SITE EVALUATION FOR FACTORY CONSTRUCTION IN KINGOLWIRA AREA, MOROGORO, TANZANIA

CONSULTANT REPORT PREPARED FOR UNNAT FRUITS PROCESSING LTD

CONSULTANTS:

Prof. B.M. Msanya
Mr. D.N. Kimaro

Department of Soil Science
Sokoine University of Agriculture
P.O. Box 3008, Morogoro
Tanzania

FEBRUARY, 2001

SITE EVALUATION OF LAND FOR CONSTRUCTION OF FACTORY BY UNNAT FRUITS PROCESSING LTD.

Background

UNNAT is a Company based in Mwanza (P.O. Box 2964). Recently the Company has acquired a piece of land of an area of about 58 acres (23.2 ha) in Morogoro at Kingolwira area where they are intending to construct a fruit-processing factory. The project Coordinator Mr. B.C. Thakore made several contacts with the Sokoine University of Agriculture to seek advice and expertise on the development of the site. Mr. Thakore (hereinafter referred to as "client") has consulted Prof. B.M. Msanya and Mr. D.N. Kimaro of P.O. Box 3008, SUA, Morogoro (hereinafter referred to as "consultants") to carry out the study.

Scope and Purpose

The objectives set out by the client are as follows:

(a) Determination and provision of some ancillary information about the site including location characteristics, climate and water availability.

(b) Selection and evaluation of a suitable site within the acquired land, for the construction of the fruit-processing factory based on soil properties and related landscape features

The job is strictly a site evaluation rather than an investment appraisal. The client intends to submit the final report for financing.

Reporting

The consultants shall submit to the client a report of the study latest on 7th February, 2001.

1.0 Study methods and materials

1.1 Soil survey methods

Grid survey techniques coupled with hand auger borings were used to select observation points for soil profiles excavation basing on variability and homogeneity of soils in the study area. A total of 10 mini-pits and two soil profiles were excavated, studied and described according to the standard procedures as outlined in the FAO (1990) guidelines. Soil samples were collected from each soil profile for laboratory analysis as follows:

i) Disturbed soil samples for routine physical and chemical analysis

ii) Undisturbed soil samples for determination of bulk densities

iii) Penetrometer readings were taken at different horizons from each soil profile

iv) Soil samples for Shear strength and Plastic limit determinations.

Global Positioning System (model GARMIN 12XL) was used to determine the geographical locations of the area.

1.2 Survey for possible sources of water

Extensive survey for possible sources of water for use in the would-be factory was done by traverse walks in the whole area and by deep augering.

1.3 Laboratory methods

Soil samples were air dried, ground and sieved through a 2 mm sieve to obtain the fine earth fractions. Particle size distribution was carried out by Hydrometer method as elaborated by Gee and Bauder (1986) after dispersing with sodium hexametaphosphate (calgon). Bulk density of the soils was determined by core method (Black and Hartge, 1986). *n-value* as an index of estimating soil carrying capacity was calculated using data on soil moisture, texture and organic matter. Shear strength was determined by vane-shear method and plastic index by Cassagrande apparatus in accordance with the procedures outlined by Njos & Singh, (1980).

The pH of the soil samples was determined potentiometrically in water and in 1MKCl at the ratio of 1:2.5 soil-water and soil-KCl respectively (McLean, 1986).

Organic carbon was determined by Walkley and Black wet-acid dichromate digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldahl digestion followed by ammonium distillation titrimetric determination (Bremner and Mulvaney, 1982). Available phosphorus was determined by Bray-1 and Kurtz method (Bray and Kurtz, 1945). The exchangeable bases were determined by atomic adsorption spectrophotometer (Thomas, 1982) and the adsorbed NH_4^+ displaced by K^+ using 1M KCl were determined by Kjeldahl distillation method for the estimation of CEC of soil. Total exchangeable bases, base saturation and ESP were determined by calculations. CEC of clay was calculated using the following formula (Baize, 1993) which corrects for the CEC contributed by organic matter; $CEC_{clay} = [CEC_{soil} - (\% \text{ OM} \times 2) \times 100]/\%$ clay.

1.4 Soil classification

Soil properties identified in the field and those determined from laboratory analysis were used to classify the soils based on FAO classification system World Reference base (WRB) (FAO, 1998) up to third level soil unit names and USDA Soil Taxonomy (Soil Survey Staff, 1999) to the subgroup level names. The field and laboratory analytical data recorded on the analogue forms were entered into the digital soil database management system SISTAN (Magoggo, 1991). Other softwares used for data processing and report writing include Microsoft Excel, Microsoft Word and Freelance Graphics.

2.0 Main findings

2.1 Physical environment

2.1.1 *Location*

The area covers approximately 23 ha. It is located between Eastings 37M 0363624 and 0364077 and Northings UTM 9250603 and 9251033 at an altitude ranging between 510-520 m.a.s.l. The area is bordered by the DIMON Factory to the West, Central Railway line to the South, Morogoro-Dar es Salaam Highway and the former Kingolwira Sisal Estate Quarters to the North and smallholder farmer's fields to the East. It is about 12.6 km NE of Morogoro Town centre.

2.1.2 *Climate*

Rainfall, temperature, relative humidity and evapotranspiration data of the area are presented in Table 1 and Figure 1.

Rainfall

The Kingolwira area receives an annual rainfall of 825 mm. The long rains *(Masika)* usually fall in February to May (412 mm) followed by dry season between June and October. The short rains *(Vuli)* occur in November to January (302 mm). The rainfall distribution in the area is weakly bimodal with two peaks occurring in December/January (113/115 mm) and April (134 mm) (Table 1).

Temperature

The area experiences an average annual temperature of about 24.4^{o}C with the hottest month in December (26.6^{o}C) and the coldest month in July (21.1^{o}C) (Table 1).

Evapotransipiration

Evapotranspiration is high in August through March ranging from 150 mm to 186 mm. The highest evapotranspiration occur in October through December (174-186 mm). From April to July the area experiences low evapotranspiration ranging from 105 mm to 123 mm.

Table 1. Mean monthly and annual climatic data of the area

Month	Rainfall (mm)	Relative humidity (%)	Temperature (^{o}C)	Evapotranspiration (mm)
January	115	69	26.3	144
February	85	70	26.3	150
March	126	73	26.2	150
April	134	80	25.0	114
May	67	80	23.5	105
June	16	73	21.6	111
July	16	71	21.1	123
August	14	66	22.1	150
September	20	63	23.2	150
October	45	61	24.6	177
November	74	63	25.7	186
December	113	66	26.6	174
Year	825	835	24.4	1734

Relative humidity

Relative humidity in the area is relatively high from March to July and ranges from 71% to 80%. The relative humidity is slightly lower in the months of August to February ranging from 61% to 70%.

2.2 Possibilities of water availability

Possibilities for obtaining good quality underground water in the area are high. Field observations indicate that groundwater levels occur at a depth of about 80 to 100 cm deep from the surface in the lower parts of the area. The water can be obtained by construction of shallow wells. Enough and good quality gravitational water could be taped at the foot of the Uluguru Mountains through pipe lining. The effectiveness and economics on this option should be investigated.

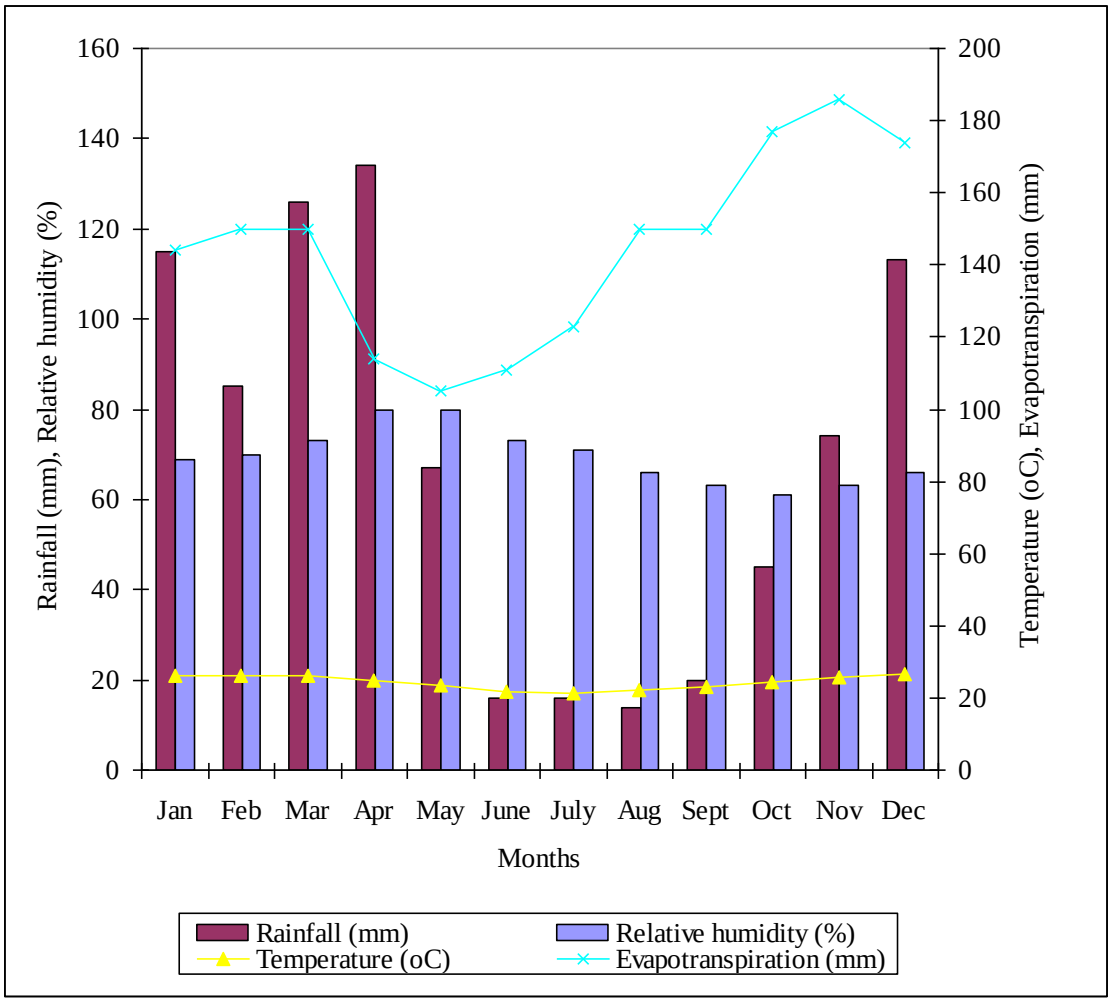

Figure 1. Climatic trends of the study area

2.3 Landscape characteristics of the area

2.3.1 *Upper/middle slopes*
The upper and middle parts of the area have gently undulating topography. The slope gradient ranges from 2 to 4 %. The mean altitude of this part is 519 m.a.s.l.

2.3.2 *Lower slopes*
The lower parts of the area have almost flat topography with slope gradient ranging from 0.5 to 1 %. The mean altitude is 510 m.a.s.l.

2.4 Soil characteristics of the area

2.4.1 *Morphological, physical and mechanical properties of the soils*
Table 2 summarises some morphological, physical and mechanical properties of the studied soils, detailed characteristics are presented in Appendix 1.

Upper/middle slopes
The soils of this part are represented by profile KING-P1. They are very deep, well drained and textures are clayey throughout. The thin topsoils are moderately developed with friable consistence. The cohesion of the subsoils is slightly firm and compacted as indicated by their relatively high bulk densities (1.5 g/cc). The carrying capacity of these soils for construction is good as substantiated by relatively high values of penetrometer resistance (0.4-0.5 MPa), shear strength (0.13 MPa) and very low n-values (0.04-0.05) (Table 2). Plasticity of the soils of this area are very low to low (0.4-9.5). Generally, the results of this study clearly show that this part of the landscape is highly suitable for construction purposes.

Table 2. Morphological, physical and mechanical properties of the studied soils

Profile/ Horizon	Depth (cm)	Moist Munsell soil colour	% Particle size distribution			Textural class	BD g/cc	PR MPa	ST MPa	Plastic index	n-value
			Sand	Silt	Clay						
KING-P1											
Ap	0-15	2.5YR2.5/4 (drb)	36	15	49	C	1.2	0.30	0.05	0.4	0.02
Bt1	15-30	10R3/6 (dr)	24	12	64	C	1.5	0.50	0.13	3.1	0.04
Bt2	30-70	10R4/8 (r)	26	12	62	C	1.5	0.40	0.13	7.5	0.05
Bt3	70-155+	10R4/8 (r)	24	12	64	C	1.5	0.40	0.13	9.5	0.05
KING-P2											
Ap	0-12	7.5YR3/3 (db)	36	19	45	C	1.3	0.30	0.07	10.2	0.02
Bt1	12-45	5YR4/4 (rb)	31	11	58	C	1.4	0.40	0.09	15.8	0.04
Bt2	45-95+	5YR4/6 (yr)	36	9	55	C	1.4	0.20	0.05	19.3	0.07

nd = not determined BD = Bulk density PR = Penetrometer resistance ST = Shear strength

Lower slopes
The soils of this part are represented by profile KING-P2. They are very deep, moderately well to imperfectly drained and textures are clayey throughout. The thin topsoils are moderately developed with friable consistence. The cohesion of the subsoils is very friable as indicated by their relatively low bulk densities (1.3 g/cc)

(Table 2). The carrying capacity of these soils for construction is limited as shown by relatively low values of penetrometer resistance (0.2-0.4 MPa) and shear strength (0.05-0.09 MPa). The plasticity index of the soils in this part of the area ranges from 10.2 to 19.3. These values are likely to pose some limitations to construction. This part of the landscape is also characterised by high ground water levels (groundwater level at 80-100 cm from the surface). These characteristics generally pose serious limitation to the use of the site for construction purposes.

2.4.2 *Soil chemical properties*

Chemical properties of the studied soils are summarised in Table 3. Further details on chemical properties of the soils are presented in Appendix 1.

Upper/middle slopes

The soils have a net negative charge as indicated by their pH (KCl) values being lower than pH (H_20). The soils are of medium acidic class (5.6-5.9) throughout. The available phosphorus levels are very low throughout the profile (1-7 mg/kg). The levels of total nitrogen (0.03-0.07%) and organic carbon (0.1-1.1%) are very low.

The soils of this site have low CEC values throughout (6-10 cmol(+)/kg). Percentage base saturation is low to medium (47-59%). The exchangeable calcium are very low to low ranging from 1.6 to 3.6 cmol(+)/kg (Table 3). Magnesium levels are low to medium throughout the profile (0.7-1.6 cmol(+)/kg) while those of exchangeable potassium are medium throughout (0.5-1.0 cmol(+)/kg). The levels of exchangeable sodium are very low to low (0.02-0.16 cmol(+)/kg). The soils are found to be non-sodic as indicated by their very low values of exchangeable sodium percentage (0.2-2%).

Lower slopes

The soils have a net negative charge as indicated by their pH (KCl) values being lower than pH (H_20). The soils are slightly acidic to neutral with pH values ranging between 6.4-6.9 (Table 3). The available phosphorus levels are very low throughout (1-3.9 mg/kg). The levels of total nitrogen (0.02-0.16%) and organic carbon (0.2-1.2%) are very low to low.

The soils of this landscape have low CEC values throughout (8.2-9.8 cmol(+)/kg) while percentage base saturation levels are high ranging from (65-80%). The exchangeable calcium levels are low ranging from 3.5 to 4.5 cmol(+)/kg while magnesium levels are medium throughout (1.3-2.8 cmol(+)/kg) and those of exchangeable potassium are low to medium ranging between (0.4-0.6 cmol(+)/kg). The levels of exchangeable sodium are very low (0.02-0.05 cmol(+)/kg). The soils are non-sodic as indicated by their very low values of exchangeable sodium percentage (0.2-0.6%).

Table 3. Selected soil chemical properties of the studied area

Profile/ Horizon	Depth (cm)	pH		% OC	%N	C:N ratio	P (mg/kg) Bray	CEC Soil	Ca	Mg	K	Na	% BS	%ESP
		H_20	KCl					(cmol(+)/kg						
KING-P1														
Ap	0-15	5.9	4.5	1.1	0.07	16	7	10	3.6	1.6	0.6	0.02	59	0.2
Bt1	15-30	5.7	4.4	0.9	0.05	18	6	8	2.6	0.9	0.6	0.16	54	2.0
Bt2	30-70	5.6	4.3	0.7	0.03	23	1	7	1.6	0.7	0.9	0.02	47	0.3
Bt3	70-155+	5.7	4.4	0.1	0.04	3	1	6	1.7	0.9	0.5	0.02	52	0.3
KING-P2														
Ap	0-12	6.4	5.6	1.2	0.16	11	3.9	9.8	4.5	2.8	0.55	0.02	80	0.2
Bt1	12-45	6.6	4.4	0.4	0.03	13	1.0	8.3	3.5	1.3	0.54	0.04	65	0.5
Bt2	45-95+	6.9	4.5	0.2	0.02	10	1.2	8.2	4.0	1.4	0.36	0.05	71	0.6

2.5. Soil classification

Tables 4 and 5 give a summary of morphological and diagnostic features while Table 6 presents the classification of the studied soils according to both WRB and USDA Soil Taxonomy systems respectively. Using both FAO system of classification and USDA Soil Taxonomy (in brackets), the soils of Upper/Middle slopes classify as Chromi-Profondic Lixisols (Typic Kandiustalfs) while those of Lower slopes classify as Stagni-Gleyic Lixisols (Aquic Paleustalfs).

Table 4. Summary of soil profile morphological and diagnostic features of the studied soils (FAO, 1998)

Profile	Diagnostic horizons	Other diagnostic features, properties/materials
KING-P1	Ochric horizon Argic horizon	Profondic, Chromic
KING-P2	Ochric horizon Argic horizon	Gleyic, Stagnic, Profondic, Chromic

Table 5. Summary of soil profile morphological and diagnostic features of the studied soils (Soil Survey Staff, 1999)

Profile	Diagnostic epipedons/horizons	Other diagnostic features, properties/materials
KING-P1	Ochric epipedon Kandic horizon	Ustic SMR Isohyperthermic STR
KING-P2	Ochric epipedon Argillic horizon	Ustic SMR Isohyperthermic STR

Table 6. Soil classification according to both WRB (FAO, 1998) and USDA (Soil Survey Staff, 1999) systems

WRB (FAO, 1998) System				USDA (Soil Survey Staff, 1999) system			
Profile	Level-1	Level-2	Level-3	Order	Suborder	Great Group	Subgroup
KING-P1	Lixisols	Profondic Lixisols	Chromi-Profondic Lixisols	Alfisols	Ustalfs	Kandiustalfs	Typic Kandiustalfs
KING-P2	Lixisols	Gleyic Lixisols	Stagni-Gleyic Lixisols	Alfisols	Ustalfs	Paleustalfs	Aquic Paleustalfs

3.0 Conclusion and recommendations

The area is very well located in terms of communication facilities. It can be served by Morogoro-Dar es Salaam highway from the north linked to the site by the DIMON Factory tarmac road. It can also be served by a railway link from the nearby railway station (about 500 m) from the south.

Good quality groundwater occurs at a depth of about 80 to 100 cm deep from the surface in the lower slopes of the area. This provides possibilities for obtaining underground water for industrial use through establishment of shallow wells.

The study clearly shows that the landscape features and soil properties of the Upper/Middle slopes of the area are highly suitable for construction of a fruit-processing factory. It is in this area where the factory should be constructed. The site should preferably be located 250 m from the railway line and about 200 m from the border with DIMON factory area.

4.0. References

Baize, D (1993) *Soil science analyses*. A guide to current use. John Wiley & Sons Ltd. West Sussex. pp. 192.

Black, G.R. and Hartge, K.H. (1986) Bulk density. In: *Methods of Soil Analysis.* Part 1. 2nd edition. (Edited by Klute, A.). Agronomy Monograph No. 9. Soil Science Society of America. Madison. Wisconsin. pp 364-376.

Bray, R.H. and Kurtz, L.T. (1945) Determination of Total Organic and Available Forms of Phosphorus in Soils. *Soil Science* 59, 39 - 45.

Bremner, J.M. and Mulvaney, C.S. (1982) Total Nitrogen. In: *Methods of Soil Analysis.* Part 2. Agronomy Monograph No. 9. (Edited by Page, A.L; Miller, R.H. and Keeney, D.R.). American Society of Agronomy. Madison. Wisconsin. pp 595-624.

FAO (1990) *Guidelines for Soil profile Description*. 3rd edition. FAO, Rome. pp 66.

FAO (1998) W*orld Reference Base for Soil Resources (WRB).* World Soil Resources Reports No. 84. Food and Agriculture Organization of the United Nations and International Society of Soil Science, Rome Italy. pp 88.

Gee, G.W. and Bauder, J.W. (1986) Particle size analysis. In: *Methods of Soil Analysis*. Part 1. 2nd edition. (Edited by Klute, A.). Agronomy Monograph No. 9. Soil Science Society of America. Madison. Wisconsin. pp 383-412.

Magoggo, J.P. (1991) SISTAN: *The Soil Information System for Tanzania.* Version 2. National Soil Service, ARTI- Mlingano Tanga, Tanzania.

McLean, E.O. (1986) Soil pH and lime requirement. In: *Methods of Soil Analysis*, part 2; Chemical and Mineralogical Properties, 2nd. (Edited by Page, A.L., Miller, R.H. and Keeney, D.R.) No. Agronomy, Madison Wisconsin. pp 199-223.

Nelson, D.W. and Sommers, L.E. (1982) Organic carbon. In: *Methods of Soil Analysis.* Part 2. Agronomy Monograph No. 9. (Edited by Page, A.L., Miller,

R.H. and Keeney, D.R.). American Society of Agronomy. Madison. Wisconsin. pp 539-578.

Njos, A. and Singh, B.R. (1980) Field and Laboratory Exercises for Graduate Course in Soil Physics. Institute of Soil Fertility and Management. Agricultural University of Norway, As, Norway. pp 29-32.

Soil Survey Staff (1999) *Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys.2nd Edition.* United States Department of Agriculture, Natural Resources Conservation Service. pp 869.

Thomas, G.W. (1982) Exchangeable cations. In: *Methods of Soil Analysis*. Part 2. Agronomy Monograph No. 9. (Edited by Page, A.L; Miller, R.H. and Keeney, D.R.). American Society of Agronomy. Madson. Wisconsin. pp 159-164.

Appendix 1

Profile number :KING-P1 Mapping unit: Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO RURAL
Map sheet no. : 183/4
Co-ordinates : 37 M 0363670E/ UTM 9250801N
Location : Kingolwira Sisal Estate about 250 m East of DIMON Factory.
Elevation : 519 m asl. Parent material: colluvium mainly red and reddish brown clays derived from mixed gneisses and granulites. Landform: Peneplain, gently undulating. Slope: 4 %; straight, middle slope, 300 m long.
Surface characteristics : Rock outcrops: none; Stones: none; Erosion: sheet and rill; moderate. Deposition: none . Natural vegetation: Regrowth of miombo woodland (*Acacia spp*., *Brachystegia spp*.) and grass species including *Panicum maximun* and *Cynodon spp*. Land use: Abandoned Sisal Estate. Natural drainage class: well drained. Groundwater level is very deep (>500 cm).

Described by B.M. Msanya, D.N. Kimaro, S.B. Mwango and E.P. Kileo on 01/02/2001.

Soil: Soils are very deep, well drained dark red to red clays slightly compacted with thin dark reddish brown clay topsoils.

Ap 0 - 15 cm: dark reddish brown (2.5YR2.5/4) moist; clay; friable moist, sticky and plastic wet; moderately strong fine and medium subangular blocky; many medium and fine pores; many fine and medium and very few coarse roots; clear smooth boundary to

Bt1 15- 30 cm: dark red (10R3/6) moist; clay; slightly firm and compacted moist, sticky and plastic wet; moderately strong fine and medium subangular blocky; many fine and few medium pores; few very fine and medium roots; gradual smooth boundary to

Bt2 30 – 70 cm: red (10R4/8) moist; clay; slightly firm and compacted moist, slightly sticky and slightly plastic wet; moderately strong fine and medium subangular blocky; many fine and very fine and very few medium pores; common faint clay cutans; very few fine and very fine roots; diffuse smooth boundary to

Bt3 70-155+ cm: red (10R4/8) moist; clay; slightly firm and compacted moist, slightly sticky and slightly plastic wet; moderately strong fine and medium subangular blocky; many fine and very fine and very few medium pores; few very fine roots; common faint clay cutans.

SOIL CLASSIFICATION: WRB (FAO, 1998): Chromi-Profondic Lixisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Kandiustalfs

ANALYTICAL DATA FOR PROFILE KING-P1

Horizon	Ap	Bt1	Bt2	Bt3
Depth (cm)	0-15	15-30	30-70	70-155
Clay (%)	49	64	62	64
Silt (%)	15	12	12	12
Sand (%)	36	24	26	24
Texture class	C	C	C	C
Bulk density (g/cc)	1.2	1.5	1.5	1.5
Penetrometer resistant MPa	0.3	0.5	0.4	0.4
Shear strength MPa	0.05	0.13	0.13	0.13
n-value	0.02	0.04	0.05	0.05
Plastic index	nd	nd	nd	nd
pH H_2O 1:2.5	5.9	5.7	5.6	5.7
pH KCl 1:2.5	4.5	4.4	4.3	4.4
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	0.2	2.0	0.3	0.3
Organic C (%)	1.1	0.9	0.7	0.1
Total N (%)	0.07	0.05	0.03	0.04
C/N	16	18	23	3
Avail. P Bray-1 (mg/kg)	7.0	6.0	1.0	1.0
CEC NH4OAc (cmol (+)/kg)	10.0	8.0	7.0	6.0
Exch. Ca (cmol (+)/kg)	3.6	2.6	1.6	1.7
Exch. Mg (cmol (+)/kg)	1.6	0.9	0.7	0.9
Exch. K (cmol (+)/kg)	0.65	0.62	0.98	0.48
Exch. Na (cmol (+)/kg)	0.02	0.16	0.02	0.02
TEB (cmol (+)/kg)	5.87	4.28	3.30	3.10
Base saturation (%)	59	54	47	52
CEC Clay (cmol (+)/kg)	21	13	11	9

nd = not determined

Profile number :KING-P2 Mapping unit: Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO RURAL
Map sheet no. : 183/4
Co-ordinates : 37 M 0363627 UTM 9250532
Location : Kingolwira Sisal Estate about 200m East of DIMON Factory.
Elevation : 510 m asl. Parent material: colluvium mainly red and reddish brown clays derived from mixed gneisses and granulites. Landform: Peneplain, almost flat. Slope 0.5%; straight along, concave across, lower slope, 100 m long.
Surface characteristics : Rock outcrops: none; Stones: none; Erosion: sheet and; moderate. Deposition: colluvium. Natural vegetation: Regrowth of miombo woodland (*Acacia spp*., *Brachystegia spp*.) and grass species including *Panicum maximun* and *Cynodon spp*. Land use: Abandoned Sisal Estate. Flooding: seasonal. Groundwater level: moderately deep (about 80-100 cm from the surface). Quality of the groundwater: fresh and milkfish. Stagnating horizon: at 90 cm and deeper form the soil surface. Natural drainage class: moderately well to imperfectly drained.

Described by D.N. Kimaro, B.M. Msanya, E.P. Kileo, and S.B. Mwango on 01/02/2001.

Soil: Soils are very deep, moderately well to imperfectly drained reddish brown to yellowish red clays with thin dark brown clay topsoils.

Ap 0 - 12 cm: dark brown (7.5YR3/3) moist; clay; friable moist, sticky and plastic wet; weak fine and medium subangular blocky; many medium and fine pores; many fine and medium and few very fine roots; clear smooth boundary to

Bt1 12- 45 cm: reddish brown (5YR4/4) moist; clay; very friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; many fine and few very fine pores; very few medium fresh and slightly weathered irregular quartz fragments; common fine hard spherical Fe & Mn nodules; common faint clay cutans; common fine and very fine roots; diffuse smooth boundary to

Bt2 45 – 95+ cm: yellowish red (5YR4/6) moist; clay; many medium prominent sharp dark red (2.5YR3/6) mottles; very friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; many fine and very fine pores; few medium fresh irregular quartz fragments; few fine hard spherical Fe & Mn nodules; common faint clay cutans; common fine and very fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Stagni-Gleyic Lixisols

USDA Soil Taxonomy (Soil Survey Staff, 1999): Aquic Paleustalfs

ANALYTICAL DATA FOR PROFILE KING-P2

Horizon	Ap	Bt1	Bt2
Depth (cm)	0-12	12-45	45-95+
Clay (%)	45	58	55
Silt (%)	19	11	9
Sand (%)	36	31	36
Texture class	C	C	C
Bulk density (g/cc)	1.2	1.3	1.3
Penetrometer resistant MPa	0.3	0.4	0.2
Shear strength MPa	0.07	0.09	0.05
n-value	0.02	0.04	0.07
Plastic index	nd	nd	nd
pH H_2O 1:2.5	6.4	6.6	6.9
pH KCl 1:2.5	5.6	4.4	4.5
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	0.2	0.5	0.6
Organic C (%)	1.2	0.4	0.2
Total N (%)	0.16	0.03	0.02
C/N	11.0	13.0	10.0
Avail. P Bray-1 (mg/kg)	3.9	1.0	1.2
CEC NH4OAc (cmol (+)/kg)	9.8	8.3	8.2
Exch. Ca (cmol (+)/kg)	4.5	3.5	4.0
Exch. Mg (cmol (+)/kg)	2.8	1.3	1.4
Exch. K (cmol (+)/kg)	0.6	0.5	0.4
Exch. Na (cmol (+)/kg)	0.02	0.04	0.05
TEB (cmol (+)/kg)	7.9	5.4	5.8
Base saturation (%)	80	65	71
CEC Clay (cmol (+)/kg)	18.3	16.2	17.9

nd = not determined