6.5-7.2	< 4	< 13-15
Saline	< 8.5	> 4	< 13-15
Saline-sodic	< 8.5	> 4	> 13-15
Sodic	> 8.5	< 4	> 13-15

Source: Brady, 1990

2.2.3 Saline soils

Saline soils contain a concentration of neutral soluble salts sufficient to interfere seriously with the growth of most plants. The electrical conductivity (EC) of a saturated extract of the soil solution is more than 4 dS/m, the ESP is less than about 15, and the pH usually is less than 8.5 because the salts are neutral and SAR is less than 13. Saline soils have been called white alkali soils because a surface incrustation if present is white in colour (Brady 1990; Gupta and Abrol, 1990; Rucroft and Amen, 1995). Saline soils are also classified into four classes depending on total soluble salt and EC (Table 3).

Table 3: Salinity classes used by USDA

Class	Total soluble salts (TSS %)	EC (dSm)	Description
0	0-0.15	0-4	salt free
I	0.15-0.35	4-8	slightly affected
II	0.35-0.65	8-15	moderately affected
III	> 0.65	> 15	strongly affected

Exchangeable sodium percent and sodium adsorption ratio are closely related in most soil
Source: FAO Irrigation and Drainage No.7. 1971

2.2.4 Saline - sodic soils

Saline-sodic soils contain appreciable quantities of neutral soluble salts and enough sodium ions to seriously affect most plants. The ESP is greater than 15 and EC of saturated extract is more than 4 dS/m. The pH is commonly 8.5 or less because of the presence of neutral salts. SAR is at least 13 in these soils (Brady, 1990; Donahue *et al.*, 1990).

2.2.5 Sodic soils

Sodic soils don't contain a great amount of soluble salts. The detrimental effects of these soils on plants are due not only to the toxicity of Na^{+}, HCO^{-}_{3} and OH^{-} ions but also due to the reduced water infiltration and aeration. The pH is largely due to hydrolysis of sodium carbonate.

$$2Na^{+} + CO^{-2}_{3} + H_2O \rightarrow 2\,Na^{+} + HCO^{-}_{3} \quad \text{.................................(3)}$$

The ESP of sodic soil is decidedly more than 15 and the SAR is more than 13. The pH always is above 8.5, oftenly rising to 10.0 or higher. The EC of saturated extract is less than 4 ds/m (Brady, 1990; Rowell, 1994).

In nature, strongly alkaline soils invariably have high sodicity. On the other hand, a sodic soil with solutions of high SAR does not necessarily mean a high pH (Kelly, 1948; Beek and Breeman, 1973). Sodic soils are classified into several groups depending on ESP.

Table 4: Alkalinity classes

ESP (%)	Description
< 10	alkaline free
10-20	slightly alkaline
20-30	moderately alkaline
30-50	strongly alkaline
> 50	very strongly alkaline

Source:Kenya Soil Survey Staff, 1987

2.3 The effect of salinity and sodicity on plants

High concentration of salts in solution inhibits the growth and development of plants. The effects differ depending on climate, soil water, salt composition, kind of the plant and the plant stage of development (Landon, 1991).

Fitter and Hay (1987) indicated that there are three main effects on plant growth;

1. Direct toxicity
2. Ionic imbalance and
3. Reduction of water by lowering the osmotic pressure.

The third effect is termed as physiological drought because plants are affected by lack of water even though the water content of the soil is apparently adequate for crop needs.

In sodic soils where the dominant ion is Na^+, active sodium exerts effect on plant growth by dispersing the soil. ESP levels, as low as 10 in fine textured (clayey) soil and 20 in coarse soil have been reported to be problematic. Colloidal dispersion makes the soil less permeable or even impermeable and causes it to form hard surface crust when dry. Soil structure in general is destroyed. The upper pores are filled with dispersed particles, and both air and water exchange into and out of the soil are reduced. The hardened crusts can physically inhibit seedling emergence (Donahue *et al.*, 1990).

Salts do not stop plants from growing and acquire water, they can regulate their osmotic potential, so the capacity of higher plants to grow satisfactorily on salty soil depends on the number of interrelated factors, including the physiological constituent of the plant, its stage of growth and its rooting habits (Brady, 1990; Davidson and Gulloway, 1993).

Plants vary in their tolerance to exchangeable sodium. Many deciduous fruits can be injured by as little as 5% ESP. Citrus, stone fruits, and black berries are among the sensitive ones, but grapes are quite sodium tolerant (Landon, 1984). Table 5 shows the salt tolerance level for some crop commonly grown by farmers in Eastern Africa farmers.

2.4 Effect of salinity and sodicity on soil properties

Saline and sodic conditions reduce the value and productivity of soils in arid and semi arid regions of the world. This is due to their effect on the chemical and physical properties of the soil. The main chemical processes occurring in soils as a result of sodicity and salinity as follows:

1. Ionic exchange between cations in irrigation water and those present on the soil exchange complex
2. Dissolution and precipitation of calcium carbonates
3. Weathering of the primary minerals in exposed rocks of the earth's crust, and
4. Upward movement of ions through capillary activity.

Among these processes, cation exchange is the most important process governing the accumulation of excessive sodium during irrigation (Michell *et al.*, 1978).

The accumulation of disperse cations such as sodium in the soil and exchange phase affects soil physical properties such as:

1. Structural stability
2. Hydraulic conductivity and
3. Infiltration rate

Table 5: Crop Salt tolerance levels using Surface irrigation

Crop	Yield potential for EC(dSm^{-1} at 25^0c) values shown								
	100%	90%		75%		50%		No yield	
	EC_e[1]	EC_w[2]	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e
<u>Field Crops</u>									
Cotton	7.7	5.1	9.6	6.4	13.0	8.4	17.0	12.0	2.7
Sorghum	4.0	2.7	5.1	3.4	7.2	4.8	11.0	7.2	1.8
Rice (paddy)	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11.5
Corn	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Cow pea	1.3	0.9	2.0	1.3	3.1	2.1	4.9	3.2	8.5
Beans	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
<u>Vegetables crops</u> Tomatoes	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	12.5
Spinach	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15.0
Cabbage	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12.0
Potato	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10.0
Onion	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.5

Source: Landon, 1991

1. EC_e = Electrical conductivity of saturated extract
2. EC_w = Electrical conductivity of the irrigation water.

2.4.1 Effect of sodicity on soil structural stability

Structural stability is a measure of the ability of a soil to retain its structural form over time against forces such as continuous cultivation, wheel traction and impact of rainfall. Structural stability has often been used as an index of soil structure (Dickson *et. al.*, 1991). Soil structure, both in its form and its stability, has a direct impact on a wide range of processes that influence plant growth (Hamblin, 1985; Letey, 1985). Structural form is the arrangement of solid and voids in space, which affects physical properties such as plant, available water, aeration and temperature.

From the point of view of soil management, soil structure may be regarded as 'the property of a soil that regulates a continuous array of various sizes of interconnected pores, and their stability and durability, governs retention and movement of water, regulates gaseous diffusion from and into the atmosphere and controls root proliferation and development (Lal, 1979).

Aggregates Stability, and hence that of pores systems, depends to a large extent upon the attractive and repulsive forces arising from inter rmolecular and electrostatic interaction between the soil solution and soil particles. When a dry aggregate is placed in contact with water, the interactive forces lower the potential energy of the water molecules. The resulting release of energy is used partly for the structural transformation of the clay surface in the aggregates, the rest being released as heat. Slaking, swelling and clay dispersion are the major mechanisms by which the aggregates, and hence soil structures are damaged during these transformations (Rengasamy and Olsson, 1991).

Saline and sodic soils structure has poor physical properties i.e. poor structure due to high pH and high exchangeable sodium percentage. At an ESP of between 10 and 15, clay soils are liable to swell and disperse causing a deterioration of soil structure particularly when the soil solution is diluted by rain-water or when quality (low salinity) irrigation water is applied (Shainberg and Letey, 1984).

The deterioration of soil structure has several important effects such as:

1. Heavy-textured soils become non-sticky and plastic when wet and hard when dry, leading to cultivation problems
2. Hydraulic conductivity is decreased and irrigation water moves more slowly through the soil leading to ponding on the soil surface. It becomes more important to leach salts out of the profile.

3. If the soil surface becomes saturated during irrigation, air entry is restricted and anaerobic condition may develop, causing denitrification and the production of plant toxins and;
4. The soil surface becomes particularly sensitive to the mechanical effects of rain or irrigation water. This leads to capping which reduces the infiltration rates (Shainberg, 1985).

2.4.2 Effect of salinity and Sodicity on hydraulic conductivity

The hydraulic conductivity of a soil is the ability of a soil to conduct water. It is defined as the volume of water, which will pass through unit cross-sectional area of a soil in unit time, given a unit difference in water potential (hydraulic head).

Water flow as soils takes place in accordance with Darcy's equation

$$K_{sat} = (Q/At).(L/H) \quad \ldots\ldots\ldots (4)$$

Where;

K_{sat} = Saturated hydraulic conductivity of the horizon (cm/hr)

Q = Volume of water passing through the soil in time t

A = Cross sectional area of the soil sample (cm^2)

L = length of the soil sample (cm)

H = Effective hydraulic head that is equal to (L + h) where h is the height of the water column above the soil core surface.

Hydraulic conductivity (HC) is usually measured experimentally and includes soil properties (tortuosity, pore size distribution, etc.) and percolating fluid properties (viscosity).

Permeability of soil to water depends on ESP of the soil and on salt concentration of the percolating solution (Frenkel *et al.*, 1978; McNeal *et al.*, 1966, 1968; Quirk and Schofield, 1955; Yaron and Thomas, 1968).

The higher the proportion of ESP and the lower the electrolyte concentration of the percolate, the larger the HC reduction.

The effects of salt concentration and ESP on soil HC vary depending on soil properties such as clay content, clay mineralogy, iron oxide or aluminum oxide content, organic matter content and bulk density.

The reduction in soil permeability can be explained through two mechanisms. Quirk and Shofield (1955) suggested that the swelling of clay particles, which increases with an increase in clay sodicity, could result in blocking or partial blocking of the conducting pores. Rowell *et al.* (1969) suggested that initial reduction of HC could be attributed to swelling.

Quirk and Shofield (1955) proposed deflocculation and dispersion as the second main mechanisms. The plugging of the soil pores by dispersed clay particles is another mechanism by which HC of sodic soil is reduced. Clay dispersion is very sensitive to low level of sodicity and increases markedly at the low level of ESP range.

The importance of dispersion in affecting soil permeability was recognized by Felhendler *et al* (1974); Frenkel *et al.* (1978); Pupisky and Shainberg (1979), Rhoades and Ingvalson (1969); and Sahinberg *et al* (1981 a & b). Park and O'Connor (1980) found that dispersing rather than swelling, was the dominant mechanism reducing HC.

A major concern in irrigated agriculture is the maintenance of sufficiently high soil permeability for salinity control. Indices of soil permeability are HC and infiltration rate (IR), both of which commonly depend on ESP of the soil and salt concentration of the percolating solution.

Increasing SAR and decreasing EC of the soil solution decrease soil permeability (McNeal ,*et.al*, 1966). Soil HC can be maintained, even at high ESP values, provided that the EC of irrigation water is above a critical (threshold) value (Quirk and Schofield, 1955).

2. 4.3 Effect of sodicity and salinity on infiltration rate

The infiltration rate (IR) is defined as the flux of water flowing into the profile per unit surface area of soils and this flux has the dimension of velocity. IR is one of the more important processes on the soil phase of the hydrological cycle. The rate of this process relative to the rate of water supply determines how much water will enter the root zone, and how much, if any will run off. In general, the soil infiltration capacity initially is high, particularly when the soil is dry, but tend to decrease monotonically until it asymptotically approaches a constant rate, the final infiltration rate or steady-state IR (Hillel, 1980; Shainberg, 1985). In soil having stable structure, decreases in infiltration capacity result from the inevitable decrease in the matric suction gradient, which occurs as infiltration proceeds (Baver *et al*., 1972; Hillel, 1980). This can also result from gradual deterioration of soil structure and the formation of surface crust which are associated with clay dispersion (due to sodicity) and movement in the soil (Shainberg, 1985 ; Hillel, 1980).

The effect of soil sodicity (ESP) on the infiltration rate varies with texture, clay mineralogy, and $CaCO_3$ content. Infiltration is sensitive to low ESP. Reduction of the infiltration rate is caused mainly by the formation of crust on the soil surface and/or by the reduction of the hydraulic conductivity of the bulk soil (Ben-Hur *et al*., 1987; Shainberg and Letey, 1984). Surface crust are characterized by greater density, higher strength, finer pores and lower saturated conductivity than the underlying soil (Gal *et al*., 1984; McLntyne, 1958).

Marin and Banjamini (1977) found the crust turned as the impact energy of the water dropped and water surface stream break down the surface aggregates, compact the upper soil layer, and from the crust. In addition to physical break down of the soil aggregates, physical and chemical dispersion of soil clays can cause clogging of the pores immediately beneath the surface (Agassi *et al.*, 1981; Kazman *et al.*, 1983). On the other hand, swelling and dispersion of clay for aggregates that migrate and lodge in pores space greatly reduce the hydraulic conductivity of the bulk soil (McNeal *et.al.*, 1966; Park and O'Connor, 1980; Shainberg *et al.*, 1981 a&b).

Infiltration rate decreases with increase of SAR and with decrease of total cation concentration (Oster and Shroer, 1979). Oster and Shroer (1979) suggested that total cation concentration is a better parameter for the prediction of infiltration rate than SAR.

Fehendler *et al.* (1974) found water with intermediate SAR values of 5 to 10 and a low solution electrolyte concentration caused soil clay particles to dispersed and reduced the hydraulic conductivity and thus infiltration rate.

2.5 Water Quality for agriculture

In general, the purer the water, the more valuable and useful it is for riverine ecology and for abstraction to meet human demands such as irrigation, drinking and industry. Conversely, the more polluted the water, the more expensive it is to treat to satisfactory levels (Dougherty and Hall, 1995).

Soil may be maintained in good condition (non-saline, non-sodic) by the use of good quality irrigation water and adequate leaching. The criteria of quality are low salinity, a low ratio of Na^+ to $Ca^{2+} + Mg^{2+}$ to prevent the development of sodicity, and small concentrations of those ions which may have specific toxic effects (Rowell, 1994).

The most widely used classification of irrigation water quality has shown in Table 8. The suitability of water, from quality standpoint, is determined by its potential to cause problems and related to the special management practices needed or the yield reduction caused. Solution in most cases is at the farm level, meaning the evaluation must be done in terms of the specific use and potential hazard to crop production under the existing management capability and farm situation (Richard, 1954).

2.6 Water quality associated problems

Water quality problems though often complex, generally occur in four categories, namely salinity, permeability, toxicity and miscellaneous. Each of the problems is discussed briefly below as presented by Ayers and Westcot (1985).

2.6.1 Salinity problems

Salinity problems related to water quality occurs if the total quantity of salts in the irrigation water is high enough that salts accumulate in the crop root zone to the extent that yields are affected. If excessive quantities of solution salts accumulate in the root zone, the crop has extra difficulty in extracting enough water. Uptake by the plant can result in slow or reduced growth and may also be shown by symptoms similar in appearance to those of drought such as early wilting. In highly saline soils, the level of available water may be very low or even zero. High salt content in irrigation water may also alter the soil pH to an extent that plant nutrients become unavailable or insoluble thus curtailing plant growth.

2.6.2 Permeability problems

Permeability refers to the case with which water enters and percolates down through the soil, and is usually measured and reported as an infiltration rate. An infiltration rat of 2.5 mm/hr is considered low while 12 mm/hr is relatively high (Ayers and Westcot, 1985). The permeability problems related to water quality occurs when the rate of water infiltrated into and through the soil is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced. Poor soil permeability makes it more difficult to supply the crop with water and may greatly add to cropping difficulties through crusting of seed beds, waterlogging of surface soil and accompanying diseases, salinity, weed, oxygen and water problem (Ayers and Westcot, 1985).

2.6.3 Toxicity problem

Toxicity problems are different from the salinity and permeability problems in that toxicity occurs within the crop itself as a result of the uptake and accumulation of certain constituents from irrigation water and may occur even though salinity is low. The toxic constituents of concern are sodium, chloride or boron. They can reduce yield and cause crop failure. Toxicity problems of sodium and chloride can occur with almost any plant if the concentrations are high enough.

Boron is one of essential elements for plant growth but is needed in relatively small amount, if excessive, then it becomes toxic. Boron toxicity is usually associated with boron in the irrigation water. The sensitivity to boron affects a wide variety of crops.

2.6.4 Miscellaneous problems

Various other problems related to irrigation water quality occur with sufficient frequency that they should be specifically noted. These include excessive vegetation growth, lodging and delayed crop maturity resulting from excessive nitrogen in the water supply, white deposits on fruit or leaves due to sprinkler irrigation with high bicarbonate water and suspected abnormalities indicated by an unusual pH of the soil.

2.7 Reclamation of salt affected soils

The reclamation of salt affected soils involves the removal of excessive salts from the root zone. Saline soils are relatively easy to reclaim for crop production if adequate amount of low salt irrigation water is available and if internal and surface drainage is feasible. After reclamation, only good quality water should be used for irrigation with proper management. The reclamation of sodic and saline-sodic soils is a difficult matter than the reclamation of saline soils. When soil contains excessive amount of exchangeable sodium, the soil clays are liable to swell and disperse causing a deterioration of soil structure and become impervious to water, so chemical and/or organic amendment are needed (Follet.*et.al*;1981; Rowel, 1994). Chemical amendment such as sulfur (S), sulfuric acid (H_2SO_4), ferric sulfate [$Fe_2(SO_4)_3.H_2O$], lime sulfur (9% Ca + 24% S), calcium chloride ($CaCl_2.H_2O$) and calcium nitrate [$Ca(NO_3)_2.2H_2O$]. The organic amendment such as crop residue, manure, filtermud.

The purpose of an amendment is to provide soluble calcium to replace exchangeable sodium. The fundamental reaction is as follows:

Na- clay +Ca (in solution) = Ca – clay + Na^+ (in solution)....................(5)

The Ca-clay is normal and desirable state - calcium stabilized from gypsum replaces sodium, and sodium is leached out (Follet *et.al*; 1981).

As chemical amendments are expensive and require expertise in application. The reclamation procedures for saline-sodic soil using chemicals usually consist of a series of stages; reclaiming the surface soil and then adding chemicals to reclaim the soil to greater depths. Sometimes it requires leaching with good low salt irrigation water with SAR = 0.6, pH 7.5 (Donahue *et al.*, 1990; Follet *et al.*, 1981).

Organic amendment is cheap, available and easy to handle by traditional farmers. Interest has increased in the land application of organic waste, for many reasons, including supply of nutrients, soil improving and conditioning and energy conservation (Bewick, 1980; Loehr, 1977). Nevertheless present day emphasis on pollution control has encouraged use of manure on farm (Abot and Tucker, 1973; Dougherty and Hall, 1995). Moreover, it is evident that the organic matter, including manure, has a beneficial effect on soil aggregation and hence, it imporous tilth and permeability (Magistad and Christiansen, 1944).

2.8 Organic amendments

Organic amendment such as crop residues, animal manure, logging and wood residue, various industrial organic wastes, food processing and fibre harvesting wastes are naturally occurring compound that are used as additives to improve soil physical condition and/or plant nutrition (Brady, 1990; Donahue *et.al*; 1990; Follet *et al.*, 1981; Chen and Avnimelech, 1986).

2.8.1 Functions of organic mater in the soil

Organic residues from plants and animals, which are on or in the soil, are beneficial in the following ways:

1. Serving as the principal storehouse for anions essential for plant growth such as nitrogen, phosphates, sulphates, borates, molybdates and chlorides.
2. Increasing the cation exchange capacity of a soil by a factor of 5 to 10 times that of clay. This is true for humified organic matter (humus). More available nutrient cations such as ammonium, potassium, calcium and magnesium are thus adsorbed by humus.
3. Buffering the soil against the rapid change due to acidity, alkalinity, salinity, pesticides and toxic heavy metals.
4. Protecting the surface soil against erosion by water and wind by reducing the impact of rain drops on soil peds and clods, increasing infiltration, reducing water runoff, increasing the soil's total and available water holding capacity and increasing surface wetness.
5. Also reduces water and wind erosion by protecting soil peds against destruction especially by high intensity storms.
6. Supplying food for beneficial soil organisms such as earthworm, symbiotic nitrogen fixing bacteria and mycorrhizae (beneficial fungi).
7. Reducing extremes of soil surface temperature. This is especially true of organic residue use as surface mulch.
8. Decreasing surface crust formation by decreasing the soil dispersing of beating rain drops.

9. Reducing the crystallization and hardening of the plinthite (laterite) layer of soils in the humid tropics that are rich in soluble irons and aluminum crystallization Organic matter reduces hardening also by maintaining more uniform soil temperature and moisture.

10. Supplying to growing plants, as organic residues decompose, small quantities of all essential plant nutrients, usually in time-sequence harmony with the needs of the plants.

11. Making phosphorous and macronutrients more readily available on a wide pH range. This is a function especially of soil humus to resistant decomposition products of soil organic matter.

12. Increasing the application of selected herbicides

13. Decreasing the bulk density of the soil. Tillage pan in naturally indurate horizons in soils may be so dense as to reduce the rate of infiltration, decreasing water storage capacity, and restrict normal root development (Follet et al., 1981).

2.8.2 Manure as a source of organic mater

Manure is by nature organic. Their organic matter is attacked and transformed by microorganisms when returned to the soil. Much of the carbon is converted to carbon dioxide and make no long term contribution to the organic matter converted to humus, a black or dark brown colloidal, very complex organic material which remain in the soil. Humus is a very valuable soil component, which increases the ability to hold water available to the plant, and through its very high cation exchange capacity reducing the leaching of nutrients.

All manure make some contribution to long-term soil fertility and maintenance of humus in the soil (Simpson, 1986). The first crop following the application recovers only one fifth to one half of the nutrients supplied by animal manure. Much of the remainder is held in humus-like compounds subjected to very slow decomposition. Thus, the humus-like compounds in manure will have continuing effects on soils, years after application (Brady, 1990).

In fact a very large amount of manure needs to be added to have significant long-term effects on the organic matter content of the soil. The reasons for this are the very high water content of manure and the loss of organic matter during the decomposition in the soil. Even bulky-straw based farm yard manure contain about 75% of water and slurries more than 90% such that one ton of these manure will add only 250 kg or 100 kg of organic matter respectively (Simpson, 1986).

2.9 Animal manure

For centuries the use of farm manure has been synonymous with a successful and stable agriculture in a semi arid area (Robert *et. al*., 1990). It is considered as a principal source of nutrients available for the crops. This provides a means of recycling nutrients, where animals have access to forage outside the cropland, it provides a means of collecting nutrients from the surrounding area. Not only does manure supply organic matter and plant nutrients to the soil but it also has beneficial effects on both the physical properties and chemical fertility of the soil (Brady, 1990; Robert *et. al*., 1990).

In comparison to chemical fertilizers, all manure supplies relatively small quantities of plant nutrients per unit of dry matter. One comparison not usually made is the macronutrient content of manure, which is usually higher in manure than in chemical fertilizers to which manufactured fertilizer have not intentionally added. Manufactured fertilizers have a high salt content (some are 100% soluble salt) than do manure (about 6-15% total soluble salts in beef/dairy cattle manure). Salt in form of sodium chloride is fed to most classes of livestock to increase appetite and reduce kidney stones. Much of this salt is avoided in manure (Donahue *et al.*, 1990).

2.9.1 Composition of animal manure

Variation in composition of animal manure are the result of differences among kind s of animal and the kinds and amounts of feeds they consume (Table 6).

Table 6: Typical composition of selected animal manure (dry weight)

Constituents	Beef/dairy (%)	Poultry (%)	Sheep (%)
Nitrogen (N)	2-8	5-8	3-5
Phosphorous (P)	0.2-1.0	1-2	0.4-0.8
Magnesium (Mg)	1.0-1.5	2-3	0-2
Potassium (K)	1.0-3.0	1-2	2-3
Sodium (Na)	1-3	1-2	0.05
Total soluble salts (TSS)	6-15	2-5	1-2

Source: Donahue *et al.*, 1990

2.10 Effect of organic amendments on yields

Biologically, manure has many attributes. It supplies a wide variety of nutrients along with organic matter that improve the physical characteristics of soils. Inspite of its high labour and handling costs, manure remains a most valuable soil organic resource (Brady, 1990).

The application of organic materials stimulates the growth and activity of heterotrophic microbial population. This in turn may affect plant growth through either the supply of biochemically important substances or through the effects of the saprophytic population of soil microorganisms causing plant diseases (Chen and Avnimelech, 1986).

Manure is the effective source of nutrients for most crops, especially those with relatively high nitrogen requirements. Crops such as corn, sorghum, small grains, and grasses respond well to manure as do vegetables and ornamental plants (Brady, 1990; William, 1992).

Ikombo (1984) observed that maize crops on plots with farm yard manure were more resistance to drought than those plants under fertilizer.

The application of organic materials has a potential to increase plant yield to an extent above that based on the application of fertilizer equivalent nutrients. Kilewe (1987) showed that 40 tonnes/ha of air dry manure yielded a crop as good as that obtained from the highest input of fertilizer which supplied 120 kg N and 40 kg P per hectare.

Hussain *et al.* (1988) found that farm yard manure application resulted in a significant yield increased of rice compared with barseem and wheat.

Corn yield increases from the contribution of N in livestock manure have been documented by research in New York, where the main effort of manure application was greater in the second and third year than on the first year (William, 1992).

In Sudan, Yousif (1983) studied the effect of chicken manure, dry sewage and farm yard manure on faba bean on saline-sodic soil. Chicken manure, farm yard manure and the control treatments gave 1.4 tonnes/ha, 1.3 tonnes/ha and 1.0 tonnes/ha of seeds. The yield was found to increase significantly with the rate of manure, while in Kenya, Gibbered (1995) found highly significant increases in both cereal and legume yield under application of animal manure.

2.11 Effect of organic amendments on soil properties

Manure, through its contribution to the soil organic matter content (OM), is considered to have a significant influence on the physical, chemical and biological properties of soils.

Organic matter incorporated into the soil surface can affect its structure, as denoted by porosity, aggregation and bulk density, as well as causing an impact as expressed in terms of content and transmission of water, air and heat, and soil strength. Nutrients are mineralized during organic matter decomposition; C, N and cation exchange capacity (CEC) increases following organic matter additions. Other soil chemical properties such as pH, electrical conductivity, and redox potential are changed. The soil biosystem can be altered by addition of new energy sources for organisms, reflected by changes in micro-and macro-biological populations, which influence synthesis and decomposition of microbiology-produced soil humic substances, nutrient availability, interaction with soil inorganic components and other exchange with soil physical and biological properties (Chen and Avnmelech, 1986).

2.12 Effect of organic manure on saline and sodic soils

The increasing intensive use of soils, particularly those that are irrigated (which have a continuous addition of salt in irrigated water), is creating new type of salted soils that must be reclaimed.

The use of organic amendment is a method of reclaiming problematic soils for crop production. Problems of soil include water logging, salinization, alkalization, chemical impairment, desertification and erosion. From literature, the application of organic manure will improve the physical and chemical properties of problematic soils. Unfortunately no literature exists concerning use of organic matter for reclamation of saline and sodic soils in East Africa. This is because very little research has so far been carried out concerning this problem.

Somani (1991) studied the effect of amendments (gypsum, *sesbania aculeata*, FYM, poultry manure or rice husk) on growth, nodulation and nitrogen fixation by berseem (*Trifollum alexandrinum*) on a calcareous saline-alkali soil in India. The results gave the greatest soil improvement compared with the control and germination increased from 50.3% (control) to 89.3% and the number of effective nodules rose from 18.1% to 85.5% with *sesbania aculeata*. Gypsum was less effective than organic manure.

The effect of farm yard manure, gypsum and zinc on the performance of maize and physical properties of sodic soil in Hisar, India was studied by Menta *et al.* (1994). They found that gypsum was the most effective of the three treatments in improving dry matter yield of maize. The highest increase was at 25% gypsum requirement. Farm yard manure increased yield up to 2.5% and improved the physical condition of the sodic soil.

Ghyl *et al.* (1995) compared gypsum (30 tonnes/ha), sulfuric acid (1.2 tonnes/ha) and farm yard manure (16 tonnes/ha) for reclamation of saline sodic soil under irrigated rice and Cameron grass in Para Iba, Brazil. The amendment had no significant effect on crop yield. At the end of three years, a marked reduction was observed in exchangeable sodium percent and electrical conductivity of the saturated extract irrespective of treatments.

More (1994) conducted a field experiment at Parbhani and Maharashtra in India to study the effect of farm waste and organic manure (press mud, dried biogas slurry, FYM and wheat straw) on soil properties, nutrient availability and yield of rice and wheat on sodic vertisol. All treatments increased the yield of both crops significantly over the control. In general, all the treatments decreased the soil pH and ESP of the soil. The infiltration rates improved due to application of organic waste and manure.

The effects of soil amendments (Farm yard manure and pressmud both at 20 at 40 tonnes/ha, gypsum at 4 and 8 tonnes/ha and sulfur at 2 and 4 tonnes/ha on the chemical properties were investigated by Bose *et .al.*; (1992) in Mysore, India. Amendments reduced soil pH and ESP considerably in all treatments, whereas EC increased. The effects of the treatments were prominent in surface soil and decreased with depth. The effectiveness of the treatments were in the following order: sulphur > gypsum > pressmud > farm yard manure > control.

A green house experiment was conducted in India to study the effect of different organic materials (green manuring with *sesbania aculeata*, farm yard manure, rice husk) and different levels of gypsum (to supply 2, 4 and 6 meq Ca/litre of sodic water in controlling the accumulation of Na in a calcareous sandy loam soil receiving sustained sodic irrigation under a rice-wheat-maize system.

Incorporation of organic manure decreased the precipitation of Ca and carbonates, increased the removal of Na in drainage water, decreased pH and exchangeable sodium percentage (ESP) in the soil and improved crop yield (Sekhon and Bajwa, 1993).

In Sudan, Gaffer *et al* (1992) studied the effects of organic manure on SAR of saline sodic soil. They found that application of farmyard manure decreased the SAR of saline sodic soils.

A field experiment on the reclamation of fine-textured saline-sodic (non gypsiferous soil in Bhawal, Pakistan was carried out by Hussain *et al.* (1988) using gypsum, sulfur, pressmud, farm yard manure and Diplachne fusca as reclamation treatments. It was found that farm yard manure application resulted in a significant yield increase of rice (compared with barseem and wheat crops. Gypsum applied at 50% of gypsum requirement (GR) was as effective in increasing yield as that of applied at 100% GR. The interaction between farm yard manure and gypsum or sulfur was not statistically significant. The EC of soil gave high correlation with crop yield compared with sodium adsorption ratio (SAR) of soil.

Bharambe *et al.* (1990) studied the effects of different soil amendments (paddy straw, sawdust, farm yard manure, gypsum and green manure) on some physical and chemical properties of alkali soil under sorghum-wheat rotation in India. The results indicated that all treatments significantly increased crop yield, improved infiltration rate and reduced soil pH, EC and ESP compared with the control.

Five years field experiments were carried out by Lomte *et al.* (1993) in Parbhain, India to study the change in soil physical properties affected by intercropping sorghum with legumes. Application of 1 tonnes/ha FYM/ha to sorghum, or intercropping with pigeon pea or cow pea increased infiltration rates, hydraulic conductivity, pH, organic carbon and number of stable aggregates; and decreased bulk densities compared with sorghum alone.

2.13 Effect of organic manure on soil physical properties

Organic amendments are known to have favourable effects on soil physical properties. Farm yard manure has been found to improve bulk density, resistance penetration, infiltration rate, pH, organic carbon, CEC and available N,P and K (Ganal and Singh, 1988). Literature is scarce on use of animal manure for reclaiming saline sodic soil in East Africa.

2.13.1 Bulk density

Bulk density is defined as the ratio of mass of oven-dry soil to its total volume (Rowell, 1994). Bulk density is an indication of the soil's physical condition. It is usually related to soil porosity, texture, hydraulic conductivity, infiltration rate, aggregation, compaction and organic matter content (Clapp *et. al.*, 1986)

Bulk density is one of the measurable functions of soil structure. Continuous cultivation tends to raise the bulk density, i.e. to compact the soil and thus reduce infiltration (Hafez, 1974).

Khaleel *et al.* (1981) surveyed results of 42 field experiments dealing with effects of manures and composts on soil properties. A highly significant correlation was found between the increase in soil organic carbon by manure application and the lowering in percent of bulk density of the soil.

An interesting finding is given by Petterson and Von Vistinghausen (1979) reporting that the subsoil was compacted in plots receiving only inorganic fertilizer for a period of 20 years. The subsoil on the manure plots had a better structure and a lower bulk density Such an effect on the deep subsoil layers would indicate that organic fraction migrate downward and are active below the plough layer in the soil. Such migration could be due to the movement of earthworms (Chen &Avnimelech, 1986).

2.13.2 Aggregation and aggregate stability

Aggregation, or the binding together of individual soil particles, gives rise to what is known as soil structure. Typically, a well-structured soil i.e. high level of strongly bound aggregates has greater resistance to the force of erosion and has improved air-water relationship. In general hydraulic conductivity, infiltration rate, air diffusivity, surface drainage and ease of root penetration will increase with increasing aggregation

Improving or increasing aggregation is more desirable on finer textured soils such as silt loam, clay loams and clays. A fine textured soil will behave much like a coarse one with respect to water infiltration and drainage, if its clay and silt particles are bound together into aggregates. Modern day farming technique, such as conventional tillage, row cropping and complete vegetation removal on some soils, can decrease the degree of aggregation at the surface and on more sensitive soils, can completely destroy surface soil structure.

The need to increase soil aggregation in many situations is apparent, however, the aggregates formed must be resistant to degradation by the force of water (e.g. rain drop and irrigation impact) and tillage operation (Chen and Avnimelech, 1986).

The addition of organic manure to soils has been found to be effective method not only to increase total aggregation but also increase the preparation of water stable aggregates.

Three years after a single application (50 kg/ha organic manure to a heavy clay soil, the soil percentage of water stable aggregates more than doubled (Vigerust, 1983).

Crumble stability of arable soils can usually be increased if regular application of farm yard manure is done, though the amounts required may be very large. Annual application of 35 tonnes/ha for a century have made a measurable increase in the crumble stability of Rothamasted soil (Russell, 1988).

On a very unstable fine sandy loam soil, 75 tonnes/ha annually did not affect the stability of the structure appreciably, but it gave a very large earth worm population which maintained aeration and drainage by the number of their burros (Russell, 1988).

2.13.3 Hydraulic conductivity

Hydraulic conductivity is the effective flow velocity or discharge velocity of water in the soil at unit hydraulic gradient (Rowell, 1994).

Shanmugan and Ravikumar (1980) showed that the application of 25 ton/ha of organic residues have improved physical properties such as hydraulic conductivity, infiltration rate, stability index and aggregate in red sandy loam soils.

Several studies have determined the maximum rate of water movement through soils, or saturated hydraulic conductivity. In all cases, hydraulic conductivity was increased significantly by the addition of organic manure. Increases in saturated hydraulic conductivity were generally greater for finer textured soil. Saturated hydraulic conductivity values continued to increase for a few weeks, but then decreased. This decline was thought to be due to clogging of pores by microbial decomposition products. When moderate rates of organic manure were added to loamy clay soil, saturated hydraulic conductivity increased and remained twice that of untreated soil for approximately one year (Morel and Guckert, 1983).

2.13.4 Moisture retention

The moisture content of a sample of soil is usually defined as the amount of water lost when dried at 105 °C (Landon, 1991). The water retention function is primarily dependent upon texture and structure (Satter and William, 1965; Macharia, 1982 and Sessanga, 1982). Storage of water by soils is a result of attractive forces between the solid and liquid phase. The solid (matrix) forces enable the soil to hold water against forces or processes such as gravity, evaporation and uptake by plant roots (Dekkev, 1991).

The addition of organic manure to soil increases water retention at both field capacity (30 kPa) and wilting point (150 kPa). The increase in water retention at various matrix potential of manure treated soil is probably due to the increase in total porosity, storage pores space, and water absorption capacity of organic matter (Chen and Avnimelech, 1986).

Kladivko and Nilson (1979) found that application of 56 kg/ha of anaerobic sludge to a blount silt loam soil caused an increase in both field capacity and wilting point of 14.9% and 14.7% respectively; whereas, the same application rate on a sandy loam soil increase these parameters by 17.1 and 51.7% respectively.

Khaleel *et al* (1981) found that approximately 80% of the observed variations in percentage increases in water retention at both field capacity and wilting point, could be explained by soil texture and increase in organic matter. This analysis indicated that with organic waste application to fine-textured soils increases in water retention at field capacity than at wilting point. This effect is probably the result of aggregation. A greater number of large size pores are produced which would not drain under gravity. In coarse textured soils, the percentage of sand present in the soils produced a large increase in water retention at wilting point than at field capacity, perhaps due to an increase in number of smaller pores not drainageable at wilting point.

Plant available water holding capacity (AWC) or the difference between moisture retained at field capacity and wilting point, increased with increasing organic manure application for medium and fine textured soils. Gupta *et al* (1977); and Kladivko and Nilson, (1979) found no significant increase in available water holding capacity even at an application of rates of organic manure as high as 450 kg/ha/yr.

Favourable effects of organic matter content on water retention and availability of water have been reported for many Incdian soils (Biswas *and Ali*., 1967, 1969; Somani and Saxeno 1976; Murali *et al*., 1979). Increase in organic matter content in soil generally results in improved water use efficiency through increased water retention in the root zone (Colloqium, 1988).

2.14 Chemical properties

Soil organic matter and added organic material not only act as a source of nutrients but also influence availability of nutrients. The influence of organic matter has been reviewed by Flaig *et al.* (1978); Stevenson (1982). They indicated an appreciable increase in the soil organic carbon content due to continued application of organic manure for several years.

Krishnamoorlhy and Ravikumar (1973) observed the increase of carbon exchange capacity of soil with basal dressing of organic manure compared with unmanured control.

In long term manure experiments, highest N build up was observed with application of organic manure and the optimal NPK dose (ICAR, 1986)

2.14.1 Soil organic matter

Soil organic matter refers to the organic fraction of the soil. It includes plant, animal and microbial residue at various stages of decomposition (Richard, 1954; Rowell, 1994). The original source of soil organic matter is plant tissue. Under natural conditions, the shoots and roots of trees, shrub, grasses and other native plants annually supply large quantities of organic residues. As these organic materials are decomposed and digested by soil organisms, they become part of the underlying soil by infiltration or by actual physical incorporation.

Animals are usually considered secondary sources of organic matter. As they attack the original plant tissues, they contribute waste products and leave their own bodies as their life cycle are consummated (Brady, 1990). Although soil organic matter is universally recognized for its effect in stabilizing soil structure, the mechanisms by which organic compounds improve soil aggregation and prevent clay dispersion are not fully understood (Baohua and Doner, 1993).

Chesire *et al* (1983, 1984) found that the aggregating effect of soil organic matter was due to its polysaccharide content, while Chaney and Swift (1984, 1986) described this effect to humic acid. They showed humic acid was capable of stabilizing soil aggregates under conditions where extracelluar polysaccharides were ineffective and that the stabilization had long term persist. Fartun *et al* (1989 a&b), however, observed the fraction most effective in increasing soil aggregation was a mixture of fluvic and humic acids. They also indicated that a higher content of carboxyl group in molecules farming fluvic-humic fraction would lead to formation of more stabilized soil aggregates. Results reported by Visser and Caillier (1988) contradicted the soil humic acids were not at all soil aggregation agents, but were dispersing agents.

The amount of organic carbon in the soil is very variable. Climate and vegetation are the most important factors affecting the soil organic carbon content under natural conditions (Brady, 1990).

Organic carbon is a major factor contributing to aggregation of soil properties. This favours soil structure by increasing total porosity and percent of micropores, decrease crust formation and reduces susceptibility to erosion. Organic carbon improves the hydraulic conductivity of soils as a result of balancing the macro and micro pores distribution (Sanchez, 1976).

Therefore reduction of organic carbon in soils is likely to lead to a higher percent of micro pores which do not favour rapid water flow (Juo and Lal, 1977; Aina, 1979; Lal 1979 and Mwoga, 1986). Hinesly *et al* (1982) and Lunt (1959) found that the application of fresh plant and animal residues increased the level of soil organic matter. Hohla *et al* (1978) found sludge application for 6 years to a Blount silt loam resulted in the composition of organic compounds towards that of sludge.

Christeren (1988) found mineral fertilizer and animal manure both increase the carbon content of the clay and silt fractions relative to unmanure samples.

Angers and N'Dayegamiye (1991) found carbon and nitrogen of whole soil samples increased with manure application.

Manure application can improve soil organic matter directly by promoting microbial activity and also indirectly by increasing crop productivity (N'Dayegamiye and Isfan, 1991).

2.14.2 Nitrogen

Of the various essential elements, nitrogen probably has been subjected to the most study, and for many good reasons still receives much attention (Hauck, 1984).

The amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large. Most soil nitrogen is unavailable to higher plants. Nitrogen is an important nutrient element that must be conserved and carefully managed.

Plants respond quickly to application of nitrogen. This element encourages above ground vegetative growth and gives a deep green colour to the leaves. It increases the plumpness of cereal grains and tends to produce succulence, a quality particularly desirable in crops such as lettuce and radishes. Nitrogen deficiency is evident when the older leaves of plants turn yellow or yellowish green and tend to drop off (Brady, 1990).

Duncomb *et a.l* (1983); Sabey (1980) and Sheater *et al.* (1979) found sewage sludge might supply a large portion of the N required for plant growth. Mineralised nitrogen from sludge derived organic matter may become available for plant uptake for several years after application.

Hohla *et al* (1978) found organic manure application to soils could influence the C/N ratio. Sludge addition for six year Blount silt loam increased the C/N ratio from 9.4 to 10.8, measured two years after application.

Aggarwal *et al* (1986) found the application of organic manure also maximized available nitrogen. William (1992) found animal manure was an important source of nitrogen for crop production in many areas, but efficient management of manure is critical to improve the economics of manure. Corn yield increases from contribution of N in livestock manure have been documented by many researchers (Khalseur and Guest, 1981; Magdoff and Amadon, 1980; Montavalli *et al*, 1981; Beaucham, 1983; Makenzie and Xie, 1986 and Miller and Makenzie, 1978).

2.14.3 pH

The pH is determined as the logarithm of the reciprocal of H^+ ion activity or symbolically

$$P_H = -\log 1/AH^+ = -\log AH^+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where;

AH^+ = the hydrogen ion activity in moles per litre Tisdale *et al*, (1990).

The soil pH significantly affects the availability of most of the chemical elements of importance to the plants and microbes. Plants vary considerably in their tolerance of acid and/or alkaline conditions. For example legume crops such as alfalfa and sweet clover grow best near neutral to alkaline soils (Brady, 1990).

Application of organic manure to soil may result in alterations in the soil pH. The magnitude change of the pH depends on many soil properties including texture, buffering capacity and length of time after the last manure application. Modification of soil pH is important also because trace metals become more plant available as the pH decreases and microbial activity decreases as the pH decreases below 6 or increases above 7 (Clapp *et al.*, 1986). Hinesly *et al.* (1982), King and Morris (1972) and Lunt (1959) have reported that soil pH decrease following sludge application.

2.14.4 Cation exchange capacity

Cation exchange capacity (CEC) is defined simply as the total sum of the exchangeable cations that a soil can adsorb. Sometimes it is called "total exchangeable capacity" and it is expressed in centimoles per kilogram (cmol/kg) of soil or of other adsorbing material such as clay (Brady, 1990).

The influence of organic manure on cation exchange capacity (CEC) depends on soil texture, initial soil CEC and the length of time from the last application. Increases in the soil organic matter may increase the CEC (Epstein *et al.*, 1976; Kladivko *et al.*, 1979; Lunt, 1959 and Mitchell *et al.*, 1978) and thus its capacity to retain nutrients.

Epstein *et al.* (1976) found in Maryland the CEC of untreated soil was low and it increased with increasing rates of sludge application.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Site characterization of the study area

3.1.1 Location

Two farms were studied at Kiboko, namely Joel Mbondo's farm (Site 1) and Albert Kyambo's farm (Site 2).

Site 1 is situated about 215 km South East of Nairobi. It is located about 10 km off the Nairobi-Mombasa highway and 15 km North East of Kiboko market (Figures 1 and 2). Site 2 is situated about 218 km South East of Nairobi. It is located about 3 km North East of Kiboko market and 0.5 km off the Nairobi-Mombasa highway at the Eastern portion of Makueni District (Figures 1 and 3).

3.1.2 Physiography

Site 1 is located on erosion plain with flat to undulating relief. The slopes generally increase to 8% near the streams. The soils are developed on Precambrian Basement System rocks mainly gneisses rich in ferro-magnesium minerals according to (Touber, 1983). Gneisses minerals include biotite hamblende, biotite and hamblende. Site 2 occurs on an alluvial plain with flat relief (slopes of less than 2%). The soils are developed as alluvial deposits derived from various rocks mainly Basement System rocks (gneisses) and recent lava flows. The physiography of the two sites is different.

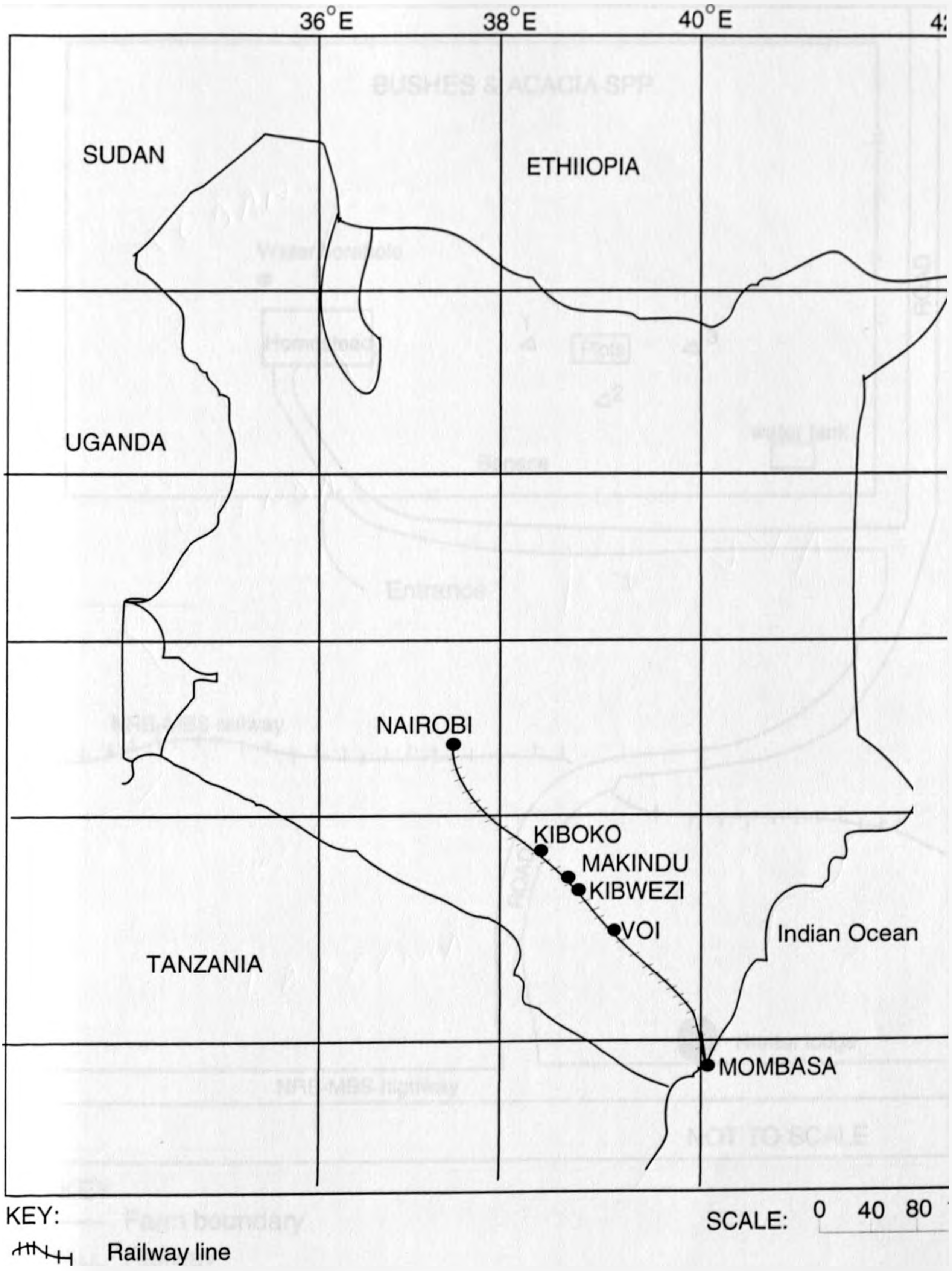


Figure 1: The approximate location of the study area on the map of Kenya

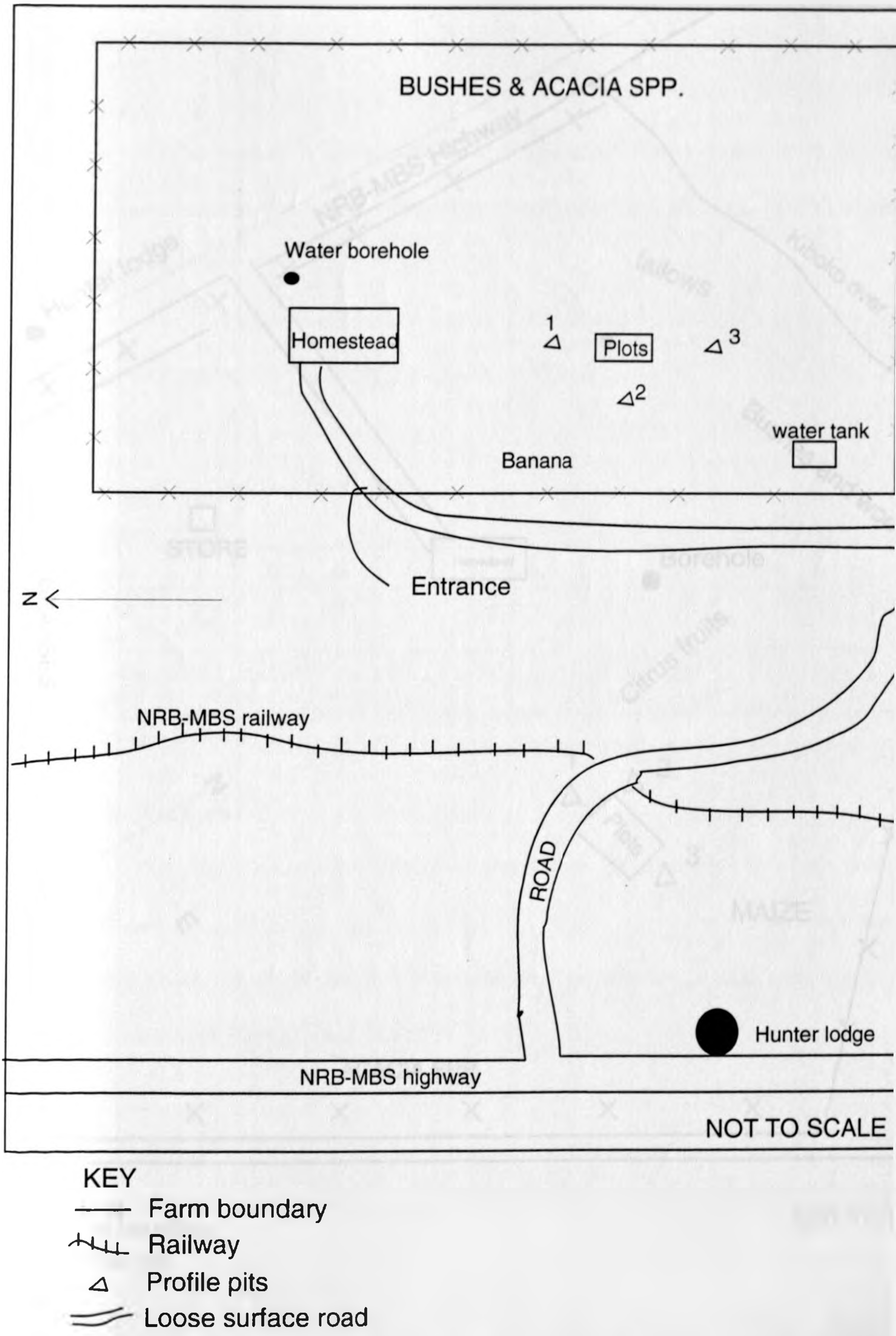


Figure 2: Sketch showing Mbond's farm and profile pits opened (S

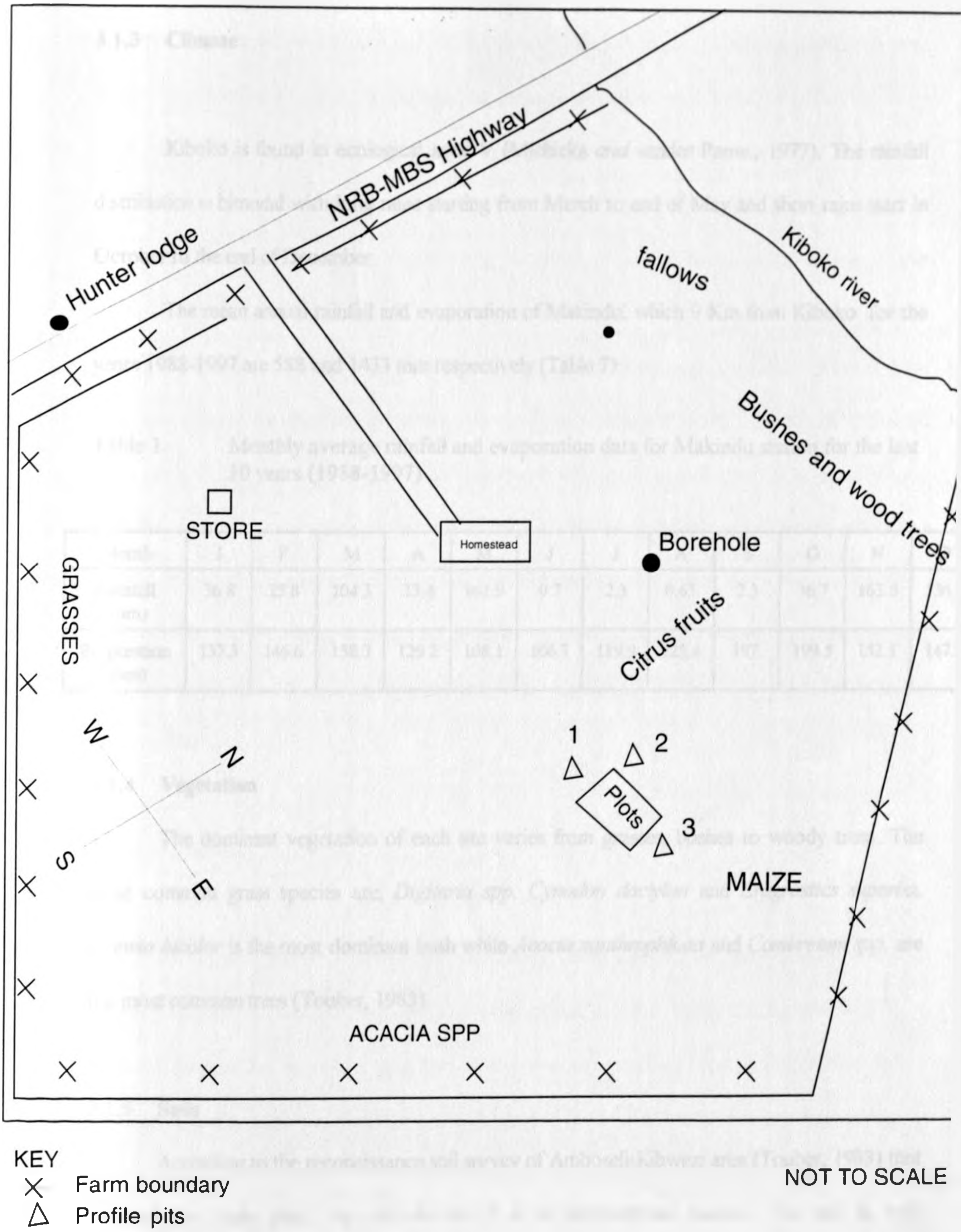


Figure 3: Sketch showing Mbond's farm and profile pits opened (Site 2)

3.1.3 Climate

Kiboko is found in ecological zone V (Michieka *and* vander Pauw., 1977). The rainfall distribution is bimodal with long rains starting from March to end of May and short rains start in October to the end of December.

The mean annual rainfall and evaporation of Makindu, which 9 Km from Kiboko for the years 1988-1997 are 588 and 1433 mm respectively (Table 7).

Table 1: Monthly average rainfall and evaporation data for Makindu station for the last 10 years (1988-1997)

Month	J	F	M	A	M	J
Rainfall (mm)	36.8	25.8	104.3	33.4	161.9	0.7
Evaporation (mm)	137.3	146.6	158.3	129.2	108.1	106.7

3.1.4 Vegetation

The dominant vegetation of each site varies from grasses, bushes to woody trees. The most common grass species are; *Digitaria spp*, *Cynodon dactylon* and *Eragrostics superba*. *Grewia bicolor* is the most dominant bush while *Acacia xanthrophloea* and *Combretum spp.* are the most common trees (Touber, 1983).

3.1.5 Soils

According to the reconaissance soil survey of Amboseli-Kibwezi area (Touber, 1983) that covered the study area, the soil at site 1 is a ferral-chronic luvisol. The soil is well drained, moderately deep to deep, dark red to dark reddish brown, friable sandy clay to clay. However according to this study the soil was taken to be well drained, moderately deep to deep, dark reddish brown to reddish brown, soft to slightly hard, friable sticky and plastic calcareous, sandy clay loam to sandy loam with moderate, medium sub angular blocky structure in places over coherent and weathering rocks. The soil was classified as chromo-haplic lixisol with sodic and saline phases (FAO-UNESCO, 1990) and Typic Khodustaff, sodic and saline phases (USDA, 1992). Michieka and vander Pauw (1977) surveyed the Kiboko range research station at semi detailed level and classified the soil at site 2 as vertic fluvisols, sodic phase. The soil was described as imperfectly drained, very deep, moderately calcareous, cracking and stratified soils of various textured and colour. Sampling done for this study at the site found the soil to be imperfectly to poorly drained, moderately to very deep, black to dark brown, hard, firm, sticky and plastic, sandy clay loam to clay with weak to moderate, medium to coarse subangular blocky structure. The soil was classified as a mollic and sodic solonchak (FAO-UNESCO, 1990) and Typic Solarthid sodic phase (USDA, 1992).

3.1.6 Land use

Land use at Kiboko is largely pastoral grazing, but in active transition to cropping as a result of migration of new settlers from the over populated uplands. The typical household of semi-arid Eastern Kenya owns a small area of land on which crops are produced and which partially supports variable numbers of cattle, sheep, and goats. The unreliability of rainfall makes crop production very risky. Crops mainly maize and pulses are produced in both seasons (McCown *et al.*, 1992).

3.2 Soil sampling

At each site, three profiles were dug to a depth of 1.5 meters if such depth could be reached. Detailed profile description was done according to Kenya Soil Survey manual (1987). Undisturbed core samples were collected from each horizon by driving a metal core ring vertically into the soil using a hammer. A shovel was used to carefully excavate the cores. This was done for each horizon in a stepwise manner. Six cores were sampled from each horizon. After labeling (date, site and depth of the horizons), each core ring was carefucovered by two lids and put in special cases. The samples were taken to the soil physics and salinity laboratory at the department of Soil Science for vertical saturated hydraulic conductivity, bulk density and moisture retention analysis.

Disturbed samples were collected from each horizon. About 5 kg of soil was placed in polythene bags. These soil samples were air dried in the laboratory, ground and passed through a 2 mm sieve to obtain the fine earth faction for chemical analysis. For organic matter analysis, the fine earth fraction was further passed through a 0.5-mm sieve. These disturbed samples analysis data were used for soil characterization.

3.3 Water sampling

Clean bottles were used for collecting water. The bottles were rinsed three times with the water to be sampled, then the water samples were collected for water quality analysis. The bottles were stoppered and the outside wall of the bottles dried, before each sample was labeled (date, source, name of the source). From the chemical analyses data the waters were classified according to Ayers and Westcot (1985).

Table 8: Guidelines for interpretation of water quality for irrigation

Irrigation problem	Degree of problem		
	No problem	Increasing problem	Severe problem
Salinity: (affects crop water availability)			
EC_w (dS/m)	< 0.75	0.75 - 3.0	> 3.0
Permeability: (affects infiltration rate into soil)			
EC_w (dS/m)	> 0.5	0.5 - 2.0	< 0.2
adj. SAR[1]			
Montmorillonite (2:1 crystal lattice)	< 6	6 - 9^2	> 9
Illite vermiculite (2:1 crystal lattice)	< 8	8 - 16^2	> 10
Kaolinite sesquioxide (1:1 crystal lattice)	< 16	16 - 24^2	> 2.0
Specific ion toxicity: (affects sensitive crops)			
Sodium[3,4] (adj. SAR)	< 3.0	3 - 9	> 9
Chloride[3,4] (meq/L)	< 4	4 - 10	> 10
Boron[3,4] (meq/L)	< 0.75	0.75 - 2.0	
Miscellaneous effects: (affects susceptible crops)			
NO_3-N (or) NH_4-N (meq/L)	< 5	5 - 30	>30
HCO_3 (meq/L) [overhead sprinkling]	< 1.5	1.5 - 8.5	>8.5
pH	[Normal range 6.5 - 8.4]		

Source: Ayer & Westcot. 1985

1. adj. SAR mean adjusted sodium adsorption ratio and can be calculated using the procedure in (Appendix 10)
2. Use the lower range if EC_w (dS/m) < 0.4 dS/m
3. use the intermediate range if EC_w (dS/m) = 0.4 dS/m
4. Use the upper limit if EC_w (dSs/m) > 1.6 dS/m
5. Most tree crops and woody ornamentals are sensitive to sodium and chloride. Most annual crops are not sensitive
6. With sprinkler irrigation on sensitive crops. sodium or chloride in excess of 3 meq/L under certain conditions has resulted in excessive leaf absorption and crop damage

3.4 Experimental set up

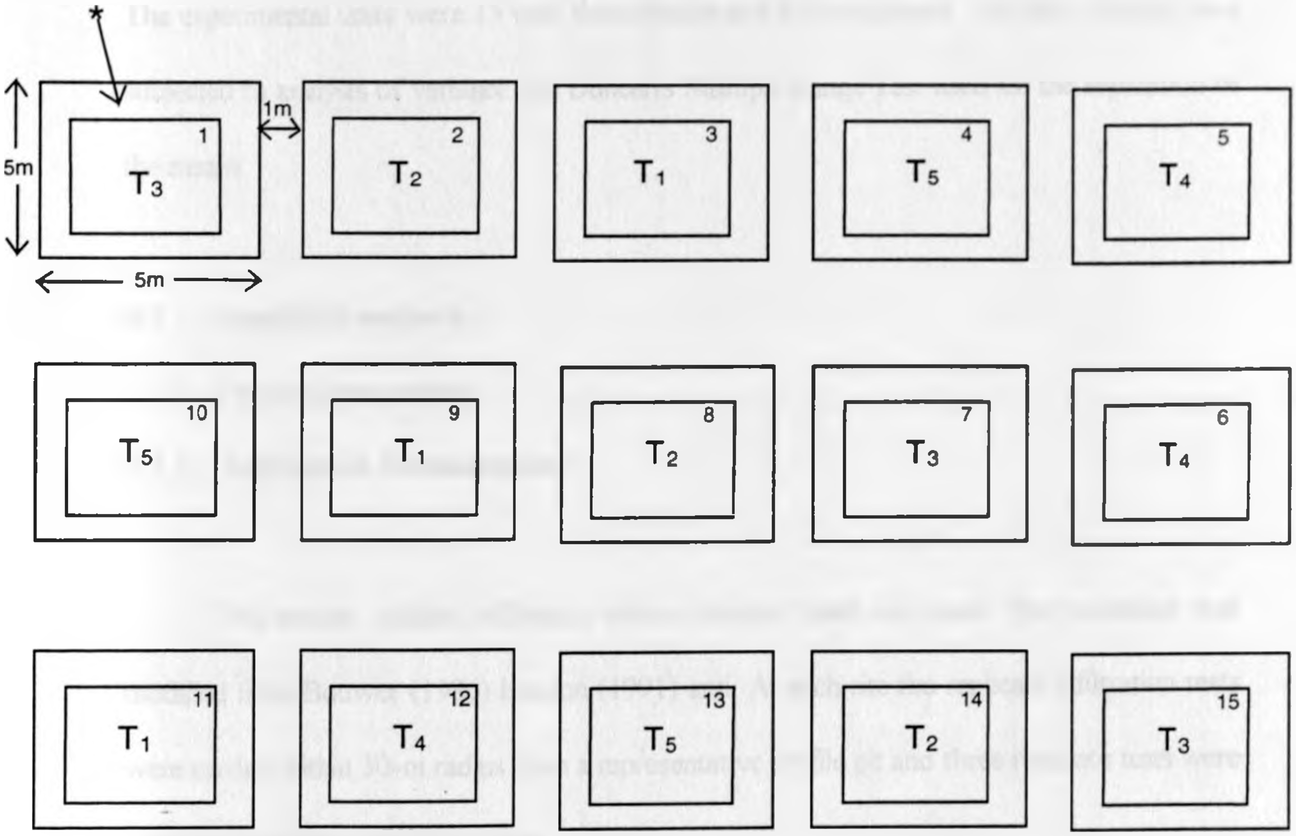
3.4.1 Treatment materials

Cow dung manure at five levels i.e. 0, 10, 20, 30 and 40 tonnes/ha which translates to 0, 25, 50, 75 and 100 kg/plot respectively was used as treatment materials in this study. The cow dung manure was collected from the dumping area at Site 1. The cow dung manure was analyzed for chemical composition(Appendix 17).

3.4.2 Preparation of plots

At each site, an area to accommodate 15 plots, each measuring 5 x 5 m was ploughed and then harrowed. Plots of 5 x 5 m^2 and 1 meter apart were demarcated (Figure 4) and the edges were leveled for 25 cm from the ground. Three plots for each treatment were randomly allocated using random number table (Steel and Torrie, 1981). The Cow dung manure was spread and mixed with the soil (plough layer) using a jembe in form of harrowing. The experiment was carried out for 18 weeks. During this period, irrigation and weeding were done at every 5-7 days' intervals. After 18 weeks, mini pits (2 horizons as the reaction was still on the surface horizons) were dug in each treatment. Horizontal hydraulic conductivity experiments were carried out for each horizon. Infiltration tests were carried out ahead in representative mini pits for each treatment. Undisturbed core samples were collected from each horizon in a stepwise manner. Each core ring was carefully covered by two lids after labeling (date, site and depth horizon) and was put in a special case. These core samples were used for measuring vertical hydraulic conductivity, bulk density and water retention in the laboratory.

Disturbed samples were also collected from representative horizons for each treatment and placed in polythene bags later, air-dried, ground and passed through 2 mm sieve to obtain the fine earth fraction and used for chemical analysis. The results obtained were used for evaluating the treatments.



* = Ridge (30 cm in height and thickness)

T_1 = 0 kg/25 cm^2

T_2 = 25kg/25 cm^2

T_3 = 50 kg/25 cm^2

T_4 = 75 kg/25 cm^2

T_5 = 100 kg/25 cm^2

Figure 4: Layout of the plots

3.4.3 Experimental layout

Randomized Complete Block Design (RCBD) was used in laying out the experiment. The experimental units were 15 with three blocks and five treatments. The data obtained was subjected to analysis of variance and Duncan's Multiple Range Test used for the separation of the means.

3.5 Analytical methods

3.5.1 Physical properties

3.5.1.1 Infiltration Measurement

The double cylinder infiltration with a constant head was used. The procedure was modified from Bouwer (1986) Landon (1991) and. At each site the replicate infiltration tests were carried within 30-m radius from a representative profile pit and three replicate tests were carried out before mini pit sampling.

Uniform and vertical penetration of the cylinders was ensured in all cases by driving them into the soil carefully and steadily to about 10-15 cm depth. Two buckets, one for the inner cylinder and the other for the outer cylinder were used to put water into the infiltrometer to a depth of about 7- cm. The depth of water was maintained constant by inserting plastic tubing to deliver water from a 25 litre aspirator into the inner cylinder. Simultaneously a stopwatch was started and readings were taken as change of water volume in the graduated aspirator. Readings were taken and recorded at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 60, 75, 90, 120, 150 and 180th minutes after initial flooding. Infiltration rate was calculated as follows:

$$I = \Delta Q / At \qquad (7)$$

Where;

I = infiltration rate in cm/hr

ΔQ = change of volume in aspirator reading in cm^3

A = area of the inner ring in cm^2

t = time interval in hours

Infiltration rate obtained for each treatment was classified according to Table 9, which gives various classes.

Table 1: Classification of Infiltration rate values

Infiltration rate (cm/hr)	Interpretation
< 0.1	very slow
0.1 - 0.5	Slow
0.5 - 2.0	Moderately slow
2.0 - 6.0	Moderate
6.0 - 12.5	Moderately rapid
12.5 - 25.0	Rapid
> 25.0	Very rapid

Source: FAO/UNEP, 1983.

3.5.1.2 Antecedent moisture content (w)

The antecedent moisture content was determined by the gravimetric method (Rowell, 1994). The samples were weighed and then placed in an oven at a temperature of 105°C for 24 hours. The oven dry weight was taken and the percentage moisture content calculated as follows:

$$\% W = 100\,(W_w - W_d)/W_d \qquad (8)$$

Where;

w = gravimetric water content (%)

w_w = weight of moist soil (g)

w_d = weight of oven dry soil (g)

3.5.1.3 Horizontal hydraulic conductivity

Horizontal hydraulic conductivity was determined in the field by installed permeameter. The installed permeameter was filled with water from the bottom to expel the air. The system was left standing with abundant water until the intake rate had been established (after 1 hour and more time). When the intake was constant, the permeameter was filled with water to head of 50 cm (measured from the centre of the permeameter) and the time for the head to drop to 20 cm was determined (Young, 1991).

Horizontal permeability was measured on each horizon. The k_{sat} (cm/hr) was calculated from the following equation

$$K_{sat} = [(aL)/\,At]\ \ln\ (H_1/H_2) \qquad (9)$$

Where;

a = cross sectional area of manometer

L = length of the soil sample

A = cross sectional area of permeameter

H_1 = head at start

H_2 = head at finish

t = time in minutes or hours from start to finish

Non homogeneity, which is the mark of the most natural soil profiles, has a very profound effect on hydraulic conductivity. If the overall conductivity of a series of layers is k_x in the x direction (horizontal) then

$$Kx = 1/H.(K_1H_1 + K_2H_2 + \ldots K_nH_n) \qquad (10)$$

Where:

k_x = Average hydraulic conductivity in the horizontal direction of the entire profile

H = entire depth of the profile,

k(1,2,...n) = saturated hydraulic conductivity of individual horizon 1,2,... and n;

H(1,2,...n) = depth of individual horizon 1,2 and n (Black, 1965).

3.5.1.4 Vertical saturated hydraulic conductivity

Saturated hydraulic conductivity was determined in the laboratory by the constant head method as outlined by Youngs (1991) and Klute and Dirkensen (1986).

Preparation of the samples was done by capping the bottom of each trimmed core samples with cheese cloth gauze supported by rubber bands. The other side of the core sample was connected to a similar but empty core ring and fastened with vinyl plastic water proof tape. The samples were then placed on a tray with shallow depth of water and soaked to saturation through capillary rise. After saturation the core samples were mounted on a constant head hydraulic conductivity apparatus.

To the top of the core, water was carefully and slowly introduced into the upper ring until it was 2/3-3/4 full. Siphon tubing was used to maintain a continuous flow and constant head. A constant hydraulic head of 1.8 to 2.0 cm was maintained. This was measured using a glass slide and a graduated ruler. A leachate from each sample was collected from 1 hour (the most rapid) to 12 hours the slowest and k_{sat} calculated from Darcy's equation

$$K_{sat} = (Q/At)\ (L/H) \qquad \text{...(11)}$$

Where;

k_{sat} = saturated hydraulic conductivity in cm/hr

Q = volume of water collected in time t

A = cross sectional area of a soil sample in cm^2

L = length of soil sample in cm.

H = effective hydraulic head (L + H), where h is the hydraulic head in cm

The overall conductivity of the entire profile is given by

$$K_v = H/(H_1/K_1 + H_2/K_2 + \ldots + H_n / K_n) \quad \ldots\ldots (12)$$

Where;

k_v = average hydraulic conductivity in the vertical direction of the entire profile

H = entire depth of the profile

k(1,2…n) = saturated hydraulic conductivity of individual horizon 1,2 ... and n

H(1,2…n)) = depth of individual horizon 1,2 ... and n

Hydraulic conductivity obtained was then classified into various classes as shown in Table 10.

Table 10: Classification of hydraulic conductivity values

Hydraulic conductivity (cm/hr)	Interpretations
< 0.8	very low
0.8 - 2.0	slow
2.0 - 6.0	moderate
6.0 - 8.0	moderately rapid
8.0 - 12.5	rapid
> 12.5	very rapid

Source: FAO, 1983

3.5.1.5 Soil texture

The fine earth fraction of soil was passed through a 2 mm sieve and taken for mechanical analysis using Bouyoucos Hydrometer method described by Gee and Baunder (1986). The organic matter was destroyed using hydrogen peroxide. The residual sample was dispersed by a sodium salt (sodium hexametaphosphate) and by mechanical shaking for at least 6 hours. The percentage of sand, clay and silt were calculated as follows:

$$\% \text{ Sand} = 100 - [H_1 + 0.2(T_1 - 68) - 2]\,2 \quad \text{.......(13)}$$

$$\% \text{ Clay} = [H_2 + 0.2\,(T_2 - 68) - 2]\,2 \quad \text{.......(14)}$$

$$\% \text{ silt} = 100 - (\% \text{ sand} + \% \text{ Clay}) \quad \text{.......(15)}$$

Where;

H_1 = Hydrometer reading at 40 seconds (g/cm^3)

T_1 = Temperature reading at 40 seconds(^oC)

H_2 = Hydrometer reading at 3 hours (g/cm^3)

T_2 = Temperature reading at 3 hours (^oC)

Temperature correction is $0.2(T_1 - T_2 - 68)$ where T_1 and T_2 are given in ^oF while the salt correlation is 2.

The textural class was determined from the standard USDA triangle (Rowell, 1994)

3.5.2.6 Bulk density

After saturated hydraulic conductivity and moisture retention measurement, the core samples were oven dried at 105°C for 24 hours and the bulk density calculated as given by Rowell (1994).

$$P_b = M_S / V_t \quad \text{.........} \quad (16)$$

Where;

P_b = bulk density in g/cm^3

M_s = mass of the oven dry sample in g

V_t = volume of sample as determined by the volume of core ring in cm^3

3.5.1.7 *Aggregate stability*

The aggregate stability was determined in the laboratory using the wet sieving methods as given by Hillel (1980). The disturbed soil samples that had not been ground were sieved with a 4 mm and 2 mm sieve. The samples that passed through the 4 mm but not the 2 mm sieve were used for the analysis. Fifty g of a representative sample from each treatment in the replicate was placed on the upper most of a set of graduated sieves 2, 1, o 5, 0.25, 0.063 and 0.038 mm and immersed in water (10-15 minutes) to stimulate flooding. The sieves were then oscillated vertically and rhythmically, so that water was made to flow up and down through the screen and the assemblage of aggregates. At the end of a specific period of sieving, 10-20 minutes, the next of the sieve was removed from the water and then oven dry weight of material left on each sieve was determined. As pointed out by Kemper (1965), the result should be corrected for the coarse primary particles retained on each sieve. Dispersing the material collected from each sieve, using a mechanical stirrer and sodic dispersing agent (hexametaphosphate), then washing the material back through the same sieve had done this. The weight of sand material after the second sieving was then subtracted from the total weight of undisturbed sample retained after the first sieving and the percentage of aggregates stability (%SA) was calculated as given by Hillel (1980)

$$\% \text{ SA} = 100 \times \frac{\text{(weight of material before dispersion)} - \text{(weight of sand)}}{\text{(Total sample weight)} - \text{(weight of sand)}} \quad \ldots (17)$$

3.5.1.8 Water Retention

The soil moisture characteristics were determined in the laboratory using the pressure chamber method (Klute and Diskensen, 1986) in the 0.0-1500 kPa range.

The undisturbed core samples were trimmed and capped with cloth membrane held in position by a strong elastic band. The samples were then saturated in irrigation water from each site by capillary action for at least 24 hours. The outside of the samples were then dried, weighed and subjected to 10, 30, 50, 70, 100, 300, 500, 700, 1000 and 1500 kPa suction pressure.

Depending on soil type, equilibrium was attained after 3 to 7 days for the low pressure and 9 to 15 days for the high pressure. After the 1500 kPa equilibrium, samples were oven dried at 105°C for 24 hours and the amount of water retained at any given suction was calculated using the following equation:

$$\theta = W_t\,(I) - W_t\,(OD) / V_t\, p_w \ldots\ldots\ldots\ldots (18)$$

Where;

θ = volumetric water content (cm^3/cm^3)

$w_t(i)$ = weight of soil sample at given tension

$w_t(OD)$ = oven dry weight of soil sample (g)

V_t = field volume of soil sample (cm3)

p_w = density of water (taken as 1 g/cm^3)

3.5.2 Chemical Determinations

3.5.2.1 Determination of pH

pH was determined in distilled water at a soil-to-water ratio of 1:2.5. The samples were shaken mechanically for 30 minutes and left to stand for 30 minutes before introducing electrode into the supernatant suspension. The buffer solution, pH_4 and pH_7 were used to calibrate and check the sensitivity of the instrument during the pH determination. The irrigation water aliquot for each site was taken for pH determination (Rowell, 1994).

3.5.2.2 EC determination

Electrical conductivity was determined by a method described by Rowell (1994) using a conductivity bridge. Soil/water suspensions of ratio 1:2.5 were shaken for one hour and left to stand for 30-60 minutes before reading. The EC readings obtained at room temperature were corrected to the standard 25°C by correction fractions as given by Dewis and Freltas (1970). The irrigation water aliquot was taken for the same determination.

3.5.2.3 CEC,Exchangeable Cation and BSP

Rhodes (1986) gives the method adopted. 5 grams of soil were leached using 25 ml of NH_4OAC adjusted at pH_7. Ten portion of this solution were added and a leachate was collected in a 250 ml volumetric flask and made to mark with NH_4OAC. Exchangeable cations were determined from this leachate. The atomic absorption spectrophotometer (AAS) was used to determine Ca and Mg while Na and K were determined using the flame photometer.

The soil was then washed with five portion of 95% ethanol, then the soil was leached with 100 ml of 1 N KCl adjusted to pH 2.5, administering the KCl in four portion of 25 ml each. The leachate was collected in a 100 ml volumetric flask and made to the mark with KCl. An aliquot of 5 ml was pipetted and distilled and the distillate (liquid ammonia) was collected in 2% boric acid and back titrated with 0.05 N H_2SO_4.

The CEC was calculated as follows:

$$CEC = \frac{\text{Titre x Normality of } H_2SO_4 \text{ dilution x 100 g of soil}}{\text{ml of aliquot x weight of soil}} \ldots\ldots\ldots\ldots\ldots(19)$$

The %BS was calculated from the following formula

$$\%BS = \frac{[Ca + Mg + K] \times 100}{CEC} \ldots\ldots\ldots\ldots\ldots(20)$$

Where:

Ca, Mg, Na and K are exchangeable values in cmol/kg

The exchangeable sodium percent (ESP) was calculated as follows:

$$ESP = \frac{\text{Exchangeable sodium} \times 100}{CEC} \quad \text{.......................................(21)}$$

The irrigation water aliquot was taken for the same determination.

3.5.2.4 Soluble Salts

A 1:5 soil/water mixture was shaken for four hours and then filtered. The filtrate was used for the determination of soluble Ca, Mg, Na, K, OH, CO_3, HCO_3, and Cl. The anions were determined as given by Rhodes (1986).

50 ml aliquot were used for each ion determination. For OH, CO_3 and HCO_3 determination, the aliquot were titrated with 0.01 N H_2SO_4 using phenolphthalein and methyl orange as indicators; while for Cl determination, the solution was titrated with 0.005 N $AgNO_3$ using 2% K_2CrO_4 as indicator water aliquot were determined in the same way for the same ions. The necessary dilution and blank titration were used in calculation

$$(HO, CO_3^{-2}, HCO_3^{-}) = \frac{100 \times N \text{ of } H_2SO_4 \times (T - B) \times D}{\text{ml of aliquot}} \quad \text{...................... (22)}$$

$$\text{ml of Cl} = \frac{100 \times N \text{ of } AgNO_3 \times (T\text{-}B) \times D}{\text{ml of aliquot}} \quad \text{.................................(23)}$$

Where;

T = Titre (volume of H_2SO_4 or $AgNO_3$ used)

B = Blank titre

D = Dilution factor

N = Normality

3.5.2.5 Organic Carobn

The Walkley and Black method as described by Rowell (1994) determined organic carbon. The fine earth fractions were passed through 0.5 mm sieve. 0.5 g of 0.5 mm-sieved sample was oxidized with potassium dichromate and the excess of potassium dichromate was titrated using standard solution of 0.5 N ferrous sulphate. The analyses were done in duplicate. The organic carbon was also determined for Cow dung manure. The organic carbon was calculated using the equation below;

$$\%OC = \frac{\text{me } K_2Cr_2O_7 - \text{me Fe } SO_4 \times 0.03 \times f \times 100}{\text{weight of dry soil used}} \quad \ldots\ldots\ldots\ldots (24)$$

Where;

f = 1.33

me = Normality x ml of solution used

3.5.2.6 Total Soil Nitrogen

The total Nitrogen was determined by Kjedahl method as described by Bremner and Mulvaney, (1982). 2 g of soil was placed in a test tube 5 ml of H_2SO_4 was added and 0.5 g of selenium reaction mixture was added. The samples were then digested using an electric 'Kjeltric' digestion block. The digested samples were distilled after addition of 20-40 ml NaOH solution and 1-2 drop phenolphthalein. The release nitrogen in form of NH_3 (aq) was captured by 2% boric acid solution. The trapped NH_3^+ was titrated with 0.01N solution of sulphuric acid as explained by Black (1965). Duplicate determinations were done and the results were expressed as percent total nitrogen The amount of nitrogen was calculated from the stoichiometric relationship that 1 ml of 0.01 N sulphuric acid used in the titration is equivalent to 0.14 mg of nitrogen. The total nitrogen percent was also determined for Cow dung manure.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

The results of various analysis of the two sites under this study are presented in different tables, figures and appendices. The discussion has been divided into three sections. The first section (4.1) presents results obtained from chemical characteristics of irrigation water, the second section (4.2) presents soil physical analysis results and the third section (4.3) the results obtained from chemical analysis and related salinity indices.

4.1 Chemical Characteristics of Irrigation Water

4.1.1 Electrical Conductivity EC

From the data on Table (11), EC in irrigation water (bore hole) as used at Site 1 is 4.1 dSm at 25 °C. While EC for river and borehole water at Site 2 are 2.0 and 5.1 dS/m respectively. For the experiment at Site 2, only water from The Kiboko river was used. According to the FAO guidelines (1985) the borehole water at Site 1 can cause severe problem of salinity which according to Richard (1954) classification it has very high salinity. It is in the same class (very high salinity) according to Donahue *et al* (1990), while the Kiboko river water used at Site 2 falls under medium to high salinity hazard (Donahue *et al.*, 1990; Richard, 1954). According to FAO (1985) guidelines use of this water may increase the problem of salinity and actually result in high EC of soil under study.

The borehole at Site 2 (used during drought) falls under very high salinity class according to Donahue *et. al;* (1990) and Richard (1954) classification, while FAO (1985) guidelines use of this water for irrigation may cause severe problems of salinity.

Table 10 Chemical characteristics of irrigation water

Location	source	pH	EC (dS/m at 25°C)	CATIONS (meq/L)					pHc	SAR_{adj}	SSP	ANIONS (meq/L)	
				ca^{++}	Mg^{++}	ca+mg	Na^{+}	K^{+}				$HC0_3$	cl^{-}
site 1	Borehole	6.60	4.08	41.90	26.96	68.86	28.00	2.0	6.2	15.27	28.90	6.55	11.07
	Kiboko river	7.60	3.06	44.25	16.54	60.79	17.00	1.5	6.20	9.87	21.85	6.00	7.03
Site 2	Kiboko river	8.20	2.04	2.85	7.67	10.52	4.00	0.3	7.15	3.92	27.55	2.5	2.98
	Borehole	7.40	5.10	41.44	24.04	65.48	22.0	1.0	6.30	11.92	25.15	4.9	10.17

4.1.2 Adjusted Sodium adsorption ratio and Soluble sodium percent

From Table 11, adjusted sodium adsorption ratio (SAR_{adj}) for irrigation waters that have been used at two sites under study are relatively high except for water from The Kiboko river as used at Site 2.

For the borehole at Site 1 the sodium adsorption ratio is 15.27 which is considered to cause medium sodium hazard (Dohanue *et al;*1990; Richard ,1954). At Site 2 the SAR_{adj} is 3.9

for the Kiboko river which is of low hazerd (Dohanue *et. al;*1990; Richard ,1954). While for the bore hole water at the same site it is 11.9 which is considered to fall under low sodium (Donahue *et. al* ;1990; Richard ,1954). The soluble sodium percent (SSP) for the borehole water at Site 1 is 28.9 while for Site 2 in the Kiboko river and borehole water is 27.6 and 25.2 respectively. According to Richard *et.al* ; (1954) there is no sodium hazard by this water values of soluble sodium percent are less than 60.

4.1.3 Chloride (Cl^-)

Chloride is considered as a toxic ion, which affects sensitive plants (Donahue *et. al;* 1990 and FAO guidelines ,1985). For irrigation waters in this study, chloride in the borehole water at Site 1 is very high (11.07 meq/l) and using this water may cause a severe problem while for the Kiboko river at Site 2, is 3.0 meq/l. According to FAO (1985) guidelines it does not have a problem. The borehole water at Site 2 has high value of chloride i.e. 10.2 meq/l which result in severe toxicity.

4.1.4 Carbonates and Bicarbonates (CO_3^{-} and HCO_3^{-})

Both carbonates and bicarbonates in the irrigation waters are undesirable. The irrigation waters under study have a considerable amount of bicarbonates, for the borehole at Site 1 is 6.6 meq/L while for the Kiboko river and borehole at Site 2 is 2.5 and 4.9 meq/L respectively. There was no carbonate in irrigation water in Site 1 and 2.

High bicarbonates in the irrigation water tend to precipitate Ca and Mg as their carbonates and the soil solution becomes more concentrated. This leads to a further reduction in the concentration of Ca and Mg thus leading to an increase in the exchangeable sodium percent of the soil.

4.2 Soil Physical Properties

The soil physical properties analysed in this study are bulk density, texture, aggregates stability, hydraulic conductivity, moisture content, organic carbon (Tables 12,13,14,15,16,17, and 18) and appendices (7,9) infiltration rate (Table 19) and Appendices (18 and 19) and water retention (Table 20) and Appendices (20 and 21). The results for each site are presented in separate Figures and appendices but in the same tables. The results for both sites were discussed together.

4.2.1. Bulk density

From the data in Table 12, the mean bulk densities for the soil at Site 1 in the first horizon (0-20 cm) ranged from 1.28 g/cm^3 to 1.43 g/cm^3. There is no significant difference at ($p \leq 0.05$) between the treatments compared with the control. The high bulk density for Treatments 3, 4 and 5 could be because of mixing of cow dung manure with soil which break the clog into fine particles and result in compaction of soil.

In the first horizon at Site 2 (0-30 cm), (Table 12), the mean bulk density ranged from 1.01 g/cm^3 to 1.15 g/cm^3 and there is no significant difference at ($p \leq 0.05$) between the treatments. These results are generally in agreement with related finding of Campbell *et. al*; (1986)

who reported the inability of organic manure treatments to show any differences in bulk density. This was not surprising since large and frequent application of manure for many years is required before a significant difference can be obtained.

In the second horizon at Site 1 (20-45 cm) the largest value was 1.44 g/cm^3 for Treatment 2 (10 t/ha) and the lowest value was 1.37 g/cm^3 for Treatment 1 (0 t/ha). There is no significant difference at ($p \leq 0.05$) between the treatments (Table 12 and Figure 5). At Site 2, in the second horizon (30-50 cm) the highest value was 1.17 g/cm^3 for the Treatment 4(30t/h) and the lowest value is 1.05 g/cm^3 for the Treatments 5 (40 t/ha). Also there is no significant difference at ($p \leq 0.05$) between the treatments (Table 12). This would be because there was no difference between the plots under all treatments so any small variation between the treatments lead to change in the bulk density . In the second horizon the bulk density improved with highly significant difference according to a small change between the plots, while there is no significant difference at the first horizon (Appendix 9). There was no significant difference ($p \leq 0.05$) among the horizon and sites (first horizon) but there was highly significant difference ($p \leq 0.01$) among the sites (the second horizon).

Generally the soils at Site 2 have relatively low bulk density. This might be due to low percentage of sand at Site 2 (< 47%) compared with Site 1 (> 60%).

The difference in bulk density was very highly significant ($p \leq 0.01$) between the two types of soils (second horizon). The high bulk density observed at Site 1 could be due to increase in sand particles that closely pack thus resulting in a compacted soil. The results of bulk density is illustrated in Figures 5 and 6.

Table 12: Mean Bulk Density (g/cm^3) of treatments and horizons at Sites 1 & 2

Treatments		Site1		Site 2	
		Depths(cm)		Depths(cm)	
	Amount (t/ha)	0-20^{ns}	20-45**	0-30^{ns}	30-50**
T_1	0	1.33^{ab1}	1.37^{a1}	1.09^{ab1}	1.14^{ab1}
T_2	10	1.28^{b1}	1.44^{a1}	1.02^{b1}	1.06^{bc1}
T_3	20	1.37^{ab1}	1.38^{a1}	1.01^{b1}	1.12^{abc1}
T_4	30	1.37^{ab1}	1.41^{a1}	1.07^{ab1}	1.17^{a1}
T_5	40	0.62^{a1}	1.41^{a1}	1.15^{a1}	1.05^{c1}
Cow dung manure		0.62^{2}			

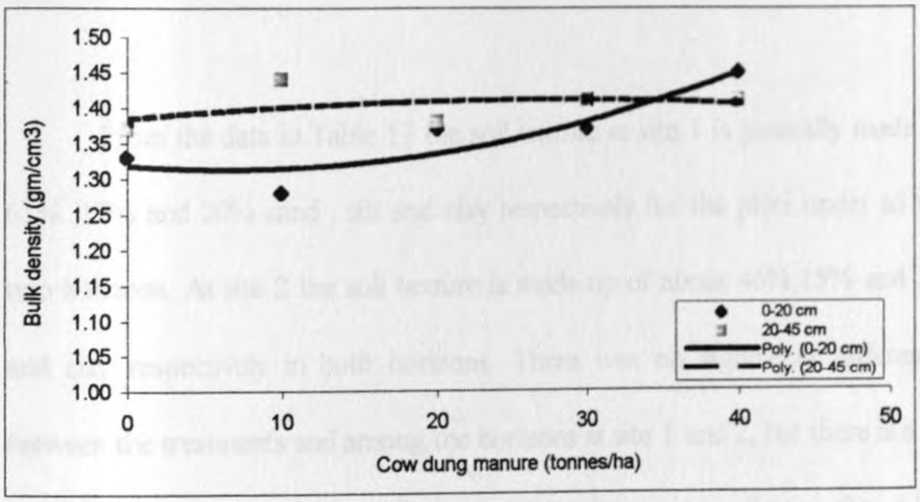
[1] t/ha = tonnes/hectare

[2] = bulk density of cow dung manure

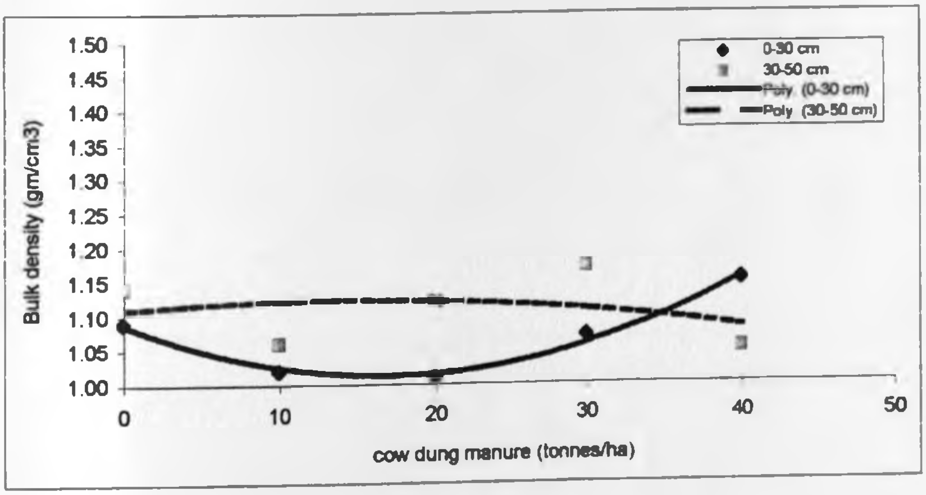
ns = non significant difference ($p \leq 0.05$) among sites (first horizons).

means with the same letter superscript within each horizon (among the treatment) and means with the same digit superscript among horizon within one site are non significantly different ($p \leq 0.05$) and according to Duncan's Multiple Range Test.

** = highly significant difference ($p \leq 0.01$) among sites (second horizons)



Firure 5. Effect of cow dung manure on bulk density in two depths (Site 1)



Firure 6. Effect of cow dung manure on bulk density in two depths (Site 2)

4.2.2 Texture

From the data in Table 13 the soil texture at site 1 is generally made up of more than 61% ,17% and 20% sand , silt and clay respectively for the plots under all treatments in the two horizons. At site 2 the soil texture is made up of about 46%,15% and 39%for sand, silt and clay respectively in both horizons. There was no significant difference at ($p \leq 0.05$) between the treatments and among the horizons at site 1 and 2, but there is a highly significant difference ($p \leq 0.01$) between the two sites according to the soil type. Site 1 is generally sandy loam and the soil texture at site 2 is sandy clay to sandy clay loam (Appendices 7 and 9).

Table 13: Mean particle size (%) of two horizons at sites1 and 2

Location	Treatment	Amount (t/ha)	Depth	sand $\%^{ns}$	silt $\%^{ns}$	clay $\%^{ns}$
s1	T_1	0	0-20	62.26^{a1}	17.96^{bc1}	19.78^{a1}
			20-45	62.42^{a1}	16.71^{bc1}	20.86^{a1}
s1	T_2	10	0-20	62.34^{a1}	18.42^{bc1}	19.25^{a1}
			20-45	61.39^{a1}	17.41^{a2}	21.21^{a1}
s1	T_3	20	0-20	62.39^{a1}	17.14^{c2}	20.81^{a1}
			20-45	62.97^{a1}	16.82^{c2}	20.21^{a1}
s1	T_4	30	0-20	62.74^{a1}	18.96^{b1}	18.30^{a1}
			20-45	62.79^{a1}	17.79^{a2}	19.41^{a1}
s1	T_5	40	0-20	61.48^{a1}	20.42^{a1}	18.22^{a1}
			20-45	61.87^{a1}	17.15^{a2}	20.98^{a1}
s2	T_1	0	0-30	45.96^{a1}	15.74^{a1}	38.3^{ab1}
			30-50	47.66^{a1}	12.60^{a1}	41.33^{a1}
s2	T_2	10	0-30	45.75^{a1}	17.40^{a1}	36.84^{b1}
			30-50	44.71^{a1}	16.48^{a1}	38.91^{a1}
s2	T_3	20	0-30	45.33^{a1}	16.05^{a1}	38.5^{ab1}
			30-50	47.66^{a1}	14.70^{a1}	37.64^{a1}
s2	T_4	30	0-30	46.54^{a1}	16.06^{a1}	37.40^{ab1}
			30-50	45.31^{ab1}	11.35^{a1}	43.34^{a1}
s2	T_5	40	0-30	45.82^{a1}	12.27^{a1}	41.91^{a1}
			30-50	47.92^{a1}	11.61^{a1}	40.79^{a1}

1 S1 = site 1
2 s2 = site 2

means with the same letter superscript within each horizon (among the treatments) and means with the same digit superscript among horizon within one site are non significantly different at ($p < 0.05$) and according to Duncan's multiple range test.

ns non significant different at $p \leq 0.05$ between two sites

- significant different at $p \leq 0.05$

4.2.3 Aggregates Stability (%SA)

aggregate Stability at Site 1 improved as a result of application of cow dung manure (Table 14). At Site 1, in the first horizon the highest value was 39.27% for Treatment 5 (40 t/ha) and the lowest value was 24.99% for Treatment 1 (control 0 t/ha). Results presented in Table 14 indicate that the aggregate stability increased with increasing rate of the manure application . Statistically there was significant difference ($p \leq 0.05$). In the second horizon (20-45 cm) also the aggregate stability improved by the application of manure. The most effective level was (40 t/ha) for Treatment 5 (31.41%) ,while the control gave the lowest value 19.28%. There difference was high significance ($p \leq 0.01$) between the treatment (Table 14, Figure 7) there was a significant difference ($p \leq 0.05$), while the difference among the horizons was also difference ($p \leq 0.05$) (Table 14).

At Site 2 in the first horizon (0-30 cm) the aggregate stability was highly significant ($p \leq 0.01$) (Table 14). The aggregate stability ranged from 41.93% for (Treatment 5) to 24.27% for (Treatment 1). The aggregate stability percent improved by increasing the rate of manure application and the same is true in the second horizon (30-50 cm). There was significant increase ($p \leq 0.05$) between two soil types. This was mainly because of different texture. At Site 2 , the clay percent was generally below 20% and at Site 2 was above 35% (Appendices 7 and 9). The results of aggregates stability are illustrated in Figures 7 and 8.

The improvement of aggregate stability is more pronounced on the finer textured soil compared with coarse textured soil. Vigerust (1983) observed that after three years application of organic manure to a heavy clay soil, the percentage stability of aggregate was more than double.

Russell (1988) explained the increasing of aggregate stability of a soil under application of organic materials could be attributed to the water proofing effect of organic materials such as waxes which are naturally hydrophobic.

The effect of applying manure on aggregate stability might have been greater if the soils had been subjected to a longer incubation period (Roth, 1971)

Baver *et al.* (1972) found a significant positive correlation between aggregation and organic matter content only for medium and heavy textured soils; (Tables 14 and 18) in lighter soils, organic matter had little or no effect upon aggregation.

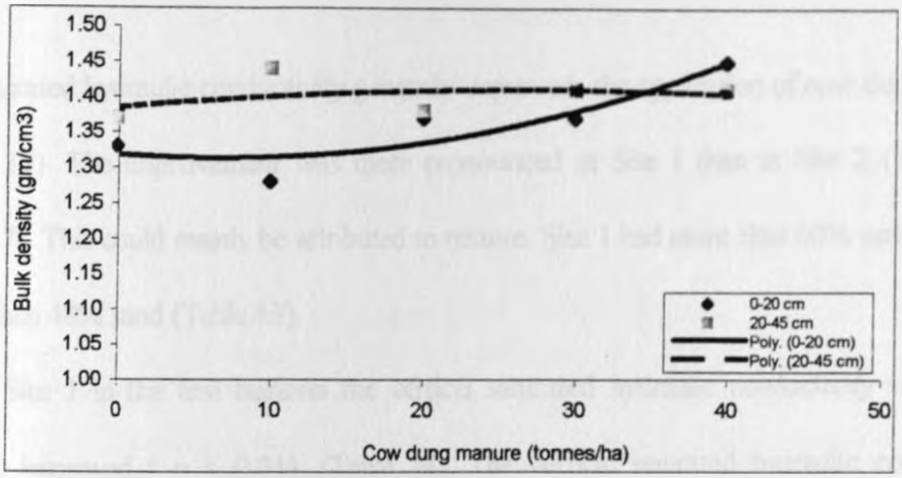
Table 14: The effect of cow dung manure on aggregate stability (wt/wt) in two depths at sites1 &2

Treatment (T)	Amount (t/ha)	site 1 Depth (cm) 0-20^{ns}	site 1 Depth (cm) 20 - 45^{ns}	site 2 Depth (cm) 0-30^{ns}	site 2 Depth (cm) 30 - 50^{ns}
T_1	0	24.99^{c1}	19.28^{c2}	24.27^{c1}	19.77^{d2}
T_2	10	28.12^{bc1}	26.21^{b2}	27.58^{c1}	23.37^{d2}
T_3	20	30.54^{bc1}	24.70^{b2}	32.89^{b1}	28.25^{b2}
T_4	30	34.33^{bc1}	28.08^{ab2}	38.91^{a1}	30.47^{b2}
T_5	40	39.27^{a1}	31.41^{a2}	41.93^{a1}	34.93^{a2}
Cow dung manure		$33.43^{1/}$			

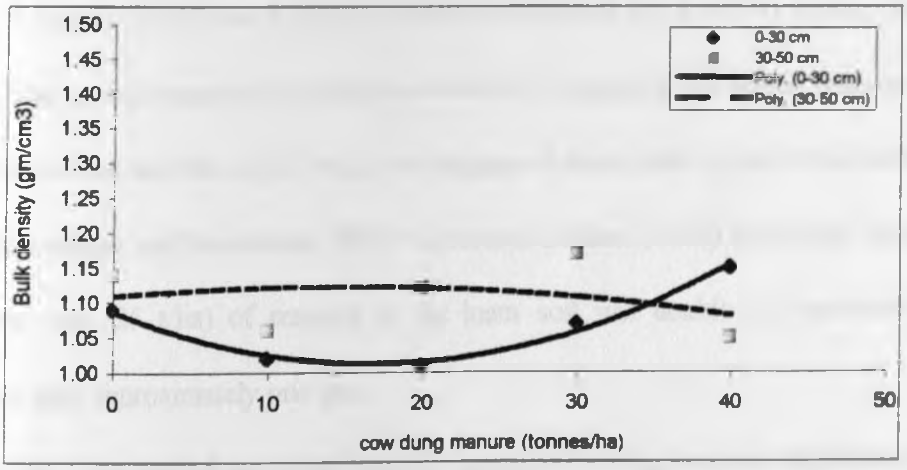
1/ =aggregate stability of cow dung manure

means with the same letter superscript within each horizon (among the treatments) and means with the same digit superscript among horizon within one site are non significantly different ($p \leq 0.05$) and according to Duncan's multiple range test.

ns =non significant different ($p \leq 0.05$) between two sites



Firure 5. Effect of cow dung manure on bulk density in two depths (Site 1)



Firure 6. Effect of cow dung manure on bulk density in two depths (Site 2)

4.2.4 Saturated Hydraulic Conductivity (K_{sat})

Saturated hydraulic conductivity generally improved the application of cow dung manure (Appendix 17). The improvement was more pronounced at Site 1 than at Site 2 (Table 15), (Appendix 7). This could mainly be attributed to texture. Site 1 had more than 60% sand and Site 2 had less than 48% sand (Table 13).

At Site 1 in the first horizon the vertical saturated hydraulic conductivity was highly significantly improved ($p \leq 0.01$), (Table 14). The vertical saturated hydraulic conductivity ranged from 0.76 cm/hr for the control (very slow) to 2.64 cm/hr for Treatment 3 (moderate) (Figure 9). In the second horizon, the saturated hydraulic conductivity is very highly significant ($p \leq 0.001$), (Table 15). The range was 1.87 cm/hr for the control (slow) to 8.62 cm/hr for Treatment 5 (rapid). There was a highly significant difference ($p \leq 0.001$) among the horizons (Table 15).The vertical saturated hydraulic conductivity is higher in the second horizon compared with the first horizon and this might be due to clogging of some pores by microbial decomposition product (Shanmugan and Ravikamer, 1980). Morel and Guckert (1983) found that the application of moderate rate (25 t/ha) of manure to the loam soil will double the saturated hydraulic conductivity after approximately one year.

At Site 2, the vertical saturated hydraulic conductivity (K_{satv}) was not significant ($p \leq 0.05$), (Table 15). It ranged from 0.08 to 0.04 cm/hr in horizon 1 and from 0.05 to 0.02 cm/hr in horizon 2. This could mainly because of increasing of microbial population which clogged the macro and micro pores of the soil resulting in slowing down of vertical hydraulic conductivity, it might be also due to clay dispersion which reduce the vertical hydraulic conductivity. The result for site two are illustrated in Figure 10.

There was no significant difference among the horizons at Site 2 (Table 15). According to the soil types there was very highly significant difference ($p \leq 0.001$). The vertical saturated hydraulic conductivity at Site 1, which showed a highly significant improvement compared with Site 2.

Table 14: The effect of cow dung manure on vertical saturated hydraulic conductivity (cm/hr) in two depths at Sites 1& 2

Treatment (T)		Site 1		Site 2	
		Depth (cm)		Depth (cm)	
	Amount (t/ha)	0-20 cm***	20-45 cm***	0-30 cm	30-50 cm
T_1	0	0.77^{b2}	1.87^{c1}	0.08^{a1}	0.02^{b1}
T_2	10	1.26^{b2}	2.23^{c1}	0.07^{a1}	0.03^{ab1}
T_3	20	2.64^{a2}	4.27^{b1}	0.04^{a1}	0.02^{b1}
T_4	30	1.09^{b2}	8.49^{a1}	0.04^{a1}	0.05^{a1}
T_5	40	0.98^{b2}	8.62^{a1}	0.04^{a1}	0.03^{ab1}

*** = very highly significant difference ($p \leq 0.001$) among the sites
means with the same letter superscript within one horizon (among treatments) and mean of same digit superscript between horizons within one site are non significant difference ($p \leq 0.05$) according to Duncan's Multiple Range Test.

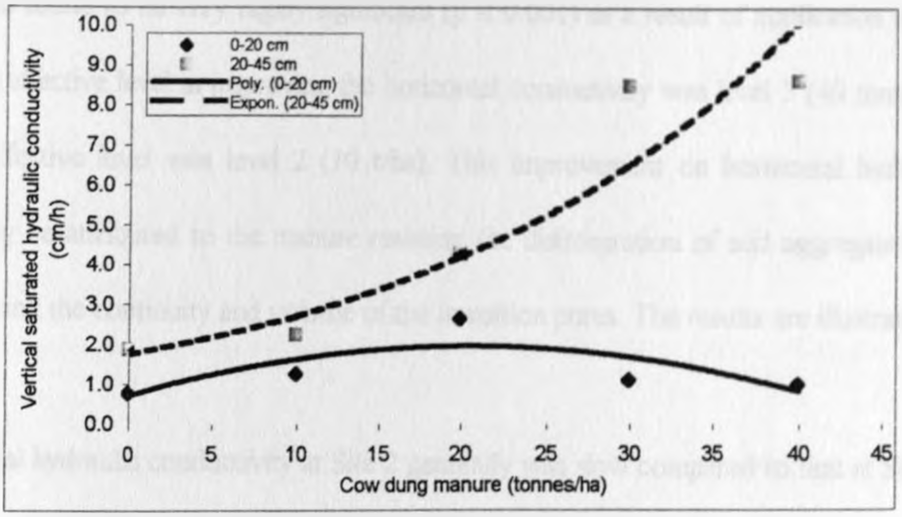


Figure 9. Effect of cow dung manure on vertical saturated hydraulic conductivity in two depths (Site 1)

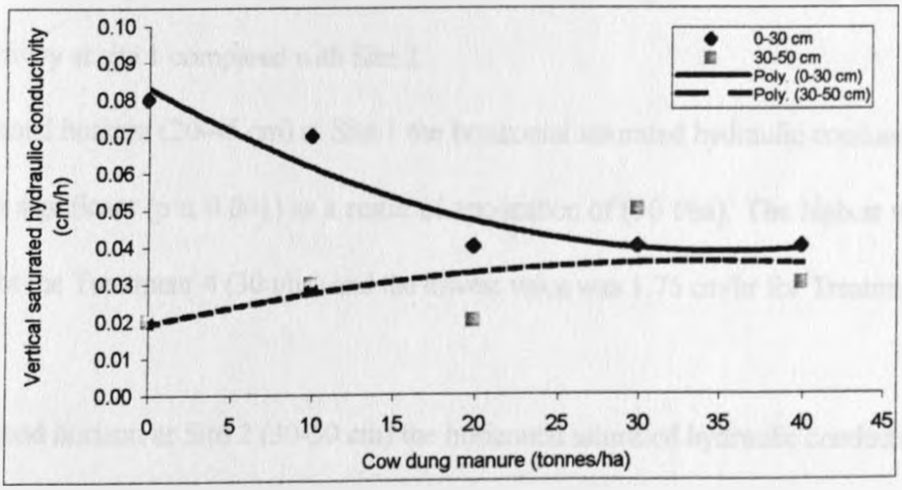


Figure 10. Effect of cow dung manure on vertical saturated hydraulic conductivity in two depths (Site 2)

According to the data in Table 16 at Site 1 in the first horizon the horizontal hydraulic conductivity was found to be very highly significant ($p \leq 0.001$) as a result of application of (40 t/ha). The most effective level in improving the horizontal conductivity was level 5 (40 tonne/ha) and the least effective level was level 2 (10 t/ha). This improvement on horizontal hydraulic conductivity may be attributed to the manure resisting the disintegration of soil aggregates and therefore enhancing the continuity and volume of the transition pores. The results are illustrated in Figure 11.

Horizontal hydraulic conductivity at Site 2 generally was slow compared to that at Site 1. From the data in Table 16 the horizontal hydraulic conductivity in the first horizon at Site 2 improved slightly and ranged from 0.02 cm/hr for Treatment 2 (10 t/ha) to 0.01 cm/hr for Treatment 5 (40 t/ha). There was a highly significant difference ($p \leq 0.01$) among the soil type (Table 16). The cow dung manure was more effective in improving the horizontal saturated hydraulic conductivity at site 1 compared with Site 2.

In the second horizon (20-45 cm) at Site 1 the horizontal saturated hydraulic conductivity was a very highly significant ($p \leq 0.001$) as a result of application of (30 t/ha). The highest value was 6.25 cm/hr for the Treatment 4 (30 t/ha) and the lowest value was 1.76 cm/hr for Treatment 3 (20 t/ha).

In the second horizon at Site 2 (30-50 cm) the horizontal saturated hydraulic conductivity was not significantly different ($p \leq 0.05$). The effect of cow dung manure was very low at Site 2. There was no significant difference among horizons at Site 2. This was due to high clay percent, which dispersed and swelled to clogged the pores. The results for Site 2 are illustrated in Figure 12. The horizontal saturated hydraulic conductivity was very highly significant ($p \leq 0.01$) between the two sites. The cow dung manure was most effective at Site 1 compared with Site

2. This could be due to texture, the soil texture at site 1 had less than 22% clay and soil texture at site 2 had more than 36% clay which dispersed and clogged the pores.

Table 15: The effect of cow dung manure on horizontal hydraulic conductivity in two depths at sites 1 &2

		site 1		site 2	
Treatment (T)		Depth (cm)		Depth (cm)	
	Amount (t/ha)	0-20 ***	20-45 ***	0-30	30-50
T_1	0	2.22^{b1}	3.09^{c1}	0.02^{a2}	0.11^{a2}
T_2	10	0.42^{d1}	2.20^{d1}	0.03^{a2}	0.01^{b2}
T_3	20	1.39^{c1}	1.76^{c1}	0.02^{a2}	0.02^{b2}
T_4	30	1.07^{c1}	6.25^{a1}	0.02^{a2}	0.01^{a2}
T_5	40	8.16^{a1}	3.70^{b1}	0.01^{a2}	0.01^{b2}

*** = very highly significant difference ($p \leq 0.001$) among horizon between two sites

The mean with the same letter superscript within one horizon (between treatment) and the mean of same digit superscript among the horizons at one site are non significant ($p \leq 0.05$) according to Duncan's Multiple Range Test.

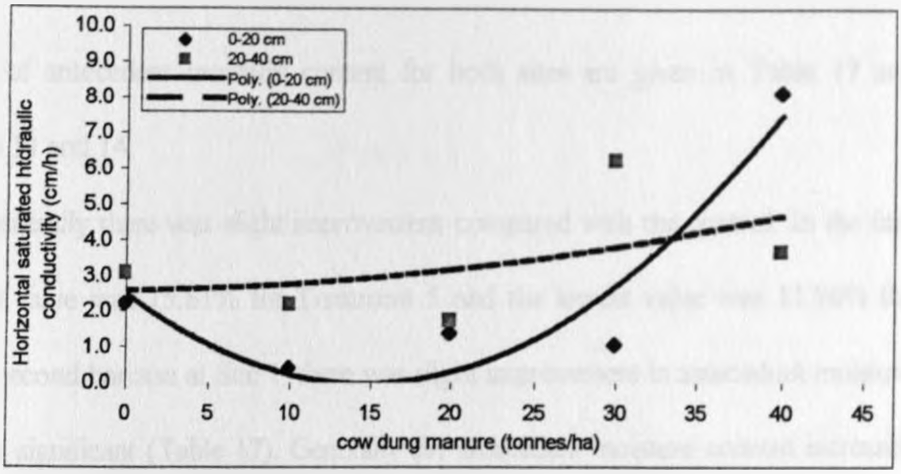


Figure 11. Effect of cow dung manure on horizontal saturated hydraulic conductivity in two depths (Site1)

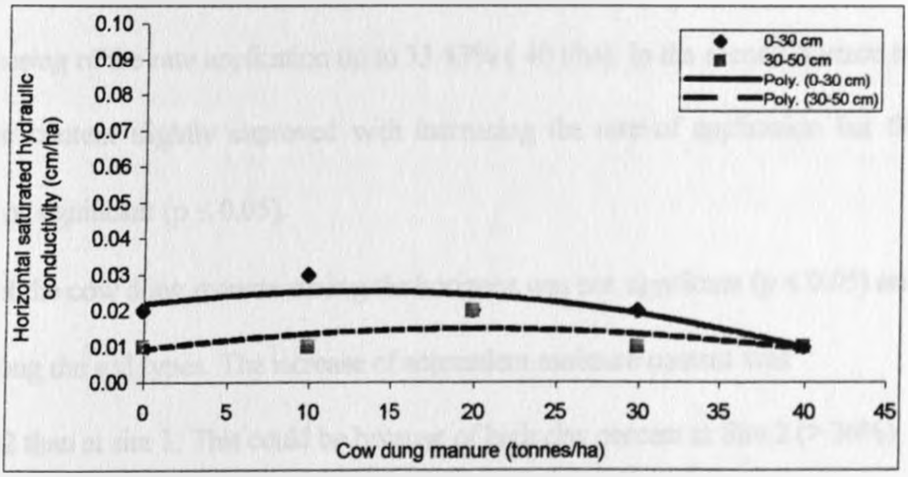


Figure 12. Effectof cow dung manure on horizontal saturated hydraulic conductivity in two depths (Site2)

4.2.5 Antecedent Soil Moisture Content

The values of antecedent moisture content for both sites are given in Table 17 and illustrated in Figures 13 and 14.

At Site 1, generally there was slight improvement compared with the control. In the first horizon, the highest value was 15.81% for Treatment 5 and the lowest value was 11.96% for Treatment 2. In the second horizon at Site 1, there was slight improvement in antecedent moisture content but was non significant (Table 17). Generally the antecedent moisture content increased with depth. There was not significant difference ($p \leq 0.05$) among the horizons.

At Site 2 the antecedent moisture content generally increased with depth. In the first horizon, the antecedent moisture content improved highly significantly ($p \leq 0.01$). The antecedent moisture content generally improved by the application of cow dung manure and the improvement increased with increasing of the rate application up to 33.43% (40 t/ha). In the second horizon the antecedent moisture content slightly improved with increasing the rate of application but this improvement was not significant ($p \leq 0.05$).

The effect of the cow dung manure among the horizons was not significant ($p \leq 0.05$) and the same is true among the soil types. The increase of antecedent moisture content was pronounced at Site 2 than at site 1. This could be because of high clay percent at Site 2 (> 36%) compared with that at Site 1 (< 22%).

Table 17: The effect of cow dung on antecedent moisture content in two depths at sites 1& 2

Treatment (T)		site 1		site 2	
		Depth (cm)		Depth (cm)	
	Amount (t/ha)	0-20 ^{ns}	20-45 ^{ns}	0-30 ^{ns}	30-50 ^{ns}
T_1	0	12.05^{a1}	13.79^{abi}	27.82^{b2}	34.16^{a2}
T_2	10	11.96^{a1}	13.49^{c1}	27.66^{b2}	36.25^{a2}
T_3	20	14.30^{a1}	15.31^{abc1}	28.31^{a2}	38.51^{a2}
T_4	30	14.30^{a1}	16.30^{a1}	30.40^{a2}	35.98^{a2}
T_5	40	14.81^{a1}	16.04^{ab1}	33.42^{a2}	38.02^{a2}
Cow dung manure		39.54$^{1/}$			

1/ = moisture content of cow dung manure

means with the same letter superscript within each horizon (between treatments) and means with the same digit superscript among horizon within one site are non significantly different ($p \leq 0.05$) and according to Duncan's Multiple Range Mest.

ns = not significant different ($p \leq 0.05$) between two sites

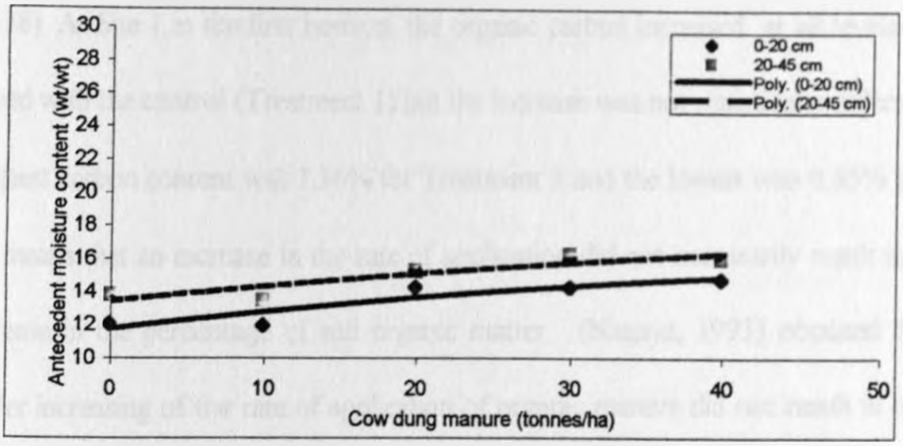


Figure 13. Effect of cow dung manure on antecedent moisture content in two depths (Site 1)

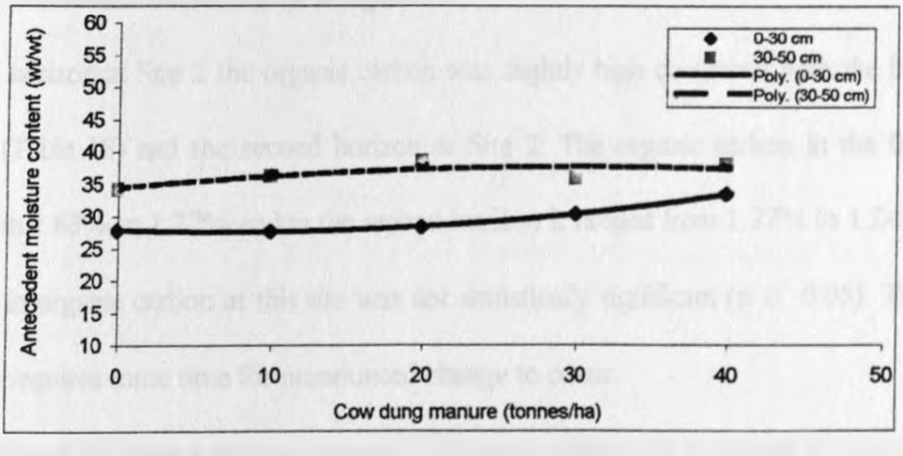


Figure 14. Effect of cow dung manure on antecedent moisture content in two depths (Site 2)

4.2.6 Organic Carbon (%OC)

Generally organic carbon slightly increased at both sites as a result of cow dung manure application (Table 18). At Site 1 in the first horizon, the organic carbon increased at all levels of application compared with the control (Treatment 1) but the increase was not statistically different ($p \leq 0.05$). The highest carbon content was 1.36% for Treatment 3 and the lowest was 0.85% for Treatment 1. This means that an increase in the rate of application did not necessarily result in a corresponding increase in the percentage of soil organic matter . (Nagaya, 1993) obtained the same result that after increasing of the rate of application of organic manure did not result in the increase of organic carbon

There was also an increase of carbon in the second horizon but not as high as in the first horizon. This means that organic carbon decreased with depth but not in a statistically significant manner ($p \leq 0.05$). The results are illustrated in Figure 15.

In the first horizon at Site 2 the organic carbon was slightly high compared with the first horizon at Site 1 (Table 18) and the second horizon at Site 2. The organic carbon in the first horizon ranged from 1.63% to 1.27% and in the second horizon it ranged from 1.37% to 1.24%. This improvement in organic carbon at this site was not statistically significant ($p \leq 0.05$). This could be because it requires some time for pronounced change to occur.

At Site 2 (Figure 16) there was the increment of organic carbon with increasing the rate of the application of cow dung manure. The highest value is 1.8% where 30 tonnes/h was applied in the first horizon. In the second horizon it increased by applying 10 tonnes/ha. However, there was no significant difference ($p \leq 0.05$) on soil organic carbon between the two sites.

Table 17: The effect of cow dung manure on organic carbon (% wt) in two depths at sites 1 & 2

Treatment (T)		site 1		site 2	
		Depth (cm)		Depth (cm)	
	Amount (t/ha)	0-20^{ns}	20-45^{ns}	0-30^{ns}	30-50^{ns}
T_1	0	0.85^{a1}	0.32^{a2}	1.27^{a1}	1.30^{a2}
T_2	10	0.94^{a1}	0.38^{a2}	1.63^{a1}	1.38^{a2}
T_3	20	1.36^{a1}	0.56^{a1}	1.52^{a2}	1.37^{a2}
T_4	30	0.94^{a1}	0.51^{a2}	1.80^{a1}	1.33^{a2}
T_5	40	0.89^{a1}	0.51^{a2}	1.59^{a1}	1.24^{a2}

ns not significant differencet ($p \leq 0.05$) among two sites

means with the same letter superscript within each horizon (between treatments) and means with the same digit superscript among horizon within one site are non significantly different ($p \leq 0.05$) according to Duncan's Multiple Range Test.

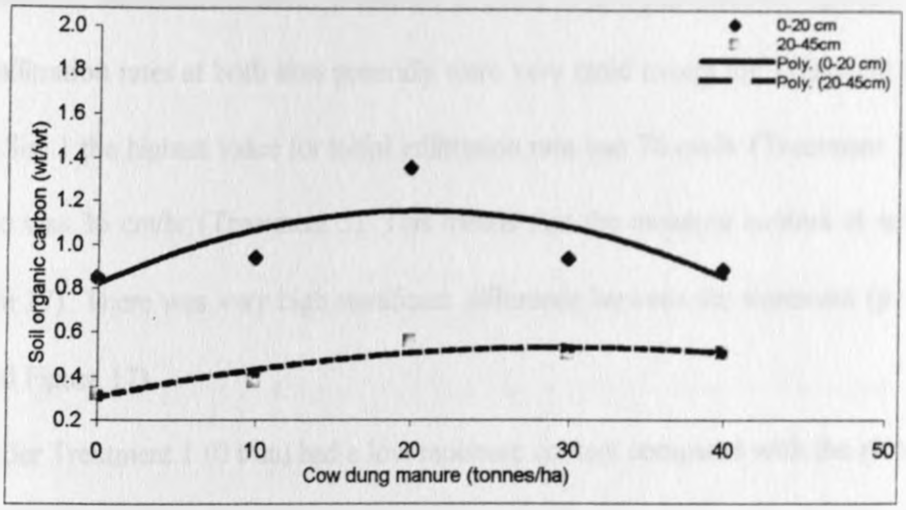


Figure 15. Efect of cow dung manure on soil organic carbon in two depths (Site 1)

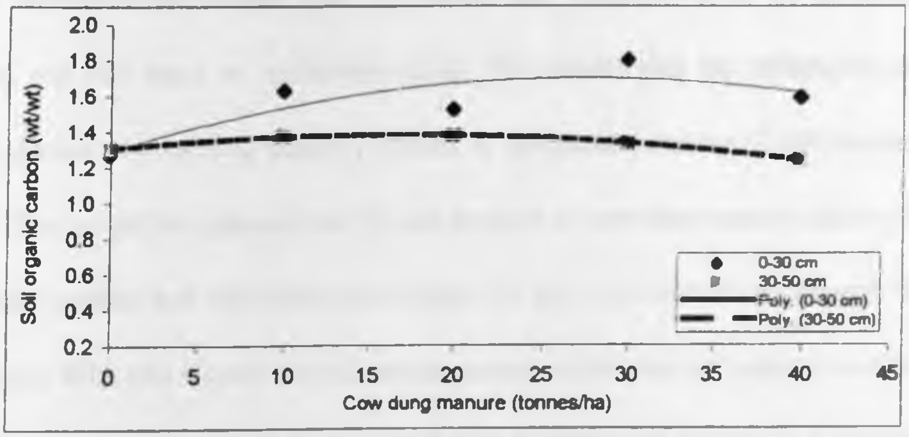


Figure 16. Effect of cow dung manure on soil organic carbon in two depths (Site 2)

4.2.7 Infiltration rate

The mean values of infiltration rates are presented in Table 19 and illustrated in Figures 17 and 18. The initial infiltration rates at both sites generally were very rapid except for Treatment 4 at Site 2 (rapid). At Site 1 the highest value for initial infiltration rate was 78 cm/hr (Treatment 1) and the lowest value was 36 cm/hr (Treatment 5). This means that the moisture content at soil surface is low (Table 17). There was very high significant difference between the treatment ($p \leq 0.001$), (Table 19 and Figure 17).

The plots under Treatment 1 (0 t/ha) had a low moisture content compared with the plots under Treatment 5 (40 t/h). This is because cow dung manure holds some water after irrigation. After 30 minutes, the infiltration rate was rapid with the highest value of 18.67 cm/hr (Treatment 2) and the lowest value was 10.9 cm/hr for Treatment 5. This was also because of the moisture content. The final infiltration rate ranged from 13.9 cm/hr for Treatment 2 to 7.6 cm/hr for Treatment 4 which was still rapid to moderately rapid. This means that the infiltration rate increased by small amount of cow dung manure (10 t/ha). If the amount increases it will decrease the infiltration rate. This would be explained that the low amount of cow dung manure reduce the effect of exchangeable sodium and clay dispersion (Table 26) and the water move through the micro and macro pores. While the highest rate of cow dung manure (40 t/ha) will reduce the effect of exchangeable sodium on clay dispersion but some will clog the pores and reduce the infiltration rate.

At Site 2 the initial infiltration rate was generally very rapid with the highest value of 36 cm/hr for Treatment 4 and lowest value of 12 cm/hr for Treatment 2. This could be explained through SAR and the total cation concentration. Oster and Schroer (19) suggested that the total cation concentration is a better parameter for the prediction of infiltration rate than is SAR. After 30 minutes, the highest value was 22.06 cm/hr for Treatment 4 (rapid) and the lowest value was 3.39 cm/hr for Treatment 1 (moderate). There was very high significant difference ($p \leq 0.001$) between the treatments.

The final infiltration rate generally was moderate with the highest value 5.37 cm/hr for Treatment 4 (moderate) and lowest value 1.63 cm/hr for Treatment 1 (moderately slow). There was very highly significant difference ($p \leq 0.001$) between the treatments (Table 19 and Figure 20). The steady state infiltration rate was obtained after 3 to 5 hours of infiltration (in this study, a minimum of 3 hours was used). The infiltration rate at Site 1 is higher compared with Site 2. This was mainly because of the texture. The clay percent at Site 1 was less than 22% and at Site 2 was greater than 45% (Table 13).

Table 19: Effect of cow dung manure on mean infiltration rates at sites 1 & 2

Treatment	Time (minutes)			
	1	30	120	180
T_1	74.74^{a}	15.47^{a}	9.01^{c}	8.56^{c}
T_2	54.03^{c}	18.27^{a}	8.39^{d}	9.2^{b}
T_3	71^{b}	17.73^{c}	13.17^{a}	12.67^{a}
T_4	52.2^{c}	5.68^{b}	9.41^{b}	5.75^{c}
T_5	36.0^{d}	6.68^{b}	6.89^{c}	6.44^{d}
T_1	30.50^{b}	3.43^{c}	5.66^{b}	1.61^{c}
T_2	12.0^{d}	5.10^{d}	2.07^{b}	2.06c
T_3	23.38^{c}	8.38c	5.95^{a}	$5.55a^{b}$
T_4	35.8^{a}	25.15^{a}	6.25^{a}	5.89^{a}
T_5	30.17^{b}	10.26^{b}	6.07^{a}	4.77^{b}

the means with the same letter superscript among the treatment within a given time had no significant difference ($p \leq 0.05$) according to Duncan's Multiple Range Test

Figure 17: Effect of cow dung manure on infilteration rate (Site 1)

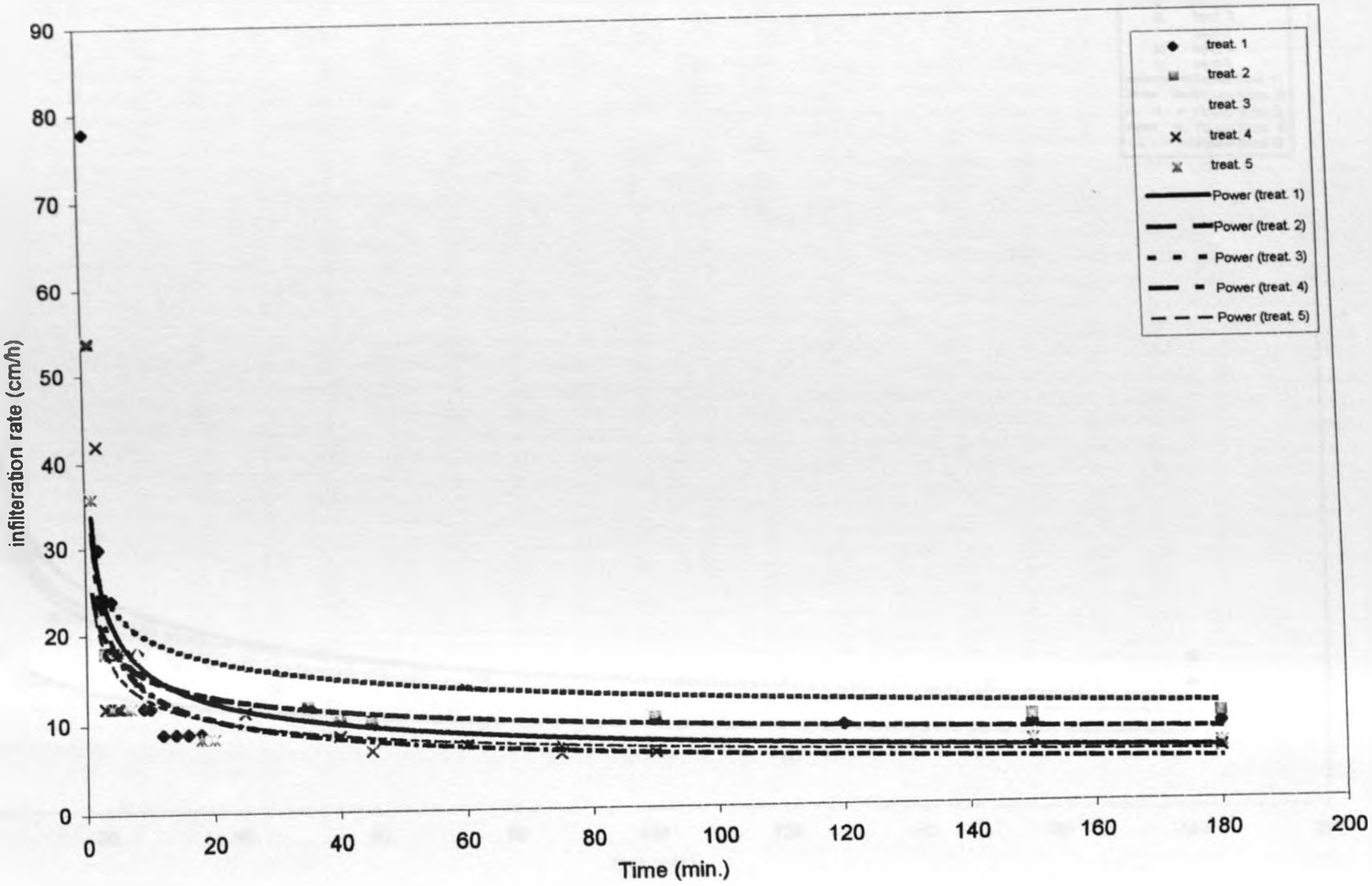
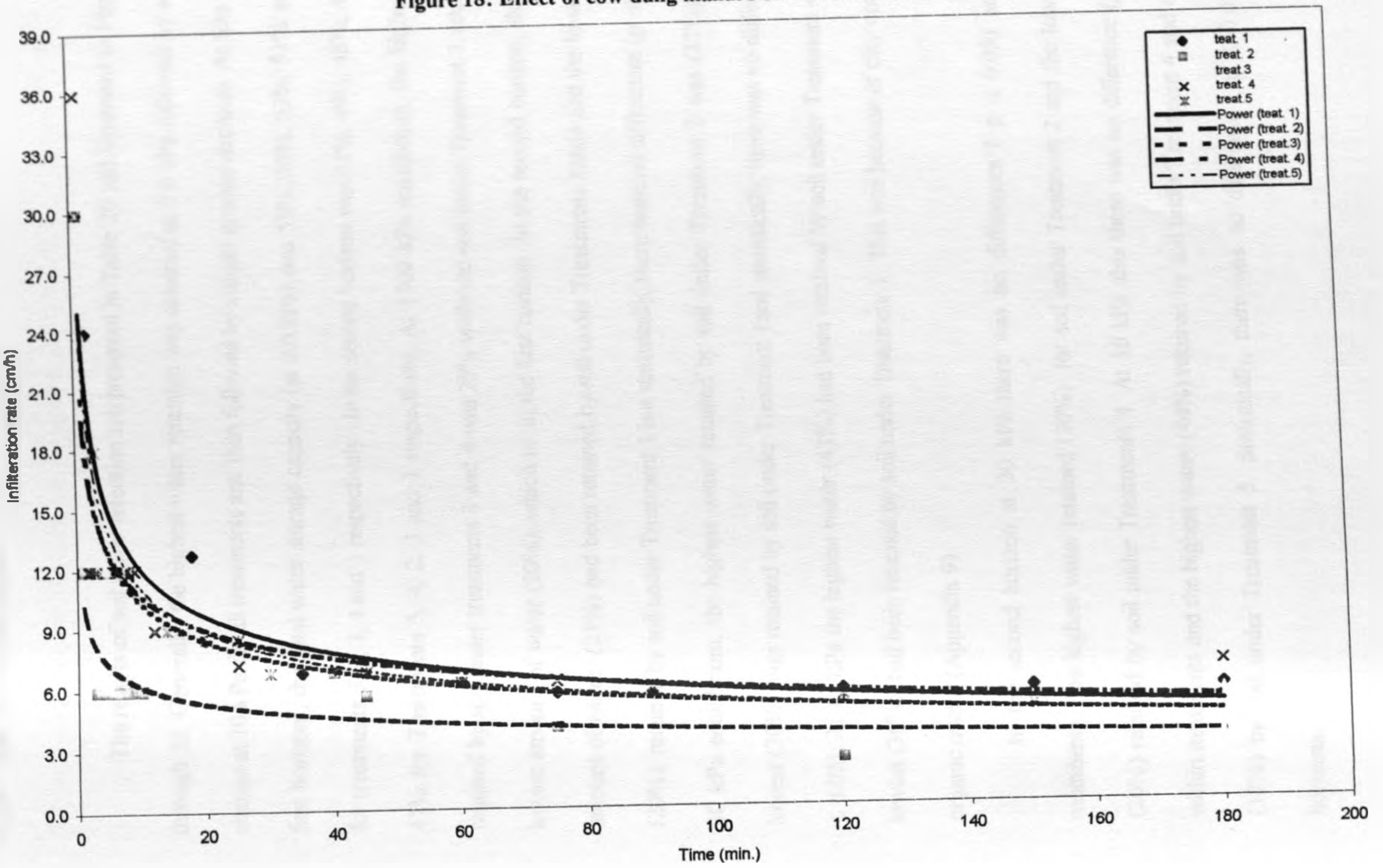


Figure 18: Effect of cow dung manure on infilteration rate (Site 2)



4.2.8 Soil Water Retention

The results of soil water retention are presented in Table 20 and illustrated in Figures 19 through 22. Generally, the highest water retention was obtained at 0.0 kPa followed by a drastic change at 10 kPa for all treatments and then followed by a slight gradual decrease At Site 1 in the first horizon , the total water storage capacity (at 0.0 kPa) was 55%, 55%, 53%, 51% and 51% for treatments 5, 2, 3, 4 and 1 respectively . In the second horizon was 51%, 49%, 48%, 47% and 47% for Treatments 5, 4, 2, 3 and 1 respectively. At 1500 kPa equilibrium, the highest water retained by soil under treatments 3 and 4 was 25% while the soil under Treatment 1 retained the lowest amount of water (20%), which is in the first horizon .In the second horizon, the highest amount of water (21%) had been retained by soil under Treatments 3and4 and the lowest water (20%) retained by soil under Treatment 1 but statistically, there were no differences ($p \leq 0.05$). At 30 kPa equilibrium, the highest water retained by soil under Treatment 2 was (37%) and the lowest (30%) was retained by soil under Treatment 1and statistically, there was no differences ($p \leq 0.05$). At 10 kPa the highest water (43%) had been retained by soil under Treatment 4 and the lowest (36%) had been retained by soil under Treatment 1. This was because of clay content and organic matter (Appendix 9).

In the second horizon at 30 kPa there was no differences ($p \leq 0.05$) among the treatments. The highest water retained (30%) for soil under Treatment 2 and the lowest water (26%) retained by soil under Treatments 4. At 10 kPa also there was no difference ($p \leq 0.05$) within treatments and the highest water (44%) retained by soil under Treatment 4 and the lowest (37%) by soil under Treatment 5. Statistically, there was no difference ($p \leq 0.05$) among horizons.

At Site 2 generally, more water was retained compared with that retained by soil at Site 1. This was mainly because of organic matter content and clay content (Appendices 7 and 9). In the first horizon the total water storage capacity was 70%, 66.5%, 65%, 58% and 61% for Treatments 1, 2, 3, 4 and 5 respectively. At 1500 kPa, the highest water retained by soil under Treatment 1was 45% and the lowest (39%) by soil under Treatments 3 and 4. At 30 kPa soil under Treatment 1 retained 56% water which is equivalent to 75% of the water storage capacity. At 10 kPa water retained by the soil under Treatment 1 was 50%. Statistically, there were no differences ($p \leq 0.05$) within treatments. In the second horizons generally soil under Treatment 3 retained more water than other treatments at all given suctions and the soil under Treatment 2 retained lowest water among all other treatments at all suctions.

Available water: The volume of water retained between field capacity (FC) and permanent wilting point (PWP) was calculated for the two sites under this study. The FC was taken as water retained by soil at 10 and 30 kPa suctions. Therefore the water for both lower suction that designated FC, both 10 and 30kPa were used. These created two suction ranges of water availability; 10 to 1500 kPa and 30 to 1500 kPa.

At Site 1 in the first horizon, the plots under Treatment 4 had higher amount of available water (10 to 1500 kPa) compared with the control. While Treatment 2 had higher amount of available water at 30 to 1500 kPa compared with the control . Statistically, there were no differences ($p \leq 0.05$) among the treatments.

In the second horizon there were no differences ($p \leq 0.05$) among the treatments at 10 to 1500 kPa while there were significant differences ($p \leq 0.05$) at 30 to 1500 kPa. The highest amount of available water was in plots under Treatment 2 and the lowest amount of available water in plots under Treatment 4. Generally, there were no differences ($p \leq 0.05$) among horizons at two suctions.

At Site 2 there was much available water was in the two horizons compared with Site 1 and there were significant differences ($p \leq 0.05$) between two sites. This could be due to differences in texture and clay content in the two sites (Appendices 7 and 9).

In the first horizon there were no significant differences ($p \leq 0.05$) among the treatments at both suctions. At 10-1500 kPa there was a very highly significant differences ($p \leq 0.01$) among the treatment with highest amount of water in the plots under Treatment 1 and lowest amount in plots under Treatment 5. While at 30-1500 kPa the plots under Treatment 3 had much available water. This could be cow dung manure held water so increasing amount of manure led to increase in the amount of water to be held.

There were no differences ($p \leq 0.05$) among horizons at two given suctions but there were significant differences ($p \leq 0.05$) among the Treatments at 10 - 1500 kPa with the highest available water in plots under Treatment 3 and the lowest amount of available water in plots under Treatment 5.

Statistically, there were no differences ($p \leq 0.05$) among the treatments at 30-1500 kPa. This means higher level of cow dung manure decreased the available water in the soil.

There were some interactions between cow dung manure and water potential/salinity levels. These results need to be verified by conducting further research studies in this area.

Table 20: Effect of Cow dung manure on water retention and available water in two depths at sites 1& 2

Treatment (T)	Location (S)	Amount (t/ha)	Depth (cm)	Suction (kPa)			Available water	
				10^{ns}	30^{ns}	1500^{ns}	$(10\text{-}1500)^{**(*)}$	$(30\text{-}1500)^{ns}$
T_1	s1	0	0-20	0.36^{a1}	0.30^{a1}	0.20^{a1}	0.16^{a1}	0.10^{ab1}
			20-45	0.36^{a1}	0.28^{a1}	0.20	0.16^{a1}	0.09
T_2	s1	10	0-20	0.41^{a1}	0.37^{a1}	0.24^{a1}	0.17^{a1}	0.13^{a1}
			20-45	0.35^{a1}	0.30^{a1}	0.19^{a1}	0.16^{ab1}	0.11^{a1}
T_3	s1	20	0-20	0.39^{a1}	0.31^{a1}	0.25^{a1}	0.14^{a1}	0.06^{b1}
			20-45	0.35^{a1}	0.29^{a1}	0.21^{a1}	0.14^{ab1}	0.08^{a1}
T_4	s1	30	0-20	0.43^{a1}	0.31^{a1}	0.25^{a1}	0.18^{a1}	0.06^{b1}
			20-45	0.44^{a1}	0.26^{a1}	0.21	0.23^{a1}	0.05^{b1}
T_5	s1	40	0-20	0.38^{a1}	0.32^{a1}	0.23^{a1}	0.15^{a1}	0.09^{ab1}
			20-45	0.32^{a1}	0.29	0.21	0.11^{b1}	0.08^{a1}
T_1	s2	0	0-30	0.57^{a}	0.56^{a}	0.45^{a}	0.15^{a2}	0.11^{a2}
			30-50	0.51^{a}	0.50	0.38	0.13^{ab2}	0.12^{a2}
T_2	s2	10	0-30	0.52^{a}	0.50^{a}	0.40^{a}	0.12^{b2}	0.10^{a2}
			30-50	0.42^{a}	0.40	0.31	0.11^{b2}	0.09^{a2}
T_3	s2	20	0-30	0.54^{a}	0.52^{a}	0.39^{a}	0.15^{a2}	0.13^{a2}
			30-50	0.55	0.53	0.40	0.15^{b2}	0.13^{a2}
T_4	s2	30	0-30	0.51^{a}	0.5^{a}	0.39	0.12^{b2}	0.11^{a2}
			30-50	0.50	0.49	0.40	0.10^{b2}	0.09^{a2}
T_5	s2	40	0-30	0.50^{a}	0.46	0.41	0.09^{c2}	0.05^{b2}
			30-50	0.51	0.52	0.45	0.06^{b2}	0.08^{a2}

(*) =significant difference ($p \leq 0.05$) between two sites in the first horizons

** =highly significant difference ($p \leq 0.01$) between two sites in second horizons

means with the same letter superscript within each horizon (among treatments) within each suction range and means with the same digit superscript within each site (among horizons) with each suction range are not significant different ($p \leq 0.05$) according to Duncan's Multiple range Test

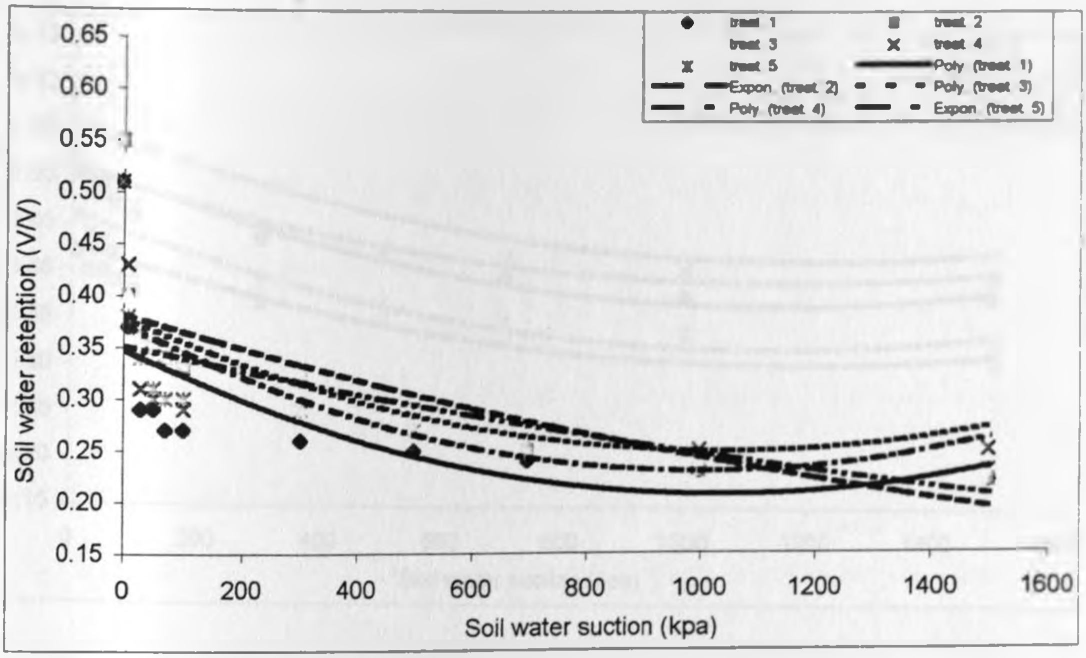


Figure 19. Effect of cow dung manure on water retention curve in the first horizon (0-20cm) (Site 1)

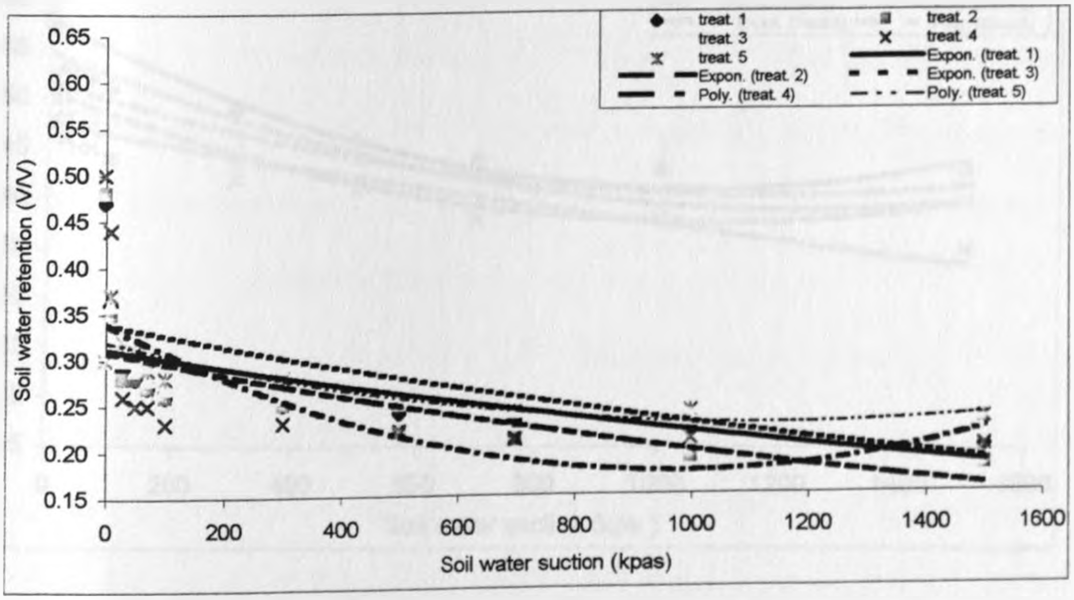


Figure 20. Effect of cow dung manure on water retention curve in the second horizon (20-45cm) (Site 1)

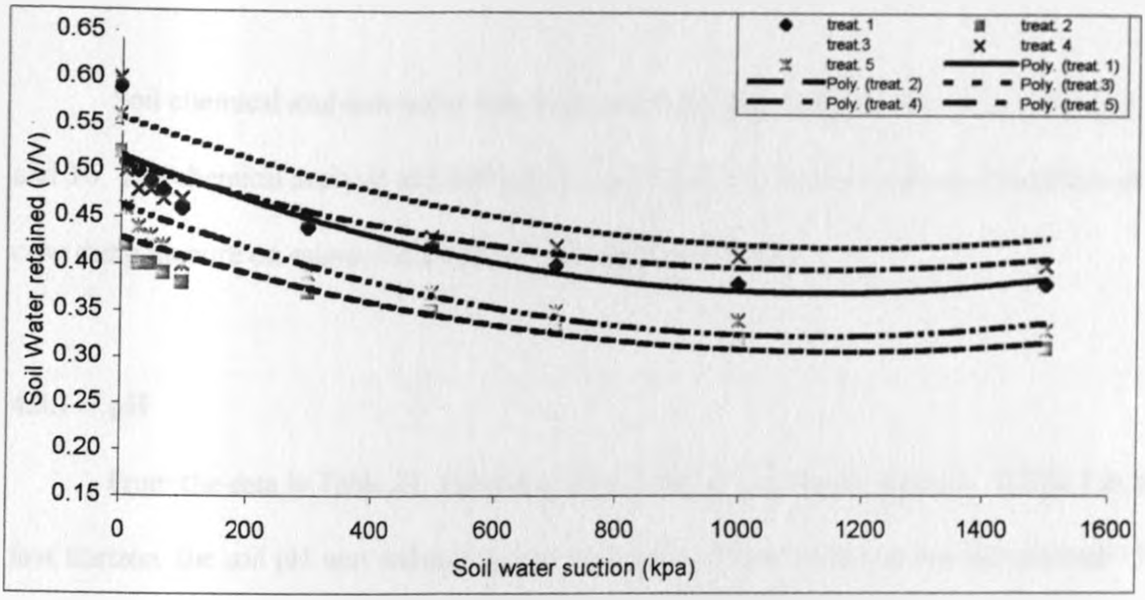


Figure 21. Effect of cow dung manure on water retention curve in the first horizon (0-30cm) (Site 2)

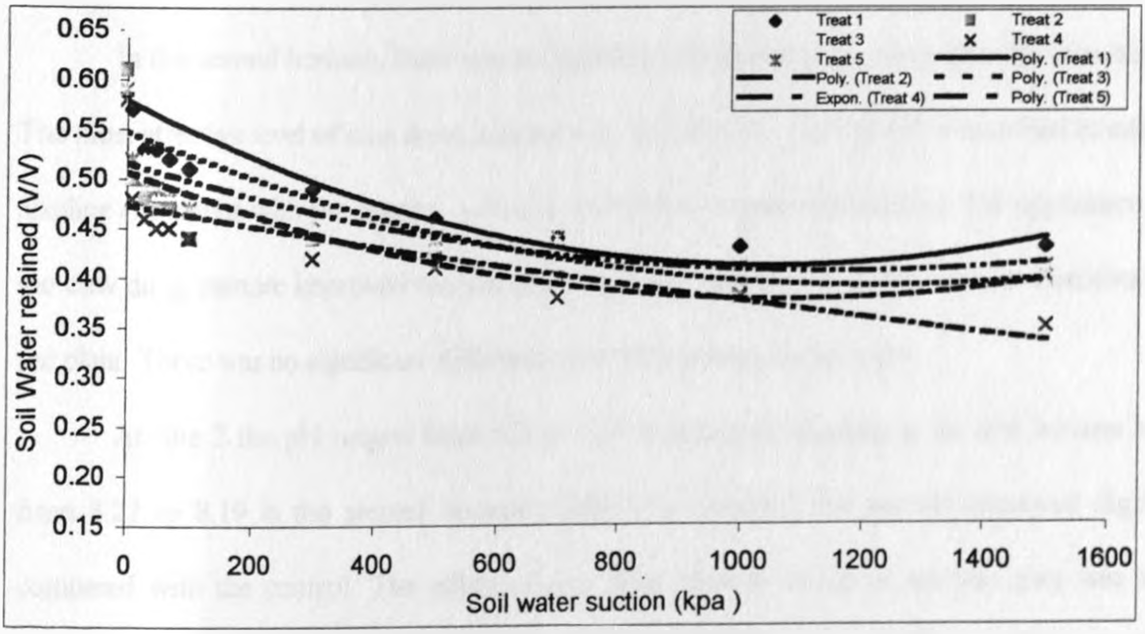


Figure 22. Effect of cow dung manure on water retention curve at the second horizon (30-50cm) (Site 2)

4.3 Soil Chemical Properties

Soil chemical analyses under this study are presented in Appendices 11,12,13,14,15, and 16. The chemical analysis and soil physical analysis were done to evaluate the effects of cow dung manure on saline-sodic soils at two sites under study.

4.3.1 pH

From the data in Table 21, soil pH at Sites 1 and 2 was slightly reduced. At Site 1 in the first horizon, the soil pH was reduced as the application of cow dung manure and reached 7.74 (mildly alkaline) by application of 20 tonnes/ha compared with the control which had the highest pH 8.1 (moderately alkaline). However, this improvement of the soil pH was not statistically significant.

In the second horizon, there was no significant difference ($p \leq 0.05$) within the treatments. The most effective level of cow dung manure was 20 tonnes/ha. The soil pH is described as mildly alkaline compared with the control, which is described as moderately alkaline. The application of the cow dung manure improved the soil pH, which will enhance the uptake of micronutrients by the plant. There was no significant difference ($p \leq 0.05$) among the horizons.

At Site 2 the pH ranged from 8.2 to 8.07 (moderately alkaline) in the first horizon and from 8.27 to 8.19 in the second horizon (Table 21). Generally the soil pH improved slightly compared with the control. The effect of cow dung manure on pH at the two sites was not significantly different ($p \leq 0.05$). The results are illustrated in Figures 23 and 24.

Table 21 Effect of cow dung manure on soil pH in two depths at Site1 and 2

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm)		Ssite 2 Depth (cm)	
		0-20 ^{ns}	20-45 ^{ns}	0-30 ^{ns}	30-50 ^{ns}
T_1	0	8.1^{a1}	7.45^{a1}	8.18^{ab2}	8.22^{a2}
T_2	10	7.93^{a1}	7.70^{a1}	8.07^{c2}	8.19^{a2}
T_3	20	7.74^{a1}	7.59^{a1}	8.12^{bc2}	8.27^{a2}
T_4	30	7.98^{a1}	7.82^{a1}	8.23^{a2}	8.27^{a2}
T_5	40	7.96^{a1}	7.59^{a1}	8.19^{ab2}	8.24^{a2}

Means with the same letter superscript within each horizon (between treatments)and means with the same digit in superscript among horizon within one site are not significantly difference ($p \leq 0.05$) according to Duncan's Multiple Range Test.

ns = not significant difference ($p \leq 0.05$)between two sites

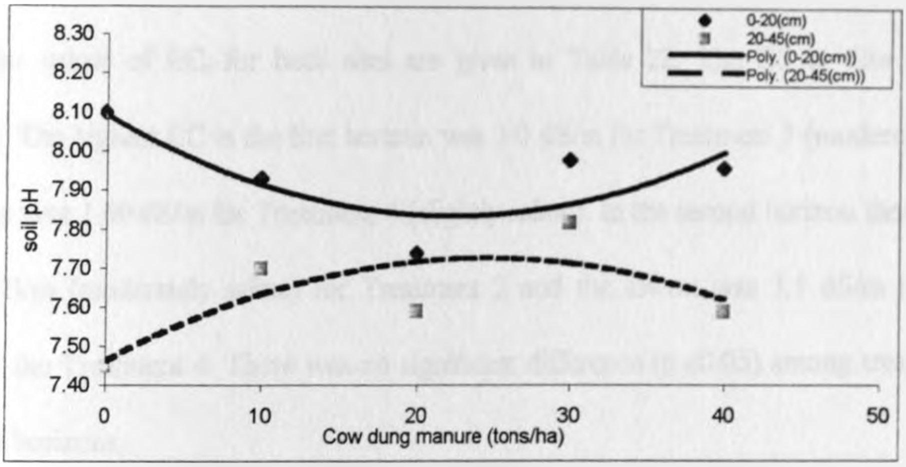


Figure 23 .Effect of cow dung manure on soil pH in two depths (Site 1)

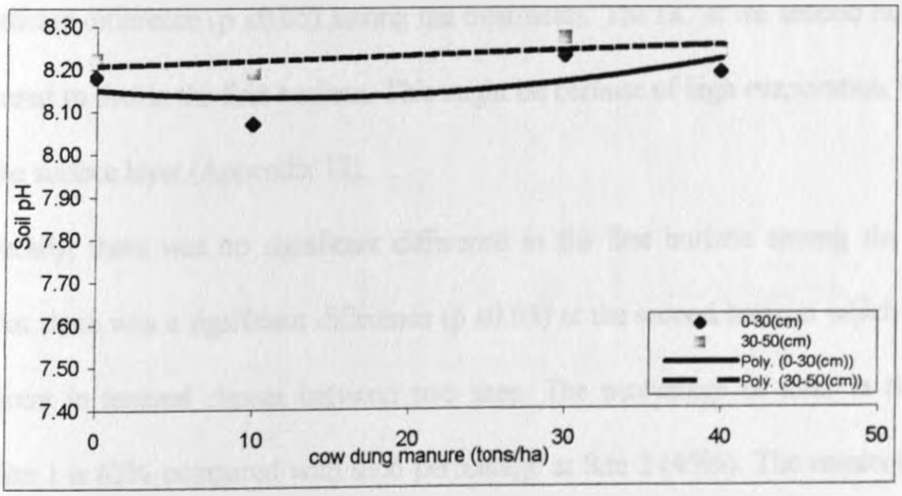


Figure 24 .Effect of cow dung manure on soil pH in two depths (Site 2)

4.3.2 Electrical Conductivity

The values of EC_e for both sites are given in Table 22. The EC at Site 1 generally decreased. The highest EC in the first horizon was 3.0 dS/m for Treatment 3 (moderately saline). The lowest was 1.60 dS/m for Treatment 4 (slightly saline). In the second horizon the highest EC was 3.6 dS/m (moderately saline) for Treatment 2 and the lowest was 3.1 dS/m (moderately saline) for the Treatment 4. There was no significant difference ($p \leq 0.05$) among treatments and among the horizons.

The soil at Site 1 fell under classes slightly saline to moderately saline. EC at Site 2 in the first horizon ranged from 2.4 to 1.7 dS/m while in the second horizon it ranged from 2.48 dS/m to 1.26 dS/m (slightly saline) which renders the soil at this site to fall under slightly saline class. There was no significant difference ($p \leq 0.05$) among the treatments. The EC at the second horizon was lower compared to that in the first horizon. This might be because of high evaporation, which left the salt on the surface layer (Appendix 12).

Generally, there was no significant difference in the first horizon among the soil type (Table 22) but there was a significant difference ($p \leq 0.05$) at the second horizon which would be due to different in textural classes between two sites. The percentage of sand in the second horizon at Site 1 is 62% compared with sand percentage at Site 2 (45%). The results of EC are illustrated in Figures 25 and 26.

Table 22: Effect of cow dung manure on electrical conductivity (dS/m) at 25^{0}c in two depths at Site 1 and 2

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm)		Site 2 Depth (cm)	
		0-20 ^{ns}	20-45 *	0-30 ^{ns}	30-50 *
T_1	0	2.09^{a1}	3.20^{a1}	1.83^{a2}	1.26^{a2}
T_2	10	2.07^{a1}	3.64^{a1}	2.39^{a2}	1.50^{a2}
T_3	20	2.99^{a1}	3.29^{a1}	2.30^{a2}	1.70^{a2}
T_4	30	1.60^{a1}	3.06^{a1}	2.00^{a2}	1.53^{a2}
T_5	40	1.97^{a1}	3.07^{a1}	1.66^{a2}	2.48^{a2}

* = Significant difference ($p \leq 0.05$) between the second horizons according to Duncan's multiple Range Test

ns = Not significant difference ($p \leq 0.05$) between first horizon according to Duncan's Multiple Range Test.

The mean with the same letter superscript among treatments and the mean with the same digit superscript among horizons at site 1 not significant ($p \leq 0.05$) according to Duncan's Multiple Range Test.

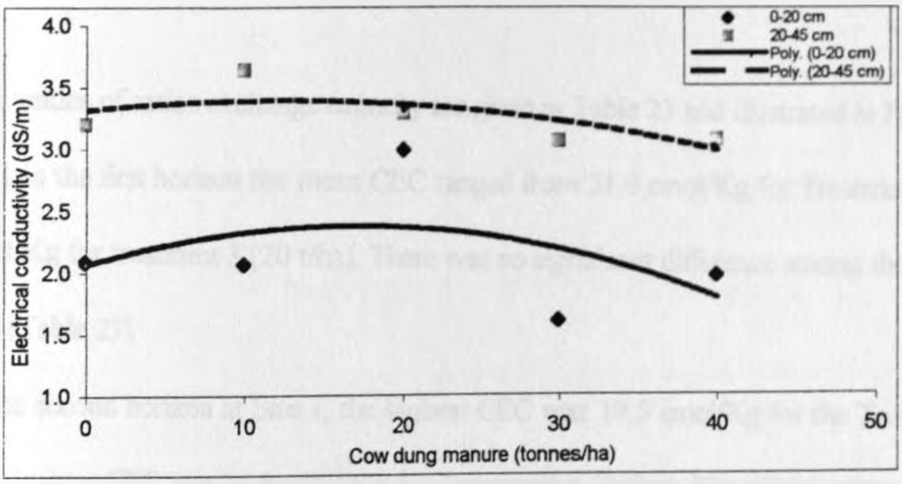


Figure 25. Effect of cow dung manure on electrical conductivity in two depths (Site 1)

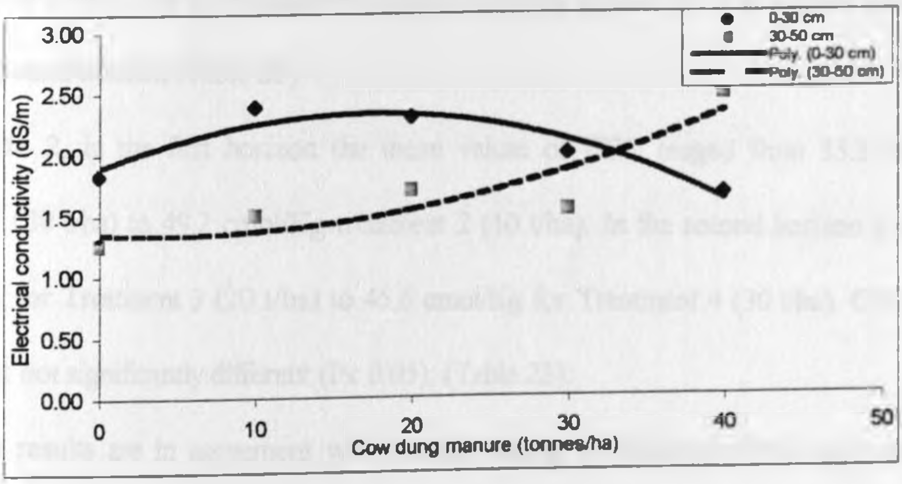


Figure 26. Effect of cow dung manure on electrical conductivity in two depths (Site 2)

4.3.3 Cation Exchange Capacity (CEC)

The values of cation exchange capacity are given in Table 23 and illustrated in Figures 27 and 28. At site 1 in the first horizon the mean CEC ranged from 21.0 cmol/Kg for Treatment 4 (30 t/ha) to 19.0 cmol/Kg for treatment 3 (20 t/ha). There was no significant difference among the treatment in this horizon (Table 23).

In the second horizon at Site 1, the highest CEC was 19.5 cmol/Kg for the Treatment 3 (20 t/ha) and the lowest CEC was 16.8 cmol/Kg for Treatment 1 (0 t/ha). The CEC increased as a result of application of cow dung manure compared to the control but statistically was not significant ($P \leq 0.05$).

Generally CEC decreased with depth but was found statistically not significantly difference ($p \leq 0.05$). Thus as a result, the exchangeable cations are slightly high at the first horizon compared with these in the second horizon (Table 25).

At Site 2, in the first horizon the mean values of CEC ranged from 53.3 cmol/Kg for Treatments 3 (20 t/ha) to 49.2 cmol/Kg treatment 2 (10 t/ha). In the second horizon it varied from 51.0 cmol/Kg for Treatment 3 (20 t/ha) to 45.6 cmol/Kg for Treatment 4 (30 t/ha). CEC decreased with depth but not significantly different ($P \leq 0.05$), (Table 23).

These results are in agreement with related finding by Aladjem (1952) who indicated no significant difference in CEC between the treatments (various level of manure and mineral fertilizer NPK) in Egyptian soil.

Generally CEC at Site 2 was higher than that at Site 1 (Table 23) but not statistically significant ($p \leq 0.05$), (Table 23). This might be because of high percentage of clay at Site 2 (41.91% in the first horizon and 43.34% in the second horizon) while at Site 1 it is less than 20% both the horizons.

Table 23: Effect of Cow Dung Manure on CEC cmol/Kg in two depths at Site1 and 2

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm)		Site 2 Depth (cm)	
		0-20 ^{ns}	20-45 *	0-30 ^{ns}	30-50 *
T_1	0	20.00^{a1}	16.8^{a1}	51.2^{a2}	47.73^{a2}
T_2	10	20.2^{a1}	17.07^{a1}	49.2^{b2}	48.8^{a2}
T_3	20	19.0^{a1}	19.47^{a1}	53.27^{a2}	51.0^{a2}
T_4	30	21.00^{a1}	18.00^{a1}	50.73^{ab2}	45.6^{a2}
T_5	40	26.01^{a1}	18.1^{a1}	52.97^{a2}	49.73^{a2}

* = Significant difference ($p = 0.05$) between the second horizons between soil types according to Duncan's Multiple Range Test

ns = not significant difference ($p = 0.05$) between first horizons between soil types according to Duncan's Multiple Range Test.

The mean with the same letter superscript among treatments and the mean with the same digit superscript among horizon not significant ($p = 0.05$) according to Duncan's Multiple Range Test.

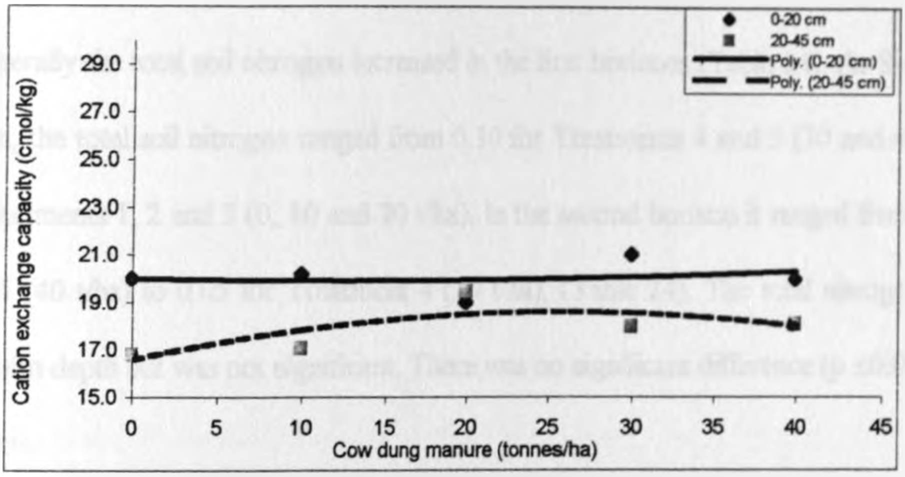


Figure 27. Effect of cow dung manure on cation exchange capacity in two depths (Site 1)

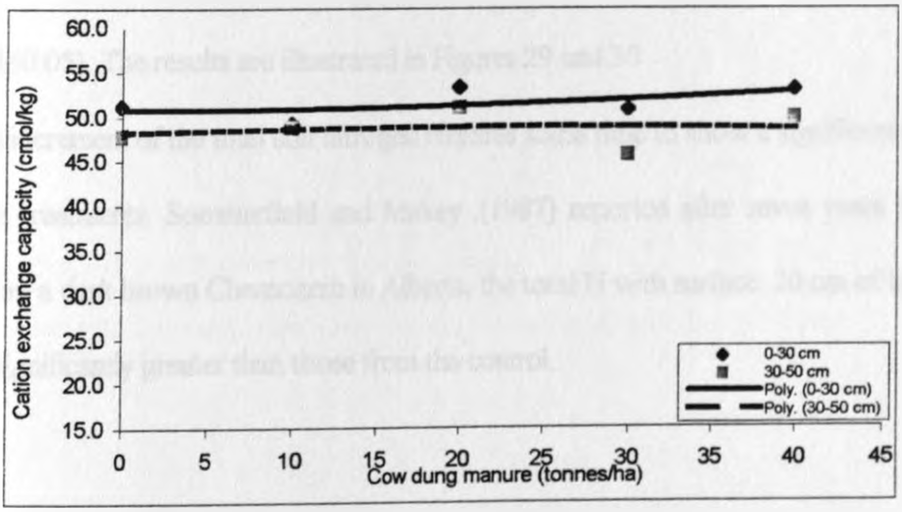


Figure 28. Effect of cow dung manure on cation exchange capacity in two depths(Site 2)

4.3.4 Total Soil Nitrogen (%N)

Generally the total soil nitrogen increased in the first horizons (Table 24). At Site 1 in the first horizon, the total soil nitrogen ranged from 0.10 for Treatments 4 and 5 (30 and 40 t/ha) to 0.09 for Treatments 1, 2 and 3 (0, 10 and 20 t/ha). In the second horizon it ranged from 0.08 for Treatment 5 (40 t/ha) to 0.05 for Treatment 4 (30 t/ha), (Table 24). The total nitrogen percent decreased with depth but was not significant. There was no significant difference ($p \leq 0.05$) among the treatments.

At Site 2 in the first horizon the highest total soil nitrogen was 0.16 for Treatment 4 (30 tonnes/ha) and the lowest was 0.13 Treatment 1 (0 t/ha). In the second horizon the total soil nitrogen was almost the same (0.11) for all the treatments (Table 24). There was no significant difference between the treatments in the two horizons and also no significant difference between two sites ($P \leq 0.05$). The results are illustrated in Figures 29 and 30

The increment of the total soil nitrogen requires some time to show a significant difference between the treatments. Sommerfield and Makey .(1987) reported after seven years of manure application on a dark brown Chernozem in Alberta, the total N with surface 20 cm of the manure plots were significantly greater than those from the control.

Table 24: Effect of cow dung manure on Total Soil Nitrogen in two depths at Site1 and 2

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm)		Site 2 Depth (cm)	
		0-20^{ns}	20-45^{ns}	0-30^{ns}	30-50^{ns}
T_1	0	0.09^{a1}	0.06^{a1}	0.13^{a2}	0.11^{a2}
T_2	10	0.09^{a1}	0.06^{b1}	0.15^{a2}	0.11^{a2}
T_3	20	0.09^{a1}	0.06^{b1}	0.14^{a2}	0.11^{a2}
T_4	30	0.10^{a1}	0.05^{b1}	0.16^{a2}	0.11^{a2}
T_5	40	0.10^{a1}	0.08^{a1}	0.15^{a2}	0.11^{a2}

ns = Not significant ($p = 0.05$) between soil type (first horizons)
Mean with the same letter superscript among treatment within the same horizon and the mean with the same digit superscript among horizons are not significantly difference ($p = 0.05$) according to Duncan's Multiple Range Test.

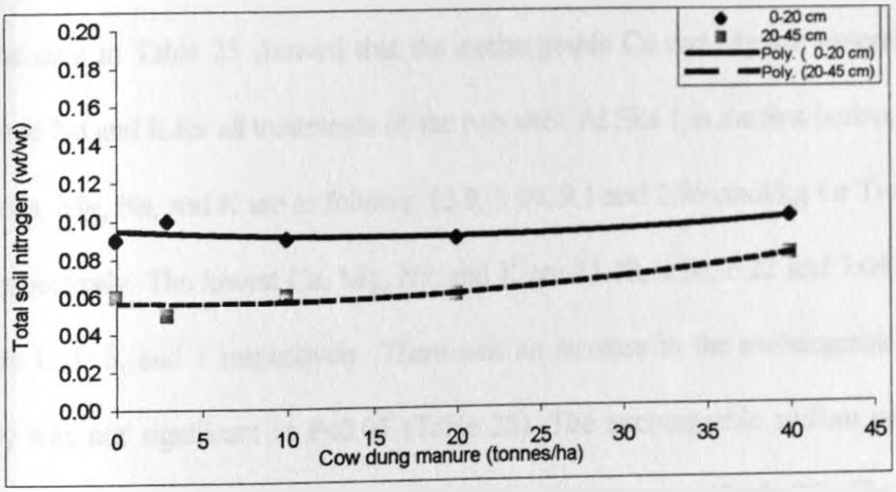


Figure 29. Effect of cow dung manure on total soil nitrogen in two depths (Site 1)

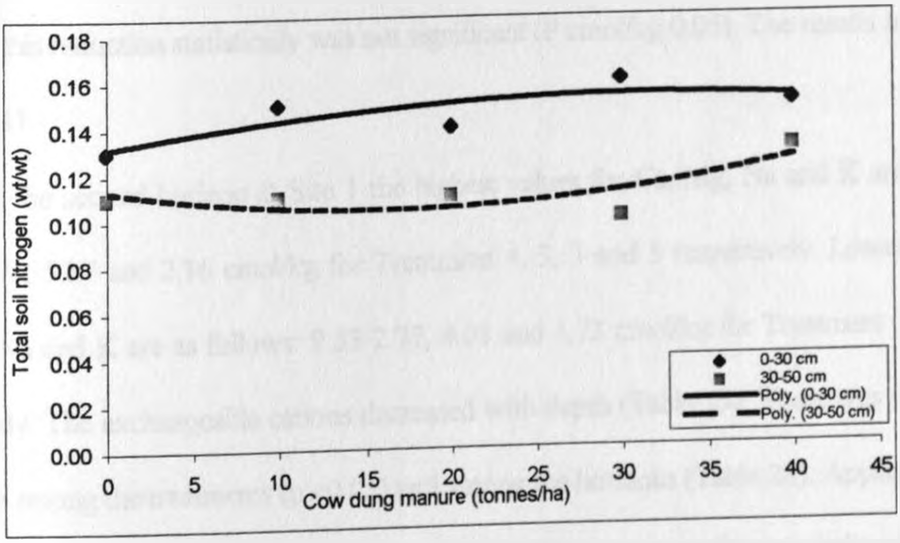


Figure30. Effect of cow dung manure on total soil nitrogen in two depths (Site 2)

4.3.5 Exchangeable Cations

The data in Table 25 showed that the exchangeable Ca and Mg are generally higher in proportion to Na and K for all treatments in the two sites. At Site 1 in the first horizon the highest values for Ca, Mg, Na, and K are as follows: 12.9, 5.09, 9.1 and 2.96 cmol/kg for Treatment 5, 2, 2 and 4 respectively. The lowest Ca, Mg, Na, and K are 11.18, 4.56, 6.22 and 1.64 cmol/kg for Treatments 1, 3, 5, and 1 respectively. There was an increase in the exchangeable cations but statistically was not significant at $P \leq 0.05$ (Table 25). The exchangeable sodium percent (ESP) decreased by increasing the rate of application of cow dung manure (Table 25). The ESP ranged from 41.08 (excessively sodic) for Treatment 2 to 32.65 (strongly sodic) for Treatment 4. The ESP in this horizon decreased with the increase in the rate of application of cow dung manure compared with the control (ESP = 37.56). The most effective level to reduce ESP was level (30 t/ha), but this reduction statistically was not significant (P cmol/kg 0.05). The results are illustrated in Figure 31.

In the second horizon at Site 1 the highest values for Ca, Mg, Na and K are as follows; 11.82, 3.73, 5.87 and 2.16 cmol/kg for Treatment 4, 3, 3 and 5 respectively. Lowest values for Ca, Mg, Na and K are as follows: 9.33 2.77, 4.08 and 1.73 cmol/kg for Treatment 1, 1, 2 and 1 respectively. The exchangeable cations decreased with depth (Table 25). There was no significant difference among the treatments ($p \leq 0.05$) and among the horizons (Table 25). Application of cow dung manure increased the exchangeable K, which is most important for metabolic process and in opening and closing stomata in the plant and elongation of the plant roots (Delvin and Witham, 1986).

ESP in the second horizon decreased with application of cow dung manure. The lowest value of 24.87% (strongly sodic) was obtained by the application of 30 t/ha and the highest value was 28.01% (strongly sodic) for Treatment 1 (0 t/ha). The ESP decreased with depth. This was because sodium chloride, which was fed to most class of livestock to increase appetite and reduce kidney stones, much was avoided in manure (Donahue *et al.*, 1990).

At Site 2 in the first horizon the highest values for Ca, Mg, Na and K are as follows: 35.15, 13.62, 3.05 and 5.32 cmol/kg for Treatments 5, 4, 1, and 5 respectively. The lowest values are as follows: 31.19, 12.53, 2.04 and 2.45 cmol/kg for Treatment 1, 2, 4 and 1 respectively (Table 25). The Treatments 5 and 4 are the most effective levels for increasing the exchangeable cations, which result in improving the fertility of the soil. ESP decreased with application of manure, the lowest ESP was 3 for treatment 3 and the highest ESP was 5.64 for treatment 1.

In the second horizon the exchangeable cations decreased compared with those in the first horizon. The mean values for exchangeable Ca, Mg, Na and K ranged from 33.93, 15.58, 2.36 and 3.45 cmol/kg for Treatments 5, 3, 3 and 2 to 30.05, 13.40, 2.14 and 2.33 cmol/kg for the Treatments 1, 1, 2 and 1 (Table 25). Reduction of ESP in the first horizon from 5.64 for the control (slightly sodic) to 3.90 (non-sodic) for Treatment 3 was because of reduction of exchangeable sodium and increase in exchangeable calcium and magnesium (Table 25).

The sodium was leached down such that the exchangeable sodium was slightly high in the second horizon. The ESP in the second horizon ranged form 7.25% (slightly sodic) for Treatment 5 to 4.22 (non-sodic) for treatment 2. The results of ESP are illustrated in Figure 32. There was no significant difference among the treatments and among the horizons (Table 25). The difference between the treatments and among the horizon to be measurable required time. There was not significant difference ($p \leq 0.05$) between the two sites.

Table25: Effect of cow dung manure on exchangeable cations(cmol/kg) and ESP in two depths at Site 1 and 2

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm) 0 - 20				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	ESP^{ns}
T_1	0	11.18^{a1}	4.70^{a1}	7.51^{a1}	1.64^{a1}	37.58^{a1}
T_2	10	11.73^{a1}	5.09^{ab1}	9.10^{a1}	2.00^{a1}	41.08^{a1}
T_3	20	12.00^{a1}	4.56^{b1}	7.40^{a1}	2.49^{a1}	36.34^{a1}
T_4	30	12.73^{a1}	4.66^{b1}	6.85^{a1}	2.96^{a1}	32.65^{a1}
T_5	40	12.89^{a1}	4.79^{b1}	6.22^{a1}	2.75^{a1}	33.19^{a1}

Table 25 : Continued

Treatment(T)	Amount (t/ha)	Site 1 Depth (cm) 20 - 45				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	ESP^{ns}
T_1	0	9.33^{a1}	2.77^{a1}	4.81^{b1}	1.73^{a1}	28.01^{a2}
T_2	10	10.05^{a1}	3.68^{a1}	4.08^{ab1}	1.86^{a1}	27.24^{a2}
T_3	20	11.15^{a1}	3.73^{a1}	5.87^{a1}	2.15^{a1}	25.33^{a2}
T_4	30	11.82^{a1}	3.56^{a1}	4.38^{ab1}	2.15^{a1}	24.87^{a2}
T_5	40	11.25^{a1}	3.60^{a1}	4.74^{ab1}	2.16^{a1}	25.83^{a2}

Table 25: Continued

Treatment (T)	Amount (t/ha)	Site 2 Depth (cm) 0 - 30				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	ESP^{ns}
T_1	0	31.19^{a1}	12.96^{a2}	3.05^{a2}	2.45^{a2}	5.64^{a2}
T_2	10	33.18^{a1}	12.58^{a2}	2.28^{a2}	3.77^{a2}	4.65^{a2}
T_3	20	33.10^{a1}	12.96^{a2}	2.07^{a2}	3.64^{a2}	3.90^{a2}
T_4	30	35.15^{a1}	13.34^{a2}	2.04^{a2}	4.94^{a2}	3.95^{a2}
T_5	40	35.9^{a1}	13.62^{a2}	2.13^{a2}	5.32^{a2}	4.07^{a2}

Treatment(T)	Amount (t/ha)	Site 2 Depth (cm) 30 - 50				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	ESP^{ns}
T_1	0	30.05^{a2}	13.40^{a2}	2.58^{a2}	2.33^{a2}	4.71^{a2}
T_2	10	31.9^{a2}	13.55^{a2}	2.14^{a2}	3.45^{a2}	4.22^{a2}
T_3	20	30.83^{a2}	15.58^{a2}	2.36^{a2}	3.07^{a2}	4.38^{a2}
T_4	30	31.35^{a2}	15.36^{a2}	2.35^{a2}	3.11^{a2}	6.97^{a2}
T_5	40	33.93^{a2}	15.36^{a2}	2.27^{a2}	3.34^{a2}	7.25^{a2}

ns = not significant difference ($p = 0.05$) between soil types

mean with the same letter superscript within horizon (between treatment) and mean with the same digit superscript among horizons at one site are not significant difference ($p = 0.05$) according to Duncan's Multiple Range Test.

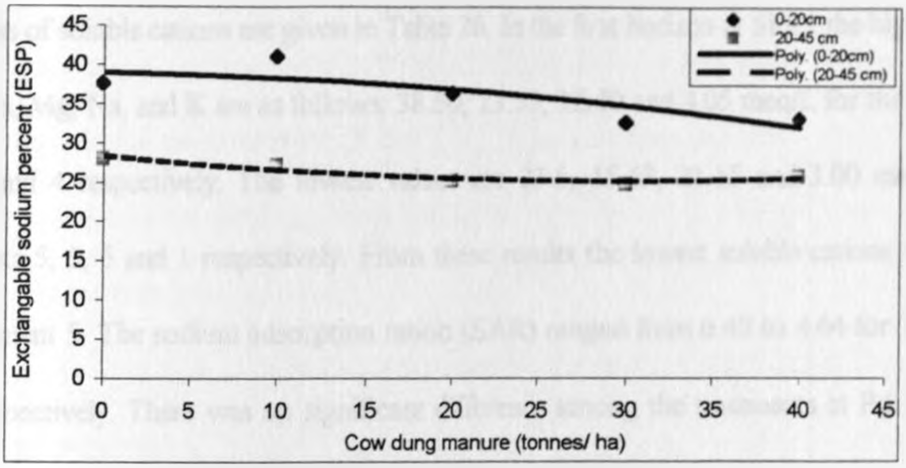


Figure 31. Effect of cow dung manure on ESP in two depths (Site1)

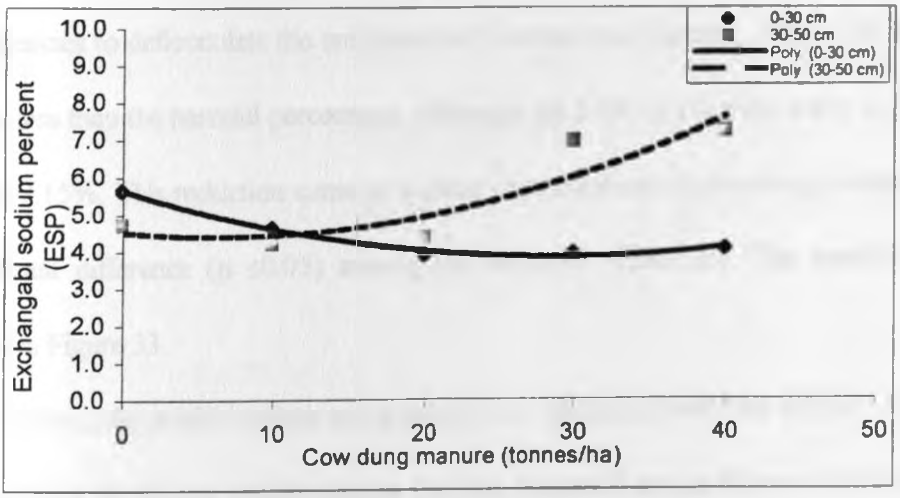


Figure 32. Effect of cow dung manure on ESP in two depths (Site2)

4.3.6 Soluble Cations

The values of soluble cations are given in Table 26. In the first horizon at Site 1 the highest soluble cations Ca, Mg, Na, and K are as follows: 38.50, 23.55, 32.40 and 4.05 meq/L for the Treatments 3, 2, 3, and 4 respectively. The lowest values are 23.5, 15.63, 21.15 and 3.00 meq/L for the Treatments 5, 5, 5 and 1 respectively. From these results the lowest soluble cations values were for Treatment 5. The sodium adsorption ration (SAR) ranged from 6.49 to 4.64 for Treatment 1 and 3 respectively. There was no significant difference among the treatments at $P \leq 0.05$ (Table 26).

In the second horizon the values of soluble cations (Ca, Mg, K and Na) were 23, 15.82, 20.28 and 3.10 meq/L for the Treatments 3, 3, 3 and 3 respectively to 15.17, 9.33, 16.9 and 1.1 meq/L for the Treatment 5, 4, 5 and 1 respectively. The soluble sodium on the first horizon is due to its tendencies to deflocculate the soil particles (Zartman and Gichuru, 1984). The percentage of SAR was less than the harmful percentage. Although the SAR of irrigation water at this site (bore hole) was 7.15%. This reduction came as a result of application of cow dung manure. There was no significant difference ($p \leq 0.05$) among the horizons (Table 26). The results of SAR are illustrated in Figure 33.

At Site 2 the soluble cations are generally low compared with that at Site 1 (Table 26). In the first horizon the highest soluble cations Ca, Mg, Na and K are as follows :42.50, 16.80, 28.20 and 3.95 meq/L for Treatments 2, 2, 3 and 4 respectively. The lowest are 11.50, 6.50, 24.63 and 0.8 meq/L for the Treatments 5, 5, 5 and 1 respectively. In the second horizon the mean values of soluble cations (Ca, Mg, Na and K) were 23, 23.22, 7.9 and 26.3 and 2.37 meq/L for Treatments

2, 4, 1, and 4 respectively to 8.0, 5.47, 22.50 and 0.8 meq/L for the Treatment 5, 1, 5, and 4 respectively.

There was no significant difference ($p \leq 0.05$) between the treatments. SAR values ranged from 7.92 to 6.12 for the Treatments 5 and 2 in the first horizon and from 9.01 to 6.54 for the Treatment 5 and 2 in the second horizon (Appendix 12). There was no significant different ($p \leq 0.05$) between treatments and horizons.

The results of SAR are illustrated in Figure 34. There was a significant different ($p \leq 0.05$) between the two sites.

4.3.7 Base Saturation (%BS)

From the data in Appendices 13 and 14, the BS percent was above 50 for the soils at both sites. At Site 1 the BS percent was above 100 as was observed by Donahue *et al.*, (1990) they reported that BS of 100 is usually formed in neutral or alkaline soils (very little hydrogen and soluble aluminium). At Site 2, the BS was above 90 which is because of alkaline soils (Saline-Sodic soil).

Table 26: Effect of cow dung manure at different levels on soluble cation (meq/L) and sodium adsorption ratio in two depths at Site 1 and 2

Treatment	Amount (t/ha)	Site 1 Depth (cm) 0 - 20				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	SAR^{ns}
T_1	0	26.75^{a1}	17.6^{ab1}	26.98^{ab1}	3.00^{a1}	6.49^{a1}
T_2	10	35.5^{a1}	23.5^{a1}	31.65^{a1}	3.65^{a1}	5.45^{a1}
T_3	20	38.5^{a1}	23.00^{b1}	32.4^{ab1}	3.95^{a1}	4.64^{a1}
T_4	30	29.01^{a1}	18.65^{ab1}	26.4^{ab1}	4.05^{a1}	5.59^{a1}
T_5	40	23.50^{a1}	15.63^{b1}	21.15^{b1}	3.75^{a1}	5.94^{a1}

Table 26: Continued

Treatment (T)	Amount (t/ha)	Site 1 Depth (cm) 20 - 45				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	SAR^{ns}
T_1	0	17.50^{ab1}	11.02^{ab1}	20.13^{a1}	1.1^{a1}	5.25^{a1}
T_2	10	17.75^{ab1}	10.20^{ab1}	20.03^{a1}	1.6^{a1}	5.88^{a1}
T_3	20	23.00^{a1}	15.82^{a1}	20.28^{a1}	2.45^{a1}	4.67^{a1}
T_4	30	15.25^{b1}	9.33^{b1}	17.80^{a1}	3.10^{a1}	4.98^{a1}
T_5	40	15.17^{ab1}	9.38^{ab1}	16.9^{a1}	3.0^{a1}	4.95^{a1}

Table 26: Continued

Treatment (T)	Amount (t/ha)	Site 2 Depth (cm) 0 - 30				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	SAR^{ns}
T_1	0	$15.0^{bc(a)}$	7.2^{b2}	25.27^{a2}	0.8^{a2}	7.80^{ab2}
T_2	10	$42.5^{a(a)}$	16.15^{a2}	28.2^{a2}	2.68^{a2}	6.12^{b2}
T_3	20	$30.5^{b(a)}$	16.8^{ab2}	27.4^{a2}	2.8^{a2}	6.77^{ab2}
T_4	30	$20.5^{bc(a)}$	12.3^{b2}	25.90^{a2}	3.95^{a2}	7.80^{ab2}
T_5	40	$11.5^{c(a)}$	6.5^{b2}	24.63^{a2}	3.68^{a2}	7.92^{a2}

Table 26: Continued

Treatment (T)	Amount (t/ha)	Site 2 Depth (cm) 30 - 50				
		Ca^{ns}	Mg^{ns}	Na^{ns}	K^{ns}	SAR^{ns}
T_1	0	14.0^{b2}	5.47^{a2}	26.3^{a2}	0.8^{a2}	8.34^{a2}
T_2	10	23.00^{a2}	6.90^{a2}	25.55^{a2}	2.09^{a2}	6.54^{a2}
T_3	20	12.25^{b2}	12.00^{a2}	22.75^{a2}	2.37^{a2}	7.82^{a2}
T_4	30	11.5^{b2}	7.9^{a2}	22.40^{a2}	1.5^{a2}	8.0^{a2}
T_5	40	8.0^{b2}	6.1^{a2}	22.15^{a2}	1.37^{a2}	9.01^{a2}

ns = Not significant difference ($p = 0.05$) between soil types

Mean with the same letter superscript within horizon (between treatment) and mean with the same digit superscript among horizona at one site are not significant difference ($p \leq 0.05$) according to Duncan's Multiple Range Test.

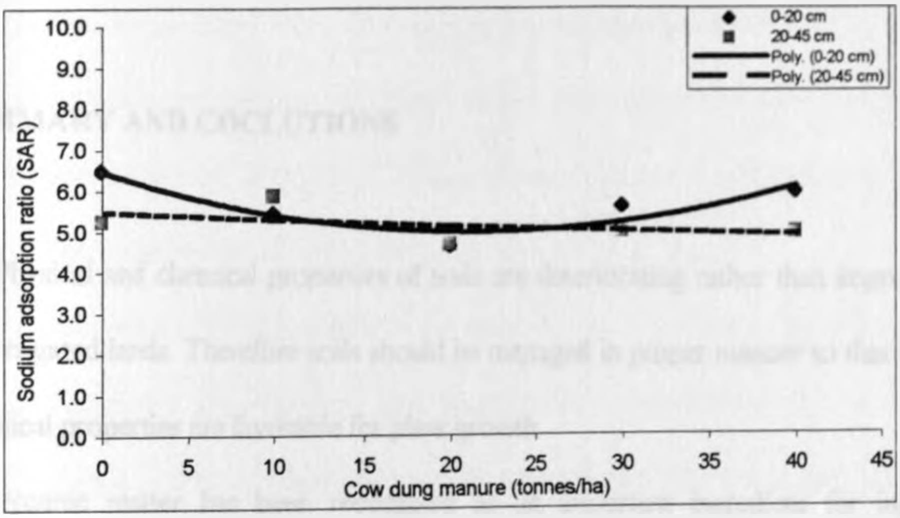


Figure 33. Effect of cow dung manure on SAR in two depths (Site 1)

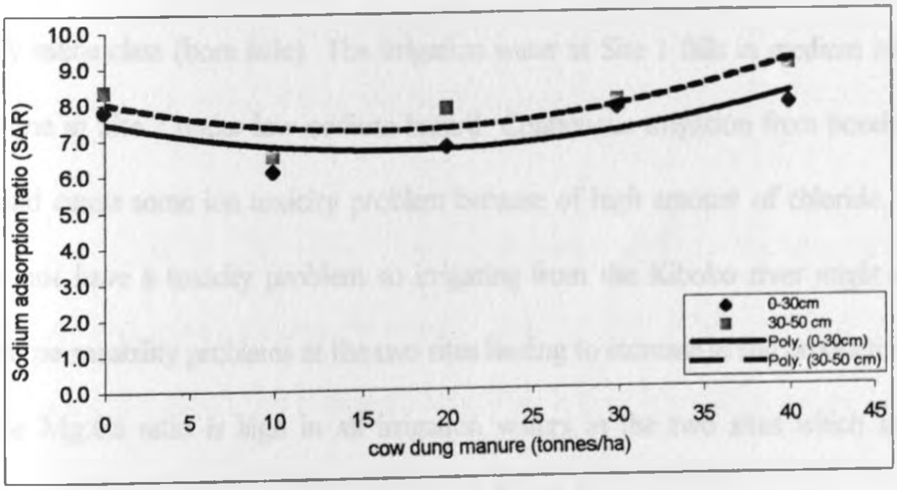


Figure 34. Effect of cow dung manure on SAR in two depths (Site 2)

CHAPTER 5

5.0 SUMMARY AND COCLUTIONS

Physical and chemical properties of soils are deteriorating rather than improving in most cases in irrigated lands. Therefore soils should be managed in proper manner so that their physical and chemical properties are favorable for plant growth.

Organic matter has been recognised as an important ingredient for increasing soil productivity through improving their physical and chemical properties.

The results of irrigation water indicated that the irrigation water used at Site 1 falls under very highly saline class and that used at Site 2 falls under medium salinity class (Kiboko river) and very highly saline class (bore hole). The irrigation water at Site 1 falls in medium sodium hazard while the one in Site 2 under low sodium hazard. Continuous irrigation from boreholes at Site1 and 2 would cause some ion toxicity problem because of high amount of chloride. The Kiboko river does not have a toxicity problem so irrigating from the Kiboko river might decrease the toxicity and permeability problems at the two sites leading to increase in soil productivity.

The Mg:Ca ratio is high in all irrigation waters in the two sites which results in soil structure deterioration and develop a magnesium solonetz.

The results obtained after 18 weeks of application of cow dung manure at various levels (0, 10, 20,30 and 40 t/ha) on saline-sodic soil at Kiboko, Makueni district led to the following conclusions:

The 18 weeks period is a short time for cow dung manure torealise differences between the various levels of application

There was evidence for improving saline-sodic properties as the result of application of cow dung manure but probably more time was required to give significant results.

The application of cow dung manure to saline -sodic soil at two sites had a little effect on soil bulk density and texture. It should be noted that modification in soil physical properties such as texture and bulk density takes longer time to be significantly evident.

The application of organic matter in the form of cow dung manure significantly improved the aggregate stability at the two sites. This might be attributed to the water proofing effect of organic matter such as waxes, which are naturally hydrophobic. There was significant difference between the two sites as there was pronounced improvement at Site 2 (fine texture).

The effect of cow dung manure on saturated hydraulic conductivity at Site 1 was observed to be significant ($P \leq 0.05$) with level 3 (20 t/ha) being the most effective while at Site 2 there was no difference ($P \leq 0.05$) among the treatments. This could due to the presence clay, which dispersed and clogged the pores. There was highly significant difference ($P \leq 0.01$) between the two sites.

The application of cow dung manure generally improved the antecedent moisture condition at two sites compared with the control. There was no difference among the treatments and the horizons and between two sites at $P \leq 0.05$. The most effective level at Site 1 is 4 (30 t/ha) and at Site 2 is level 5 (40 t/ha). The antecedent moisture content increased with depth.

Generally, organic carbon and total nitrogen increased compared with the control. The organic carbon at Site 1 increased with increasing the rates of cow dung manure up to level 3 (20 t/ha) and started to decrease with increasing rate of application of cow dung manure, but still has a high percentage compared with the control. At Site 2 the organic carbon increased with increasing the rate of application of cow dung manure up to level 4 (30 t/ha) and decreased with increasing the rate of the application of cow dung manure but had higher percentage compared with control. This means that an increase in the rate of cow dung manure does not result in a corresponding increase in the percentage of soil organic matter. The organic carbon decreased with depth. Statistically, there was no difference ($P \leq 0.05$) among the treatments and horizons and between the sites.

The improvement of total nitrogen was very slight at the two sites. This means, cow dung manure requires some time to give significant results.

Generally, infiltration rate were very highly significant ($P \leq 0.001$) between two sites. At Site 1, initial infiltration rates were very highly significant ($P \leq 0.001$) among the treatments. The most effective level was the control (0 t/ha) and the lowest level 5 (40 t/ha), this could be attributed to cow dung manure holding some water, which increase the antecedent moisture. This is good for the shallow rooted crops. Final infiltration rate range from rapid (Treatment 3) to moderate (Treatment 4).

Site 2 had low values of infiltration rates compared with that at site 1. This could be due to high percentage of sand at Site1. Initial infiltration rates ranged from very rapid to moderatly rapid. The most effective level is 4 (30 t/ha). The final infiltration rate ranged from moderate to moderately slow with being 4 (30 t/ha) as the most effective level.

The steady-state infiltration rates were obtained after 3-5 hours of infiltration (in this study, a minimum of 3 hours was used).

Site 2 retained high amount of water compared to Site 1 at any given suction. There was no significant difference ($P \leq 0.05$) among the treatments and the horizons and between sites. Site 2 had more available water compared with that at Site 1. Statistically, there was no significant difference ($P \leq 0.05$). This would be explained by low infiltration rate leading to more available water in the two horizons compared with those of Site 1, which had very rapid to rapid infiltration.

The application of cow dung manure generally decreased the soil pH at the two sites but this was more pronounced at Site 1. Statistically, there was no difference ($P \leq 00.05$) between the sites. At Site 1, soil pH decreased with increasing rate of application of cow dung manure. Compared with the control, level 3 (20 t/ha)was the most effective level. At Site 2, the reaction of cow dung manure was very slow. The soil pH decreased with application of 10 to 20 t/ha with 2 (10 t/ha) most effective level.

Electrical conductivity generally reduced, but there was no consistent trend. The most effective level at Site 1 was 4 (30 t/ha) while in Site 2 was level 5 (40 t/ha).

The application of cow dung manure improved the fertility of the soil through improving the CEC. The most effective level in Site 1 was 4 (30 t/ha) and in Site 2 was 3 (20 t/ha). Statistically, there was no difference ($P \leq 0.05$) among the treatments and horizons and between sites.

The cow dung manure reduced ESP for all the treatments except Treatment 2. The most effective level in Site 1 was 4 (30 t/ha) and at Site 2 was 3 (20 t/ha). Statistically, there was no significant difference ($P \leq 0.05$) among the treatments and horizons and between sites.

The application of cow dung manure generally reduced SAR. At Site 1 the most effective level was 3 (20 t/ha) and in Site 2 (10 t/ha). Statistically, there was no difference ($P \leq 0.05$) among treatments and horizons and between sites.

CHAPTER 6

6.0 RECOMMENDATIONS

I. This study only lasted for 18 weeks (15 of June – 31 of October 1997), therefore the long term effects of cow dung manure would require further monitoring to evaluate their role in improving the physical and chemical properties of the saline-sodic soil.

II. The use of organic manure should be encouraged wherever available and efforts be directed towards teaching farmers the need of using the effective level (not to use more than necessary). using higher of manure some tims leads to negative effects . Proper storage is necessary to conserve nutrients in the manure is also required.

III. When the feedlot waste applied at rates generally considered adequate to supply nutrient requirement for plants (22 t/ha), they had no statistically significant effects on soil condition. The effects on soil condition were significant as the rate of application increased. Using large amount of manure than nutrient requirement is recommended for reclamation of saline-sodic soil.

IV. The study examined the question of how much cow dung manure could be used to assist the farmer to improve the saline-sodic soil. Since conclusive results were not obtained from this study more research need to be carried out to examine the effects of cow dung manure in increasing the productivity of saline-sodic soils.

V. There is need to evalute various organic manures for different soils and agro-climatic conditions.

VI. The rate of decomposition and mineralization of cow dung manure should be determined and the process of decomposition modeled.

VII. Determine the effect of cow dung on N and other plant nutrients transformation in diverse soil and climatic conditions.

VIII. Further study for investigating the most effective time for manure application before seeding of crops.

IX. Effective placement of manure. Would it be more effective if it were localised below or along the rows as it is some time applied around tree crops such as citrus or coffee. This question needs to be answered through field study.

X. Frequency of application of manure. For how long the residual effect of manure will be in the soil. Also this needs to be investigated.

XI. Farmers should grow shallow rooted crop during short term of reclamation

XII. Farmers should add cow dung manure before seeding to improve the aggregate stability as to enhance germination.

XIII. Excessive application of irrigation water should be avoided as this raises the water table and after evaporation leads to increase in salt accumulation on or near the soil surface.

XIV. High salinity water could preferably be used on light textural soil as long as better water management practices are followed.

XV. There is need for further research to be conducted to study the interaction between the cow dung manure/ saline-sodic soils and water potential regimes levels.

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APPENDICES

Appendix 1: Soil profile description No. 1 Site 1

General site information

Survey area/district: Kiboko/Makueni
Observation No./date: 1; 3/6/97
Soil Classification (FAO/UNESCO, 1990): Chromo-haplic Lixisol, sodic and salic phase
Geological formation: precambrian basement system rocks
Parent material: Gneisses
Physiography: Erosional plain
Macro relief: slope: Flat to undulating: 2.8%
Microrelief: None
Vegetation/Land use: Shamba/cultivation
Erosion: Nil
Ground water table level: Deep
Surface sealing/crusting /cracking: Nil/nil/nil
Drainage class: Well drained
Effective soil depth: > 113

Soil profile description

Ap	0-23 cm	Dark reddish brown (5YR3/3)moist; sandy loam; weak medium subangular blocky; friable moist, slightly sticky and slightly plastic wet; many common pores; few fine medium roots, clear and smooth transition to:
B_{t1}	23-55 cm	Dark reddish brown (2.5YR3/3) moist sandy clay loam; weak to moderate medium subangular blocky; friable moist, slightly sticky wet; common fine to medium pores; common very fine to fine roots; gradual and smooth transition to:
B_{t2}	55-98 cm	Dark reddish brown (2.5YR3/4) moist; sandy clay loam; weak to moderate medium subangular blocky; common medium iron concretion; friable moist, slightly wet; common fine to medium pores; few very fine to fine roots; gradual and smooth transition to:
B_{t2}	55-98 cm	Dark reddish brown (2.5YR3/4) moist; sandy clay loam; moderately strong medium subangular blocky; common medium iron concretion; friable moist, slightly sticky wet; common fine to medium pores; few very fine to fine roots; gradual and smooth transition to: abrupt and wavy transition to:
C	113 cm +	Weathering parent material

Appendix 2 : Soil profile description No. 2 Site 1

General site information

Survey area/district: Kiboko/Makueni
Observation No./date: 2; 3/6/97
Soil Classification (FAO/UNESCO, 1990): Chromo-haplic Lixisol, sodic and salic phase
Geological formation: precambrian basement system rocks
Parent material: Gneisses
Physiography: Erosional plain
Macro relief: slope: Flat to undulating: 2.8%
Microrelief: None
Vegetation/Land use: Shamba/cultivation
Erosion: Nil
Ground water table level: Deep
Surface sealing/crusting /cracking: Nil/nil/nil
Drainage class: Well drained
Effective soil depth: > 62 cm

Soil profile description

Ap	0-17 cm	Dark reddish brown (5YR3/3) moist; sandy loam; weak medium subangular blocky; friable moist, slightly sticky and slightly plastic wet; many common pores; few fine medium roots, clear and smooth transition to:
B_{t1}	17-31 cm	Reddish brown (2.5YR3/3) moist sandy clay loam; weak to moderate medium subangular blocky; friable moist, slightly sticky wet; common fine to medium pores; common very fine to fine roots; gradual and smooth transition to:
B_{t2}	31-62 cm	Reddish brown (5YR3/4) moist; sandy clay loam; weak to moderate medium subangular blocky; common medium iron concretion; friable moist, slightly wet; common fine to medium pores; few very fine to fine roots; gradual and smooth transition to:abrupt and wavy to:
C	62 cm +	Weathering parent material

Appendix 3 : Soil profile description No. 3 Site 1

General site information

Survey area/district:	Kiboko/Makueni
Observation No./date:	3; 4/6/97
Soil Classification (FAO/UNESCO, 1990):	Chromo-haplic Lixisol, sodic and salic phase
Geological formation:	precambrian basement system rocks
Parent material:	Gneisses
Physiography:	Erosional plain
Macro relief: slope:	Flat to gentle undulating: 0-2%
Microrelief:	None
Vegetation/Land use:	Shamba/cultivation
Erosion:	Nil
Ground water table level:	Deep
Surface sealing/crusting /cracking:	Nil/nil/nil
Drainage class:	Well drained
Effective soil depth:	> 88 cm

Soil profile description

Ap	0-20 cm	Dark reddish brown (2.5YR3/4) moist; sandy loam; weak medium subangular blocky; friable moist, slightly sticky and slightly plastic wet; many common pores; few fine medium roots, clear and smooth transition to:
B_{t1}	20-58 cm	Reddish brown (2.5YR4/4) moist sandy clay loam; weak to moderate medium subangular blocky; friable moist, slightly sticky wet; common fine to medium pores; common very fine to fine roots; gradual and smooth transition to:
B_{t2}	58-88 cm	Reddish brown (5YR4/4) moist; sandy clay loam; weak to moderate medium subangular blocky; common medium iron concretion; friable moist, slightly wet; common fine to medium pores; few very fine to fine roots; abrupt and wavy to:
C	+ 88 cm	Weathering parent material

Appendix 4 : Soil profile description No. 1 Site 2

General site information

Survey area/district:	Kiboko/Makueni
Observation No./date:	1; 9/6/97
Soil Classification (FAO/UNESCO, 1990):	Mollic Solonchak
Geological formation:	Basement system rocks
Parent material:	Alluvium and recent lava flow
Physiography:	Alluvial plain
Macro relief: slope:	Flat 0-2%
Microrelief:	Gilgai
Vegetation/Land use:	Open grassland/fallow
Erosion:	Nil
Ground water table level:	Deep
Surface sealing /cracking:	Nil/nil/nil
Drainage class:	Imperfectly to poorly drained
Effective soil depth:	> 150 cm

Soil profile description

Ap	0-27 cm	Very dark greyish brown (10YR3/2) moist; sandy clay to loam; weak medium subangular blocky; friable moist, sticky and plastic wet; many, very fine and fine, common medium and few coarse pores;clear and smooth transition to
B_{w1}	27-52cm	Black (10YR2/1) moist; sandy clay; moderate, fine subangular blocky; friable moist, sticky and plastic wet; many, very fine pores; common very fine and dead roots; clear and smooth transition to:
B_{w2}	52-77cm	Very dark greyish brown (2.5YR3/2) moist; sandy clay; moderate to medium subangular blocky; friable moist, sticky and plastic wet; many very fine pores, common very fine and fine roots; clear and smooth transition to:
B_{w3}	77-110cm	Dark brown (10YR3/3) moist; sandy clay loam; weak, medium subangular blocky; moist, slightly sticky to slightly plastic wet; very few, very fine roots; clear and smooth transition to:
B_{w4}	110-150cm	Greyish brown (10YR5/2) moist; sandy loam; weak to moderate subangular blocky; friable moist, slightly sticky and slightly plastic wet; common very fine and fine pores; very few; very fine roots; abrupt and wavy transition to:
C	+ 150 cm	Weathering parent material

Appendix 5 : Soil profile description No. 2 Site 2

General site information

Survey area/district:	Kiboko/Makueni
Observation No./date:	2; 9/6/97
Soil Classification (FAO/UNESCO, 1990):	Sodic Solonchak
Geological formation:	Basement system rocks
Parent material:	Alluvium and recent lava flow
Physiography:	Alluvial plain
Macro relief: slope:	Flat 0-2%
Microrelief:	Furrows and Gilgai
Vegetation/Land use:	Open grassland/fallow
Erosion:	Nil
Ground water table level:	Deep
Surface sealing/cracking:	Nil/random
Drainage class:	Imperfectly to poorly drained
Effective soil depth:	> 150 cm

Soil profile description

Ap 0-34 cm	Very dark greyish brown (10YR3/2) moist; sandy clay; moderate, fine to medium crumbs; friable moist, sticky and plastic wet; many, very fine and fine pores; many fine medium and coarse roots; clear and smooth transition to:
B_{w1} 34-54 cm	Black (10YR2/1) moist; sandy clay; moderate to medium subangular blocky breaking into crumbs; friable moist, sticky and plastic wet; common medium and few coarse pores; common fine and many coarse roots; clear and smooth transition to:
B_{w2} 54-84 cm	Very dark greyish brown (2.5YR3/2) moist; sandy clay loam; moderate, medium subangular blocky; friable moist, slightly sticky and slightly plastic wet; common medium pores; very few, very fine roots; clear and smooth transition to:
B_{w3} 84-124 cm	Dark brown (10YR3/3) moist; sandy clay loam; weak to moderate and medium subangular blocky; friable moist, sticky and plastic wet; few, fine and medium pores; gradual and smooth transition to:
B_{w4} 124-150 cm	Greyish brown (10YR5/2) moist; loamy sand; weak to moderate medium subangular blocky; friable moist, sticky and plastic wet; very few, very fine pores; abrupt and wavy transition to:
C + 150 cm	Weathering parent material

Appendix 6 : Soil profile description No. 3 Site 2

General site information

Survey area/district:	Kiboko/Makueni
Observation No./date:	3; 9/6/97
Soil Classification (FAO/UNESCO, 1990):	Sodic Solonchak
Geological formation:	Basement system rocks
Parent material:	Alluvium and recent lava flow
Physiography:	Alluvial plain
Macro relief: slope:	Flat to very gentle undulating 0-2%
Microrelief:	Furrows and Gilgai
Land use/vegetation:	Open grassland/fallow
Erosion:	Nil
Ground water table level:	Deep
Surface sealing/cracking:	Nil/random
Drainage class:	Imperfectly to poorly drained
Effective soil depth:	> 75 cm

Soil profile description

Ap	0-23 cm	Very dark greyish brown (7.5YR3/2) moist; clay; moderate, medium subangular blocky; friable moist, sticky and plastic wet; many very fine and fine pores; many fine and medium roots; clear and smooth transition to:
B_{u1}	23-51 cm	Very dark grey (7.5YR2/1) moist; sandy clay to clay; moderate, medium subangular blocky patchy slickensides; friable moist, sticky and plastic wet; common very fine pores; common very fine and fine roots; clear and smooth transition to:
B_{u2}	51-75 cm	Black (10YR2/1) moist; clay; moderate, medium subangular blocky; patchy slickensides; friable moist, sticky and plastic wet; few very fine common fine pores; few fine roots; abrupt and wavy transition to:
C	150 cm +	Weathering parent material

Appendix 7 : Mean values of some soil physical properties at Site 1

Treatment	Plot	Soil depth (cm)	Bulk density (g/cm^3)	Texture			Textural class	aggregate stability (w/w)	Vert. K_{sat} (cm/hr)	Hor. K_{sat} (cm/hr)	Moisture content	%OC
				%sand	%silt	%clay						
T_1	3	0-20	1.31	63.31	18.48	18.48	SL	29.83	0.62	2.14	13.57	0.97
		20-45	1.38	63.13	16.94	16.94	SL	20.0	2.27	2.81	15.54	0.66
T_1	9	0-20	1.9	61.48	17.96	20.56	SCL	20.04	0.90	2.10	12.0	0.78
		20-45	1.36	61.66	13.57	24.77	SCL	18.83	1.74	2.91	14.18	0.38
T_1	11	0-20	1.30	61.98	17.71	20.31	SL/SCL	25.10	0.75	2.43	10.59	0.80
		20-45	1.37	62.98	16.64	20.88	SCL	19.01	1.60	3.43	11.66	0.26
T_2	2	0-20	1.32	60.34	19.18	20.48	SCL	30.15	0.43	0.41	12.01	0.95
		20-45	1.48	61.63	18.43	19.94	SL/SCL	30.15	2.35	1.79	13.20	0.68
T_2	8	0-20	1.27	63.19	18.86	17.95	SL	29.10	1.92	0.41	11.0	0.68
		20-45	1.54	61.48	17.61	20.91	SCL	21.10	2.34	2.35	13.25	0.30
T_2	14	0-20	1.25	63.48	17.21	19.31	SL	25.90	1.42	0.45	12.86	0.93
		20-45	1.40	61.05	16.18	22.77	SCL	21.39	1.99	2.45	14.02	0.46
T_3	1	0-20	1.50	61.90	17.63	20.74	SCL	30.32	2.35	1.35	13.46	1.84
		20-45	1.42	61.94	17.11	20.95	SCL	24.41	4.7	1.76	14.76	0.62
T_3	7	0-20	1.29	63.48	17.57	18.95	SL	30.10	2.47	1.44	16.89	0.88
		20-45	1.36	63.48	15.64	20.88	SCL	25.2	5.02	1.75	17.04	0.50
T_3	15	0-20	1.31	61.05	16.21	22.74	SCL	31.21	3.11	1.39	12.54	0.47
		20-45	1.37	63.48	17.71	18.81	SL	24.5	3.1	1.77	14.12	0.91

Appendix 7 (continued)

Treatment	Plot	Soil depth (cm)	Bulk density (g/cm^3)	Texture			Textural class	aggregate stability (w/w)	Vert. K_{sat} (cm/hr)	Hor. K_{sat} (cm/hr)	Moisture content	%OC
				%sand	%silt	%clay						
T_4	5	0-20	1.41	63.44	19.64	16.92	SL	30.6	1.38	1.07	15.52	0.78
		20-45	1.37	63.48	16.64	19.88	SL/SCL	23.01	8.65	5.95	16.84	0.46
T_4	6	0-20	1.36	63.48	19.50	17.02	SL	29.10	0.6	1.07	14.12	0.60
		20-45	1.45	64.59	20.53	14.86	SL	20.10	10.39	6.55	17.21	0.20
T_4	12	0-20	1.34	61.30	17.75	20.95	SCL	42.50	1.28	1.06	13.25	0.94
		20-45	1.42	60.30	16.21	23.49	SCL	31.12	6.42	6.25	14.75	0.62
T_5	4	0-20	1.42	61.37	20.72	17.92	SL	29.60	1.14	7.82	15.96	1.05
		20-45	1.48	62.55	17.71	19.88	SL/SCL	23.01	10.05	3.32	16.45	0.54
T_5	10	0-20	1.48	61.55	19.71	18.74	SL	46.18	0.65	8.65	14.23	0.94
		20-45	1.39	60.62	17.14	22.24	SCL	46.06	8.61	3.94	15.64	0.62
T_5	13	0-20	1.39	61.17	20.82	18.01	SL	41.96	1.15	8.01	14.23	0.84
		20-45	1.36	62.59	16.60	20.81	SCL	37.10	7.21	3.85	16.06	0.66

[1]SL = sandy loam [2]SCL = sandy clay loam

Appendix 8 : Mean saturated hydraulic conductivity of soil at Site 1

Treatment	Plot	Soil depth (cm)	vertical K_{sat} (cm/hr)	Horizontal K_{sat} (cm/hr)	Average vertical K_{sat} (cm/hr)	Average Horizontal K_{sat} (cm/hr)
T_1	3	0-20 20-45	0.62 2.27	2.14 2.81	0.83	2.51
T_1	9	0-20 20-45	0.90 1.74	2.10 2.91	1.23	2.55
T_1	11	0-20 20-45	0.75 1.60	2.43 3.43	1.06	2.99
T_2	2	0-20 20-45	0.43 2.35	0.41 1.79	0.80	1.18
T_2	8	0-20 20-45	1.92 2.34	0.41 2.35	2.12	1.49
T_2	14	0-20 20-45	1.42 1.99	0.45 2.45	1.69	1.36
T_3	1	0-20 20-45	2.35 4.70	1.35 1.76	3.25	1.58
T_3	7	0-20 20-45	2.47 5.02	1.44 1.75	3.44	1.61
T_3	15	0-20 20-45	3.11 3.10	1.39 1.77	3.10	1.60
T_4	5	0-20 20-45	1.38 8.65	1.07 5.95	2.59	3.78
T_4	6	0-20 20-45	0.60 10.39	1.07 6.55	1.26	4.11
T_4	12	0-20 20-45	1.28 6.42	1.06 6.25	2.31	3.94
T_5	4	0-20 20-45	1.14 10.05	7.82 3.32	2.25	5.32
T_5	10	0-20 20-45	0.65 8.61	8.65 3.94	1.34	6.03
T_5	13	0-20 20-45	1.15 7.21	8.01 3.85	2.16	5.70

Appendix 9 : Mean values of some soil physical properties at Site 2

Treatment	Plot	Soil depth (cm)	Bulk density g/cm^3	Texture			Textural class	Aggregate stability (w/w)	vert. K_{sat} (cm/hr)	Hor. K_{sat} (cm/hr)	Moisture content	%OC
				%sand	%silt	%clay						
T_1	3	0-30	0.97	46.56	15.42	38.02	SC^1	27.10	0.12	0.02	26.53	1.38
		30-50	1.16	46.56	13.43	40.01	SC	20.10	0.02	0.11	33.04	1.17
T_1	9	0-30	1.14	44.70	18.93	36.37	CL^2	23.46	0.07	0.01	27.02	1.21
		30-50	1.12	46.63	12.86	40.51	SC	19.10	0.01	0.12	32.65	1.41
T_1	11	0-30	1.17	46.63	12.86	40.51	CL	22.25	0.05	0.01	29.91	1.22
		30-50	1.14	45.09	11.57	43.46	SC	18.56	0.02	0.11	36.80	1.31
T_2	2	0-30	0.99	46.28	18.86	34.86	SCL^3	29.01	0.06	0.02	26.35	1.28
		30-50	1.07	46.28	18.86	34.86	SC	23.51	0.40	0.01	33.75	1.45
T_2	8	0-30	1.02	44.71	16.92	38.37	C^4	27.12	0.07	0.03	25.64	1.69
		30-50	1.05	43.74	14.43	41.83	CL	22.50	0.02	0.02	33.38	1.59
T_2	14	0-30	1.05	46.27	16.43	37.30	SC	26.60	0.08	0.03	30.99	1.57
		30-50	1.05	44.10	15.86	40.04	SC	24.90	0.03	0.01	41.41	1.10
T_3	1	0-30	1.02	44.70	18.61	36.67	CL	35.10	0.04	0.03	26.10	1.63
		30-50	1.10	49.63	24.86	25.51	SCL	30.10	0.02	0.02	42.10	1.32
T_3	7	0-30	0.96	46.06	14.33	39.40	SC	33.01	0.02	0.01	27.74	1.51
		30-50	1.16	47.07	9.53	43.40	SC	29.06	0.01	0.02	35.50	1.39
T_3	15	0-30	1.04	45.27	15.21	39.52	SC	30.56	0.05	0.02	31.10	1.26
		30-50	1.09	46.27	9.71	44.02	SC	28.60	0.03	0.03	37.93	1.40

Appendix 9 (Continued)

Treatment	Plot	Soil depth (cm)	Bulk density g/cm^3	Texture			Textural class	Aggregatestability (w/w)	vert. K_{sat} (cm/hr)	Hor. K_{sat} (cm/hr)	Moisture content	%OC
				%sand	%silt	%clay						
T_4	5	0-30	1.08	47.91	15.57	36.52	SC	35.82	0.02	0.01	31.90	1.61
		30-50	1.17	45.92	12.82	41.26	SC	30.12	0.07	0.01	35.71	1.15
T_4	6	0-30	1.08	46.74	15.64	37.62	SC	38.82	0.06	0.02	33.51	1.11
		30-50	1.22	43.92	11.67	44.41	C	32.21	0.01	0.01	33.51	1.02
T_4	12	0-30	1.05	44.98	16.97	38.05	SC/CL	33.10	0.05	0.03	31.80	1.98
		30-50	1.13	46.08	9.58	44.34	SC	29.06	0.06	0.01	38.71	1.82
T_5	4	0-30	1.17	46.27	7.71	46.02	SC	40.50	0.04	0.01	33.61	0.97
		30-50	1.05	46.78	13.28	39.90	SC	32.15	0.03	0.003	37.73	1.19
T_5	10	0-30	1.17	45.06	14.42	40.52	SC	45.20	0.02	0.01	32.67	1.47
		30-50	0.99	47.03	9.89	44.08	SC	37.10	0.02	0.01	39.56	0.89
T_5	13	0-30	1.10	46.13	14.67	39.20	SC	40.10	0.05	0.02	34.01	1.70
		30-50	1.10	49.95	11.67	38.38	SC	35.59	0.04	0.03	36.78	1.53

[1] = sandy loam [2] = clay loam [3] = sandy clay loam [4] = clay

Appendix 10 : Mean saturated hydraulic conductivity of soil at Site 2

Treatment	Plot	Soil depth (cm)	vertical K_{sat} (cm/hr)	Horizontal K_{sat} (cm/hr)	Average vertical K_{sat} (cm/hr)	Average Horizontal K_{sat} (cm/hr)
T_1	3	0-30 30-50	0.12 0.02	0.02 0.11	0.04	0.06
T_1	9	0-30 30-50	0.07 0.01	0.01 0.12	0.02	0.05
T_1	11	0-30 30-50	0.05 0.02	0.01 0.11	0.03	0.05
T_2	2	0-30 30-50	0.06 0.40	0.02 0.01	0.09	0.02
T_2	8	0-30 30-50	0.07 0.02	0.03 0.02	0.04	0.03
T_2	14	0-30 30-50	0.08 0.03	0.03 0.01	0.05	0.02
T_3	1	0-30 30-50	0.04 0.02	0.03 0.02	0.03	0.03
T_3	7	0-30 30-50	0.02 0.01	0.01 0.02	0.01	0.01
T_3	15	0-30 30-50	0.05 0.03	0.02 0.03	0.04	0.02
T_4	5	0-30 30-50	0.02 0.07	0.01 0.01	0.03	0.01
T_4	6	0-30 30-50	0.06 0.01	0.02 0.01	0.02	0.02
T_4	12	0-30 30-50	0.05 0.06	0.03 0.01	0.05	0.02
T_5	4	0-30 30-50	0.04 0.03	0.01 0.003	0.07	0.01
T_5	10	0-30 30-50	0.02 0.02	0.01 0.01	0.02	0.01
T_5	13	0-30 30-50	0.05 0.04	0.02 0.03	0.05	0.02

Appendix 11 : Mean values of soil reaction, salinity, SAR[1], SSP[2] and RSC[3] at Site 1

Treatment	Plot	Soil depth (cm)	pH_{H2O}	EC at 25°C ds/cm	SAR	SSP	RSC
T_1	3	0-20 20-45	8.70 8.04	2.00 3.97	6.63 4.39	31.93 36.34	-99.2 -28.93
T_1	9	0-20 20-45	7.70 6.90	1.50 2.80	5.17 6.91	34.59 53.32	-47.05 -17.90
T_1	11	0-20 20-45	7.90 7.40	2.17 2.83	6.34 4.46	41.22 33.95	-40.12 -37.07
T_2	2	0-20 20-45	8.00 7.70	2.07 3.81	6.27 4.87	34.47 37.33	-69.90 -32.94
T_2	8	0-20 20-45	7.90 7.60	1.60 3.37	10.36 10.19	49.68 59.24	-54.30 -24.02
T_2	14	0-20 20-45	7.90 7.80	1.50 3.75	4.62 6.89	29.17 54.09	-62.35 -16.53
T_3	1	0-20 20-45	7.90 7.40	3.37 3.37	5.44 5.09	32.90 34.87	-61.30 -44.40
T_3	7	0-20 20-45	7.90 7.60	2.99 1.50	7.78 4.58	46.80 40.48	-38.57 -21.69
T_3	15	0-20 20-45	7.42 7.78	3.30 3.20	3.83 4.33	27.86 30.35	-48.63 -48.55
T_4	5	0-20 20-45	8.13 7.85	1.70 3.70	8.46 5.39	46.43 44.50	-46.60 -21.16
T_4	6	0-20 20-45	7.97 8.00	1.40 3.30	6.92 11.03	37.91 76.48	-42.57 -4.95
T_4	12	0-20 20-45	7.83 7.60	1.70 2.17	5.00 4.57	32.25 38.19	-54.6 -26.96
T_5	4	0-20 20-45	8.14 7.97	1.70 3.30	6.16 4.84	37.25 41.85	-53.00 -22.2
T_5	10	0-20 20-45	7.90 7.31	2.77 2.83	5.50 5.63	40.60 43.79	-31.54 -25.69
T_5	13	0-20 20-45	7.83 7.50	2.99 1.96	6.15 4.39	39.32 35.14	-30.26 -31.81

SAR[1] Sodium Adsorption Ratio
SSP[2] Soluble Sodium Percent
RSC[3] Residual Sodium Carbonate

Appendix 12 : Mean values of soil reaction, salinity, SAR[1], SSP[2] and RSC[3] at Site 2

Treatment	Plot	Soil depth (cm)	pH_{H2O}	EC at 25°C ds/cm	SAR	SSP	RSC
T_1	3	0-30 30-50	8.15 8.17	1.63 1.30	7.81 3.56	53.67 69.56	-21.17 -5.89
T_1	9	0-30 30-50	8.20 8.28	2.34 1.09	8.23 6.93	57.44 15.00	-17.62 -1.94
T_1	11	0-30 30-50	8.20 8.22	1.90 1.39	7.36 3.63	52.98 54.49	-20.46 -21.00
T_2	2	0-30 30-50	8.02 8.10	1.85 1.58	6.38 5.20	36.70 38.82	-59.98 -39.18
T_2	8	0-30 30-50	8.14 8.23	2.39 1.58	5.88 3.24	37.75 52.93	-45.52 -15.34
T_2	14	0-30 30-50	8.05 8.23	2.94 3.64	6.16 8.09	35.07 38.91	-80.04 -80.04
T_3	1	0-30 30-50	7.96 8.32	2.66 2.77	6.77 9.51	39.73 69.90	-51.81 -30.39
T_3	7	0-30 30-50	8.18 8.2	2.17 1.74	9.01 3.45	59.69 54.23	17.27 -17.78
T_3	15	0-30 30-50	8.22 8.30	2.61 1.79	7.56 12.50	46.02 70.19	-37.46 -12.48
T_4	5	0-30 30-50	8.17 8.39	2.23 1.38	7.80 13.37	50.34 78.02	-28.09 -5.48
T_4	6	0-30 30-50	8.31 8.18	2.28 1.69	8.81 15.88	51.55 78.38	-32.37 -7.70
T_4	12	0-30 30-50	8.22 8.25	1.90 1.52	8.00 6.29	59.48 67.50	-17.45 -7.66
T_5	4	0-30 30-50	8.06 8.17	3.59 2.70	15.61 9.01	73.21 64.67	-15.34 -10.67
T_5	10	0-30 30-50	8.25 8.45	1.85 2.40	9.80 30.83	62.96 91.60	-14.95 -1.62
T_5	13	0-30 30-50	8.25 8.10	1.47 2.34	7.92 4.14	59.72 34.02	-12.40 -30.50

[1] SAR Sodium Adsorption Ratio
[2] SSP Soluble Sodium Percent
[3] RSC Residual Sodium Carbonate

Appendix 13 : Mean values of exchangeable cations, cation exchange capacity, ESP[1], BSP[2] and total soil nitrogen of soil extract at Site 1

Treatment	Plot	Soil depth (cm)	Exchangeable cations (meq/100g)				CEC (Cmol/Kg)	ESP	BSP	% N	%OC
			Ca	Mg	Na	K					
T_1	3	0-20	10.35	5.3	7.87	2.40	21.2	37.12	> 100	0.10	0.97
		20-45	12.50	4.60	4.40	2.12	17.00	25.00	> 100	0.07	0.66
T_1	9	0-20	11.25	4.58	7.15	1.65	18.80	38.03	> 100	0.08	0.78
		20-45	8.70	2.64	3.04	1.17	16.00	19.00	97.19	0.06	0.38
T_1	11	0-20	11.95	4.82	6.79	1.63	20.00	33.95	> 100	0.09	0.80
		20-45	9.95	2.90	5.21	1.91	16.00	31.00	> 100	0.05	0.26
T_2	2	0-20	13.10	5.11	8.87	2.77	20.00	44.35	> 100	0.10	0.95
		20-45	10.60	2.75	5.10	2.19	15.60	32.00	> 100	0.07	0.68
T_2	8	0-20	11.80	5.07	6.11	1.96	18.40	33.20	> 100	0.08	0.68
		20-45	9.50	4.08	3.52	1.85	17.60	20.00	> 100	0.06	0.30
T_2	14	0-20	10.30	3.97	9.32	2.04	20.40	45.69	> 100	0.01	0.93
		20-45	8.90	3.60	4.63	1.53	18.00	25.72	> 100	0.04	0.46
T_3	1	0-20	10.85	4.56	4.97	2.40	19.60	25.36	> 100	0.09	1.84
		20-45	9.10	3.80	5.67	2.21	20.00	28.35	> 100	0.07	0.62
T_3	7	0-20			7.31	2.67	16.80	43.51	> 100	0.09	0.88
		20-45	11.10	3.93	6.06	2.15	20.80	29.91	> 100	0.06	0.50
T_3	15	0-20		2.87	7.50		18.40	40.16	> 100	0.06	0.47
		20-45	11.20	3.47	6.25	2.10	17.60	35.51	> 100	0.04	0.90
T_4	5	0-20	13.9	5.42	7.43	2.85	20.00	37.15	> 100	0.09	0.78
		20-45	10.50	3.47	4.31	2.79	18.00	23.94	> 100	0.06	0.46
T_4	6	0-20	11.55	4.92	7.89	3.07	23.00	34.30	> 100	0.09	0.60
		20-45	13.50	5.18	5.91	2.12	22.00	25.95	> 100	0.04	0.20
T_4	12	0-20	4.6		6.27	1.68	20.10	31.19	> 100	0.11	0.94
		20-45	11.45	3.64	4.45	1.83	18.00	24.72	> 100	0.06	0.62
T_5	4	0-20	13.75	4.69	6.87	3.51	20.00	34.35	> 100	0.12	1.05
		20-45	11.25	3.60	4.46	2.92	18.00	24.78	> 100	0.08	0.54
T_5	10	0-20	12.00	4.87	7.95	1.95	20.00	39.75	> 100	0.01	0.94
		20-45	10.70	3.14	4.86	1.60	16.80	28.93	> 100	0.07	0.62
T_5	13	0-20	10.15	4.43	5.38	1.99	16.80	32.02	> 100	0.09	0.84
		20-45	10.20	3.15	4.89	1.96	18.20	26.87	> 100	0.09	0.66

ESP[1] Exchangeable sodium percent
BSP[2] Base saturation percent

Appendix 14 : Mean values of exchangeable cations, cation exchange capacity, ESP[1], BSP[2] and total nitrogen percent at Site 2

Treatment	Plot	Soil depth (cm)	Exchangeable cations(meq/100g)				CEC (Cmol /Kg)	ESP	BSP	% N	%OC
			Ca	Mg	Na	K					
T_1	3	0-30	35.00	12.70	1.95	2.60	50.40	3.86	> 100	0.13	1.39
		30-50	30.15	13.52	1.65	2.94	40.40	3.56	> 100	0.13	1.17
T_1	9	0-30	30.50	14.60	3.82	2.16	55.40	6.90	92.09	0.13	1.21
		30-50	28.10	15.06	3.41	2.33	46.2	6.93	99.39	0.09	1.14
T_1	11	0-30	33.3	13.22	2.27	2.65	52.00	4.37	98.92	0.12	1.22
		30-50	31.90	13.27	1.73	2.65	47.60	3.63	> 100	0.13	1.31
T_2	2	0-30	31.75	12.10	2.40	4.07	48.80	4.92	> 100	0.14	1.28
		30-50	33.60	13.28	2.75	2.82	52.80	5.20	99.34	0.11	1.45
T_2	8	0-30	32.00	13.05	1.87	3.66	42.80	3.91	> 100	0.16	1.69
		30-50	31.50	13.81	1.76	3.78	54.40	3.24	93.49	0.12	1.59
T_2	14	0-30	34.35	11.93	2.16	3.88	49.60	4.36	> 100	0.14	1.57
		30-50	32.30	15.35	3.95	3.75	48.80	8.09	> 100	0.11	1.10
T_3	1	0-30	33.40	12.22	2.28	3.64	52.60	4.34	97.99	0.10	1.63
		30-50	31.10	15.42	3.83	2.62	51.00	7.51	> 100	0.10	1.32
T_3	7	0-30	32.35	13.70	1.87	3.27	54.00	3.46	94.80	0.12	1.51
		30-50	30.55	16.26	1.76	3.52	51.01	3.45	> 100	0.12	1.39
T_3	15	0-30	32.80	14.71	3.22	4.00	53.20	6.05	> 100	0.14	1.26
		30-50	28.60	17.67	2.94	2.45	55.40	5.31	93.25	0.11	1.40
T_4	5	0-30	30.65	12.21	1.86	0.45	48.80	3.81	92.56	0.16	1.61
		30-50	28.00	13.78	4.05	0.02	52.40	8.30	87.50	0.09	1.15
T_4	6	0-30	30.85	13.27	2.59	4.68	49.00	4.94	> 100	0.15	1.11
		30-50	31.35	14.53	4.45	2.45	45.60	9.76	> 100	0.10	1.02
T_4	12	0-30	35.15	13.41	2.22	5.01	54.40	4.08	> 100	0.17	1.98
		30-50	48.35	16.19	1.73	3.76	60.40	2.86	> 100	0.14	1.82
T_5	4	0-30	29.80	13.80	4.45	3.39	54.50	8.17	94.39	0.09	0.97
		30-50	31.70	13.89	2.23	3.06	52.40	4.22	98.28	0.12	1.19
T_5	10	0-30	32.55	13.45	2.20	4.99	52.40	4.19	> 100	0.13	1.47
		30-50	25.90	16.79	7.80	2.27	51.60	15.12	> 100	0.09	0.99
T_5	13	0-30	39.25	13.55	2.05	5.64	52.00	3.94	> 100	0.17	1.70
		30-50	44.20	11.06	1.09	3.61	42.20	2.41	> 100	0.14	1.53

ESP[1] Exchangeable sodium percent
BSP[2] Base saturation percent

Appendix 15 : Mean values of soluble salts at Site 1

Treatment	Plot	Soil depth (cm)	Soluble cations (Meq/L)				Soluble anions (meq/L)	
			Ca	Mg	Na	K	HCO^-_3	Cl^{-1}
T_1	3	0-20	76.00	24.00	46.90	3.50	0.73	4.10
		20-45	19.00	10.60	16.90	1.30	0.67	1.20
T_1	9	0-20	29.00	18.85	25.30	2.50	0.80	2.50
		20-45	11.00	7.30	20.90	0.30	0.40	1.30
T_1	11	0-20	24.50	16.35	28.65	0.70	0.73	2.67
		20-45	22.50	15.15	19.35	1.70	0.22	1.60
T_2	2	0-20	41.00	30.00	37.35	3.30	1.1	4.07
		20-45	20.50	12.90	19.90	1.60	0.46	1.52
T_2	8	0-20	33.00	22.10	54.40	4.00	0.80	3.63
		20-45	15.00	9.60	35.75	0.50	0.58	1.50
T_2	14	0-20	38.00	25.00	25.95	0.50	0.65	3.71
		20-45	9.00	8.10	20.15	0.30	0.58	2.45
T_3	1	0-20	39.00	23.00	30.40	5.30	0.70	2.53
		20-45	26.50	18.60	24.15	2.90	0.70	2.53
T_3	7	0-20	24.10	15.00	34.40	2.60	0.53	2.99
		20-45	13.00	9.00	15.20	2.00	0.31	1.50
T_3	15	0-20	38.00	11.20	19.00	1.10	0.57	2.45
		20-45	29.50	19.85	21.20	0.03	0.80	1.70
T_4	5	0-20	29.00	18.65	14.30	5.50	1.05	4.72
		20-45	14.50	7.30	17.80	3.10	0.69	1.15
T_4	6	0-20	26.00	17.40	26.50	3.35	0.83	4.31
		20-45	3.00	2.75	18.70	3.10	0.80	2.33
T_4	12	0-20	29.00	26.25	26.30	8.86	0.65	4.01
		20-45	16.00	11.35	16.90	0.46	0.39	1.56
T_5	4	0-20	34.00	19.90	32.00	6.90	0.90	2.21
		20-45	14.50	8.15	16.30	4.00	0.45	1.26
T_5	10	0-20	18.50	13.90	22.15	4.00	0.86	3.13
		20-45	15.50	10.60	20.33	2.00	0.41	2.49
T_5	13	0-20	18.00	13.10	20.15	3.50	0.84	3.90
		20-45	15.50	16.80	17.50	0.40	0.46	1.90

* there was no available carbonates in the soil samples

Appendix 16 : Mean values of soluble salts at Site 2

Treatment	Plot	Soil depth (cm)	Soluble cations (meq/L)				Soluble anions (meq/L)	
			Ca	Mg	Na	K	HCO_3^-	Cl^{-1}
T_1	3	0-30	15.00	7.70	26.30	0.80	1.53	2.63
		30-50	1.50	5.70	16.45	0.70	1.31	1.51
T_1	9	0-30	13.00	5.60	25.10	13.20	0.98	2.12
		30-50	1.00	2.40	0.60	15.80	1.41	2.03
T_1	11	0-30	15.00	6.70	24.40	0.80	1.29	2.13
		30-50	14.00	8.30	26.70	0.90	1.30	2.13
T_2	2	0-30	43.00	17.80	25.25	3.30	0.82	3.47
		30-50	34.00	6.25	25.55	0.71	1.07	2.49
T_2	8	0-30	32.50	14.50	28.56	2.42	1.48	2.51
		30-50	10.00	6.90	19.00	1.35	1.56	1.89
T_2	14	0-30	42.00	21.70	34.40	2.90	1.38	2.91
		30-50	25.00	56.50	51.90	4.20	1.46	2.15
T_3	1	0-30	36.00	16.80	34.80	2.60	0.99	3.17
		30-50	12.25	19.70	74.20	5.40	1.02	1.38
T_3	7	0-30	14.50	4.00	27.40	1.20	1.23	2.37
		30-50	10.00	9.20	22.75	1.20	1.42	1.85
T_3	15	0-30	25.00	14.30	33.50	3.00	1.84	3.40
		30-50	7.00	7.10	33.20	0.50	1.62	2.50
T_4	5	0-30	19.00	10.60	30.00	4.50	1.51	1.75
		30-50	3.00	4.10	25.20	0.20	1.62	1.34
T_4	6	0-30	22.00	12.30	36.50	3.40	1.73	2.26
		30-50	6.00	3.60	34.80	0.40	1.90	1.93
T_4	12	0-30	10.00	4.85	21.80	0.50	1.40	2.07
		30-50	1.50	7.90	19.60	1.50	1.74	2.15
T_5	4	0-30	11.50	4.80	44.55	4.10	0.96	1.50
		30-50	6.00	6.10	22.15	1.00	1.43	0.66
T_5	10	0-30	10.50	6.50	28.15	1.75	1.55	2.20
		30-50	2.00	2.00	43.60	0.20	2.38	2.29
T_5	13	0-30	9.00	5.30	21.2	3.25	1.90	2.30
		30-50	8.00	24.20	16.6	2.90	1.30	1.99

* there was no available carbonates in the soil samples

Appendix 17: Chemical and Physical properties of cow dung manure (dry weight)

pH $_{(H_2O)}$	pH $_{(0.01CaCl_2)}$	% C	% N	meq/100g				CEC(cmol/kg)	pb$^{1/}$	%SA$^{2/}$	%W$^{3/}$
				K	Na	Ca	Mg				
9.00	8.70	20.65	1.23	65.00	9.00	19.50	31.58	38.80	0.62	33.43	39.54

1/= Bulk density (gm/cm3)

2/= Aggregate stability (%)

3/= Moisture content (%)

Appendix 18 : Mean* infiltration rates (cm/hr) per treatment per time at Site 1

Time (min)	T_1	T_2	T_3	T_4	T_5
1	78.0	54.0	72.0	54.0	36.0
2	30.0	24.0	24.0	42.0	24.0
3	24.0	18.0	18.0	12.0	18.0
4	24.0	12.0	18.0	12.0	12.0
5	12.0	12.0	18.0	12.0	6.0
6	18.0	12.0	18.0	6.0	18.0
7	12.0	18.0	12.0	6.0	12.0
8	18.0	12.0	18.0	12.0	6.0
9	12.0	6.0	12.0	6.0	12.0
10	12.0	18.0	12.0	6.0	6.0
12	9.0	12.9	15.0	6.0	6.0
14	9.0	12.0	13.0	15.9	6.0
16	15.0	11.5	6.79	14.5	33.0
18	9.0	10.9	6.79	13.9	8.4
20	9.0	10.2	15.27	12.7	8.4
25	8.4	30.0	15.27	11.3	8.4
30	8.4	18.67	16.96	5.05	6.49
35	11.8	11.88	13.58	5.05	6.49
40	6.7	10.18	16.96	8.49	10.18
45	10.1	10.8	14.14	6.79	6.46
60	8.4	4.5	14.14	6.79	7.3
75	9.05	4.5	14.14	5.05	6.2
90	9.62	6.8	16.44	6.2	7.3
120	10.6	8.4	14.00	6.2	6.79
150	9.05	9.9	12.44	5.9	7.07
180	8.8	9.6	12.27	3.11	6.51

* means using three replicates

Appendix 19: Mean* infiltration rates (cm/hr) per treatment per time at Site 2

Time (min)	T_1	T_2	T_3	T_4	T_5
1	30.0	12.0	24	36.0	30.0
2	24.0	12.0	18	12.0	12.0
3	12.0	6.0	12	12.0	18.0
4	6.0	6.0	6	12.0	12.0
5	6.0	6.0	6	6.0	12.0
6	6.0	6.0	12	12.0	6.0
7	6.0	6.0	6	6.0	12.0
8	6.0	6.0	12	12.0	12.0
9	6.0	6.0	6	12.0	6.0
10	6.0	6.0	6	6.0	6.0
12	16.97	3.0	9	9.0	6.0
14	106.6	3.0	9	9.0	9.0
16	42.42	3.0	9	6.0	6.0
18	12.72	12.73	12	6.0	6.0
20	8.48	8.48	6	6.0	6.0
25	11.79	1.97	8.98	7.2	8.48
30	3.39	5.09	8.48	8.7	6.79
35	6.79	3.39	5.09	22.6	5.09
40	5.09	6.79	6.79	5.09	10.18
45	6.79	5.65	5.09	6.79	6.79
60	6.22	7.92	6.22	7.35	6.22
75	5.66	3.96	5.66	6.22	5.90
90	5.66	3.96	5.09	5.94	5.80
120	5.66	5.09	5.06	5.66	5.70
150	5.66	2.26	5.06	5.51	5.60
180	1.63	2.20	5.03	5.1	4.81

* means using three replicates

Appendix 20 : Soil water retention at Site 1

Treatment	plot	Soil depth (cm)	Pressure (kPa)											Pb (g/cm^3)
			0.0	10	30	50	70	100	300	500	700	1000	1500	
T_1	3	0-20	.49	.39	.32	.32	.31	.30	.29	.27	.27	.24	.24	1.44
		20-45	.46	.38	.30	.29	.28	.27	.29	.25	.24	.23	.21	1.50
	9	0-20	.53	.36	.30	.29	.27	.26	.24	.22	.21	.21	.20	1.32
		20-45	.48	.35	.27	.26	.26	.25	.24	.22	.21	.20	.19	1.51
	11	0-20	.50	.37	.27	.26	.25	.24	.23	.21	.20	.19	.19	1.35
		20-45	.47	.36	.29	.28	.27	.26	.25	.23	.22	.21	.21	1.51
T_2	2	0-20	.56	.38	.36	.35	.34	.33	.32	.28	.26	.23	.22	1.18
		20-45	.49	.33	.29	.28	.27	.26	.25	.22	.20	.19	.18	1.49
	8	0-20	.54	.40	.37	.36	.35	.35	.35	.31	.28	.25	.24	1.53
		20-45	.46	.35	.31	.30	.29	.28	.26	.23	.22	.20	.19	1.34
	14	0-20	.55	.41	.35	.34	.33	.33	.32	.28	.26	.23	.22	1.32
		20-45	.47	.36	.28	.27	.26	.26	.25	.22	.20	.19	.18	1.40
T_3	1	0-20	.54	.39	.31	.30	.30	.30	.29	.29	.27	.26	.25	1.30
		20-45	.47	.35	.29	.27	.27	.25	.24	.22	.22	.20	.19	1.30
	7	0-20	.52	.41	.34	.33	.33	.32	.32	.30	.30	.29	.26	1.39
		20-45	.45	.36	.30	.29	.28	.27	.27	.26	.26	.25	.25	1.53
	15	0-20	.55	.40	.33	.32	.31	.30	.29	.28	.27	.26	.25	1.34
		20-45	.49	.34	.30	.29	.28	.27	.26	.25	.24	.23	.20	1.48
T_4	5	0-20	.51	.43	.32	.31	.30	.29	.28	.27	.26	.24	.24	1.37
		20-45	.49	.51	.26	.25	.25	.24	.24	.23	.22	.22	.21	1.40
	6	0-20	.50	.41	.30	.31	.31	.31	.31	.28	.27	.27	.27	1.38
		20-45	.48	.31	.26	.25	.25	.24	.24	.23	.22	.22	.21	1.44
	12	0-20	.53	.45	.30	.29	.29	.28	.27	.26	.25	.24	.24	1.39
		20-45	.50	.49	.25	.24	.23	.22	.21	.20	.19	.19	.19	1.45
T_5	4	0-20	.60	.38	.34	.34	.33	.33	.32	.29	.29	.27	.27	1.42
		20-45	.55	.36	.38	.37	.36	.35	.34	.31	.31	.30	.30	1.51
	10	0-20	.51	.38	.31	.31	.30	.29	.28	.26	.26	.24	.23	1.37
		20-45	.48	.35	.29	.28	.27	.26	.25	.22	.22	.21	.21	1.41
	13	0-20	.54	.39	.30	.29	.28	.27	.27	.25	.22	.20	.19	1.39
		20-45	.50	.40	.28	.27	.26	.26	.26	.23	.21	.20	.19	1.44

* means using three replicates

Appendix 21: Soil water retention at Site 2

Treatment	plot	Soil depth (cm)	Pressure (kPa)											Pb (g/cm^3)
			0.0	10	30	50	70	100	300	500	700	1000	1500	
T_1	3	0-30	.80	.61	.57	.56	.55	.55	.53	.49	.47	.46	.45	0.94
		30-50	.55	.50	.48	.47	.47	.45	.42	.40	.38	.35	.35	1.14
	9	0-30	.60	.54	.49	.49	.48	.46	.45	.42	.41	.40	.39	0.95
		30-50	.62	.51	.50	.50	.48	.46	.45	.43	.41	.40	.40	1.16
	11	0-30	.70	.57	.53	.52	.52	.50	.49	.45	.44	.43	.42	0.95
		30-50	.61	.51	.49	.48	.47	.45	.44	.42	.40	.38	.38	1.15
T_2	2	0-30	.59	.48	.46	.45	.44	.42	.41	.40	.38	.37	.37	1.04
		30-50	.45	.40	.38	.37	.36	.35	.34	.31	.28	.27	.25	1.14
	8	0-30	.63	.52	.50	.49	.48	.46	.46	.43	.41	.40	.40	1.03
		30-50	.58	.44	.42	.42	.41	.40	.39	.38	.38	.37	.36	1.08
	14	0-30	.66	.56	.53	.53	.53	.50	.50	.47	.44	.44	.42	1.02
		30-50	.52	.42	.40	.39	.39	.37	.37	.34	.33	.32	.31	1.11
T_3	1	0-30	.64	.54	.52	.52	.51	.49	.48	.46	.44	.42	.39	0.98
		30-50	.734	.53	.52	.51	.51	.49	.48	.46	.46	.45	.43	1.09
	7	0-30	.652	.53	.51	.50	.49	.47	.45	.44	.42	.40	.38	0.96
		30-50	.56	.56	.54	.53	.53	.51	.49	.46	.43	.42	.40	1.10
	15	0-30	.65	.53	.52	.51	.50	.48	.47	.45	.43	.41	.39	0.97
		30-50	.68	.55	.54	.53	.52	.50	.48	.46	.44	.44	.42	1.11
T_4	5	0-30	.58	.51	.50	.49	.48	.48	.46	.44	.42	.41	.39	1.14
		30-50	.56	.49	.47	.47	.47	.46	.45	.43	.41	.41	.40	1.21
	6	0-30	.57	.44	.42	.41	.41	.38	.38	.36	.34	.33	.31	1.09
		30-50	.63	.49	.48	.48	.47	.46	.45	.43	.41	.41	.39	1.09
	12	0-30	.57	.48	.46	.45	.44	.43	.41	.40	.39	.38	.36	1.12
		30-50	.59	.49	.48	.47	.47	.46	.45	.43	.41	.41	.39	1.15
T_5	4	0-30	.56	.47	.46	.45	.45	.43	.42	.41	.40	.37	.38	1.14
		30-50	.53	.41	.39	.38	.38	.36	.35	.34	.32	.31	.29	1.13
	10	0-30	.62	.54	.52	.52	.51	.50	.49	.48	.47	.45	.45	1.09
		30-50	.58	.51	.48	.47	.46	.44	.42	.39	.37	.36	.36	1.03
	13	0-30	.60	.50	.49	.49	.48	.46	.46	.44	.43	.43	.42	1.12
		30-50	.56	.49	.44	.42	.42	.40	.39	.36	.35	.34	.32	1.10

* means using three replicates

Appendix 22 : Soil Water Release at Site 1

Treatment	Amount (t/ha)	Plot	Soil depth (cm)	Pressure (kPa)									
				10	30	50	70	100	300	500	700	1000	1500
T_1	0	3	0-20 20-45	0.1 0.9	0.16 0.17	0.17 0.18	0.18 0.19	0.19 0.20	0.20 0.21	0.22 0.22	0.22 0.23	0.25 0.24	0.25 0.24
T_1	0	9	0-20 20-45	0.16 0.11	0.23 0.18	0.24 0.19	0.25 0.19	0.27 0.20	0.28 0.21	0.31 0.23	0.32 0.23	0.32 0.24	0.33 0.25
T_1	0	11	0-20 20-45	0.14 0.12	0.20 0.17	0.21 0.18	0.22 0.19	0.23 0.20	0.24 0.21	0.26 0.22	0.27 0.23	0.29 0.24	0.30 0.24
T_2	10	2	0-20 20-45	0.18 0.13	0.20 0.17	0.21 0.18	0.22 0.19	0.23 0.20	0.24 0.22	0.28 0.25	0.30 0.26	0.33 0.28	0.34 0.29
T_2	10	8	0-20 20-45	0.14 0.10	0.18 0.16	0.18 0.17	0.19 0.18	0.20 0.19	0.20 0.20	0.21 0.21	0.22 0.21	0.24 0.23	0.26 0.24
T_2	10	14	0-20 20-45	0.16 0.12	0.19 0.17	0.20 0.18	0.21 0.19	0.22 0.20	0.23 0.21	0.24 0.24	0.26 0.26	0.29 0.28	0.31 0.28
T_3	20	1	0-20 20-45	0.16 0.12	0.24 0.19	0.25 0.21	0.25 0.22	0.25 0.23	0.25 0.24	0.26 0.27	0.27 0.27	0.29 0.28	0.36 0.28
T_3	20	7	0-20 20-45	0.11 0.11	0.16 0.14	0.17 0.15	0.19 0.17	0.20 0.19	0.20 0.19	0.21 0.20	0.21 0.21	0.23 0.22	0.24 0.22
T_3	20	15	0-20 20-45	0.13 0.13	0.18 0.17	0.19 0.18	0.20 0.19	0.20 0.19	0.20 0.20	0.22 0.21	0.22 0.21	0.26 0.21	0.29 0.22
T_4	30	5	0-20 20-45	0.09 0.20	0.20 0.24	0.21 0.25	0.22 0.25	0.23 0.26	0.23 0.26	0.24 0.27	0.25 0.28	0.27 0.28	0.27 0.29
T_4	30	6	0-20 20-45	0.08 0.18	0.17 0.21	0.18 0.22	0.19 0.23	0.19 0.23	0.19 0.23	0.21 0.25	0.22 0.26	0.23 0.27	0.23 0.28
T_4	30	12	0-20 20-45	0.10 0.17	0.18 0.22	0.19 0.23	0.20 0.25	0.20 0.25	0.21 0.25	0.22 0.26	0.23 0.27	0.24 0.27	0.24 0.28
T_5	40	4	0-20 20-45	0.13 0.13	0.17 0.17	0.17 0.18	0.18 0.19	0.18 0.20	0.19 0.21	0.22 0.22	0.24 0.23	0.27 0.25	0.24 0.28
T_5	40	10	0-20 20-45	0.21 0.15	0.29 0.19	0.29 0.20	0.30 0.20	0.31 0.21	0.31 0.22	0.34 0.26	0.34 0.26	0.36 0.26	0.25 0.37
T_5	40	13	0-20 20-45	0.19 0.12	0.25 0.20	0.25 0.20	0.26 0.20	0.27 0.21	0.28 0.22	0.29 0.24	0.30 0.25	0.30 0.25	0.31 0.25

Appendix 23 : Soil Water Release at Site 1

Treatment	Amount (t/ha)	Plot	Soil depth (cm)	Pressure (kPa)									
				10	30	50	70	100	300	500	700	1000	1500
T_1	0	3	0-30 30-50	0.19 0.11	0.23 0.12	0.24 0.13	0.25 0.14	0.25 0.16	0.27 0.18	0.31 0.19	0.34 0.21	0.34 0.23	0.35 0.25
T_1	0	9	0-30 30-50	0.07 0.04	0.11 0.06	0.12 0.07	0.13 0.08	0.15 0.09	0.15 0.11	0.19 0.13	0.20 0.16	0.21 0.19	0.22 0.19
T_1	0	11	0-30 30-50	0.13 0.08	0.17 0.09	0.18 0.10	0.19 0.11	0.20 0.13	0.21 0.15	0.25 0.16	0.27 0.19	0.28 0.21	0.29 0.22
T_2	10	2	0-30 30-50	0.11 0.13	0.13 0.15	0.14 0.16	0.14 0.16	0.17 0.18	0.18 0.18	0.19 0.19	0.21 0.20	0.22 0.20	0.23 0.22
T_2	10	8	0-30 30-50	0.10 0.06	0.13 0.07	0.14 0.08	0.14 0.09	0.16 0.19	0.16 0.12	0.19 0.15	0.22 0.18	0.22 0.18	0.24 0.20
T_2	10	14	0-30 30-50	0.10 0.12	0.12 0.13	0.13 0.14	0.14 0.15	0.15 0.17	0.16 0.18	0.17 0.19	0.19 0.21	0.20 0.21	0.22 0.22
T_3	20	1	0-30 30-50	0.11 0.001	0.12 0.02	0.12 0.02	0.13 0.03	0.15 0.05	0.16 0.07	0.18 0.10	0.20 0.13	0.22 0.14	0.25 0.16
T_3	20	7	0-30 30-50	0.12 0.20	0.14 0.21	0.15 0.22	0.16 0.22	0.18 0.24	0.19 0.25	0.21 0.26	0.23 0.27	0.24 0.28	0.27 0.30
T_3	20	15	0-30 30-50	0.12 0.14	0.13 0.15	0.14 0.16	0.15 0.17	0.17 0.19	0.18 0.20	0.20 0.21	0.21 0.22	0.23 0.24	0.26 0.24
T_4	30	5	0-30 30-50	0.06 0.06	0.08 0.08	0.09 0.09	0.10 0.09	0.11 0.10	0.12 0.12	0.13 0.13	0.15 0.15	0.16 0.15	0.18 0.16
T_4	30	6	0-30 30-50	0.12 0.11	0.15 0.14	0.16 0.15	0.16 0.15	0.19 0.16	0.19 0.18	0.21 0.20	0.23 0.22	0.24 0.22	0.25 0.24
T_4	30	12	0-30 30-50	0.09 0.08	0.12 0.11	0.13 0.12	0.13 0.12	0.15 0.15	0.16 0.17	0.17 0.18	0.19 0.19	0.20 0.20	0.21 0.21
T_5	40	4	0-30 30-50	0.09 0.08	0.10 0.10	0.11 0.11	0.12 0.13	0.13 0.14	0.14 0.16	0.15 0.20	0.16 0.22	0.17 0.22	0.18 0.22
T_5	40	10	0-30 30-50	0.09 0.13	0.10 0.14	0.11 0.15	0.11 0.16	0.12 0.17	0.13 0.18	0.15 0.20	0.16 0.22	0.17 0.22	0.17 0.24
T_5	40	13	0-30 30-50	0.09 0.10	0.10 0.12	0.11 0.13	0.12 0.14	0.13 0.15	0.14 0.16	0.18 0.20	0.16 0.22	0.17 0.22	0.18 0.23

Appendix 24 : Calculation of pHc

$$SAR_{adj} = \frac{Na}{\frac{\sqrt{Ca + Na}}{2}}[1 + 8.4 - pHc]$$

pHc = $(pK_2 - pK_c)$ + p(Ca +Mg) + p(ALK)

$(pK_2 - pK_c)$ is obtained from using the sum of Ca + Mg + Na in meq/L

p(Ca + Mg) is obtained from using the sum of Ca + Mg in meq/L

p(ALK) is obtained from using the sum of CO_3 + HC_3 in meq/L

Sum of concentration (meq/L)	$pK_2 - pK_c$	p(Ca + Mg)	p(ALK)
0.05	2.0	4.6	4.3
0.10	2.0	4.3	4.0
0.15	2.0	4.1	3.8
0.20	2.0	4.0	3.7
0.25	2.0	3.9	3.6
0.30	2.0	3.8	3.5
0.40	2.0	3.7	3.4
0.50	2.1	3.6	3.3
0.75	2.1	3.4	3.1
1.00	2.1	3.3	3.0
1.25	2.1	3.2	2.9
1.50	2.1	3.1	2.8
2.00	2.2	3.0	2.7
2.50	2.2	2.9	2.6
3.00	2.2	2.8	2.5
4.00	2.2	2.7	2.4
5.00	2.2	2.6	2.3
6.00	2.2	2.5	2.2
8.00	2.3	2.4	2.1
10.00	2.3	2.3	2.0
12.50	2.3	2.2	1.9
15.00	2.3	2.1	1.8
20.00	2.4	2.0	1.7
30.00	2.4	1.8	1.5
50.00	2.5	1.6	1.3
80.00	2.5	1.4	1.1

Appendix 25 : Climatic data for Makindu station in the year 1997

Month	Rainfall (mm)	Evaporation (mm)	Temperature (°C)	Wind speed (Km/day)
January	0.6	223.4	24.50	180.3
February	0.5	-	25.10	201.3
March	10.0	-	24.90	221.2
April	128.9	150.4	25.0	161.3
May	137.4	148.4	22.0	143.4
June	3.7	119.1	21.50	141.3
July	TR	-	20.90	142.2
August	-	-	21.35	194.3
September	TR	223.0	22.75	222.5
October	33.9	202.4	23.05	219.2
November	262.8	128.5	23.35	151.8
December	294.0	135.0	22.4	117.9

Appedix 26. Figures showing effect of cow dung manure on bulk density in two depths at Sites 1 and 2 including eqautions and R2

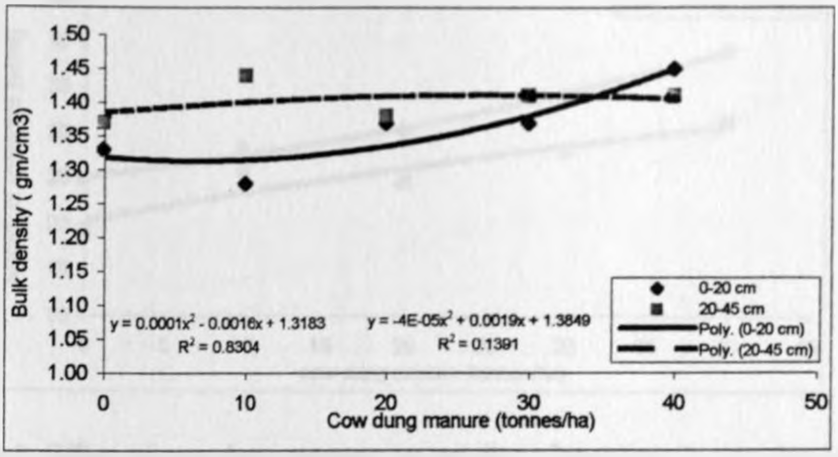

Figure 1. Effect of cow dung manure on bulk desity in two depths (Site 1)

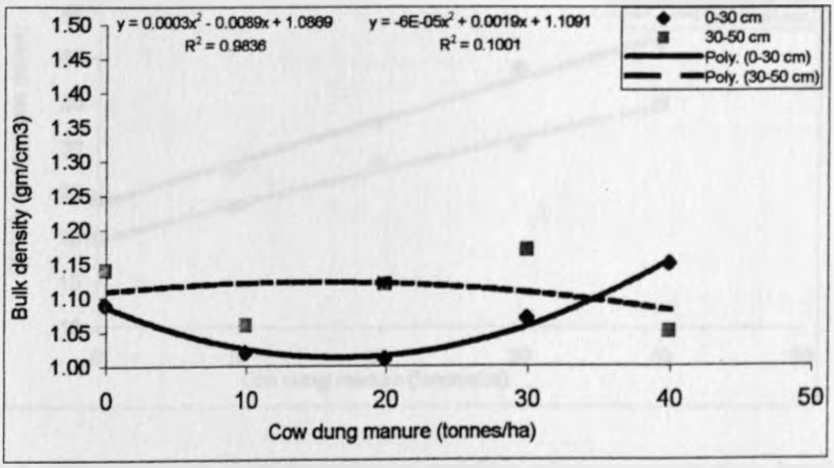

Figure 2. Effect of cow dung manure on bulk desity in two depths (Site 2)

Appedix 27. Figures showing effect of cow dung manure on aggregate stability in two depths at Sites 1 and 2 including equations and R2

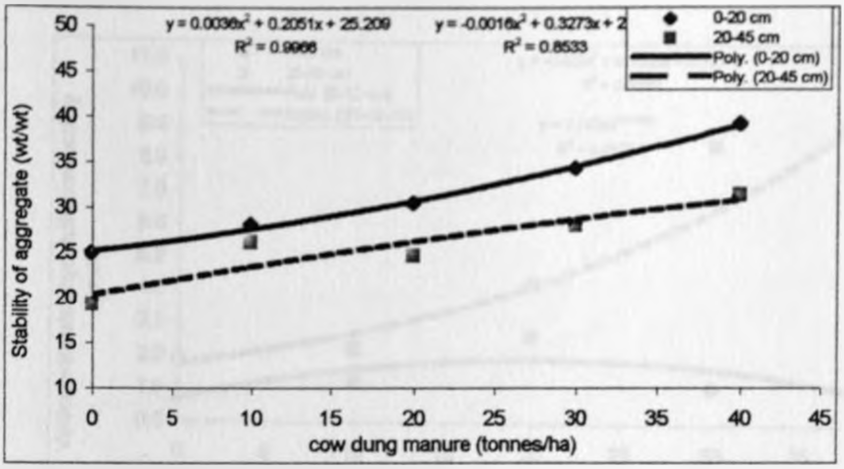

Figure 3. Effect of cow dung manure on stability of aggregae in two depths (Site 1)

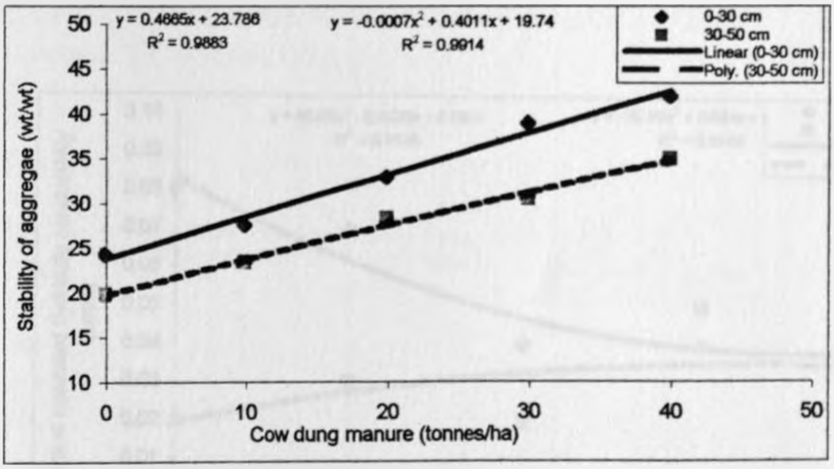

Figure 4. Effect of cow dung manure on stability of aggregae in two depths (Site 2)

Appedix 28. Figures showing effect of cow dung manure on Vertical Ksat in two depths Sites 1 and 2 including eqautions and R2

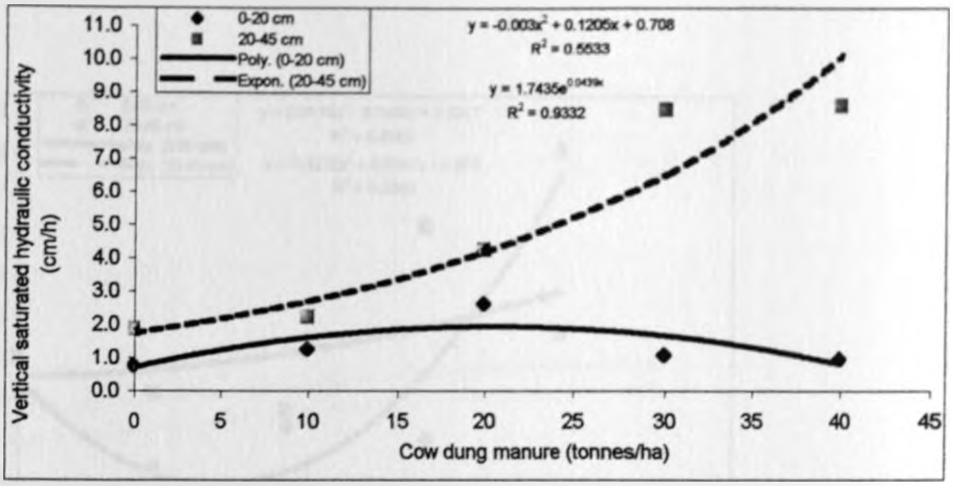

Figure 5. Effect of cow dung manure on vertical saturated hydraulic conductivity in two depths (Site 1)

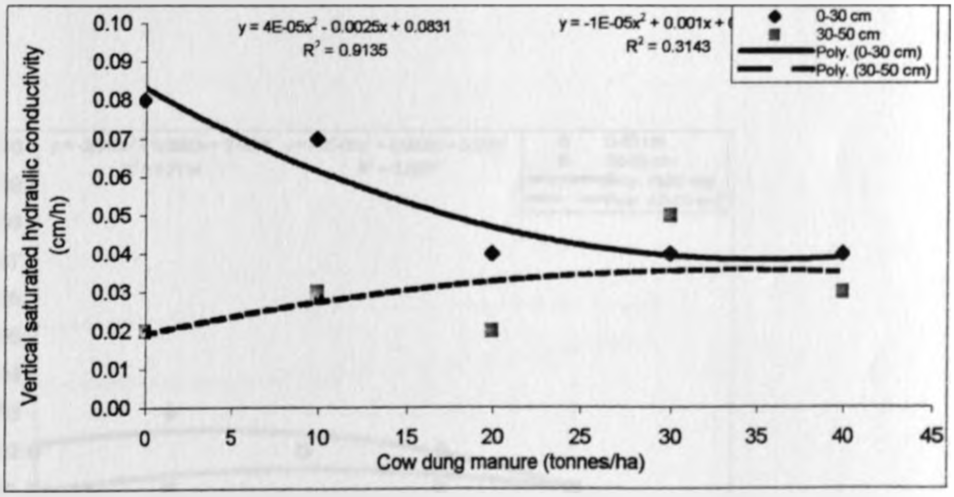

Figure 6. Effect of cow dung manure on vertical saturated hydraulic conductivity in two depths (Site 2)

Appedix 29. Figures showing effect of cow dung manure on Horizontal Ksat in two depths in Sites 1 and 2 including eqautions and R2

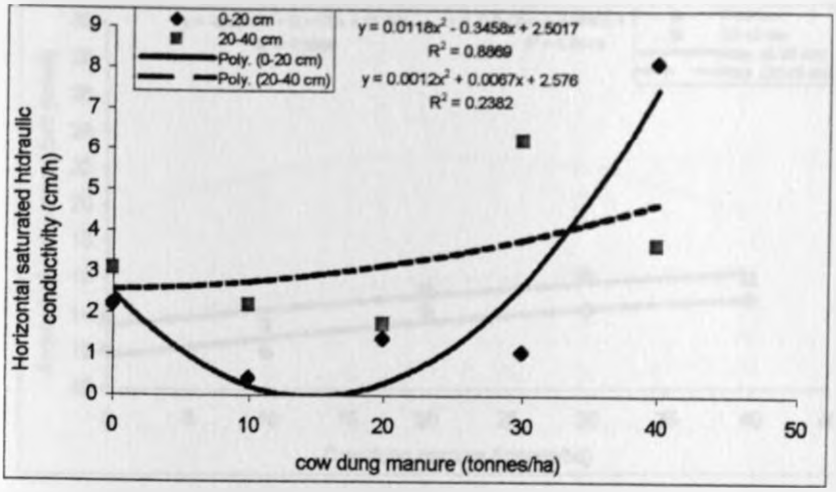

Figure 7. Effectof cow dung manure on horizontal saturated hydraulic conductivity in depths (Site1)

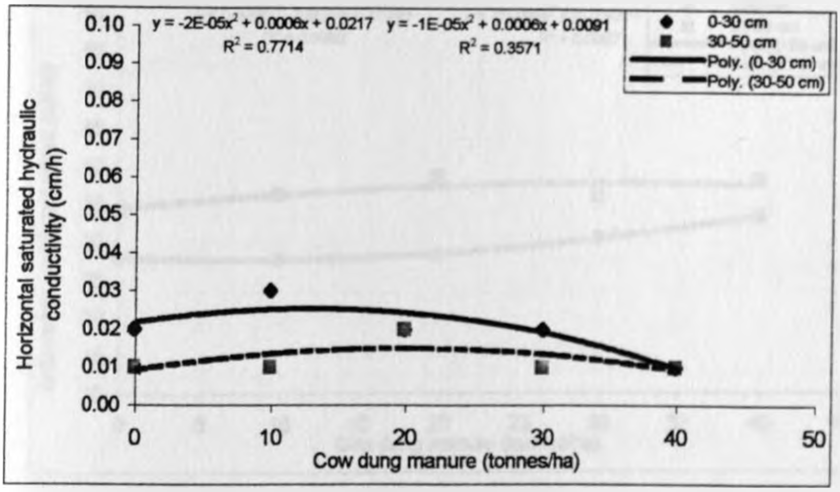

Figure 8. Effectof cow dung manure on horizontal saturated hydraulic conductivity in depths (Site2)

Appedix 30. Figures showing effect of cow dung manure on antecedent soil moisture content i
two depths at Sites 1and 2 including eqautions and R2

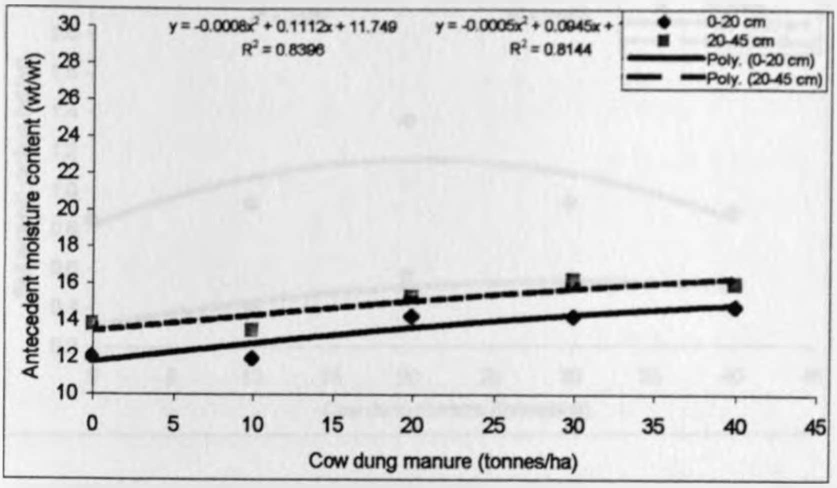

Figure 9. Effect of cow dung manure on antecedent moisture content in two depths (Site 1)

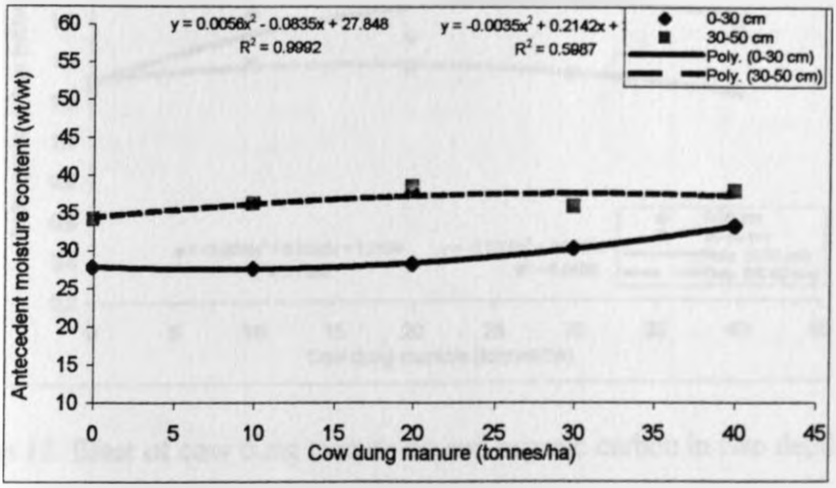

Figure 10. Effect of cow dung manure on antecedent moisture content in two depths (Site2)

Appedix 31. Figures showing effect of cow dung manure on soil organic carbon in two depths in Sites 1 and 2 including equations and R2

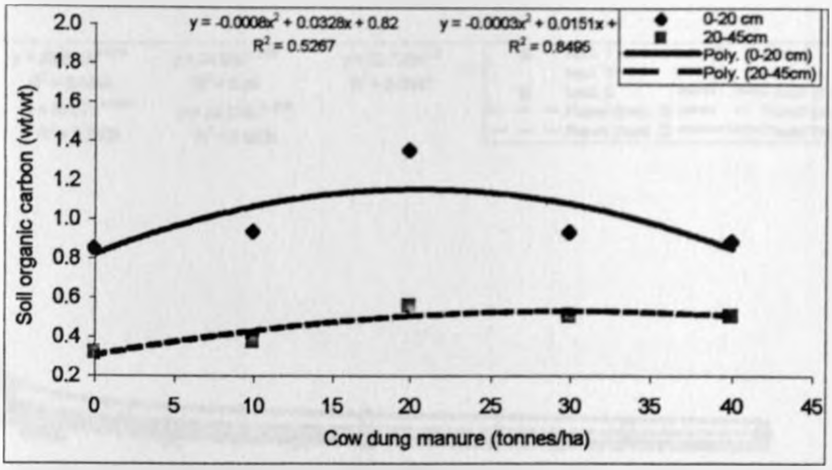

Figure 11. Efect of cow dung manure on soil organic carbon in two depths (Site 1)

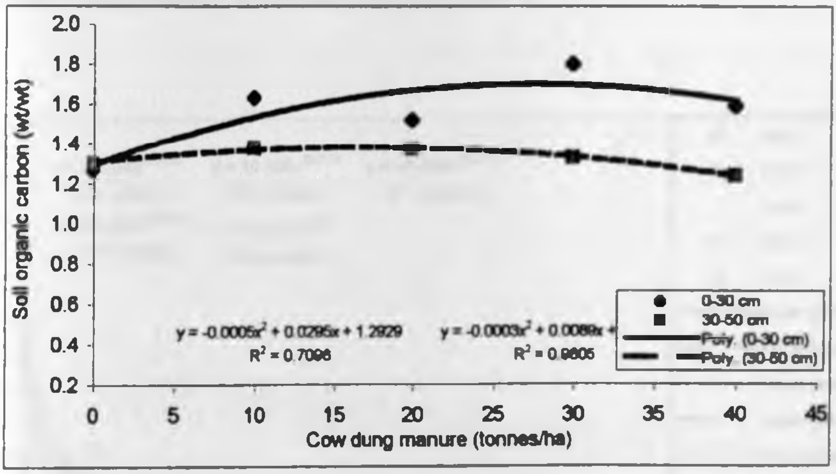

Figure 12. Efect of cow dung manure on soil organic carbon in two depths (Site 2)

Appendix 32 : Figures showing effect of cow dung manure on infilteration rate in two depthes in Sites 1 and 2 including equations and R2

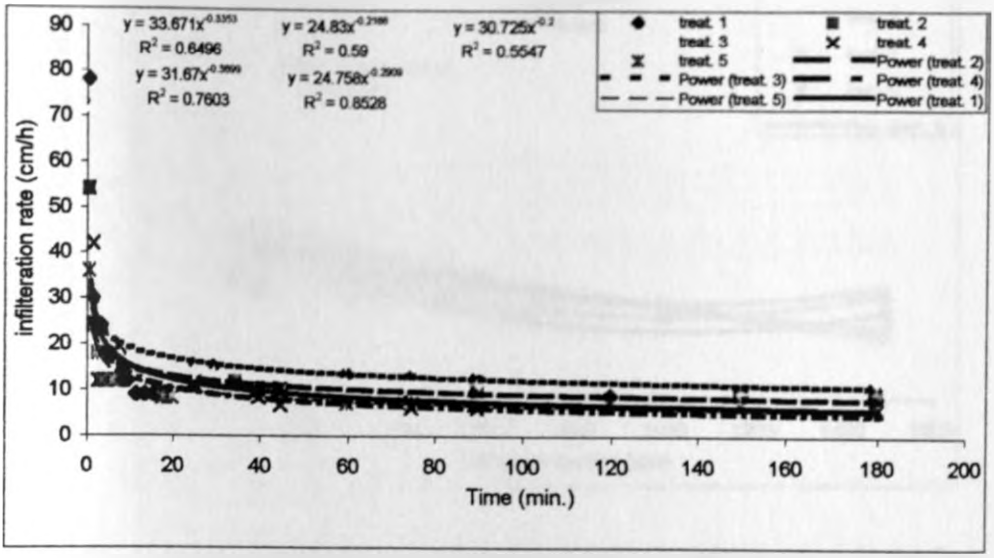

Figure 13. Effect of cow dung manure on infilteration rate (Site 1)

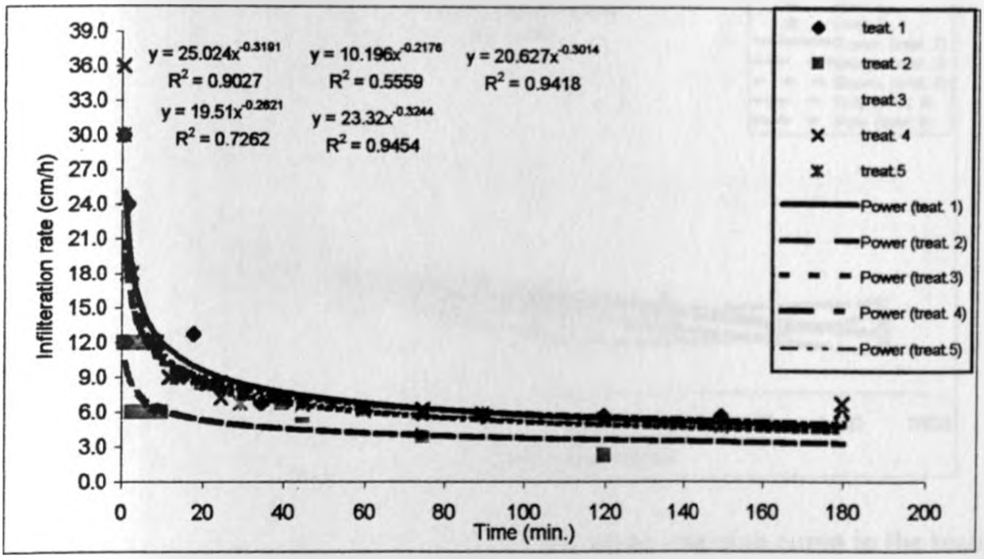

Figure 14. Effect of cow dung manure on infilteration rate (Site 2)

Appedix 33. Figures showing effect of cow dung manure on water retention curve in two depths at Sites 1 and 2 including equations and R2

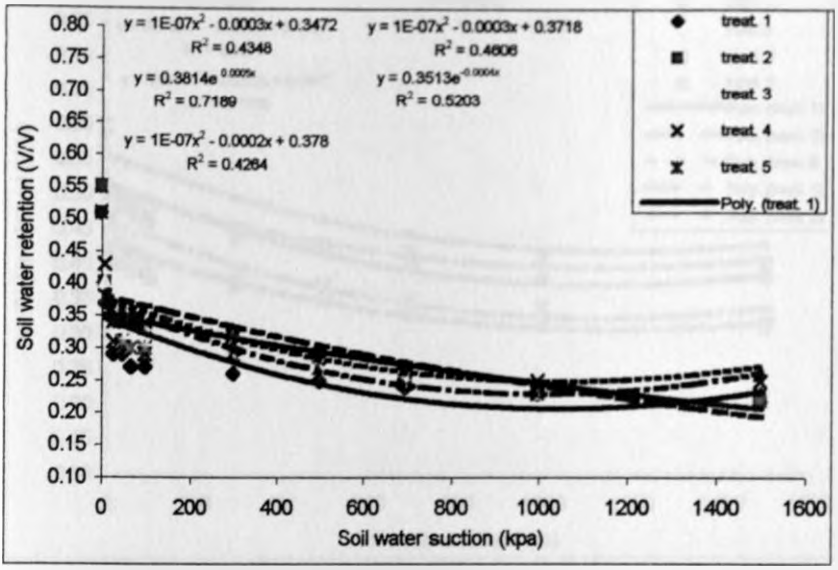

Figure 15. Effect of cow dung manure on water retention curve in the first horizon (0-20cm) (Site 1)

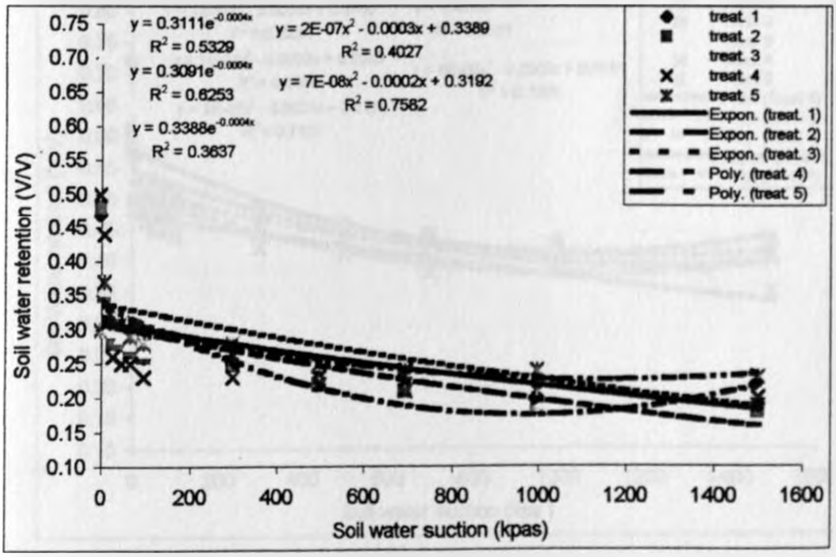

Figure 16. Effect of cow dung manure on water retention curve in the second horizon (20-45 cm) (Site 1)

Appendix 33: Continued

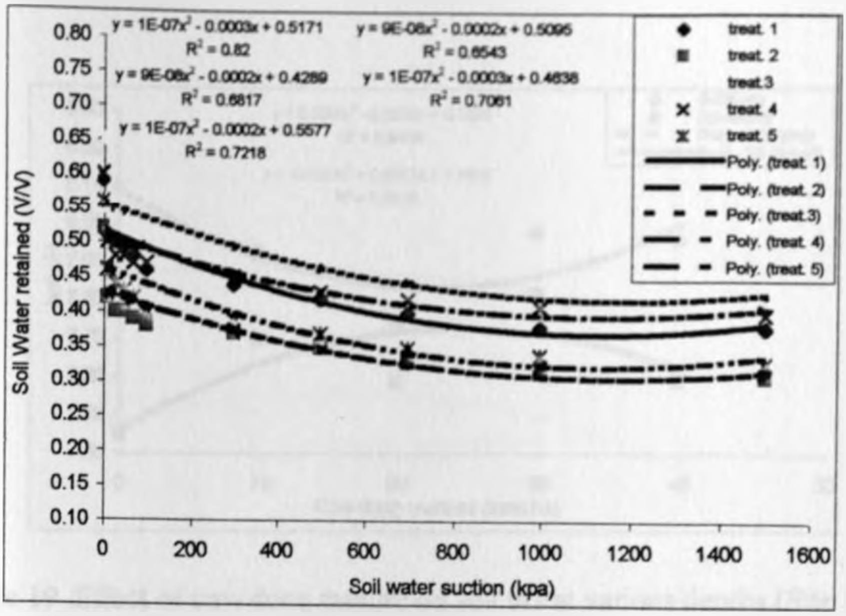

Figure 17. Effect ofcow dung manure on water retention curve in the first horizon (0-30cm) (Site 2)

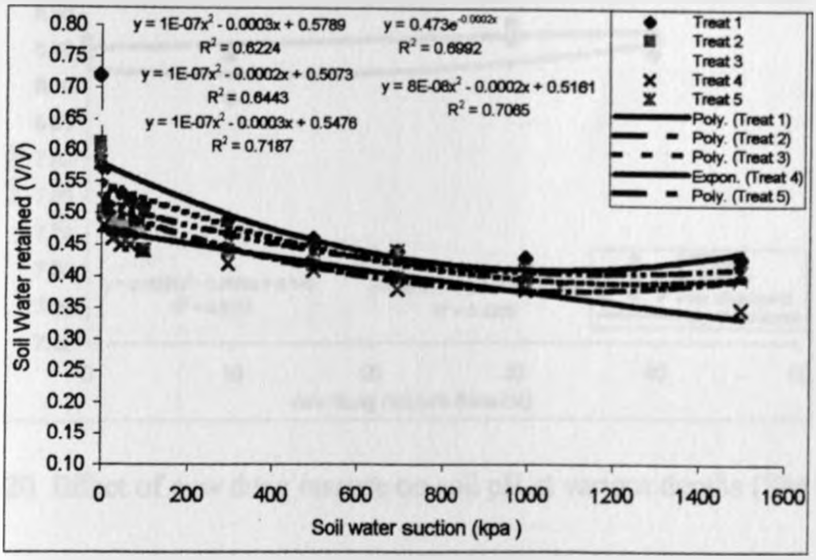

Figure 18. Effect ofcow dung manure on water retention curve in the second horizon (30-50 cm) (Site 2)

Appedix 34. Figures showing effect of cow dung manure on soil pH in two depths at Sites 1 and 2 including equations and R2

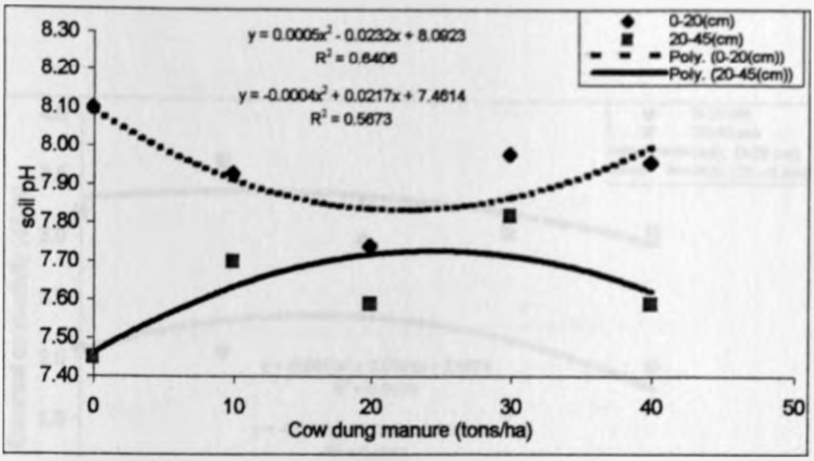

Figure 19 .Effect of cow dung manure on soil pH at various depths (Site 1)

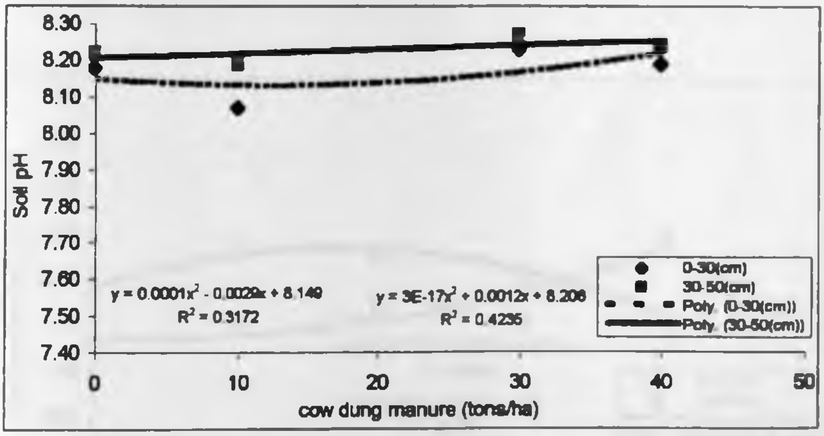

Figure 20 .Effect of cow dung manure on soil pH at various depths (Site 2)

Appedix 35. Figures showing effect of cow dung manure on electrical conductivity(dS/m) in two depths at Sites 1 and 2 including equations and R2

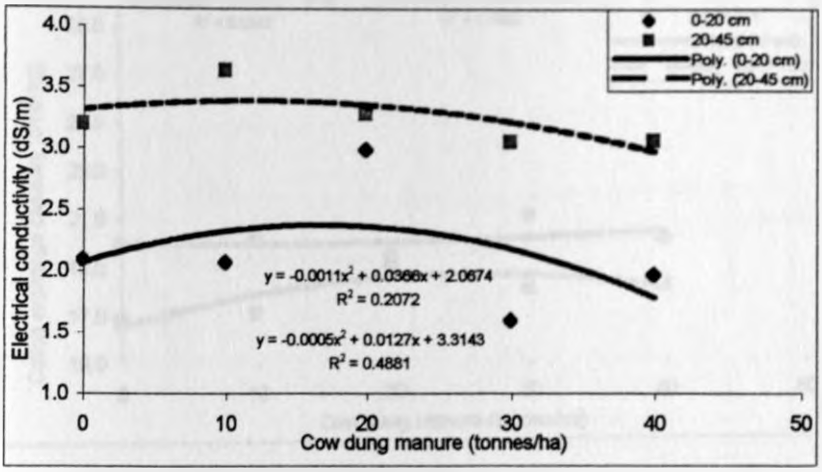

Figure 21. Effect of cow dung manure on electrical conductivity in two depths (Site 1)

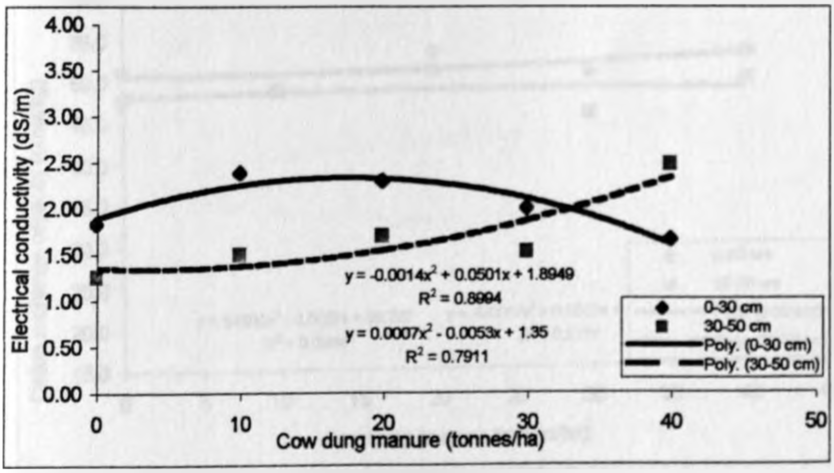

Figure 22. Effect of cow dung manure on electrical conductivity in two depths (Site 2)

Appedix 36. Figures showing effect of cow dung manure on cation exchange capacity (cmol/kg) in two depths at Sites 1 and 2 including equations and R2

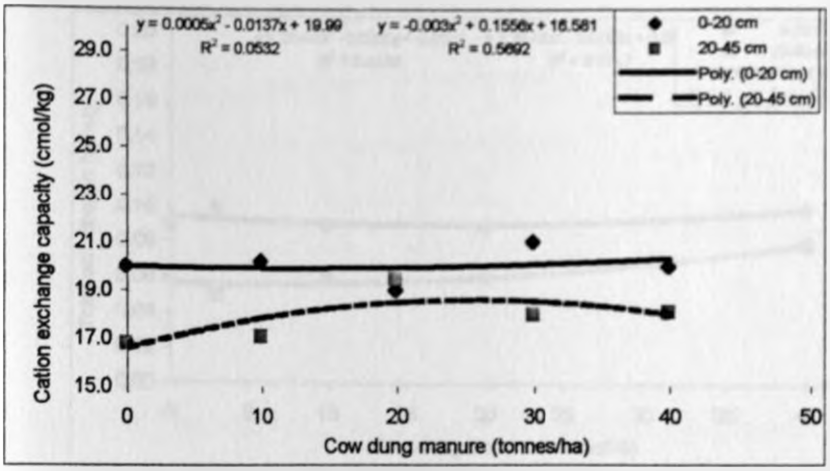

Figure 23. Effect of cow dung manure on cation exchange capacity in two depths (Site 1)

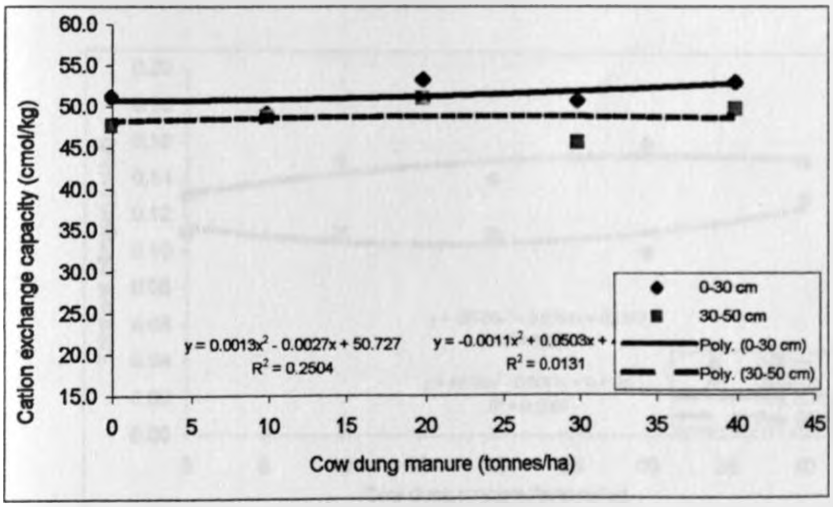

Figure 24. Effect of cow dung manure on cation exchange capacity in two depths (Site 2)

Appedix 37. Figures showing effect of cow dung manure on total soil nitrogen in two depths at Site 1 and 2 including equations and R2

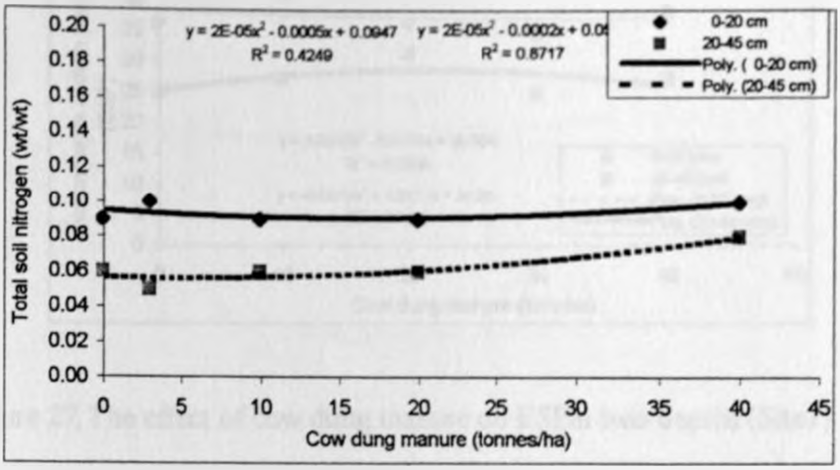

Figure 25. Effect of cow dung manure on total soil nitrogen in two depths (Site 1)

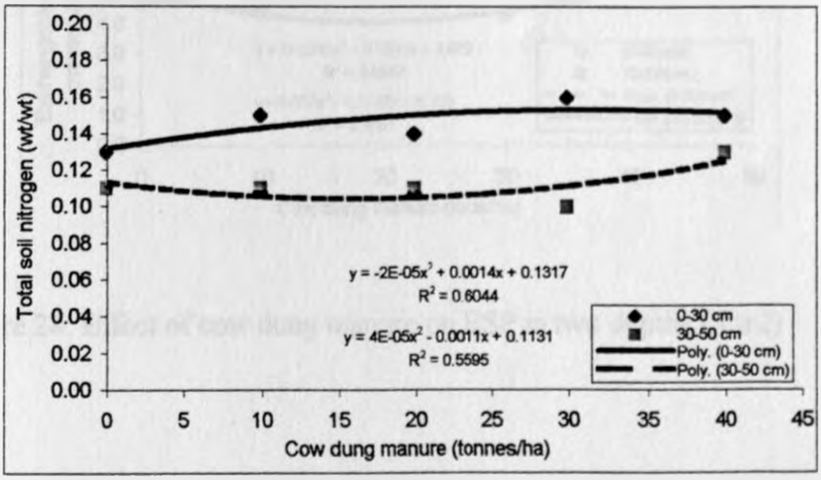

Figure 26. Effect of cow dung manure on total soil nitrogen in two depths (Site 2)

Appendix 38. Figuers showing effect of cow dung manure on ESP in two depthes at Sites 1 and 2

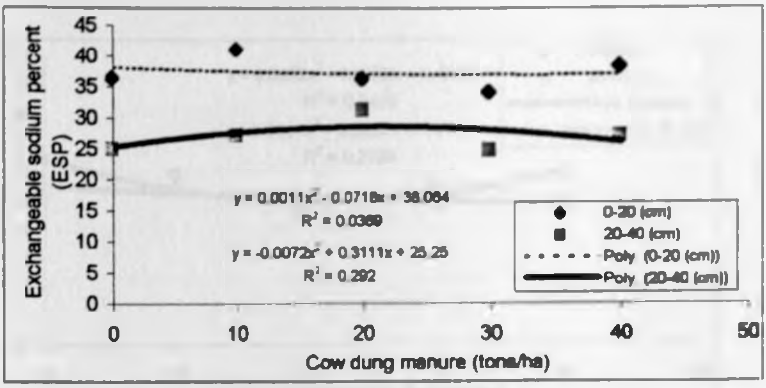

Figure 27. The effect of cow dung manure on ESPin two depths (Site1)

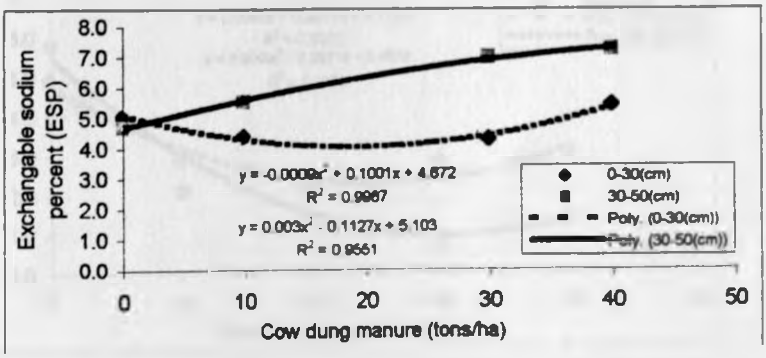

Figure 28. Effect of cow dung manure on ESP in two depths (Site2)

Appendix 39. Figures showing effect of coow dung manure on SAR
in two depes at Sites 1 and 2 including equation and R2

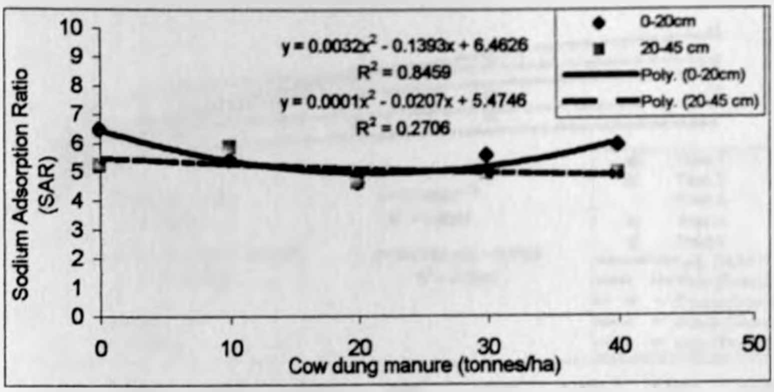

Figure 29. Effect of cow dung manure on SAR in two depths (Site 1)

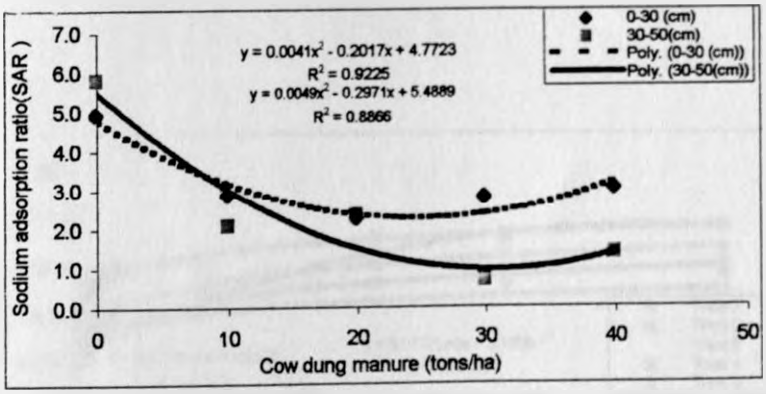

Figure 30. Effect of cow dung manure on SAR in two depths (Site 2)

Appedix 40. Figures showing effect of cow dung manure on soil water release in two depths at Sites 1 and 2 including equations and R2

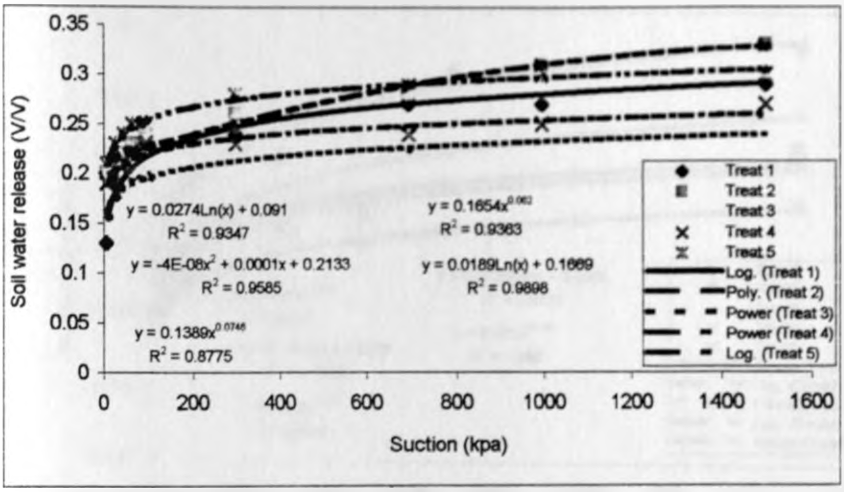

Figure 31. Effect of cow dung manure on water release in the first horizon (Site 1)

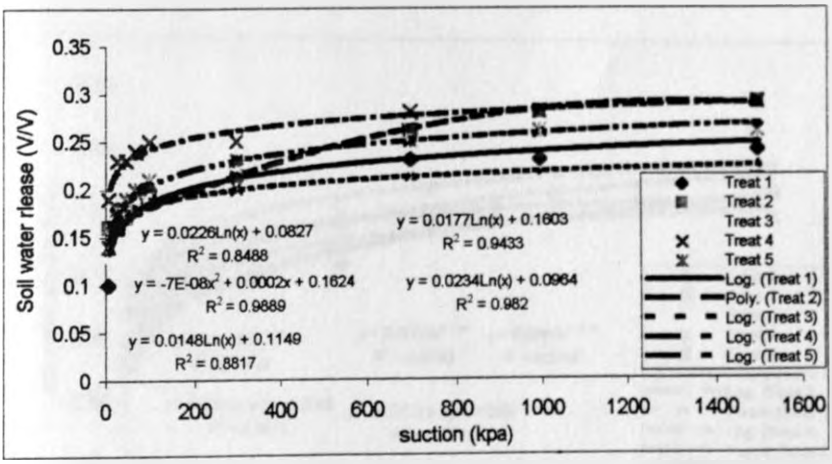

Figure 32. Effect of cow dung manure on water release in the second horizon (Site 1)

Appendix 40: Continued

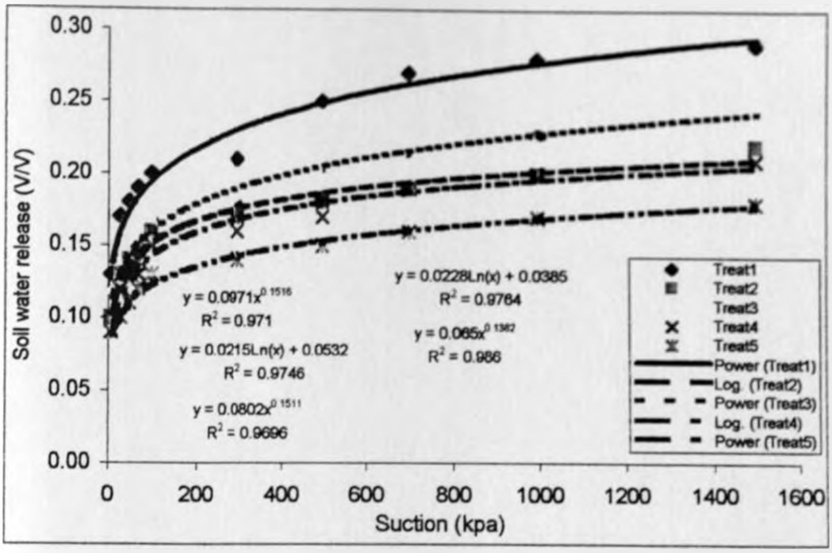

Figure 33. Effect of cow dung manure on water release in the first horizon (Site 2)

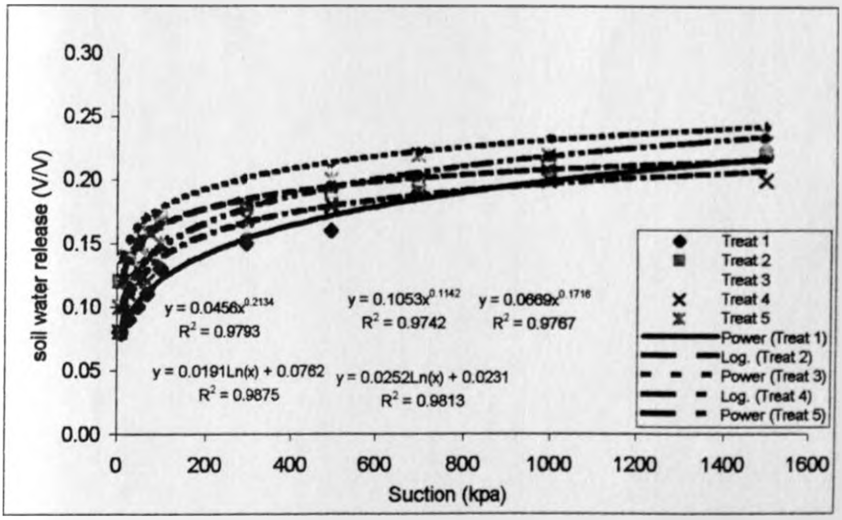

Figure 34. Effect of cow dung manure on water release second horizon (Site 2)