DIFFERENCES AND RELATIONSHIPS WITHIN PHYSICAL AND CHEMICAL CHARACTERISTICS OF FIVE SELECTED SOILS IN KENYA

JOHN ALI MWANGI

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DECLARATION

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

Signed.......................................Date...26th JULY '89...............

JOHN ALI MWANGI

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

Signed.......................................Date. JULY 26th 1989..............

S. M. KINYALI

Dedicated to my parents who strove hard to earn the little they used on my education and other family needs.

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LIST OF ABBREVIATIONS AND NOTATIONS

		UNITS
a	-Sectional area of the glass tube in falling head apparatus.	me/100gsoil
A	-Sectional area of the core-ring sample.	cm^2
ACR1	-Acrisol sample 0-15cm.	---
ACR2	-Acrisol sample 15-30cm.	---
ACR3	-Acrisol sample 30-45cm.	---
ACR4	-Acrisol sample 45-60cm.	---
Amorph	-Amorphous clay	---
AND1	-Andosol sample 0-15cm.	---
AND2	-Andosol sample 15-30cm.	---
AND3	-Andosol sample 30-45cm.	---
AND4	-Andosol sample 45-60cm.	---
b	-Contact angle.	---
c	-log K(w).	---
CEC	-Cation Exchange Capacity.	me/100gsoil
d	-Particle diameter.	---
d_{10}	-Diameter of the particles which represent 10% of total weight of porous media.	---
d_p	-Linear diameter of the pores.	---
D	-Specific weight of the fluid.	---
e	-porosity.	---
EC	-Electric Conductivity.	mmhhos/cm
g	-Acceleration due to gravity.	---
h	-Height.	cm
h_c	-Height of water in capillary tube.	cm
i	-Hydraulic gradient.	---
ill&kao	-illite and kaolinite	---
H	-Hydraulic head size.	cm
K_{sat}	-Saturated hydraulic conductivity.	cm/min
Koal	-Kaolinite	---
K(w)	-Hydraulic conductivity as a function of wetness.	cm/min
l	-Length of the sample in the core-ring.	cm
l_w	-Length of water column.	cm

LUV1	-Luvisol sample 0-15cm.	---
LUV2	-Luvisol sample 15-30cm.	---
LUV3	-Luvisol sample 30-45cm.	---
LUV4	-Luvisol sample 45-60cm.	---
m	-Mass of absorbed water.	g
meq	-Milliequivalent	---
mont.	-Montimorillonite	---
M_d	-Mass of the dry sample.	g
M_e	-Weight of the core ring only.	g
M_w	-Weight of the wet sample plus core ring.	g
n	-Viscosity.	---
NIT1	-Nitosol sample 0-15cm.	---
NIT2	-Nitosol sample 15-30cm.	---
NIT3	-Nitosol sample 30-45cm.	---
NIT4	-Nitosol sample 45-60cm.	---
P_g	-Density of gas.	---
P_l	-Density of liquid.	g
q	-Flux.	cm/min
Q	-Quantity of infiltrated water.	Q/min
Q_l	-log w.	---
Q_r	-Water quantity infiltrated per unit time.	g/min
r	-Radius of capillary tube.	cm
s	-Specific surface area.	m^2g^{-1}
SAR	-Sodium Adsorption Ratio	---
s_a	-Sorptivity.	---
t	-Time.	min
VER1	-Vertisol sample 0-15cm.	---
VER2	-Vertisol sample 15-30cm.	---
VER3	-Vertisol sample 30-45cm.	---
VER4	-Vertisol sample 45-60cm.	---
V_d	-Volume of the dry sample.	cm^3
V_f	-Volume occupied by both air and water in soil.	cm^3
V_t	-Volume occupied by water, air and solids in soil.	cm^3
V_s	-Volume of the solid particles of the soil.	cm^3
V_w	-Volume of the wet sample.	cm^3

w	-Wetness.	---
W_a	-Weight of the flask and air.	g
W_l	-Weight of the flask and water.	g
W_s	-Weight of the flask and dry sample.	g
W_{sl}	-Weight of the flask water and soil sample.	g
x	-Distance of the wetting front.	cm
y	-Surface tension between liquid and air.	---

LIST OF SYMBOLS

		UNITS
ρ_d	*Dry bulk density*---------------	gcm^{-3}
ρ_b	*Wet bulk density*---------------	gcm^{-3}
ρ_p	*Particle density*---------------	gcm^{-3}
ρ_w	*Water density*------------------	gcm^{-3}
θ	*Volumetric wetness*-------------	V_w/V_t

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ABSTRACT

Knowledge on physical and chemical factors in any soil is important to any one who uses the soil. This may be in agriculture or any other purposes as engineering eg. road construction, dam construction and large civil engineering works.

In the study here the properties such as capillary movement of water, saturated hydraulic conductivity, bulk density, organic carbon, cation exchange capacity, electric conductivity, clay mineralogy, were analysed and results tabulated. Variation in properties within the samples was observed. Capillary rise was studied and later correlation with other factors was done. It was found that capillary was highly correlated to most of the properties analysed. Measure of capillary rise was done with the use of wetting front height. Also the weight of cumulative weight of water was determined along with wetting front height. This also had good correlation with both physical and chemical properties although the latter is better correlated.

In conclusion it can be stated that when factors of good correlation are known estimate on how soil will conduct water by capillary means can be estimated.

Conversely when the capillary curves from a set of soils are drawn, deduction of some soil properties can be made such as clay mineralogy, texture, and organic carbon content.

CHAPTER ONE

1. INTRODUCTION

The study deals with some physical and chemical aspects of five selected Kenya soils in relation to their productivity. The five soils are the Vertisols, Andosols, Nitosols, Luvisols and Acrisols. Of the five soils only the Nitosols are representative of the Humid Highlands. The remaining four are more representative of the semi-arid regions of the country.

The Nitosols were obtained from the university of Nairobi Kabete farm and described as Humic Nitosols(FAO) or Rhodic paleulstalf (USDA) (D'Costa, and Nyandat, 1969). The farm is situated in upper Kabete and altitude of 1940 m above the sea level. The farm is about 1km from main Nairobi-Nakuru road and between latitudes 1° 14' 20"S and 1° 15' 15"S and longitudes of 36° 44'E and 36° 45' 20"E. Mathari river forms most of its Northern fence line. The rock of the farm comprises of Kabete trachites. Soils at the point of sampling are well drained and excess water during the rains, flows westward where it finds its way to Mathari river. The area has a slope of 8-12°. It is well drained with subangular blocky structure.

The Vertisols analysed were classified are as Pellic Vertisols (FAO) or Typic Pellustert (USDA) (D'Costa, and Ominde 1973) and is taken from Ahero irrigation experimental station. The station is located North of Nyando river and South of Miriu river 2 km NNE of Ahero town and in Kisumu district and Nyanza province. Central co-ordinates are 0° 09'S-34° 56'E.

Physiognomy of the station is described as infilled alluvial plain overlain by reworked lacustrine sediments. Local relief is formed by old and recent stream courses and deposits with back-swamps. Altitude is 1153 M above sea level.

The Acrisols and Luvisols used in the experiment were taken from Kampi ya Mawe Experimental station. They are the common soils of the station and classified as Orthic acrisol and Chromic luvisol (FAO) respectively (Muchena, 1975) The station is situated in Makueni Northern division, and Machakos district. It lies at approximately 1° 50'S latitude and 37° 40'E longitude.

Its altitude is 1125m above the sea level.

The Andosol used in the experiment was taken from Nakuru district of Rift Valley Province. It is classified as Humic Andosols (Gachene 1982). Site of sampling was 36° 33' 32"E and 0° 56'13"S. This is about 16 Km south of Naivasha town and about 2 Km West of Naivasha Nairobi road. It was near the foot of Longonot crater and it is developed from volcanic ash.

Work done on the soils shows that mainly chemical aspects were considered and less in physical aspects. Thus this study lays more emphasis on the physical aspects.

This study is not in any way an implication that physical properties are more essential than the other, but rather we have chemical properties which are attributes of chemical fertility, while on the other hand there are physical properties in the case of physical. Changes in the above categories of properties affects crop productivity. Where as there are interactions within any one of the category; there are interaction from one group to the other. All the analysis carried out in the laboratory can be broadly divided into two; chemical and physical analysis.

1.1 OBJECTIVES

Some analysis carried out here were done sometimes ago on the same soils when the five soils were being classified by authors mentioned above at the outset of this report. Their main task was towards classification for soil survey purposes where classification is done on the general properties of the soils in any classified field.

In this study I wish to do more comprehensive study on fertility of five soils with more bias on physical fertility. Here accurate figures are used for comparison of quantitative properties analysed.

On physical properties capillary rise of water has been given special treatment much more than in any literature cited so far. Some interesting results were obtained which allowed better observation on how it correlates with some chemical and other physical properties.

A summary of the properties looked into and treatment of the results is shown below.

(i) Determination of physical properties of five soils; saturated hydraulic conductivities, unsaturated hydraulic conductivities, soil texture, soil water tension, soil particle density, bulk density, capillary water movement, water at field capacity

(ii) Determination of chemical properties of the five soils; soil pH, CEC, EC, organic carbon, potassium, calcium, magnesium, sodium, base saturation, clay mineralogy of the soils.

(iii) Comparison of the determined properties among the five soils.

(iv) Determination of inter-relations within the properties obtained, eg capillary and organic carbon.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 INTRODUCTION

When we discuss the physical and chemical factors in relation to the soils then we are discussing the subject on certain aspects of soil fertility. This highlights on the climax of fauna and flora in the field, within a set of prevailing equilibria of factors. The flora and fauna includes all the living forms that affect man existence on earth. The subject is then on certain aspects of soil fertility. The subject is important to anyone directly involved in crop production or its research among other fields.

The study deals with soil fertility aspects in relation to the soil properties. The said facet is not an island in itself but an area with indefinite limits which have different modes of approach by different people. In part the research carried out here is a soil chemistry problem while on the other hand its a soil physics problem. The factors considered are: Soil and water, specific surface area, clay mineralogy, soil texture and some soil fertility aspects.

The five soils to be discussed are vertisols, andosols, nitosols, luvisols and acrisols.

2.2. SOIL AND WATER

Soil and water are essential to plant life. Soil acts as water and nutrient reservoir to plants. Water contributes towards soil development processes e.g. weathering which affects the nutrient reservoir function of the soil. The amount of water is not all but also the factors which need consideration are the ones affects its availability.

2.2.1. water in plants

One of the contributions of water in plants is to increase the plant dry weight or matter. This importance can be expressed by different values of transpiration ratio as exhibited by different plants. Transpiration ratio is defined as an amount of water required to produce a unit weight of dry matter. Goss (1973) gave the following table of transpiration ratio for different plants:

Table 2:1 Transpiration ratio in some plants.

SPECIES	TRANSPIRATION RATIO
Pine	50
Corn	350
Wheat	450
Apple	500
Alfalfa	800

source: Data from Physiology of Plants and their Cells. Goss (1973).

Also Thomas (1973) gave the following on the same ratio:

Table 2:2 Transpiration ratio in some plants.

SPECIES	TRANSPIRATION RATIO
Peach	100
Maize	250
Oak	350
Lucerne	1000

Source: Plant physiology, Thomas (1973).

Also Square (1990) gave the following table on two crops namely Pearmillet and Groundnut at different stands numbered from 1-5 in Table 2:3 below.

Table 2:3 Transpiration Ratio for Pear millet and Ground nuts at Different Stands.

	STAND	TRANSPIRATION RATIO
Pear millet	1	160
	2	260
	3	220
	4	480
Ground nuts	1	190
	2	330
	3	380
	4	670
	5	500

Source: The Physiology of Tropical Crop Production (Squire 1990)

Thus any factor affecting water availability in the soil to any plant are as important as the presence of water in the soil and would come into play when determining suitability of a given plant to a given soil.

Factors to be looked into are water release and retention, and hydraulic conductivity of the soil under both saturated and unsaturated condition, and water availability to the plants. Two types of water flow are considered. The two are saturated and unsaturated flows. Under the former case all the pores are filled with water and hence tends to be poorly aerated. In such condition only a few crops can tolerate e.g. rice. In the case of unsaturated condition only capillary pores are filled with water. Most plants prefer such condition and water available to them flow under this mode.

There are different factors and quantities which are associated with the flow e.g. hydraulic conductivity, volumetric wetness, gravimetric wetness, infiltration rate, cumulative infiltration capillary rise, diffusivity of water, matric potential, water potential, and bulk density. When the temperature is a constant these factors can be determined by physical and chemical characters of the soil. The factors varies from one type of soil to another.

The soils behaves as porous material and hence can allow water to flow through. The rate varies from one soil type to another e.g. sandy soil have high rate while clay have very low.

2.3. TEXTURE

The texture refers to the relative proportion of the primary particles of sand silt and other skeletal material of the soil body.

When Kars Et al (1979) were working on artificially synthesized soils they showed the direct relation between particle size distribution and average micropore radius. This was shown to affect rice root growth. Thus it was found that the root growth was in the following order; silt clay loam > sandy loam > silt> sand > loam > clay loam > clay > silt clay. The largest macrospore radius was in sand.

2.4. POROSITY

Hillel (1980b) give the value of porosity to 30-60%. This depends on the soil type.

2.5. WATER CONTENT.

This ranges from water logged condition to water held by adsorptive force fields.

Hillel (1980c) expresses the importance of soil water content on some physical properties which will always be dependent on water content. These are consistency, plasticity, strength, penetrability, stickiness and trafficability.

2.6. MOISTURE POTENTIAL.

Another factor which would be used in characterizing the soil is the soil water retention.

This is measured in pF, cm, atmospheres and bars. The relationship of these is given by 1atm.=1036cm and Log(cm)=Pf. This is also one of the factors which affects the water availability to plants in the soil at different wetness. Thus we have three points of water tension based on the effects on plants. These are field capacity, wilting point and permanent wilting point. Experimental results show that wilting point correspond with Pf 4.2 which is equivalent to 15 atmospheres (Lyon and Buckman 1947b).

Moisture potential of a salt free soils also varies e.g. clay tends to have a high moisture potential while sandy soils tends to be very low. The tension will be an indication of how easily the water in the soil will be available to the plants.

Thus the knowledge will be important when irrigation water is applied to the field since it gives how much more water should be applied or added to a given soil.

Amount of wetness at any suction is dependent on the type of the soil eg sandy soil may retain less than 5% of water.

2.6.1. Effects of texture.

Bear (1965) gave the data on water retained at about 15 bars. Comparatively, clay soil may retain three to four times as much (Hillel 1980c).

Michael and Ojha (1978) stated that the soil moisture tension in salt free soil at field capacity ranges from less than 0.1 to 0.7 atmospheres depending on soil texture. The Table 2.4 contain given average values of the soils.

Also Richards and Weaver (1944) are quoted to had found that the effective value of moisture equivalent ranged from 0.3 bar in coarse textured soils to 0.5 bar in clays (Slatyer 1967). The figures given are function of texture and structure. Biggar et al (1960) stated that soil structure and texture influence the energy with which water is retained in the soil. The water retained is so much affected by inter-facial forces between the solid and liquid and between the liquid and vapour.

Table 2.4: Water tension at field capacity

SOIL	TENSION IN ATMOSPHERES
sandy soil	0.06
loamy soil	0.1
silt	0.3
clay and clay silt	0.6

Source: Agricultural Engineering Volume II Michael and Ojha (1978)

This can be interpreted to mean that the sand can drain completely and at very low pressure, while the fine textured soil will require a higher tension.

Bear (1965) gave the following data on water retained in soil column at the height indicated in 60 days as follows:

Table 2.5: Water retained in sandy loam and clay loam in soil column at different mark in cm.

HEIGHT OF SOIL COLUMN LENGTH	SANDY LOAM	CLAY LOAM
84	16.16	21.26
72	16.55	31.05
60	17.59	31.21
48	18.50	31.99
36	20.90	32.45
24	21.46	34.40
12	22.68	35.97
6	27.69	37.19

Source: Soil in Relation to Crop Growth. Bear, (1965).

From the data above it can be seen that at any given height the water contained in sandy loam is less than in clay loam.

When dry soil is wetted the wetting fluid can affect the water retention of the samples and the most affected are fine textured soils that contains significant of swelling clays (Klute 1986)

Drivers and Shipp (1978) found that in all textural classes there is significance in correlation between total percentage of very fine sand plus silt plus clay vs individual percentage of sample water at field capacity and under 1/10, 1/15 and 1/20 bar. Another example to show the effect of texture on water at field capacity can be seen in table 2.4

Hillel et al (1975) states that moisture tension of the soil at permanent wilting point ranges between 7-32atms depending on the soil texture, kind of the plant, and amount of soluble salt in the plant. Briggs and Shantz (1911, 1912) are quoted by Kramer (1969) to have conducted experiment on a wide varieties of plants and found wilting points to occur in between -10 bars to -20 bars, with a mean of -15 bars. The wilting point can not be expressed in terms of water percentages since a certain water percentage can be in saturation in sand while the same amount will be at permanent wilting point in clay soils. The ease with which a plant can extract water from the soil varies with the moisture content and the form of capillary system.

2.7 SPECIFIC SURFACE AREA AND CLAY MINERALOGY

Specific surface area is another factor which varies from one soil to another e.g. sandy soil tends to have lower specific surface area compared with clay soil. Clay mineral content and clay mineralogy contribute towards certain physical behavior of soils eg. landslide. Due to the expanding nature of clay the landslide-prone soils is a function of clay content since high clay content soils expands more and low clay content less (Ciolcosz Et al 1979). The conclusion was reached when they were working on four soils from Pennsylvania and Ohio. It was also pointed out that what contributed to this was coefficient of linear extensibility which depend on percentage of montimollironite vermiculite and layer silicates, as kaolinite and illite were found not to contribute towards the extensibility. Nature and type of solutes will affect the swelling of swelling clay. Lagerwerff Et al (1969) points out that the measure of swelling of double layer clay depends on the electrolyte concentration and composition of ambient solution. Clay mineralogy varies within different soils. It affects hydraulic properties of soils, since different clay minerals exhibit different properties due to their chemical structure. Certain chemical properties can be ascribed to the same chemical structure e.g. CEC, pH. The water availability is very much affected by the specific surface area. Besides the water availability, specific surface area has been found to correlate with Cation Exchange Capacity, retention and release of various chemicals e.g. nutrients and certain potential pollutants of environment, swelling water retention, plasticity, cohesion and strength (Hillel 1980b). Also the importance of cation exchange is expressed by Donahue (1983) who says that it is important in correcting soil acidity and basicity, in changes altering soil properties, and as mechanism in purifying or altering percolating waters.

Carter et al (1986) gives the following to be some of the factors which are determined by the specific surface area: physical adsorption of the molecules, heat loss or gain resulting from the adsorption, swelling and shrinking, water retention and movement cation exchange capacity and pesticide adsorption.

2.7.1 Effects by texture

The specific surface area also varies with particle size distribution. The external surface area of 1g of colloidal clay is at least 1000 times that of 1gm of sand (Brady, 1984). Thus the specific surface area is even better than sand, silt and clay characterization, of soil. Goss (1973), gave the figures in table 2.6 of different specific surface area and particle size diameter.

Table 2.6: A table to show relationship between particle size diameter and specific surface area of some soils.

PARTICLE DIAMETER(mm)	CLASSIFICATION	SPECIFIC SURFACE AREA IN Sq. CM per Cu.CM
10	course gravel	6
2.5	fine gravel	24
1.0	course sand	60
0.1	fine sand	600
0.01	silt	6000
0.001	clay	60000

Source: Physiology of Plant and Their Cells Goss 1973.

2.7.2. specific surface and clay mineralogy

The specific surface area will also vary within different clays. The specific surface area of layered silicate clays will range from $10m^2$ per gm for clays with external surfaces to more than $800m^2$ per gm for those with external and internal surfaces (Brady, 1984).

The specific surface area has a close relation with hydraulic behavior of a given soil. Mortland is quoted to have found that the field capacity, moisture equivalent and 27.1 atm moisture retention value are related to specific surface area of the soil (Gill and Reaves 1957). Kramer (1969) also explains that the extensive surface enables clay particles to hold more water and minerals than sandy soils. He further states that the soil of clay fraction largely controls chemical and physical properties of mineral soils.

2.7.3. Hydraulic behavior

When Kutilek (1971) was comparing the moisture retention curves of two clays, he had two conclusions:- the affinity of water to kaolins is higher than montimollironite's when considering per

unit area; specific surface area of montimollironite is of higher magnitude than that of kaolinite.
It was found by Kutilk (1971) that the specific surface area plays a dominant role while the quality of the surface was subordinate.

2.8 HYDRAULIC CONDUCTIVITY.

2.8.1 Saturated conductivity

Saturated conductivity is another factor which was used in the analysis. If the flow rate decreased to a point where the infiltrate volume error percent was large due to evaporation falling head technique was used. This is in line with suggestion put by Rosenak (1963) who said that the constant head is fit for fine grained soils of 10^{-1} to 10^{-8} sec.$^{-1}$ The conductivity K from a constant head apparatus can be calculated from the following derivation:

$$q = Ki \qquad \text{-------------------------1}$$

where q has dimensions of velocity and is given by:

$$q = \frac{Q}{At} \text{ and } i = \frac{H}{L} \text{ the hydraulic gradient-----2}$$

Equating the two equations for ie Eq 1 and 2, we have:

$$\frac{Q}{At} = \frac{KH}{L} \qquad \text{-----------------------3}$$

from where K can be found to be given by Eq 4.

$$K_{sat} = \frac{Q}{At} \times \frac{L}{H} \quad \text{------------------4}$$

where Q-volume of water passing through the sample at time t.

A-cross-sectional area of the sample

H/L-hydraulic gradient, H being the hydraulic head of the water given by H=L+h and L the length of the sample.

h-height of water on the sample.

Loveday (1974) suggests that the hydraulic, gradient should not exceed 4. From past observation on vertisols, which one of the soils in the analysis it would require a gradient of 3-4 to have any water.

Different heights h_1 and h_2 are taken at time t_1 and t_2 respectively on the standpipe B.During a small change in time dt corresponding to the change in height dh an amount of water taken is given by:

$$Q_r = -a \frac{dh}{dt} \quad \text{---------------------5}$$

Also the same can be given by:

$$Q_r = K A \frac{h}{L} \quad \text{---------------------6}$$

Thus:

$$-a \frac{dh}{dt} = K A \frac{h}{L} \text{ hence } - \frac{dh}{h} = \frac{K A}{aL} \times dt \quad \text{---7}$$

Integrating both sides with h_2 and h_1; and t_1 and t_2 as limits respectively results to Eq 8

$$\text{Ln} \frac{h_2}{h_1} = K\ A\ a\ x(t_2-t_1) \quad \text{---------------8}$$

Thus K can be given by:

$$K = \frac{L\ .\ a\ .\ \text{Ln}\ (h_1/h_2)}{A\ .\ (t_2-t_1)} \quad \text{----------9}$$

Different soils have different saturated hydraulic conductivities Hans (1980) states that it is an important and sensitive soil characteristic. The equation is suitable for soils with very low permeability eg. soils with very high amount of clay.

2.8.2. Effects of texture on conductivity

Water moves fast through the sand while very slowly in clay soils. Some clays will give a value of K to be less than one cm per day. This is the reason why this soil tends to be poorly drained.

2.8.3. Effects due to clay mineralogy

Kramer (1969) quotes Smith and Brown (1946) to have given value of hydraulic conductivity to be less than 0.0025cm per hr in least permeable to greater than 25cm per hr in most permeable soils. Largerwaff et al. (1969) points out that the swelling affect the small pores more than the large ones. The reason for this he gives to be Poiseuille's law which states that the flow rate is proportional to second power of the pore diameter. Also tortuosity is affected by swelling. Largerwerff et al. (1969) points out that swelling in soils cause the small pores to increase in size at the expense of large pores and the same time affecting them as flow channels this because most flow take place within large channels. Baver et al (1972) also said that swelling of colloidal clays varies with the type of clay mineral and the nature of adsorbed cations. they also point that expanding lattice type of colloids such as montimorillonite and biedellite swells more than fixed lattice type such kaolinite and halloysite. They also pointed out that sodium caused swelling more than calcium and thus sodium reduces flow in swelling soils more. McNeal (1968) while working with Pachappa soils found that when Sodium Adsorption Ratio (SAR) was a constant, the hydraulic gradient decreased with concentration of salts in percolating solution. He also found that the rate of the decrease was much higher at higher values of Sodium Adsorption ratio. He also found the correlation decreased with the swelling of extracted clay. McNeal (1966) pointed out that clays in the soil affect the swelling at different amounts and the most being montimorillonite rich soils.

The saturated conductivity is related to the geometry of the constituent and pores of the soil. Larouss (1981) quotes the following equations which relates saturated hydraulic conductivity K with the geometry:

(i) Equation of Hazen(1893)

$$K=c_1 \times d_{10} \text{------------------------------------} 10$$

(ii)Equation of Schlicter(1897)

$$K=C_2 \times e^{3.3} \times d^2 \text{----------------------------------} 11$$

(iii)Equation of Kozeny(1930)

$$K=C \times \frac{V_s^2}{S^2} \times \frac{e^3}{(1-e)^2} \text{------------------------} 12$$

where; C, C_1 and C_2 are constants,

d_{10}- is the diameter of the particles which represent 10 % of the total weight of the porous media, e -is the porosity,

d -is the diameter of the homogeneous particles,

S -is the specific surface of the particles.

V_s-volume of the solid

The geometry is very closely related to the texture of the soil. Texture was be determined and was related to both capillary rise and K-value.

Larouss (1981) shows a derivation of an equation that also relates K-value with the geometry of the soil particles and comes up with an equation:

$$K = \frac{gD \times d_p^2}{n \times C_3} \quad \text{----------------13}$$

where; g - acceleration due to gravity,

d_p- is a linear dimension of the pores,

n - is the viscosity of the fluid,

D - the specific weight of the fluid,

C_3- a constant.

He farther points out the linear relationship between the mean pore diameter d_p and mean particle density d to be:

d_p = 0.35d and hence the equation for K becoming:

$$K = C_1 \times \bar{d}^2 \quad \text{---------------------------14}$$

where:

$$C_1 = (0.35^2/C_3) \times (gD/n) \quad \text{----------------------15}$$

This was established while using glass beads which can be projected to the soil particles. It was also pointed out that the equation gas modification when porous media has both large and small particles. Thus the large pores can be occupied by small particles. The modification will give Eq 16:

$$K = C_1 \times \bar{d}^2 - b \quad \text{-----------}16$$

2.8.4. Unsaturated conductivity

In the past study on unsaturated hydraulic conductivity has been done by several authors amongst whom is Ahuja (1974) on unsaturated flow of water. He used a method of determining the wetting phase conductivity function obtained from cumulative inflow mass in a uniform soil column where water was allowed to enter through the porous plate of high resistance. He based his method on piece wise application approach of Green and Ampt(1911) to the process of infiltration. In the analysis of this description, water was introduced from the bottom of the soil column. Thus water movement will solely depend on capillary rise. Such setting was made by Swartzendruber (1956). He was trying to find out the reason why the usage of the assumption that porous material of soil do not have water capillary rise as in a set of non-interconnected capillary tubes hence the movement in accordance to the Poiseuilles law. Sharma and Uehara (1968) did an experiment on unsaturated conductivity of some two soils of different texture. They concluded that the difference in hydraulic conductivity is consistent with Poiseuilles law which states that a flow through a porous medium is proportional to the fourth power of the radius of the conducting tubes. They found that soil with courser texture emptied its fluid at comparatively lower tension where as it was contrary in case of the higher texture. Earlier Swartzendruber et al (1954) did an experiment on the relation between the capillary intake and the soil structure. It was concluded that for soil containing variable amount and kinds of organic matter, the capillary intake rate is not a reliable index of structure while for the soil constant amount and kinds of organic matter, the capillary intake rate can be a reliable index. This is because the wetting angle is known to be affected by organic matter. It would be better if the index is compared with other physical indices.

Kirkham et al(1972) reported that the wetting front distance x on a horizontal flow can given by the formula:

$$X=nt^{B} \quad \text{----------------17}$$

where: t -the time taken,

B -a constant where $0< B \leq .5$

n -a constant

This equation has been given by several authors when they were working on soil columns and porous materials. Among them is Swartzendruber et al (1954) who was using soils of varying physical properties; Malik et al (1981) who used glass beads and soils of varying bulk density; Jackson (1963) who used soils of varying particle densities, texture, bulk density and porosity Jackson (1963). One common observation among all these authors is that a plot of distance versus square root time gave a straight line and a question on whether they had to pass through the origin or not depended on whether the soil is wetted or not prior to the experiment. The capillary rise is unsaturated conductivity. It is a water content dependent form of flow. The conductivity-water content relationship has been shown by Ragab et al (1981) and is in a straight line of the form of:

$$\log K(\theta)= B \log \theta + \log a$$

or

$$C=BQ_{l} + A \quad \text{---------------------------18}$$

Where; C -log (hydraulic conductivity),

A and B -constants,

Q -water Log content,

k -hydraulic conductivity,

θ -wetness,

a -a constant.

In case of downwards flow this is not followed (Miller and Gardner 1962). This is also the case with upwards flow. The reason for this is explained as the superposition of gravitational and matric potential.

Several authors have given the value of B in equation 17 to be

1/2. The value of n will vary from one type of soil to another. (Swartzendruber et al 1954) Kirkham and Feng are quoted to had reported that soil in good structure might have a higher value for the square root time proportionality constants than soils in poor structure. Water accumulating in the flow has the same form of equation:

$$m= s_a t^B \quad ------------------------19$$

where; t -time,
m -mass,
B and s -constants.

The constant S has been referred to as sorptivity (Ray 1963) by Philip (1957). In Eq 17, n has been referred to as penetrability (Jackson. 1963) Malik et al (1981) has given the value of B as 1/2 and has referred the n as the distance of wetting front, per square root of unit time, traversed in air dry soil with a zero hydrostatic head for horizontal infiltration.

Most workers on unsaturated flow among whom we have Hillel (1980) have used the Darcy's law in combination with continuity equation ie

$$\vec{q}=-k(\theta)\nabla\vec{H} \text{---------------------} 20a$$

$$\nabla.\vec{q}=\frac{\partial\theta}{\partial t} \text{----------------------} 20b$$

where; q -the flux, K-unsaturated hydraulic conductivity,
H -the hydraulic head, θ-volumetric wetness

In case of horizontal movement:

$$\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial x}\left(K(\theta)\frac{\partial\vec{H}}{\partial x}\right) \text{------------------------} 21$$

This equation is similar to the heat equation.Function K unlike in the heat equation is not a constant. Kirkham and Feng (Ceylen et al. 1962) are quoted to had reported that diffusion equation is not an acceptable mathematical model for movement of water in unsaturated soil where diffusivity is considered a constant for calculations. In case of vertical flow we have:

$$\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial z}\left(k(\theta)\,\frac{\partial\vec{H}}{\partial z}\right)+\frac{\partial k(\theta)}{\partial z} \text{------------------------------} 22$$

The Eq 21 and 22 are formed from reduction of

$$\frac{\partial\theta}{\partial t}=\nabla.\,k(\theta)\,\nabla\vec{H} \text{--------------------------------------} 23$$

This has been referred to as Richards equation or diffusivity equation.

Since the equation formed are non-linear in nature it is difficult to get their solution analytically. Maybe empirical solutions can be tried on trial and error method. Several authors have tried numerical analysis in getting numerical solutions e.g. Kunze and Nielson (1982).

2.9 CAPILLARY RISE

The capillary movement of water is important to crop production under certain conditions. One of the conditions is when the water table is shallow. In this case water can be supplied to the root zone. At the same time capillary movement can infuse root zone with harmful salts (Hillel et al 1975). From their experiment they also concluded that capillary movement supply water from lower unsaturated layer and this at a lesser extent.

2.9.1. Effects of texture

The capillary movement of water is affected by soil texture. The effects are on the rate of movement of the water and the distance it can move.

This is also in agreement with quotation made from Richards (1952) by Marshall (1977). In the experiment cited four soils were used. The readings for water capillary movement at both 0cm per hr and 200cm per hr are given at table 2.8 below.

The amount of water available to the crop is determined by field capacity of the soil, extent of evaporation and capillarity of the soil which refers to the ability of water to move from the lower depths to the roots which are higher. The rise of the water also depends on the texture of the soil. Bear, (1965) also gives the following table for different textural groups of soil at different time:

Table 2.7: Capillary rise in different soils at different times in cm.

	HEIGHT IN CM AFTER INDICATED TIME		
TIME	SAND	SILT LOAM	CLAY
0.5hr.	13.5	7.3	5.4
1hr.	14.3	11.2	8.0
6hr.	16.6	26.6	15.5
12hr.	17.2	35.3	18.5
1day	18.4	46.4	21.0
3days	20.5	65.4	24.7
6days	21.8	78.5	27.3
9days	23.6	86.3	28.8
18days	25.3	99.2	33.2

Source: Soil in Relation to Crop Growth. Bear 1965.

The table above is in agreement with the statement by Lyon, and Buckman (1947b) who stated that the capillary rise in heavier soils is greater. With heavier soils sufficient time is allowed and interstices are not too small.

Capillary rise will tend to be of high rate and of relatively low height in sandy soil, while it is of low rate and is capable of rising to a higher height in clay soil. This can be observed in table 2.7 and 2.8.

The water movement with in this mode is in unsaturated condition. Lyon and Buckman (1947) stated that the movement covers tension range of about pF 4.5 and to about pF 1.6.

Table 2.8: Table to show the rate of capillary rising rate as relates to time in different soils.

SOIL TYPE	RATE OF CAPILLARY MOVEMENT($cm\ hr^{-1}$) At Tension 0cm Of 0cm Water	At Tension Of 200cm Water
Super position sand	6.59	0.00012
Coachella loamy fine sand	2.40	0.00058
Milville silt loam	1.69	0.0059
Chino silty clay loam	0.723	0.00115

Source: The Physical Chemistry and Mineralogy of the Soil. Marshall 1977.

However Marshall (1977) points out that it is a common observation that soils with heavy clay swells on re-wetting to an extent of resealing themselves almost completely.

Thus as the pores becomes finer the resistance to water movement becomes bigger. In case of clay soil the pores are much more reduced by colloidal swelling which occurs in many fine material (Miller and Gardner 1962).

2.10 BULK DENSITY

Bulk density is another factor that tends to vary within soils. The dry bulk density is given by Hillel (1980b) to range from 1.3-1.35gm cm^{-3}. Lyon and Buckman (1947) gave the values of the same in specific gravity to be 1.0-1.6 for clay, clay loam, and silt loam, 1.2-1.8 for sand and sandy loam. A very compact soil is said to have up to 2.0. In any given soil compaction tends to increase with bulk density thus low in uncompacted soil uncompacted soil and higher in compacted soil. Trouse Jr.(1979) states that the bulk density is used to describe soil compaction. Also Donahue et al. (1983) states that the bulk density can be used in estimating compaction of a given soil such as might result after tillage with heavy equipment on heavy clay. He further gives the best bulk density for crop growth 1.4 gm cm^{-3} for clay and 1.6gm cm^{-3} for sands. It also can give the amount of water held in the soil when the wet bulk density is compared with the dry. It will also in evaluation of average weight of soil per hectare. Mason et al. (1957) found that when soil is classified by texture there is positive correlation between hydraulic conductivity, percentage of large pores and bulk density, and explains that both hydraulic conductivity and bulk density decrease as texture become finer but log hydraulic conductivity increase as bulk density decreases if texture is a constant.

De Ricaud and Hainnaux (1979) expressed importance of bulk density in root growth. They stated that root development in plants is limited when the apparent dry bulk density is above 1.5gm cm^{-3}. He also gave an example of pineapple which he noted reduction in root development below 1.4gm cm^{-3}.

Maurya and Lal (1979) further gave the different rates of elongation at different bulk density in soya beans where he was working with sandy clay silt. Maximum rate was 2cm per day at 1.5gm cm^{-3} and 9%. Maximum rate of 7.2cm at 1.3g cm^{-3} bulk density and moisture percentage of 11% that is gravimetric. Thus both moisture content and bulk density affect the root elongation rate. Elongation rate declined with increase with bulk density and moisture content. At the bulk density of 1.9 or 2.0gm cm^{-3}, soya bean roots were unable to penetrate the soil and were flattened over the compacted layer. Other crops that they worked on were the pigeon peas, cow peas and maize and all had the same effects by the bulk density but at different amounts.

2.11. ELECTRIC CONDUCTIVITY

Electrical resistance is another factor which will also vary from one soil type to another. The electrical resistance of a soil volume depends not only upon water content but also on its composition, texture and water soluble salt concentration (Hillel 1980c). The importance of electric conductivity is on the fact that it gives the direct reflection on the amount of solutes in the soil. Solutes will affect osmotic potential in a given soil. Also it will affect permeability when soil contains clay minerals. This is due to flocculation of clay particles beyond critical salt concentration which is characteristic of any given salt and soil pH (Arora and Coleman 1979). Mustafa and Hamid (1977) found that salt concentration will also affect the swelling of soil rich in montimorillonite clay mineral by increasing the values of macroscopic swelling as the salt concentration decreases and exchangeable sodium potential increases. They found this while working with montimorillonitic soils from Sudan.

Bases are determined from the soils. Among the bases is calcium. This is important due to its effects on soil properties and also due to its vast requirement by plants Sayegh et al (1978) points out that content in the soil is too high in the soil, such physical properties as permeability, structural stability, water retention and cohesion are adversely affected. He further points out that it also corrodes structures such as irrigation canal. One of the effects can be explained by Kramer (1969) who states that when the exchange complex is dominated by sodium ions, clay micelles are dispersed and appears to have finer texture than when calcium or hydrogen ions are dominant, because sodium ions cause dispersion of aggregates the decrease in pore space and thus in effect reducing the amount of large pore space and increasing the small capillary pores. Baver et al. (1972) points out that increase in bulk density will also increase thermal conductivity as it decreases hydraulic conductivity.

CHAPTER THREE

3.MATERIALS AND METHODS

3.1 INTRODUCTION

The experiment described in this account was meant to be on five selected soils from semi-arid regions in the country: namely vertisols rich in montimollironite from Ahero, andisols rich in allophanes from Naivasha, luvisols rich in illite and kaolinite, from Machakos, acrisols rich in illite and kaolinite, from Machakos. The four will be compared with nitosols of kabete. This study was geared towards understanding the soil water relationship and how it is related to certain chemical factors.

3.2.SAMPLING

Four sampling sites were located namely:
1)Ahero with soil classified to be vertisols(FAO classification),
2)Naivasha soil near Longonot crater which is classified to be andisols(FAO classification),
3)Kabete with soil classified to be Nitosols(FAO classification)
4)Kampi ya Mawe where two soil types were sampled and are classified as chromic luvisols and orthic acrisols according to FAO classification (Muchena 1975)

At each of the locations a profile was made and a depth of 90cm on one side of the profile pit. On the opposite side of the steep edge stairs were made of about 15cm. At every stair, sampling was done. Thus samples were at horizons 0-15cm, 15-30cm, 30-45cm, 45-60cm, 60-75cm, 75-90cm and 90-105cm.

The stairs were wetted to saturation and left over night for the water to drain. Two category of samples were taken: disturbed and undisturbed. Disturbed samples were for all chemical analysis, soil texture, high pF moisture values particle density, clay mineralogy, unsaturated conductivity and capillary rise experiments.

The undisturbed samples were taken in the core rings. These were for saturated hydraulic conductivity and wet and dry bulk density. The core rings were of 5.3cm diameter and a length of 10.7cm. Maximum care was taken to ascertain minimum disturbance.

3.3. SOIL TEXTURE

Method used for this analysis was hydrometer method as described Gee and Bauder, (1986). Also the same analysis by Hinga et al. (1980) 50gm of oven dried soil ie at 40-45°c were used. Sieving was done using a 2mm sieve. Dispersing agent used was 5% calgon solution. Organic material in the soil is destroyed using 30% hydrogen peroxide. The shaking was done using a reciprocal shaker which was done over night.

After sieving 50gm of the sieved samples they were transferred to 300ml containers of water. 50ml of calgon was after which shaking was done. The suspension were transferred to 1000ml measuring cylinders after which they were filled with water to 1000ml mark. Mixing was done using brass plunger.

3.4. BULK DENSITY

The method used here is core-ring method as outlined by Blake and Hartge (1986). Dimensions of the core ring samples were taken and their weights. This for both when wet and dry. Weight of the empty core ring was also taken. From these readings wet and dry bulk densities.

ie ρ_b, ρ_d respectively were calculated

Thus;

$$\rho_b=\frac{M_w-M_e}{V_w}\ ,\ \rho_d=\frac{M_d-M_e}{V_d} \qquad \text{------------------------------24}$$

where: M_w=weight of the wet sample plus core ring,
M_e=weight of the core ring only,
M_d=weight of the sample plus core ring,
V_w and V_d=volumes of wet and dry samples respectively.

3.5.POROSITY

Porosity f was calculated using equation given by:

$$f=\frac{V_f}{V_t} \quad thus \quad \frac{\rho_p-\rho_d}{\rho_p}=1-\frac{\rho_d}{\rho_p} \text{------------------------------------} 25$$

V_f - *volume occupied by air / water*
V_t - *total volume of soil mass*
ρ_p - *particle density*
ρ_d - *dry bulk density*

The second equation is derived from the first. Since the quantities in the second can be determined it is the equation used in evaluation of f.

3.7. PARTICLE DENSITY

The method used is as outlined by Blake and Hartge (1986). The samples were oven dried for about 48hrs and then sieved through 2mm sieve. Different weights of 100ml flask were taken: when it had air (W_a), when it was filled with water to a 100ml mark it was weighed to get (W_l). Its weight when it contained about 100g sample weight was also taken (W_s). The flask was filled with water to 100ml mark and weighed to get (W_{ls}
$_s$). These were used in calculation of particle density and shown in Eq 26.

$$\rho_p=\frac{\rho_w \times (W_s-W_a)}{(W_s-W_a)-(W_{sl}-W_l)} \text{--------------------------------} 26$$

where
ρ_w - *density of water*
ρ_p - *particle density*

3.8. SATURATED HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of the soil was done using two methods ie constant and falling head. Constant head for more porous soil samples such as luvisols andisols and acrisols. The falling head was for less porous soils such as nitosols and vertisols. Thus the constant head technique was used if the flow rate was great enough. In either case a constant flow was awaited.

3.8.1. Constant head:

The principle behind this is as set by several authors such as Hillel (1971), and Klute and Dirksen (1986). the apparatus used in the constant head are shown in Plate 1(a) and (b) below. Water from a reservoir R from where constant head h above the sample, is set by tube length L1-L2. The water flows from samples S1...S7 and flows through the tube T which has branches to individual samples. Containers 1-7 collected the water that infiltrated through the samples. The water flowed through the sample of cross-sectional area A and length l. Water quantity Q, through the sample is collected and measured after time t. According to the Darcy's law hydraulic conductivity can be calculated using equation below whose derivation is shown by Eqs 1-4

$$K = \frac{Q}{At} \times \frac{L}{H} \qquad \text{----------------27}$$

In the setting more than seven samples are tested simultaneously.

Plate
1 (a)

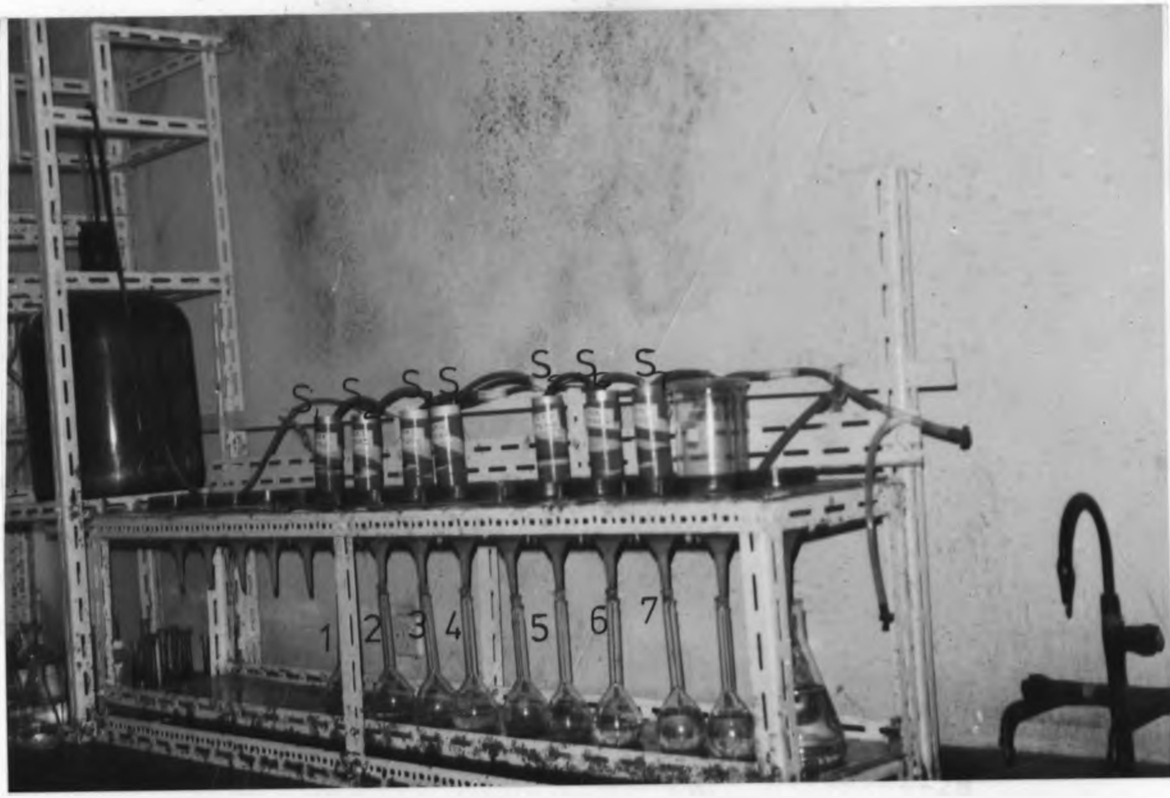


Plate
1 (b)

plates
to illustrate the setting of apparatus used in constant head.

3.8.2. Falling head:

The method used here is as described by several authors among whom are Klute and Dirksen (1986) and Rosenak (1969).
The apparatus used for the falling head are shown in plate 2. The plate shows two sets of apparatus. Water is allowed to flow the stand pipe B of sectional area a and then through sample S whose sectional area is A through funnel F. Height h_1 from the bottom of the sample is by letting water flow from reservoir R by raising table Z using knob N. The h_2 is height after water level fall in B. Water from flows through tube Y.
Water quantity Q flows through G and is collected in measuring cylinder T. Water level at E2 is at same level with E1.

$$K_{sat} = \frac{l \cdot a \cdot Ln\,(h_1/h_2)}{A(t_2-t_1)} \qquad \text{---------28}$$

where t is time taken by falling head on height h., and l is the length of the soil sample.

Plate 2-To show the set up the falling head apparatus.

3.9. WATER CONTENT AND SUCTION.

This is done as described by Klute (1986). Undisturbed sample in a core ring was used. Dimensions of the samples used were: Length 5.1cm and diameter 5cm. In this case it is only two pF values were selected ie 4.2 and 3.7. The results obtained were on water content in the two suction values.

3.10. MOISTURE CONTENT

The analysis is as described by Cassel and Nielsen (1986). The water content of a sample is defined as the amount of water lost when soil is dried at 105C° and is expressed as weight of water per unit weight of soil or water volume per unit volume of soil.

The samples were weighed about 100g each and oven dried at 105°C for about 48hrs. The difference between the weight of wet and dry samples was found which was the gravimetric moisture content and later given in percentages. These samples were initially taken from the field while at their field capacity and care was taken to have a minimum amount of water loss between the sampling time and experiment time. This is as described by Gardner (1986). The dryness of the sample is ascertained after noting a no change in weight in the drying samples Thus:

$$\text{mass wetness or water content(w) in \%} = \frac{M_w - M_d}{M_d} \times 100 \quad \text{-------29}$$

or

$$\text{volumetric water content}(\Theta) \text{ in \%} = \frac{V_w}{V_t} \times 100 \quad \text{----------30}$$

3.11. CAPILLARY MOVEMENT

All the samples were air dried in the laboratory all were then sieved at 0.5mm the soil was then put in glass-tube of about 60cm length and diameter of about 1cm. The columns were left for about

48hrs at a vertical position. At the bottom of each column was a muslin cloth to hold the soil in place. The tubes were positioned vertically and placed in water source at the bottom. The water at the bottom was maintained at a constant head. A diagrammatic view of the setup is shown in Plates 3(a) and (b) below. The flask B was left with the smallest air space possible in the region R. The purpose of the flask was to ensure a constant head source of water in the jar C on the balance F. The water from B is delivered through tube D. Glass tube G sets the head at H. Clamp I is held in a way that tube E can move freely.

The scribe marks on E for volumetric measurement are used to facilitate the measurement of advance of the wetting front in the sample. These distances are later converted to read in centimeters.

Weight readings from the initial value on the balance reflects the weight of water absorbed by the soil. Uniform treatment on the samples is ascertained both before and during the experiment on all the samples. Hence gravimetric determination of the amount water absorbed by the soil. The soil in the columns were hand packed. Care was taken to pack the columns to as homogeneous a bulk density as possible. Tap water was used in the experiment.

In this case water was introduced from the bottom the bottom of a column of glass tube in a room temperature of maintained at 21(±1)°C. The height of the wetting front was read also the weight of the sample at different wetting front. The two above were recorded with time.

3.12. pH

pH was determined potentiometrically in both water and KCl at the ratio of 1:2.5. This is as described by Hinga et al (1980). 20gm of air dried soil was taken and was put in 100ml shaking bottle. 50ml of water was added and was left overnight. It was then shaken for half an hour. Determination of pH was done using a pH meter. The same was repeated with a solution of 1m KCl. Before determination the soil particles were allowed to settle.

Plate 3 (a)

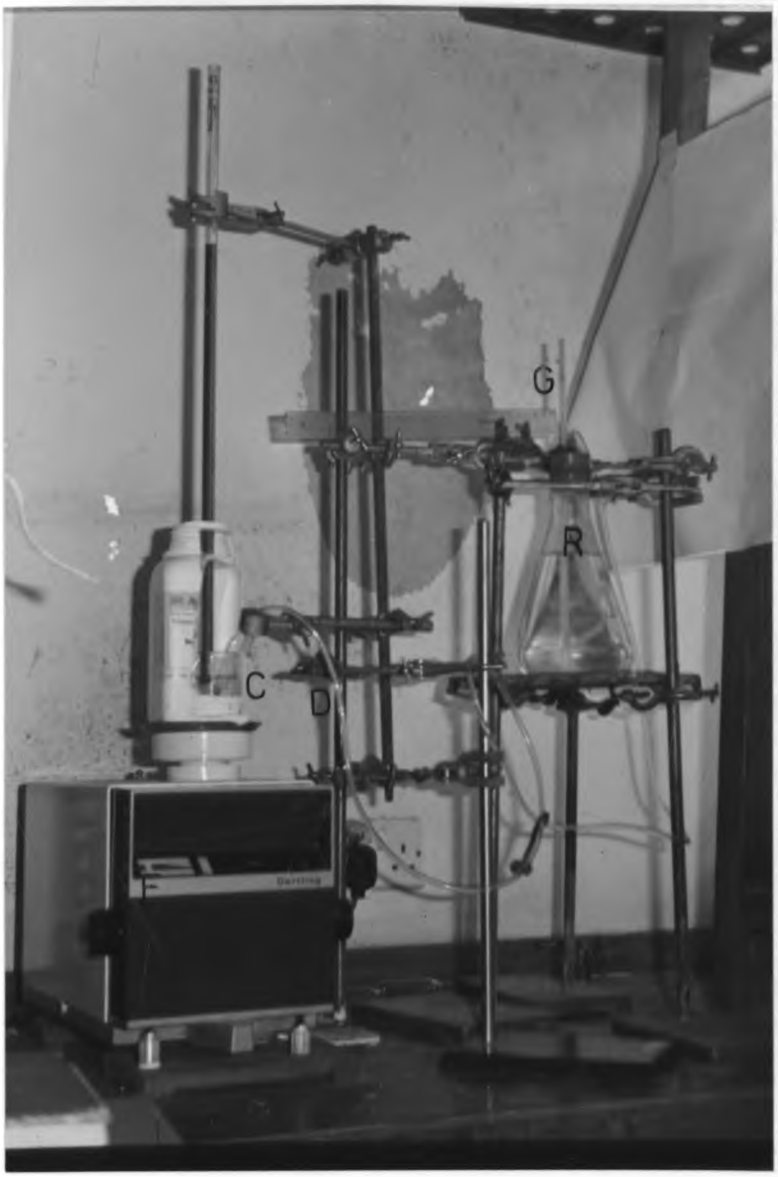
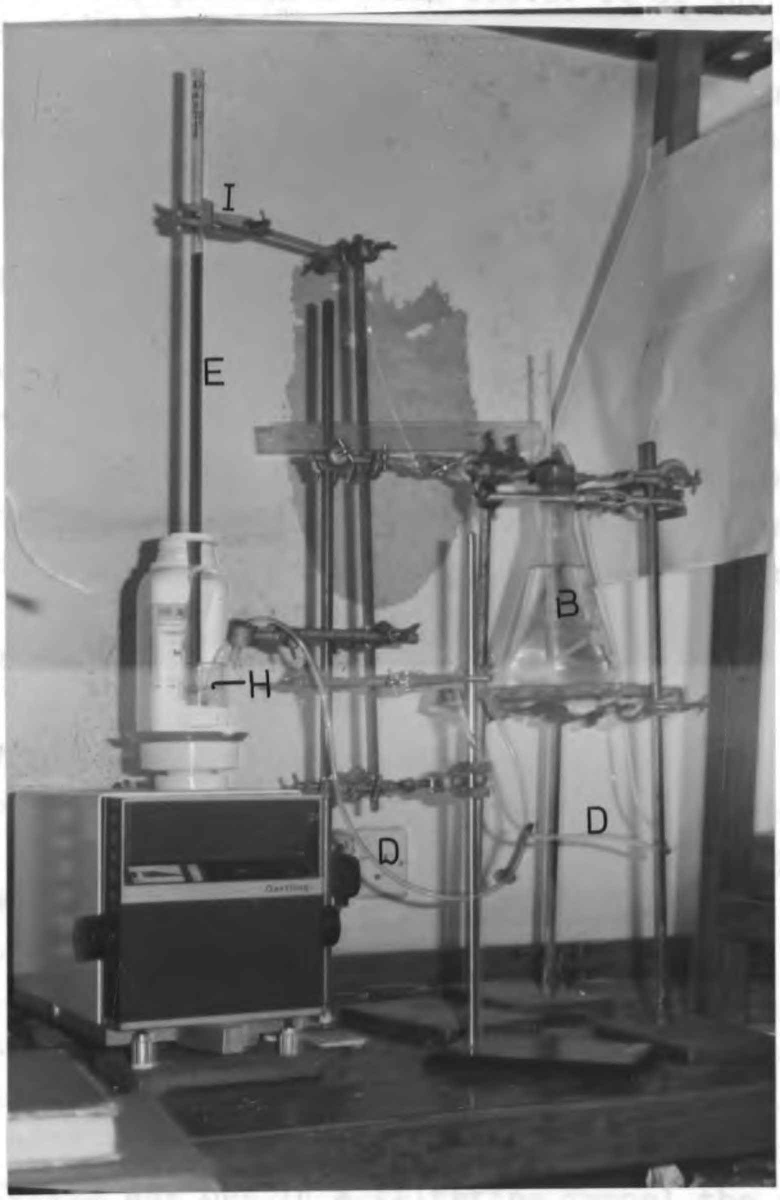


Plate 3 (b)



Plates 3(a) and (b) to shows the apparatus used in the capillary water movement.

3.13. CARBON

Organic carbon was determined using Walkley-Black method. soil was ground and sieved through a 0.5mm sieve. 1g of the soil was weighed out accurately to about ±0.005g. This was the sample which was used for soil analysis. In the case of NIT 1 0.5g was required since it had 2.63% organic carbon. this is as outlined by Hinga et al (1980). Also described by Allison (1965).

3.14. ELECTRIC CONDUCTIVITY

This was determined at the ratio of 1:2.5 of water and was done as outlined by Hinga et al (1980). 20g of air-dried soil was taken and put in a 100ml plastic bottle where it was added 50 ml of distilled water. shaking was done for two hours after which electric conductivity was measured using a conductivity meter.

3.15. EXCHANGEABLE BASES

This was found by leaching with 1N ammonium acetate. This was done as outlined by Hinga et al (1980). the standard solutions of Na, K, Ca, and Mg were prepared. Their concentrations were:

0	0.5	1.0	2.0	3.0	4.0	and	5.0	meq Na/100gsoil
0	0.2	0.4	0.8	1.2	1.6	and	2.0	meq K/100gsoil
0	2.0	4.0	8.0	12.0	16.0	and	20.0	meq Ca/100gsoil
0	0.8	1.6	3.2	4.8	6.4	and	8.0	meq Mg/100gsoil

2.50gm of soil was weighed accurately and mixed with about 10ml of purified sand. Cotton was put in a filtering funnel the sand followed by the sample and then cotton. The soil was washed with 95% ethyl alcohol to ensure that all chlorides and sulphate were removed. This was ascertained by testing the leacheate with barium chloride and silver nitrate solutions. The sample was then leached with 1N ammonium acetate as outlined. After all the bases were removed the leacheate was diluted to 100ml and preserved for Ca, Mg, K, and Na determination.

The samples were left for CEC determination. The samples were leached with alcohol as outlined. This was continued until traces of ammonium ions were no longer in the alcohol leacheate. The samples were then leached with sodium acetate as outlined. The sodium acetate was to remove all the ammonium ions which were on the adsorption or exchangeable sites. This leacheate was preserved for CEC determination.

Determination of Ca, K and Na was done on frame photometer while Mg was done on atomic adsorption spectrometer.

3.16. CATION EXCHANGE CAPACITY

This was found by leaching with 1N sodium acetate. 10ml of the last leacheate was taken and transferred to distillation apparatus. Distilled ammonia was collected in boric acid and methyl-red, in ethyl alcohol was used as an indicator. After collection of ammonia titration with HCL was done. CEC was calculated and like Ca, Mg, Na and K was done in milliequivalent per 100g of soil.

3.17. CLAY MINERALOGY

The procedure is as outlined by Hinga et al (1980). organic matter was destroyed using H_2O_2 as outlined. This was followed by dispersion using 5% calgon solution. Separation of sand from silt and clay was done using 50 micrometer wet sieving. After this process then followed separation of silt and clay. Silt and clay mixture was allowed to stand for 8hrs for each 10cm depth. The clay suspension was syphoned in to a larger baker. After this the remaining suspension was centrifuged with a solution of 0.5% calgon. This was followed by the analysis using X-ray diffraction analysis. Qualitative information was obtained.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 DRY BULK DENSITY.

In the samples analysed here gave values of 0.88-1.56gm cm^{-3}. The results are in Table 4.1. Generally the magnitude tends to increase with depth. Except in Luvisol where the highest depth has the highest value of dry bulk density. On the surface the bulk density is a bit higher and could be due to compaction by animals or people.

4.2 TOTAL(wet) BULK DENSITY

All the samples analysed for the total bulk density gave a range of 1.379-1.859gm cm^{-3} and this was done at field capacity. The data obtained is as given in the Table 4.1 below.

In vertisols the highest density was at 45-60 cm and the trend is that the lowest is at the surface and increases with depth. In Andosols the trend is the same except that the surface layer is higher than at 15-30 cm. In Nitosols the trend is the same except 30-45 cm which has a bit higher than the deepest sampling depth. Luvisols is the same except 15-30 cm which a bit higher than 30-45 cm. Acrisols don't seem to be following any order because the highest value is at 0-15 cm followed by 45-60 cm then 15-30 cm and finally 30-45 cm.

4.3 POROSITY

In the experiment done on the five profiles the data obtained is tabulated in Table 4.1 below. Porosity increases with depth up to 45 cm. In 45-60 cm the porosity changes abruptly to lower value much more than any other superincubent layers. Porosity in Andosols decreases with depth except 15-30 cm which was more than at 0-15 cm.

In nitosols the porosity decreased as the depth increased. It was only at 30-45 where the trend deviated. In Acrisols porosity increased with depth and only 0-15 which deviated from the trend.

Table 4.1: To show the variation of porosity and wet bulk density and hydraulic conductivity.

soil type	wet bulk density ($gmcm^{-3}$)	dry bulk density ($gmcm^{-3}$)	porosity	hydraulic conductivity ($cmday^{-1}$)
VER1	1.54	1.03	0.60	0.163
VER2	1.59	1.02	0.61	0.047
VER3	1.57	1.02	0.62	0.336
VER4	1.67	1.33	0.50	0.061
AND1	1.55	1.02	0.58	58.320
AND2	1.53	1.00	0.59	56.880
AND3	1.68	1.24	0.51	18.720
AND4	1.75	1.39	0.45	13.838
NIT1	1.38	0.88	0.64	0.263
NIT2	1.41	0.93	0.63	0.050
NIT3	1.53	1.03	0.00	0.606
NIT4	1.51	1.04	0.60	0.710
LUV1	1.70	1.52	0.42	499.680
LUV2	1.73	1.54	0.42	332.640
LUV3	1.70	1.53	0.42	81.648
LUV4	1.74	1.52	0.42	115.056
ACR1	1.86	1.56	0.40	9.634
ACR2	1.75	1.40	0.48	7.085
ACR3	1.74	1.40	0.47	6.394
ACR4	1.78	1.43	0.46	2.347

4.4 PARTICLE DENSITY.

It is stated by Hillel (1980b) that average particle density of mineral soil is 2.6-2.7gm cm^{-3}. The same is given by Lyon and Buckman (1947) but in specific gravity; thus 2.6-2.7. In the analysis carried out here the density was found to be 2.4-2.7gm cm^{-3} thus in agreement with the quoted authors above. Difference in the lower limit is due to the presence of organic material in some soils. This can be noted in the table of chemical and physical data shown in Table 4.1 and 4.2.

In Vertisols the particle density increases with depth. In Andosols the same trend is followed except the 15-30 cm which deviates from the trend. In Nitosols the particle density increases with depth. In both Luvisols and Acrisols no trend seems to be followed.

4.5 SATURATED HYDRAULIC CONDUCTIVITY

The lowest value of saturated hydraulic conductivity (Ksat) was in the range of 3.25×10^{-5}cm min^{-1} to 2.336×10^{-4}cm min^{-1} and 3.47×10^{-5} to 4.93×10^{-4}cm min^{-1} in andosols. This is in agreement with the value quoted by Kramer, (1969) where the lowest value is stated to be 2.5×10^{-3}cm hr^{-1} or 4.167×10^{-5}cm min^{-1} for soils with the lowest hydraulic conductivity. In the experiment here the soils were both vertisols and Nitosols. The Vertisol sample with the lowest conductivity had 3.25×10^{-5}cm min^{-1} and had Ec of 0.36mmho cm and second lowest had 4.86×10^{-5}cm min^{-1} and Ec of 0.40mmho cm.

In vertisols the lowest value of saturated conductivity was 3.25^{-5}cm min^{-1} which was determined from core ring samples at 15-30 cm. this was followed by samples at 45-60 cm which had 4.86×10^{-5}cm min^{-1} then 0-15 cm with 1.113×10^{-4}cm min^{-1} and finally 2.336×10^{-4}cm min^{-1}.

The trend in Andosols was a bit different because the hydraulic conductivity value decreased with depth until the highest depth which had the highest conductivity.

In Nitosols the hydraulic conductivity generally increased with depth. It is only at 15-30 cm depth which deviated from the tread. In Luvisols the conductivity decreased with depth and only 30-45 cm which deviated from the tread. Acrisols had the lowest value of conductivity.

TABLE 4.2: Some properties determined from the soil samples indicated

SOIL TYPE	DEPTH (CM)	PARTICLE DENSITY ($gmcm^{-3}$)	ORGANIC CARBON (%)	SAND (%)	SILT (%)	CLAY (%)	TEXTURAL CLASS
Vertisol	0-15	2.60	1.97	21	14	65	clay
Vertisol	15-30	2.65	1.37	19	13	68	clay
Vertisol	30-45	2.67	1.50	19	12	69	clay
Vertisol	45-60	2.67	1.32	18	11	71	clay
Andosol	0-15	2.45	1.59	42	48	10	loam
Andosol	15-30	2.46	0.84	49	45	6	loam
Andosol	30-45	2.52	0.68	47	47	6	loam
Andosol	45-60	2.54	0.29	49	46	5	loam
Nitosol	0-15	2.45	2.63	27	27	47	clay
Nitosol	15-30	2.52	1.71	21	25	54	clay
Nitosol	30-45	2.57	1.43	20	20	60	clay
Nitosol	45-60	2.60	0.78	17	17	66	clay
luvisol	0-15	2.64	0.75	80	6	14	clay
Luvisol	15-30	2.65	0.64	77	4	19	clay
Luvisol	30-45	2.64	0.36	77	4	19	clay
Luvisol	45-60	2.61	0.36	73	3	24	clay
Acrisol	0-15	2.60	0.35	57	8	35	s.loam
Acrisol	15-30	2.65	0.28	51	6	43	s.loam
Acrisol	30-45	2.64	0.25	49	5	46	s.loam
Acrisol	45-60	2.65	0.20	49	5	46	s.loam

4.6 CAPILLARY RISE

The graphs drawn are of wetting front height in centimeters and weight in grams Vs time in minutes. The samples considered are numbered 1-4 which signifies the depth. The soil names are given in abbreviations. Whether the graph is of weight or height it is indicated on the axis. Thus:

Table 4.3: Abbreviations of the four soils studied.

VER1-Vertisols at 0-15cm.	ACR1-Acrisols at 0-15cm.
VER2-Vertisols at 15-30cm.	ACR2-Acrisols at 15-30cm.
VER3-Vertisols at 30-45cm.	ACR3-Acrisols at 30-45cm.
VER4-Vertisols at 45-60cm.	ACR4-Acrisols at 45-60cm.
AND1-Andosols at 0-15cm.	LUV1-Luvisols at 0-15cm.
AND2-Andosols at 15-30cm.	LUV2-Luvisols at 15-30cm.
AND3-Andosols at 30-45cm.	LUV3-Luvisols at 30-45cm.
AND4-Andosols at 45-60cm.	LUV4-Luvisols at 45-60cm.
NIT1-Nitosols at 0-15cm.	
NIT2-Nitosols at 15-30cm.	
NIT3-Nitosols at 30-45cm.	
NIT4-Nitosols at 45-50cm.	

In any one of the graphs a combination of different depths in any one profile was drawn. This was for both wetting front water weight absorbed. A combination of different soil types and at given depths was also drawn. Also for both height and water weight.

It was also observed that in all the soils there was a change in wetting front height and water absorbed weight. In all the soils the rate of change of wetting front and water weight was high initially and declined with time. The values of the readings went up to different values in the twelve hours the experiments were done. The lowest value recorded was in vertisols which went up to 1.64cm and with a range of 1.64-4.65cm. On the other side the absorbed water mass vertisols ranked the lowest with the lowest of 1.43gm and a range of 1.43-5.75gm. The highest mass of water recorded was 29.53gm in Andosols and had a range of 21.50-29.53gm.

4.6.1. Introduction

Each of the soil sample in the experiments can be considered to be containing various sizes of pores in different proportions as this is also supported by different values of particle size distribution in the Table 4.2 above. In the rise different pore sizes can be compared with the capillary tubes of different sizes in which water rise can be given by(Hillel 1980a):

$$h_c = \frac{2Y \cos b}{g(p_l - p_g)r} \qquad \text{--------------31}$$

where:

P_g - is the density of gas which can be neglected,
P_l - is the density of the liquid,
g - is the acceleration due to gravity.
b - is the contact angle,
r - is the radius of capillary tube,
Y - is the surface tension between liquid and air.

This explains why the initial water rising rate is high and the rate decreases as wetting front rises. At the bottom both small and large pores are responsible while at higher heights it is only the small pores that are responsible.

In case of Ahero soil the water is absorbed at very low rate. This can be explained by the fact that this soil is dominated by small pores. Also the soil is of swelling type and hence as soon as water is absorbed the pores are reduced in size and hence lowering the rising rate of wetting front. The data obtained has been condensed to a form of a graph while the data is in the appendix I.

This is in line with argument by Marshal, (1967) who states that in a soil of high clay content the geometry of pore system change with changing water content. Haines is quoted by the same author to have noted that when wet clay is dried, its loss of volume is at first equal to the volume of water withdrawn and this was referred to normal shrinkage, then a stage is reached at which air to block and loss of volume is less than loss of water and thus residual shrinkage. Finally there no change of volume occurs anymore with loss of water. When the water is being absorbed a reverse of the above occurs with minor difference due to hysterisis. The swelling and shrinking of clay rich soil will depend on both the amount of water and tension of water in the soil.

4.6.2. Wetting front distance.

The graphs shown below of wetting Figures 1-5, 11-14 and 19-22 and show the variation of wetting front with time.

The rise of water was found to be in consistent with the Table 2.7 and 2.8 given by Bear (1965) and Marshal respectively shown above. In this table the texture was found to affect the rise. In the soils the order of rise was sand>silt loam>clay. Vertisol is classified to be in clay textural class. Textural classification is done according to the triangle given by Rosenak (1968). Andosol is in the loam class, Luvisol sandy loam and Acrisol in sandy clay. In the Figures 11, 12, 13 and 14 which are plots of wetting front height and time shows that at the end of about 720min in the four Figures the four curves are in the order of AND, ACR, LUV, NIT and VER from the highest to the lowest respectively. This in the order of textural class is: loam, sandy clay, sandy loam, clay and clay respectively.

4.6.2.1. Profile

Figure 1-5 are figure to show different profiles. Figure 1 is of vertsols 0-60 cm. VER1 0-15 cm, VER2 15-30 cm, VER3 30-45 cm and VER4 45-60cm. Figure 2 is of Andosol (AND). The depths are as in Vertisol. Figure 3 is of Nitosol (NIT), while in figure 4 and 5 are Luvisols (LUV) and Acrisols (ACR) respectively the 2 depths are as indicated above for Vertisols.

FIG.1—AHERO VERTISOLS 0 TO 60cm.

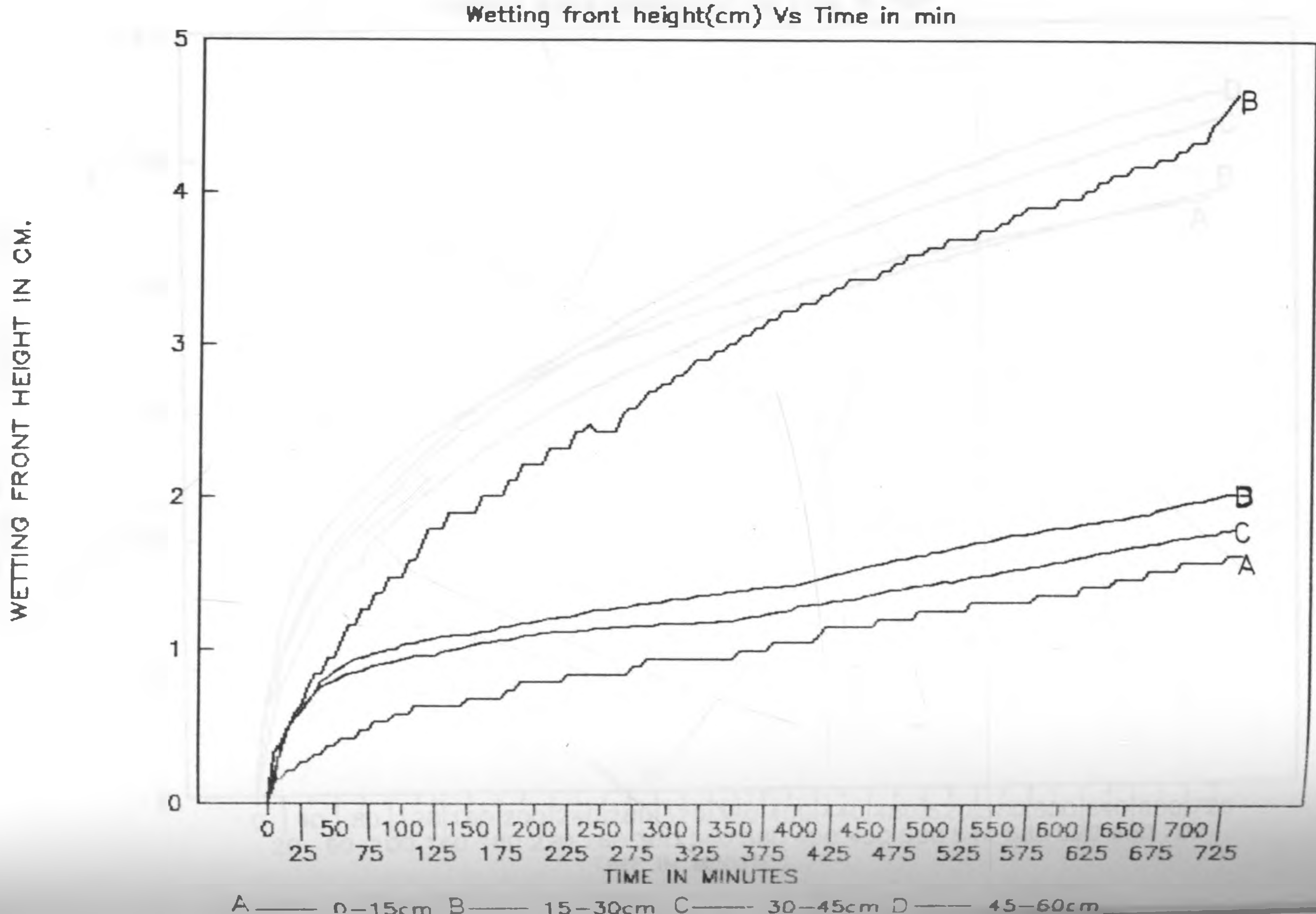


FIG.2—NAIVASHA ANDOSOLS 0 TO 60cm.

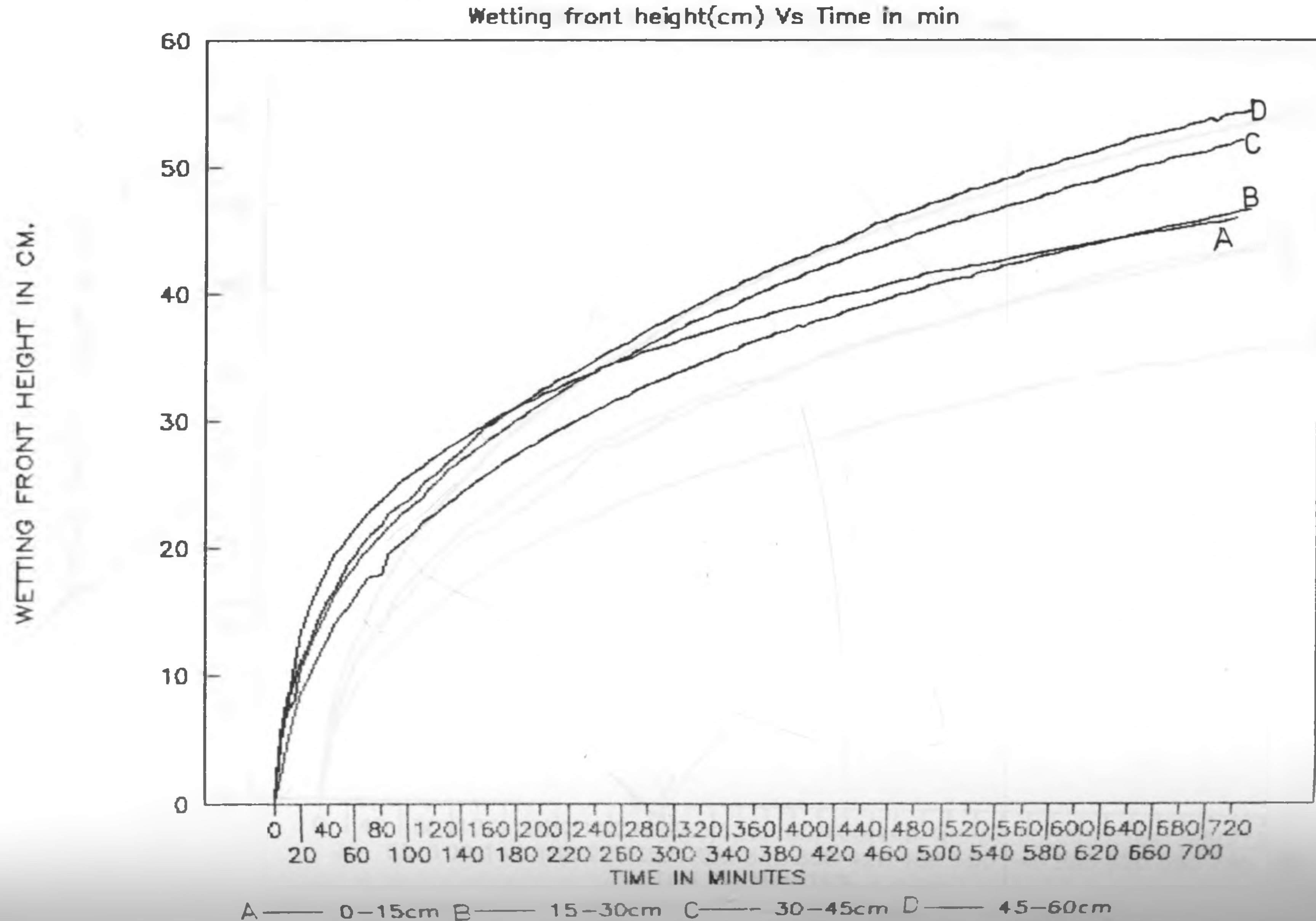


FIG.3—KABETE NITOSOLS 0 TO 60cm.

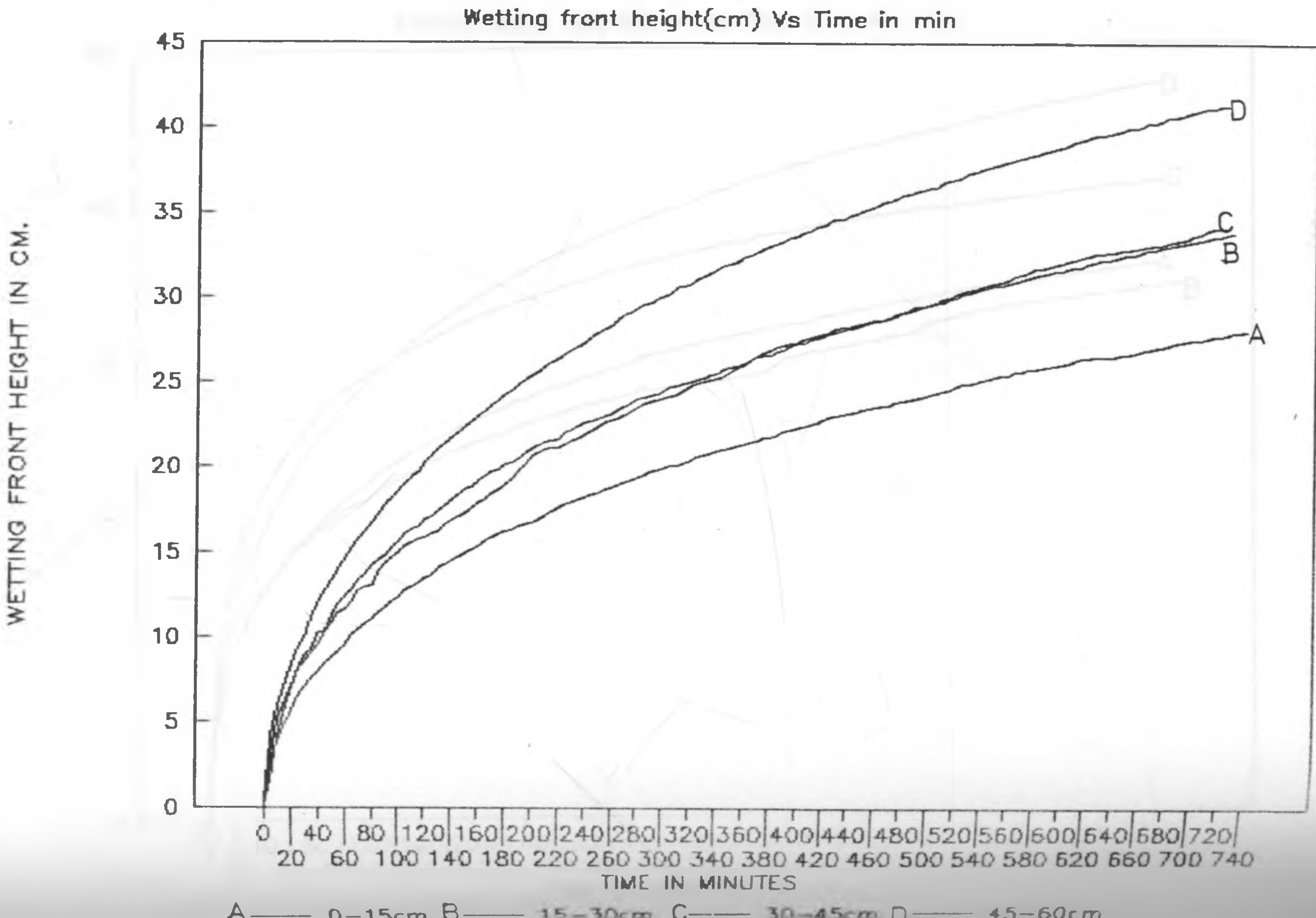


FIG.4—MAKUENI LUVISOLS 0 TO 60cm.

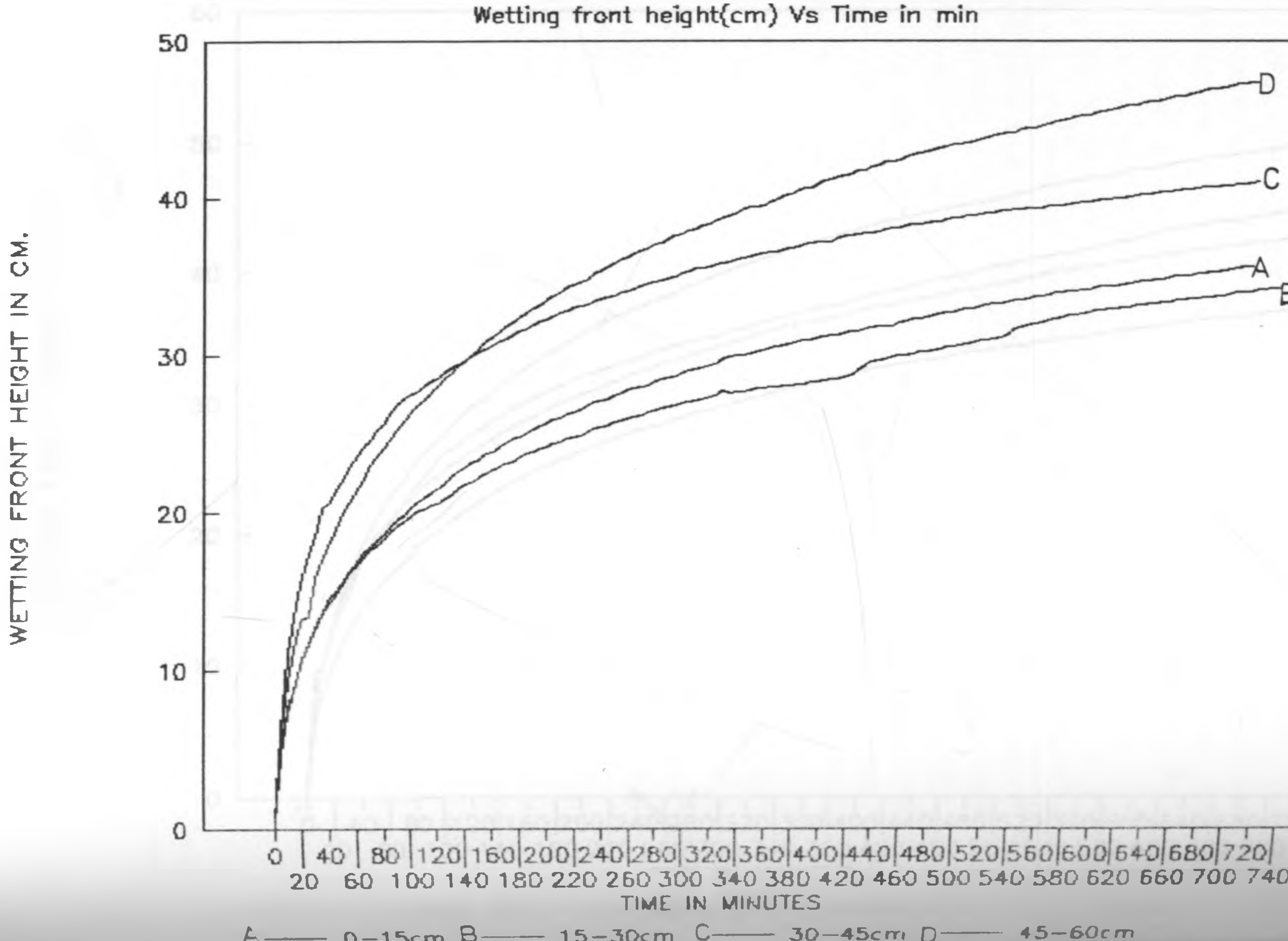
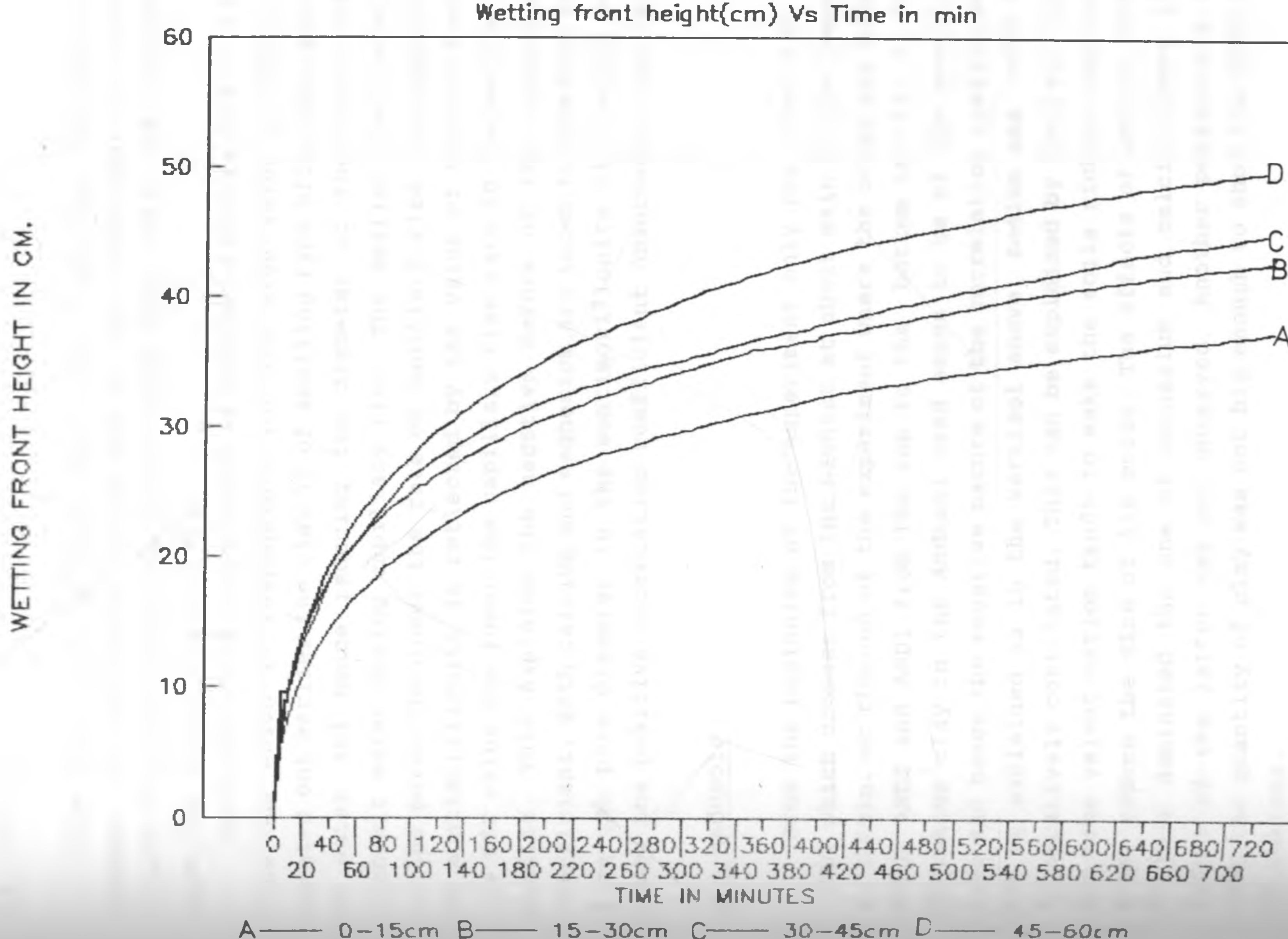


FIG.5—MAKUENI ACRISOLS 0 TO 60cm.



(a) Vertisols

From 40min the curves do not cross again but the space in between the continues to the end of the experiment. At about 720min the position of the curves ranks VER2, VER4, VER3 and VER1 from top to the bottom (Fig. 1).

Dominant clay in Vertisols is montimorillonite and it is the one which is responsible for its high value of CEC. As pointed out earlier the clay is of swelling type after absorption of water and hence reducing the diameter of the pores that transmit water during capillary rise. The smaller the diameter of the pores the lower the rate of capillary rise. The quantity of montimorillonite is reflected by the value of CEC and hence the CEC value the lower the capillary rise rate in the vertisols profile. This explains the negative nature of the regression coefficient. Both calcium and magnesium are known to increase the size the pore diameter in the montimorillonite rich soils and hence the positive correlation coefficient observed in the two.

(b) Andosols

From the beginning of the experiment only the curve for AND1 which crosses from the highest at about main to the lowest at 720min. At the end of the experiment where the order was AND4, AND3, AND2 and AND1 from the top to the bottom in Fig. 2. The amorphous clay in the Andosol used seems to be of the swelling type and hence the negative nature of the correlation coefficient can be explained as in the vertisol above. Sodium was found to be negatively correlated. This can be explained by the fact that the mono valent cation tends to make the soils rich in swelling clay, reduce the size of its pores. The effects of sodium seems to have dominated the one of magnesium and calcium hence the effect of the latter was not observed. Another possibility is that the quantity of clay was not big enough to show the effects by cations.

(c)Nitosols

From the beginning it is only NIT2 NIT3 that crosses each other at about 480min from the start of the experiment. At the end of the experiment the order of curves was NIT4, NIT3, NIT2 and NIT1 from the top to the bottom as shown in Fig. 3. Kaolinite was the dominant clay in the Nitosol used. This clay is not of the swelling type and hence the higher the CEC the higher the capillary rise. As indicated by CEC value, the amount of clay is relatively high and hence explaining the fact that CEC, magnesium and calcium are positively correlated.

(d)Luvisols

The curves for luvisols are shown in Figure 4 and have LUV4 crossing with LUV 3 at 140 min. From this point the distance between the curves increases until at 720min where the order is LUV4, LUV3, LUV1 and LUV2 from the top to the bottom. The dominant clay mineral in this soil was kaolinite and illite. Illite which is swelling type is the one which dominated over kaolinite and hence a negative correlation coefficient. Also the effects due to the effects of potassium seems to have dominate over the ones for magnesium.

(e)Acrisols

The curves for Acrisols are shown in figure 5. From about 60min the space between the curves continues increasing to about 720 min which was the end of the experiment. Order of the curves at 720min was ACR4, ACR3, ACR2 and ACR1 from top to the bottom. The clay mineralogy of this soil was similar to Luvisol above and hence similarity in observed results on CEC and potassium.

(f) regression

On regressing the height of the wetting front with chemical and physical properties the following was obtained.

Table 4.4: Regression Coefficient for Maximum h and Different Properties in the Five Soils.

Quantities of good correlation	r squared	sign of r
Figure 1 (vertisols)		
PH in KCl	0.39	-ve
EC in water	0.38	-ve
CEC in water	0.54	-ve
Ca	0.74	+ve
Mg	0.54	+ve
Figure 2 (Andosols)		
Clay (%)	0.50	-ve
Bulk density	0.98	+ve
PF at 3.7	0.94	-ve
PF at 4.2	0.93	-ve
Ksat	0.99	+ve
Water(%) field capacity	0.98	-ve
Porosity	0.98	-ve
Wet bulk density	0.98	+ve
Organic carbon	0.71	-ve
PH in water	0.62	+ve
PH in Kcl	0.87	+ve
Calcium	0.92	-ve
CEC	0.51	-ve
Magnesium	0.38	-ve
Na	0.61	-ve
Figure 3 (Nitosols)		
Sand (%)	0.94	-ve
Silt (%)	0.83	-ve
Clay (%)	0.92	+ve
Bulk density	0.71	+ve
pF at 3.7	0.73	+ve

Table 4.4: cont...

Quantities of good correlation	r squared	sign of r
Figure 3 (Nitosols) cont...		
Ksat	0.42	+ve
Water at field capacity	0.89	-ve
Particle density	0.86	+ve
Porosity	0.58	+ve
Wet bulk density	0.51	+ve
Organic carbon	0.96	-ve
pH in water	0.72	+ve
pH in KCl	0.48	+ve
EC in water	0.66	-ve
Calcium	0.84	+ve
Magnesium	0.93	+ve
Potassium	0.86	+ve
Sodium	0.52	+ve
CEC	0.85	+ve
Figure 4 (Luvisols)		
Sand (%)	0.96	-ve
Silt (%)	0.47	-ve
Clay (%)	0.51	+ve
pF at 3.7	0.61	+ve
pF at 4.2	0.56	+ve
Ksat	0.71	-ve
Water at field capacity	0.55	+ve
Particle density	0.86	+ve
Porosity	0.51	+ve
pH in water	0.73	-ve
pH in KCl	0.83	-ve
EC in water	0.47	-ve
Magnesium	0.98	-ve
Potassium	0.83	-ve
CEC	0.71	-ve

Table 4.4: cont...

Quantities of good correlation	r squared	sign of r
Figure 5 (Acrisols)		
Sand (%)	0.81	-ve
Silt (%)	0.84	-ve
Clay (%)	0.78	+ve
Bulk density	0.50	-ve
Ksat	0.97	+ve
Particle density	0.69	+ve
Porosity	0.50	+ve
Wet bulk density	0.42	-ve
Organic carbon	1.00	-ve
pH in water	0.41	-ve
pH in KCl	0.70	-ve
Calcium	0.90	-ve
Magnesium	0.96	-ve
Potassium	0.42	-ve
Sodium	0.98	-ve

(g) comments

After regression of wetting front at 720 min with the soil properties the following had r^2-value greater than 0.36 only positive correlation coefficient as: Particle density while negatively correlated as: sand, silt, CEC, EC and organic carbon.

4.6.2.2. Variation in depth levels in all profiles

Figures 6, 7, 8 and 9 show variation in any given depth for all the five soils. Figure 6 for 0-15cm, 7 for 15-30cm, 8 for 30-45cm and 9 for 45-60cm.

(a)Fig. 6 level 1 (0-15cm)

The curves for this level are shown in figure 6 and the samples are from all profiles and at 0-15cm. The curves do not cross but from the beginning of the experiment they continue to have their distance apart increasing with time to the end of the experiment. At 720 min the order of the curves was AND1, ACR1, LUV1, NIT1 and VER1 from the top to the bottom.

(b)Fig.7 Level 2 (15-30cm)

The curves for this level are shown in figure 7 and the samples are from all profiles and at 15-30cm. The curves crosses at about 80min. This is between AND2 and LUV2. The other crossing is at 350min and this is between AND2 and ACR2. At 720min the order is AND2, ACR2, LUV2, NIT2 and VER2 from top to bottom.

(c)Fig. 8 level 3 (30-45cm)

The curves for this level are shown in figure 8 and the samples are from all profiles and at 30-45cm. The curves crosses at 200min between AND3 and LUV3; at 220min between AND3 and ACR3; and at 260min between ACR3 and LUV3. The order of wetting front rise at 720min was AND3, ACR3, LUV3, NIT3 and VER3 from the top to the bottom.

(d)Fig. 9 Level 4 (45-60cm)

The curves for this level are as shown in figure 9 and the samples are from all the profiles and at 45-60cm. The curves crosses at 275min and is between AND4 and LUV4. Also the curves crosses at 410min and this is between ACR4 and AND4. The order of the wetting front at 720min was AND4, ACR4, LUV4, NIT4 and VER4 from the top to the bottom.

(e) Regression

On regressing the height of the wetting front against both chemical and physical properties results in Table 4.5 below were obtained.

FIG.6—FROM ALL PROFILES 0 TO 15cm.

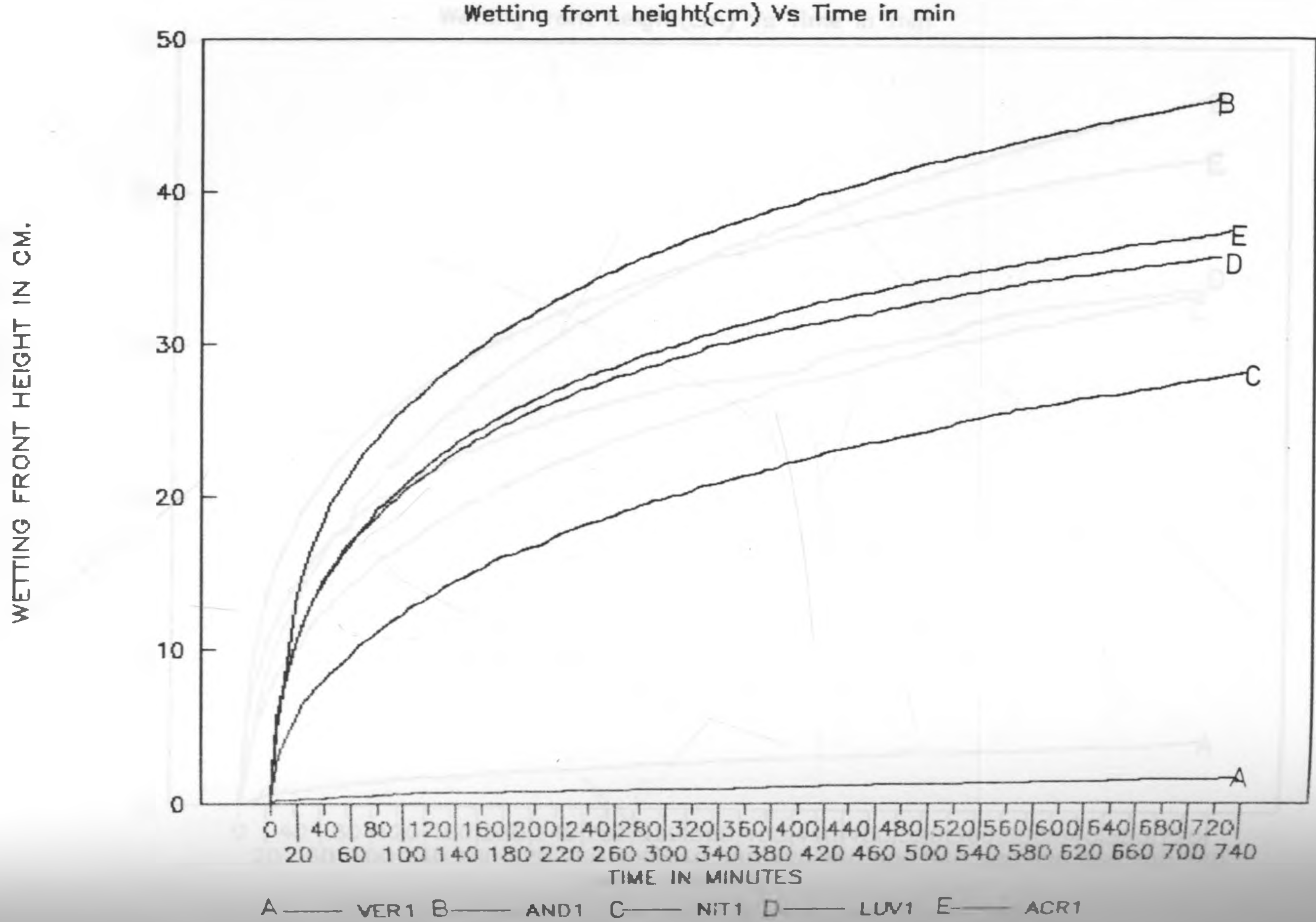


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FIG.7–FROM ALL PROFILES 15 TO 30cm.

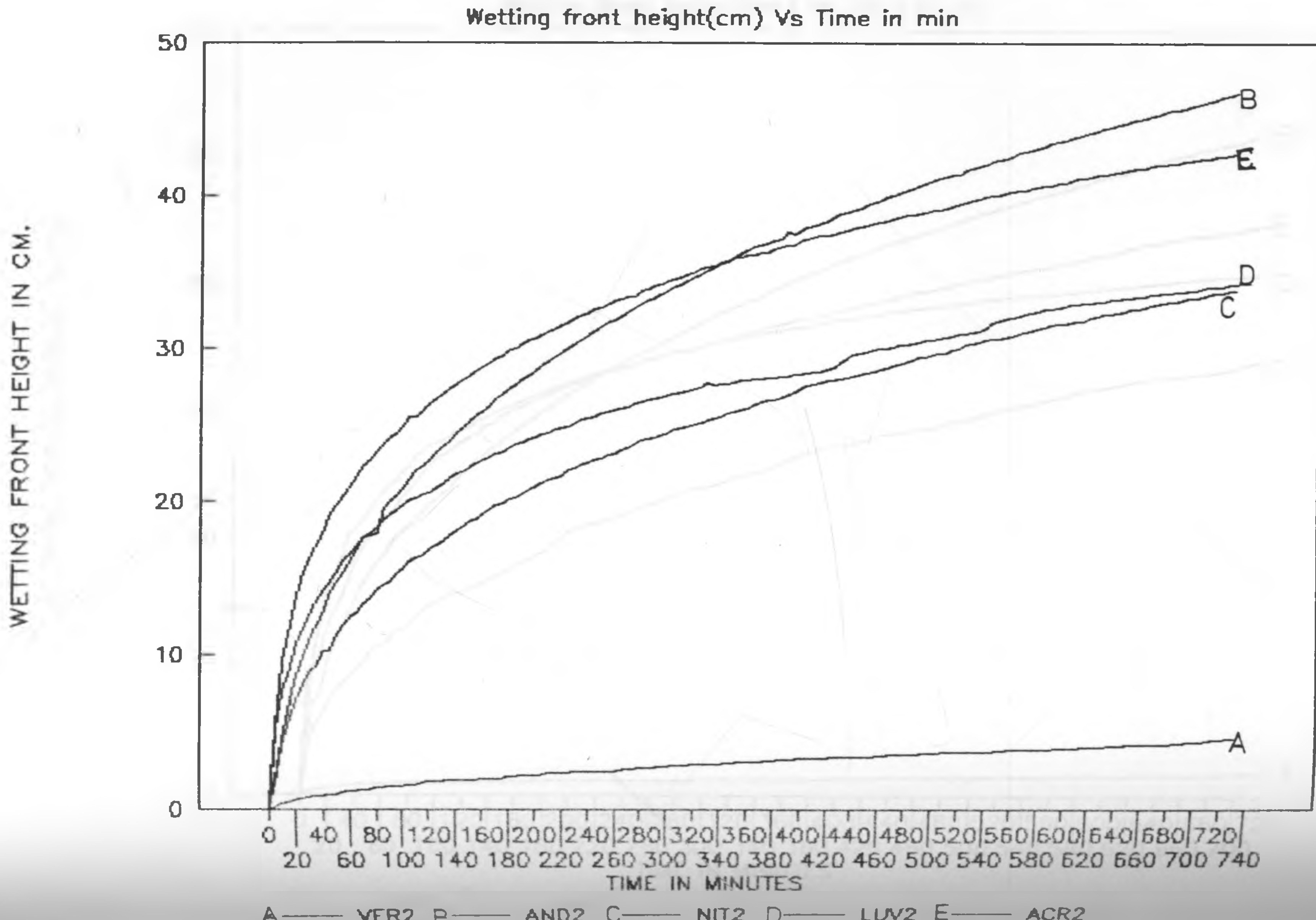

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FIG.8—FROM ALL PROFILES 30 TO 45cm.

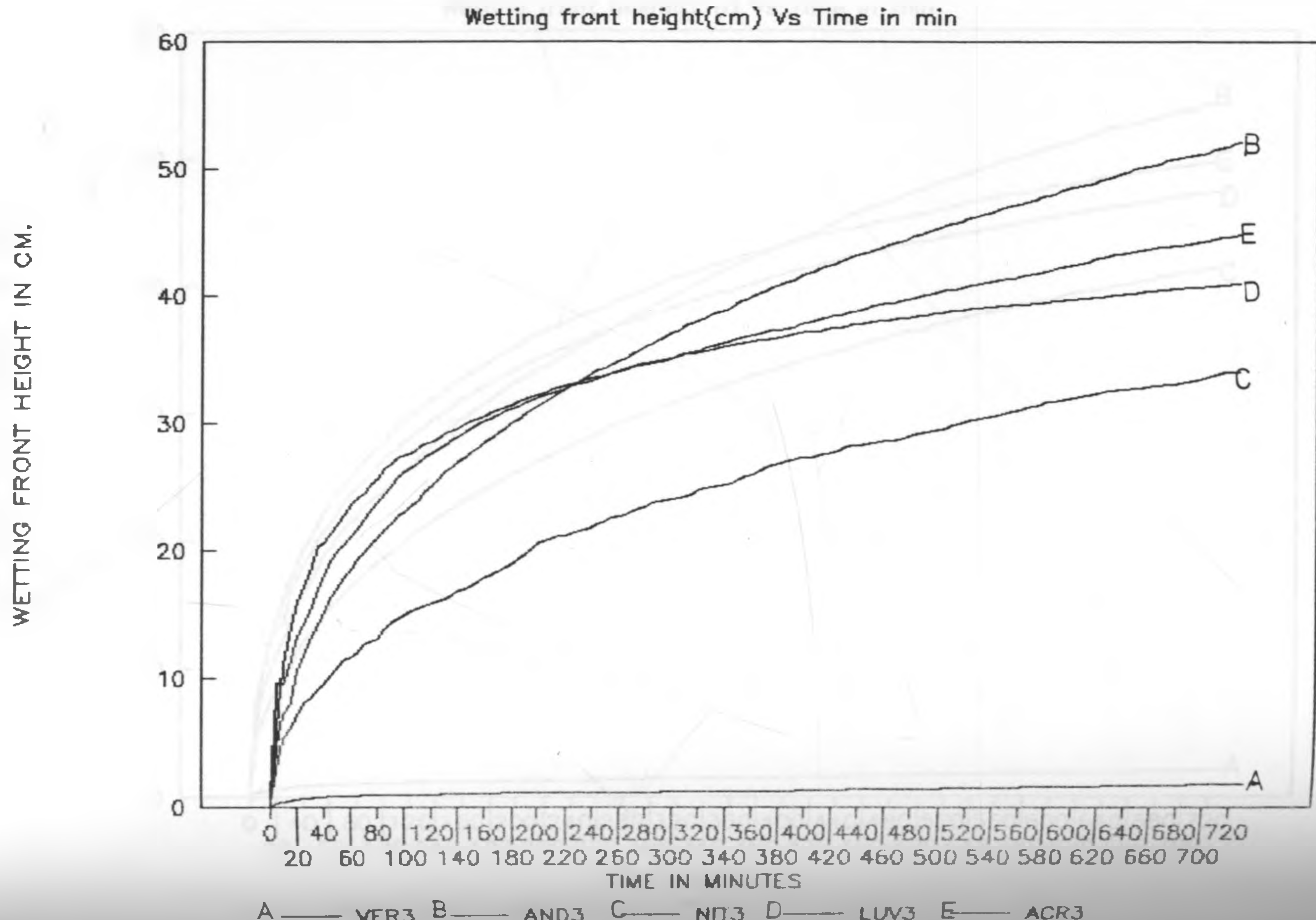


FIG.9—FROM ALL PROFILES 45 TO 60cm.

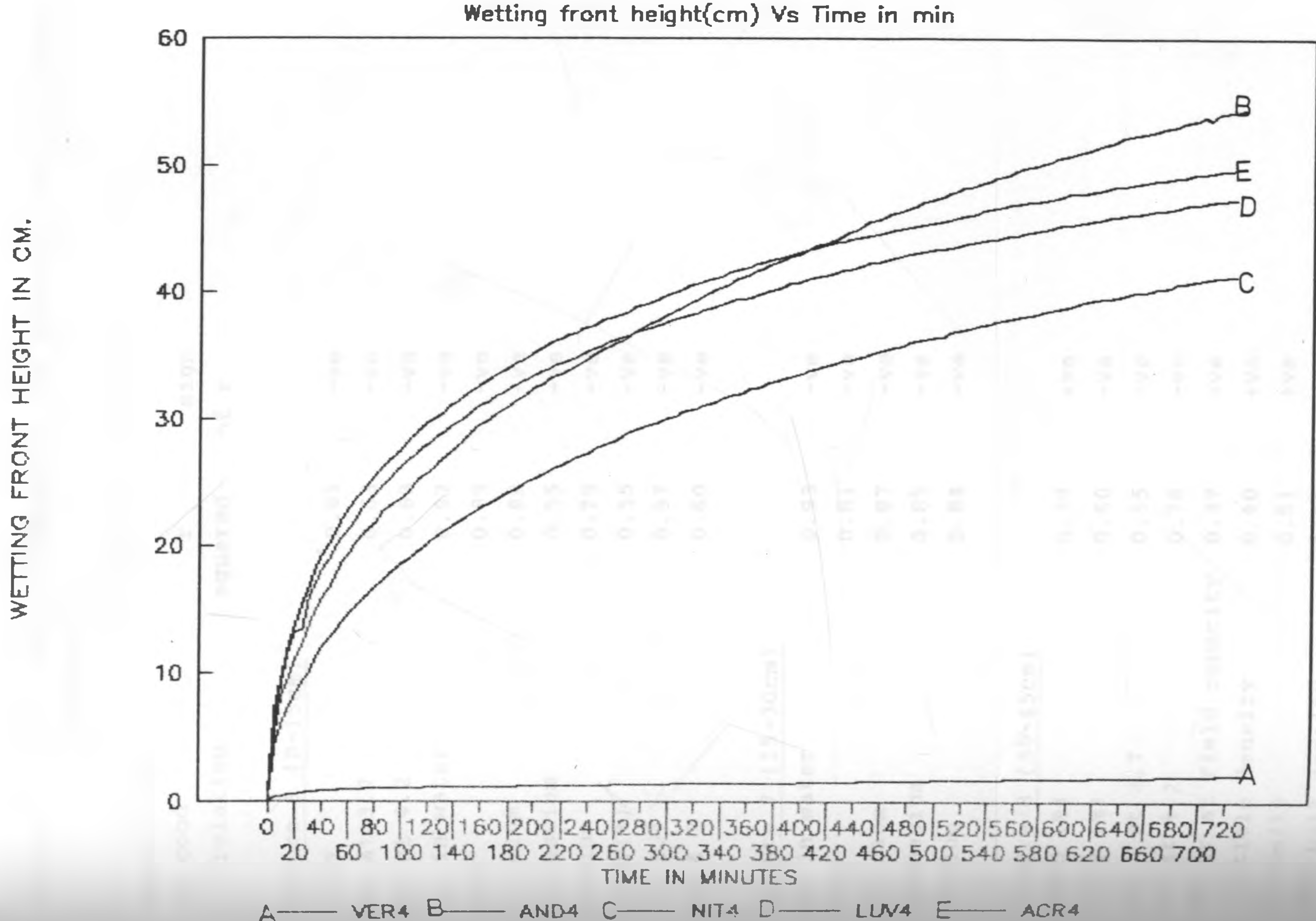


Table 4.5: Regression Coefficient for Maximum h With Different Properties.

Quantities of good correlation	r squared	sign of r
Figure 6 (0-15cm)		
Clay	0.81	-ve
pF at 3.7	0.63	-ve
pF at 4.2	0.63	-ve
EC in water	0.97	-ve
CEC	0.89	-ve
Calcium	0.88	-ve
Potassium	0.55	-ve
Sodium	0.79	-ve
Clay(%)	0.55	-ve
pF 3.7	0.57	-ve
pF 4.2	0.60	-ve
Figure 7 (15-30cm)		
EC in water	0.93	-ve
CEC	0.81	-ve
Calcium	0.87	-ve
Magnesium	0.89	-ve
Sodium	0.84	-ve
Figure 8 (30-45cm)		
Sand (%)	0.37	+ve
Clay (%)	0.60	-ve
pF at 3.7	0.55	-ve
pF at 4.2	0.78	-ve
Water at field capacity	0.37	-ve
Particle density	0.40	+ve
Porosity	0.51	+ve
Wet bulk density	0.52	+ve

Table 4.5: cont...

Quantities of good correlation	r squared	sign of r
Figure 8 (30-45cm) cont...		
Organic carbon	0.79	-ve
EC in water	0.91	-ve
CEC	0.87	-ve
Calcium	0.95	-ve
Magnesium	0.93	-ve
Sodium	0.88	-ve
Figure 9 (45-60cm)		
Sand (%)	0.40	+ve
Clay (%)	0.51	-ve
pF at 3.7	0.55	-ve
pF at 4.2	0.74	-ve
Water at field capacity	0.61	-ve
Particle density	0.46	+ve
Organic carbon	0.85	-ve
EC in water	0.95	-ve
CEC	0.85	-ve
Calcium	0.94	-ve
Magnesium	0.96	-ve
Sodium	0.95	-ve

(f) comments

When the r^2-value greater than 0.36 is considered in correlation of wetting front height at 720 min, for samples of different levels, it was found that the following had only positive values: particle density, sand, porosity, and wet bulk density. Those with only negative values were: clay, water at pF 3.7, water at pF 4.2, water at field capacity, organic carbon, EC in water, CEC, calcium, magnesium, potassium and sodium. In all the levels in this case the curves are AND, ACR, LUV, NIT and finally the lowest being VER. This seems to be following the amount of swelling clay in the soil.

4.6.2.3. Curves of similar pattern

The Figures 10, 11, 12 and 13 shows curves with similar patterns, of samples of different depths and soil types. The curves in Figure 10 are in the following order: AND4, AND3, AND2, NIT4, NIT2 and NIT1 from the top to the bottom. The curves in graph of Figure 11 are in the following order AND4, AND3, AND2, NIT3, NIT2 and NIT1 from the top to the bottom.

The graphs of Figure 12 occurs in the following order: ACR4, LUV4, AND1, ACR3, ACR2 and ACR1, from the top to bottom.

The graphs of Figure 13 occurs in the following order: ACR3.ACR2, LUV3, ACR1, LUV1 and LUV2 from the bottom to the bottom.

FIG.10—HEIGHT WITH SIMILAR PATTERN.

Wetting front height(cm) Vs Time in min

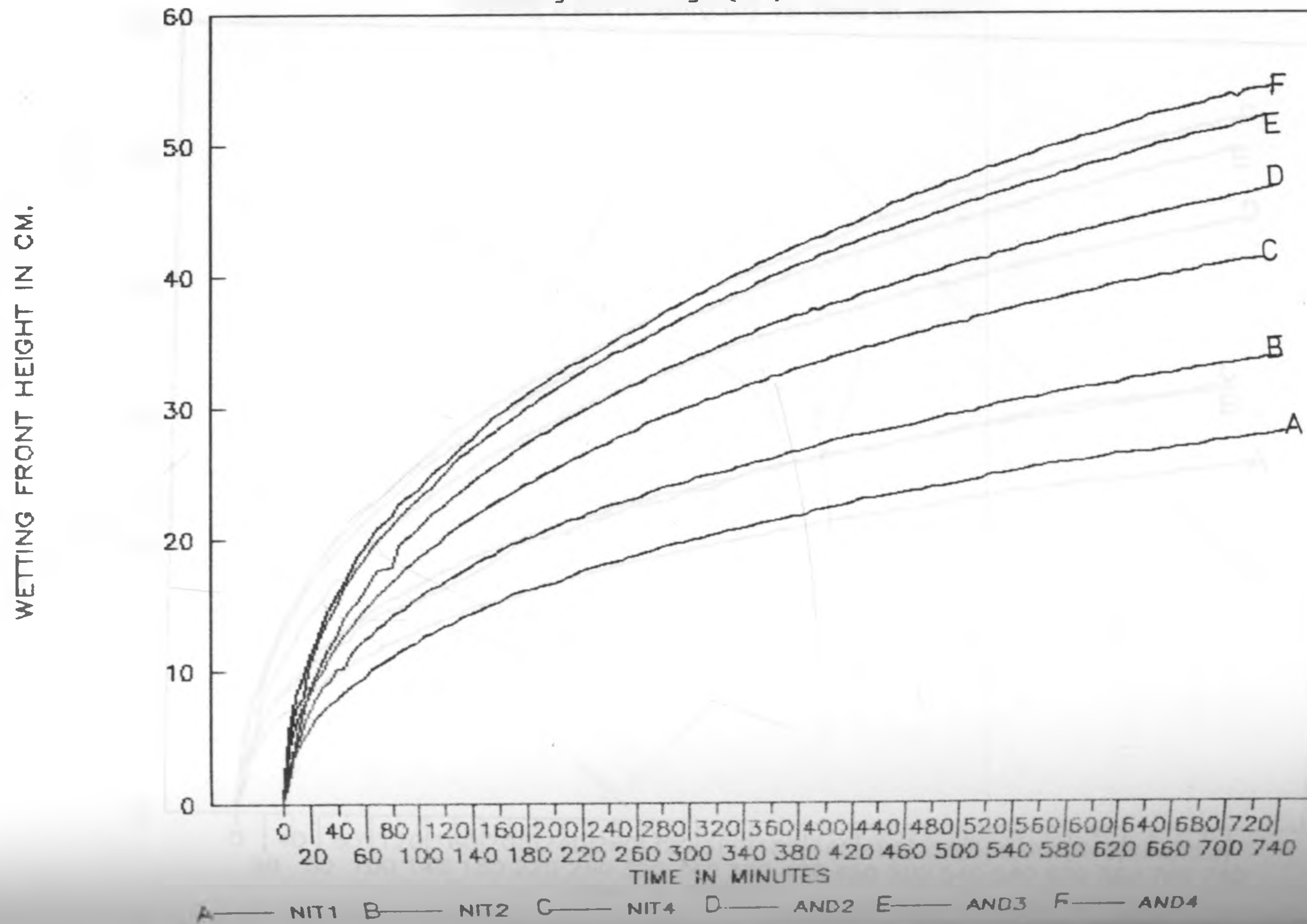
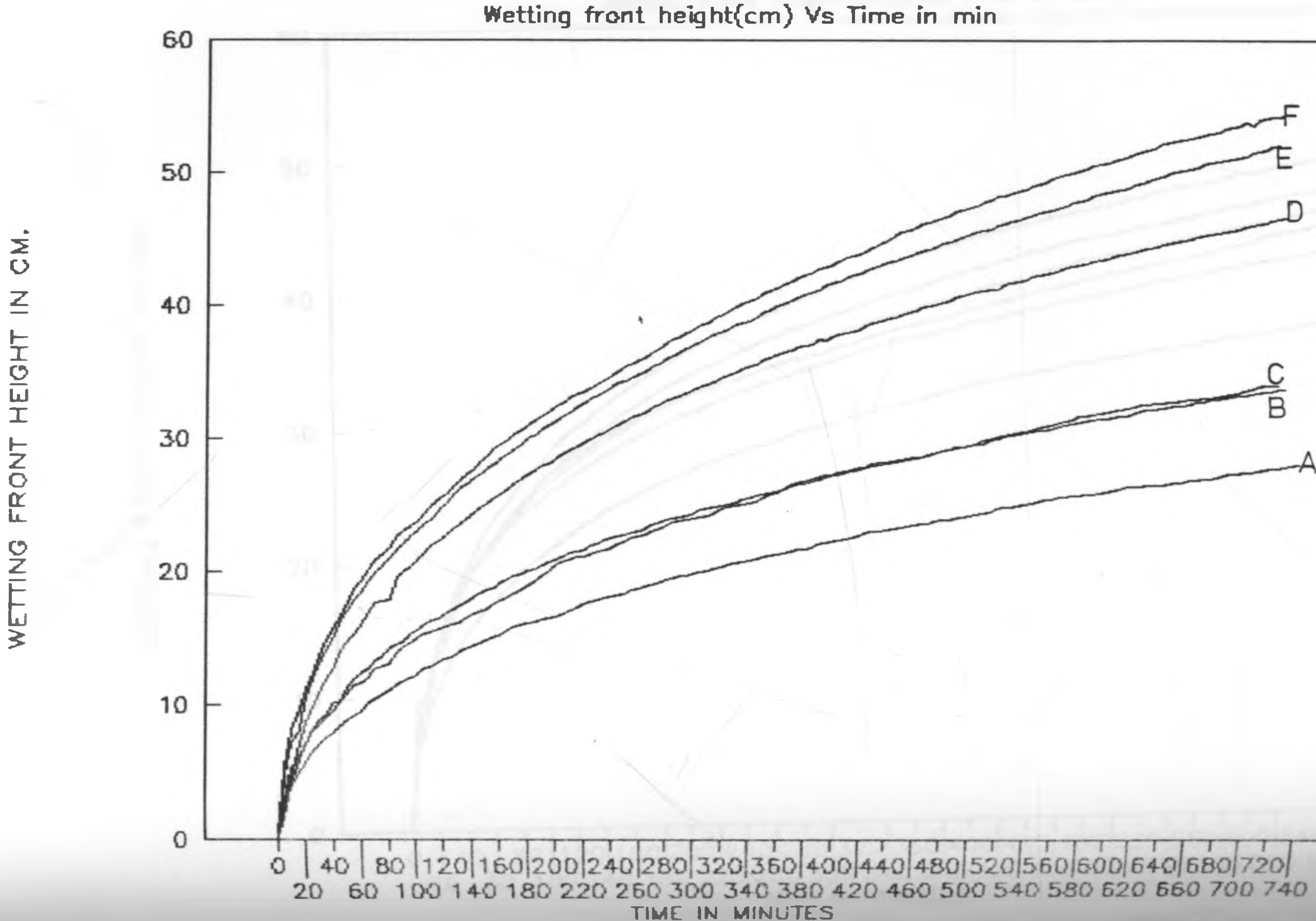


FIG.11 — HEIGHT WITH SIMILAR PATTERN.



A —— NIT1 B —— NIT2 C —— NIT3 D —— AND2 E —— AND3 F —— AND4

FIG.12—HEIGHT WITH SIMILAR PATTERN.

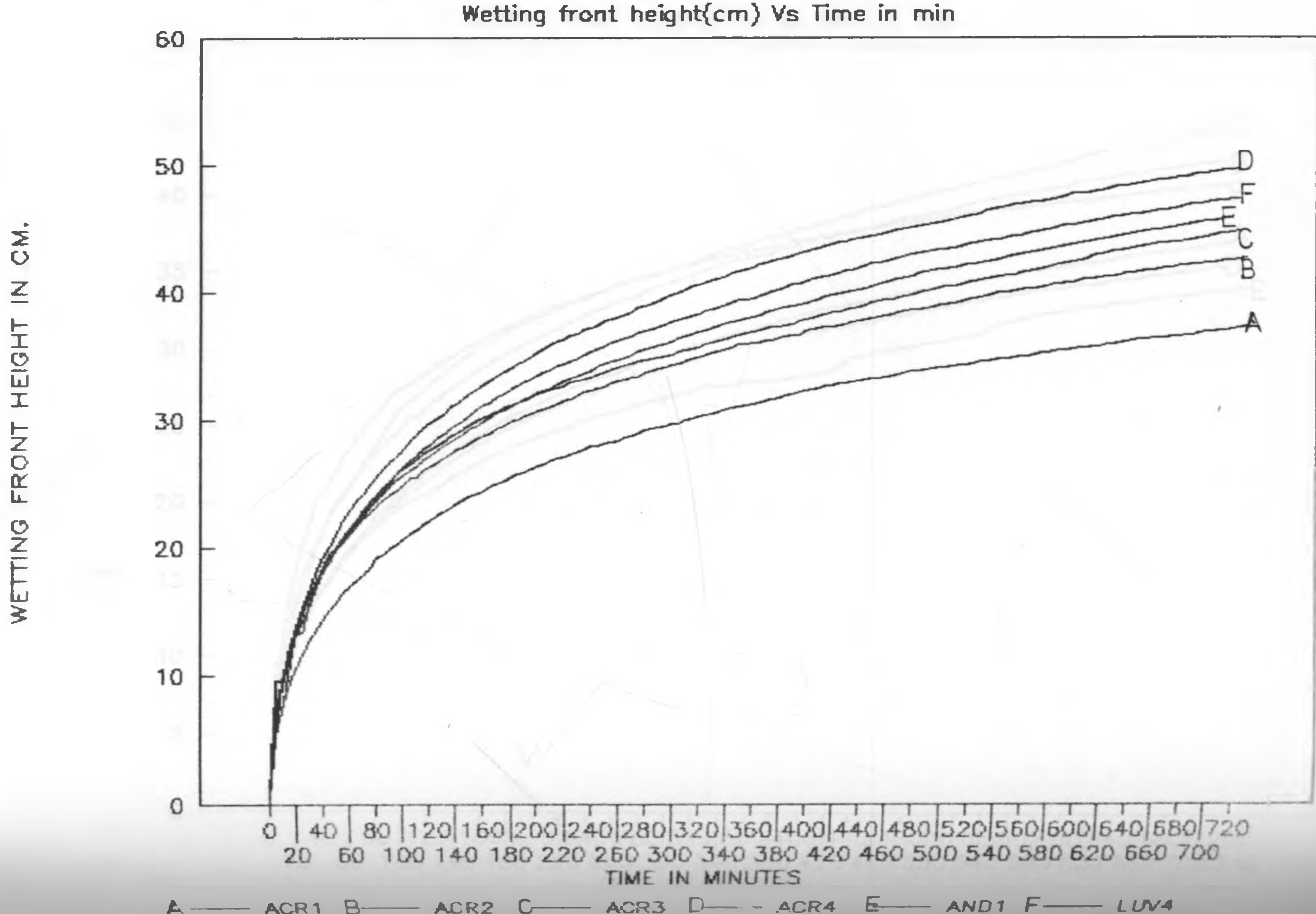


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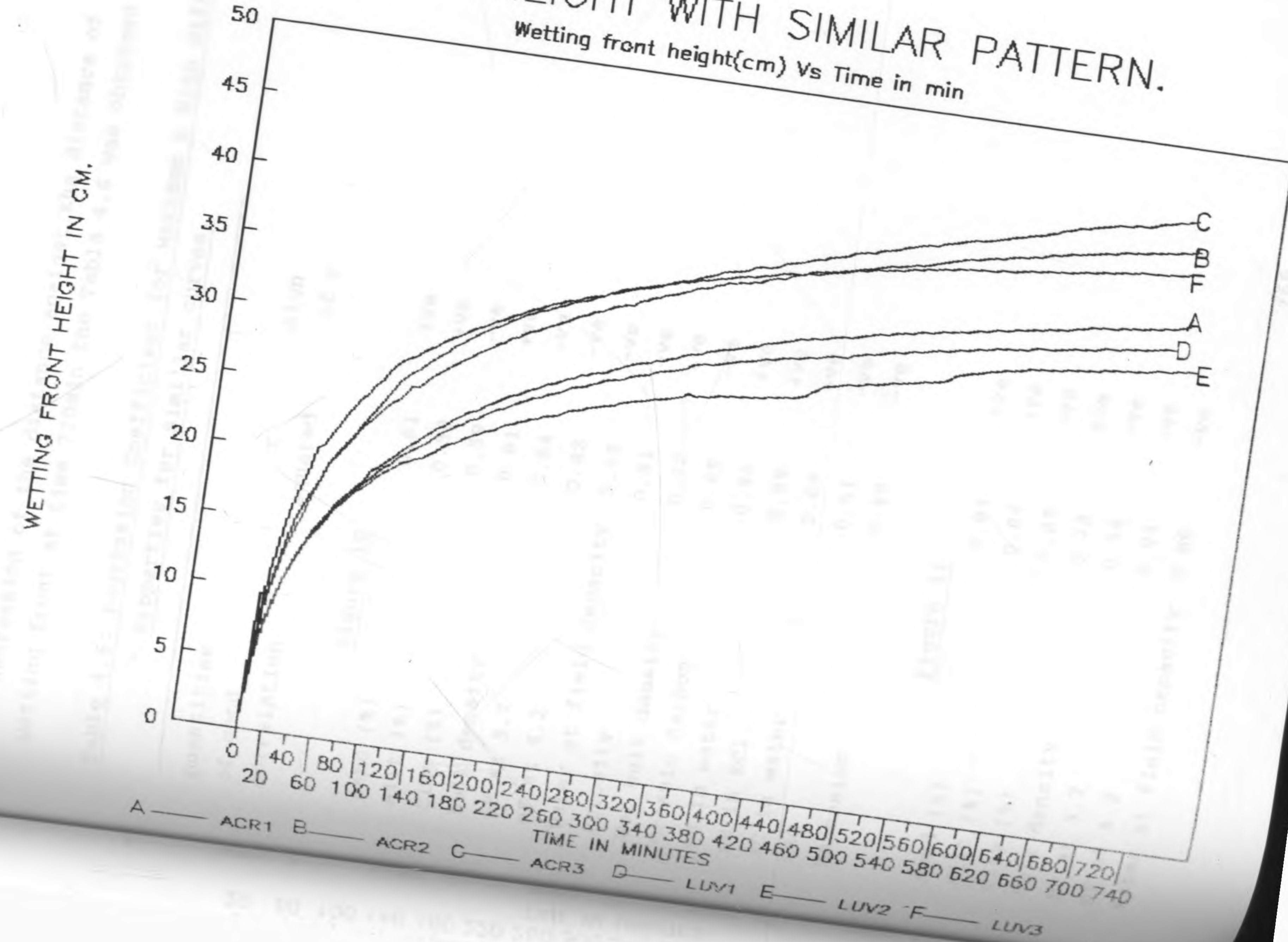
FIG.13-HEIGHT WITH SIMILAR PATTERN.



(a) Regression

Regression of the distance against the distance of the wetting front at time 720min the Table 4.6 was obtained.

Table 4.6: Regression Coefficient for Maximum h With Different Properties for Simillar curves.

Quantities of good correlation	r squared	sign of r
Figure 10		
Sand (%)	0.61	+ve
Silt (%)	0.58	+ve
Clay (%)	0.59	-ve
Bulk density	0.81	+ve
pF at 3.7	0.64	-ve
pF at 4.2	0.83	-ve
Water at field capacity	0.68	-ve
Porosity	0.81	-ve
Wet bulk density	0.92	+ve
Organic carbon	0.89	-ve
pH in water	0.96	+ve
pH in KCl	0.89	+ve
EC in water	0.69	+ve
CEC	0.51	-ve
Magnesium	0.48	-ve
Figure 11		
Sand (%)	0.83	+ve
Silt (%)	0.84	+ve
Clay (%)	0.83	-ve
Bulk density	0.78	+ve
pF at 3.7	0.94	-ve
pF at 4.2	0.94	-ve
Water at field capacity	0.66	-ve

Table 4.6 cont...

Quantities of good correlation	r squared	sign of r
Figure 11 cont...		
Porosity	0.82	-ve
Wet bulk density	0.86	+ve
Organic carbon	0.91	-ve
pH in water	0.90	+ve
pH in KCl	0.72	+ve
EC in water	0.56	+ve
CEC	0.78	-ve
Calcium	0.70	-ve
Magnesium	0.77	-ve
Potassium	0.47	-ve
Figure 12		
Silt (%)	0.78	-ve
Clay (%)	0.50	+ve
Bulk density	0.51	+ve
Water at field capacity	0.54	-ve
Particle density	0.79	+ve
Porosity	0.41	-ve
Organic carbon	0.64	-ve
pH in water	0.36	-ve
Calcium	0.41	-ve
Magnesium	0.77	-ve
Potassium	0.54	-ve
Sodium	0.37	-ve
Figure 13		
Sand (%)	0.50	-ve
Clay (%)	0.55	+ve
Bulk density	0.67	-ve
pF at 3.7	0.43	+ve
pF at 4.2	0.53	+ve
Ksat	0.63	-ve

Table 4.6 cont...

Quantities of good correlation	r squared	sign of r
Figure 13 cont..		
Water at field capacity	0.59	+ve
Porosity	0.60	+ve
Organic carbon	0.72	-ve
EC in water	0.46	-ve
CEC	0.45	+ve

(b) comments

When the r^2-value greater than 0.36 is considered in correlation of wetting front height at 720 min, properties that had r-value positive only were: wet bulk density, particle density and pH in KCl. Those that only r-value were: organic carbon, calcium, potassium, sodium and Ksat. One notable thing about the curves of similar pattern is that a set with same clay mineralogy tended to be together and hence identifying clay mineralogy.

4.6.3. Cumulative water weight

The graphs that shows the amount water absorbed by individual samples in figures 14, 15, 16, 17 and 18 in case of different profiles and figures 19, 20, 21 and 22 for different levels.

4.6.3.1. Profiles

(a) Vertisols

Graphs for this profile are shown in figure 14. The cumulative amount of water absorbed at 720min in different samples is in the order of VER1, VER2, VER3 and VER4 from the highest to lowest.

FIG.14-AHERO VERTISOLS 0 TO 60cm.

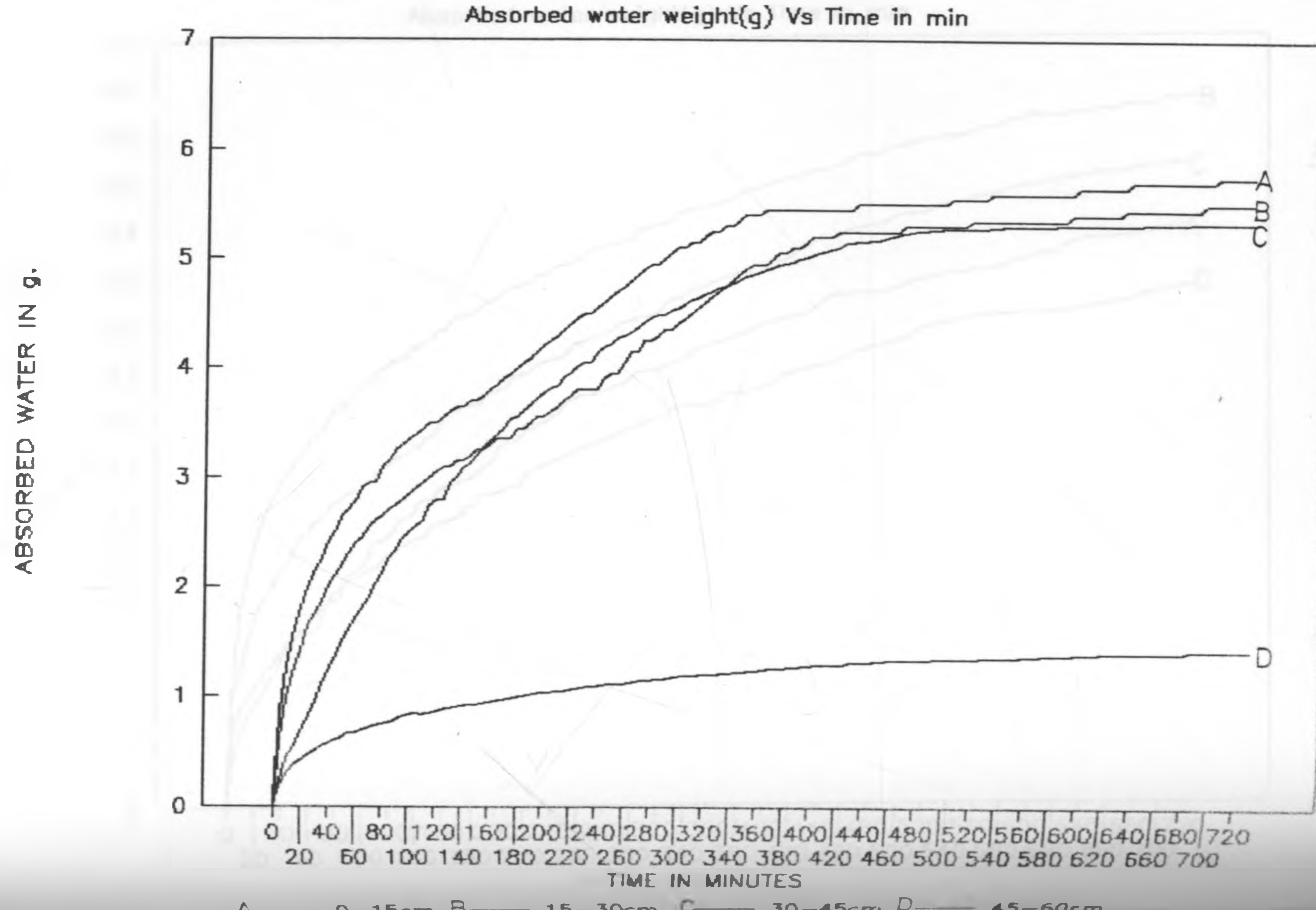


FIG.15—NAIVASHA ANDOSOLS 0 TO 60cm.

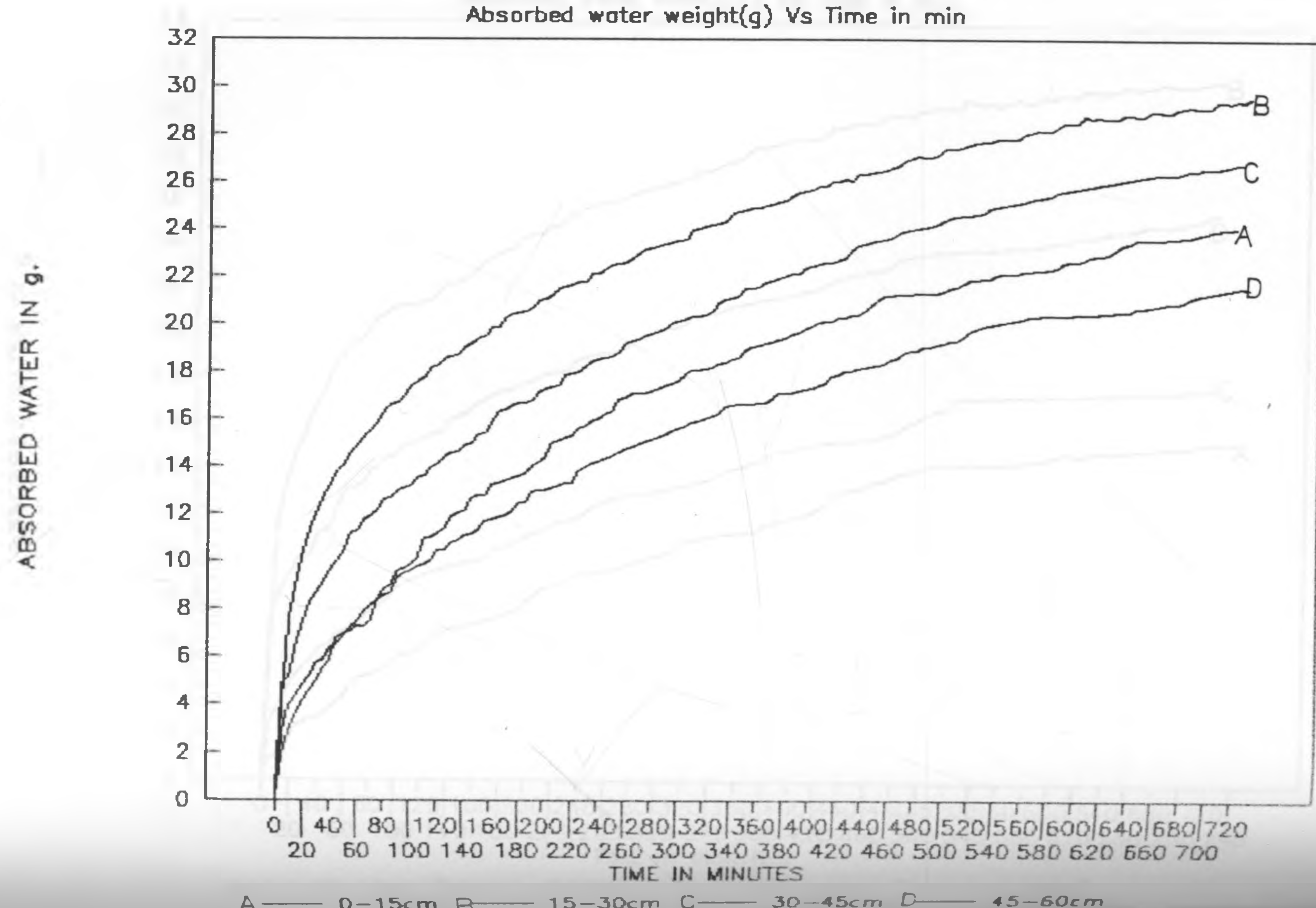


FIG.16—KABETE NITOSOLS 0 TO 60cm.

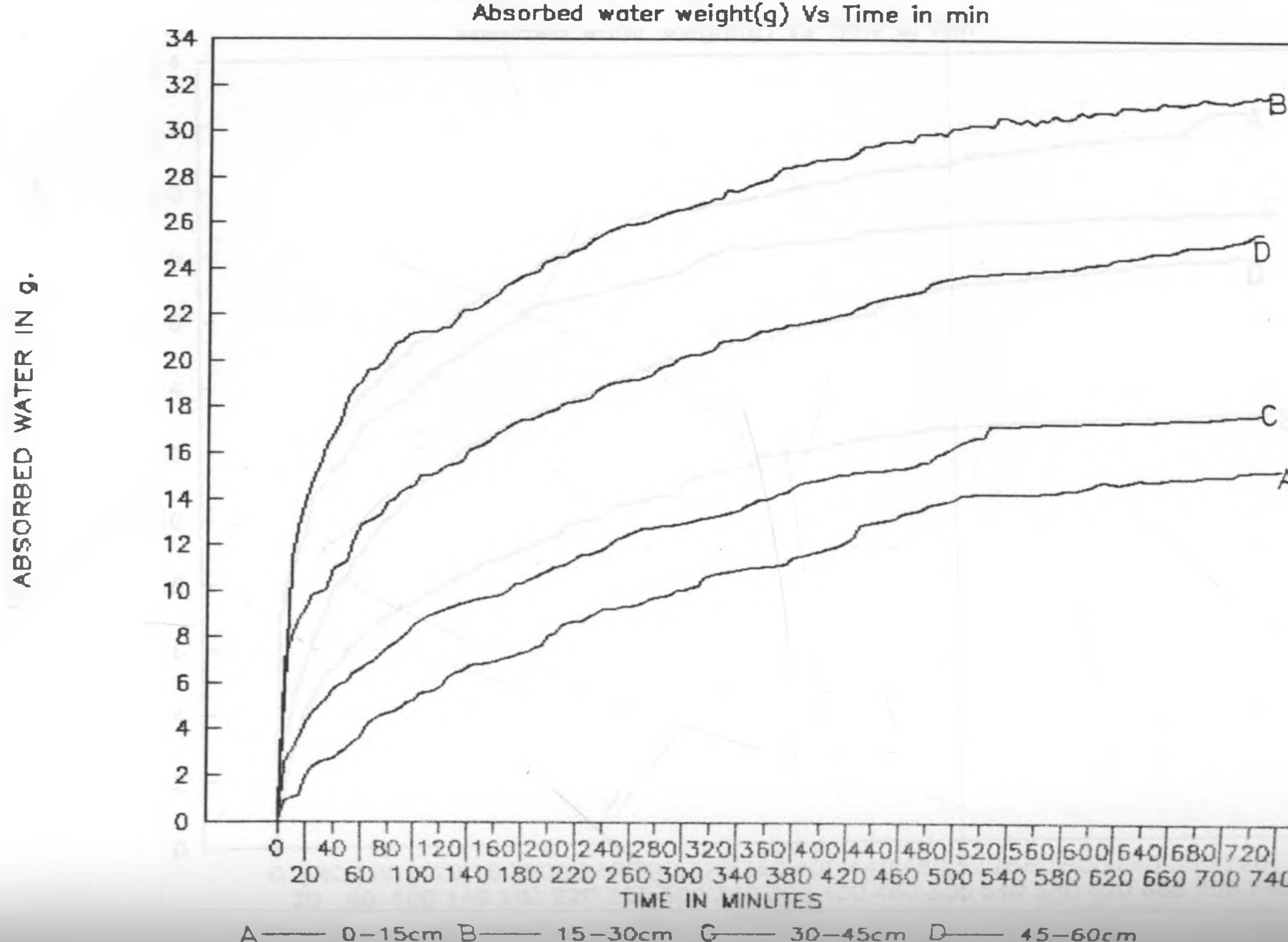


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FIG.17—MAKUENI LUVISOLS 0 TO 60 CM

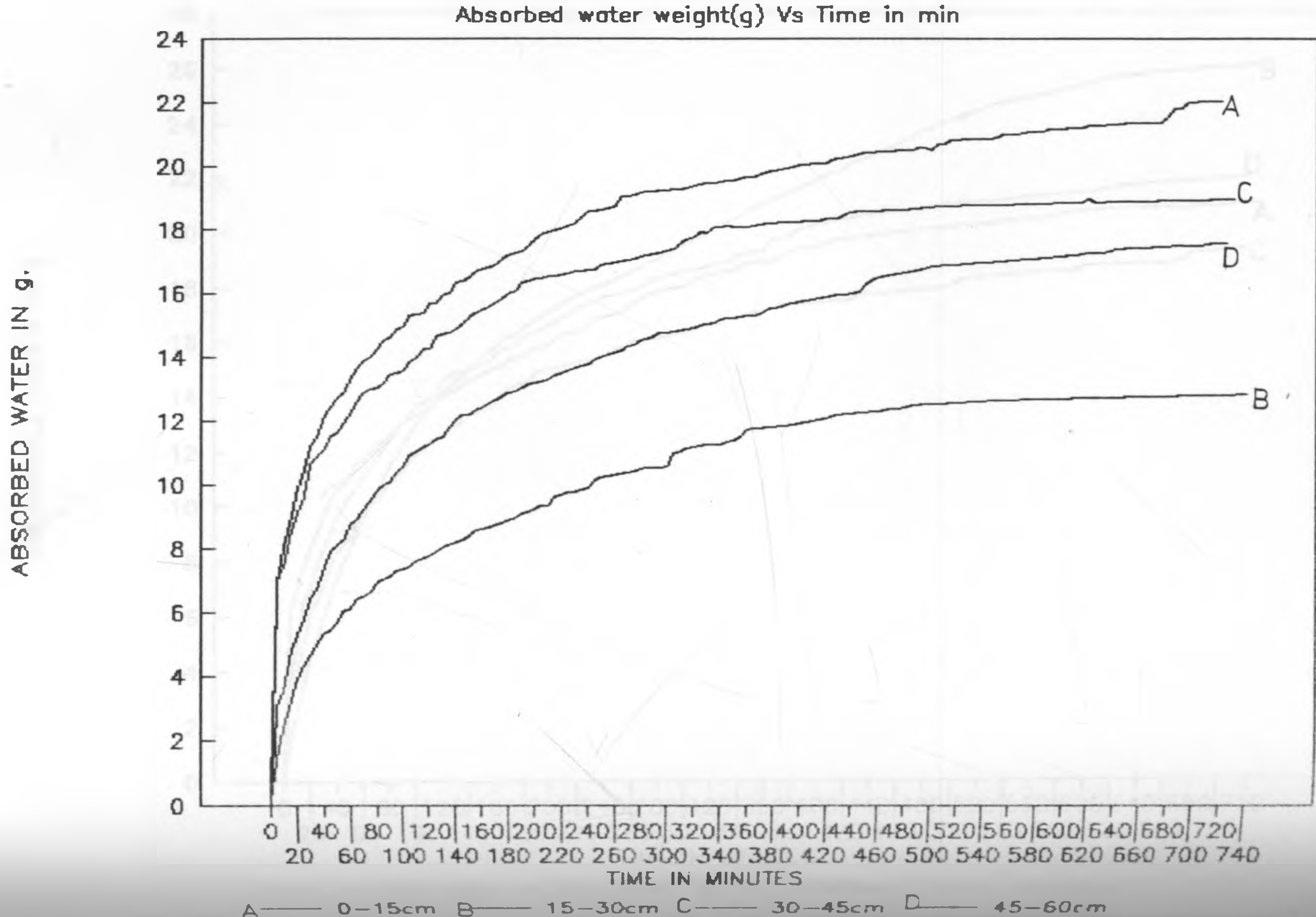
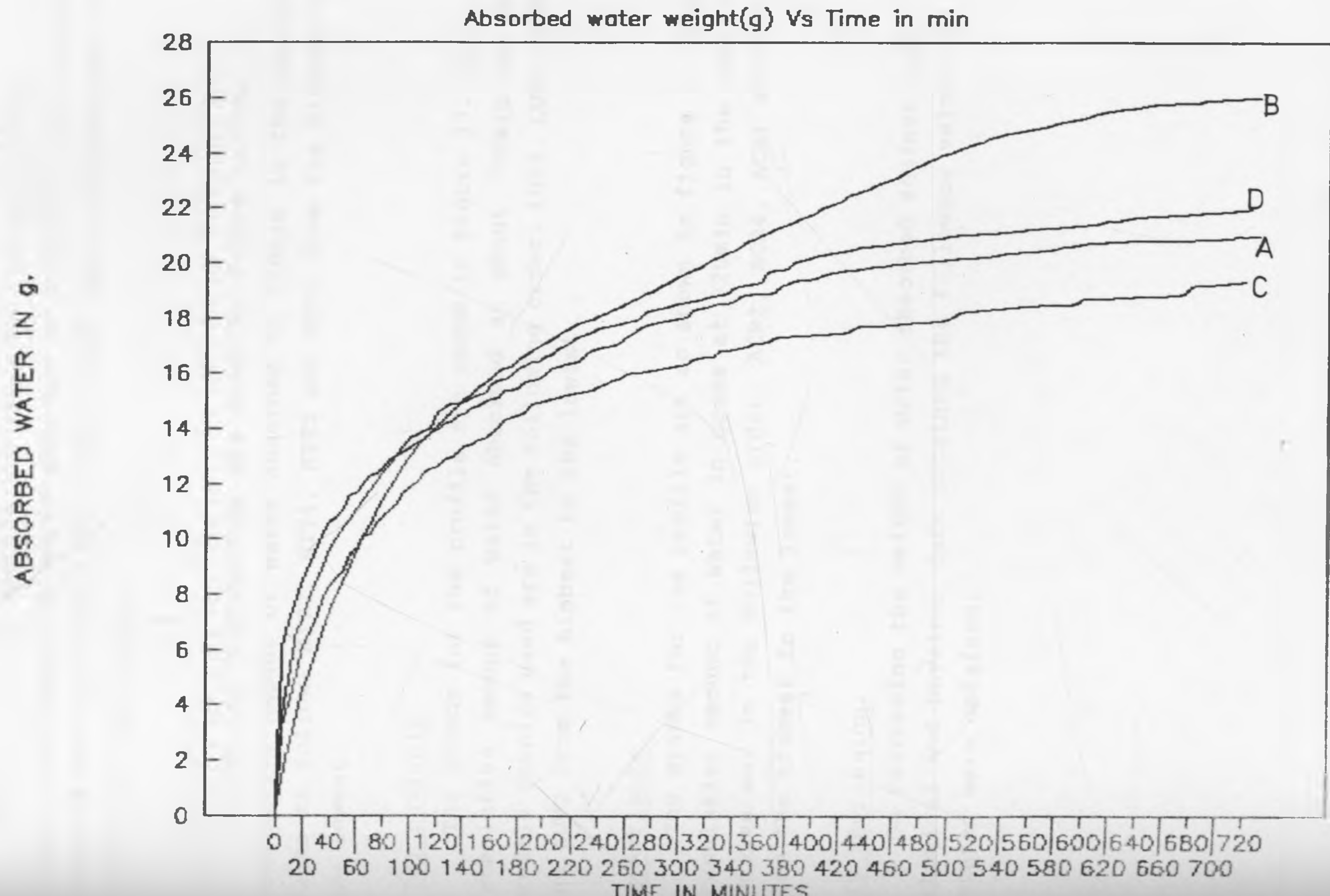


FIG.18—MAKUENI ACRISOLS 0 TO 60 CM



A—— 0–15cm B—— 15–30cm C—— 30–45cm D—— 45–60cm

(b) Andosols

Graphs for the profile are shown in figure 15. The cumulative amount of water absorbed at 720min in the profile ranks in the following order: AND2, AND3, AND1 and AND4 from the highest to the lowest.

(c) Nitosols

Graphs for this profile are shown in figure 16. The cumulative amount of water absorbed at 720min in the profile ranks as follow: NIT2, NIT4, NIT3 and NIT1 from the highest to the lowest.

(d) Luvisols

The graphs for the profile are shown in figure 17. The cumulative amount of water absorbed at about 720min in the profile samples used are in the following order: LUV1, LUV3, LUV4 and LUV2 from the highest to the lowest.

(e)Acrisols

The graphs for the profile are as shown in figure 18. The cumulative amount of water in grams at 720min in the profile samples was in the following order: ACR2, ACR4, ACR1 and ACR3 from the highest to the lowest.

(f) Regression

On regressing the weight of water absorbed against both chemical and physical data obtained the following values of r squared were obtained.

Table 4.7: Regression Coefficient for Maximum h With Different Properties.

Quantities of good correlation	r squared	sign of r
Figure 14 (Vertisols)		
Sand (%)	0.51	+ve
Silt (%)	0.68	+ve
Clay (%)	0.62	-ve
Bulk density	0.99	-ve
Water at field capacity	0.99	+ve
Porosity	0.96	+ve
Wet bulk density	0.88	-ve
pH in water	0.60	-ve
pH in KCl	0.79	-ve
EC in water	0.73	-ve
Calcium	0.44	+ve
Sodium	0.86	-ve
Figure 15 (Andosols)		
Bulk density	0.42	-ve
Water at field capacity	0.42	+ve
Porosity	0.44	+ve
Wet bulk density	0.42	-ve
Potassium	0.60	+ve
Figure 16 (Nitosols)		
None has the r value of the considered level.		
Figure 17 (Luvisols)		
Silt (%)	0.71	+ve
Bulk density (%)	0.66	+ve
Wet bulk density	0.56	+ve
PH in water	0.42	-ve
Calcium	0.94	+ve
Sodium	0.43	-ve
CEC	0.49	+ve

Table 4.7: cont...

Quantities of good correlation	r squared	sign of r
Figure 18 (Acrisols)		
pF at 3.7	0.49	+ve
pF at 4.2	0.42	+ve
CEC	0.49	+ve

(g) comments

When the r^2-value greater than 0.36 is considered in correlation of cumulative amount of water in g at 720 min, correlation was not as good as the earlier considered cases. The properties which had positive r-value were: silt, sand, water content at field capacity, porosity, water content at pF 3.7, water content at 4.2, calcium, potassium and CEC. Those that had r-value as negative were: clay wet bulk density, pH in water, pH in KCl, EC in water and sodium. When CEC is correlated with the amount of water absorbed, it gave a positive value of regression coefficient. This was contrary to what was obtained when it was correlated wetting front height which was determined by clay mineralogy.

4.6.3.2. Variations in depth levels in all profiles.

Figures 19, 20, 21 and 22 shows variations of water weight absorbed in any given depth sample from all profiles. Figure 19 for 0-15cm, 20 for 15-30cm, 21 for 30-45cm and 22 for 45-60cm.

(a) Figure 19 Level 1 (0-15cm)

Graphs to show variation in water weights in this level are shown in figure 19. At 720min the order of the curves from the highest to the lowest was: AND1, LUV1, ACR1, NIT1 and VER1.

(b) Figure 20 Level 2 (15-30cm)

Graphs to show variation in water weights in this level are shown in figure 20. At 720min the order of the curves from the highest to the lowest was: NIT2, AND2, ACR2, LUV2 and VER2.

FIG.19--FROM ALL PROFILES 0 TO 15cm.

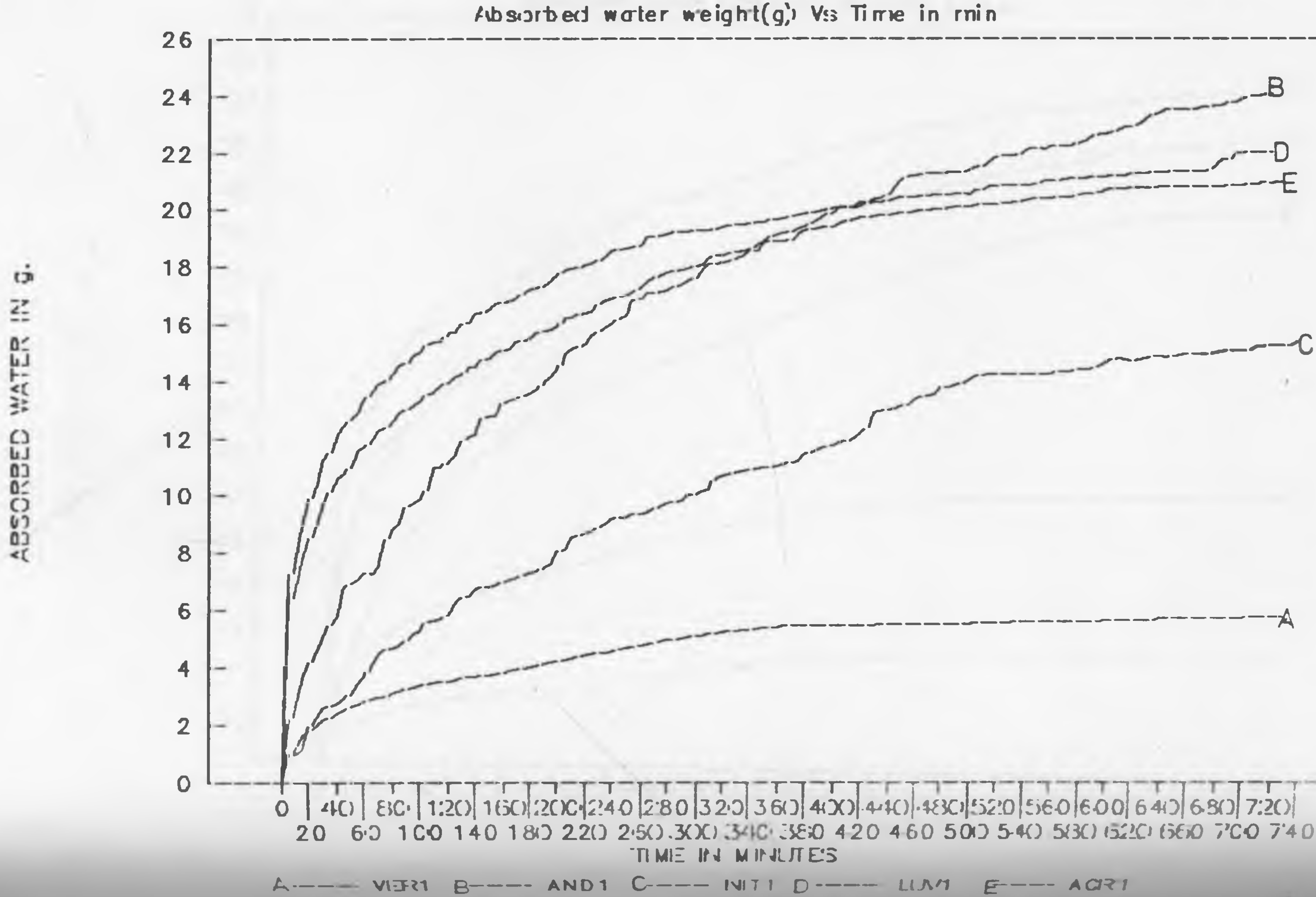


FIG.20—FROM ALL PROFILES 15 TO 30CM

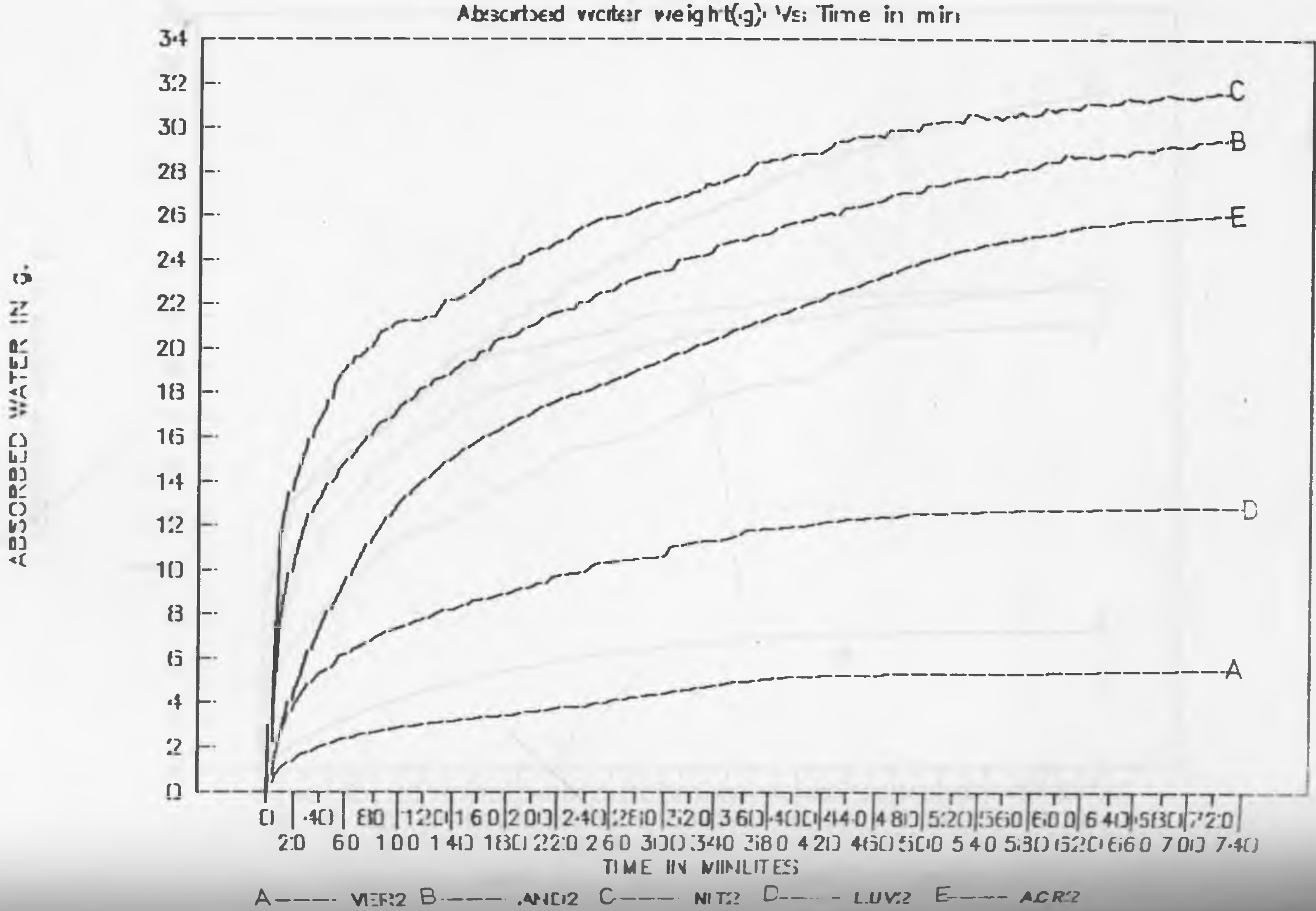


FIG.21–FROM ALL PROFILES 30 TO 45CM

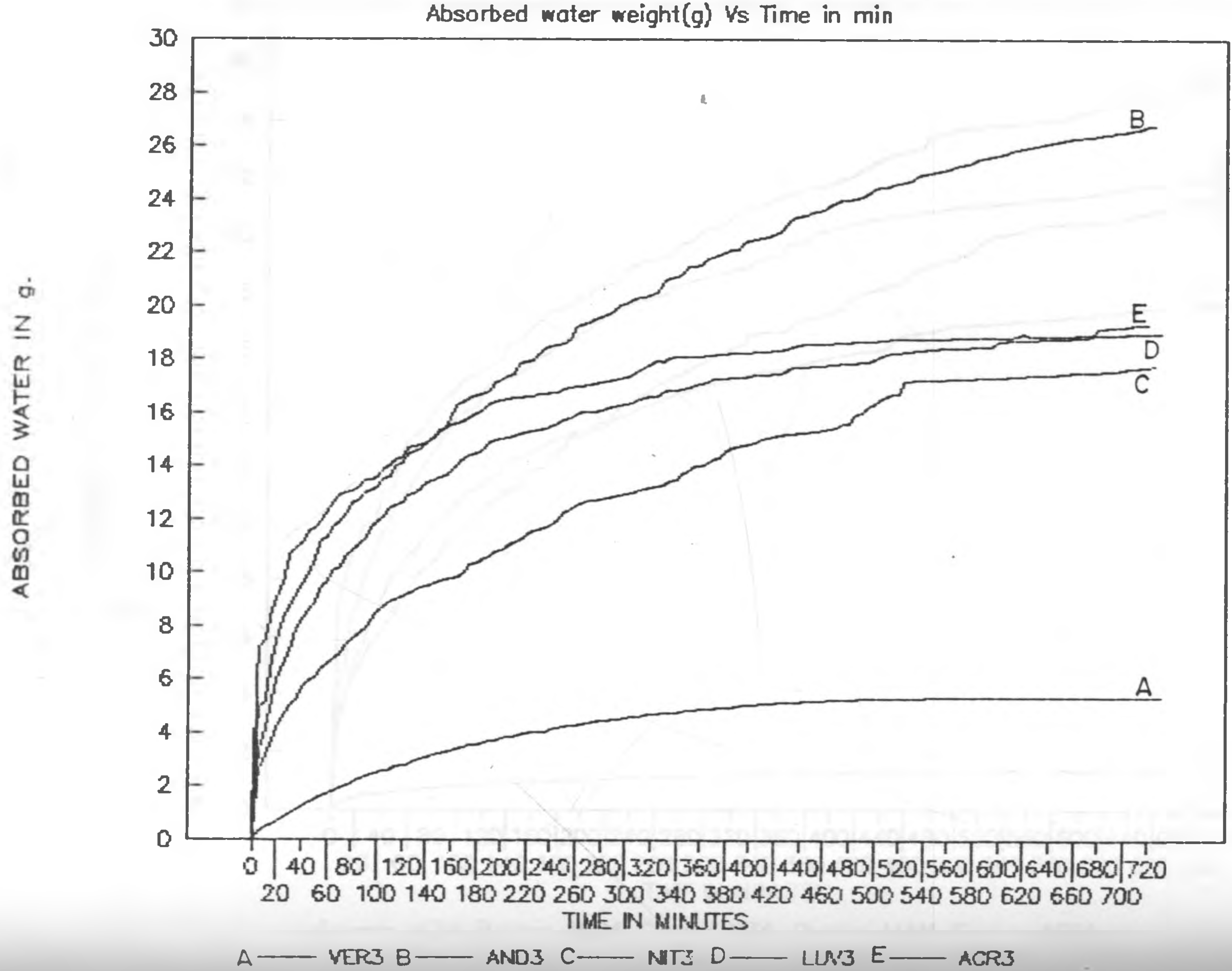
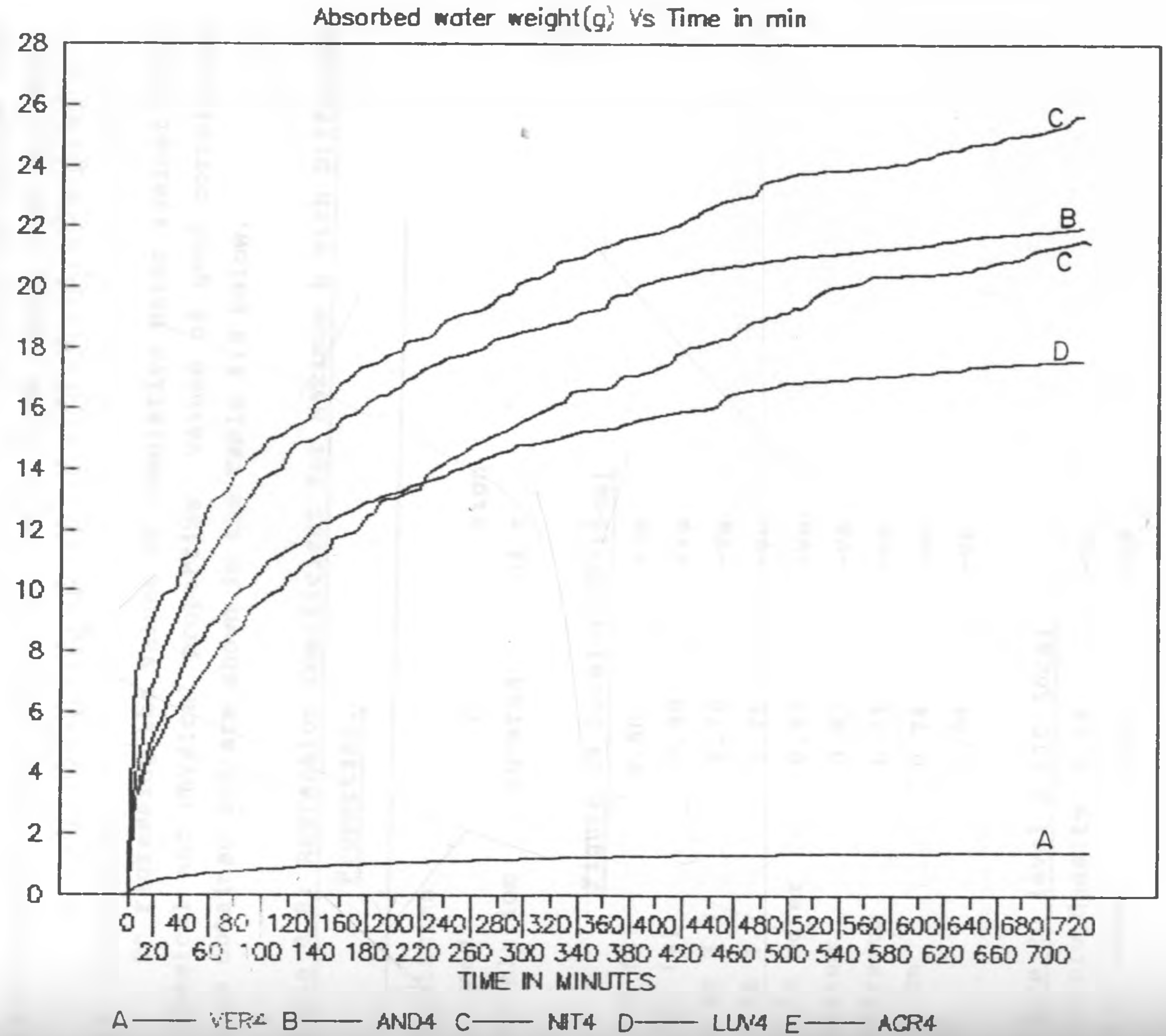


FIG.22-FROM ALL PROFILES 45 TO 60CM



(c)Figure 21 Level 3 (30-45cm)

Graphs to show variation in water weights in this level are shown in figure 21. At 720min the order of the curves from the highest to the lowest was: AND3, ACR3, LUV3, NIT3 and VER3.

(d)Figure 22 Level 4 (50-60cm)

Graphs to show variation in water weights in this level are shown in figure 22. At 720min the order of the curves from the highest to the lowest was: NIT4, ACR4, AND3, LUV4 and VER4.

(e) Regression

On regressing the values of cumulative water against both chemical and physical properties values of good correlation were obtained and are shown in the Table 4.8 below.

Table 4.8: Regression Coefficient for Maximum h With Different Properties.

Quantities of good correlation	r squared	sign of r
Figure 19 level 1 (0-15cm)		
Sand (%)	0.50	+ve
Clay (%)	0.88	+ve
pF at 3.7	0.78	-ve
pF at 4.2	0.78	-ve
EC in water	0.93	-ve
CAlcium	0.87	-ve
Potassium	0.71	-ve
Sodium	0.74	-ve
CEC	0.94	-ve
Figure 20 level 2 (15-30cm)		
Particle density	0.52	-ve
EC in water	0.65	-ve

Table 4.8: cot...

Quantities of good correlation	r squared	sign of r
Figure 21 level 3 (30-45cm)		
Clay (%)	0.68	-ve
pF at 3.7	0.70	-ve
pF at 4.2	0.70	-ve
Particle density	0.60	-ve
Organic carbon	0.37	-ve
EC in water	0.82	-ve
Calcium	0.82	-ve
Sodium	0.76	-ve
CEC	0.77	-ve
Figure 22 level 4 (45-60cm)		
Particle density	0.36	+ve
Organic carbon	0.60	-ve
EC in water	0.88	-ve
Calcium	0.61	-ve
Magnesium	0.65	-ve
Sodium	0.67	-ve
CEC	0.44	-ve

(f) comments

When the r^2-value greater than 0.36 is considered in correlation of cumulative amount of water in g at 720 min, property which had positive r-value was sand only. while negative were: pF at 3.7, pF at 4.2, organic carbon, EC in water, calcium, potassium, sodium, magnesium and CEC.

Also like in the wetting front height the clay mineralogy a role in determining the amount of water absorbed when soils of different mineralogy are considered. This was deduced from the negative value of the regression coefficient after correlation with CEC water weight.

4.7 TEXTURE

Another factor that seems to affect the density on the table is the texture. The fraction that is the highest corresponds with the order of change in density. In Vertisol clay is the one with the highest fraction and it ascends in percentage while at the same time the density does the same.

4.8 MOISTURE RETENTION AT FIELD CAPACITY

This property can not be represented in a large area due to variation in factors which it is sensitive to. Babulola, of (1978) found that high variability in soil physical properties, such as sand, silt clay gravel content and bulk density can result in a high variability in soil water retention characteristics and hydraulic conductivity. He found this when he was working on tropical soils in Nigeria.

Andosols used in the experiment had moisture retention of 4.9-12.5 at pF of 3.7 and 3.5-10.5 at pF of 4.2 (Appendix II). This is in agreement with Shoji and Ono (1978), who found that andosols exhibit such properties as low bulk density, high water retention, striking accumulation of organic matter, high fluoride pH value, weak cation retention and phosphate absorbing capacity. This is also in the properties determined in the other four soils.

4.9 CLAY MINERALOGY

Diffractograms from the x-ray during the analysis showed that the clay mineralogy varied from profile to profile. Ahero Vertisols had montimorillonite as dominant and some traces of illite.

Naivasha Andosols had amorphous clay being dominant and traces of palygorskite. In Kabete Nitosols, kaolinite was the only clay mineral that was found in the samples that were analysed. Machakos Luvisol and Acrisol had both illite and kaolinite but with more domination of illite over kaolinite.

CHAPTER V

5. CONCLUSION

It was found that organic carbon do affect the amount of water, in gm, absorbed in a given soil when time considered is about 12hrs. The wetting front distance is also affected. Both the weight and the distance mentioned above, shows negative correlation when correlated with organic carbon.
This brings about the even greater importance of organic carbon in the study of water movement through capillary rise.
When the movement of water is in this mode involves water to the root zone from the lower levels, the soil rich in organic carbon bears some disadvantage in this respect. When water loss is being discouraged from the surface due to evaporation, soils rich inorganic carbon have an advantage in that after evaporation from the surface replacement is not fast enough due to slow rise from the lower levels. This expresses the importance of organic carbon in conservation of moisture which is for crop production.

Capillary rise experiments can be used in the relative amount of organic carbon in any given set of soils.
CEC was highly correlated to the rise in wetting front.
whether the correlation coefficient was to be negative or positive was to be determined by clay mineralogy and the quantity in a given soil.

(a)(i) In all the profiles there was no observable variations within any of them. In any given profile, the measure of the quantity of the amount of clay minerals was inferred from the value of CEC. Thus the higher the CEC the higher the quantity of clay minerals at any given level in a profile.

(ii) The soils which a negative correlation coefficients were Ahero soils (Vertisols), Naivasha soils (Andosols) and Makueni soils (Acrisols and Luvisols). These soils are rich in swelling type of clay which increases in volume when wetted with water. The swelling decreases the amount of macropores while at the same time increasing the amount of micropores. As a result water flow rate in capillary rise decreases. Thus the higher the CEC,which is a reflection of an amount of swelling clay,the lower the capillary rise rate. Vertisols was rich in montimorillonite, Andosols in allophanes, and Acrisols and luvisols in illite and kaolinite.

In Nitosols the dominant type of clay was kaolinite. Correlation of the wetting front rise gave a positive value of correlation coefficient. The reason for this was due to the fact that kaolinite is not of the swelling type and hence its presence provided increased specific surface area without change in volume and this enhanced capillary rise rate.

The above described soil behavior can be used in assessing relative quantities of clay minerals in field where clay mineral does not vary.

(iii) When different level of all profiles were considered the rank in the rise of the wetting front was; allophanes found in the Andosols, illite-kaolinite and illite-kaolinite found in Acrisols and Luvisols respectively, kaolinite in Nitosols, and montimorillonite found in Vertisols; from the highest to the lowest. In the above rank allophane and kaolinte rich soils were not found where the were expected. This could be due to influence other properties and the most likely one being organic carbon. Also from the rank above it can be seen that Acrisols and Luvisols contains more of illite than kaolinite. When there is no interference by other properties the rank set can be used in estimating the dominant clay mineralogy in a given soil.

(iv) From curves of similar pattern it was found that curves of similar clay mineralogy were found to group together. This when used with earlier sets of curves on levels can be used in grouping the soils according to their clay mineralogy without necessarily having to go for expensive x-ray equipments which are in most cases not available.

(b)As for the cumulative amounts of water by weight, not much seemsto be got. More work needs to be done on the experiment in a way of improving the apparatus particularly the balance. A with negligible vertical movement of the pan needs to be used before one can exploit uses off such a data.

Data obtained from the wetting front experiment also needs more improvement and also seeking for more relationships with other chemical and physical properties. It is felt that this kind of data can cheaply be collected and can of much use in fields such as soil survey, crop production and soil engineering; which are the only existing better alternative now.

5.1 FURTHER RESEARCH

(i) It is recommended that further research be done on the improvement of the apparatus used in the capillary rise experiments for acquisition of even better accuracy.

(ii) Further research on how data on capillary rise can be tabulated in a form of handbook, needs to be done. The presentation can be in form of graphs where data on organic carbon, clay mineralogy, CEC and quantitative amount of clay will be tabulated for various soils in kenya.

(iii) Research on the relationship between the specific surface area and all the properties determined in the above, needs to be done further, as very little seems to have been done on such.

CHAPTER SIX

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Appendix I:Results obtained for the wetting front rise in cms and cummulative amount of water by weight in grams.

Time	xVE1	mVE1	xVE2	mVE2	xAND2	mAND2	xNI2	mNI2	xAC2	mAC2
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.16	0.90	0.11	0.65	2.20	4.33	1.80	6.00	5.71	1.45
10	0.16	1.30	0.37	1.00	4.62	7.70	4.23	11.50	9.78	2.50
15	0.21	1.60	0.48	1.25	6.92	9.26	5.81	13.00	11.76	3.55
20	0.21	1.80	0.58	1.40	8.57	10.40	6.97	14.00	13.74	4.50
25	0.26	2.00	0.63	1.65	9.78	11.42	8.03	14.78	15.27	5.20
30	0.26	2.15	0.75	1.75	10.99	12.15	8.87	15.49	16.37	6.00
35	0.32	2.25	0.85	1.85	11.98	12.80	9.30	16.30	17.25	6.70
40	0.32	2.40	0.85	2.00	12.86	13.20	10.25	16.80	18.13	7.30
45	0.37	2.50	0.95	2.10	14.07	13.81	10.25	17.29	19.23	7.95
50	0.37	2.65	0.95	2.20	14.84	14.10	11.41	18.40	19.89	8.50
55	0.42	2.70	1.06	2.30	15.38	14.59	11.94	18.80	20.44	8.95
60	0.42	2.80	1.16	2.40	16.15	14.91	12.46	19.10	21.10	9.55
65	0.42	2.90	1.16	2.45	16.92	15.24	12.78	19.63	21.65	10.05
70	0.48	2.95	1.27	2.55	17.69	15.56	13.31	19.61	22.31	10.50
75	0.48	2.95	1.27	2.60	17.80	15.88	13.73	19.91	22.75	11.00
80	0.53	3.10	1.37	2.65	17.91	16.36	14.26	20.30	23.30	11.50
85	0.53	3.15	1.37	2.70	19.56	16.64	14.58	20.77	23.74	11.85
90	0.53	3.25	1.48	2.75	20.00	16.70	14.79	20.80	24.18	12.25
95	0.58	3.30	1.48	2.80	20.44	17.00	15.32	21.16	24.51	12.65
100	0.58	3.35	1.48	2.85	20.88	17.38	15.63	21.18	24.95	13.00
105	0.58	3.40	1.58	2.90	21.43	17.60	16.06	21.25	25.49	13.35
110	0.63	3.45	1.58	2.95	22.09	17.78	16.37	21.26	25.49	13.65
115	0.63	3.50	1.69	3.00	22.31	18.17	16.48	21.24	26.04	13.85
120	0.63	3.50	1.80	3.05	22.75	18.27	16.90	21.41	26.37	14.10
125	0.63	3.55	1.80	3.10	23.19	18.60	17.11	21.43	26.70	14.35
130	0.63	3.60	1.80	3.10	23.63	18.63	17.43	21.81	27.03	14.60
135	0.63	3.65	1.90	3.15	23.96	18.73	17.75	22.18	27.36	14.85
140	0.63	3.65	1.90	3.15	24.51	19.06	18.06	22.19	27.69	15.05
145	0.63	3.70	1.90	3.20	24.84	19.20	18.38	22.21	27.91	15.25
150	0.69	3.70	1.90	3.25	25.27	19.43	18.70	22.47	28.24	15.50
155	0.69	3.75	1.90	3.25	25.60	19.47	18.80	22.69	28.57	15.65
160	0.69	3.80	2.01	3.30	25.93	19.84	19.23	22.85	28.79	15.85
165	0.69	3.85	2.01	3.35	26.26	19.87	19.44	23.17	29.01	16.05
170	0.69	3.90	2.01	3.35	26.70	20.28	19.75	23.31	29.34	16.20
175	0.69	3.95	2.01	3.35	27.03	20.43	19.86	23.48	29.56	16.25
180	0.74	4.00	2.11	3.45	27.36	20.49	20.18	23.64	29.89	16.50
185	0.74	4.05	2.11	3.45	27.69	20.53	20.28	23.76	30.00	16.65
190	0.79	4.10	2.22	3.50	28.02	20.70	20.49	23.80	30.33	16.80
195	0.79	4.15	2.22	3.55	28.24	20.99	20.81	24.29	30.55	16.95
200	0.79	4.20	2.22	3.55	28.57	21.03	21.02	24.33	30.66	17.10
205	0.79	4.25	2.22	3.60	28.90	21.20	21.23	24.49	30.88	17.25
210	0.79	4.30	2.32	3.65	29.23	21.48	21.44	24.46	31.10	17.40
215	0.79	4.35	2.32	3.70	29.45	21.57	21.55	24.70	31.32	17.55
220	0.79	4.40	2.32	3.75	29.78	21.64	21.65	24.80	31.54	17.65
225	0.85	4.45	2.32	3.80	30.00	21.74	22.08	24.90	31.65	17.80
230	0.85	4.50	2.43	3.80	30.33	21.75	22.18	25.24	31.98	17.90
235	0.85	4.50	2.43	3.80	30.55	22.10	22.39	25.35	32.20	17.95
240	0.85	4.55	2.48	3.80	30.88	22.10	22.61	25.55	32.31	18.10
245	0.85	4.60	2.43	3.90	31.10	22.30	22.71	25.68	32.53	18.15
250	0.85	4.65	2.43	3.95	31.43	22.47	22.82	25.81	32.64	18.30
255	0.85	4.70	2.43	3.95	31.65	22.54	23.03	25.90	32.86	18.40
260	0.85	4.75	2.43	4.05	31.87	22.58	23.13	25.88	33.08	18.50
265	0.85	4.80	2.54	4.15	32.09	22.80	23.35	25.98	33.19	18.65
270	0.85	4.85	2.59	4.15	32.42	23.01	23.56	26.04	33.41	18.75

Appendix I: cont...

Time	xVE1	mVE1	xVE2	mVE2	xAND2	mAND2	xNI2	mNI2	xAC2	mAC2
275	0.90	4.90	2.59	4.25	32.64	23.12	23.77	26.19	33.41	18.90
280	0.90	4.95	2.64	4.25	32.86	23.19	23.98	26.29	33.74	19.00
285	0.95	4.95	2.69	4.30	33.08	23.31	24.08	26.41	33.85	19.15
290	0.95	5.00	2.69	4.35	33.30	23.36	24.19	26.48	34.07	19.25
295	0.95	5.05	2.75	4.35	33.52	23.43	24.30	26.57	34.18	19.35
300	0.95	5.10	2.75	4.40	33.74	23.52	24.51	26.63	34.40	19.50
305	0.95	5.10	2.80	4.45	33.96	23.55	24.72	26.75	34.51	19.65
310	0.95	5.15	2.80	4.50	34.18	23.97	24.82	26.84	34.62	19.75
315	0.95	5.15	2.85	4.55	34.40	24.04	24.93	26.90	34.84	19.85
320	0.95	5.20	2.90	4.60	34.62	24.12	25.04	27.07	34.95	20.00
325	0.95	5.25	2.90	4.65	34.84	24.18	25.14	27.08	35.16	20.15
330	0.95	5.25	2.90	4.70	35.05	24.19	25.25	27.42	35.27	20.20
335	0.95	5.30	2.96	4.75	35.27	24.30	25.46	27.36	35.38	20.35
340	0.95	5.30	2.96	4.80	35.49	24.66	25.56	27.43	35.60	20.45
345	0.95	5.35	3.01	4.85	35.60	24.74	25.77	27.60	35.71	20.60
350	0.95	5.40	3.01	4.90	35.93	24.79	25.88	27.70	35.93	20.75
355	1.00	5.40	3.06	4.95	36.15	24.88	25.99	27.80	35.93	20.85
360	1.00	5.40	3.06	4.95	36.37	24.86	26.09	27.84	36.04	21.00
365	1.00	5.45	3.12	4.95	36.59	25.00	26.30	28.15	36.04	21.05
370	1.00	5.45	3.12	5.00	36.70	25.07	26.51	28.42	36.26	21.20
375	1.00	5.45	3.17	5.05	36.92	25.11	26.62	28.43	36.26	21.30
380	1.06	5.45	3.17	5.05	37.03	25.18	26.62	28.52	36.48	21.40
385	1.06	5.45	3.22	5.10	37.14	25.40	26.83	28.53	36.59	21.50
390	1.06	5.45	3.22	5.10	37.58	25.56	26.94	28.65	36.70	21.60
395	1.06	5.45	3.22	5.15	37.47	25.63	27.15	28.73	36.70	21.70
400	1.06	5.45	3.27	5.20	37.69	25.67	27.36	28.74	37.03	21.80
405	1.06	5.45	3.27	5.20	37.91	25.79	27.57	28.80	37.14	21.95
410	1.06	5.45	3.27	5.20	38.02	25.80	27.68	28.80	37.25	22.05
415	1.11	5.45	3.33	5.20	38.13	26.02	27.78	28.83	37.36	22.15
420	1.16	5.45	3.33	5.25	38.35	26.03	27.89	28.90	37.36	22.25
425	1.16	5.45	3.38	5.25	38.57	26.09	27.89	29.10	37.47	22.45
430	1.16	5.45	3.38	5.25	38.79	26.03	27.99	29.36	37.58	22.50
435	1.16	5.50	3.43	5.25	38.90	26.32	28.10	29.33	37.69	22.60
440	1.16	5.50	3.43	5.25	39.01	26.34	28.20	29.39	37.80	22.70
445	1.16	5.50	3.43	5.25	39.12	26.38	28.31	29.58	37.91	22.80
450	1.16	5.50	3.43	5.25	39.34	26.44	28.42	29.57	38.02	22.90
455	1.16	5.50	3.43	5.25	39.56	26.49	28.52	29.57	38.13	23.00
460	1.21	5.50	3.49	5.25	39.67	26.60	28.63	29.59	38.24	23.10
465	1.21	5.50	3.49	5.25	39.89	26.70	28.73	29.56	38.35	23.25
470	1.21	5.50	3.54	5.30	40.00	26.87	28.84	29.89	38.46	23.35
475	1.21	5.50	3.54	5.30	40.11	27.01	28.94	29.88	38.57	23.50
480	1.21	5.50	3.59	5.30	40.33	27.06	29.15	29.88	38.68	23.60
485	1.21	5.50	3.59	5.30	40.44	27.05	29.26	29.93	38.68	23.70
490	1.27	5.50	3.59	5.30	40.66	27.05	29.47	29.87	38.79	23.80
495	1.27	5.50	3.64	5.30	40.77	27.12	29.47	30.17	38.90	23.95
500	1.27	5.50	3.64	5.30	40.99	27.39	29.58	30.20	39.01	24.00
505	1.27	5.55	3.64	5.30	41.10	27.40	29.68	30.21	39.01	24.10
510	1.27	5.55	3.70	5.30	41.21	27.40	29.68	30.26	39.12	24.15
515	1.27	5.55	3.70	5.30	41.32	27.50	29.89	30.27	39.23	24.25
520	1.27	5.55	3.70	5.35	41.32	27.60	30.00	30.27	39.45	24.35
525	1.27	5.55	3.70	5.35	41.65	27.65	30.21	30.23	39.56	24.40
530	1.32	5.55	3.70	5.35	41.76	27.70	30.32	30.62	39.67	24.50
535	1.32	5.60	3.75	5.35	41.87	27.72	30.42	30.61	39.78	24.55
540	1.32	5.60	3.75	5.35	41.98	27.80	30.53	30.50	39.89	24.65
545	1.32	5.60	3.75	5.35	42.20	27.81	30.63	30.39	40.00	24.70
550	1.32	5.60	3.80	5.35	42.31	27.82	30.69	30.56	40.00	24.75
555	1.32	5.60	3.80	5.35	42.42	27.80	30.74	30.34	40.11	24.80

Appendix I: cont...

Time	xVE1	mVE1	xVE2	mVE2	xAND2	mAND2	xNI2	mNI2	xAC2	mAC2
560	1.32	5.60	3.86	5.35	42.53	28.02	30.85	30.57	40.22	24.85
565	1.32	5.60	3.86	5.35	42.75	28.04	30.95	30.49	40.33	24.90
570	1.32	5.60	3.91	5.35	42.86	28.15	31.06	30.74	40.33	24.95
575	1.32	5.60	3.91	5.35	42.97	28.15	31.16	30.58	40.44	25.00
580	1.37	5.60	3.91	5.35	43.08	28.15	31.27	30.56	40.55	25.05
585	1.37	5.60	3.91	5.35	43.19	28.32	31.37	30.60	40.66	25.10
590	1.37	5.60	3.91	5.35	43.41	28.47	31.48	30.89	40.66	25.15
595	1.37	5.60	3.96	5.40	43.52	28.49	31.58	30.70	40.77	25.20
600	1.37	5.65	3.96	5.40	43.63	28.48	31.58	30.89	40.77	25.25
605	1.37	5.65	3.96	5.40	43.74	28.80	31.69	30.89	40.99	25.35
610	1.37	5.65	3.96	5.40	43.85	28.66	31.80	30.89	41.10	25.40
615	1.43	5.65	4.01	5.40	43.96	28.70	31.80	30.82	41.10	25.45
620	1.43	5.65	4.01	5.40	44.07	28.69	32.01	31.12	41.21	25.50
625	1.43	5.65	4.07	5.40	44.23	28.66	32.11	31.07	41.32	25.55
630	1.43	5.65	4.07	5.40	44.40	28.66	32.22	31.10	41.32	25.60
635	1.43	5.65	4.12	5.45	44.51	28.83	32.27	31.02	41.43	25.60
640	1.48	5.70	4.12	5.45	44.62	28.82	32.32	31.10	41.54	25.65
645	1.48	5.70	4.12	5.45	44.73	28.79	32.43	31.10	41.59	25.70
650	1.48	5.70	4.17	5.45	44.84	28.77	32.54	31.30	41.65	25.75
655	1.48	5.70	4.17	5.45	44.95	28.98	32.54	31.29	41.76	25.80
660	1.48	5.70	4.17	5.45	45.05	28.98	32.64	31.26	41.76	25.80
665	1.53	5.70	4.17	5.45	45.16	28.96	32.80	31.20	41.87	25.80
670	1.53	5.70	4.23	5.45	45.27	28.92	32.85	31.30	41.98	25.85
675	1.53	5.70	4.23	5.45	45.38	29.09	32.96	31.30	41.98	25.85
680	1.53	5.70	4.23	5.45	45.55	29.16	33.01	31.47	42.09	25.85
685	1.53	5.70	4.28	5.45	45.60	29.17	33.06	31.45	42.09	25.85
690	1.58	5.70	4.28	5.45	45.71	29.15	33.17	31.38	42.20	25.90
695	1.58	5.70	4.33	5.50	45.82	29.15	33.27	31.37	42.25	25.90
700	1.58	5.70	4.33	5.50	45.93	29.14	33.33	31.31	42.31	25.90
705	1.58	5.75	4.33	5.50	46.10	29.37	33.38	31.38	42.36	25.95
710	1.58	5.75	4.44	5.50	46.15	29.37	33.49	31.50	42.42	25.95
715	1.58	5.75	4.49	5.50	46.32	29.36	33.59	31.50	42.53	25.95
720	1.58	5.75	4.54	5.50	46.43	29.44	33.59	31.57	42.58	26.00
725	1.64	5.75	4.60	5.50	46.54	29.39	33.75	31.56	42.64	26.00
730	1.64	5.75	4.65	5.50	46.70	29.53	33.80	31.58	42.69	26.00
735	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
740	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I: cont...

Time	xAND1	mAND1	xLU1	mLU1	xNI1	mNI1	xAC4	mAC4	xAND4	mAND4
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5.70	2.00	4.95	6.99	2.70	0.90	7.23	3.70	5.61	2.98
10	7.39	2.90	7.36	8.14	3.88	1.00	9.71	5.00	8.20	3.99
15	10.77	3.60	9.12	8.97	4.86	1.14	12.19	6.64	9.71	4.39
20	13.42	4.10	10.55	9.86	5.61	1.92	13.81	7.00	11.12	4.80
25	15.00	4.60	11.65	10.42	6.47	2.30	15.43	7.90	12.30	5.19
30	16.37	4.98	12.86	11.24	7.01	2.56	16.83	8.50	13.77	5.75
35	17.43	5.50	13.63	11.53	7.55	2.67	18.35	9.00	14.96	5.90
40	18.38	5.80	14.62	12.16	7.99	2.74	19.21	9.60	15.93	6.30
45	19.54	6.80	14.95	12.43	8.42	2.90	20.18	10.00	16.68	6.55
50	20.18	6.98	15.60	12.75	8.85	3.13	21.15	10.40	17.87	6.90
55	20.81	7.06	16.26	12.90	9.17	3.43	22.12	10.70	18.73	7.23
60	21.55	7.30	16.81	13.37	9.60	3.64	22.99	11.10	19.49	7.50
65	22.18	7.26	17.47	13.66	10.14	4.11	23.63	11.40	20.24	7.86
70	22.82	7.50	17.80	13.90	10.47	4.40	24.28	11.75	20.89	8.20
75	23.35	8.40	18.24	14.00	10.79	4.60	24.98	12.10	21.43	8.37
80	23.77	8.86	18.68	14.28	11.12	4.65	25.58	12.41	21.86	8.60
85	24.30	9.00	19.12	14.57	11.44	4.75	26.22	12.70	22.73	8.70
90	24.82	9.60	19.56	14.61	11.76	4.90	26.76	13.05	23.16	9.30
95	25.35	9.73	19.89	14.89	12.09	5.17	27.19	13.35	23.48	9.50
100	25.67	9.87	20.33	14.98	12.30	5.25	27.73	13.70	23.81	9.60
105	26.09	10.17	20.66	15.31	12.73	5.57	28.38	13.80	24.35	9.80
110	26.41	10.97	20.99	15.37	12.95	5.64	28.92	13.90	24.99	9.90
115	26.83	10.98	21.32	15.38	13.17	5.67	29.35	14.00	25.53	10.00
120	27.25	11.19	21.54	15.72	13.49	5.84	29.78	14.60	25.86	10.47
125	27.68	11.40	21.87	15.70	13.60	6.20	30.11	14.77	26.40	10.50
130	27.99	11.86	22.31	15.98	14.03	6.44	30.43	14.90	26.83	10.77
135	28.31	12.07	22.64	16.03	14.24	6.47	31.14	14.90	27.37	10.90
140	28.63	12.12	22.86	16.37	14.46	6.70	31.29	15.00	27.69	11.09
145	28.94	12.71	23.19	16.38	14.68	6.78	31.73	15.12	28.34	11.15
150	29.37	12.77	23.41	16.50	14.89	6.80	32.16	15.20	28.77	11.30
155	29.58	12.80	23.74	16.70	15.11	6.85	32.48	15.30	29.31	11.70
160	29.89	13.22	23.85	16.77	15.32	6.95	32.81	15.60	29.63	11.76
165	30.21	13.32	24.18	16.81	15.65	7.05	33.13	15.75	29.96	11.85
170	30.63	13.38	24.40	16.90	15.86	7.10	33.45	15.80	30.39	11.90
175	30.85	13.49	24.73	17.10	16.08	7.20	33.78	15.90	30.71	12.10
180	31.06	13.58	24.84	17.22	16.19	7.30	34.10	16.20	31.08	12.46
185	31.37	13.72	25.05	17.27	16.29	7.35	34.42	16.30	31.47	12.50
190	31.58	14.00	25.27	17.33	16.51	7.50	34.64	16.41	31.79	12.93
195	31.80	14.16	25.49	17.50	16.62	7.61	34.96	16.42	32.12	12.99
200	32.11	14.40	25.71	17.70	16.73	8.06	35.29	16.60	32.55	13.01
205	32.32	14.97	25.93	17.87	16.83	8.11	35.61	16.70	32.76	13.10
210	32.54	15.10	26.04	17.94	17.16	8.50	35.94	16.90	33.19	13.20
215	32.85	15.20	26.26	17.98	17.37	8.60	36.15	17.00	33.41	13.29
220	33.06	15.30	26.37	18.04	17.59	8.67	36.37	17.20	33.63	13.30
225	33.27	15.60	26.59	18.11	17.81	8.70	36.69	17.30	33.84	13.80
230	33.49	15.73	26.81	18.20	17.91	8.90	36.80	17.38	34.17	13.95
235	33.70	15.90	27.03	18.40	18.13	9.00	37.12	17.50	34.49	14.10
240	33.91	16.00	27.14	18.57	18.24	9.19	37.23	17.60	34.81	14.20
245	34.23	16.20	27.25	18.60	18.35	9.20	37.45	17.65	35.14	14.35
250	34.44	16.30	27.47	18.63	18.45	9.21	37.77	17.70	35.46	14.45
255	34.65	16.82	27.58	18.68	18.67	9.34	37.88	17.75	35.68	14.60
260	34.75	16.87	27.80	18.75	18.78	9.35	38.09	17.85	36.00	14.75
265	34.96	17.09	27.91	19.05	18.99	9.40	38.31	17.90	36.22	14.85
270	35.18	17.11	28.02	19.06	19.10	9.50	38.53	18.00	36.54	14.95
275	35.39	17.12	28.13	19.10	19.21	9.65	38.85	18.20	36.86	15.05
280	35.60	17.18	28.35	19.15	19.42	9.70	38.96	18.30	37.19	15.15

Appendix I: cont...

Time	xAND1	mAND1	xLU1	mLU1	xNI1	mNI1	xAC4	mAC4	xAND4	mAND4
285	35.70	17.30	28.46	19.20	19.53	9.75	39.17	18.35	37.51	15.25
290	35.92	17.40	28.57	19.22	19.75	9.80	39.39	18.40	37.73	15.35
295	36.02	17.50	28.68	19.24	19.80	10.01	39.60	18.45	38.05	15.50
300	36.23	17.60	28.90	19.25	19.96	10.02	39.82	18.50	38.27	15.60
305	36.44	17.90	29.01	19.27	20.07	10.15	40.04	18.55	38.59	15.70
310	36.55	18.08	29.12	19.27	20.13	10.20	40.25	18.60	38.81	15.85
315	36.76	18.09	29.23	19.32	20.29	10.60	40.47	18.65	39.13	15.90
320	36.97	18.12	29.34	19.39	20.40	10.70	40.58	18.74	39.35	16.00
325	37.08	18.16	29.45	19.43	20.61	10.75	40.79	18.80	39.67	16.15
330	37.18	18.30	29.78	19.46	20.72	10.80	41.01	18.85	39.88	16.20
335	37.39	18.40	29.89	19.46	20.83	10.85	41.12	18.90	40.21	16.50
340	37.61	18.54	30.00	19.51	20.94	10.90	41.33	19.11	40.42	16.60
345	37.71	18.57	30.00	19.54	21.04	10.95	41.55	19.15	40.64	16.62
350	37.82	18.87	30.11	19.55	21.15	11.00	41.65	19.20	40.96	16.63
355	38.03	19.04	30.22	19.63	21.26	11.00	41.87	19.25	41.18	16.64
360	38.13	19.12	30.33	19.65	21.37	11.05	41.98	19.30	41.40	16.66
365	38.24	19.17	30.44	19.68	21.47	11.10	42.19	19.62	41.61	16.70
370	38.45	19.24	30.55	19.75	21.58	11.15	42.30	19.72	41.83	16.85
375	38.56	19.34	30.66	19.80	21.74	11.20	42.52	19.73	42.15	17.09
380	38.77	19.40	30.77	19.87	21.80	11.46	42.63	19.80	42.37	17.10
385	38.87	19.54	30.88	19.90	21.91	11.53	42.73	20.00	42.58	17.11
390	38.98	19.65	30.99	19.94	22.12	11.60	42.95	20.10	42.80	17.20
395	39.08	19.81	30.99	19.97	22.23	11.70	43.06	20.15	42.91	17.25
400	39.19	19.90	31.10	20.04	22.34	11.75	43.17	20.21	43.12	17.30
405	39.40	20.09	31.21	20.06	22.45	11.85	43.38	20.25	43.34	17.38
410	39.51	20.10	31.32	20.07	22.55	11.90	43.49	20.33	43.66	17.50
415	39.72	20.12	31.32	20.08	22.66	12.00	43.71	20.35	43.77	17.80
420	39.82	20.25	31.43	20.10	22.88	12.16	43.81	20.40	43.99	17.85
425	39.93	20.26	31.54	20.20	22.99	12.38	43.92	20.44	44.20	18.01
430	40.04	20.40	31.54	20.25	23.09	12.90	43.97	20.50	44.42	18.02
435	40.14	20.40	31.65	20.27	23.15	12.95	44.14	20.56	44.74	18.10
440	40.25	20.50	31.76	20.30	23.20	13.00	44.24	20.60	44.96	18.17
445	40.35	20.80	31.87	20.40	23.31	13.05	44.35	20.63	45.28	18.20
450	40.46	21.00	31.87	20.45	23.42	13.10	44.46	20.65	45.60	18.29
455	40.67	21.20	31.88	20.45	23.53	13.15	44.57	20.70	45.71	18.32
460	40.77	21.20	32.09	20.46	23.58	13.38	44.68	20.74	45.93	18.46
465	40.99	21.24	32.20	20.47	23.63	13.45	44.78	20.74	46.14	18.60
470	41.09	21.26	32.31	20.47	23.69	13.50	44.89	20.75	46.25	18.80
475	41.20	21.27	32.31	20.50	23.85	13.55	45.00	20.78	46.47	18.89
480	41.30	21.28	32.42	20.50	23.96	13.76	45.11	20.80	46.68	18.87
485	41.51	21.30	32.53	20.50	24.01	13.80	45.22	20.85	46.90	19.02
490	41.62	21.31	32.64	20.58	24.06	13.85	45.32	20.89	47.12	19.02
495	41.73	21.32	32.75	20.58	24.17	13.90	45.43	20.90	47.22	19.16
500	41.83	21.40	32.75	20.51	24.28	14.02	45.54	21.00	47.44	19.17
505	41.88	21.47	32.86	20.70	24.39	14.17	45.65	21.01	47.55	19.32
510	41.94	21.53	32.97	20.70	24.50	14.20	45.76	21.02	47.76	19.31
515	42.04	21.70	32.98	20.80	24.60	14.25	45.86	21.03	47.98	19.44
520	42.20	21.87	33.08	20.80	24.82	14.26	45.97	21.04	48.30	19.70
525	42.25	21.88	33.19	20.85	24.93	14.27	46.08	21.05	48.30	19.80
530	42.36	21.91	33.30	20.85	24.98	14.27	46.19	21.07	48.52	19.90
535	42.46	21.91	33.30	20.85	25.04	14.27	46.40	21.09	48.66	19.98
540	42.57	22.05	33.41	20.85	25.14	14.27	46.51	21.11	48.83	20.00
545	42.68	22.13	33.52	20.86	25.25	14.27	46.62	21.13	49.06	20.05
550	42.78	22.13	33.52	20.90	25.36	14.27	46.73	21.15	49.17	20.10
555	42.89	22.12	33.63	21.00	25.47	14.27	46.94	21.17	49.38	20.15
560	42.99	22.24	33.74	21.00	25.47	14.27	46.94	21.19	49.60	20.23
565	43.10	22.23	33.74	21.00	25.68	14.32	47.05	21.21	49.81	20.34

Appendix I: cont...

Time	xAND1	mAND1	xLU1	mLU1	xNI1	mNI1	xAC4	mAC4	xAND4	mAND4
570	43.20	22.25	33.85	21.05	25.68	14.33	47.16	21.24	49.92	20.35
575	43.31	22.25	33.96	21.10	25.79	14.33	47.16	21.25	50.03	20.36
580	43.42	22.35	33.96	21.10	25.79	14.41	47.27	21.27	50.24	20.37
585	43.52	22.40	34.07	21.10	25.90	14.41	47.37	21.29	50.35	20.38
590	43.63	22.58	34.07	21.15	25.95	14.41	47.48	21.31	50.57	20.39
595	43.73	22.64	34.18	21.15	26.01	14.53	47.59	21.34	50.68	20.40
600	43.79	22.64	34.18	21.15	26.12	14.60	47.79	21.36	50.78	20.41
605	43.89	22.70	34.29	21.20	26.17	14.77	47.81	21.39	51.00	20.42
610	43.94	22.83	34.40	21.20	26.33	14.78	47.81	21.40	51.11	20.43
615	44.05	22.88	34.40	21.20	26.44	14.75	47.91	21.50	51.32	20.44
620	44.15	22.90	34.45	21.27	26.44	14.70	48.02	21.52	51.43	20.46
625	44.26	23.01	34.51	21.27	26.49	14.75	48.13	21.54	51.65	20.48
630	44.37	23.20	34.56	21.27	26.55	14.80	48.24	21.56	51.76	20.50
635	44.42	23.35	34.62	21.30	26.55	14.88	48.35	21.60	51.97	20.52
640	44.52	23.40	34.73	21.30	26.55	14.87	48.35	21.65	52.19	20.54
645	44.63	23.55	34.73	21.30	26.65	14.84	48.45	21.66	52.29	20.69
650	44.68	23.55	34.84	21.35	26.71	14.85	48.56	21.68	52.40	20.70
655	44.79	23.55	34.84	21.35	26.76	14.90	48.67	21.70	52.51	20.75
660	44.89	23.54	34.95	21.35	26.92	14.95	48.78	21.71	52.62	20.80
665	44.95	23.55	35.00	21.37	26.98	14.95	48.88	21.73	52.73	20.85
670	45.05	23.60	35.05	21.37	27.03	14.96	48.88	21.75	52.94	20.87
675	45.11	23.60	35.05	21.37	27.09	14.96	48.99	21.77	53.05	20.90
680	45.21	23.68	35.16	21.57	27.19	15.00	49.10	21.78	53.16	20.95
685	45.32	23.68	35.16	21.80	27.30	15.05	49.10	21.80	53.37	21.10
690	45.42	23.77	35.27	21.80	27.41	15.07	49.21	21.82	53.48	21.20
695	45.48	23.80	35.27	22.00	27.46	15.07	49.32	21.84	53.59	21.25
700	45.58	23.90	35.38	22.00	27.52	15.07	49.32	21.86	53.81	21.29
705	45.63	23.99	35.44	22.03	27.57	15.07	49.42	21.89	53.62	21.35
710	45.74	24.00	35.49	22.03	27.63	15.22	49.53	21.91	54.02	21.40
715	45.79	24.01	35.55	22.04	27.73	15.21	49.64	21.92	54.13	21.45
720	45.95	24.08	35.60	22.04	27.79	15.26	49.64	21.94	54.24	21.50
725	0.00	0.00	0.00	0.00	27.84	15.26	49.75	21.96	54.24	21.57
730	0.00	0.00	0.00	0.00	27.95	15.26	0.00	0.00	54.45	21.50
735	0.00	0.00	0.00	0.00	28.00	15.26	0.00	0.00	0.00	0.00
740	0.00	0.00	0.00	0.00	28.06	15.37	0.00	0.00	0.00	0.00

Appendix I: cont...

Time	xAC1	mAC1	xNI4	mNI4	xAND3	mAND3	xNI3	mNI3	xAC3	mAC3
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5.49	6.16	4.40	7.10	5.05	4.89	3.13	2.60	9.67	3.23
10	7.58	7.02	6.04	8.00	7.25	5.15	5.29	3.05	9.56	4.06
15	9.34	7.81	7.36	8.76	8.02	6.62	6.15	3.66	11.43	5.06
20	10.55	8.48	8.35	9.20	10.55	7.47	7.01	4.23	13.19	6.07
25	11.76	9.05	9.34	9.80	11.87	8.32	8.09	4.66	14.40	6.60
30	12.86	9.64	10.00	9.94	13.19	8.76	8.53	5.00	15.49	7.14
35	13.63	10.21	11.21	10.03	14.18	9.17	9.06	5.26	16.92	7.87
40	14.40	10.60	12.09	10.98	15.16	9.58	9.60	5.70	18.02	8.28
45	15.16	10.77	12.75	11.10	16.37	10.02	10.25	5.96	19.23	8.60
50	15.82	11.09	13.41	11.30	17.14	10.46	10.90	6.06	20.00	8.87
55	16.48	11.57	14.07	12.15	17.91	11.20	11.44	6.40	20.55	9.44
60	17.03	11.69	14.73	12.80	18.57	11.30	11.65	6.60	21.21	9.67
65	17.47	11.97	15.27	13.00	19.34	11.75	12.09	6.80	21.76	10.10
70	17.91	12.28	15.82	13.10	19.89	11.90	12.73	6.90	22.53	10.15
75	18.46	12.35	16.26	13.30	20.55	12.16	12.95	7.23	23.19	10.57
80	19.23	12.60	16.81	13.86	21.10	12.62	13.06	7.50	23.85	10.81
85	19.45	12.89	17.25	13.96	21.65	12.70	13.92	7.70	24.51	11.02
90	19.89	13.00	17.80	14.30	22.20	13.00	14.35	7.90	25.16	11.26
95	20.22	13.17	18.24	14.47	22.75	13.10	14.68	8.20	25.82	11.67
100	20.66	13.30	18.68	14.60	23.08	13.20	15.00	8.51	26.26	11.89
105	21.10	13.52	19.01	15.00	23.63	13.55	15.32	8.70	26.59	12.08
110	21.43	13.60	19.45	15.04	23.96	13.60	15.54	8.90	26.92	12.40
115	21.76	13.84	19.78	15.10	24.62	13.98	15.76	9.00	27.36	12.52
120	22.20	13.95	20.33	15.30	25.16	14.10	15.86	9.10	27.69	12.60
125	22.53	14.18	20.66	15.45	25.71	14.44	16.08	9.20	28.02	12.90
130	22.86	14.21	21.10	15.50	26.26	14.55	16.19	9.30	28.35	12.94
135	23.08	14.48	21.43	15.60	26.59	14.65	16.62	9.44	28.79	13.14
140	23.52	14.52	21.76	16.10	27.03	14.90	16.83	9.50	29.01	13.35
145	23.74	14.77	22.09	16.24	27.36	15.00	17.05	9.60	29.34	13.40
150	24.07	14.80	22.42	16.30	27.80	15.37	17.29	9.65	29.67	13.59
155	24.29	15.00	22.75	16.50	28.13	15.42	17.59	9.70	30.00	13.62
160	24.51	15.07	23.08	16.84	28.57	15.88	17.91	9.75	30.22	13.83
165	24.84	15.10	23.30	16.93	28.90	16.30	18.13	9.80	30.44	14.05
170	25.05	15.37	23.63	17.14	29.23	16.40	18.45	10.00	30.66	14.30
175	25.27	15.40	23.96	17.30	29.67	16.56	18.67	10.28	30.99	14.40
180	25.49	15.49	24.29	17.40	30.11	16.66	18.99	10.32	31.21	14.50
185	25.82	15.70	24.51	17.45	30.33	16.70	19.32	10.50	31.43	14.60
190	25.93	15.75	24.84	17.55	30.77	16.80	19.75	10.60	31.65	14.90
195	26.15	15.81	25.16	17.70	31.10	17.13	20.18	10.76	31.87	14.95
200	26.37	15.90	25.38	17.80	31.43	17.23	20.61	10.85	32.09	15.00
205	26.59	16.19	25.60	17.85	31.76	17.37	20.83	11.00	32.20	15.05
210	26.81	16.22	25.93	18.16	32.09	17.41	21.04	11.10	32.42	15.10
215	27.03	16.32	26.15	18.20	32.42	17.86	21.15	11.20	32.53	15.21
220	27.14	16.37	26.37	18.25	32.75	17.93	21.15	11.40	32.75	15.25
225	27.36	16.42	26.70	18.30	33.08	17.98	21.37	11.55	32.97	15.30
230	27.58	16.70	26.92	18.40	33.30	18.20	21.58	11.60	33.08	15.35
235	27.69	16.83	27.14	18.71	33.63	18.42	21.69	11.70	33.19	15.40
240	28.02	16.90	27.36	18.90	33.96	18.50	21.91	11.80	33.41	15.51
245	28.02	16.95	27.69	19.00	34.29	18.56	22.12	12.00	33.63	15.60
250	28.24	16.99	27.91	19.05	34.40	18.61	22.34	12.25	33.74	15.75
255	28.35	17.10	28.13	19.10	34.62	18.77	22.66	12.35	33.96	15.80
260	28.42	17.30	28.35	19.15	34.95	19.20	22.77	12.50	34.18	15.95
265	28.68	17.45	28.68	19.20	35.16	19.29	22.88	12.60	34.40	16.01
270	28.79	17.60	29.01	19.30	35.49	19.35	23.09	12.70	34.51	16.03
275	29.01	17.73	29.12	19.40	35.71	19.50	23.31	12.70	34.62	16.05
280	29.23	17.79	29.34	19.67	36.04	19.60	23.53	12.75	34.73	16.10

Appendix I: cont...

Time	xAC1	mAC1	xNI4	mNI4	xAND3	mAND3	xNI3	mNI3	xAC3	mAC3
285	29.34	17.85	29.56	19.75	36.26	19.70	23.74	12.80	34.84	16.15
290	29.45	17.90	29.67	19.80	36.59	19.80	23.85	12.85	34.95	16.20
295	29.56	17.94	29.89	20.09	36.81	20.05	23.96	12.90	35.05	16.25
300	29.78	18.00	30.11	20.19	37.14	20.10	24.06	12.95	35.16	16.30
305	29.78	18.05	30.22	20.25	37.36	20.20	24.17	13.00	35.38	16.35
310	30.00	18.30	30.65	20.25	37.69	20.30	24.28	13.10	35.49	16.50
315	30.11	18.37	30.66	20.40	37.91	20.30	24.50	13.15	35.60	16.56
320	30.33	18.40	30.77	20.50	38.13	20.40	24.82	13.20	35.71	16.60
325	30.44	18.45	31.10	20.78	38.35	20.50	24.93	13.25	35.93	16.61
330	30.55	18.50	31.21	20.85	38.57	20.90	25.04	13.30	36.04	16.80
335	30.66	18.54	31.43	20.90	38.79	21.07	25.14	13.41	36.26	16.84
340	30.88	18.60	31.65	20.95	38.90	21.10	25.25	13.50	36.37	16.85
345	30.99	18.80	31.87	21.00	39.12	21.20	25.36	13.70	36.59	16.90
350	31.10	18.85	31.98	21.13	39.56	21.49	25.58	13.83	36.70	16.95
355	31.21	18.87	32.09	21.28	39.78	21.50	25.90	13.98	36.81	17.07
360	31.32	18.88	32.42	21.29	40.00	21.55	26.01	14.00	36.92	17.10
365	31.43	18.90	32.47	21.40	40.22	21.76	26.33	14.09	37.03	17.15
370	31.54	18.93	32.64	21.45	40.44	21.80	26.55	14.25	37.25	17.29
375	31.65	19.15	32.86	21.57	40.66	21.90	26.76	14.30	37.36	17.30
380	31.76	19.25	33.02	21.60	40.88	22.00	26.87	14.53	37.36	17.31
385	31.98	19.33	33.19	21.65	41.10	22.10	27.09	14.70	37.47	17.34
390	32.09	19.37	33.30	21.70	41.21	22.10	27.19	14.75	37.58	17.35
395	32.20	19.39	33.52	21.75	41.54	22.37	27.30	14.80	37.80	17.36
400	32.31	19.40	33.63	21.80	41.76	22.43	27.30	14.85	37.91	17.38
405	32.42	19.50	33.85	21.85	41.87	22.50	27.30	14.90	38.02	17.40
410	32.53	19.60	33.96	21.96	42.09	22.55	27.52	15.00	38.19	17.42
415	32.75	19.65	34.18	22.00	42.31	22.60	27.63	15.05	38.35	17.44
420	32.75	19.70	34.29	22.10	42.42	22.70	27.73	15.10	38.46	17.46
425	32.86	19.74	34.51	22.26	42.75	22.80	27.95	15.15	38.52	17.48
430	32.86	19.75	34.62	22.35	42.86	23.09	28.17	15.20	38.68	17.60
435	32.97	19.80	34.62	22.54	43.08	23.28	28.27	15.22	38.79	17.70
440	33.08	19.82	34.84	22.60	43.30	23.37	28.27	15.23	38.90	17.72
445	33.19	19.87	34.95	22.75	43.41	23.43	28.38	15.25	39.01	17.72
450	33.30	19.89	35.16	22.80	43.63	23.50	28.49	15.29	39.23	17.74
455	33.30	19.90	35.27	22.86	43.74	23.55	28.60	15.32	39.34	17.76
460	33.41	19.94	35.44	22.90	43.96	23.60	28.71	15.35	39.45	17.78
465	33.52	19.96	35.60	22.95	44.18	23.80	28.71	15.40	39.46	17.80
470	33.63	19.98	35.71	23.00	44.29	23.90	28.81	15.45	39.67	17.82
475	33.74	20.00	35.82	23.05	44.51	23.97	29.03	15.60	39.78	17.84
480	33.85	20.03	36.04	23.40	44.73	24.00	29.14	15.60	39.79	17.86
485	33.85	20.07	36.15	23.51	44.84	24.05	29.24	15.95	40.00	17.88
490	33.96	20.09	36.26	23.55	45.05	24.10	29.35	16.00	40.11	17.89
495	34.07	20.10	36.37	23.60	45.16	24.20	29.46	16.20	40.22	17.90
500	34.18	20.12	36.48	23.65	45.38	24.40	29.57	16.30	40.38	18.00
505	34.18	20.14	36.48	23.70	45.60	24.45	29.68	16.50	40.49	18.10
510	34.29	20.17	36.81	23.75	45.71	24.50	29.89	16.60	40.55	18.20
515	34.40	20.18	36.92	23.75	45.82	24.55	30.00	16.70	40.56	18.24
520	34.40	20.19	37.03	23.75	46.04	24.60	30.22	16.70	40.77	18.26
525	34.51	20.20	37.14	23.80	46.15	24.65	30.32	17.20	40.88	18.28
530	34.62	20.22	37.36	23.84	46.37	24.70	30.43	17.21	40.99	18.30
535	34.62	20.25	37.47	23.86	46.48	24.90	30.54	17.22	41.10	18.34
540	34.73	20.31	37.58	23.87	46.70	24.95	30.65	17.23	41.21	18.36
545	34.84	20.36	37.69	23.88	46.81	25.00	30.76	17.24	41.32	18.38
550	34.84	20.38	37.80	23.90	47.03	25.05	30.86	17.25	41.37	18.41
555	34.95	20.39	37.91	23.92	47.14	25.10	30.97	17.26	41.43	18.42
560	35.05	20.40	38.02	23.94	47.25	25.15	31.08	17.27	41.54	18.43
565	35.05	20.42	38.13	23.96	47.47	25.25	31.29	17.28	41.65	18.44

Appendix I: cont...

Time	xAC1	mAC1	xNI4	mNI4	xAND3	mAND3	xNI3	mNI3	xAC3	mAC3
570	35.16	20.45	38.24	24.00	47.58	25.30	31.40	17.29	41.76	18.45
575	35.27	20.46	38.35	24.00	47.80	25.35	31.51	17.30	41.87	18.46
580	35.27	20.50	38.46	24.05	47.91	25.40	31.73	17.31	41.98	18.47
585	35.38	20.57	38.57	24.06	48.02	25.55	31.73	17.32	42.09	18.47
590	35.49	20.58	38.68	24.07	48.24	25.60	31.83	17.33	42.20	18.49
595	35.49	20.62	38.79	24.19	48.46	25.65	31.94	17.34	42.31	18.51
600	35.60	20.70	38.90	24.23	48.57	25.70	32.05	17.35	42.42	18.69
605	35.71	20.72	39.01	24.25	48.68	25.75	32.16	17.36	42.53	18.70
610	35.71	20.73	39.23	24.28	48.79	25.80	32.27	17.37	42.64	18.71
615	35.82	20.74	39.34	24.43	48.90	25.85	32.37	17.38	42.86	18.72
620	35.82	20.75	39.45	24.49	49.12	25.90	32.48	17.39	42.97	18.73
625	35.93	20.76	39.56	24.50	49.23	25.95	32.59	17.40	43.08	18.74
630	35.93	20.77	39.56	24.51	49.45	26.00	32.59	17.41	43.30	18.75
635	36.04	20.78	39.67	24.60	49.67	26.05	32.70	17.42	43.30	18.76
640	36.15	20.79	39.78	24.72	49.78	26.10	32.70	17.43	43.41	18.77
645	36.26	20.80	39.89	24.73	50.00	26.15	32.81	17.44	43.52	18.78
650	36.37	20.81	40.00	24.74	50.11	26.20	32.81	17.48	43.63	18.79
655	36.37	20.81	40.05	24.75	50.22	26.25	32.91	17.49	43.68	18.80
660	36.48	20.81	40.11	24.80	50.33	26.30	32.97	17.51	43.79	18.81
665	36.48	20.82	40.33	24.94	50.44	26.30	33.02	17.52	43.85	18.84
670	36.48	20.82	40.33	25.00	50.66	26.35	33.13	17.53	43.85	18.85
675	36.59	20.82	40.44	25.00	50.77	26.35	33.13	17.54	43.96	18.86
680	36.59	20.82	40.66	25.01	50.88	26.40	33.24	17.55	43.96	19.16
685	36.70	20.83	40.66	25.04	50.99	26.45	33.29	17.56	44.01	19.18
690	36.70	20.84	40.77	25.07	51.10	26.45	33.40	17.57	44.18	19.20
695	36.81	20.84	40.88	25.08	51.21	26.55	33.45	17.58	44.29	19.22
700	36.92	20.86	40.99	25.20	51.32	26.56	33.67	17.64	44.40	19.24
705	36.92	20.89	41.10	25.25	51.54	26.60	33.78	17.66	44.51	19.26
710	37.03	20.90	41.21	25.30	51.65	26.65	33.99	17.68	44.62	19.28
715	37.03	20.97	41.21	25.40	51.76	26.70	34.10	17.70	44.67	19.30
720	37.14	20.96	41.32	25.63	51.98	26.79	34.10	17.72	44.78	19.32
725	37.25	20.97	41.32	25.63	52.09	26.80	34.10	17.74	44.84	0.00
730	37.36	20.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
735	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
740	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I: cont...

Time	xLU3	mLU3	xVE4	mVE4	xLU2	mLU2	xLU4	mLU4	xVE3	mVE3
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.47	7.15	0.33	0.20	5.39	1.50	6.48	3.11	0.19	0.25
10	11.33	7.45	0.38	0.30	7.71	2.45	9.45	3.60	0.32	0.44
15	13.92	8.50	0.49	0.37	9.08	3.21	11.87	4.80	0.49	0.54
20	15.86	9.10	0.55	0.41	10.67	3.90	13.30	5.30	0.55	0.66
25	17.27	9.61	0.60	0.46	11.62	4.31	13.41	5.75	0.59	0.80
30	18.67	10.66	0.66	0.50	12.68	4.66	15.93	6.48	0.65	0.94
35	20.31	10.90	0.71	0.54	13.52	5.02	17.03	6.74	0.71	1.10
40	20.61	11.14	0.79	0.57	14.26	5.35	18.13	7.40	0.76	1.22
45	21.37	11.52	0.82	0.60	14.79	5.45	18.90	7.89	0.78	1.35
50	22.12	11.65	0.86	0.62	15.53	5.70	20.00	8.15	0.80	1.50
55	22.88	11.92	0.88	0.66	16.16	6.07	20.66	8.30	0.82	1.60
60	23.63	12.29	0.91	0.67	16.69	6.15	21.43	8.80	0.84	1.72
65	24.17	12.64	0.93	0.69	17.11	6.43	22.09	8.94	0.85	1.80
70	24.60	12.90	0.95	0.71	17.64	6.50	22.97	9.20	0.86	1.90
75	25.25	13.02	0.97	0.73	17.96	6.65	23.63	9.50	0.88	2.02
80	25.68	13.04	0.98	0.75	18.38	6.95	24.18	9.83	0.90	2.12
85	26.44	13.20	0.99	0.76	18.80	7.05	24.73	10.00	0.91	2.26
90	26.87	13.48	1.00	0.78	19.12	7.15	25.27	10.11	0.92	2.34
95	27.30	13.50	1.00	0.81	19.44	7.33	25.82	10.40	0.93	2.44
100	27.52	13.60	1.03	0.83	19.75	7.35	26.37	10.60	0.94	2.50
105	27.73	13.86	1.04	0.85	20.07	7.45	26.81	10.94	0.95	2.56
110	28.06	14.00	1.04	0.84	20.28	7.65	27.25	11.05	0.96	2.60
115	28.38	14.27	1.05	0.85	20.49	7.70	27.69	11.20	0.96	2.74
120	28.60	14.30	1.07	0.86	20.60	7.80	28.13	11.30	0.96	2.80
125	28.92	14.68	1.08	0.88	20.92	7.90	28.57	11.45	0.96	2.80
130	29.24	14.75	1.09	0.89	21.13	8.05	28.90	11.53	0.98	2.94
135	29.46	14.80	1.09	0.90	21.55	8.15	29.34	11.79	0.99	3.01
140	29.68	14.90	1.10	0.91	21.87	8.20	29.67	12.06	1.00	3.09
145	30.00	15.05	1.10	0.92	21.97	8.30	30.00	12.19	1.01	3.13
150	30.22	15.30	1.10	0.93	22.29	8.40	30.44	12.21	1.03	3.20
155	30.43	15.40	1.11	0.94	22.50	8.59	30.88	12.35	1.04	3.27
160	30.65	15.53	1.12	0.95	22.71	8.62	31.21	12.45	1.05	3.33
165	30.86	15.60	1.12	0.96	22.92	8.68	31.43	12.55	1.05	3.39
170	31.08	15.70	1.13	0.97	23.13	8.74	31.87	12.65	1.06	3.45
175	31.29	15.85	1.15	0.98	23.24	8.82	32.09	12.77	1.07	3.53
180	31.51	16.00	1.15	0.99	23.56	8.90	32.42	12.91	1.07	3.56
185	31.73	16.10	1.16	1.00	23.77	8.99	32.75	12.92	1.08	3.61
190	31.94	16.34	1.18	1.01	23.87	9.09	32.97	13.05	1.09	3.67
195	32.16	16.41	1.18	1.02	24.08	9.17	33.19	13.15	1.10	3.72
200	32.27	16.46	1.19	1.03	24.19	9.23	33.52	13.21	1.10	3.77
205	32.48	16.49	1.20	1.04	24.40	9.36	33.74	13.25	1.11	3.82
210	32.70	16.55	1.21	1.05	24.51	9.38	33.96	13.34	1.11	3.83
215	32.81	16.57	1.21	1.05	24.72	9.65	34.29	13.45	1.12	3.91
220	33.02	16.59	1.22	1.06	24.82	9.70	34.51	13.50	1.12	3.96
225	33.13	16.61	1.22	1.07	24.93	9.77	34.62	13.60	1.12	4.01
230	33.24	16.70	1.23	1.08	25.14	9.80	34.84	13.65	1.12	4.05
235	33.45	16.72	1.24	1.09	25.35	9.85	35.16	13.75	1.13	4.05
240	33.56	16.74	1.25	1.09	25.46	9.90	35.38	13.80	1.13	4.14
245	33.67	16.76	1.26	1.10	25.56	10.15	35.60	13.94	1.14	4.19
250	33.78	16.90	1.26	1.11	25.77	10.23	35.82	14.00	1.14	4.22
255	33.99	16.94	1.26	1.12	25.88	10.28	36.04	14.10	1.14	4.27
260	34.10	16.98	1.27	1.12	25.99	10.31	36.26	14.15	1.15	4.29
265	34.21	17.00	1.29	1.13	26.09	10.35	36.48	14.20	1.15	4.33
270	34.42	17.05	1.29	1.14	26.20	10.40	36.59	14.37	1.15	4.37
275	34.53	17.10	1.30	1.15	26.41	10.45	36.81	14.40	1.17	4.42
280	34.64	17.15	1.31	1.15	26.51	10.50	37.03	14.55	1.17	4.46

Appendix I: cont...

Time	xLU3	mLU3	xVE4	mVE4	xLU2	mLU2	xLU4	mLU4	xVE3	mVE3
285	34.75	17.21	1.31	1.16	26.62	10.54	37.14	14.60	1.17	4.48
290	34.86	17.25	1.32	1.16	26.73	10.54	37.36	14.65	1.17	4.49
295	34.96	17.30	1.32	1.17	26.83	10.56	37.58	14.79	1.18	4.53
300	35.18	17.35	1.33	1.18	26.94	10.61	37.69	14.80	1.18	4.54
305	35.29	17.40	1.34	1.19	27.04	11.02	37.91	14.81	1.18	4.59
310	35.50	17.57	1.34	1.19	27.15	11.07	38.02	14.85	1.18	4.62
315	35.50	17.70	1.34	1.19	27.25	11.15	38.24	14.90	1.18	4.64
320	35.61	17.80	1.35	1.20	27.36	11.21	38.35	14.95	1.18	4.68
325	35.72	17.95	1.36	1.20	27.46	11.25	38.57	15.00	1.19	4.70
330	35.83	17.90	1.36	1.21	27.78	11.28	38.68	15.05	1.19	4.73
335	35.94	18.07	1.37	1.22	27.62	11.29	38.90	15.10	1.19	4.75
340	36.04	18.08	1.37	1.22	27.68	11.30	39.01	15.22	1.20	4.77
345	36.15	18.11	1.38	1.23	27.73	11.35	39.23	15.25	1.20	4.80
350	36.26	18.08	1.38	1.23	27.78	11.40	39.45	15.26	1.20	4.83
355	36.37	18.09	1.40	1.24	27.89	11.50	39.45	15.29	1.21	4.85
360	36.47	18.10	1.40	1.24	27.89	11.75	39.56	15.31	1.22	4.88
365	36.58	18.13	1.41	1.25	27.99	11.78	39.78	15.33	1.23	4.90
370	36.58	18.17	1.41	1.26	27.99	11.80	39.89	15.35	1.23	4.92
375	36.69	18.19	1.42	1.26	28.10	11.82	40.11	15.50	1.24	4.94
380	36.80	18.20	1.42	1.26	28.10	11.84	40.22	15.55	1.25	4.96
385	36.91	18.23	1.42	1.27	28.20	11.85	40.44	15.60	1.26	4.97
390	37.01	18.24	1.43	1.27	28.20	11.88	40.66	15.65	1.26	5.00
395	37.12	18.25	1.43	1.28	28.31	11.90	40.66	15.70	1.27	5.01
400	37.23	18.25	1.44	1.28	28.31	11.94	40.88	15.75	1.29	5.03
405	37.23	18.28	1.45	1.29	28.42	11.97	41.10	15.79	1.29	5.05
410	37.23	18.29	1.46	1.29	28.52	12.02	41.21	15.83	1.31	5.07
415	37.45	18.30	1.47	1.30	28.52	12.05	41.32	15.87	1.31	5.09
420	37.55	18.34	1.48	1.30	28.63	12.10	41.43	15.90	1.32	5.10
425	37.55	18.34	1.49	1.30	28.73	12.15	41.54	15.93	1.33	5.15
430	37.66	18.37	1.51	1.31	29.05	12.20	41.76	15.96	1.33	5.15
435	37.77	18.50	1.52	1.31	29.37	12.25	41.76	15.99	1.34	5.16
440	37.77	18.56	1.53	1.32	29.58	12.26	41.98	16.02	1.34	5.16
445	37.88	18.57	1.54	1.32	29.68	12.28	42.09	16.05	1.35	5.17
450	37.99	18.58	1.55	1.33	29.79	12.30	42.31	16.30	1.36	5.17
455	38.09	18.59	1.56	1.33	29.89	12.32	42.31	16.45	1.37	5.19
460	38.09	18.60	1.57	1.34	30.00	12.34	42.42	16.50	1.38	5.20
465	38.20	18.61	1.58	1.34	30.00	12.37	42.64	16.55	1.39	5.22
470	38.31	18.62	1.59	1.34	30.11	12.39	42.75	16.60	1.40	5.24
475	38.31	18.63	1.60	1.34	30.21	12.41	42.86	16.63	1.40	5.25
480	38.42	18.64	1.60	1.34	30.21	12.45	42.97	16.66	1.41	5.26
485	38.53	18.66	1.62	1.34	30.32	12.52	43.08	16.70	1.42	5.26
490	38.53	18.67	1.63	1.34	30.42	12.53	43.19	16.74	1.42	5.27
495	38.63	18.69	1.63	1.35	30.53	12.54	43.30	16.80	1.44	5.27
500	38.69	18.70	1.65	1.35	30.53	12.55	43.41	16.86	1.44	5.28
505	38.74	18.75	1.65	1.35	30.63	12.56	43.41	16.87	1.45	5.28
510	38.85	18.75	1.66	1.35	30.74	12.57	43.52	16.88	1.46	5.28
515	38.85	18.76	1.67	1.35	30.85	12.58	43.63	16.89	1.45	5.28
520	38.96	18.76	1.68	1.35	30.95	12.59	43.74	16.91	1.47	5.28
525	39.01	18.77	1.69	1.35	30.95	12.60	43.85	16.92	1.48	5.28
530	39.06	18.77	1.70	1.36	31.06	12.62	43.96	16.93	1.49	5.28
535	39.17	18.78	1.71	1.36	31.16	12.63	44.07	16.96	1.49	5.29
540	39.17	18.78	1.71	1.36	31.27	12.64	44.18	16.97	1.50	5.29
545	39.28	18.79	1.73	1.36	31.69	12.65	44.18	16.98	1.50	5.30
550	39.28	18.79	1.74	1.36	31.80	12.66	44.40	17.02	1.51	5.30
555	39.39	18.80	1.75	1.36	31.90	12.67	44.51	17.03	1.52	5.30
560	39.39	18.80	1.76	1.37	32.01	12.68	44.51	17.04	1.53	5.30
565	39.39	18.81	1.76	1.37	32.11	12.68	44.62	17.06	1.54	5.30

Appendix I: cont...

Time	xLU3	mLU3	xVE4	mVE4	xLU2	mLU2	xLU4	mLU4	xVE3	mVE3
570	39.50	18.81	1.76	1.37	32.22	12.69	44.73	17.08	1.54	5.30
575	39.50	18.82	1.77	1.38	32.32	12.69	44.84	17.09	1.55	5.30
580	39.55	18.82	1.78	1.38	32.43	12.70	44.95	17.10	1.55	5.30
585	39.60	18.83	1.79	1.38	32.54	12.70	45.05	17.11	1.56	5.31
590	39.66	18.83	1.80	1.38	32.54	12.71	45.16	17.12	1.58	5.31
595	39.71	18.84	1.81	1.38	32.64	12.71	45.27	17.17	1.59	5.31
600	39.77	18.84	1.81	1.39	32.75	12.72	45.27	17.18	1.59	5.31
605	39.82	18.85	1.81	1.39	32.85	12.72	45.38	17.19	1.60	5.31
610	39.87	18.85	1.82	1.39	32.85	12.73	45.49	17.20	1.61	5.32
615	39.93	18.86	1.84	1.39	32.96	12.73	45.60	17.26	1.62	5.32
620	39.98	18.96	1.85	1.40	32.96	12.74	45.71	17.27	1.63	5.32
625	40.04	18.87	1.85	1.40	33.06	12.74	45.82	17.28	1.64	5.32
630	40.09	18.87	1.86	1.40	33.06	12.75	45.93	17.29	1.65	5.32
635	40.14	18.88	1.86	1.40	33.17	12.75	45.93	17.31	1.65	5.32
640	40.25	18.88	1.87	1.40	33.17	12.76	46.04	17.40	1.66	5.32
645	40.25	18.89	1.87	1.40	33.27	12.76	46.15	17.41	1.67	5.32
650	40.31	18.89	1.88	1.41	33.27	12.77	46.15	17.42	1.68	5.33
655	40.36	18.90	1.89	1.41	33.38	12.77	46.26	17.43	1.69	5.33
660	40.41	18.90	1.90	1.41	33.38	12.78	46.37	17.44	1.69	5.33
665	40.47	18.91	1.90	1.41	33.49	12.78	46.48	17.45	1.71	5.33
670	40.52	18.91	1.92	1.41	33.49	12.79	46.48	17.47	1.71	5.33
675	40.58	18.92	1.93	1.41	33.59	12.79	46.59	17.48	1.72	5.33
680	40.63	18.92	1.95	1.41	33.59	12.80	46.70	17.49	1.73	5.33
685	40.68	18.93	1.96	1.43	33.70	12.80	46.81	17.50	1.74	5.34
690	40.68	18.93	1.97	1.43	33.70	12.81	46.92	17.51	1.75	5.34
695	40.74	18.94	1.98	1.43	33.80	12.81	46.92	17.52	1.75	5.34
700	40.79	18.94	1.99	1.43	33.80	12.82	47.03	17.53	1.76	5.34
705	40.79	18.95	1.99	1.43	33.91	12.82	47.14	17.53	1.76	5.34
710	40.85	18.95	2.00	1.43	34.01	12.82	47.25	17.55	1.77	5.34
715	40.90	18.96	2.01	1.43	34.01	12.83	47.25	17.57	1.77	5.34
720	40.95	18.96	2.02	1.43	34.01	12.84	47.36	17.58	1.79	5.34
725	41.01	18.97	2.03	1.43	34.12	12.84	47.36	17.59	1.79	5.34
730	0.00	18.97	2.03	1.43	34.12	12.84	0.00	0.00	1.80	5.34
735	0.00	0.00	0.00	0.00	34.23	12.85	0.00	0.00	0.00	0.00
740	0.00	0.00	0.00	0.00	34.23	12.85	0.00	0.00	0.00	0.00

Appendix IIA: Results on chemical and physical properties.

FIG	DISCE-NDING ORDER	SAMPLE	CLAY MINER-ALOGY	WEIGHT HEIGHT AT 720	ORGANIC CARBON	PH-WATER 1:2.5	pH-KCL 1:2.5	E.C. 1:2.5 WATER	C.E.C IN me /100g
1	B	VER2	monti.	4.54	1.37	7.23	5.27	0.36	58.00
1	D	VER3	monti.	1.79	1.50	7.40	5.37	0.37	59.03
1	C	VER4	monti.	2.02	1.32	7.50	5.53	0.40	61.67
1	A	VER1	monti.	1.58	1.97	7.10	5.37	0.38	61.43
2	D	AND4	amorp.	54.24	0.29	7.23	5.67	0.03	4.30
2	C	AND3	amorp.	51.98	0.68	7.27	5.60	0.04	6.93
2	B	AND2	amorp.	46.43	0.84	7.13	5.50	0.04	6.20
2	A	AND1	amorp.	45.95	1.59	6.86	5.37	0.01	10.63
3	D	NIT4	kaoli.	41.32	0.78	6.70	5.50	0.05	36.50
3	C	NIT3	kaoli.	34.10	1.43	6.70	5.55	0.05	33.85
3	B	NIT2	kaoli.	33.59	1.71	6.37	5.47	0.07	28.67
3	A	NIT1	kaoli.	27.79	2.63	5.95	5.35	0.19	23.50
4	D	LUV4	ill&kao.	47.36	0.63	4.83	3.67	0.04	3.13
4	C	LUV3	ill&kao.	40.95	0.36	5.03	3.77	0.06	3.10
4	A	LUV1	ill&kao.	35.60	0.75	5.07	4.30	0.16	3.33
4	B	LUV2	ill&kao.	34.01	0.64	5.47	4.17	0.08	3.50
5	D	ACR4	ill&kao.	49.64	0.20	6.20	5.00	0.08	12.97
5	C	ACR3	ill&kao.	44.78	0.25	6.50	4.97	0.05	13.43
5	B	ACR2	ill&kao.	42.58	0.28	6.40	5.03	0.07	15.43
5	A	ACR1	ill&kao.	37.14	0.35	6.43	5.33	0.11	11.17
6	B	AND1	amorp.	45.95	1.59	6.86	5.37	0.01	10.63
6	E	ACR1	ill&kao.	37.14	0.35	6.43	5.33	0.11	11.17
6	D	LUV1	ill&kao.	35.60	0.75	5.07	4.30	0.16	3.33
6	C	NIT1	kaoli.	27.79	2.63	5.95	5.35	0.19	23.50
6	A	VER1	monti.	1.58	1.97	7.10	5.37	0.38	61.43
7	B	AND2	amorp.	46.43	0.84	7.13	5.50	0.04	6.20
7	E	ACR2	ill&kao.	42.58	0.28	6.40	5.03	0.07	15.43
7	D	LUV2	ill&kao.	34.01	0.64	5.47	4.17	0.08	3.50
7	C	NIT2	kaoli.	33.59	1.71	6.37	5.47	0.07	28.67
7	A	VER2	monti.	4.54	1.37	7.23	5.27	0.36	58.00
8	B	AND3	amorp.	51.98	0.68	7.27	5.60	0.04	6.93
8	E	ACR3	ill&kao.	44.78	0.25	6.50	4.97	0.05	13.43
8	C	LUV3	ill&kao.	40.95	0.36	5.03	3.77	0.06	3.10
8	D	NIT3	kaoli.	34.10	1.43	6.70	5.55	0.05	33.85
8	A	VER3	monti.	1.79	1.50	7.40	5.37	0.37	59.03
9	B	AND4	amorp.	54.24	0.29	7.23	5.67	0.03	4.30
9	E	ACR4	ill&kao.	49.64	0.20	6.20	5.00	0.08	12.97
9	D	LUV4	ill&kao.	47.36	0.63	4.83	3.67	0.04	3.13
9	C	NIT4	kaoli.	41.32	0.78	6.70	5.50	0.05	36.50
9	A	VER4	monti.	2.02	1.32	7.50	5.53	0.40	61.67
10	F	AND4	amorp.	54.24	0.29	7.23	5.67	0.03	4.30
10	E	AND3	amorp.	51.98	0.68	7.27	5.60	0.04	6.93
10	D	AND2	amorp.	46.43	0.84	7.13	5.50	0.04	6.20
10	C	NIT4	kaoli.	41.32	0.78	6.70	5.50	0.05	36.50
10	B	NIT2	kaoli.	33.59	1.71	6.37	5.47	0.07	28.67
10	A	NIT1	kaoli.	27.79	2.63	5.95	5.35	0.19	23.50

Appendix IIA: cont...

FIG	DISCENDING ORDER	SAMPLE	CLAY MINERALOGY	WEIGHT HEIGHT AT 720	ORGANIC CARBON	PH-WATER 1:2.5	pH-KCL 1:2.5	E.C. 1:2.5 WATER	C.E.C IN me /100g
11	F	AND4	amorp.	54.24	0.29	7.23	5.67	0.03	4.30
11	E	AND3	amorp.	51.98	0.68	7.27	5.60	0.04	6.93
11	D	AND2	amorp.	46.43	0.84	7.13	5.50	0.04	6.20
11	C	NIT3	kaoli.	34.10	1.43	6.70	5.55	0.05	33.85
11	B	NIT2	kaoli.	33.59	1.71	6.37	5.47	0.07	28.67
11	A	NIT1	kaoli.	27.79	2.63	5.95	5.35	0.19	23.50
12	D	ACR4	ill&kao.	49.64	0.20	6.20	5.00	0.08	12.97
12	F	LUV4	ill&kao.	47.36	0.63	4.83	3.67	0.04	3.13
12	E	AND1	amorp.	27.79	1.59	6.86	5.37	0.01	10.63
12	C	ACR3	ill&kao.	44.78	0.25	6.50	4.97	0.05	13.43
12	B	ACR2	ill&kao.	42.58	0.28	6.40	5.03	0.07	15.43
12	A	ACR1	ill&kao.	37.14	0.35	6.43	5.33	0.11	11.17
13	C	ACR3	ill&kao.	44.78	0.25	6.50	4.97	0.05	13.43
13	B	ACR2	ill&kao.	42.58	0.28	6.40	5.03	0.07	15.43
13	F	LUV3	ill&kao.	40.95	0.36	5.03	3.77	0.06	3.10
13	A	ACR1	ill&kao.	37.14	0.35	6.43	5.33	0.11	11.17
13	D	LUV1	ill&kao.	35.60	0.75	5.07	4.30	0.16	3.33
13	E	LUV2	ill&kao.	34.01	0.64	5.47	4.17	0.08	3.50
14	A	VER1	monti.	5.75	1.97	7.10	5.37	0.38	61.43
14	B	VER2	monti.	5.50	1.37	7.23	5.27	0.36	58.00
14	C	VER3	monti.	5.34	1.50	7.40	5.37	0.37	59.03
14	D	VER4	monti.	1.43	1.32	7.50	5.53	0.40	61.67
15	B	AND2	amorp.	29.44	0.84	7.13	5.50	0.04	6.20
15	C	AND3	amorp.	26.79	0.68	7.27	5.60	0.04	6.93
15	A	AND1	amorp.	24.08	1.59	6.86	5.37	0.01	10.63
15	D	AND4	amorp.	21.50	0.29	7.23	5.67	0.03	4.30
16	B	NIT2	kaoli.	31.57	1.71	6.37	5.47	0.07	28.67
16	D	NIT4	kaoli.	25.63	0.78	6.70	5.50	0.05	36.50
16	C	NIT3	kaoli.	17.72	1.43	6.70	5.55	0.05	33.85
16	A	NIT1	kaoli.	15.26	2.63	5.95	5.35	0.19	23.50
17	A	LUV1	ill&kao.	22.04	0.75	5.07	4.30	0.16	3.33
17	C	LUV3	ill&kao.	18.96	0.36	5.03	3.77	0.06	3.10
17	D	LUV4	ill&kao.	17.58	0.63	4.83	3.67	0.04	3.13
17	B	LUV2	ill&kao.	12.84	0.64	5.47	4.17	0.08	3.50
18	B	ACR2	ill&kao.	26.00	0.28	6.40	5.03	0.07	15.43
18	D	ACR4	ill&kao.	21.94	0.20	6.20	5.00	0.08	12.97
18	A	ACR1	ill&kao.	20.96	0.35	6.43	5.33	0.11	11.17
18	C	ACR3	ill&kao.	19.32	0.25	6.50	4.97	0.05	13.43
19	B	AND1	amorp.	24.08	1.59	6.86	5.37	0.01	10.63
19	D	LUV1	ill&kao.	22.04	0.75	5.07	4.30	0.16	3.33
19	E	ACR1	ill&kao.	20.96	0.35	6.43	5.33	0.11	11.17
19	C	NIT1	kaoli.	15.26	2.63	5.95	5.35	0.19	23.50
19	A	VER1	monti.	5.75	1.97	7.10	5.37	0.38	61.43

Appendix IIA: cont...

FIG	DISCE-NDING ORDER	SAMPLE	CLAY MINER-ALOGY	WEIGHT HEIGHT AT 720	ORGANIC CARBON	PH-WATER 1:2.5	pH-KCL 1:2.5	E.C. 1:2.5 WATER	C.E.C IN me /100g
20	C	NIT2	kaoli.	31.57	1.71	6.37	5.47	0.07	28.67
20	B	AND2	amorp.	29.44	0.84	7.13	5.50	0.04	6.20
20	E	ACR2	ill&kao.	26.00	0.28	6.40	5.03	0.07	15.43
20	D	LUV2	ill&kao.	12.84	0.64	5.47	4.17	0.08	3.50
20	A	VER2	monti.	5.50	1.37	7.23	5.27	0.36	58.00
21	B	AND3	amorp.	26.79	0.68	7.27	5.60	0.04	6.93
21	E	ACR3	ill&kao.	19.32	0.25	6.50	4.97	0.05	13.43
21	D	LUV3	ill&kao.	18.96	0.36	5.03	3.77	0.06	3.10
21	C	NIT3	kaoli.	17.72	1.43	6.70	5.55	0.05	33.85
21	A	VER3	monti.	5.34	1.50	7.40	5.37	0.37	59.03
22	C	NIT4	kaoli.	25.63	0.78	6.70	5.50	0.05	36.50
22	E	ACR4	ill&kao.	21.94	0.20	6.20	5.00	0.08	12.97
22	B	AND4	amorp.	21.50	0.29	7.23	5.67	0.03	4.30
22	D	LUV4	ill&kao.	17.58	0.63	4.83	3.67	0.04	3.13
22	A	VER4	monti.	1.43	1.32	7.50	5.53	0.40	61.67

Appendix IIB: Results on chemical and physical properties.

FIG	DISC-NDING ORDER	SAM-PLE	Ca Me /100g SOIL	Mg Me /100g SOIL	K Me /100g SOIL	Na Me /100g SOIL	HEIGHT AT 720	SAND %	SILT %	CLAY %
1	B	VER2	37.53	15.83	2.31	2.73	4.54	19	13	68
1	D	VER3	36.00	14.37	2.03	3.45	1.79	19	12	69
1	C	VER4	34.90	15.37	1.97	4.63	2.02	18	11	71
1	A	VER1	35.67	15.10	2.89	2.43	1.58	21	14	65
2	D	AND4	2.00	0.67	1.47	0.50	54.24	49	46	5
2	C	AND3	2.80	1.27	1.60	0.52	51.98	47	47	6
2	B	AND2	3.50	1.27	1.57	0.53	46.43	49	45	6
2	A	AND1	4.17	19.33	1.44	0.60	45.95	42	48	10
3	D	NIT4	14.90	5.60	6.05	1.68	41.32	17	17	66
3	C	NIT3	11.60	4.95	4.87	1.82	34.10	20	20	60
3	B	NIT2	8.07	4.39	3.28	0.72	33.59	21	25	54
3	A	NIT1	7.20	3.42	2.48	0.55	27.79	26	27	47
4	D	LUV4	1.23	0.14	0.28	0.18	47.36	73	3	24
4	C	LUV3	1.40	0.35	0.38	0.20	40.95	77	4	19
4	A	LUV1	1.57	0.61	0.39	0.54	35.60	80	6	14
4	B	LUV2	0.40	0.60	0.50	0.23	34.01	77	4	20
5	D	ACR4	3.10	1.66	0.45	0.29	49.64	49	5	46
5	C	ACR3	3.37	1.84	1.10	0.54	44.78	49	5	46
5	B	ACR2	3.97	2.12	1.39	0.59	42.58	51	6	44
5	A	ACR1	4.20	2.43	1.06	0.98	37.14	57	8	35
6	B	AND1	4.17	19.33	1.44	0.60	45.95	42	48	10
6	E	ACR1	4.20	2.43	1.06	0.98	37.14	57	8	35
6	D	LUV1	1.57	0.61	0.39	0.54	35.60	80	6	14
6	C	NIT1	7.20	3.42	2.48	0.55	27.79	26	26	47
6	A	VER1	35.67	15.10	2.89	2.43	1.58	21	14	65
7	B	AND2	3.50	1.27	1.57	0.53	46.43	49	45	6
7	E	ACR2	3.97	2.12	1.39	0.59	42.58	51	6	44
7	D	LUV2	0.40	0.60	0.50	0.23	34.01	77	3	20
7	C	NIT2	8.07	4.39	3.28	0.72	33.59	21	25	54
7	A	VER2	37.53	15.83	2.31	2.73	4.54	19	13	68
8	B	AND3	2.80	1.27	1.60	0.52	51.98	47	47	6
8	E	ACR3	3.37	1.84	1.10	0.54	44.78	49	5	46
8	C	LUV3	1.40	0.35	0.38	0.20	40.95	77	4	19
8	D	NIT3	11.60	4.95	4.87	1.82	34.10	20	20	60
8	A	VER3	36.00	14.37	2.03	3.45	1.79	19	12	69
9	B	AND4	2.00	0.67	1.47	0.50	54.24	49	45	5
9	E	ACR4	3.10	1.66	0.45	0.29	49.64	49	5	46
9	D	LUV4	1.23	0.14	0.28	0.18	47.36	73	3	24
9	C	NIT4	14.90	5.60	6.05	1.68	41.32	17	17	66
9	A	VER4	34.90	15.37	1.97	4.63	2.02	18	11	71
10	F	AND4	2.00	0.67	1.47	0.50	54.24	49	45	5
10	E	AND3	2.80	1.27	1.60	0.52	51.98	47	47	6
10	D	AND2	3.50	1.27	1.57	0.53	46.43	49	45	6
10	C	NIT4	14.90	5.60	6.05	1.68	41.32	17	17	66
10	B	NIT2	8.07	4.39	3.28	0.72	33.59	21	25	54
10	A	NIT1	7.20	3.42	2.48	0.55	27.79	26	26	47

Appendix IIB: cont...

FIG	DISC-NDING ORDER	SAM-PLE	Ca Me /100g SOIL	Mg Me /100g SOIL	K Me /100g SOIL	Na Me /100g SOIL	HEIGHT AT 720	SAND %	SILT %	CLAY %
11	F	AND4	2.00	0.67	1.47	0.50	54.24	49	45	5
11	E	AND3	2.80	1.27	1.60	0.52	51.98	47	47	6
11	D	AND2	3.50	1.27	1.57	0.53	46.43	49	45	6
11	C	NIT3	11.60	4.95	4.87	1.82	34.10	20	20	60
11	B	NIT2	8.07	4.39	3.28	0.72	33.59	21	25	54
11	A	NIT1	7.20	3.42	2.48	0.55	27.79	26	26	47
12	D	ACR4	3.10	1.66	0.45	0.29	49.64	49	5	46
12	F	LUV4	1.23	0.14	0.28	0.18	47.36	73	3	24
12	E	AND1	4.17	19.33	1.44	0.60	27.79	42	48	10
12	C	ACR3	3.37	1.84	1.10	0.54	44.78	49	5	46
12	B	ACR2	3.97	2.12	1.39	0.59	42.58	51	6	44
12	A	ACR1	4.20	2.43	1.06	0.98	37.14	57	8	45
13	C	ACR3	3.37	1.84	1.10	0.54	44.78	49	5	46
13	B	ACR2	3.97	2.12	1.39	0.59	42.58	51	6	44
13	F	LUV3	1.40	0.35	0.38	0.20	40.95	77	4	19
13	A	ACR1	4.20	2.43	1.06	0.98	37.14	57	8	35
13	D	LUV1	1.57	0.61	0.39	0.54	35.60	90	6	14
13	E	LUV2	0.40	0.60	0.50	0.23	34.01	77	3	20
14	A	VER1	35.67	15.10	2.89	2.43	5.75	21	14	65
14	B	VER2	37.53	15.83	2.31	2.73	5.50	19	13	68
14	C	VER3	36.00	14.37	2.03	3.45	5.34	19	12	69
14	D	VER4	34.90	15.37	1.97	4.63	1.43	18	11	71
15	B	AND2	3.50	1.27	1.57	0.53	29.44	49	45	6
15	C	AND3	2.80	1.27	1.60	0.52	26.79	47	47	6
15	A	AND1	4.17	19.33	1.44	0.60	24.08	42	48	10
15	D	AND4	2.00	0.67	1.47	0.50	21.50	49	45	5
16	B	NIT2	8.07	4.39	3.28	0.72	31.57	21	25	54
16	D	NIT4	14.90	5.60	6.05	1.68	25.63	17	17	66
16	C	NIT3	11.60	4.95	4.87	1.82	17.72	20	20	60
16	A	NIT1	7.20	3.42	2.48	0.55	15.26	26	26	47
17	A	LUV1	1.57	0.61	0.39	0.54	22.04	80	6	14
17	C	LUV3	1.40	0.35	0.38	0.20	18.96	77	4	19
17	D	LUV4	1.23	0.14	0.28	0.18	17.58	73	3	24
17	B	LUV2	0.40	0.60	0.50	0.23	12.84	77	3	20
18	B	ACR2	3.97	2.12	1.39	0.59	26.00	51	6	44
18	D	ACR4	3.10	1.66	0.45	0.29	21.94	49	5	46
18	A	ACR1	4.20	2.43	1.06	0.98	20.96	57	8	35
18	C	ACR3	3.37	1.84	1.10	0.54	19.32	49	5	46
19	B	AND1	4.17	19.33	1.44	0.60	24.08	42	48	10
19	D	LUV1	1.57	0.61	0.39	0.54	22.04	80	6	14
19	E	ACR1	4.20	2.43	1.06	0.98	20.96	57	8	35
19	C	NIT1	7.20	3.42	2.48	0.55	15.26	26	26	47
19	A	VER1	35.67	15.10	2.89	2.43	5.75	21	14	65

Appendix IIB: cont...

FIG	DISC-NDING ORDER	SAM-PLE	Ca Me /100g SOIL	Mg Me /100g SOIL	K Me /100g SOIL	Na Me /100g SOIL	HEIGHT AT 720	SAND %	SILT %	CLAY %
20	C	NIT2	8.07	4.39	3.28	0.72	31.57	21	25	54
20	B	AND2	3.50	1.27	1.57	0.53	29.44	49	45	6
20	E	ACR2	3.97	2.12	1.39	0.59	26.00	51	6	44
20	D	LUV2	0.40	0.60	0.50	0.23	12.84	77	3	20
20	A	VER2	37.53	15.83	2.31	2.73	5.50	19	13	62
21	B	AND3	2.80	1.27	1.60	0.52	26.79	47	47	6
21	E	ACR3	3.37	1.84	1.10	0.54	19.32	49	5	46
21	D	LUV3	1.40	0.35	0.38	0.20	18.96	77	4	19
21	C	NIT3	11.60	4.94	4.87	1.82	17.72	20	20	60
21	A	VER3	36.00	14.37	2.03	3.45	5.34	19	12	69
22	C	NIT4	14.90	5.60	6.05	1.68	25.63	17	17	66
22	E	ACR4	3.10	1.66	0.45	0.29	21.94	49	5	46
22	B	AND4	2.00	0.67	1.47	0.50	21.50	49	45	5
22	D	LUV4	1.23	0.14	0.28	0.18	17.58	73	3	24
22	A	VER4	34.90	15.37	1.97	4.63	1.43	18	11	71

Appendix IIC: Results on chemical and physical properties.

FIG	DISC-NDING ORDER	SAM-PLE	BULK DEN-SITY	pF AT 3.7	pF AT 4.2	Ksat	FIELD CAPA-CITY	DEN-SITY	PORO-SITY	WET BULK DENSITY
1	B	VER2	1.02	39.3	38.8	.0000325	54.54	2.65	0.614	1.59
1	D	VER3	1.02	40.5	37.8	.0002336	54.45	2.67	0.620	1.57
1	C	VER4	1.33	40.2	37.7	.0000486	52.12	2.67	0.503	1.67
1	A	VER1	1.03	34.7	32.4	.0001113	55.00	2.60	0.604	1.54
2	D	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
2	C	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
2	B	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
2	A	AND1	1.02	12.5	10.5	.04050	51.90	2.45	0.584	1.55
3	D	NIT4	1.04	39.7	28.5	.000493	45.34	2.60	0.602	1.51
3	C	NIT3	1.03	30.2	28.5	.000421	47.99	2.57	0.597	1.53
3	B	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
3	A	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38
4	D	LUV4	1.52	5.8	5.2	.0799	14.78	2.61	0.418	1.74
4	C	LUV3	1.53	5.8	5.2	.0567	11.29	2.64	0.421	1.70
4	A	LUV1	1.52	4.5	3.7	.247	11.46	2.64	0.422	1.70
4	B	LUV2	1.54	5.1	4.5	.231	12.22	2.65	0.420	1.73
5	D	ACR4	1.43	13.5	12.3	.00183	23.08	2.65	0.460	1.78
5	C	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
5	B	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
5	A	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
6	B	AND1	1.02	12.5	10.5	.04050	51.90	2.45	0.584	1.55
6	E	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
6	D	LUV1	1.52	4.5	3.7	.247	11.46	2.64	0.422	1.70
6	C	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38
6	A	VER1	1.03	34.7	32.4	.0001113	55.00	2.60	0.604	1.54
7	B	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
7	E	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
7	D	LUV2	1.54	5.1	4.5	.231	12.22	2.65	0.420	1.73
7	C	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
7	A	VER2	1.02	39.3	38.8	.0000325	54.54	2.65	0.614	1.59
8	B	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
8	E	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
8	C	LUV3	1.53	5.8	5.2	.0567	11.29	2.64	0.421	1.70
8	D	NIT3	1.03	30.2	28.5	.000421	47.99	2.57	0.597	1.53
8	A	VER3	1.02	40.5	37.8	.0002336	54.45	2.67	0.620	1.54
9	B	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
9	E	ACR4	1.43	13.5	12.3	.00183	23.08	2.65	0.460	1.78
9	D	LUV4	1.52	5.8	5.2	.0799	14.78	2.61	0.418	1.74
9	C	NIT4	1.04	39.7	28.5	.000493	45.34	2.60	0.602	1.51
9	A	VER4	1.33	40.2	37.7	.0000486	52.12	2.67	0.503	1.67
10	F	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
10	E	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
10	D	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
10	C	NIT4	1.04	39.7	28.5	.000493	45.34	2.60	0.584	1.51
10	B	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
10	A	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38

Appendix IIC: cont...

FIG	DISC-NDING ORDER	SAM-PLE	BULK DEN-SITY	pF AT 3.7	pF AT 4.2	Ksat	FIELD CAPA-CITY	DEN-SITY	PORO-SITY	WET BULK DENSITY
11	F	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
11	E	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
11	D	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
11	C	NIT3	1.03	30.2	28.5	.000421	47.99	2.57	0.597	1.53
11	B	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
11	A	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38
12	D	ACR4	1.43	13.5	12.3	.00183	23.08	2.65	0.460	1.78
12	F	LUV4	1.52	5.8	5.2	.0799	14.78	2.61	0.418	1.74
12	E	AND1	1.02	12.5	10.5	.04050	51.90	2.45	0.584	1.55
12	C	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
12	B	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
12	A	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
13	C	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
13	B	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
13	F	LUV3	1.53	5.8	5.2	.0567	11.29	2.64	0.421	1.70
13	A	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
13	D	LUV1	1.52	4.5	3.7	.247	11.46	2.64	0.422	1.70
13	E	LUV2	1.54	5.1	4.5	.231	12.22	2.65	0.420	1.73
14	A	VER1	1.03	34.7	32.4	.0001113	55.00	2.60	0.604	1.54
14	B	VER2	1.02	39.3	38.8	.0000325	54.54	2.65	0.614	1.59
14	C	VER3	1.02	40.5	37.8	.0002336	54.45	2.67	0.620	1.57
14	D	VER4	1.33	40.2	37.7	.0000486	52.12	2.67	0.503	1.67
15	B	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
15	C	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
15	A	AND1	1.02	12.5	10.5	.04050	51.90	2.45	0.584	1.55
15	D	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
16	B	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
16	D	NIT4	1.04	39.7	28.5	.000493	45.34	2.60	0.602	1.51
16	C	NIT3	1.03	30.2	28.5	.000421	47.99	2.57	0.597	1.53
16	A	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38
17	A	LUV1	1.52	4.5	3.7	.247	11.46	2.64	0.422	1.70
17	C	LUV3	1.53	5.8	5.2	.0567	11.29	2.64	0.421	1.70
17	D	LUV4	1.52	5.8	5.2	.0799	14.78	2.61	0.418	1.74
17	B	LUV2	1.54	5.1	4.5	.231	12.22	2.65	0.420	1.73
18	B	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
18	D	ACR4	1.43	13.5	12.3	.00183	23.08	2.65	0.460	1.78
18	A	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
18	C	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
19	B	AND1	1.02	12.5	10.5	.04050	51.90	2.45	0.584	1.55
19	D	LUV1	1.52	4.5	3.7	.247	11.46	2.64	0.422	1.70
19	E	ACR1	1.56	13.2	10.4	.00669	19.69	2.60	0.400	1.86
19	C	NIT1	0.88	30.9	29.5	.000183	56.58	2.45	0.640	1.38
19	A	VER1	1.03	34.7	32.4	.0001113	55.00	2.60	0.604	1.54

Appendix IIC: con...

FIG	DISC-NDING ORDER	SAMPLE	BULK DENSITY	pF AT 3.7	pF AT 4.2	Ksat	FIELD CAPACITY	DENSITY	POROSITY	WET BULK DENSITY
20	C	NIT2	0.93	32.5	31.1	.0000347	51.43	2.52	0.631	1.41
20	B	AND2	1.00	11.1	8.8	.039500	53.49	2.46	0.593	1.53
20	E	ACR2	1.40	13.9	13.8	.00492	23.59	2.65	0.475	1.75
20	D	LUV2	1.54	5.1	4.5	.231	12.22	2.65	0.420	1.73
20	A	VER2	1.02	39.3	38.8	.0000325	54.54	2.65	0.614	1.59
21	B	AND3	1.24	8.3	6.5	.01300	36.27	2.52	0.508	1.68
21	E	ACR3	1.40	13.6	12.4	.00444	34.39	2.64	0.469	1.74
21	D	LUV3	1.53	5.8	5.2	.0567	11.29	2.64	0.421	1.70
21	C	NIT3	1.03	30.2	28.5	.000421	47.99	2.57	0.597	1.53
21	A	VER3	1.02	40.5	37.8	.0002336	54.45	2.67	0.620	1.57
22	C	NIT4	1.04	39.7	28.5	.000493	45.34	2.60	0.602	1.51
22	E	ACR4	1.43	13.5	12.3	.00183	23.08	2.65	0.460	1.78
22	B	AND4	1.39	4.9	3.5	.00691	26.05	2.54	0.453	1.75
22	D	LUV4	1.52	5.8	5.2	.0799	14.78	2.61	0.418	1.74
22	A	VER4	1.33	40.2	37.7	.0000486	52.12	2.67	0.503	1.67

Appendix III: Correlation coefficient and regression coefficient squared of wetting front height in cms and cummulative weight in grams against chemical properties.

	ORGANIC CARBON		pH-WATER W-1:2.5		pH-KCL K-1:2.5	
FIGURE	R.Sq	X-COEF.	R.Sq	X-COEF.	R.Sq	X-COEF.
1	0.24	-0.11	0.03	-0.02	0.39	-0.05
2	0.71	-0.11	0.62	0.04	0.87	0.03
3	0.96	-0.14	0.72	0.05	0.48	0.01
4	0.09	-0.01	0.73	-0.04	0.83	-0.05
5	1.00	-0.01	0.41	-0.02	0.70	-0.03
6	0.30	0.08	0.60	-0.07	0.79	-0.05
7	0.03	0.03	0.01	0.00	0.07	-0.01
8	0.23	-0.05	0.10	0.01	0.09	0.00
9	0.01	0.00	0.42	-0.05	0.00	0.01
10	0.00	0.00	0.07	-0.01	0.01	-0.01
11	0.19	-0.02	0.12	-0.02	0.04	-0.01
12	0.27	-0.02	0.09	-0.01	0.00	0.00
13	0.54	-0.02	0.12	-0.02	0.03	-0.01
14	0.85	-0.02	0.23	-0.02	0.08	-0.01
15	0.30	-0.07	0.18	-0.05	0.12	-0.02
16	0.00	0.00	0.00	0.00	0.23	0.02
17	0.37	-0.05	0.04	-0.02	0.00	0.00
18	0.60	-0.04	0.11	-0.04	0.00	-0.01
19	0.89	-0.08	0.96	0.05	0.89	0.01
20	0.91	-0.07	0.90	0.05	0.72	0.01
21	0.64	-0.05	0.36	-0.05	0.33	-0.04
22	0.72	-0.04	0.26	0.09	0.09	0.04

Appendix III: cont...						
	E.C.1:2.5 WATER		C.E.C.me/100g SOIL		CaMe/100g SOIL	
FIGURE	R.Sq	X-COEF.	R.Sq	X-COEF.	R.Sq	X-COEF.
1	0.38	-0.01	0.54	-0.96	0.74	0.69
2	0.14	0.00	0.51	-0.46	0.92	-0.22
3	0.66	-0.01	0.85	0.96	0.84	0.58
4	0.47	-0.01	0.71	-0.03	0.14	0.03
5	0.32	0.00	0.13	0.12	0.90	-0.09
6	0.73	-0.01	0.31	-0.48	0.44	0.35
7	0.31	0.00	0.01	0.07	0.18	0.12
8	0.31	-0.01	0.08	0.22	0.02	0.06
9	0.29	0.01	0.24	-0.02	0.94	0.13
10	0.00	0.00	0.49	0.43	0.12	0.06
11	0.97	-0.01	0.89	-1.29	0.88	-0.79
12	0.93	-0.01	0.81	-1.22	0.87	-0.87
13	0.91	-0.01	0.87	-1.11	0.95	-0.72
14	0.95	-0.01	0.85	-1.09	0.94	-0.66
15	0.90	-0.02	0.94	-3.03	0.87	-1.79
16	0.65	-0.01	0.25	-0.98	0.43	-0.88
17	0.82	-0.02	0.77	-2.64	0.82	-1.70
18	0.88	-0.02	0.44	-1.76	0.61	-1.18
19	0.69	0.00	0.51	-0.94	0.28	-0.25
20	0.56	0.00	0.78	-1.04	0.70	-0.28
21	0.13	0.00	0.01	-0.04	0.41	-0.09
22	0.46	-0.01	0.45	0.90	0.31	0.21

Appendix: III cont...						
	MgMe/100g SOIL		KMe/100g SOIL		NaMe/100g SOIL	
FIGURE	R.Sq	X-COEF.	R.Sq	X-COEF.	R.Sq	X-COEF.
1	0.55	0.33	0.01	-0.03	0.07	-0.19
2	0.38	-1.38	0.01	0.00	0.61	-0.01
3	0.93	0.16	0.86	0.27	0.52	0.08
4	0.98	-0.04	0.83	-0.01	0.29	-0.02
5	0.96	-0.06	0.42	-0.05	0.98	-0.05
6	0.04	-0.06	0.35	0.12	0.86	-0.44
7	0.06	-0.64	0.60	0.02	0.00	0.00
8	0.15	0.05	0.03	0.04	0.01	-0.01
9	0.00	0.00	0.27	-0.01	0.43	0.03
10	0.03	0.02	0.14	0.05	0.01	-0.01
11	0.03	-0.08	0.55	-0.05	0.79	-0.04
12	0.89	-0.36	0.10	-0.02	0.84	-0.06
13	0.93	-0.28	0.05	-0.02	0.88	-0.07
14	0.96	-0.29	0.02	-0.02	0.95	-0.09
15	0.04	-0.24	0.71	-0.12	0.74	-0.09
16	0.41	-0.36	0.09	0.03	0.42	-0.06
17	0.82	-0.67	0.02	-0.03	0.75	-0.15
18	0.65	-0.54	0.07	0.07	0.67	-0.16
19	0.48	-0.13	0.15	-0.07	0.03	-0.01
20	0.77	-0.15	0.47	-0.08	0.17	-0.02
21	0.77	-0.80	0.54	-0.04	0.37	-0.02
22	0.17	0.09	0.35	0.06	0.00	0.00

Appendix IV: Correlation coefficients and regression coefficients squared of the wetting front height in cm and cummulative weight in grams against physical properties.

	SAND(%)		SILT(%)		CLAY(%)		BULK DENSITY	
FIG	R.Sq	X-COEF	R.Sq	X-COEF	R.Sq	X-COEF	R.Sq	X-COE
1	0.07	-0.23	0.02	0.13	0.00	0.11	0.06	-0.03
2	0.27	0.42	0.01	-0.04	0.50	-0.38	0.98	0.05
3	0.94	-0.66	0.83	-0.75	0.92	1.41	0.71	0.01
4	0.69	-0.40	0.47	-0.14	0.51	0.49	0.30	0.00
5	0.81	-0.66	0.84	-0.25	0.78	0.90	0.50	-0.01
6	0.51	0.44	0.68	0.52	0.62	-0.96	0.99	-0.07
7	0.04	0.20	0.01	-0.04	0.00	-0.04	0.42	-0.04
8	0.27	-0.26	0.01	-0.05	0.10	0.35	0.02	0.00
9	0.17	0.31	0.71	0.31	0.33	-0.62	0.66	0.00
10	0.00	-0.04	0.00	0.03	0.01	0.17	0.08	-0.01
11	0.35	0.83	0.14	0.38	0.81	-1.22	0.11	0.01
12	0.30	0.80	0.11	0.35	0.55	-1.14	0.06	0.00
13	0.37	0.75	0.12	0.31	0.60	-1.07	0.38	0.01
14	0.40	0.71	0.08	0.23	0.51	-0.94	0.04	0.00
15	0.50	2.31	0.07	0.62	0.88	-2.92	0.21	0.02
16	0.00	-0.09	0.32	0.86	0.12	-0.76	0.08	-0.01
17	0.27	1.61	0.30	1.25	0.68	-2.85	0.23	0.01
18	0.07	0.68	0.06	0.43	0.14	-1.12	0.06	0.00
19	0.61	1.13	0.58	0.95	0.59	-2.08	0.81	0.02
20	0.83	1.19	0.84	1.02	0.83	-2.22	0.78	0.02
21	0.22	0.63	0.78	-1.93	0.50	1.30	0.51	0.02
22	0.50	-2.80	0.00	0.03	0.55	2.41	0.67	-0.01

Appendix; IV cont...

	pF=3.7		pF=4.2		Ksat		FIELD CAPACITY	
FIG	R.Sq	X-COEF	R.Sq	X-COEF	R.Sq	X-COEF	R.Sq	X-COEF
1	0.07	0.50	0.34	1.21	0.33	0.00	0.02	0.13
2	0.94	-0.79	0.93	-0.71	0.99	0.00	0.98	-3.17
3	0.73	0.67	0.15	-0.09	0.42	0.00	0.89	-0.82
4	0.61	0.08	0.56	0.09	0.71	-0.01	0.55	0.20
5	0.14	0.02	0.25	0.13	0.97	0.00	0.13	0.44
6	0.20	-0.59	0.09	-0.43	0.15	0.00	0.99	0.63
7	0.30	0.54	0.25	0.44	0.26	0.00	0.42	2.49
8	0.21	0.27	0.35	0.10	0.10	0.00	0.13	-0.24
9	0.07	-0.04	0.11	-0.06	0.01	0.00	0.07	-0.11
10	0.44	0.07	0.42	0.32	0.00	0.00	0.21	-1.04
11	0.63	-0.61	0.63	-0.60	0.09	0.00	0.16	-0.51
12	0.57	-0.68	0.60	-0.70	0.02	0.00	0.10	-0.38
13	0.78	-0.68	0.78	-0.65	0.11	0.00	0.37	-0.51
14	0.55	-0.63	0.74	-0.61	0.07	0.00	0.61	-0.58
15	0.78	-1.55	0.78	-1.53	0.19	0.01	0.27	-1.53
16	0.05	-0.29	0.07	-0.34	0.12	0.00	0.03	0.30
17	0.70	-1.62	0.70	-1.56	0.07	0.00	0.26	-1.08
18	0.14	-0.71	0.31	-0.88	0.00	0.00	0.22	-0.78
19	0.64	-1.14	0.83	-1.14	0.20	0.00	0.68	-0.93
20	0.94	-1.14	0.94	-1.15	0.25	0.00	0.66	-0.87
21	0.05	-0.09	0.00	-0.02	0.00	0.00	0.54	-1.23
22	0.43	0.72	0.53	0.76	0.63	-0.02	0.59	1.66

APPENDIX IV: cont...

	PARTICLE DENSITY		POROSITY		WET BULK DENSITY	
FIG.	R.Sq	X-COEF.	R.Sq	X-COEF.	R.Sq	X-COEF
1	0.03	0.00	0.06	0.01	0.01	0.00
2	1.00	0.01	0.98	-0.02	0.98	0.03
3	0.86	0.01	0.55	0.00	0.51	0.01
4	0.86	0.00	0.51	0.00	0.18	0.00
5	0.69	0.00	0.50	0.00	0.42	-0.01
6	0.28	-0.01	0.96	0.03	0.88	-0.03
7	0.24	-0.01	0.44	0.01	0.42	-0.02
8	0.12	0.00	0.00	0.00	0.00	0.00
9	0.04	0.00	0.10	0.00	0.56	0.00
10	0.16	0.00	0.12	0.00	0.06	0.00
11	0.10	0.00	0.16	0.00	0.10	0.00
12	0.24	0.00	0.11	0.00	0.01	0.00
13	0.40	0.00	0.51	0.00	0.52	0.00
14	0.46	0.00	0.08	0.00	0.09	0.00
15	0.03	0.00	0.27	-0.01	0.18	0.01
16	0.52	-0.01	0.05	0.00	0.19	-0.01
17	0.60	-0.01	0.35	-0.01	0.27	0.01
18	0.36	0.00	0.02	0.00	0.01	0.00
19	0.11	0.00	0.81	-0.01	0.92	0.01
20	0.04	0.00	0.82	-0.01	0.86	0.01
21	0.79	0.01	0.41	-0.01	0.35	0.01
22	0.03	0.00	0.60	0.01	0.00	0.00