SOKOINE UNIVERSITY OF AGRICULTURE
FACULTY OF AGRICULTURE
DEPARTMENT OF SOIL SCIENCE
P.O. BOX 3008 CHUO KIKUU MOROGORO TANZANIA
TEL. 3511/4 DIRECT 3999 TELEX 55308 UNIVMOG TZ TELEGRAMS "UNIAGRIC" MOROGORO

SOILS OF THE ALLIDINA AND LUTINDI ESTATES IN KILOSA DISTRICT AND THEIR AGRICULTURAL POTENTIAL

Balthazar M. Msanya (BSc, MSc, PhD)

JUNE, 1991

TABLE OF CONTENTS

SUMMARY AND RECOMMENDATIONS

This report presents the results of a feasibility study for agirucltural development of the Allidina and Lutindi Estates in Kilosa district, following a request by the owners i.e. Azania Agricultural Enterprises Ltd.

The study was undertaken in form of site evaluations coupled with soil profile descriptions and sampling and laboratory analysis of both soil and water samples. The environmental conditions were also assessed, and finally the agricultural development potential was determined.

The farms are situated within Mkata plain farming part of the Wami drianage basin. They are flat (slopes less than 1%) and their altitude is about 410 m above sea level.

The farms are connected to Kilosa and Morogoro as the major commercial centres by all-weather earth road (Kilosa - Dumila) and tarmac road (Dumila - Morogoro). They are also connected to Dar es Salaam through Kimamba railway station.

The rainfall pattern is essentially monomodal with a single long and warm rainy season from November to May with a peak in April and a relatively cooler dry season from June to October. The mean annual rainfall is 1072 mm. The mean annual temperature is about 25°C with mean monthly maximum temperatures varying from 27°C to 33°C and mean monthly minimum temperatures varying from 22°C to 27°C.

The natural vegetation in Allidina is Acacia woodland with grass undergrowth. At the time of study about 400 ha had been cleared and cultivated for maize, rice, sorghum, sunflower and tobacco. In Lutindi the natural vegetation is wooded grassland dominated by tall grass. At the time of study, 200 ha had been cleared and cultivated for maize, sorghum and sugarcane.

The soils in Allidina (with an exception of those in marshy areas bordering rivers) look rather similar. They are dark in color and have loamy surface textures. The soils in Lutindi are also dark colored but are characterized by heavy surface and subsoil textures.

General soil fetility assessment indicates that the soils in both farms are fairly fertile as shown by medium to high organic matter content, high CEC and BS, medium levels of nitrogen, medium to high levels of phosphorus and high levels of micronutrients. To maintain and even to improve the natural soil fertility, nitrogen - fixing legumes should be grown in appropriate rotations with other crops. Plowing back crop residues into the soil after harvest is also recommended as a means of maintaining and improving natural soil fertility. With intensive use of the soil, inorganic N and P fertilization may be necessary in future.

Irrigation has been felt necessary for some crops to complete their growth cycles:

- Results on water analysis indicate that water from Wami and Kisangata rivers can be used safely for irrigation without risks of salinization and alkalinization.

- Evaluation of soil properties and environmental conditions indicate that the two farms are highly suitable (Allidina) and suitable (Lutindi) for irrigated agriculture.

- On the basis of soil properties, physical environment of the farms and their intended use and on the basis of edvantages over other systems, sprinkler irrigation is recommended as the most approprite system to adopt on the farms.

Suitable crops to grow on the farms have been suggested based on the crop requirements and the land qualities. They include paddy, maize, sorghum, millets, soybeans, chick peas, groundnuts, sunflower, sesame, sugarcane, sugar-beet, cotton, kenaf, castor beans and tobacco. In addition, suggestions have also been given on whether these crops should be grown under rainfed or irrigated conditions.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1 : INTRODUCTION

1.1 Objectives of the study

The Azania Agricultural Enterprises (AAE) Ltd. based in Dar es Salaam owns two farms in Kilosa District, Morogoro, namely Allidina Estate and Lutindi Estate which together form a total area of 1,600 ha. The company is interested to grow different crops including foreign exchange earning ones. So far they have cleared about 600 ha (38% of total land) in which they are growing among other crops maize, rice, sorghum, sunflower and tobacco under rainfed conditions.

As the soil and environmental conditions on the two farms are largely unknown, the Management of AAE Ltd. visited the Department of Soil Science at Sokoine University of Agriculture on 23rd March 1991 for an expert advice. They made a formal request for a feasilibity study to be carried out to determine the agricultural potential of the two farms. The Department of Soil Science accepted to undertake the study and the first expert visit to the farms was made on 8th April, 1991.

The terms of reference were :-

i. to study the environmental conditions at the farms including physiography, geology, hydrology and climate

ii. to study the soil conditions at the farms and characterize them in terms of standard field and analytical methods

iii. to give a suitability of the farms for various crops under both rainfed and irrigated conditions.

iv. to write a report on the above.

1.2 Organization of the study

Both the field work and laboratory work were organized and done by Dr. B. M. Msanya, Senior Lecturer in the Department of Soil Science, SUA. Messrs. Rasmus Ostergard and Ally Nassor both of AAE Ltd. offered field assistance during the field work.

1.3 Acknowledgements

The completion of this work would not have been possible without the help of the following people to whom I express my sincere gratitudes:

: Messrs. Rasmus Ostergard, Ally Nassor and M. Kibuga who arranged accomodation for me and offered field assistance during the field survey.

: Dr. A.J. Shayo-Ngowi, Head of Soil Science Department at SUA for allowing me to use laboratory facilities for the study.

: Messrs A. Shamte, G.P. Malekela and Ms. E. Kafui who assisted in the laboratory analysis of soil samples.

: Ms. E.R. Mkulasyai for typing the report.

CHAPTER 2: GENERAL DESCRIPTION OF THE STUDY AREA

2.1 Location, size and infrastructure (see figure 1).

2.1.1 Allidina Estate

Allidina Estate is located between longitude E37° 11'30" and E37° 13'30" and between latitudes S6° 35'36" and S6°38'22" in Kilosa district. It is about 40 km north east of Kilosa town and about 25 km north of Kimamba. The farm shares a border with Mvumi village and is about 6 km east of the Dumila - Kimamba road. On average it has an altitude of 410 m above mean sea level and slopes are generally negligible (less than 1%).

The major commercial centres include Kilosa and Morogoro towns in which it is connected respectively by earth road, and earth-and tarmac road. Kimamba is the nearest railway station and links the farm to Dar es Salaam and up country through Morogoro and Kilosa towns.

Allidina Estate has an areas of 1,200 ha but at the time of this study only 400 ha had been cleared.

2.1.2 Lutindi Estate

Lutindi Estate is also located within Kilosa district not far from Allidina Estate. It lies between longitudes E37°13'53" and E37°15'17" and between latitude S6°34'08" and S6°36'14". The lower boundary is only about 1 km north east of Allidina Estate. The farm is connected to the Dumila - Kimamba road by a farm road which passes close to Msowero Sisal Estate belonging to the Tanzania Sical Authority. When compared with Allidina, the farm has almost the same altitude and slopes are also generally negligible (less than 1%).

The farm is also connected by road to Kilosa and Morogoro as the major commercial centres. The railway station at Kimamba which connects the farm to Dar es Salaam and other towns is about 30 km away. Lutindi Estate has a total of 400 ha out of which only half had been cleared at the time of the study.

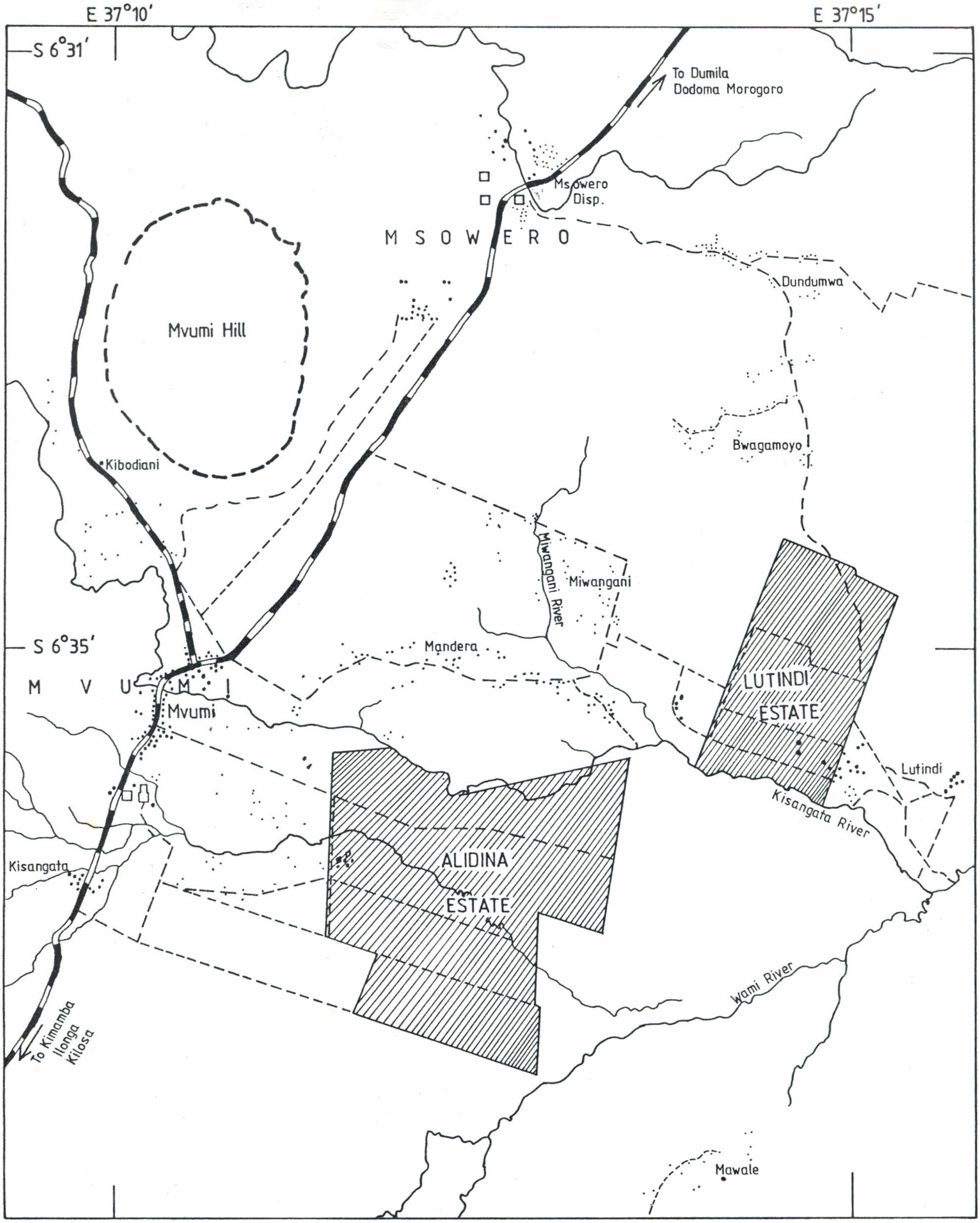
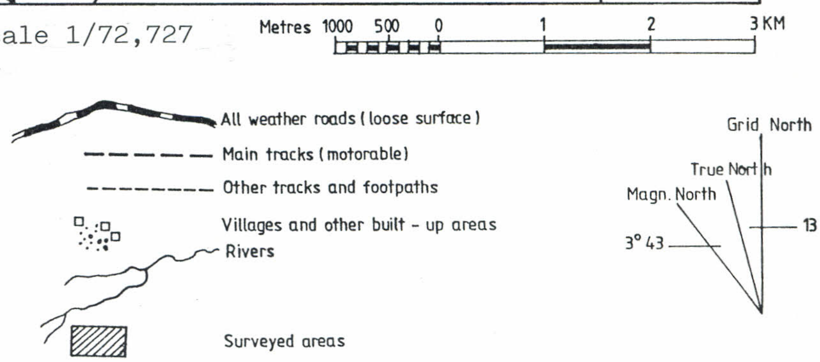


Figure 1. Location map

Scale 1/72,727



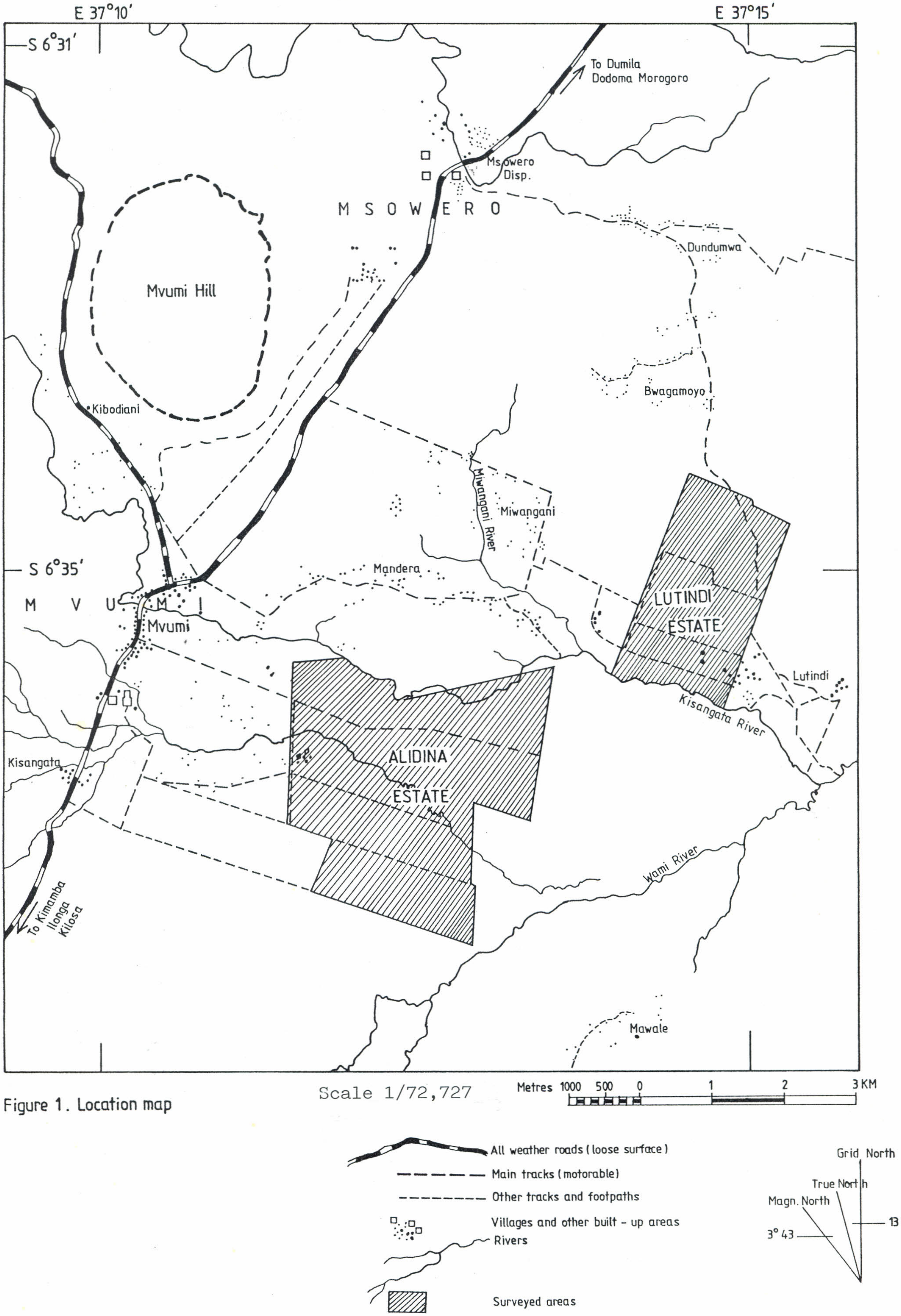


Figure 1. Location map

Scale 1/72,727

2.2 Soil parent material, geology, physiography and hydrology

The two estates are situated in the Mkata plain forming part of the Wami drainage basin which discharges ultimately into the Indian Ocean. The plain can be referred to as a "flood-plain". In some places it is still an active flood-plain receiving new materials annually through flooding by the Wami River. The plain is bordered by a chain of foot hills (mostly Ukaguru Foothills) on the north west.

The parent material has been described as superficial deposits of Neogence age consisting mainly of mbuga soils and alluvium (Geological Survey Division, 1965). These materials are of diverse origin and composition consisting of particles of various sizes including gravel, sand, silt and clay. In both farms, in-situ observation of soil profiles from surface to depths greater than 1.5 m, shows that the materials deposited by the river in different cycles had consistently been very rich in mica as indicated by the presence of high amounts of shiny mica flakes.

The two farms are situated near Wami River and one of its major tributaries called Kisangata. In most years during the rainy season some parts of the farms are flooded by rainfall, runoff from the neighbouring hills and from the two rivers.

2.3 Climate

The two estates have not meteorological station and hence have no data on climate. The nearest meteorological station is at Ilonga Experimental Station, and the data for this station (see table 1 and figure 2) are used to represent the climatic conditions at the two farms. Ilonga station is at a higher altitude (about 503 m above mean sea level), hence the climatic data to be discussed here may be slightly different from the actual conditions. However, for most practical purposes they can be used to assist in the evaluation of climate for different land uses.

The climate of the surveyed areas can be described as having a monodal pattern of rainfall whereby there is a warm rainy season from November to May with its peak in April and dry season from June to October. The mean annual rainfall is approximately 1072 mm. Temperatures start to fall at the peak of the rainy season and in fact May to August are the coolest months of the year and coincide with the driest period.

Table 1 : Rainfall, temperature and relative humidity at Ilonga Agrometeorological station

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean rainfall (mm)	149.5	121.7	195.6	212.7	74.2	12.9	10.5	13.4	16.4	36.5	81.9	146.6
Temperature:												
Mean maximum temp. °C	31.3	31.8	31.8	30.0	28.4	27.6	27.4	28.2	30.3	32.0	32.7	31.8
Mean minimum temp. °C	20.9	20.9	20.7	20.5	19.0	16.3	15.9	17.0	18.3	20.2	21.1	21.4
Mean temp. °C	26.1	26.4	26.3	25.3	23.7	22.0	21.7	22.6	24.3	26.1	26.9	26.6
Mean relative humidity %												
0900 hours	85	85	85	85	81	78	79	77	73	71	74	82
1500 hours	60	58	57	62	61	55	51	49	45	44	47	58
Mean	73	72	71	74	71	67	65	63	59	58	61	70

NB: Rainfall data are means computed for 46 years (1944 - 1989) while temperature and relative humidity have been computed for 12 years (1978 - 1989).

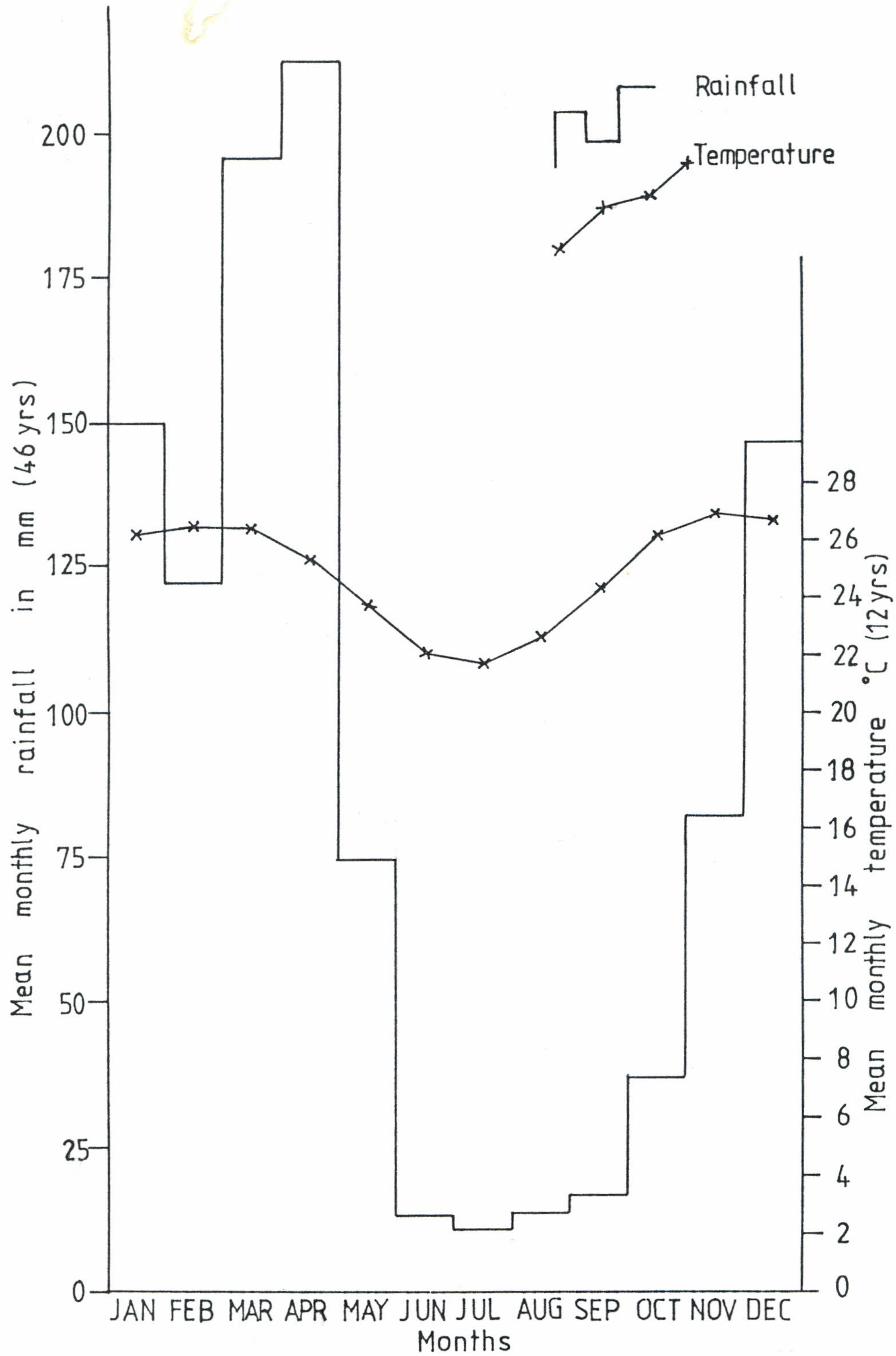
The climatic data indicate that there is a growing period of about seven months (November - May) during which there is enough moisture for crop growth. It should however be borne in mind that availability of moisture for crop growth is also a function of other factors including soil storage capacity, and landform characteristics which are likely to influence runoff, and evapotransipiration.

The realibility of the rainfall at Ilonga was tested statistically by taking rainfall means of five periods and comparing them.

- 1st 10 years (1944 - 1953) - period 1
- 2nd 10 years (1954 - 1963) - period 2
- 3rd 10 years (1964 - 1973) - period 3
- 4th 10 years (1974 - 1983) - period 4
- remaining 6 years (1984 - 1989) - period 5

The z (normal) test was applied to test for evidence of any mean differences for the five periods using the formula:

Figure 2. Rainfall and temperature patterns at Ilonga



$$Z = \frac{\overline{X}_i - \overline{X}_j}{\sqrt{\frac{Si^2}{ni} + \frac{Sj^2}{nj}}} \quad \text{for } i, j = 1, 2, 3, 4, 5 \quad i \neq j \quad n1, n2, n3, n4, = 120, n5 = 75$$

where $\overline{X}_k$ are the rainfall means for the different periods and S_k^2 and n_k are the samples variances and sample sizes respectively. The results of comparison are presented in table 2.

Table 2 : Comparison of rainfall means for five periods

		Periods				
		1	2	3	4	5
Periods	1					
	2	0.81				
	3	0.28	0.55			
	4	0.04	0.77	1.04		
	5	0.01	0.79	0.27	1.16	

The values obtained in table 2 were then compared with the tabular value from standard normal tables at P = 0.05 i.e. $Z_{0.05} = 1.96$. The results indicate that there are essentially no significant differences for the rainfall means for the five periods under consideration. In other words the rainfall over the period of 46 years has been quite consistent and reliable and no erratic changes are expecte.

2.4 Land use and vegetation

At present only 400 ha of land (33%) are cultivated in the Allidina Estate for various crops including maize, sorghum, cotton, sunflower, tobacco, paddy and simsim, all under rainfed conditions. In the case of Lutindi Estate 200 ha (50%) have been cultivated for sugarcane, maize and sorghum, also under rainfed conditlions. In both farms mechanized agriculture is practised whereby plowing, harrowing, ridging, seeding and insecticide spraying are done by tractors fitted with appropriate implements. Flood control is done using recipient canals which receive flooding water and divert it from the fields.

The uncleared land in both two estates is under robust natural vegetation which ranges from acacia woodland to wodded grassland to waterlogged grass near the rivers. Grazing of animals in these areas by neighbouring villagers had been rampant, but currently the owners of the land have restricted this kind of land use to a minimum.

CHAPTER 3 : MATERIALS AND METHODS

3.1 Pre-field work

Existing documents including field maps, topographical and geological maps were collected and studied. Climatological data were collected and compiled at the Directorate of Meteorology in Dar es Salaam.

3.2 Field work

The field work was effected in three stages. First, a reconnaissance survey of the farms was made using soil auger and soil color charts to check homogeneity/variability of soils in the various blocks of the farms. The field maps (see appendices 1a and 1b) of the farms together with the topographical and geological maps covering the two farms were used as base documents. Soil homogeneity/variability was established by looking at soil color, soil field texture, drainage and soil depth. Since the two farms are very flat, topography could not be used to differentiate soil units.

The soils were fairly homogenous, hence only three representative soil profile sites were chosen for Allidina estate and one for Lutindi estate. Profile sites are plotted on the field maps (see appendices 1a and 1b).

Second, the selected sites were dug to a depth of at least 1.8 m to expose the various soil layers/horizons. The soil profiles were then described using the FAO (1977) Guidelines for Soil Profile Description and the Soil Survey Manual (Soil Survey Staff, 1951). Soil colors were described using the Japanese Soil Color Charts (Oyama and Takehara, 1988). Both disturbed and undisturbed (core) soil samples were taken from each horizon for the laboratory determination of physical and chemical properties. Field descriptions are presented in appendices 2a, 2b, 2c and 2d.

Third surface (0 - 25 cm) soil samples were taken at random from various parts of the two farms and were thoroughly mixed to obtain composite samples for general soil fertility evaluation. Five composite samples were obtained from Allidina and three samples from Lutindi.

3.3 Laboratory analysis

3.3.1 Preparation of soil samples

The disturbed soil samples were air-dried, ground and sieved through 2 mm sieve to obtain the fine earth fraction to be analysed.

3.3.2 Analysis of chemical properties

Soil samples

The pH was determined potentiometrically in soil/water and soil/1MKCl suspensions in a ratio of 1:2.5 in both cases. Organic carbon was determined by the wet oxidation method of Walkley-Black as outlined by Nelson and Sommers (1982). Organic matter content was estimated by multiplying the % O.C by the factor of 1.724. Total nitrogen content was determined by the macro-Kjeldahl method as outlined by Bremner and Mulvaney (1982). The CEC and exchangeable bases were determined by saturating soils with neutral 1M NH_4OAc (Thomas, 1982), then displacing adsorbed NH_4^+ with K^+ using 1M KCl and determining the NH_4^+ by macro-Kjeldahl distillation for estimation of CEC. The bases Ca^{2+}, Mg^{2+}, K^+ and Na^+ displaced by the NH_4^+ were measured by atomic absorption spectrophotometry. The BS was calculated from :

$$\%BS = \frac{\text{sum of exchangeable bases (meq/100 g soil)}}{\text{CEC (meq/100 g soil)}} \times 100$$

The CEC of clay was estimated from that of soil by using the following formula outlined by ILACO (1985).

$$\text{CEC clay (meq/100 g)} = \frac{[\text{CEC soil (meq.100 g)} - (1.5 \times \text{OM\%})]}{\text{clay \%}} \times 100$$

where OM = organic matter content.

Phosphorus was extracted by Bray and Kurtz No. 1 method (Bray and Kurtz, 1945) and determined by spectrophotometer based on the intensity of the blue color developed by the ascorbic acid-ammonium molybdate complex. The available Cu, Zn, Fe and Mn were extracted using 0.005M Diethylene triamine pentaacetate (DTPA) at pH 7.3 and measured by atomic absorption spectrophotometry (Lindsay and Norvell, 1978). Electrical conductivity was measured by an electrical conductivity meter of extracts from 1:5 soil/water suspension as described by

International Soil Reference and Information Cente (1987).

Water samples

Both underground water and water from Kisangata river were sampled for analysis. Water quality with respect to irrigation was assessed by determining: the pH potentiometrically; the electrical conductivity (EC_w) by an electrical conductivity meter; the amount of dissolved cations by atomic absorption spectrophotmeter; and the amount of CO_3^{2-} and HCO_3^- by titrating with dilute H_2SO_4 and Cl^- by titrating with dilute $AgNO_3$ as described by the US Salinity Laboratory Staff (1963).

3.3.3 Analysis of physical properties

Particle size distribution (texture) was determined by the Bouyoucos hydrometer method as described by Day (1965), after dispersion using sodium hexametaphosphate. Bulk density was determined using the core sample method as described by Blake (1965). Soil moisture content was determined by ovendrying 5 gm of airdry soil at 105°C for 36 hours (to constant weight). The weight of the expelled moisture was then expressed as a percentage of the airdry weight. Available moisture content and infiltration rate (Appendix 4b) were estimated by using weighted average texture over 1 m depth (Appendix 4a).

3.4 Post-field work

3.4.1 Soil classification

The field and laboratory data were used to classify the soils up to subgroup level according to the Keys to Soil Taxonomy (Soil Survey Staff, 1990). The soils were also classified according to the FAO-UNESCO (1989) classification system up to level-2 soil unit names.

Land evaluation was done according to the FAO Framework for land evaluation (FAO, 1976), the FAO Guideline for Land Evaluation for Rainfed Agriculture (FAO, 1984) and according to the methods elaborated by Sys (1985) for both rainfed and irigated agriculture. Crop requirement data were also obtained from the works of Ochse et al. (1970), Acland (1977) and Euroconsult (1989).

CHAPTER 4: RESULTS AND DISCUSSION

4.1 General soil fertility evaluation

Table 3 gives the soil properties of the composite samples for both Allidina and Lutindi Estates.

4.1.1 Soil pH

This ranges from 5.9 to 7.5 which implies that the soils are slightly acid to slightly alkaline. These pH values are favourable for most crops. There is neither acidity nor alkalinity problem in the study areas.

4.1.2 Organic carbon

The values range from 1.5 to 2.5. The soils can said to have moderate organic matter content suitable for most crops. Plowing back into the soil crop residues after harvest may improve further the organic matter content and hence the natural fertility of the soils.

4.1.3 Total nitrogen

The total N contents can be considered medium for the soils of Allidina and Lutindi estates. For cereal crops like rice and maize it may be necessary to apply inorganic N-fertilizer. The farms lie within ecological zone 18 (Samki et al. 1982) and the recommended fertilizer rate is 40 kg N/ha. It may be worth while to grow nitrogen fixing legumes in rotations as a way of enhancing natural fertility.

4.1.4 Cation exchange capacity and base saturation

The soils have good CEC coupled with rather high BS indicating the inherent high fertility of the soils of the studied areas.

4.1.5 Available phosphorus

The P content ranges from medium to high indicating that there is no immediate requirement for P-fertilizers. However, with continued use of the soils for agriculture there may be a need for addition of inorganic-P particularly for cereal crops.

4.1.6 Micronutrients

The DTPA-extractable micronutrient contents are quite adequate according to the data reported by Viets and Lindsay (1973). For Zn and Mn any value greater than 1 mg/kg is considered adequate. Fe levels greater than 4.5 mg/kg are considered adequate whereas Cu levels exceeding 0.2 mg/kg are considered as non-deficient. For all the studied soils it can be said that there is no need for any addition of inorganic micronutrient fertilizers.

Table 3 : Soil characteristics of composite samples

Soil characteristics	Samples							
	1	2	3	4	5	6	7	8
	Allidina					Lutindi		
pH H_2O	6.7	6.3	6.3	5.9	6.6	6.4	6.7	7.5
pHKCl	5.3	5.1	5.2	4.6	5.2	5.2	5.9	5.7
OC%	1.9	1.5	2.2	1.6	1.6	1.5	1.5	2.1
OM (%)	3.3	2.6	3.8	2.8	2.8	2.6	2.6	3.6
Total N (%)	0.15	0.12	0.18	0.14	0.11	0.16	0.16	0.15
CEC soil (meq/100g)	18.0	15.5	20.7	17.6	13.1	13.3	10.6	14.8
CEC clay(meq/100g)	46.6	36.3	44.1	31.9	28.7	23.5	35.3	36.2
Bases (meq/100 g)								
Ca	9.00	7.80	10.10	6.70	5.50	6.70	6.70	7.80
Mg	5.68	3.67	4.18	4.68	3.42	2.92	1.67	2.17
K	0.92	0.23	0.51	0.28	0.28	0.28	0.51	0.92
Na	0.39	0.26	0.44	0.39	0.48	0.39	0.26	0.22
BS (%)	88.8	77.2	73.6	68.5	73.9	77.4	86.2	75.0
Avail. P (mg/kg)	19.6	16.8	35.1	17.9	19.1	25.3	35.5	60.4
Micronutrients (mg/kg)								
Cu	4.37	4.62	4.37	4.87	3.25	2.50	1.50	1.50
Zn	1.75	1.81	2.25	1.25	1.19	2.00	1.62	1.87
Fe	72.50	76.26	108.75	72.50	63.75	112.50	31.25	10.00
Mn	10.00	20.00	15.00	5.00	10.00	10.00	2.50	6.87
EC (mS/cm)	0.10	0.11	0.15	0.08	0.07	0.12	0.16	0.18
Moisture content(%)	4.0	3.20	3.40	4.20	3.40	3.20	3.20	2.80
Texture								
Clay	28	32	43	42	31	40	19	26
Silt	33	15	17	13	14	11	14	15
Sand	39	53	49	45	55	49	67	59
Textural class	CL	SCL	SCL	C	SCL	SC	SL	SCL

CL = clay loam
C = clay
SCL = sandy clay loam
SL = sandy loam

4.1.7 Electrical conductivity

The electircla conductivity values for all the samples are less than 0.5 mS/cm indicating that there are no salt problems in the studies areas.

4.1.8 Texture

The textures vary from sandy loam to sand clay loam to clay loam to clay. These textures are quite favourable for moisture storage.

4.2 Quality of water for irrigation

In irrigation planning and development the quality of the available water is important in determining the suitability of a tract of land for irrigated agriculture. Water samples from Kisangata river and from a well dug at Allidina estate (about 8 m deep) were analysed for some relevant parameters and the results are presented in Table 4. Due to unavailability of chemical reagents SO_4= ions could not be determined. Table 5 gives interpretive guidelines (adapted from FAO, 1979) for evaluating water quality for irrigation. According to this table both the river water and the underground water are good quality waters for irrigation. This means that they can be used safely without the risk of salinization and alkalinization.

Table 4 : Analytical data for assessment of water quality

meq/l							mS/cm		
Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	Cl^-	NO_3^-	ECw	pH	*SAR
Water from Kisangata river:									
0.18	0.06	0.26	0.23	0.00	0.24	0.12	0.27	7.00	0.36
Underground water:									
0.34	0.05	0.40	0.49	0.00	1.17	1.08	0.31	7.05	0.51

Table 5 : Guideline for evaluating water quality

Parameter	Critical levels for good quality water
Salinity (mS/cm)	0.7
SAR (sodium adsorption ratio):	
Soils rich in montimorillonite-smectite	6
Soils rich in illite-vermiculite	8
Soils rich in kaolinite-sesquioxides	16
Sodium (meq/l):	
Surface irrigation	3
Sprinkler irrigation	3
Chloride (meq/l):	
Surface irrigation	4
Sprinkler irrigation	3
Nitrate (meq/l)	5
Bicarbonate with sprinklers(meq/l)	1.5
pH	6.5 - 8.4

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

4.3 Soil profile characteristics

The soil profile analytical data are presented in appendices 3a, 3b, 3c and 3d respectively for profiles I, II, III and IV. pH values are all in the acceptable range, the highest pH H_2O being 8.1 in profile III at a depth of more than 1 m and the lowest value 5.9 in profile 1 at a depth of about 36 cm.

Texture ranges from sandy loam to sandy clay loam to clay loam to clay. The highest clay contents were observed in profile IV (Lutindi) where all horizons except the second one have a "clay" textural class.

Bulk density values range from 1.24 to 1.79 g/cc. Except for profile IV, there is a clear tendency of BD increasing with depth at least to a certain depth. Normally this is because of lower levels of organic matter, less aggregation and more compaction in the subsoil. The highest values of BD were observed in profile III (1.6 in the surface and 1.79 in the subsoil). These values are nevertheless not alarming. Profile III was dug in the uncleared land of Allidina estate, and tramping by grazing animals must be responsible for the relatively higher values when compared with the other profiles. However, with plowing and other tillage operations soil pore space will increase and eventually decrease BD.

Moisture content values ranged from 0.60 to 7.4% and there is a clear relationship between the amounts with texture; the higher the clay content the higher the soil moisture content.

The organic carbon and total nitrogen for the surface horizons can be considered medium for all the soil profiles just like was the case for the composite samples (see table 3). There was a general tendency of these values to decrease with depth to a certain depth although in some cases the trend was irregular.

The cation exchange capacity and base saturation values can generally be rated as medium to high not only for the surface horizons but also for most of the subsurface horizons. This points to the inherent natural fertility of the soils.

The available P can be considered medium to high for the surface horizons of profile I and II and relatively low for the other profiles. Phosphorus is most likely inadequate is some areas of the two farms.

The electrical conductivity and soidum adsorption ratio values are quite below critical levels in all the horizons indicating that there are no problems of salinity or alkalinity.

The micronutrient levels are quite adequate in all the profiles in the upper 50 cm and in some cases even at great depths.

4.4 Soil classification

The field data (appendices 2a, 2b, 2c and 2d) together with the soil analytical data (appendices 3a, 3b, 3c and 3d) were used to classify the soil profiles.

Profile I has a mollic epipedon and a cambic horizon as the diagnostic horizons. This profile exhibits properties indicative of aquic soil moisture regime.

Profile III has a mollic epipedon as the diagnostic surface horizon. There is no diagnostic subsurface horizon. The profile has properties indicative of aquic soil moisture regime. It has also clear indications of fluvic properties (sensu FAO-UNESCO, 1989).

Profile IV has a mollic epipedon as the diagnostic surface horizon. It has no diagnostic subsurface horizon. The profile has also properties indicative of both aquic soil moisture regime and fluric nature.

Although all the profiles exhibit properties indicative of aquic soil moisture regime (presence of mottles) only in profile III these properties could be reflecting active reducing conditions for some period particularly during the rainy season. In the other profiles the mottles appear to be relict since the profiles were rather well drained to a depth of more than 1.5 m even during the rainy season when these soils were described. For current use and management of the soils it would be misleading to describe profiles I, II and IV as having waterlogging conditions. Hence the aquic soil moisture regime has not been used as a diagnostic feature in the classification of these profiles but only for profile III. Ustic soil moisture regime has instead been assigned to the said profiles to give a more realistic picture of the soils. The results of the classification exercise are presented in table 6.

Table 6 : Classification of the studies soil profiles

Soil profile	Soil names	
	USDA Soil Taxonomy (Soil Survey Staff, 1990)	FAO-UNESCO (1989) Classification
I	Typic Haplustoll	Haplic Phaeozem
II	Pachic Haplustoll	Haplic Phaeozem
III	Fluvaquentic Haplaquoll	Mollic Fluvisol
IV	Fluventic Haplustoll	Mollic Fluvisol

4.5 Suitability evaluation of the farms for irrigated agriculture

4.5.1 Basic assumptions

This section focusses on the interpretation of the collected data for evaluation of land suitability for irrigated agriculture. What is presented here is the evaluation of the physical environment for irrigation based on the specific physical requirements of land for irrigation and the environmental conditions of the farms. The following land charactieristics were considered in the assessment:

a. Topography including slope and microrelief
b. Wetness including flooding and internal drainage
c. Physical soil conditions including texture, surface stoniness, surface rockiness and soil depth
d. Salinity and alkalinity.

The farms are to be developed for both irrigated and rainfed agriculture. For the evaluation of the land for irrigated agriculture the following assumptions are made:

a. The amount of irrigation water is not a limitation. In fact this is true as Wami and Kisangata rivers which flow near the farms are permanent rivers.
b. The quality of irrigation water is not a limitation. This has been established to be true (see section 4.2).
c. The Azania Agricultural Enterprises Ltd. will have the finances to establish major infrastructure and drainage system that may be required in irrigation farming.
d. Mechanized form of agriculture is to be adopted whereby, tractors and other machinery will be used for land preparation, plowing, planting and harvesting. Weeding may be done by hand.
e. There are no limitations with regard to mechanization. This is true as the two farms are fairly flat (slope less than 1%), have no micro-relief, surface gravels, stones or rocks.
f. There is slight or no chemical soil fertility problem. This has been established true (see sections 4.1 and 4.3).
g. The Azania Agricultural Enterprises Ltd. has competent field and administrative staff to coordinate and manage farm activities.

4.5.2 Land suitability classes and subclasses

Different land suitability classes and subclasses are defined according to FAO (1976).

Classes:

S1 Highly suitable land: Land having no significant limitations. No special management or improvements are required. This kind of land permits high yields with relatively low inputs.

S2 Suitable land: Land having minor limitations that may require some special management practices or minor land improvements which can be implemented easily.

S3 Moderately suitable land: Land with moderate limitations which will reduce productivity or require special inputs or land improvements. Its use, although still attactive, will yield significantly less than that expected under S1.

S4 Marginally suitable land: Land with severe limitations which seriously reduce productivity or require corrections or inputs that will only be marginally justified.

N Unsuitable land: Land with limitations which preclude its successful and sustained use.

Subclasses

Land suitability subclasses are subdivisions of classes distinguished by the nature of the main limitation or limitations which determine their classification. Subclasses are indicated by lower case letters e.g

t = topography, w = wetness, s = physical soil conditions,

n = salinity and alkalinity

Although the soils on both farms look similar in many aspects, the data for the 4 studied profiles were used separately as if representing different land units, for the land suitability evalualtion. The results of this exercise are presented in table 7. The results indicate that Allidina estate is highly suitable (S1) for irrigation. The data for the 3 profiles excavated in this farm indicate favourable conditions for the said land use. There is slight flooding hazard but this according to the system of evaluation does not affect the suitability class of the farm as it is not a significant limitation. In the case of Lutindi estate, the land is rated as suitable (S2s) for irrigation. This land has minor limitations in this particular case due to the heavy subsoil texture represented by the lower case letter s. These may be also a slight flooding hazard which does not affect the suitability class of the land.

Table 7: Irrigation suitability land classification in Allidina and Lutindi Estates

Profile	Land characteristics									
	Topography	Flooding	*Internal drainage	Texture	Surface stoniness	Surface rockiness	Soil depth	Salinity	Alkalinity	Overall suitability
1 (Allidina)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2 (Allidina)	S	S1	S1	S1	S1	S1	S1	S1	S1	S1
3 (Allidina)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
4 (Lutindi)	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2s

*Internal drainage (infitration rate) estimated from texture (see appendices 4a and 4b).

In the management of both farms, it will be advisable to avoid using the mashy areas that border the rivers. These are likely to be highly waterlogged and having heavy textures.

4.5.3 The type of irrigation to be used

Although costly (in terms of initial high cost of equipment and high operational costs), sprinkler irrigation will be preferred to surface irrigation in this particular area of study for the following reasons:-

a. Surface irrigation will require land preparations aimed at creating a slope necessary for the flow of water on the farms. This means high costs of land preparation and will involve removal of the fertile surface soil. In the case of sprinkler irrigation this problem is avoided.

b. Surface irrigation involves establishment of field ditches and hence reduction in cultivatable areas. In the the case of sprinkler irrigation this shortcoming is eliminated, and one source of weed propagation is also eliminated.

c. With sprinkler irrigation, sandy or highly permeable soils can be irrigated without excessive losses by deep percolation, so that drainage problems are reduced.

d. Where or when available water supply is small, a greater efficiency in water use and labor can be achieved by sprinkler irrigation than by surface irrigation.

e. Sprinkler irrigation is adaptable to small applications of water which may be required in seedbed preparation, seed germination and transplanting of seedlings.

f. Sprinkler irrigation is easily adaptable to infiltration rate of the soil.

g. Sprinkler irigarion is suitable for a wide choice of crops.

h. High degree of automation is possible with sprinkler irrigation particularly when frequent irrigations are required.

4.5.4 Crops that can be grown

This section discusses about the crops that can perform best under the prevailing climatic and soil conditions of the Allidina and Lutindi Estates. Table 8 gives a summary of the crops together with the most appropriate culture (whether rainfed or irrigated agriculture).

Cereal crops

Paddy rice (Oryza sativa)

This crop requires heavy soils with a low permeability so as to reduce water losses. It requires about 1500 mm per crop. Under planned irrigation and with the prevailing soil conditions rice can perform very well in both

Allidina and Lutindi farms. However, since the AAE Ltd. are interested to grow a number of other crops including forex earning ones, paddy should be grown more on the marshy areas bordering the rivers. In these areas the soils are mostly heavy-textured, and natural river floods during the rainy season can easily be used to raise the crop. If well timed the floods may suffice without supplimentary irrigation particularly when early maturing varieties are used.

Maize (Zea mays)

This crop requires from 600 to 900 mm of well distributed rainfall under rainfed conditions. Moisture stress at the time of flowering is very critical, whereas maturation and harvesting should take place during dry weather. The crop requires well structured, permeable soils with high content of organic matter. It is seriuosly affected by waterlogging. Under the prevailing conditions at the two farms maize is expected to perform very well (except in the waterlloged marshy areas). Depending on whether one grows late-maturing or early-maturing variety irrigation may or may not be necessary.

Sorghum (Sorghum bicolor)

This crop is drought tolerant and to a certain degree can withstand waterlogging. Good yields are obtained with a rainfall of 600 mm or over. Sorghum yields relatively well even on poor soils because of its efficient root system. Under the prevailing conditions in the two farms, this crop is expected to perform very well under rainfed conditions.

Millets

These include Bulrush millet (Pennisetum typhoides), Finger millet (Eleusine coracana), common millet (Panicum miliaceum) and Italian millet (Setaria italica). Millets are drought resistant and do not require fertile soils. Hence under the prevailing climatic and soil conditions of the two farms they will do very well. Irrigation is not necessary unless one intends to produce more than one crop.

Table 8: Crops that can be grown in Allidina and Lutindi estates

Crop	Allidina		Lutindi	
	Rainfed	Irrigated	Rainfed	Irrigated
Paddy	x (natural floods)	–	x(natural floods)	–
* Maize	x	x	x	x
Sorghum	x	–	x	–
Millet	x	–	x	–
* Soyabeans	x	x	x	x
* Chick pea	x	x	x	x
Groundnuts	x	–	–	–
Sunflower	x	–	–	–
Sesame	–	x	–	x
*Sugarcane	–	x	–	x
*Sugarbeat	x	x	x	x
Cotton	x	–	x	–
Kenaf	x	–	x	–
Castor bean	x	–	x	–
Tobacco	x	–	x	–

x = Yes

– = No

*In the case of irigated culture, it should be planned such that part of the moisture requirement is supplied by rain.

Oil and protein crops

Soya beans (Glycine max)

The requirements of soybeans in terms of climate and soil conditions are the same as those for maize. Hence, this crop is also expected to do well under the prevailing conditions of the two farms. Depending on the variety, supplimentary irrigation may/or may not be necessary. Soya bean is a suitable crop in rotation with graminaceous crops.

Chick pea (Cicer arietinum)

Chick pear or gram is very drought resistant and does not require high levels of soil fertility. It shrives well even on heavy textured soils provided they are well drained. Under the prevailing conditions in the two farms this crop is expected to perform very well. Depending on variety supplimentary irrigation may/or may not be necessary.

Groundnuts (Arachis hypogea)

This crop requires 400 - 800 mm of well distibuted rainfall and grows best in light-textured soils. A dry weather is required during maturing and harvesting to ensure quality. In view of this, groundnuts are expected to perform well only in the Allidina farm where the top soils are relatively light textured. The crop should be grown under rainfed conditions. In the Lutindi farm the soils are too heavy textured.

Sunflower (Helianthus annuus)

Sunflower is drought tolerant and a rainfed crop can be grown with a rainfall from 300 - 800 mm. Heavy textured and poorly drained soils are not suitable for this crop. Hence this crop is expected to perform well in Allidina farm where most topsoils are relatively light textured. With the prevailing conditions sunflower is expected to grow very well under rainfed conditions. In Lutindi farm the soils are too heavy textured and hence unsuitable for this crop.

Sesame (Sesamum indicum)

This is also a drought tolerant crop requiring about 400 mm of well distributed rainfall. It is sensitive to excess soil moisture and thus periods with heavy rainfall should be avoided. The crop needs well aerated soils. It can thus be grown in both farms except in the marshy areas where there is waterlogging. Since it has a very short growing period (70 days) it should be grown as rotation crop after harvest of another, under irrigation. It can be grown in the stubble of the previous crop.

Sugar producing crops

Sugarcane (Saccharum officinarum)

This crop needs an annual supply of about 1600 mm, with distinct dry season of 4 - 5 months for adequate ripening. Sugarcane can grow on a variety of soils ranging from light textured to heavy textured ones. Under the prevailing conditions in the two farms sugarcane will perform well under irrigation.

Sugar - beet (Beta vulgaris)

This crop requires about 750 mm of water. When grown in the tropics a dry period is required at the end of the growing season to induce maturation. Soils should have a depth of at least 50 cm and should be fertile and well drained. Under the prevailing conditions sugar - beet can do well in both farms except in the marshy areas with poor drainage. It can be grown under rainfed conditions if early maturing varieties are used, otherwise supplimentary irrigation may be necessary. To control nematodes sugar-beet should be grown on the same land only once every 4 years.

Fibre - producing crops

Cotton (Gossypium spp.)

Cotton grows well in dry climates, but requires irrigation. A rainfed crop requires at least 450 mm of rain. Sufficient moisture is required during the flowering period. Excessive rainfall at flowering and boll formation may result in shedding. Abundant sunshine (more than 6h/day) is required during flowering. Cotton can be grown on heavy soils if they are well - drained. Under the prevailing conditions the crop is expected to perform well in both farms under rainfed conditions. Planting should be well timed so that the period of heavy rains does not coincide with flowering and boll formation.

Kenaf (Hibiscus cannabinus)

Kenaf is fairly drought resistant. It requires 125 mm per month during the growing period. Dry weather is required during maturation period and during harvesting. It requires high relative air humidities. As far as soils are concerned kenaf can do well even in cases of fair soil fertility and can tolerate a few days of inundation. In the conditions at the two farms, kenaf is expected to perform well under rainfed conditions (growth period varies from 3 - 5 months depending on variety).

Industrial crops

Castor bean (Ricinus communis)

This crop is drought tolerant and has a minimum requirement of 600 mm of well distributed rain, most of which should be available during the vegetative period i.e. months following sowing. The plant needs hot, dry weather for good seed setting and harvest. It is a perennial plant and grows on a great variety of soils provided that they are well-drained. Under the conditions at the two farms, this crop is expected to do well under rainfed conditions.

Stimulant crops

Tobacco (Nicotiana tabacum)

This crop shrives well in a wide range of climates. Water requirements range from 400 - 1000 mm for different types of tobacco. The crop requires an evenly distributed rainfall until harvesting starts, and dry period thereafter. Different types of toabacco require different types of soils. Generally, well-drained, light to medium-textured soils are the most suitable. Under the prevailing conditions this crop is expected to perform well in the Allidina farm excluding the marshy areas bordering the rivers. The crop can be grown under rainfed conditions. Crop rotation is essential for the control of nematodes and bacterial and viral diseases. Cotton and maize are good rotation crops.

REFERENCES

Acland, J.D. (1977). East African Crops. An introdution to the production of field and plantation crops in Kenya, Tanzania and Uganda. Longman Group Ltd. 252 pp.

Blake, G.R. (1965). Bulk density. In: Methods of Soil Analysis, part 1, pp. 374 - 394. Editors: C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark. ASA, Madison, USA.

Bray, R.H. and L.T. Kurtz (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59 : 39 - 45.

Bremner, J.M. and C.S. Mulvaney (1982). Total nitrogen. In: Methods of Soil Analysis, part 2, , 2nd Edition. pp. 595 - 624.. Editors: A.L. Page, R.H. Miller and D.R. Keeney. ASA, SSSA Monograph No. 9. Madison, Wisc, USA.

Day, P.R. (1965). Particle fractionation and particle size analysis. In: Methods of Soil Analysis, part 1 pp. 545 - 566. Editors: C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark. ASA, Madison, USA.

Euroconsult (1989). Agricultural compendium for rural development in the tropics and subtropics. 3rd revised edition. Ministry of Agriculture and Fisheries, The Hague, The Netherlands. Elsevier Science Publishers, B.V. 740 pp.

FAO (1976). A Framework for Land Evaluation. FAO Soils Bull. No. 32. FAO, Rome. 72 pp.

_______(1977). Guideline for Soil Profile Description. 2nd edition FAO, Rome 66 pp.

______ (1979). Soil Survey Investigations for Irrigation. FAO Soils Bull. No. 42, Rome. 188 pp.

_______ (1984). Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soils Bull. No. 52. FAO, Rome, 237 pp.

FAO-UNESCO (1989). Soil map of the world revised legend. International Soil Reference and Information Centre, Wageningen. Technical Paper 20, 138 pp.

Geological Survey Division (1965). Geological survey of Tanzania, Quarter degree sheet 182, Kimamba. 1st edition, Ministry of Industries, Mineral Resources and Power. Dodoma

ILACO, B.V. (1985). Agricultural compendium for rural development in the tropics and subtropics. 2nd revised edition. Elsevier Science Publishers, Amsterdam. 738 pp.

International Soil Reference and Information Centre (1987). Procedures for Soil Analysis, 2nd edition. Wageningen, The Netherlands.

Lindsay, W.L. and W.A. Norvell (1978). Development of DTPA test for zinc, iron, manganese and copper. SSSA Journal 42 : 421 - 428.

Nelson, D.W. and L.E. Sommers (1982). Total carbon, organic carbon and organic matter. In : Methods of Soil Analysis, part 2, 2nd edition. pp. 539 - 579. Editors: A.L. Page, R.H. Miller and D.R. Keeney. ASA, SSSA Monograph No. 9. Madison, Wisc. USA.

Ochse, J.J., J. Soule, M.J. Dijkman and C. Wehlburg (1970). Tropical and subtropical agriculture. MacMillan Co. 1446 pp.

Oyama, M. and H. Takehara (1988). Revised standard soil color charts. Japan.

Samki, J.K., J.F. Harrop, H.C. Dewan and F. Miany (1982). Fertilizer recommendations related to ecological zones in Tanzania. URT/73/006 Technical Paper. National Soil Service, Mlingano. Ministry of Agriculture, Tanzania.

Soil Survey Staff (1951). Soil Survey Manual. Agriculture Handdbook No. 18. Soil Conservation Service. USDA. Washington D.C., 503 PP.

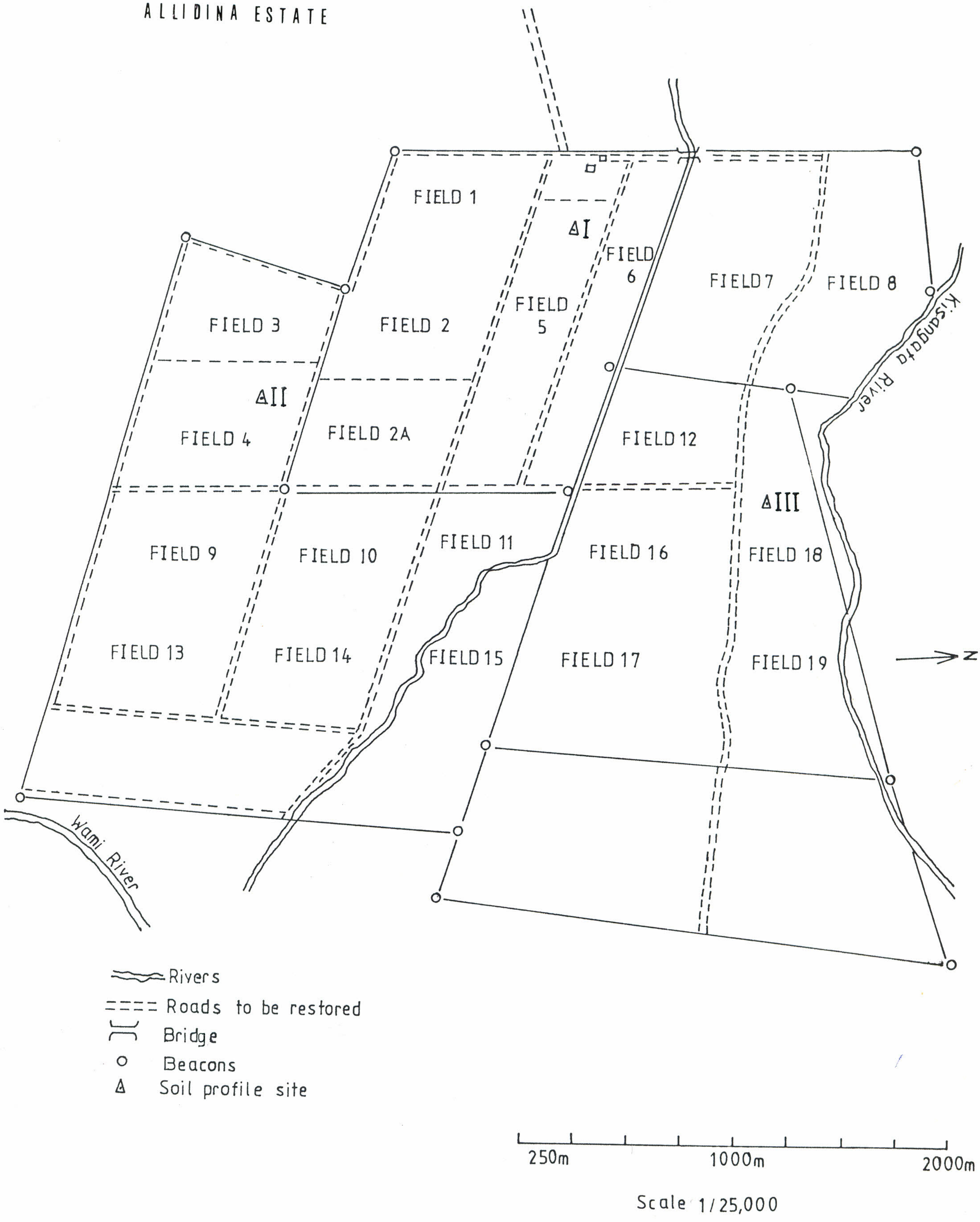
________ (1990). Keys to Soil Taxonomy. Agency for International Development, USDA, Soil Management Support Services. SMSS technical monograph no. 19, 4th edition. 422 pp.

Sys, C. (1985). Land evaluation. Parts I, II and III. State University of Ghent, International Training Centre for Postgraduate Soil Scientists, Ghent, Belgium. 247 pp.

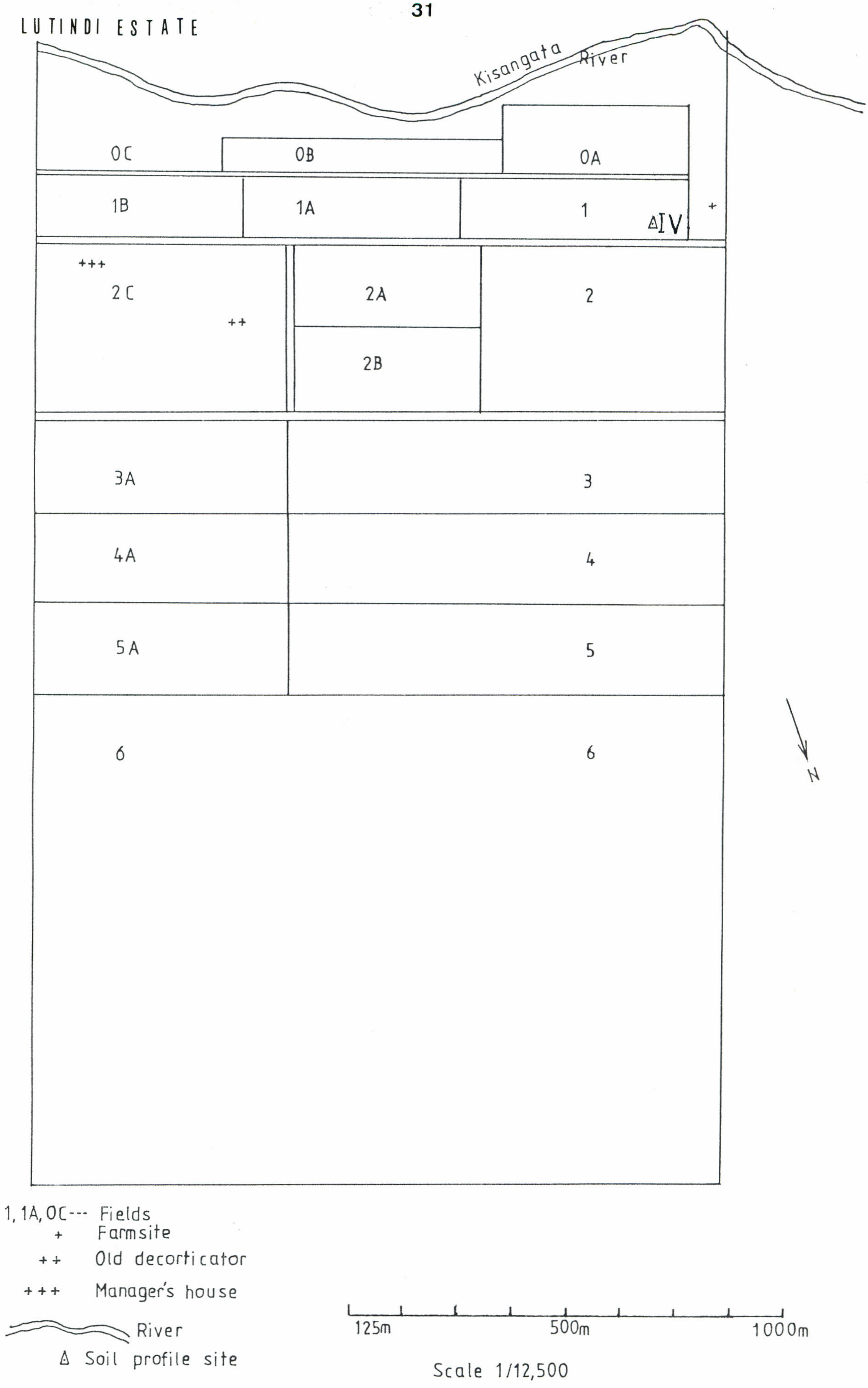
Thomas, G.W. (1982). Exchangeable cations. In: Methods of Soil Analysis, part 2, 2nd edition pp. 159 - 165. Editors: A.L. Page, R.H. Miller and D.R. Keeney. ASA, SSSA monograph no. 9. Madison, Wisc, USA.

US Salinity Laboratory Staff (1963). Diagnosis and Improvement of Saline and Alkaline soils. Agriculture Handbook no. 60.USDA. Indian Edition. Oxford and IBH Publishing Co. Calcutta, Bombay, New Delhi. 150 pp.

Viets, F.G. and W.L. Lindsay (1973). Testing soils for zinc, copper, manganese and iron. In: Soil Testing and Plant Analysis. Editors: L.M. Walsh and J.D. Beaton. SSSA, Inc. Madison, Wisconsin, USA.



Appendix 1a. Location of soil profiles



Appendix 1b. Location of soil profiles

Appendix 2a: Soil profile description - Profile I

Date of description and sampling: 19/4/91. Author: Dr. B.M. Msanya.
Survey area: Allidina Estate - Kilosa district.
Map No: Topo sheet 182/1 (Rudewa).
Location: Block 5 (currently under sunflower).
Geological formation: Neogene superficial deposits.
Parent material: Alluvium of diverse origin and composition.
Physiograph: Alluvial plain (flood - plain).
Macrorelief: Flat. Slope of site: less than 1%.
Elevation of site: about 410 m a.m.s.l.
Land use/vegetation : under cultivation with sunflower.
Moisture condition : surface moist due to rains
Groundwater level: deeper than 1.8 m.
Drainage: Well drained. Effective soil depth: more than 1 m.

Horizon description

Ap 0-24.5 cm: Brownnish black (7.5YR 2/2, moist); clay loam; weak fine su bangular blocky; friable when moist, slightly sticky and slightly plastic when wet; many fine to medium pores; many fine and few medium roots; common fine mica flakes; clear wavy boundary.

Bw 24.5-48cm: Very dark brown (7.5 YR 2/3, moist); clay; moderate medium subangular blocky; firm when moist, sticky and plastic when wet; many fine pores; common fine roots; common fine mica flakes; clear smooth boundary.

C1g* 48-66 cm:Bright brown (7.5 YR 5/6, dry), brown (7.5 4/4, moist); sandy loam; massive; soft to slightly hard when dry, slightly sticky and slightly plastic when wet; many fine pores; common fine roots; common fine mica flakes; common fine to medium reddish brown (5 YR 4/8) district clear mottles; common fine mica flakes; abrupt smooth boundary.

C2 66-86 cm: Brown (7.5 YR 4/4, dry), dark brown (7.5 YR 3/4, moist); sandy loam; single grained; soft when dry, non sticky and non plastic when wet; many fine pores; few fine roots; many fine mica flakes; abrupt smooth boundary.

C3g* 86-110 cm: Reddish brown (5 YR 4/6, dry), dark reddish brown (5 YR 3/6, moist); sandy loam; single grained; soft when dry, nonsticky and nonplastic when wet; many fine to medium pores; few roots; common fine reddish brown (5YR 4/8) faint diffuse mottles; many fine mica flakes; abrupt smooth boundary.

C4g* 110-180 + cm Black (7.5 YR 2/1, dry); clay; massive; very hard when dry, very sticky and very plastic when wet; common fine to medium pores; few fine roots; few fine reddish brown (5 YR 4/8) faint diffuse mottles; common fine mica flakes.

---

* relict

Appendix 2b: Soil profile description - Profile II

Date of description and sampling : 20/4/91. Author: Dr. B.M. Msanya.
Survey area : Allidina Estate - Kilosa District.
Map No: Topo sheep 182/1 (Rudewa).
Location : Block 4 (under tobacco).
Geological formation : Neogene superficial deposits.
Parent material : Alluvium of diverse origin and composition.
Physiography : Alluvial plain (flood-plain). Macrorelief: Flat.
Slope of site: Less than 1% : Elevation of site: About 410 m a.m.s.l.
Land use/vegetation: Under cultivation with tobbaco, nearby natural vegetation acacia woodland-wooden grassland.
Moisture condition: Surface moist due to rains.
Groundwater level: deeper than 1.8 m.
Drainage : Well drained. Effective soil depth: More than 1 m.

Horizon description

Ap 0 - 23 cm Brownish black (10 YR 3/2, moist); clay loam; weak fine su bangular blocky; loose when moist, slightly sticky to sticky and slightly pl-astic when wet; many fine pores; common fine and few medium and coarse roots; clear smooth boundary.

Bw 23 - 50 cm Brownish black (7.5 YR 3/2, dry), brownish black (7.5 YR 3/1, moist); clay; moderate fine to medium subangular blocky; slightly hard when dry, slightly sticky and slightly plastic when wet; common fine to medium pores; few medium and few fine roots; few fine mica flakes; abrupt smooth boundary.

C1 50 - 74 cm Brown (7.5 YR 4/6, dry), brown (7.5 YR 4/9, moist); sandy loam; massive, soft when dry, nonsticky and nonplastic when wet; many fine pores; few medium roots; many fine mica flakes; clear smooth boundary.

C2g[x] 74-117 cm Brown (7.5 YR 4/4, dry), brown (7.5 YR 4/3, moist); sandy loam; massive; soft to slightly hard when dry, nonsticky and non plastic when wet; common fine to medium pores; few medium roots; common fine to medium reddish brown (5 YR 4/8) faint diffuse mottles; many fine mica flakes, stoneline with FeMn powdery segregations; clear smooth boundary.

C3g[x] 117-180 + cm Bright brown (7.5 YR 5/8 dry), brown (7.5 YR 4/6 moist); clay; massive; soft to slightly hard when dry, nonsticky and nonplastic when wet; common fine to medium pores; few medium roots; many medium reddish brown (5 YR 4/8) distinct clear mottles; common fine mica flakes; stoneline with FeMn powdery segregations.

---

[x] relict

Appendix 2c: Soil profile description - Profile III

Date of description and sampling: 20/4/91: Author Dr. B.M. Msanya.
Survey area: Allidina Estate - Kilosa district.
Map No: Topo sheet 182/1 (Rudewa).
Location : Block 18 (uncleared land) wooded grassland dominated by acacia trees.
Geological formation : Neogene superficial deposits.
Parent material: Alluvium of diverse origin and composition.
Physiography : Alluvial plain (flood-plant). Macrorelief: flat.
Slope of site: less than 1%. Elevation of site: about 410 m a.m.s.l.
Landuse/vegetation: wooded grassland dominated by acacia trees-Uncleared land.
Moisture condition: surface moist due to rains.
Groundwater level: deeper than 1.5 m
Drainage class : imperfectly to moderately well drained. Effective soil depth: more than 1 m.

Horizon description

A1 0 - 26 cm Brownish black (7.5 YR 3/1, moist), brownish gray (7.5 4/1, dry); sandy loam; weak to moderate fine crumby and subangular blocky; friable when moist, slightly hard when dry, nonsticky to slightly sticky and nonplastic to slightly plastic when wet; many fine and medium pores; many fine few medium roots; clear wavy boundary.

AC11g 26-46 cm Brown (7.5 YR 4/3, dry), grayish brown (7.5 YR 4/2, moist); sandy clay; massive; very hard when dry, firm when moist, sticky and plastic when wet; many fine and medium pores; common fine and few medium roots; common fine orange (7.5 YR 6/8) faint diffuse mottles; clear smooth boundary.

AC12g 46-90 cm Olive brown (2.5 YR 4/3, dry); brownish black (2.5 YR 3/2, moist); sandy clay; massive; extremely hard when dry, very firm when moist, sticky and plastic when wet; many fine and few medium pores; few fine roots; common fine orange (7.5 YR 6/8) distinct clear mottles; gradual smooth boundary.

AC13g 90-180 + cm Olive brown (2.5 YR 4/4, dry), dark grayish yellow (2.5 YR 4/2, moist); sandy clay loam; massive; very hard when dry, firm when moist, sticky and plastic when wet; common fine pores; few fine roots; common fine orange Fe (7.5 YR 6/8) distinct clear mottles and common fine bluish black Mn (5 PB 2/1) distinct clear mottles.

---

[1] By augering.

Appendix 2d : Soil profile description - Profile IV

Date of description and sampling: 20/4/91: Author: Dr. B.M. Msanya.

Survey area: Lutindi - Kilosa district. Map No: Topo sheets 182/1 (Rudewa) and 182/2 (Lutindi)

Location: Block 1 (under maize crop), neighbouring areas grassland dominated by tall grass.

Geological formation: Neogene superficial deposits

Parent material : Alluvium of diverse origin and composition

Physiography: Alluvial plain (flood-plain). Macrorelief: Flat.

Slope of site : Less than 1%. Elevation of site: About 410 m a.m.s.l.

Land use/vegetation : Site under maize, neighbouring blocks with sugarcane, sorghum, trees and grasses

Moisture condition : Surface moist due to rains, groundwater level: deeper than 1.9 m

Drainage class : Well drained. Effective soil depth: more than 1 m

Horizon description

Ap 0 - 42.5 cm Black (7.5YR 2/1, moist); clay; weak fine subangular blocky; friable when moist, sticky and plastic when wet; many fine and medium pores; common fine and few medium roots; abrupt wavy boundary

C1 42.5 - 68.5 cm Brown (7.5 YR 4/6, moist); clay loam, massive; friable when moist, slightly sticky and slightly plastic when wet, many fine pores; common fine roots; many fine mica flakes; abrupt smooth boundary.

C2g[x] 68.5-116cm Dark brown (7.5 YR 3/3, dry) brownish black (7.5 YR 3/2, moist); clay; massive, very firm when moist, sticky and plastic when wet; common fine pores; few fine roots; common pressure faces medium brown (7.5 YR 4/6) distinct clear mottles; gradual smooth boundary.

C4g[x] 116-190cm Brownish black (7.5 YR 3/2, dry), brownish black (7.5 YR 2/2, moist); clay; massive; very firm when moist, sticky and plastic when wet; common fine pores; few fine roots; common pressure faces; common medium brown (7.5 YR 4/6) distinct clear mottles.

---

[x]relict

Appendix 3a: Soil analytical data - Profile 1 (Allidina)

Depth (cm)	pH		Texture %			Textural class	B.D. g/cc	% moist-ure
	H_2O	KCl	Sand	Silt	Clay			
0 - 24.5	6.5	5.7	39	29	37	CL	1.24	3.40
24.5-48	5.9	4.9	27	30	43	C	1.36	5.00
48 - 66	6.0	4.3	77	7	16	SL	1.53	1.40
66 - 86	6.3	4.4	69	22	9	SL	1.32	0.60
86 - 110	6.0	4.3	69	13	18	SL	1.25	2.40
110- 180+	6.4	4.7	37	14	49	C	1.42	5.60

OC%	N%	C/N	Exch. bases meq/100g soil				CEC soil	CEC clay	BS%
			Ca	Mg	Na	K	meq/100g		
1.77	0.15	11.80	11.20	4.68	0.26	0.56	18.50	37.62	90.3
1.59	0.11	14.45	10.10	5.85	0.35	0.18	18.00	32.30	91.6
0.35	0.05	7.00	3.50	2.38	0.49	0.15	8.70	48.69	74.9
0.17	0.03	5.67	2.30	1.56	0.43	0.10	5.60	57.33	78.4
0.49	0.09	5.44	6.70	3.92	0.26	0.13	12.00	59.61	91.8
0.50	0.06	8.30	7.80	5.34	0.35	0.09	14.60	27.16	93.0

Avail. P mg/kg	Electrical conductivity mS/cm	SAR*	Micronutrients mg/kg			
			Cu	Cu	Fe	Mn
30.88	0.25	0.09	3.50	2.12	18.75	20.00
4.91	0.15	0.12	6.75	1.75	60.00	52.50
5.61	0.07	0.29	3.00	0.62	50.00	15.00
9.12	0.10	0.31	1.50	0.56	31.25	10.00
6.32	0.06	0.11	4.37	0.94	57.50	26.25
0.70	0.08	0.14	5.25	1.44	10.00	52.50

* SAR = Sodium Adsorption Ratio

Appendix 3b : Soil analytical data - Profile II (Allidina)

	pH		Texture %			Textural	B.D.	%Moist-
Depth (cm)	H_2O	KCl	Sand	Silt	Clay	class	g/cc	ure
0 - 23	6.8	5.6	39	29	32	CL	1.29	3.80
23 - 50	6.0	4.7	29	30	41	C	1.35	5.40
50 - 74	6.8	4.9	79	6	15	SL	1.63	1.40
74 - 117	6.8	4.9	73	8	19	SL	1.48	1.80
117- 180+	6.8	4.8	29	29	42	C	1.39	5.20

			Exch. bases meq/100 soil				CEC soil	CEC clay	BS%
OC%	N%	C/N	Ca	Mg	Na	K	meq/100 g		
2.35	0.21	11.19	11.20	4.93	0.35	0.66	20.80	46.00	82.4
1.16	0.13	8.92	11.20	3.67	0.30	0.18	22.30	47.07	68.8
0.32	0.08	4.00	3.20	2.00	0.39	0.18	7.40	43.80	78.0
0.21	0.04	5.25	5.50	4.43	0.22	0.05	11.60	58.21	87.9
0.75	0.08	9.38	9.00	2.22	0.08	0.09	19.40	41.57	62.4

Avail. P.	Electrical	SAR	Micronutrients mg/kg			
mg/kg	conductivity mS/cm		Cu	Zn	Fe	Mn
40.70	0.11	0.12	3.00	2.65	31.25	12.50
0.70	0.12	0.11	5.75	0.87	31.25	28.75
2.81	0.11	0.24	0.62	0.56	10.00	10.00
0.70	0.06	0.10	1.50	0.44	7.50	31.25
0.70	0.08	0.34	6.75	1.06	71.25	10.00

Appendix 3c : Soil analytical data - Profile III (Allidina)

Depth(cm)	pH H_2O	pH KCl	Texture % Sand	Texture % Silt	Texture % Clay	Textural class	B.D. g/cc	% moist- ure
0 - 26	7.0	5.1	71	10	19	SL	1.56	1.20
26 - 46	6.7	4.9	53	6	41	SC	1.71	3.80
46 - 90	6.9	5.5	53	8	39	SC	1.79	3.20
90 - 180+	8.1	6.7	63	7	30	SCL	n.d.	3.00

OC%	N%	C/N	Exch. bases meq/100 g soil Ca	Mg	Na	K	CEC soil meq/100g	CEC clay	BS%
1.35	0.14	9.64	4.20	2.80	0.48	0.18	13.20	51.10	58.03
0.49	0.04	12.25	5.50	5.42	1.37	0.13	13.90	30.80	89.40
0.75	0.07	10.71	4.00	6.18	0.89	0.13	17.50	39.90	65.50
0.13	0.04	3.25	3.30	3.53	1.41	0.23	11.70	37.87	72.40

Avail. P. mg/kg	Electrical conductivity mS/cm	SAR	Micronutrients mg/kg Cu	Zn	Fe	Mn
6.71	0.09	0.26	2.00	0.56	57.50	4.12
0.70	0.10	0.59	2.50	0.99	2.50	10.00
0.70	0.33	0.39	2.00	0.25	1.25	5.25
0.70	0.30	0.76	1.00	0.44	1.25	1.00

n.d. = not determined.

Appendix 3d : Soil analytical data : Profile IV (Lutindi)

	pH		Textural %			Textural	B.D.	% moist-
Depth(cm	H_2O	KCl	Sand	Silt	Clay	class	g/cc	ure
0-42.5	6.4	5.2	15	33	52	C	1.32	6.60
42.5-53.5	6.9	5.0	39	31	30	CL	1.39	2.60
53.5-68.5	6.9	5.0	21	24	55	C	1.30	6.00
68.5-116	7.3	5.3	13	12	75	C	1.30	7.40
116-190+	7.3	5.7	15	13	73	C	1.35	7.20

			Exch. bases meq/100 g soil				CEC soil	CEC clay	BS %
OC%	N%	C/N	Ca	Mg	Na	K	meq/100g		
2.13	0.20	10.65	13.50	2.67	0.30	0.34	25.40	38.25	66.20
0.90	0.08	11.25	9.00	4.68	0.26	0.28	14.50	40.57	98.10
1.45	0.11	13.18	11.20	3.26	0.65	0.13	23.30	35.55	65.40
0.97	0.06	16.17	9.75	4.18	0.39	0.13	16.10	18.12	89.80
0.84	0.09	9.33	9.75	3.92	0.65	0.23	23.30	29.34	62.40

Avail. P.	Electrical	SAR	Micronutrients mg/kg			
mg/kg	conductivity mS/cm		Cu	Zn	Fe	Mn
8.42	0.12	0.11	5.25	1.69	63.75	31.25
0.70	0.06	0.10	2.37	0.62	18.75	10.00
0.70	0.06	0.24	5.50	1.25	31.25	23.75
0.70	0.11	0.15	3.00	0.81	5.00	9.00
0.70	0.16	0.25	2.00	0.44	2.50	10.00

Appendix 4a : Weighted average texture over 1 m depth

Profile	Weighted averages			Textural class
	Clay	Silt	Sand	
1	26.37	20.41	53.22	SCL
2	26.97	18.29	54.74	SCL
3	33.30	8.02	58.68	SCL
4	47.22	29.64	23.13	C

Appendix 4b : * Estimated available water and infiltration rate based on weighted average texture

Profile	cm of water/m soil	Infiltration rate (cm/ h)
1	15.80	1 - 3.5
2	15.80	1 - 3.5
3	15.80	1 - 3.5
4	19.00	0.1 - 0.5

* Based on data drived from Sys (1985).