SOILS OF LAKI LAKI ESTATE
(ARUSHA DISTRICT)
AND THEIR SUITABILITY FOR SEEDBEANS

prepared for Rotian Seed Company Ltd

NATIONAL SOIL SERVICE
TARO AGRICULTURAL RESEARCH INSTITUTE, MLINGANO
TANGA TANZANIA

...port S10 1988

SOILS OF LAKI LAKI ESTATE
(ARUSHA DISTRICT)
AND THEIR SUITABILITY FOR SEEDBEANS

prepared for Rotian Seed Company Ltd

NATIONAL SOIL SERVICE
TARO AGRICULTURAL RESEARCH INSTITUTE, MLINGANO
TANGA TANZANIA

Site - Evaluation Report S10 1988

Table of Contents

Summary

1. At the request of Rotian Seed Company Ltd., the National Soil Service conducted a rapid study to evaluate the soil conditions at Laki Laki Estate.
This Estate, with an extent of approximately 400 ha, is located 8 km west of Arusha town, along the road to Dodoma.
Most of the Estate area is presently left fallow. Minor parts are under wheat and coffee. Plans exist to cultivate seedbeans.

2. Climatological conditions are optimal for the cultivation of seedbeans. The optimal planting date is probably in March.

3. The western part of the Estate is almost flat, the central part has a hilly topography with slopes over 9%, and the eastern part, south of the farm premises, is undulating and almost flat.

4. Two dominant soil types, both developed in volcanic parent materials, are found on Laki Laki Estate:
- light coloured loamy soils, presently under coffee in the most eastern, almost flat part of the Estate.
- dark coloured, cracking clay soils in the rest of the Estate.

5. The loamy soils under coffee have a better soil fertility than the dark, cracking clay soils.

The pH values of the cracking clay soils is invariably above 7, which can give rise to deficient levels of some nutrients (e.g. zinc). In the loamy soils the pH is within the optimal range for beans.

The organic matter levels in the upper 20 cm are much higher in the loamy soils than in the cracking clay soils, respectively around 4 and 2%. The total nitrogen levels show the same trend.

The available phosphorus content is medium to high in the topsoils of both soil types.

In the loamy as well as in the clayey soils the cation exchange capacities are high, as are the levels of all exchangeable bases, i.e. calcium, magnesium, potassium and sodium. Imbalances exist however between the bases: The very high potassium contents in the loamy soils may induce magnesium deficiencies. The very high sodium contents at some sites in the flat, western part, will adversely affect the growth of many crops.

6. The actual soil physical conditions of the cracking clay soils are not optimal.- A dense ploughpan has developed, which adversely affects rooting and enhances run-off erosion.

- the accessibility with heavy machinery is limited to a short period only: the soils are either too dry or too wet to cultivate.

7. Suitability assessment shows that presently the dark cracking clay soils in the flat, western and central, part are dominantly marginally suitable for the cultivation of seedbeans. The dark, cracking clay soils in the eastern part are moderately suitable and the loamy soils under coffee are considered to be highly suitable.

8. Several soil, water and crop management practices are required which may help to improve the suitability of the soils for the cultivation of seedbeans. The most important are :

- breaking up of ploughpans through chiseling and mould-board ploughing.
- the construction of ridges, i.e. contour ridges in the flat western part and graded ridges on the steeper slopes in the central and eastern part of the Estate
- rotations with beans and viz. wheat or barley must be practised strictly, together with stubble mulching or trash farming in the main growing season.

9. During the short rainy season, i.e. November to January, it has to be avoided to leave fields bare. A green manure crop like

Crotolaria juncea may be grown and ploughed in before the beans are planted. This adds to the organic matter and total nitrogen contents of the soils and prevents weeds from becoming a problem.

11. Magnesium fertilizer like kieserite may be necessary on the loamy soils while Zinc fertilizer may be needed on the cracking, clay soils.

1 INTRODUCTION

A rapid site evaluation of Laki Laki Estate was carried out by the National Soil Service. Rotian Seed Company Ltd. requested an investigation into suitability of the soils of this Estate for the cultivation of seedbeans and some recommendations on appropriate soil, crop and water management practices.

Laki Laki Estate, covering an area of about 400 ha, is located 8 km west of Arusha town, along the road to Dodoma. A relatively small part of the estate is used for the cultivation of coffee. The rest of the area is mostly fallow; only some fields are under wheat.

Most information on the morphological and physical characterisitcs of the soils was obtained from a study by Presant (1973). To complete the data required, composite topsoil samples for the characterization of the soil fertility status were collected.

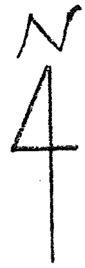
The collection of the composite topsoil samples was carried out on June 23, 1988 by Messrs. J.M. Shaka, A.J.M. Brom and F. van der Wal. The soil samples collected were analysed in the Central Laboratory of the National Soil Service at Mlingano, Tanga.

2. ENVIRONMENT

2.1 Description of the Estate area

Figure 1 gives the topography of Laki Laki Estate as shown on the 1:50,000 scale toposheet (sheet 55/3, Directorate of overseas Survey,). The average altitude is about 1400 m.

The Estate area can be divided into 3 more or less equal parts:
- the eastern, gently sloping to almost flat part which is partly used for the cultivation of coffee and wheat
- the central, hilly part which is presently not used for cultivation
- the western, flat part which is mainly left fallow at the moment.



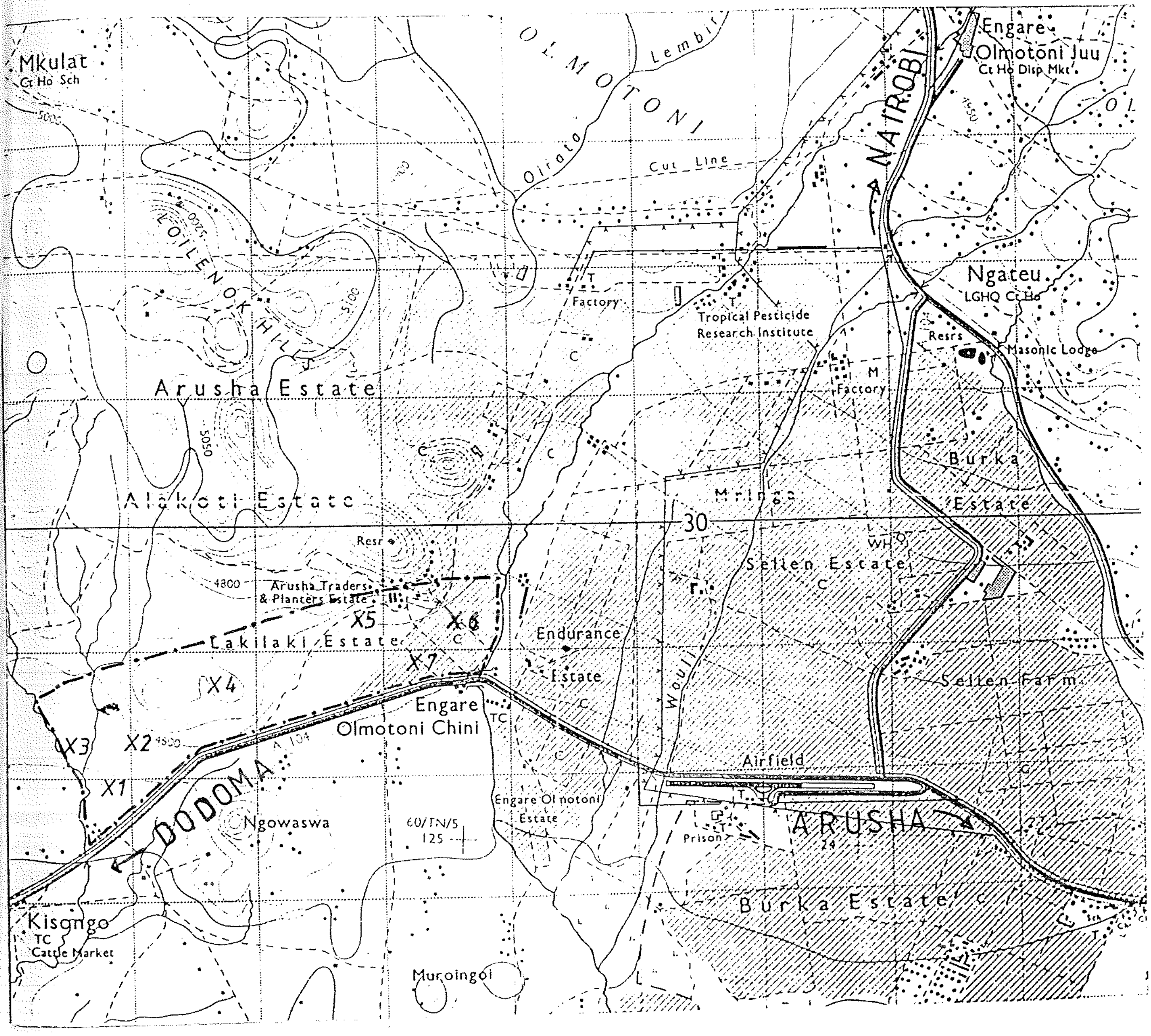


FIG 1 LOCATION AND TOPOGRAPHY OF LAKI LAKI ESTATE

2.2 Climate

The meteorological data available are rainfall and temperature recorded between 1960 and 1970 at Arusha Airport, about 2 km east of Laki Laki Estate (E. African Met. Dept., 1975). The data are presented in Table 1 and Figure 2.

Table 1 Monthly rainfall and temperature data recorded at Arusha Airport (1960 - 1970)

	monthly rainfall (mm)			monthly temperature (°C)		
	mean	highest	lowest	mean	maximum	minimum
January	71	172	1	20.6	27.7	13.4
February	88	225	14	21.1	28.2	14.0
March	145	256	47	21.3	27.1	15.4
April	249	456	39	20.4	24.7	16.0
May	66	152	3	19.0	23.0	14.9
June	18	67	1	17.4	21.9	12.8
July	11	40	0	16.9	21.5	12.3
August	7	45	0	17.6	22.7	12.5
September	10	59	0	18.8	24.8	12.8
October	25	124	1	20.4	26.8	13.9
November	139	469	1	20.7	26.7	14.7
December	98	260	16	20.4	26.9	13.9

The mean annual rainfall at Arusha Airport is 927 mm; the variation between the years is considerable with a recorded minimum of 514 mm and a maximum of 1543 mm. As the amount of rainfall decreases towards the west, slightly lower figures are expected at Laki Laki Estate.
The rainfall distribution pattern is bimodal with one peak in April and a second one in November (see Fig. 2). Nearly 50%, i.e. 460 mm of the yearly rainfall occurs in the period March-May (the long rains), which is the main cropping season in the area. After these rains a really dry season starts in June and continues up to November (ca. 5 months)

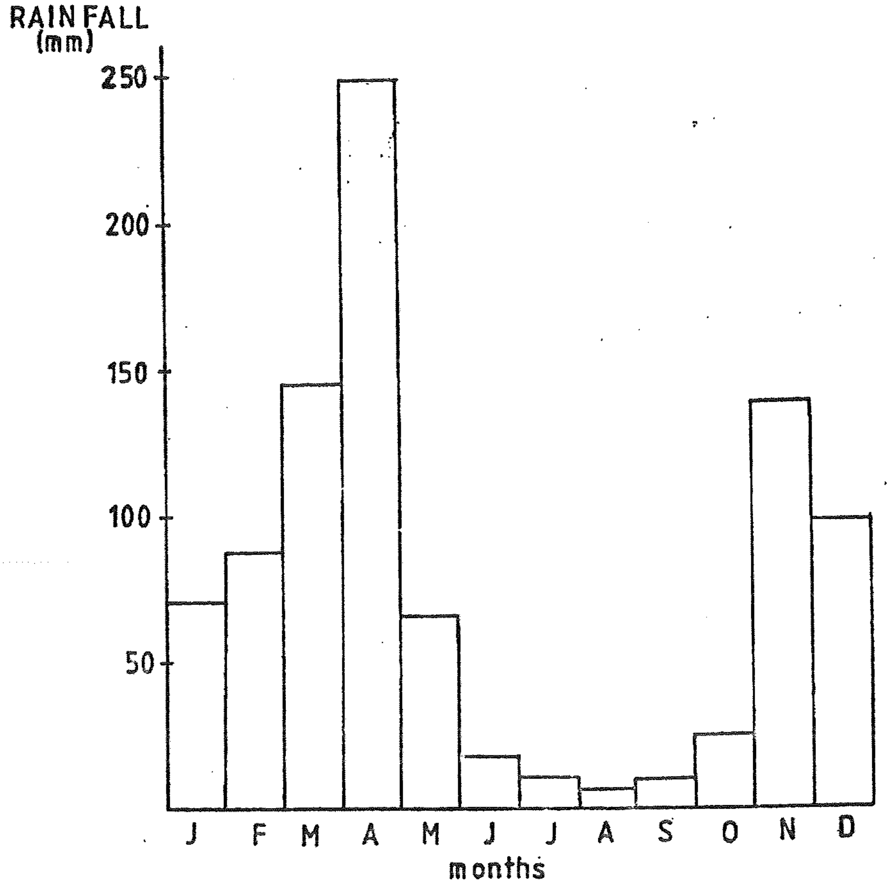


Fig. 2 Mean montly rainfall at Arusha Airport (1960-1970)

which receives an average total amount of only 71 mm. The rest, nearly 400 mm, falls in the period of November to February (short rains). There is no real dry period between the short and long rains. As beans and wheat need dry weather during harvest the short rains are not very suitable for the cultivation of these crops.

2.3 Geology

The geology of most of the Northern Highlands Region, in which the study area is located, is closely related to the faulting and vulcanism associated with formation of the rift valleys. Alkaline volcanic rocks, such as olivine and alkali basalts, overlie the Ancient Precambrian rocks to a considerable depth. The youngest volcanic sediments originating from Mt. Meru, are tuffs and agglomerates that form the parent material of most soils in the area. These materials were initially deposited sub-aerially, but have been extensively redistributed by sheet flood and wind.

3 SOILS

3.1 General soil conditions

No detailed information on the soil types present in the study area was collected during the fieldwork as this information was available from a study carried out by E.W. Presant (1973).
According to this soil survey, of selected areas near Arusha and Monduli carried out at a scale of 1:250,000, 4 different soil associations can be distinguished in the area of Laki Laki Estate:

- 2 associations of young, fertile "Eutrophic Brown Soils" on volcanic and alluvial sediments in the eastern part of the Estate.
- somewhat leached, "Ferruginous Tropical Soils" on rocks rich in ferromagnesian minerals in the central, hilly part, and
- "Mineral Hydromorphic Soils" on alluvial and lacustrine sediments in the flat, western part of the Estate.

"Eutrophic Brown Soils"

According to the Legend of Presant's Soil map, the Eutrophic Brown Soils on slopes less than 5% are distinguished from those on slopes steeper than 5%. The soils have predominantly medium textures (loamy, silty). In the nearly flat and gently sloping areas (slopes less than 5%), inclusions of alluvial soils occur. In the moderately and strongly sloping areas (slopes over 5%) textures can also be clayey and inclusions of brown, calcareous soils are reported.
In the accompanied report Presant (1973) states further that:
"The textures of the surface horizons of the Eutrophic Brown Soils are mainly loam or silty clay loam. Moist colours are very dark brown (10YR 2/2 - 3/2) and dry colours are brown to grayish brown (10YR 4/3-5/2). The surface horizon often grades downwards into a lighter-coloured A horizon with lower organic matter content. This light-coloured A horizon is absent on many slopes where soil erosion has truncated the soil profile, and at these locations the surface horizon rests directly on the B horizon. Most B-horizons are weakly developed

and can usually only be distinguished from adjacent horizons by minor differences in colour or structure.
The B horizons of Eutrophic Brown soils gradually grade into the parent materials of C horizons. The colour of the C horizons material is usually dark brown to brown. There are many soils that have free carbonates in the C horizon at 75 cm. or deeper."

"Ferruginous Tropical Soils"

According to the soil map the Ferruginous Soils are mostly found on slopes of 9-15% and have medium textures (silty, loamy).
Clayey, brown, calcareous soils can be found in places with more gentle slopes.
In his report Presant states further that:
"The surface A horizons of these soils are usually shallow because most occur on moderate to steep slopes, and A horizon materials have been eroded. The remaining A horizon soil materials are silty clay loam to silty clay in texture, with low organic matter content, and fine granular structure. The B horizons are more clayey than the A horizons, with clay to heavy clay texture and angular blocky structure. The C horizons are usually lighter in texture and have better defined platy structures than the B horizons."

"Mineral Hydromorphic Soils"

The soil map by Presant indicates that the slopes in the western part of the Estate are mostly less than 2%. The clayey soils are mainly "Mineral Hydromorphic Soils" associated with Vertisols (Black Cotton Soils). In places medium textured, young soils and brown, calcareous soils can be found.

The "Mineral Hydromorphic Soils" according to Presant (1973) are "mostly poorly drained silty clays and clays, apparently derived from lacustrine sediments. They are often associated with Vertisols and sometimes difficult to distinguish from them. They are usually somewhat better. A drained than Vertisols and generally have browner and better defined soil horizons.

The textures of the surface horizons vary from silty clay loam to clay. Most colours of the surface A horizons are very dark gray to very dark brown; most dry colours range between dark grayish brown and very dark grayish brown. The C horizons usually have clay textures and columnar structures. Like Vertisols they tend to shrink when dry, so that narrow cracks, up to 1 or 2 cm. wide, often occur up to the soil surface The C horizons are usually gleyed and colours vary, although moist [illegible] colours of very dark brown and dry colours of very dark grayish brown are most common. Free carbonates are not usually present in these soils above the 60 cm depth."

Present (1973) also studied the agricultural capabilities of the area around Arusha and Monduli.

The "Eutrophic Brown Soils" present in the eastern part of the Estate on slopes less than 5% are capable of sustained production of most common crops of the region. They are deep, fertile, mostly well drained and have good moisture-holding capacities.
These soils require few conservation measures. Strip-cropping on long, gently slopes or on large cultivated fields can practically eliminate soil loss by water or wind erosion.

The other soils on the Estate, i.e. the Ferruginous Tropical Soils, the Mineral Hydromorphic Soils and the Eutrophic Brown Soils on slopes over 5% have moderate to severe limitations for cultivated crops.
The Ferruginous Tropical soils, occuring on moderate and steep slopes have an erosion hazard. If these soils are cultivated, conservation measures such as strip cropping, permanent grassed strips or terraces should be applied to reduce water runoff and soil erosion. In addition, the practice of crop rotations, with a grass-legume component, should be considered. If they are not cultivated these soils should not be overgrazed by livestock.

The "Mineral Hydromorphic Soils" have physical limitations, wetness arising from their heavy soil texture and a poor drainage. Crop damage from waterlogging can occur on these soils. The soils are difficult to till. Presant notes that beans seem to adapt better to these soils than cereal crops like maize or wheat.

The "Eutrophic Brown Soils" on slopes over 5% have erosion limitations of varying severity depending on the steepness of slope. Soils on the moderate slopes between 5 and 9% have, in addition to the erosion hazard, droughtiness or structural limitations.
If these erodible soils are cultivated, erosion control measures ksuch as contoured strip cropping or terraces should be taken. If possible, rotations with long term grass-legume crops should also be planned, so that land on moderate to steep slopes would be broken up for cultivated crops like beans or wheat only once in 4 or 5 years. The sloping land that is not cultivated, should not be overgrazed by livestock. Such land, if exposed by overgrazing or livestock trails, is very susceptible to erosion.

3.2 Soil fertility status

In order to evaluate the actual fertility status of the soils at Laki Laki Estate, 7 composite topsoil samples were taken from a depth of 0-20 cm. Each of these samples is composed of about 10 subsamples from randomly chosen points around the observation site. The sampling sites are indicated in Figure 1.

Three composite topsoil samples were taken in the flat, western part of the Estate (sites 1,2,3), one was taken in the central, hilly part (site 4) and three were collected in the eastern part (sites 5, 6 and 7). In the latter part site 5 was under wheat (slope 5%) and sites 6 and 7 were under coffee (slope 0-1%). Sites 1-5 are all on heavy, cracking clay soils. Site 6 and 7, however, have more loamy topsoil textures.
Table 2 gives the results of the chemical analysis of the composite topsoil samples. The analytical procedures used for the determinations can be found in the Annex.
The data in Table 2 are interpreted according to Table 3.

(a) Soil fertility status of the dark, cracking clay soils (site 1-5):

- The pH of the topsoils is above 7, mainly due to the presence of calcium carbonate. In the flat, low lying western part of the the estate, however, pH values can be found even above 8 (moderately alkaline soil reaction) which is mainly due to high amounts of sodium (compare with the soils at the Umoja and Fil Estate!).
- The organic matter contents (1.72 x %C) are around 2% which is low.
- The C/N ratios range from 8-12, indicating a good quality of the organic matter.
- The total nitrogen content is predominantly low (0.09-0.14%).
- The available phosphorus content is predominantly high: 9-15 ppm P determined by the Olsen method.
- The cation exchange capacity, reflecting the capacity of a soil to retain nutrients, is high: 24-30 meq/100 g soil.
- The levels of all exchangeable bases, i.e. calcium, magnesium, potassium and sodium, are high to very high.

At site 3, a bare area in the flat western part of the estate, the amounts of exchangeable sodium are far too high. This will have an adverse effect on the growth of many crops, especially beans, and also on the physical conditions of the soils. The exchangeable sodium percentage (ESP) is 26%. It will not be possible to grow a good crop on this site. In the rest of the area exchangeable sodium percentages do not present a problem as the ESP remains below 7%.

Soil fertility status of the loamy topsoils under coffee (sites 6,7)

- The pH of the topsoils is 6.8, which is a neutral soil reaction.
- The organic matter contents (1.72 x %C) isconsiderably higher than measured in the cracking topsoils: 3.6-4.5%, which is considered to be of a medium to high level. The quality of this organic matter is good as the C/N ratio is 12-13.
- The total nitrogen content is low to medium (0.18-0.20%).
- The available phosphorus content is of a medium level: 16-18 ppm P as evaluated according to the Bray I method. Note that the data obtained from the Olsen and Bray I methods need to be interpreted in different ways.

Table 2 Chemical characteristics of 7 composite topsoil samples collected at Laki Laki Estate

Soil chemical characteristics	Site 1	2	3	4	5	6	7
pH-H_2O	7.5	7.6	8.2	7.5	7.4	6.8	6.8
pH-KCl	6.0	6.1	6.4	5.9	5.9	5.5	5.5
Organic matter (%)	2.0	1.9	1.9	2.0	2.0	4.5	3.6
total N (%)	0.11	0.11	0.09	0.10	0.14	0.20	0.18
C/N	10	10	12	11	8	13	12
avail. P (ppm)							
Bray I	-	-	-	-	-	16	18
Olsen	15	12	12	9	13	-	-
CEC (meq/100g soil)	29.6	27.4	27.5	23.5	30.3	24.7	28.0
exch. Ca	23.4	22.9	24.5	13.1	21.1	18.7	16.4
exch. Mg	4.8	4.8	5.6	7.9	8.4	3.8	4.5
exch. K	4.6	4.7	3.2	2.5	4.6	8.8	8.3
exch. Na	1.5	1.3	7.2	1.6	0.8	1.1	1.0
Base saturation (%)	100^+	100^+	100^+	100^+	96	100^+	100^+
ESP (%)	5	5	26	7	2	4	4

Table 3. Criteria for soil fertility evaluation as used in this study

Soil chemical characteristics	classes very low	 low	 medium	 high	 very high
organic matter(%)	< 1	1-2.2	2.2-4.3	4.3-6.0	> 6.0
total nitrogen (%)	<0.1	0.1-0.2	0.2-0.5	>0.5	
avail. P (mg/kg)					
Bray I		<7	7-20	>20	
Olsen		<5	5-10	>10	
Cation exchange capacity, CEC (me/100 g soil)	< 6	6-12	12-25	25-40	> 40
Exch. calcium (me/100 g soil)					
- clayey soils	< 2	2-5	5-10	10-20	> 20
- loamy soils	<0.5	0.5-2	2-4	4-6	> 6
Exch. magnesium (meq/100 g soil)	<0.3	0.3-1	1-3	3-6	> 6
Exch. potassium (me/100 g soil)	<0.2	0.2-0.4	0.4-1.2	1.2-2.0	>2.0
Exch. sodium (me/100 g soil)	<0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2.0

(Source: KIT, soil analysis training course, Amsterdam and Bengham, 1973)

Soil reaction classification ($pH-H_2O$)

pH	6.6-7.3	neutral
pH	7.4-7.8	mildly alkaline
Ph	7.9-8.4	moderately alkaline

(Source: agricultural compendium, ILACO, 1981)

- The cation exchange capacity is high: 25-28 meq/100 g soil.
- The levels of all exchangable bases are high to very high. Absolute levels however, are such that imbalances exist between exchangeable potassium and exchangeable magnesium. The amount of potassium is about twice as high as the amount of magnesium. This is not favourable as crops prefer more magnesium than potassium. When the Mg/K ratio is less than 1, as is the case here, magnesium uptake by plants may be restrictied. Application of magnesium may be necessary on these soils, especially if Mg deficiency is observed in the plants, i.e. interveinal chlorosis and necrosis along the leaf-edges.

3.3 Soil physical conditions

Although soil physical conditions, like soil structure and soil moisture retention capacity were not studied, a few remarks can be made.

During the collection of the composite topsoil samples it was observed that a considerable ploughpan has developed in most places, at a depth of 10-15 cm. Due to mechanization, the soil has formed a compacted layer, 15-20 cm thick, below the plough layer with a soil structure which is weaker and coarser and extremely hard when dry.
Plough pans are impeding root penetration to greater depths. Thus, nutrient uptake is limited as is water utilization. Ploughpans also affect soil permeability and the water infiltration rates. Water penetrates less easily into the subsoil and considerable quantities of rain water will disappear as run-off, increasing the risks of rill and gully erosion. Erosion is very severe in the central, hilly part but also at some sites in the flat, western part.
Uncontrolled runoff from the surrounding hills has resulted here in both deposition after flooding, and in rills and gullies which seem to extend with each downpour. In some places in this western area soils are relatively shallow (less than 1 m deep) overlying layers of hardened calcium carbonates and/or volcanic rocks.

The high clay content together with the shrinking and swelling properties of the claytype, present in most parts of the Estate, result in a very limited accessibility to the lands during the growing season.
When the soil is too dry the soil material is too hard and it is impossible to cultivate the soil properly. When the soil material is too wet, heavy machinery cannot enter the fields. This means that tillage of the dark-coloured cracking soils has to be conducted in a relatively short period.

Considering the soil water availability it is supposed that the loamy soils have a higher available water content than the cracking clay soils. The latter contain most probably more water but less is available for the plants: the remaining water is held in very small pores and can not be released through suction by the plant roots.

4 LAND SUITABILITY AND LIMITING FACTORS FOR THE CULTIVATION OF SEEDBEANS

4.1 Introduction

In this chapter, the environmental data presented in the previous sections are interpreted in terms of the physical suitability of the recognized parts of the Estate for the cultivation of seedbeans, The limiting factors affecting the suitability are assessed.

The approach adopted follows the Framework for Land Evaluation (FAO, 1976). First the diagnostic environmental requirements of beans are presented (similar to those presented in reports D9-D12). These requirements are then compared with the existing environmental conditions at the farms, resulting in a suitability assessment.
It is assumed the crops are cultivated at a large scale farm level where the use of farm machinery and proper soil and crop management practices, including the use of moderate amount of fertilizers, are part of the normal farm operations.

4.2 Envieonmental requirements of seedbeans

Beans (*Phaseolus vulgaris*) grow well in areas with 300-380 mm of rainfall over a 10-week growing period followed by 4 weeks of dry, cool weather. During the ripening stage dry weather is preferred to avoid the occurrence of fungus diseases and to ease harvesting. The rain has to be well distributed over the growing season.
For optimum growth average temperatures of between 16-24°C are required and the beans are grown best under decreasing temperature conditions. Growth stops at temperatures below 10°C. A temperature of 30°C appears to be the upper limit for successful cultivation; above this temperature blossom-drop is very serious (source: Kay, 1979).
Hot dry winds during flowering can cause severe blossom-drop as well, resulting in lower yields and non-uniform ripening of the seed.

The crop prefers freely drained, well structured deep soils. The optimum pH for seedbeans is between 6.0 and 6.8; pH values of as low as 5.2 and as high as 7.0 are tolerated.
Little is known about specific nutrient requirements of seedbeans. Being a leguminous crop, beans are capable of fixing nitrogen and apart from a starter dose, the nitrogen requirements are low. The phosphorus and potassium requirements are moderate. The crop has a relatively high zinc requirement. Zinc deficiency, resulting in poor pod-set, may occur on calcareous soils with pH values above 7. The crop is very sensitive to soil salinity.
Seedbeans are also considered not to be very tolerant to high amounts of sodium in the soil. According to Landon (1984), beans are sensitive to Exchangable Sodium Percentages (ESP values) as low as 10 tp 20 already. It is reported that yield reductions of 50% may occur at ESP values of below 15.

4.3 Suitability of the Laki Laki lands for seedbeans

The climatological requirements for seedbeans are met at Laki Laki Estate. The amount of rainfall during the growing season is favourable and temperatures are optimal. The optimal planting date for beans would be around March 1st. Then the soil would contain enough available moisture, cracks would be closed and dry and cool weather during harvesting is most probable.

Soil and terrain factors, however, do limit the present physical suitability of the lands of Laki Laki Estate :

In the flat, western part actual physical soil conditions are not very favourable: (1) The soils are heavy cracking clays which have to be cultivated in a relatively short period: outside this period the soil is too dry or too wet.

(2) A compact ploughpan has developed at a depth of about 10-15 cm from the surface, probably due to the continuous cultivation of crops during long period. This ploughpan hampers rooting and the infiltration of rainwater to greater depths.

(3) Due to the lack of erosion control measures in the surrounding bare area, on and off the Estate, floods occur regularly in the rainy season. Local depressions may be waterlogged for some days, seeds or plants can be swept away while deposition at other sites may restrict further crop development. In some parts the soils can rather shallow due to erosion, i.e. close to gullies.
Also chemically these soils are not optimal :

- the pH of the soils is too high for beans which may result, f.e., in zinc deficiency
- the low organic matter levels indicate a low availability of nitrogen
- in places the high sodium contents will seriously hamper crop growth.

Conclusion: The flat, western area is presently marginally suitable for the cultivation of seedbeans.

In the central, hilly part of the Estate steep slopes are the major limitation for the cultivation of seedbeans. Severe soil erosion is a very common phenomenon on these cultivated volcanic soils, even on very gentle slopes. As slopes in the central part of the Estate are all over 5%, satisfactory cultivation is not possible without expensive erosion control measures, like the construction of terraces.
In some places severe erosion has already resulted in deep gullies and badlands which can never be used again for agriculture.

The soil physical limitations of these soils are similar to those of the ones described above: a limited accessibility and the presence of a ploughpan on sites which have been cultivated in the past.
Again: the ploughpan hampers rooting, and penetration of rainfall and favours runoff and therefore erosion.

The limiting soil chemical characteristics for the cultivation of beans are again a high pH and low organic matter contents.

Conclusion: The central, hilly part is in generally marginally suitable for the cultivation of beans. The steepest parts are unsuitable.

In the eastern part of the Estate, 2 main soil types are found, each at present under a characteristic crop.

- dark coloured, cracking soils under wheat, and
- light coloured, non-cracking loamy soils under coffee.

Chemical and physical soil properties are different, leading to a different suitability.

The cracking clay soils are more or less similar to those found in the western part. Similar limiting characteristics like limited accessibility, the presence of a ploughpan, a high pH and low organic matter contents are valid. Although in places slopes are steeper than those in the western part, less soil erosion has been observed. Contour-ridges have controlled erosion quite effectively in the past.

The loamy soils under coffee do not have severe limiting physical conditions. The chemical properties are also more favourable: the pH is within the optimal range for seedbeans and organic matter contents are much higher. The only limiting factor could be a magnesium deficiency induced by the very high contents of exchangeable potassium.

Conclusion: The eastern part is most suitable for the cultivation of seedbeans. The cracking clay soils are on general moderately suitable as slopes are more gentle and no high sodium contents are found while the loamy soils under coffee are highly suitable.

5. SOIL, WATER AND CROP MANAGEMENT REQUIREMENTS

5.1 Soil and water conservation management

Although volcanic soils are in principal very permeable and infiltration rates are high, not all of the rainwater penetrates the soil. A considerable part is lost as run-off, largely due to the presence of a ploughpan. Excess run-off brings about rill and gully erosion, especially in the steepest central part of the Estate and at some sites in the western part.

1. The most important practice is to avoid the formation of ploughpans and the breaking up of ploughpans already formed. This is discussed in section 5.2.

2. Ridging

   This is done by constructing earthen banks.

- contour ridges, constructed along the contour on very gentle slopes (1-2%), are intended particularly to hold the water so that it infiltrates the soil. This practice is required for the western area and the flattest part in the eastern part of the Estate. A system of rotational cropping, viz. beans and wheat or barley, can be added to increase the effectiveness of this erosion control measure.
- graded ridges have to be constructed, with associated channels immediately above them, on steeper slopes i.e. in the whole eastern part and locally in the central part of the Estate. The graded ridges are meant for conveying the run-off water slowly across the land for discharge through suitable outlets. The ridges must run at a slight gradient to the contour, the gradient increasing a bit in the direction of the outlet.

All banks should be given a permanent protective cover of stoloniferous grasses or cover crops. The distance between the ridges and their dimensions depend on the slope characteristics and must be carefully determined.

It is recommended to seek advice from erosion control specialists. The outlets, natural drainage ways or constructed grassed waterways (see report D10) must be chosen and designed in such a way that the disposal of the accumulated water does not cause erosion on adjacent land.

5.2 Soil tillage practices

As mentioned already in earlier paragraphs, most soils at Laki Laki Estate have a well developed ploughpan. Ploughpans restrict water infiltration and increase run-off and erosion. They also hinder the formation of deep and optimal rooting systems and thus increase drought-stress.
Ploughpan formation is particular due to the use of disc-ploughs and tillage practices during periods when the soils are too moist (making the soil just below the plough too smeary). Ploughpan formation can be prevented by :

- the use of the mould-board plough and ploughing at variable depths
- chiseling; chisels are also used to break up existing ploughpans (to be used just before the rains)
- limiting the number of passings with heavy machinery

Ploughing with the mould-board and chiseling have as extra advantages that excessive breakdown of soil aggregates is avoided. Although fine and homogeneous seedbeds are preferred to have uniform crop stands which eases harvesting, the advantages of a very fine seedbed are off-set by the disadvantages of ploughpans, run-off erosion and less available water.

5.3 Crop management

Stubble mulching or trash farming

It is recommended to practice stubble mulching which consists in leaving crop residues and weeds as a protective cover on the soil surface. It is carried out by working the land after harvest to a depth of 5-7 cm, using a special plough or cultivator that cuts the plant root and leaves the stubble and weeds on the surface.
It is even better to partially incorporate the stubble by using the one-way disc, i.e. trash farming. It gives the soil an open structure and a good drainage.

Rotations

It is essential to stick to a strict rotation scheme, rotating the strips of beans and wheat or barley every growing season. In this way, the practice of stubble mulching or trash farming can easily be fit into the system.

The introduction of a short growing green manure crop in the period November to January is recommended. Crotolaria juncea may be an appropriate crop. It is ahardy and drought resistant crop and it is known to be grown in rotation with beans and cereals. Its seed has to be broadcast as dense as possible. When ploughed in, it requires a relatively short time to decay. The best time for ploughing in the sunnhemp is at about 1½-2 months after planting to reach the maximum effect.
Soil erosion (run-off) will be restricted to a large extent, which is especially important in the short growing season as normally a large part of the land is bare. Moreover, the crop will add to the organic matter and nitrogen contents of the soils.
Another advantage is the fact that sunnhemp will severely restrict weed growth in the short growing season.

5.4 Soil fertility management

Except for the sodic soils in the western part of Laki Laki Estate it can be said that the fertility status of the soils is generally good.

The only chemical soil properties which need attention are :

- the organic matter and total nitrogen levels in the dark-coloured cracking clay soils

- the availability of magnesium to the plants which is most probably restricted by the very high exchangeable potassium contents in the loamy topsoils under coffee.

Although the nitrogen requirement of beans is not very high, the low total nitrogen levels may limit optimal yields on the cracking clay soils. Simple comparative trials with nitrogen fertilizers may confirm this. In the case of proven nitrogen deficiencies, low rates of nitrogen fertilizers are recommended at planting.

Soil- and water-conservation practices, as described in the previous section 5.1 may also assist to prevent a further decline of the organic matter and total nitrogen contents or even assist to increase these levels slightly.
The practice of stubble mulching or trash farming could also lead to a possible increase of the organic matter content (see 5.3). Alternatively the cultivation and incorporation of green manure crops may have a beneficial effect on crop yields (see 5.3) and may help to increase ~~the~~ organic matter and total nitrogen levels.

If magnesium deficiency symptoms occur as described in section 3.2, application of magnesium fertilizers is necessary to arrest this situation.
On neutral soils kieserite ($MgSO_4 . H_2O$) is recommended as it doesnot increase the pH Spraying with magnesium salts can also be affective. Spraying has the advantage that less fertilizer is needed but the disadvantage that it has to be repeated in each growing period.

Presently, the levels of available phosphorus are medium to high all over the Estate. In the future, however, the amount of this important plant nutrient will probably decrease. Regular soil testing can indicate the moment when application of TSP phosphate fertilizer is necessary.

On the cracking clay soils zinc deficiency may occur as pH values are high. Foliar analyses can indicate the severity of the possible deficiency.

REFERENCES

Acland, J.D. 1971, East African Crops, Longman, London.

Directorate of Overseas Surveys, Topographical map, Sheet 55/3 on scale 1:50,000

E.A. Meteorological Department, 1975, Climatological statistics for East Africa, Part III, Nairobi.

FAO, 1977, Guidelines for soil profile description, Rome.

FAO, 1979, Yield responses to water, FAO irrigation and drainage paper 33, Rome.

Kay, Daisy E., 1979, Food Legumes, Crop and Production Digest no. 3, Tropical Products Institute, London.

Landon, J.R., 1984, Booker Tropical Soil Manual, Longman, New York.

Munsell Color, 1975, Soil Color Charts, Baltimore.

National Soil Service, 1987, Laboratory procedures for routine soil analysis (second edition), Report M7, TARO, Mlingano, Tanga - Tanzania.

National Soil Service, 1986, Soils and their productivity and management at Namuai Estates, West Kilimanjaro, Report S2, TARO Mlingano Tanga, Tanzania.

National Soil Service, 1987, Soils of the Naberera Farms, their suitability and management requirements for the cultivation of seedbeans wheat and barley. Report D9, TARO Mlingano Tanga, Tanzania.

National Soil Service, 1987, Soils of the Simba Farms, their suitability and management requirements for the cultivation of seedbeans, wheat and barley, Report D10, TARO Mlingano, Tanga Tanzania

National Soil Service, 1987, Soils of the Lolkisale Farms, their suitability and management requirements for the cultivation of seedbeans, wheat and barley, Report D11, TARO Mlingano, Tanga - Tanzania.

National Soil Service, 1988, Soils of Umoja and Fil Estates and their suitability for seedbeans, Report D12, TARO Mlingano, Tanga, Tanzania

Presant, E.W. 1973, Report on the soils of selected areas near Arusha and Monduli, Tanzania for the agronomic Research Project (wheat) sponsored by CIDA.

Purseglove, J.W., 1984, Tropical Crops, Dicotyledons, Longman.

Purseglove, J.W., 1985, Tropical Crops, Monocotyledons, Longman.

Soil Survey Staff, 1975, Soil Taxonomy- Agriculture Handbook no. 436, Soil Conservation Service, US Department of Agriculture, Washington.

NATIONAL SOIL SERVICE

These reports are available from the National Soil Service

P.O. Box 5088, Tanga or Private Bag, Ngomeni