

**REPORT ON THE POTENTIAL OF THE SOILS OF
KALAITA COMPANY'S FARM, MVOMERO DISTRICT,
MOROGORO, TANZANIA, FOR VARIOUS AGRICULTURAL
LAND USES – A RAPID ASSESSMENT**

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1.0. Background

Kalaita Company Ltd. of P.O. Box 610, Morogoro, has requested for consultancy services relating to the assessment of their farm to assess its potential for various agricultural land uses including production of maize, rice, sunflower, bananas, vegetables, onions, beans, millets; and extensive grazing. The farm is designated as “**Farm No. 47**” with title deed No. 39484 and Land Office No. (LON) 108135, located in Wami Luhindo, Mvomero District, and having an area of 409.21 ha (equivalent to 1023.02 acres). In Mid-December this year, Mr. Herry Kalaita, Director of Finance and Administration of Kalaita Company Ltd. visited Sokoine University of Agriculture to seek advice and expertise on the development of the farm for production of the said crops, and was directed to see Prof. B.M. Msanya. After discussion and consultation, both Mr. Herry Kalaita (herein referred to as the client) and Prof. B.M. Msanya (herein referred to as the consultant) agreed on terms of reference for the execution of the work.

2.0. Scope and Purpose

The objectives set out by the client are as follows:

- (a) Identification of the farm boundaries and inspection of the existing beacons
- (b) Determination and provision of some ancillary information about the site including location characteristics and climatic information
- (c) Reconnaissance survey to identify the major land units of the farm and their corresponding representative soil profiles, soil description and sampling
- (d) Laboratory analysis for physical and chemical soil properties
- (e) Interpretation of both field and laboratory data to determine the suitability of the farm for various agricultural land uses

3.0. The Study

3.1. Study methods and materials

3.1.1. Soil survey methods

The work started by identifying the existing beacons following the boundary lines around the farm. Global Positioning System (model GARMIN 12XL) was used to determine the geographical locations of the beacons. Having inspected the beacons, reconnaissance survey of the area was carried out coupled with hand auger borings to observe soil characteristics, identify and delineate major landscape units, and select observation points for soil profile excavation based on the variability/homogeneity of soils in the study area. A total of 15 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 density

3.1.2. 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 (Gee and Bauder, 1986) after dispersing with sodium hexametaphosphate (calgon). Bulk density of the soils was determined by core method (Black and Hartge, 1986).

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 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.

3.1.3. Soil classification

Soil properties identified in the field and those determined from laboratory analysis were used to classify the soils based on FAO World Reference Base (WRB) System (FAO, 1998) up to second level soil names and United States Department of Agriculture (USDA) Soil Taxonomy (Soil Survey Staff, 1999) to the subgroup level.

3.2. Main findings

3.2.1. Location

Figure 1. presents a detailed map of the Farm no. 47 indicating also neighbouring farms. The farm lies at an average elevation ranging from 380 to 398 m.a.s.l. The four beacons namely BT 213, 214, 215 and 216 demarcating the farm boundaries are all located and geo-referenced on the Nguru ya Ndege toposheet. Representative soil profile locations (Black soil and Red soil) are also plotted on the map to indicated the sites where soil profiles were dug and described.

The study area is very well located in terms of communication facilities. The farm is located just about 30 km from Morogoro Municipality along the tarmac Morogoro-Dodoma highway, and about 15 km west of the highway. Accessibility to market opportunities in Morogoro Municipality and other towns is quite easy.

3.2.2. Climate

The most important climatic factors influencing plant growth in the Wami-Luhindo area are rainfall, temperature and evapotranspiration.

Rainfall

The average rainfall in Wami Plains ranges from 768 mm in the southern part to about 1036 mm in the northern part (Kileo, 2000). The farm is situated in the southern part and hence its mean rainfall will be closer to the 768 mm. The rainfall pattern is largely monomodal. Rains start in December through May with a slight decrease in February (Table 1). April is the wettest month in the study area with a mean rainfall varying between 139 and 204 mm. Rainfall decreases sharply in the months of May (59 - 94 mm).

Temperature

Temperature is almost uniform throughout the surveyed area with the coldest month in July (20.8-21.4°C) and the hottest month in December (26.2-26.8°C) (Table 1).

Evapotranspiration (ET_p)

Generally evapotranspiration increases during the dry season. Maximum evapotranspiration is experienced in the months of November and December (162-165 mm), just in the onset of the rainy season and it is minimum in the months of July (142-145 mm) (Table 1). Seasonal variation in potential evapotranspiration is rather small compared to the seasonal variation in rainfall (Figure 2).

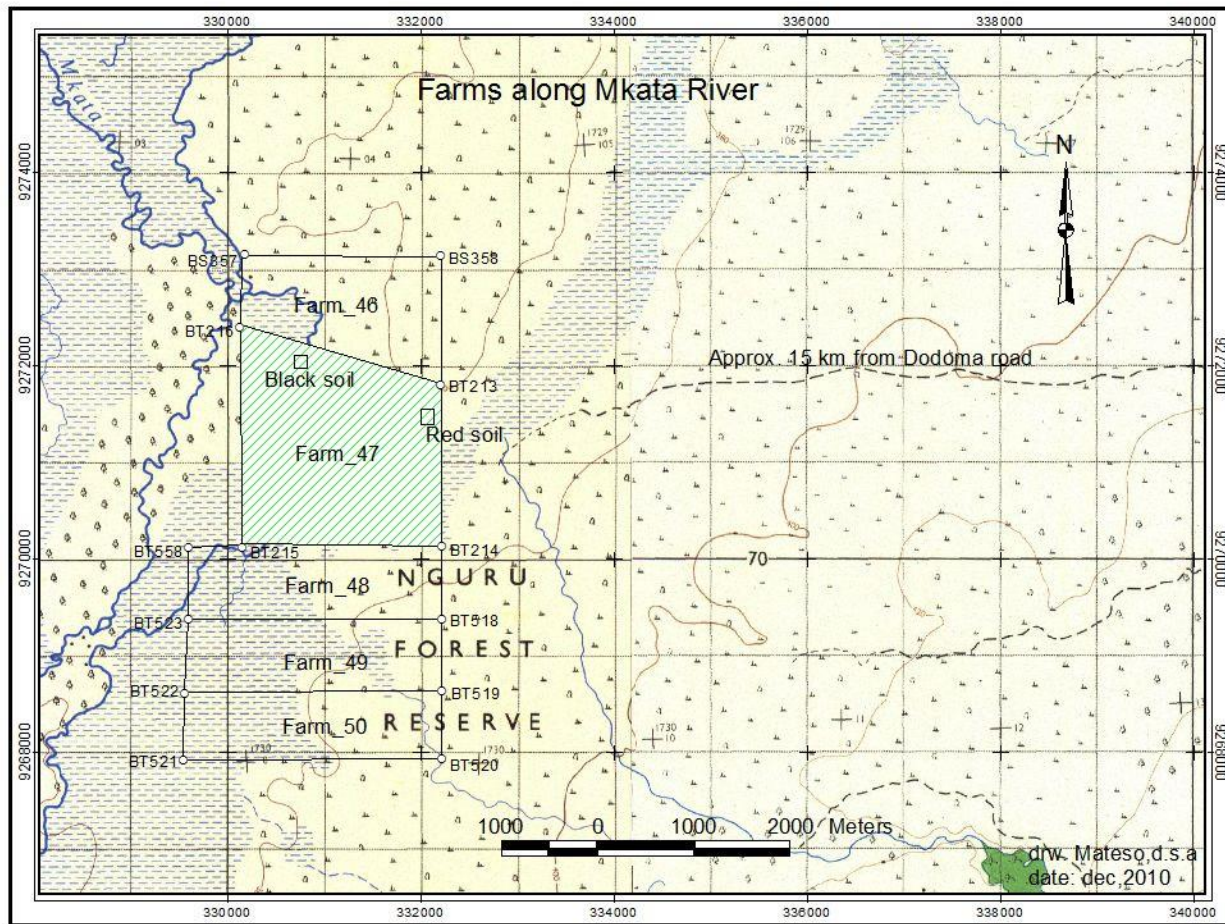


Figure 1. Detailed map showing the location and boundaries of Kalaita Company's Farm (Farm No.47), Mvomero District, Morogoro Region

Table 1. Rainy season, humid months and growing season, calculated according to FAO (1984) for selected rainfall stations in Wami Plains

| Met. Station | Climatic parameter | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Year |
|--------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| Wami | Temperature (°C) | 22.9 | 24.3 | 25.4 | 26.2 | 26.0 | 26.0 | 25.8 | 24.7 | 23.2 | 21.3 | 20.8 | 21.8 | 24.0 |
| Prison (579 m) | ET _o | 150.1 | 155.3 | 159.4 | 162.4 | 161.7 | 161.7 | 160.9 | 156.8 | 151.2 | 144.2 | 142.3 | 146.0 | 1429 |
| | 0.5ET _o | 75.1 | 77.7 | 79.7 | 81.2 | 80.9 | 80.9 | 80.5 | 78.4 | 75.6 | 72.1 | 71.2 | 73.0 | 1852 |
| | Rainfall (mm) | 17 | 43 | 68 | 139 | 138 | 110 | 161 | 204 | 94 | 19 | 11 | 7.5 | 1036 |
| | Rain season | | | | + | + | + | + | + | + | | | | |
| | Humid months | | | | | | | | + | | | | | |
| | Growing season | | | | + | + | + | + | + | + | | | | |
| Kihonda (480 m) | Temperature (°C) | 23.5 | 24.9 | 26.0 | 26.8 | 26.6 | 26.6 | 26.4 | 25.3 | 23.8 | 21.9 | 21.4 | 22.4 | 24.6 |
| | ET _o | 152.4 | 157.6 | 161.7 | 164.7 | 163.9 | 163.9 | 163.2 | 159.1 | 153.5 | 146.4 | 144.5 | 148.3 | 1879 |
| | 0.5ET _o | 76.2 | 78.8 | 80.8 | 82.4 | 82.0 | 82.0 | 81.6 | 79.5 | 76.7 | 73.2 | 72.3 | 74.1 | |
| | Rainfall (mm) | 13 | 26 | 70 | 117 | 129 | 90 | 121 | 139 | 59 | 9.2 | 9.5 | 5.1 | 768 |
| | Rain season | | | | + | + | + | + | + | | | | | |
| | Humid months | | | | | | | | | | | | | |
| | Growing season | | | | + | + | + | + | + | | | | | |

ET_o = Potential evapotranspiration (Penman); 0.5 ET_o = half of the potential evapotranspiration; + = this month is part of the rainy season (if rainfall > 0.5 ET_o); a humid month (rainfall > ET_o) or part of the growing season.

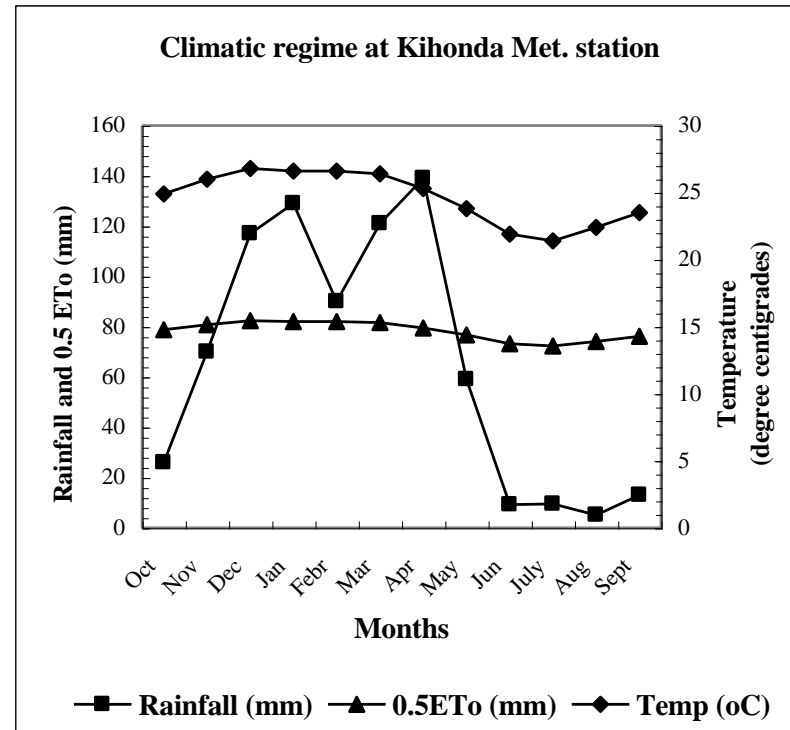
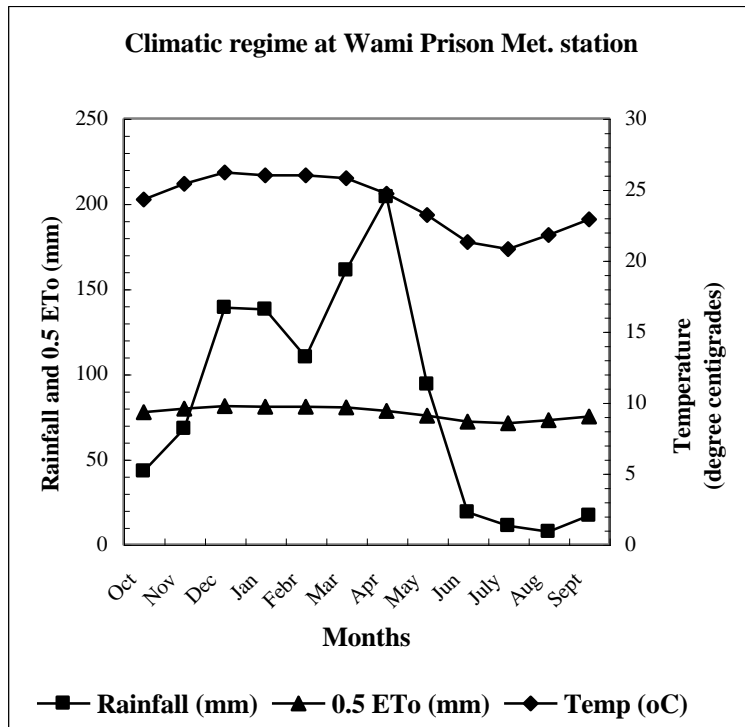


Figure 2. Climatic regimes from two meteorological stations nearest to Kalaita Company's Farm

3.2.3. Geology and landforms

Geology

The geology of the area is comprised of Neogene deposits (sands, red clays and mbuga clays) mostly derived from Usagaran metasedimentary rocks of the Mindu, Lugala and Nguru ya Ndege Hills. These rocks are rich in muscovite-biotite gneisses and migmatites (Sampson and Wright, 1964).

Landforms

The topography of the farm is dominantly flat and almost flat with slopes ranging between 0.5 and 1%. The physiography is low-lying with altitude ranging between 380 and about 400 m.a.s.l. and is comprised of Mbuga, Flats, and to a small extent Floodplains. So the major land units in the farm are Mbuga and Flats.

3.2.4. Vegetation and land use

Natural vegetation

Under natural conditions almost the whole of the Wami plains including the Farm No. 47 would be lightly or thickly wooded with very little open grassland. However, native cultivation, charcoal burning and cutting trees for timber have replaced the natural vegetation to a very large extent. This, together with uncontrolled grazing has led to severe soil erosion leaving bare land in some places. There are remnants of *miombo woodland* in which the typical species are *Brachystegia boehmii*, *B. bussei*, *Isobertina* spp, *Pterocarpus angolensis* (mninga), *Afzelia quanzensis* (mkongo), and *Acacia nigrescens* as characteristic tree species. *Pterocarpus angolensis* (mninga) and *Afzelia quanzensis* (mkongo) are tree timber species of economic importance and they are very valuable. These are among the few timber species that are resistant to termite and ant damage. Thickets, bushes, scrub and tussock grasses dominated by *Panicum maximum*, *Cynodon* spp. and *Hyparrhenia rufa* are mostly found in the surveyed area.

Land use

Smallholder farming dominates the major part of the study area. Various food crops are grown at subsistence level under rainfed conditions. These include maize, cowpeas, cassava, beans and bananas. Some neighbouring farms are also cultivated for rice. Few scattered fruit trees such as mango, oranges and some cashew and coconuts are observed in some places. Extensive grazing, clearing of woody vegetation for fire wood, timber and charcoal burning are the most important human activities in the study area.

3.2.5. Major soils

The main soils of the farm are given in Table 2. The black soils are found more in the Mbuga landform unit while the red soils are found in the land unit described as “*Flats with Red Soils*”. The black Mbuga soils with very deep wide cracks are associated with valley bottom soils developed from fluvial deposits which are a complex of deep, moderately well drained black to dark brown sandy clay loam soils. The soils are stratified as a result of cyclic deposition of materials of diverse origin (Msanya *et al.*, 2000).

Table 2. Major land units and soils of Kalaita Company’s Farm, Mvomero District, Morogoro Region

| Mapping unit symbol | Landform | Dominant slopes (%) | Vegetation/ Land use | Soil description |
|---------------------|-----------------------|---------------------|--|---|
| PL1 | Mbuga | 0.5-1 | Acacia woodland scrubs and grasses. It is used for extensive grazing and rice cultivation. | Deep, poorly to very poorly drained, very dark grey sandy clays, with very thick black sandy clay topsoils developed on recent alluvial deposits (black clays) derived from banded muscovite-biotite gneiss and migmatites of Nguru ya Ndege mountains. Profile is MV-P1 representative. |
| PL2 | Flats with red clays. | 0.5-1 | Acacia woodland and few scattered miombo trees, bushes, thickets and grasses. This area is used for extensive grazing. | Association of: Very deep, well drained, reddish brown to yellowish red sandy clay to clays, with thick dark brown sandy clay loam topsoils <u>and</u> very deep, well drained, dark reddish brown sandy clay to clays, with thin dark reddish brown sandy clay loam topsoils developed on colluvium (red clays) derived from banded muscovite-biotite gneiss and migmatites of Nguru ya Ndege mountains. Representative profile is MV-P2 |

3.2.6. Characteristics of the soils of the area

Morphological and physical properties of the soils

Table 3 is a summary of some morphological and physical properties of the studied soils; detailed characteristics are presented in Appendix 1. Appendix 2 is a guide to general rating of both chemical and physical soil properties.

The Mbuga Soils

The soils of this land unit are represented by profile MV-P1. The land unit is an extensive area of Mbuga soils and comprises flat to almost flat topography with slopes ranging between 0 to 1% and an elevation of about 385 m.a.s.l. It is mainly a depositional area of materials from higher geomorphic units. The unit has a low gilgai microrelief, which occur nearly everywhere. The unit is also characterized by acacia woodland, scrubs and grasses and it is mainly used for extensive grazing and cultivation of rice and maize in areas neighbouring Kalaita's farm.

The thick topsoils (45 cm) have weak to moderate subangular blocky structures and are sandy clay textured. Subsoils have moderate angular blocky and wedge-shaped structures with clayey textures. The deeper subsoils to a depth below 100 cm from the surface have weak, very coarse prisms. The consistence of these soils is very hard when dry, firm to very firm when moist and sticky and plastic to very sticky and very plastic when wet. These soils are moderate to strongly calcareous in the subsoils. Deep, moderately to widely spaced hexagonal cracks are common during dry season due to alternate swelling and shrinking of the expanding clays. Very few moderately thick slickensides are present in the profiles below a depth of 100 cm from the surface. The bulk densities of these soils range from 1.6 g/cc in the topsoils to 1.8 g/cc in the subsoils. These BD values are likely to be a limitation to water and plant root growth. The soils are also characterized by surface sealing a phenomenon indicating reduced permeability.

The Red Soils

The soil profile represents a mapping unit which is almost flat to very gently undulating with slopes between 0.5 and 1 % and it is situated at an elevation of about 400 m.a.s.l. This mapping unit is characterized by acacia woodland and few scattered miombo trees, bushes, thickets and grasses and it is mainly used for extensive grazing.

Table 3. Morphological and physical properties of the studied soils

| Profile/ Horizon | Depth (cm) | Munsell soil colour | | % Particle size distribution | | | Textural class | BD g/cc |
|---------------------|---------------|---------------------|-------------------|---------------------------------|------|------|-------------------|------------|
| | | Dry colour | Moist colour | Sand | Silt | Clay | | |
| MV-P1 | | | | | | | | |
| Ah | 0-25/45 | nd | N2.5/0 (bl) | 50 | 10 | 40 | SC | 1.6 |
| ACk | 25/45-100 | nd | N3/0 (vdg) | 49 | 10 | 41 | SC | 1.7 |
| Ck | 100-160 | nd | 2.5Y5/2 (gb) | 27 | 10 | 63 | C | 1.8 |
| MV-P2 | | | | | | | | |
| Ah | 0-20 | 7.5YR3/2 (db) | 7.5YR3/1 (vdg) | 62 | 10 | 28 | SCL | 1.7 |
| Bts1 | 20-40 | 5YR5/6 (yr) | 5YR4/3 (rb) | 46 | 6 | 48 | SC | - |
| Bts2 | 40-125 | 5YR5/8 (yr) | 5YR4/6 (yr) | 28 | 6 | 66 | C | 1.3 |
| BCk | 125+ | 5YR5/8 (yr) | 5YR4/6 (yr) | 36 | 8 | 56 | C | - |

Soil colour notation: bl = black; db = dark brown; gb = grayish brown; rb = reddish brown; vdg = very dark gray; yr = yellowish red

Soil texture notation: SCL = sandy clay loam; SC=sandy clay; C=clay

The thick topsoils (20 cm) are sandy clay loam to sandy clay textured with moderate sub-angular blocky structure while most of the subsoils have moderately strong structures with sandy clay to clay texture. The topsoils have soft to slightly hard consistence when dry, friable when moist and slightly sticky and slightly plastic to sticky and plastic when wet. The consistence of the subsoils is slightly hard to hard when dry, friable when moist, sticky and plastic to very sticky and very plastic when wet. Few, fine clay cutans are found in the subsoils of this unit which is an indication of clay illuviation from the overlying horizons. CaCO₃ concretions are common in the subsoils of this mapping unit. The bulk density values of the topsoil are relatively high (1.7 g/cc) due to overgrazing by cattle and may pose a slight limitation in terms of reduced permeability and increased surface runoff. The subsurface BD values are not a problem at all.

Soil moisture characteristics of the Mbuga Soil and the Red Soil

Figure 3(a) and 3(b) presents the soil moisture characteristics curves for Mbuga Soil and Red Soil respectively. The soil moisture release curves indicate that the Mbuga Soil apparently with the type of clay mineral present (expanding type 2:1 silicate clay) holds moisture more tenaciously and release it more gradually compared to the Red Soil whose clay mineralogy is more of the non-expanding 1:1 silicate clays.

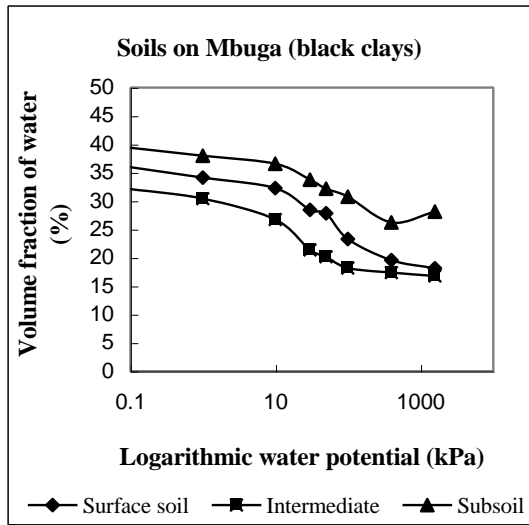


Fig. 3.a

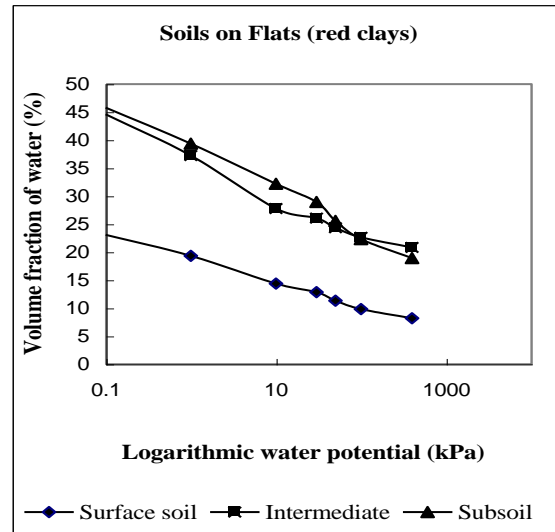


Fig. 3.b.

Fig. 3.a. Soil moisture characteristics curves for the Mbuga Soil

Fig. 3.b. Soil moisture characteristics curves for the Red Soil

Soil chemical properties

Chemical properties of the studied soils are summarized in Table 4. More details on chemical properties of the soils are presented in Appendix 1.

The Black Soils

The soils of this unit have pH (KCl), which is lower than pH (H₂O), indicating that the soils have a net negative charge. The topsoils are mildly alkaline (pH 7.7) and pH increases gradually with soil depth to moderately and strongly alkaline (pH 8.4 to 8.6) in the subsoils. The levels of total nitrogen and organic carbon are generally very low and low respectively in the topsoils and are both very low in the subsoils. These soils have good quality organic matter with the C:N ratio ranging from 8-13. The available phosphorus contents in the topsoils are very low (0.96 mg/kg), suggesting the need for phosphorus fertilization of soils of this unit when used for crop production. The soils have high CEC and high % base saturation indicating that the soils are generally fertile in terms of macronutrients, which is a general characteristic of many Vertisols. The topsoils CEC values are 21.2 cmol(+)/kg and increases with soil depth to 35.9 cmol(+)/kg soil. BS is >50% with high calcium and magnesium contents. The Ca:Mg ratio is 3.02 in the topsoils which is favourable for most crops. The levels of exchangeable potassium are medium

Table 4. Selected soil chemical properties of the studied soils

| Profile/ Horizon | Depth (cm) | pH | | % | % | C:N | P | P | CEC Soil | Ca | Mg | K | Na | % BS | EC dS/m | ESP |
|---------------------|---------------|------------------|-----|------|------|-------|---------|---------|-------------|------|------|------|------|-------|------------|------|
| | | H ₂ O | KCl | OC | N | ratio | (mg/kg) | (mg/kg) | | | | | | | | |
| | | | | | | | Bray-1 | Olsen | | | | | | | | |
| MV-P1 | | | | | | | | | | | | | | | | |
| Ah | 0 - 25/45 | 7.7 | 6.1 | 0.79 | 0.08 | 9.9 | - | 0.96 | 21.2 | 15.1 | 5.0 | 0.71 | 0.90 | 102.4 | 0.09 | 4.25 |
| ACk | 25/45 - 100 | 8.4 | 7.0 | 0.52 | 0.04 | 13.0 | - | 1.68 | 20.0 | 14.2 | 18.0 | 0.76 | 3.82 | 184.9 | 0.38 | 19.1 |
| Ck | 100 - 160 | 8.6 | 7.2 | 0.08 | 0.03 | 2.3 | - | 0.31 | 32.6 | 14.3 | 12.2 | 1.37 | 13.8 | 127.8 | 0.94 | 42.3 |
| MV-P2 | | | | | | | | | | | | | | | | |
| Ah | 0 - 20 | 6.5 | 4.8 | 0.91 | 0.06 | 15.2 | 2.23 | - | 5.2 | 3.50 | 2.41 | 0.99 | 0.12 | 135.0 | 0.03 | 1.44 |
| Bts1 | 20 - 40 | 5.7 | 4.0 | 1.03 | 0.05 | 20.6 | 2.52 | - | 7.0 | 2.02 | 2.70 | 0.66 | 0.21 | 79.9 | 0.03 | 2.60 |
| Bts2 | 40 - 125 | 5.9 | 3.7 | 0.79 | 0.04 | 19.8 | 1.04 | - | 11.0 | 0.63 | 1.80 | 0.44 | 0.44 | 30.0 | 0.02 | 5.2 |
| BCK | 125 -155+ | 6.2 | 3.7 | 0.51 | 0.04 | 12.8 | 0.52 | - | 8.0 | 4.80 | 3.20 | 0.80 | 1.15 | 124.4 | 0.03 | 14.6 |

while those of exchangeable sodium in the topsoils are high (0.90 cmol(+)/kg) and increases with soil depth. Exchangeable Na percent (ESP) values indicate the topsoils are non-sodic whereas the sodicity of subsoils ranges between strongly sodic to extremely sodic. This may pose a problem particularly if the soils are not managed by proper drainage management.

Vertisols are generally known to have high agricultural potential, but require special management practices for optimal rainfed or irrigated agriculture. They are characterized by having relatively high chemical fertility with poor workability due to their poor physical properties. Poor infiltration of water and high vulnerability to erosion are the major problems associated with poor physical properties of these soils. Management practices should therefore aim at increasing infiltration rates of water as well as reducing erosion hazard in these soils. Mulching with crop residues, contour cultivation and contour banding are some of the management practices that have proved to be successful for production of crops (rice and maize) in these soils.

The Red Soils

Topsoils have slightly acid to neutral soil reaction (pH 6.5 to 6.7). The electrical conductivity of these soils is very low thus no any yield reduction due to soluble salts is expected in this mapping unit. The levels of total nitrogen range from very low to low (0.06-0.14%) in the topsoils while those of organic carbon are low to medium (0.91-1.35%) with moderate to good quality organic matter. The available phosphorus levels range from very low to medium thus phosphorus fertilization is required in these soils for optimum crop production. These soils have low levels of CEC. Percent base saturation levels are high (>50%). The exchangeable calcium levels range from medium to high (3.4 to 4.53 cmol(+)/kg) in the topsoils and decrease with soil depth. The exchangeable magnesium levels are high. Exchangeable potassium levels range from medium to high while those of exchangeable sodium are low in topsoils (0.12 cmol(+)/kg) and high (1.15 cmol(+)/kg) in the subsoils. The topsoils and subsoils are non-sodic as indicated by their very low values of exchangeable sodium percentage (<6%) while deeper subsoils below a depth of 125 cm from the surface are moderately sodic (14.6%).

Soil classification

Tables 5 and 6 give summaries of the morphological and diagnostic features and 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 and in italics),

Table 5. Summary of soil profile morphological and diagnostic features and classification of the studied soils (FAO, 1998)

| Profile | Diagnostic horizons | Other diagnostic features, properties/materials | Soil name |
|---------|-----------------------------------|---|--|
| MV-P1 | Ochric horizon, Vertic horizon | Hypereutric, Pellic, Endosodic | Endosodi-Pellic Vertisols (Hypereutric) |
| MV-P2 | Ochric horizon, Argic horizon | Profondic, Chromic | Chromi-Profondic Lixisols (Haplic) |

Table 6. Summary of morphological and diagnostic features and classification of the studied soils (Soil Survey Staff, 1998)

| Profile | Diagnostic horizons | Other diagnostic features, properties/ materials | Soil name |
|---------|--------------------------------------|---|-----------------------|
| MV-P1 | Ochric epipedon | Ustic SMR, Isohyperthermic STR, Slickensides, gilgai micro-relief | Sodic Haplusterts |
| MV-P2 | Ochric epipedon, Argillic horizon | Ustic SMR, Isohyperthermic STR | Kanhaplic Haplustalfs |

the black Mbuga Soils classify as Endosodi-Pellic Vertisols (Hypereutric)- (*Sodic Haplusterts*) while Red Soils classify as Chromi-Profondic Lixisols (Haplic)- (*Kanhaplic Haplustalfs*).

3.3. Conclusions on the agricultural production potentials/ limitations of the soils of Kalaita Company's Farm

Kalaita Company's Farm is very well located in terms of communication facilities. It can be served by both Morogoro-Dar es Salaam and Morogoro-Dodoma highways to link to different market destinations, both nationally, regionally and internationally. However, few limitations were recorded which might affect agricultural potential of Kalaita Company's farm:

- The low and uncertain rainfall of the area. For most crops save for the drought resistant crops like sorghum, cassava and millets, the rainfall received at the farm is not enough and the onset of the rains is quite unpredictable.

- The inherent low fertility status of the soils of the farm. Although the Black soils are relatively more fertile than the Red soils, the overall fertility of both types of soils can be rated as marginal.
- Poor soil drainage condition particularly in the mbuga and floodplain soils is another constraint.
- There is an emerging problem of salinity particularly in the Mbuga soils. At the moment it may not pose a serious problem but in future this problem may intensify.

3.4. Recommendations

- Despite the limitations pointed out in 3.3 above, it is the opinion of the consultant that Kalaita Company's Farm can be a very profitable business venture if managed under irrigation, and recommends that financial credit be extended to the company to allow establishment of an irrigation system as part of whole agricultural production venture.
- In relation to 3.4.i above, Kalaita Company Ltd. should construct dams in selected areas of the farm, under the guidance of an irrigation engineer. These dams will store run-off water during the rainy season which will supply water for both crop and livestock production. Some crops can also be produced through irrigation using water directly from River Mkata which crosses one corner of the farm. Crops that can be grown include maize, rice, sunflower, sorghum, millets, beans, and bananas. With irrigation, some of these crops can be produced twice a year i.e. during the rainy season and off-season during the dry season.
- To address problems of low natural fertility of the soils, emphasis should be put on integrated nutrient management strategies. Use of animal manure and other sources of organic and inorganic fertilizers is recommended. For example the use of our locally available fertilizers such as rock phosphate could immensely contribute to the improvement of soil fertility particularly in the red soils of the farm.
- To address the problem of impeded drainage and flooding which commonly occurs during the rainy season, the Company is advised to construct drainage systems that will effectively control water levels.
- Regular flushing of the soils through drainage systems; proper crop selection and planting of salt tolerant crops such as sorghum, which can cope very well with drought and saline

environments, could largely control the problem of saline soils found mostly in the Mbuga.

- vi. On the basis of landform and soil characteristics, a great part of the Mbuga and floodplain soils (black soils) should be reserved more for crop production particularly of rice during the rainy season and other crops e.g. maize, sorghum, millets, vegetables, bananas, sunflower and beans during the dry season under irrigation. Some part of the Mbuga soils should also be reserved for establishment of improved pastures for feeding livestock. For ease of bulb formation, onions should only be grown in the relatively coarse textured soils of the floodplain.
- vii. A big part of the red soils should be confined to “*controlled extensive grazing*” of cattle and sheep, whereas the remainder could be set aside for crop production involving crops such as maize, sorghum, millets, sunflower and beans. The red soils can also support production of currently high-priced crops like simsim.
- viii. Grazing land for livestock should be fenced out, and there should be proper grazing rotation within the grazing land to avoid making the soil bare.
- ix. Grazing in the arable fields after harvest should not be allowed. Stubble and other plant residues should be left on the fields and ploughed in when preparing the fields for the next growing season. This will also protect the soil against erosion and increase the available water holding and nutrient retention capacities of the arable lands.
- x. Another land utilization type worth considering other than extensive grazing, is the establishment of beef cattle feedlot on the red soil. The company is urged to think about this venture and seek guidance from relevant animal specialists in Sokoine University of Agriculture.

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Profile number: MV-P1 Mapping unit: PL1 Agro-ecol. zone:
 Region: MOROGORO District: Mvomero Map sheet no. : 183/1
 Coordinates: 37° 28' 13.2" E/ 6° 35' 2.8" S

Elevation: 383 m asl. Parent material: Recent alluvium materials mainly clay derived from banded muscovite-biotite migmatites of Nguru ya Ndege mountains. Landform: Mbuga; flat or almost flat. Slope: 1 %; concave. Natural vegetation. Acacia woodland and grass undergrowth. Land use: Grazing
 Surface characteristics: Surface sealing: 1-2 mm. Cracks: very deep cracks (>100 cm); 3-10 cm wide with gilgai micro-relief. Erosion: none or slight. Deposition: Alluvial materials.

Natural drainage class: poorly to very poorly drained

Described by B.M. Msanya

Soils are deep, poorly to very poorly drained very dark grey sandy clays, with very thick black sandy clay topsoils.

Ah 0 - 25/45 cm: black (N2.5/0) sandy clay; firm moist, sticky and plastic wet; weak coarse and medium subangular blocks; medium and many fine pores; many fine roots; clear wavy boundary to

ACk 25/45 - 100 cm: very dark grey (N3/0) moist; sandy clay; very firm moist, very sticky and very plastic wet; moderate coarse angular wedge-shaped blocks and angular prismatic blocks; continuous thick slickensides/press cutans; very fine pores; abundant medium spherical hard carbonates nodules; common fine roots; moderately calcareous; abrupt smooth boundary to

Ck 100 - 160+ cm: greyish brown (2.5Y5/2) moist; clay; very firm moist, very sticky and very plastic wet; weak very coarse prisms; very few moderately thick slickensides/press cutans; common very fine pores; diffuse fine and medium spherical hard carbonates nodules; strongly calcareous

SOIL CLASSIFICATION: WRB (FAO 1998): Endosodi-Pellic Vertisols (Hypereutric)

USDA-Soil Taxonomy (Soil Survey Staff, 1998): Sodic Haplusterts

ANALYTICAL DATA FOR PROFILE MV-P1

| Horizon | Ah | ACk | Ck |
|------------------------------------|---------|-----------|---------|
| Depth (cm) | 0-25/45 | 25/45-100 | 100-160 |
| Clay % | 40 | 41 | 63 |
| Silt % | 10 | 10 | 10 |
| Sand % | 50 | 49 | 27 |
| Texture class | SC | SC | C |
| Bulk density g/cc | 1.6 | 1.7 | 1.8 |
| AWC mm/m | nd | 113.41 | nd |
| pH H ₂ O 1:2.5 | 7.7 | 8.4 | 8.6 |
| pH KCl 1:2.5 | 6.1 | 7.0 | 7.2 |
| EC 1:2.5 mS/cm | 0.09 | 0.38 | 0.94 |
| ESP | 4.25 | 19.1 | 42.3 |
| Organic C % | 0.79 | 0.52 | 0.08 |
| Total N % | 0.08 | 0.04 | 0.03 |
| C/N | 9.9 | 13 | 2.7 |
| Avail. P Bray-1 mg/kg | nd | nd | nd |
| Avail. P Olsen mg/kg | 0.96 | 1.68 | 0.31 |
| CEC NH ₄ OAc cmol(+)/kg | 21.2 | 20.0 | 32.6 |
| Exch. Ca cmol(+)/kg | 15.1 | 14.2 | 14.3 |
| Exch. Mg cmol(+)/g | 5.0 | 18.0 | 12.2 |
| Exch. K cmol(+)/kg | 0.71 | 0.76 | 1.37 |
| Exch. Na cmol(+)/kg | 0.90 | 3.82 | 13.8 |
| TEB cmol(+)/kg | 21.7 | 36.8 | 41.7 |
| Base saturation % | 102 | 184 | 128 |
| CEC clay cmol(+)/kg | 45.7 | 43.9 | 50.9 |

nd= not determined

Profile number: MV-P2 Mapping unit: PL2 Agro-ecol. zone:
 Region: MOROGORO District: Mvomero Map sheet no. : 183/1

Coordinates: 37° 28' 56.6" E/ 6° 35' 10.2" S

Elevation: 398 m asl. Parent material: Colluvium mainly red clays derived from banded muscovite-biotite migmatites of Nguru ya Ndege mountains. Landform: Red flats; flat or almost flat. Slope: 0.5 %; straight. Natural vegetation: Secondary miombo woodland, thickets, bushes and grasses. Land use: Extensive grazing. Human influences: Charcoal burning.

Surface characteristics: Cracks: None

Erosion: Moderate sheet erosion. Deposition: Alluvial materials. Natural drainage class : well drained

Described by B.M. Msanya

Soils are very deep, well drained reddish brown to yellowish red sandy clay to clays, with thick dark brown sandy clay loam topsoils.

Ah 0 - 20 cm: dark brown (7.5YR3/2) dry, red dark grey (7.5YR3/1) moist; sandy clay loam; soft dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and few medium pores; many fine and medium roots; clear smooth boundary to

Bts1 20 - 40 cm: yellowish red (5YR5/6) dry, reddish brown (5YR4/3) moist; sandy clay; hard dry, friable moist, sticky and plastic wet; moderate coarse subangular blocks; continuous moderately thick clay cutans; many fine and common medium pores; many fine and few medium roots; gradual wavy boundary to

Bts2 40 - 125 cm: yellowish red (5YR5/8) dry, yellowish red (5YR4/6) moist; clay; slightly hard dry, friable moist, very sticky and very plastic wet; moderately strong medium and fine subangular blocks; continuous moderately thick clay cutans; many fine and medium pores; common very fine and few medium roots; abrupt smooth boundary to

BCK 125 - 160 cm: yellowish red (5YR5/8) dry, yellowish red (5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderately strong fine and medium subangular blocks; few fine and common medium pores; very many fine and medium angular and irregular slightly weathered quartz fragments; very few very fine and medium roots; slightly calcareous

SOIL CLASSIFICATION: WRB (FAO 1998): Chromi-Profondic Lixisols (Haplic)

USDA-Soil Taxonomy (Soil Survey Staff, 1998): Kanhaplic Haplustalfs

ANALYTICAL DATA FOR PROFILE MV-P2

| Horizon | Ah | Bts1 | Bts2 | BCK |
|------------------------------------|------|-------|--------|---------|
| Depth (cm) | 0-20 | 20-40 | 40-125 | 125-160 |
| Clay % | 28 | 48 | 66 | 56 |
| Silt % | 10 | 6 | 6 | 8 |
| Sand % | 62 | 46 | 28 | 36 |
| Texture class | SCL | SC | C | C |
| Bulk density g/cc | 1.7 | nd | 1.3 | nd |
| AWC mm/m | nd | nd | 164 | nd |
| pH H ₂ O 1:2.5 | 6.5 | 5.7 | 5.9 | 6.2 |
| pH KCl 1:2.5 | 4.8 | 4.0 | 3.7 | 3.7 |
| EC 1:2.5 mS/cm | 0.03 | 0.03 | 0.02 | 0.03 |
| ESP | 1.44 | 2.60 | 5.20 | 14.6 |
| Organic C % | 0.91 | 1.03 | 0.79 | 0.51 |
| Total N % | 0.06 | 0.05 | 0.04 | 0.04 |
| C/N | 15.2 | 20.6 | 19.8 | 12.8 |
| Avail. P Bray-1 mg/kg | 2.23 | 2.52 | 1.04 | 0.52 |
| Avail. P Olsen mg/kg | nd | nd | nd | nd |
| CEC NH ₄ OAc cmol(+)/kg | 5.2 | 7.0 | 11.0 | 8.0 |
| Exch. Ca cmol(+)/kg | 3.50 | 2.02 | 0.63 | 4.80 |
| Exch. Mg cmol(+)/g | 2.41 | 2.70 | 1.80 | 3.20 |
| Exch. K cmol(+)/kg | 0.99 | 0.66 | 0.44 | 0.80 |
| Exch. Na cmol(+)/kg | 0.12 | 0.21 | 0.44 | 1.15 |
| TEB cmol(+)/kg | 7.02 | 5.59 | 3.31 | 9.95 |
| Base saturation % | 135 | 79.9 | 30 | 124 |
| CaCO ₃ % | 0.10 | 1.3 | 4.0 | 3.1 |
| CEC clay cmol(+)/kg | 7.3 | 7.3 | 12.5 | 11.1 |

nd= not determined

Appendix 2. Guide to general rating of some chemical and physical soil properties
Compiled from EUROCONSULT (1989), Landon (1991), Sys (1993), Baize (1993),
Msanya *et al.* (1996) and Kileo, (2000).

1. Organic matter and total nitrogen

| | Very low | Low | Medium | High | Very high |
|------------------|----------|-----------|-----------|-----------|-----------|
| Organic matter % | < 1.0 | 1.0-2.0 | 2.1-4.2 | 4.3-6.0 | > 6.0 |
| Organic carbon % | < 0.6 | 0.60-1.25 | 1.26-2.50 | 2.51-3.50 | >3.5 |
| Total nitrogen % | < 0.10 | 0.10-0.20 | 0.21-0.50 | > 0.50 | |

C/N ratios give an indication of the quality of organic matter:

C/N 8-13: good quality

C/N 14-20: Moderate quality

C/N > 20: Poor quality.

2. Soil reaction

| | pH <4.5 | Neutral | pH 6.6 to 7.3 |
|--------------------|---------------|------------------------|---------------|
| Extremely acid | pH <4.5 | Neutral | pH 6.6 to 7.3 |
| Very strongly acid | pH 4.5 to 5.0 | mildly alkaline | pH 7.4 to 7.8 |
| Strongly acid | pH 5.1 to 5.5 | moderate alkaline | pH 7.9 to 8.4 |
| Medium acid | pH 5.6 to 6.0 | strongly alkaline | pH 8.5 to 9.0 |
| Slightly acid | pH 6.1 to 6.5 | very strongly alkaline | pH > 9.0 |

3. Available phosphorus

| mg/kg | Low | Medium | High |
|-------------------------|-----|--------|------|
| Avail. P (Bray-Kurtz 1) | < 7 | 7-20 | > 20 |
| Avail. P (Olsen) | < 5 | 5-10 | > 10 |

NB. Available phosphorus is determined by the Bray-Kurtz 1 method if the pH H₂O of the soil is less than 7.0. In soils with a pH H₂O of more than 7.0 the Olsen method is used.

4. Cation exchange capacity (CEC)

| cmol(+)/kg | Very low | Low | Medium | High | Very high |
|------------|----------|----------|------------|------------|-----------|
| CEC | < 6.0 | 6.0-12.0 | 12.1- 25.0 | 25.0- 40.0 | > 40.0 |

CEC is determined using 1 M ammonium acetate in soils with pH less than 7.5. In soils with pH greater than 7.5 CEC is determined using 1 M sodium acetate.

5. Electrical conductivity (ECe)

| | | |
|-----|----------------|----------------------------|
| ECe | < 1.7 dS/m | no yield reduction |
| ECe | 1.7 - 2.5 dS/m | up to 10% yield reduction |
| ECe | 2.5 - 3.8 dS/m | up to 25% yield reduction |
| ECe | 3.8 - 5.9 dS/m | up to 50% yield reduction |
| ECe | 5.9 - 10 dS/m | up to 100% yield reduction |

6. Exchangeable calcium

| cmol(+)/kg | Very low | Low | Medium | High | Very high |
|-------------------------------------|----------|---------|----------|-----------|-----------|
| Ca (clayey soils rich in 2:1 clays) | < 2.0 | 2.0-5.0 | 5.1-10.0 | 10.1-20.0 | > 20.0 |
| Ca (loamy soil) | < 0.5 | 0.5-2.0 | 2.1-4.0 | 4.1-6.0 | > 6.0 |
| Ca (kaolinitic and sandy soils) | < 0.2 | 0.2-0.5 | 0.6-2.5 | 2.6-5.0 | > 5.0 |

7. Exchangeable magnesium (Mg)

| cmol(+)/kg | Very low | Low | Medium | High | Very high |
|-------------------|----------|-----------|----------|---------|-----------|
| Mg (clayey soils) | < 0.3 | 0.3-1.0 | 1.1-3.0 | 3.1-6.0 | > 6.0 |
| Mg (loamy soils) | < 0.25 | 0.25-0.75 | 0.75-2.0 | 2.1-4.0 | > 4.1 |
| Mg (sandy soils) | < 0.2 | 0.2-0.5 | 0.5-1.0 | 1.1-2.0 | > 2.0 |

The desired saturation level of exchangeable Mg is 10 to 15 percent; for sandy and kaolinitic soils 6 to 8 percent Mg saturation is still sufficient. Ca/Mg ratios of 2 to 4 are favourable.

8. Exchangeable potassium (K)

| cmol(+)/kg | Very low | Low | Medium | High | Very high |
|------------------|----------|-----------|-----------|-----------|-----------|
| K (clayey soils) | < 0.20 | 0.20-0.40 | 0.41-1.20 | 1.21-2.00 | > 2.00 |
| K (loamy soils) | < 0.13 | 0.13-0.25 | 0.26-0.80 | 0.81-1.35 | > 1.35 |
| K (sandy soils) | < 0.05 | 0.05-0.10 | 0.11-0.40 | 0.41-0.70 | > 0.70 |

The desired saturation level of exchangeable K is 2 to 7 percent.

Favourable Mg/K ratios for most crops are in the range of 1 to 4.

9. Exchangeable sodium (Na)

| cmol(+)/kg | Very low | Low | Medium | High | Very high |
|------------|----------|-----------|-----------|-----------|-----------|
| Na | < 0.10 | 0.10-0.30 | 0.31-0.70 | 0.71-2.00 | > 2.00 |

More important than the absolute level of exchangeable Na is the exchangeable sodium percentage (ESP) calculated by dividing exchangeable Na by CEC (x 100). ESP values are a measure of the sodicity of the soil.

10. Soil sodicity

| | Non-sodic | Slightly sodic | moderately sodic | Strongly sodic | Very strongly sodic | Extremely sodic |
|-------|-----------|----------------|------------------|----------------|---------------------|-----------------|
| ESP % | < 6 | 6-10 | 11-15 | 16-25 | 26-35 | > 35 |

ESP < 15% - up to 50 percent yield reduction of sensitive crops (maize, beans)

ESP 16-25% - up to 50 percent yield reduction of semi-tolerant crops (rice, wheat, sorghum, sugarcane)

ESP 35% - up to 50 percent yields reduction of tolerant crops (barley, cotton).

11. Basic infiltration rate (IR)

| | |
|-------------------|------------------|
| IR < 0.1 cm/h | extremely slow |
| IR 0.1-0.3 cm/h | very slow |
| IR 0.3-0.5 cm/h | slow |
| IR 0.5-2.0 cm/h | moderately slow |
| IR 2.0-6.5 cm/h | moderate |
| IR 6.5-12.5 cm/h | moderately rapid |
| IR 12.5-25.0 cm/h | rapid |
| IR > 25.0 cm/h | very rapid |

Basic infiltration rate is the constant at which water enters the (pre-wetted) soil and which develops after 3 to 5 hours of infiltration.

12.0 Available water capacity (AWC)

| | | |
|-----|--------------|---------------|
| AWC | < 25 mm/m | extremely low |
| AWC | 25-50 mm/m | very low |
| AWC | 50-100 mm/m | low |
| AWC | 100-150 mm/m | medium |
| AWC | 150-200 mm/m | high |
| AWC | > 200 mm/m | very high |

Available water capacity is the capacity of the soil to store water that is readily available for uptake by plant roots; usually expressed in millimetres of water per metro depth of soils; technically the difference between the percentage of soil water at field capacity (normally taken as the water content at pF 2.0) and the percentage at wilting point (taken as the water content at pF 4.2). This is applicable for most tropical soils.

13. Aluminium saturation

| | | | | | |
|-----------------|----------|-------|--------|-------|-----------|
| | Very low | low | Medium | High | Very high |
| Al saturation % | < 10 | 10-30 | 31-50 | 51-80 | > 80 |

Aluminium saturation as measure of toxicity is calculated by dividing exchangeable Al by the sum of exchangeable bases and exchangeable Al.