SOILS OF UMOJA AND FIL ESTATES
(ARUMERU DISTRICT, ARUSHA REGION)
AND THEIR SUITABILITY FOR SEEDBEANS

Prepared for Rotian Seed Company Ltd

NATIONAL SOIL SERVICE
TARO-AGRICULTURAL RESEARCH INSTITUTE, MLINGANO
TANGA-TANZANIA

12

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Semi-detailed Report D12 1988

The National Soil Service does not accept responsibility for any damage or loss resulting from the use of the results of this study or from the application of its recommendations.

The conclusions and recommendations given in this report are those considered appropriate at the time of its preparation. They may be modified and/or adjusted in the light of further knowledge gained through additional research.

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In back cover : - soil map
- location of observations map.

Summary

1. At the request of Rotian Seed Company Ltd., the National Soil Service conducted a study of the soil conditions at Umoja and part of Fil Sisal Estates.
The area has a total extent of about 1500 ha and is located in Arumeru District, Arusha Region.
The main crop grown presently is sisal. Plans are made to use the area for the cultivation of seedbeans, part of it under irrigation.

2. The area is located in a large, almost flat, sedimentary plain, in which alluvial volcanic sediments have been deposited. The altitude of the area is just below 1000 m.

3. The climate is semi-arid. The few available rainfall data give an average annual rainfall of 410 mm of which about 250 mm in the main growing season. The rainfall can be very erratic however. The risks of serious moisture deficiency and thus of crop failures, are considerable.

4. The distribution of the soil types is presented on a 1:25,000 soil map. The soils are mainly developed in unconsolidated sediments of volcanic origin. The soils vary in texture from sandy (unit Ss) to loamy (unit Sl) and loamy to clayey (unit Scl). Most profiles show a clear stratification.

5. In general, soil structures are unfavourable, being very weakly developed.

6. The soil fertility is of medium to high level and well related to the material in which the soils are formed.

The highly alkaline soil reaction of some soils can give rise to deficiency of some nutrients (e.g. zinc).

The organic matter levels in the upper 20 cm are medium in all soils.

The total nitrogen contents are very low to low.

The available phosphorus content is very high in the relatively heavy textured topsoils of mapping unit Slc. In the other soils the available phosphorus contents are of a medium to sometimes low level.

The cation exchange capacities vary from medium (in the sandy soils) to high and very high (in resp. the loamy and clayey soils of units Sl and Scl). The levels of all exchangeable bases are high to very high in all soils. Severe imbalances exist however between the bases. The high potassium contents may induce magnesium deficiencies. The high to very high sodium contents in the subsoils will adversely affect the growth of many crops.

7. Soil moisture retention capacities are high, but crops can not make optimal use of this as sodicity limits rooting depth.

8. The water of the river Temi is of a medium saline and low sodium quality. This implies that using this water for irrigation of seed-beans is very risky as beans are very sensitive to salinity and rather sensitive to sodicity. The fact that sodium levels in the soils are quite high already, adds only to the risk.

9. Suitability assessment shows that the soils of mapping unit Slc (210 ha) are the only ones that are moderately suitable for the cultivat-ion of seedbeans under irrigation. This practice however is still rather risky. If no measures are taken the question is how soon the soil will salinize and sodicity become more severe, not whether!

10. If Rotian Seed Company still decides to grow irrigated seedbeans in the area, special management measures will have to taken.

- The construction of a water basin has to be taken into consideration to collect water during the rainy period, when the concentration of salts and sodium is lowest.
- Regular monitoring, after each crop, of the salinity and alkalinity levels in the soil is necessary.
- In order to avoid magnesium deficiencies, small amounts of a magnesium fertilizer should be applied.
- Small gifts of nitrogen might be favourable to the bean crop as well.
- Zinc fertilizer will have to be given to avoid poor pod-set of the beans.

1 INTRODUCTION

At the request of Rotian Seed Company Ltd., the National Soil Service carried out a study of the soil conditions at Umoja Estate and part of Fil Estate. The Rotian Seed Company is planning to use the lands of these old sisal estates for the cultivation of seedbeans. Parts of the area (200 ha) are planned to be irrigated and 2 ha should be used for plant breeding.

The purpose of the study was to evaluate the suitability of the area for the cultivation of seedbeans, both rainfed and irrigated, and to advice on appropriate management requirements which maintain or improve soil productivity and which avoid soil degradation.
In order to meet these objectives, the soils of the farms were studied and mapped and their physical and chemical properties determined.

The study area, with a total extent of about 1500 ha, is located approximately 35 km south-east of Arusha, along the river Temi, in Arumeru District, Arusha Region (see Fig. 1).
Presently most of the area is still under sisal.

The study took place in April 1987 and was carried out by a team consisting of two survey parties: Messrs. F. van der Wal, J.D.J. Mbogoni and R.K. Kimaro in one, and Messrs. A.J.M. Brom, P.H. Silayo and N.R. Lesika in the other.

The report and the map were prepared by Messrs. A.J.M. Brom, F. van der Wal, J.D.J. Mbogoni and P.H. Silayo, of whom the first two had the final responsibility.
Soil samples collected were analysed in the Central Laboratory of the National Soil Service at Mlingano.

The National Soil Service acknowledges the kind assistance and hospitality offered by the management of Rotian Seed Company.

2 THE ENVIRONMENT

2.1 General description of the study area

The study area is located at the northern edge of the Masai Steppe at the eastern bank of the river Temi, about 35 km south east of Arusha at an altitude ranging from 945 to 975 m. The blocks of Umoja Estate are bordered by blocks of Fil and Lucy Sisal Estates.
The topography of the surveyed blocks is shown in Fig. 2.
The extent of the Umoja Estate is 957 ha (2360 acres) of which at least two-third is still under sisal. The remaining part is cleared land or planted with fruit trees (bananas, citrus, date palms a.o.).
The studied part of Fil Estate has a total extent of about 550 ha (1360 acres).

The sisal has been neglected during the past years. Trees and shrubs have infested the area and make accessibility difficult. Some parts have been burned. Nowadays the area is mainly used for extensive grazing.

The river Temi originating from Mt. Meru, has water thoughout the year. In every rainy season, i.e. mostly in April, its water floods part of the study area which then remains inundated for some days.

2.2 Climate

Nearly no meteorological data are available of the area in which the Umoja and Fil Farms are located. The only data available are the total annual rainfall figures recorded from 1954 to 1962 at Umoja Farm (pers. comm.); the data of 1957 and 1959 are missing. Monthly rainfall data are only known of 1982 and 1984.

The mean annual rainfall during the period 1954-1962 (7 years) was 410 mm, which implies that the area can be classified as semi-arid. The highest amount recorded was 568 mm and the lowest 258 mm. The monthly data over 1982 and 1984 are given in the table 1 as to give a rough idea of the rainfall distribution.

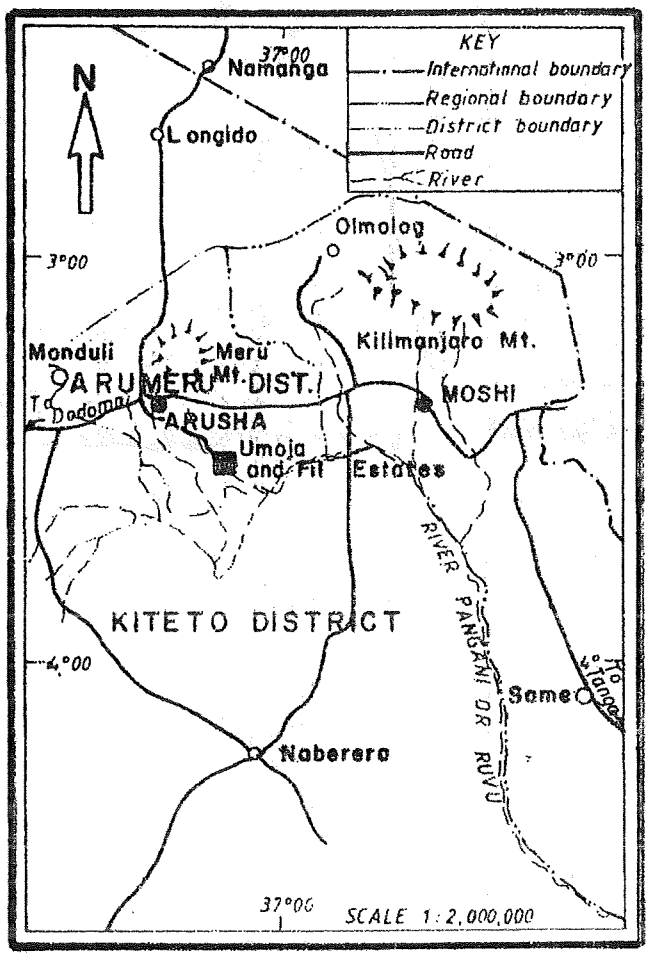
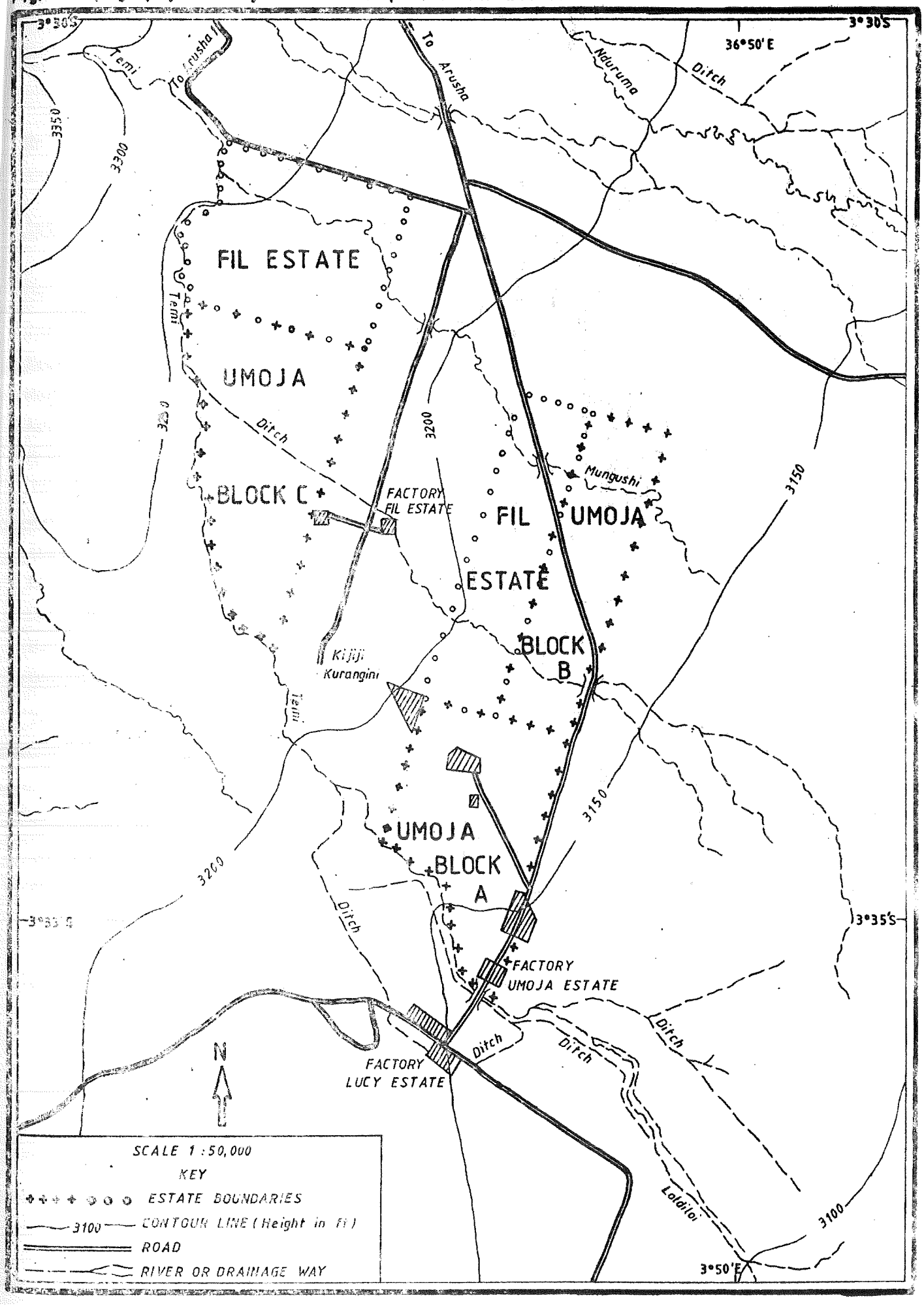


Fig.1. Location of the Umoja and Fil Estates

Fig. 2. Topography of Umoja Estate and part of Fil Estate



No data from representative, neighbouring meteorological stations are available to confirm these figures.

Table 1. Monthly rainfall data recorded at Umoja Farm (mm)

Month	1982	1984
January	1	40
February	16	7
March	126	104
April	48	223
May	77	30
June	25	9
July	5	0
August	0	0
September	25	0
October	80	0
November	0	53
December	0	86
Total	403	552

(Source: Umoja Farm Office)

The total annual rainfall data recorded in 1982 and 1984 fit within the range recorded during the period 1954-1962. The rainfall distribution is not very consistent. The main rainy season appears to be in the months March to May; two-third of the annual rainfall is recorded in this period.

Temperature is not recorded at Umoja Farm. Through extrapolation the mean annual temperatures are estimated to be about 23°C. The mean maximum temperatures will be around 28-30°C (According to the Agro-climatic Zones Map of Kenya, 1983).

2.3 Physiography and Geology

The study area is located in a large flat to nearly flat sedimentary or outwash plain (slopes 0-1%), in which unconsolidated, volcanic sediments have been deposited. The sediments, originating from Mt. Meru, are most probably transported by water as the soils are stratified and as rounded basaltic pebbles are found.

Various floods of the river Temi and other streams have transported and deposited volcanic ashes with different textures.

Immediately north of the study area the landscape is undulating. There, no sedimentation has taken place but erosion and basaltic volcanic rocks are exposed at the surface.

3 SOILS

3.1 Previous work

No detailed information on the soils of the study area is available. The most recent soil data are from the 1:2,000,000 Soils and Physiography Map made by De Pauw (1984). According to this map the area is located in :

> "flat to undulating plains developed on volcanic ashes and sediments. The soils are mainly well drained, shallow to deep dark brown or dark gray calcareous sandy loams and loams, with weak structure and profile development. The soils have a good natural fertility (15-25% clay, pH topsoil 6.5-6.8, pH subsoil 7-9, 1-3% organic carbon, total exchangeable bases 20-40 meq/100 gr soil, base saturation 80-100%) and moderate moisture storing capacities (50-100 mm/m).
>
> In depressions, deep, dark, cracking clays occur. Those soils are moderately well to imperfectly drained, usually calcareous, black, dark gray or brown overlying paler subsoils. The natural fertility is good. Subsoils often have a high exchangeable sodium percentage. Moreover, there are inclusions of well drained, deep, dark gray or brown loamy soils, rich in allophanic clays with weak structure and profile development, low bulk densities and with a high natural fertility and favourable moisture storage properties."

3.2 Study methods

Relevant literature on the soils of the study area (see 3.1, previous work), information about topography (1:50,000 toposheet, no. 71/2, Directorate of Overseas Surveys, 1964) and aerial photographs (approximately 1:70,000 scale, 1982, D.O.S. constract 201, Film TN2, frames 013-017 and 084-087) were consulted preceding the fieldwork. The quality of the photographs was rather poor due to the high percentage of cloud cover.

In the field, augerhole and soil pit observations were made at carefully selected sites. Special attention was paid to the areas which possibly are to be irrigated or to be used for breeding purposes.

Field work included the description of 27 augerholes to a depth of about 1.50 m and 5 soil profile pits, approximately 1.80 m deep. The soils have been described according to the guidelines for soil profile descriptions of the FAO (FAO, 1977). Soil classification (see Annex 3) conforms to the legend of the FAO/Unesco Soil Map of the World (1974) and Soil Taxonomy (Soil Survey Staff, 1975). Soil colours were described according to the Munsell Colour Chart (1975). Soil samples (bulk samples and undisturbed core samples) for chemical and physical analyses were taken from the major soil horizons identified and described in the soil pits. Composite samples of the first 20 cm were collected at 15 selected sites. Each composite topsoil sample is composed of about 15 subsamples from randomly chosen spots around the selected side.
The aerial photographs were used to mark the location of all observations and sampling sites.
Some water samples have been taken as well, to evaluate the quality of the irrigation water.

All soil and water samples were analysed according to the internationally accepted methods which are used in the National Soil Service laboratory (for details on these methods, see annex 1).

Both the 1:50,000 topographical sheet and the aerial photographs (approximate scale 1:70,000) have been used to compile a 1:25,000 base map for the presented soil and locations maps: The toposheet was enlarged to a 1:25,000 scale with the help of an optical pantograph and more detailed information was obtained from the aerial photographs.

3.3 Soil map and legend

The soil map is presented at scale of 1:25,000 (Annex 4). A brief description of the mapping units is given in the legend of the map; a complete description is presented in section 3.4.

The main differentiating criterion in the legend of the soil map is the nature of the parent material.

S Nearly the whole study area is part of a sedimentary plain with unconsolidated Sediments of volcanic origin.

R Only in the north-western corner of the area no sediments are being found. Here, the soils are developed in the weathering products of volcanic Rock.

The second criterion for subdivision is the texture of the soils.

s sandy (or: ashy) sediments are found in the north-western part of the study area along the river Temi and along some minor drainage ways.

l loamy (or: medial) textured sediments; mainly they are found at some distance from the river Temi.

lc loamy to clayey sediments are found in the most southern part of the Umoja Estate, along the river Temi.

The soils in the study area are invariably very deep and well drained.

Each mapping unit is described in terms of morphological, chemical and physical characteristics.

3.4 Description of the Mapping Units

The following data have been used to describe the mapping units:

- augerhole observations
- soil profile descriptions (see Annex 3)
- analytical data of the described soil profiles (see Annex 3)
- analytical data of the composite topsoil samples (0-20 cm) (Annex 2).

The soil chemical data are summarized per mapping unit in Table 2 and interpreted according to Table 3.

Mapping unit Ss

Setting: Unit Ss is situated along the river Temi and along some other drainage ways in the north western blocks of the Umoja and Fil Estates. The area is flat to almost flat (0-1%) and is part of a sedimentary plain in which volcanic material, originating from Mt. Meru is deposited after being transported by water. The soils of this unit are developed in relatively coarse volcanic ashes. Unit Ss covers 340 ha.

General soil properties: The soils are very deep and well to somewhat excessively drained. Profiles are stratified and have predominantly a sandy texture. In the deeper subsoil layers with pebbles (rounded stones of volcanic origin) may occur.
The topsoil is mostly dark grayish brown and the subsoil is dark gray. In places the subsoil material is calcareous. At a depth of 15-25 cm the soil is sodic already which implicates that hardly any roots are found at greater depths.
The soil fertility is of medium level but imbalances between the exchangeable bases and sodicity are factors which are limiting growth.

Topsoil characteristics: The topsoils are dark grayish brown and have a sandy (or: ashy) texture. The structure is very weakly developed and consists of fine and medium subangular blocks with many single grains. The soil material is loose to very friable when moist, and loose when dry.
The pH of the topsoil (0-20 cm) ranges from 7.4-8.1. The organic matter content ranges from 1.9 to 3.1%. The available phosphorus content varies between 5 and 10 mg/kg. The cation exchange capacity is 10-20 meq/100 gr soil.

Subsoil characteristics: The sandy, stratified subsoils are mostly dark gray and nearly structureless: single grains and in places even massive (cemented). The deeper subsoils may have a somewhat heavier (loamy) texture.
In places the subsoil is calcareous.
The pH of the subsoil ranges from 7.6 to 8.1. More loamy layers have a higher pH (9.0-9.4). The amount of organic matter decreases regularly with depth. Deeper than 25 cm the organic matter content is less than 1.4%; at a depth of 100 cm the organic matter content is around 0.7%. The available phosphorus content of the sandy subsoil is less than 4 mg/kg. The cation exchange capacity is 11-18 meq/100 gr soil. The exchangeable sodium percentage in the sandy layers is ranging from 19-27%. In the more loamy layers this percentage can be even 33-36%.

Fertility aspects: The organic matter level in the topsoil is in general of medium level, rapidly decreasing with depth to low and very low. C/N ratios are around 16-17 which is rather high and not very favourable. The soil reaction of the sandy layers, which are dominant in the profiles, is mildly to moderately alkaline. More loamy layers in the subsoil have a very strongly alkaline reaction.
The available phosphorus content is medium in the topsoil and low in the subsoil.
The capacity to retain nutrients (CEC) is mainly medium in the whole profile.
The level of exchangeable calcium is nearly always very high in the topsoil; in the subsoil the levels vary from medium to very high.
The content of exchangeable magnesium varies from high to very high in the topsoil. The magnesium contents in the subsoil are somewhat

lower, but still of a high level .
The amount of exchangeable potassium is very high throughout the whole profile.
The Mg/K ratio ranges in value from 0.5 to 1.8 in the topsoils and from 0.3 to 0.9 in the subsoils, which is very unfavourable. Although the magnesium content is high (absolutely), not much of the magnesium will be available to the plant as the very high potassium saturations will inhibit this.
The amount of sodium in the topsoils is high, and very high in the subsoils. The exchangeable sodium percentage (ESP) is high and the growth of most crops is severely limited.

Mapping unit S1

Setting: Unit S1 covers most of the surveyed area, and is found at some distance from the river Temi. The area is flat to almost flat (0-1%) and is part of a sedimentary plain in which volcanic material, originating from Mt. Meru, is deposited after being transported by water. The soils of this unit are developed in loamy (or: medial) volcanic sediments.
Unit S1 covers 930 ha.

General soil properties: The soils of this unit are very deep and well drained. They are stratified and they have predominantly a loamy texture. In places the subsoil material is calcareous. In the deeper subsoil layers with pebbles (rounded stones of volcanic origin) may occur.
The topsoil is mostly dark grayish brown to brown in colour and overlies a pale brown to brown subsoil. The subsoil may be sodic from a depth of 40 cm onwards.
The soil fertility is of medium to high level but imbalances between the exchangeable bases and sodicity are limiting plant growth.

Topsoil characteristics: The topsoils are mainly dark grayish brown to brown and have a loamy texture (or:medial). The structure is only very weakly developed and consists of medium subangular blocks and granules. The soil material is very friable to friable when moist, and loose to soft when dry.
The pH of the topsoil is ranging from 7.1 to 8.0. The organic matter content is 1.9-4.0%. Available phosphorus contents vary between 3 and 16 mg/kg. The cation exchange capacity of the topsoil is 20-44 meq/100 gr soil.

Subsoil characteristics: The stratified subsoil has predominantly a loamy texture, varying from sandy loam to silty loam and clay loam. The colour is mainly pale brown to brown. In places the subsoil is calcareous. The deeper subsoil may have a lighter, sandy texture.

The structure of the subsoil is only very weakly developed, consisting of medium and fine subangular blocks and single grains.
The pH of the subsoil increases regularly with depth: at a depth of about 100 cm the pH is 8.6-9.2. The organic matter at this depth varies from 0.3 to 1.2%. The available phosphorus content decreases rapidly with depth; the values vary from 1 to 4 mg/kg. The cation exchange capacity is very variable and depends largely on the texture of the concerning layer. CEC values range from 25 to 69 meq/100 gr soil. The exchangeable sodium percentage is apparently depending on the clay content: in the loam and silty loam layers the ESP varies from 16-30% whereas in sandy loam layers the ESP is below 16%.

Fertility aspects: The organic matter level in general is medium in the topsoils and low to very low in the subsoils. C/N ratios vary from 10 to 19; most values are between 15 and 17.
The soil reaction is neutral to moderately alkaline in the topsoil and strongly to very strongly alkaline at a depth of 100 cm.
The available phosphorus content is mostly low or medium but in places it can be high.
The capacity to retain nutrients (CEC) is mostly high to very high in the whole profile. Sometimes the level is medium in the topsoil.
The levels of exchangeable calcium and potassium are very high within the whole profile. The content of exchangeable magnesium varies considerably, but they are all high and very high. The magnesium/potassium ratio ranges from 0.3-1.8 in the topsoil and from 0.3-0.9 in the subsoil, which is unfavourably low.
It implicates a likely potassium-induced magnesium deficiency.
The sodium contents in the topsoils are high to very high. In the subsoil the content increases enormously. The exchangeable sodium percentage (ESP) is high in the loamy layers and is of moderate level in the sandy layers.

Mapping unit S1c

Setting: Unit S1c is found only in Block A of the Umoja Estate, along the river Temi. The area is flat to almost flat (0-1%) and is part of a sedimentary plain in which volcanic material, originating from Mt. Meru, is deposited after being transported by water. The soils of this unit are developed in loamy to clayey volcanic sediments.
Unit S1c covers approximately 210 ha.

General soil properties: The soils of this unit are very deep and well drained. The texture of these stratified soils is dominantly loamy to clayey. In the subsoil sandy layers may occur. The topsoil is very dark grayish brown to brown and overlies a dark brown to brown coloured subsoil.
The subsoil is slightly sodic and not saline.
Presently, many fruittrees are grown on these soil.
The soil fertility is high but imbalances between the exchangeable bases do exist.

Topsoil characteristics: The topsoils are mainly very dark grayish brown to brown and have a loamy to clayey texture.
The structure is moderately strong developed and consists of medium subangular blocks. The soil material is friable when moist and slightly hard when dry.
The pH of the topsoil ranges between 7.9 and 8.2. The organic matter content is 3.0-4.2%, and the available phosphorus content varies from 23 to 33 mg/kg. The cation exchange capacity is 38-46 meq/100 g soil.

Subsoil characteristics: The stratified, dark brown to brown subsoil has mainly a loamy to clayey texture although lighter textured layers may occur. The structure in the loamy to clayey layers is moderately well developed and consists of medium and coarse subangular blocks. The material is mostly friable when moist and slightly hard when dry. The subsoils are not calcareous.
The obtained data show a pH of around 8.0, an organic matter content of around 2.5% at a depth of 45 cm decreasing to around 0.7% at a depth of 70 cm. The phosphorus content decreases rapidly with depth as well: 8 mg/kg at 45 cm and 3 mg/kg at 70 cm. The cation exchange capacity is 30-49 meq/100 g soil. The exchangeable sodium percentage is 6-12% in the relatively heavy textured material and 3-7% in the sandy layers.

Fertility aspects: The organic matter level in the topsoil is medium The C/N ratio is 11-12, indicating a good quality of the organic matter.
The soil reaction is moderately alkaline.
The available phosphorus content is high in the topsoils and medium to low in the subsoil.
The capacity to retain nutrients (CEC) is high to very high in the whole profile.
The levels of all exchangeable bases are high. The magnesium/potassium ratio (Mg/K) is about 1.5 which is below optimal. It implicates that magnesium deficiency may occur due to the high level of exchangeable potassium.
The exchangeable sodium percentage (ESP) is less than 16% and therefore of moderate level.

Mapping unit R

Setting: Unit R is only found in a block of Fil Estate which is situated north of block C of Umoja Estate. The unit is located in a depression along a tributary intermittent stream of the river Temi.
The soils are developed in the weathering products of volcanic rock originating from Mt. Meru.
Unit R covers an area of approximately 20 ha only .

General soil properties: The soils are very deep and well drained and have a clayey texture. The dominant colours are dark reddish brown and dark brown. In places the soils are stony: gravel, stones and boulders of volcanic origin are found on the surface.
No further soil morphological data and soil chemical data have been collected.

Table 2. Summary of the soil analytical data per mapping unit

soil chemical characteristics	Mapping units					
	Ss		Sl		Slc	
	topsoil	subsoil	topsoil	subsoil	topsoil	subsoil
Organic matter (%)	1.9-3.1	<1.4	1.9-4.0	<1.2	3.0-4.2	<2.5
Total nitrogen (%)	0.07-0.09	-	0.08-0.15	-	0.14-0.20	-
pH	7.4-8.1	7.6-8.1 9.0-9.4	7.1-8.0	8.6-9.2	7.9-8.2	± 8.0
Avail.phosphorus (mg/kg)	5-10	<4	3-16	1-4	23-33	3-8
CEC (meq/100 g soil)	10-20	11-18	20-44	25-69	38-46	30-49
Exch. calcium (me/100 g soil)	5.6-11.6	3.7-8.0	10.1-16.4	11.0-24.0	18.0-22.4	22.6-23.7
Exch. magnesium (meq/100 g soil)	1.6-8.3	0.8-2.0	2.8-10.0	2.4-7.7	5.6-8.7	8.3-9.3
Exch. potassium (meq/100 g soil)	1.8-5.0	2.2-5.5	5.5-10.6	5.8-9.6	5.5-8.4	3.5-7.9
Exch. sodium (meq/100 g soil)	0.8-1.4	2.9-5.7	1.0-3.3	3.0-15.3	2.0-3.6	2.6-5.2

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. phosphorus Olsen (mg/kg)		<5	5-10	>10	
Cation Exchange Capacity (meq/100 g soil)	<6	6-12	12-25	25-40	>40
Exch. calcium (meq/100 g soil)	<0.5	0.5-2	2-4	4-6	>6
Exch. magnesium (meq/100 g soil)					
- sandy soils	<0.2	0.2-0.5	0.5-1.0	1.0-2.0	>2.0
- loamy soils	<0.25	0.25-0.75	0.75-2.0	2.0-4.0	>4.0
Exch. potassium (meq/100 g soil)					
- sandy soils (<10% clay)	<0.05	0.05-0.1	0.1-0.4	0.4-0.7	>0.7
- general	<0.1	0.1-0.3	0.3-0.6	0.6-1.2	>1.2
Exch. sodium (meq/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 Bingham, 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
pH 8.5-9.0	strongly alkaline
pH >9.0	very strongly alkaline

(Source: Agricultural Compendium, ILACO 1981)

3.5 Soil fertility status

The fertility of the soils in this area is largely linked to the volcanic character of the deposits, originating from Mt. Meru. The volcanic character manifests itself most strongly in the high capacities to absorb cations and in the related high levels of exchangeable bases, in particular those of sodium and potassium.
A summary of the soil analytical data / mapping unit, is given in table 2, p. 14.

Organic matter levels are medium in the top 20 cm of all soils at the Umoja and Fil Estates. The lowest values are found in the relatively coarse textured soils of mapping unit Ss. Below a depth of about 20 cm the values of organic matter decrease rapidly to a low or very low level, especially in the soils of the mapping units Ss and Sl.

The C/N ratios range from 10 to 18 in the study area. The lowest values, indicating a good quality of the organic matter, are found in the topsoils of mapping unit Slc. The organic matter in the two other mapping units is mostly of an inferior quality.

The total nitrogen content is very low to low in all soils. The relatively highest values are measured in the heavier textured topsoils of mapping unit Slc.

The soil reaction is dominantly mildly to moderately alkaline in all topsoils and in most subsoils as well; subsoils of mapping units Ss and Sl though, may be very strongly alkaline. The high pH values are mainly due to the presence of large amounts of sodium (see below), next to the presence of carbonates.

The amount of available phosphorus is very high in the relatively heavy textured topsoils of mapping unit Slc. The topsoils of mapping unit Ss show medium levels while those of mapping unit Sl show mainly low and medium levels. In the subsoils levels are invariably low.

The cation exchange capacity (CEC), reflecting the capacity of a soil to retain nutrients (determined at a pH of 8.2 with sodium acetate,

(see Annex 1), is high to very high in the loamy and clayey soils (mapping units S1 and S1c) and medium in the sandy soils (unit Ss). The relatively high values (as compared to the texture) are mainly due to the volcanic origin of the sediments in which these soils have developed. The sediments are young and not much weathering has taken place yet. The amount of silt can be very high in these soils. The clay is mainly of the allophanic type, which is characterized by a high cation exchange capacity.

The levels of all exchangeable bases, i.e. calcium, magnesium, potassium and sodium, are high to very high in all soils of the study area. Absolute levels, however, are such that severe imbalances exist between the bases. Especially the magnesium/potassium ratio (Mg/K) is completely imbalanced. For most crops the optimum Mg/K ratio is between 1 and 4. In many samples there is more exchangeable potassium than magnesium, leading to a Mg/K ratio below 1. This is not favourable as the high potassium levels will induce a magnesium deficiency in the plants. The Mg/K ratio is better in soils of mapping unit S1c.

The high to very high amounts of sodium, especially in the subsoils, will have an adverse effect on the growth of many crops and also on the physical conditions of the soils. The exchangeable sodium percentage (ESP)* is especially high in the subsoils of mapping unit Ss (19-27%). The ESP values in the subsoils of unit S1 are moderately to high and those in the subsoils of mapping unit S1c are moderate.

3.6 Soil physical conditions

Soil moisture retention capacity

From 3 selected profiles undisturbed ring samples were collected to estimate the amount of water which is available to the crop. Table 4 presents the soil moisture data of the 3 profiles.

The total available soil moisture content is the difference in moisture content between field capacity (determined at a suction of pF 2.4)

* $ESP = \frac{Na}{CEC} \times 100\%$

and permanent wilting point (pF 4.2). Field capacity is defined as the amount of water remaining in the soil 2-3 days after having been throughly wetted. Permanent wilting point is defined as the water content in a soil at which an indicator plant growing in that soil wilts and fails to recover after the soil is wetted again. The available water is that portion of the soil moisture that can be absorbed by the plant roots.

Table 4: Mean total available moisture contents and bulk densities per mapping unit in three profiles

Mapping unit	Profile no.	Depth (cm)	Total avail. moisture(vol%)	Bulk density (g/cm^3)
Sl	UP1	0-23	14.6	1.09
	(coarse	23-48	14.3	1.17
	loamy)	48-70	15.5	1.25
		Total: 73 mm in 50 cm soil		
Sl	UP5	0-20	15.9	0.98
	(fine	20-36	25.3	0.86
	loamy)	36-80	22.7	0.91
		80-124	28.3	0.82
		Total: 104 mm in 50 cm soil		
Scl	UP4	0-18	7.1	0.82
		18-54	22.1	1.00
		54-88	23.5	1.13
		Total: 84 mm in 50 cm soil		
		142 mm in 75 cm soil		

The total available moisture percentages (vol%) are all above 14%, with one exception; values up to 28% were calculated. These high values are normal for soils having high percentages of silt and very fine sand. Due to the high sodicity of the subsoils in mapping unit Sl, forming a chemical barrier to root development, the rooting depth is restricted to 50 cm. For soils of mapping unit Slc a depth of 75 cm is taken into account, as sodicity is less severe in these soils.
The high waterholding capacities of the soils imply that the field crops can stand a reasonably long dry period, in particular on the soils of unit Slc. Within that period, the water requirements of the crop can be met by the soil moisture reserves.

A waterbalance, assessing the moisture availability for a crop during the growing period, could not be calculated as long-term rainfall data are not available (see chapter 2.2). It may be stated though, that the mean amount of rainfall during the growing period (March-May) will not exceed 250-275 mm in an average year, which is low. The amount of water in the soils is not supplied by precipitation only, however, but as well, at least in part of the area, by floods and by a rising groundwater table. In the rainy season, mostly in April, the river Temi normally floods the flat area and the relatively lowest lying parts adjacent to the river get inundated for a period of some days. Beans can only be planted after passing of the yearly floods and inundations. This implicates that the plants have to rely mainly on the waterholding capacity of the soils; it is the main course for available water as the amount of rainfall is relatively small after passing of the floods.
It may be concluded thus that the amount of water available to a bean crop, in an average year, is not sufficient for a satisfactory yield.

Soil structure

In general most soils at the Umoja and Fil Estates, i.e. those of mapping units Ss and Sl, have very weakly developed, unfavourable structures. This is mainly induced by the high sodium

content of the soils. In places, the subsoils can be even massive due to the weathering of volcanic minerals, forming cementing agents.

Only in the heavy textured topsoils of mapping unit Slc the structure is more favourable. The topsoils consist moistly of moderately strong developed, medium, subangular blocks.

As most of the study area is presently under sisal no soil compaction has been observed. It is suspected, however, that plough pans, hampering rooting, will develop easily in these volcanic soils if seedbeans are going to be cultivated. As cultivation most probably will result in lower levels of organic matter, surface sealing is expected to occur as well.

The loose or soft consistency of the dry topsoils of mapping units Ss and Sl makes those soils very vulnerable to wind erosion.

4 WATER

4.1 The quality of the irrigation water

Three samples of the water in the river Temi have been taken in the beginning of April, just before the start of the rains. This was done to study the quality of the water which is planned to be used for irrigation of seedbeans, in some parts of the area.
Table 5 gives the results of the analyses.

Table 5 Results of water analysis (means)

Na	K	Ca	Mg	EC	pH	SAR*
		(meq/liter)		(mS/cm)		
3.35	1.93	1.16	0.80	0.52	8.2	3.4

*SAR = Sodium Adsorption Ratio

According to the USDA classification of (sulphate-free) irrigation water (Booker Tropical Soil Manual), the water can be classified as a medium saline and low sodium water.
Medium saline water can be used for irrigation only if leaching is sufficiently high. Plants with a moderate salt-tolerance can be grown in most cases without special practices for salinity control.
Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops may accumulate injurious concentrations of sodium.

A sodium content in irrigation water of above 3 meq/liter will lead to increasing problems (affecting sensitive crops) when sprinkler or surface irrigation is practised (acc. to FAO guidelines for evaluating irrigation water quality, Booker Tropical Soil Manual).

Soil properties as crop-water availability (due to osmotic effects) and permeability will not be affected by water of this quality.

According to FAO guidelines for evaluating irrigation water quality a pH value of irrigation water ranging between 6.5 and 8.4 is considered to be normal, not causing imbalances in nutrient uptake. The pH of the Temi water falls within this range, but is nevertheless rather high.

Of seedbeans it is known that they are sensitive to sodicity and very sensitive to salinity. Considering this, one may conclude that using the Temi water for irrigation of the seedbeans, will certainly lead to negative effects on plantgrowth. The bean plants will be adversely affected by salinity right from the beginning and there will be a considerable risk of accumulation of harmful concentrations of sodium in the plants. The latter the more so as the sodium content in the soils reaches considerably high to harmful levels already.
Although bean yields may be high during the first years of irrigated cropping in case of favourable rainfall conditions, yields will only decrease with time and detrimental salt and sodium levels will be reached in a few years time.
Without special measures it is not advisable to practice irrigation. The creation of a large basin where river water is collected during the rainy season so that concentrations of salts and sodium will be much diluted, can be of great help. Also one has to make sure that (surplus) irrigation water be given, in addition to what is needed for the plants, to leach the salts from the soils. A leaching requirement (surplus) of 15% can be taken as a guide. Whether these measurements will be sufficient to keep concentrations below harmful levels however, will have to be monitored via regular sampling of soil and water.

5 SUITABILITY FOR THE CULTIVATION OF SEEDBEANS

5.1 Introduction

Rotian Seed plans to grow seedbeans at the lands of the neglected sisal estates Umoja and Fil. It is the intention to have an area of approximately 200 ha under irrigation and the rest of the land under rainfed conditions. An area of 2 ha will be used for plant breeding. In the following sections the suitability of the area for seedbeans, both rainfed and irrigated, is discussed. The approach adopted is a simplified version, as proposed in the framework for land evaluation (FAO, 1976). First the most important environmental requirements of the crops are presented. Next, those requirements are matched with the existing environmental conditions at the farms, resulting in a suitability assessment.

It is assumed that the seedbeans will be cultivated at a large scale farm level, making use of farm machinery and proper soil and crop management practices including the use of moderate amounts of fertilizers.

5.2 Environmental requirements of seedbeans

Beans (Phaseolus vulgaris) grwo 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 yield and non-uniform ripening of the seed.

The crop prefers freely drained, well structured and 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 besides a starter dose, the nitrogen requirements are limited. 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 to be not very tolerant to high amounts of sodium in the soil. According to Landon (1984), beans are already sensitive to Exchangeable Sodium Percentages (ESP values) of between 10 and 20. It is reported that yield reductions of 50% may occur at ESP values of below 15 already.

5.3 Suitability of the Umoja and Fil lands for seedbeans

The suitability of the soils at the Umoja and Fil Estates for the cultivation of seedbeans, for both rainfed and irrigated conditions, is presented in tables 5 and 6. The tables present the suitability of each mapping unit together with the major limiting soil factors.

It follows clearly from tables 5 and 6 that the cultivation of seedbeans, either rainfed or irrigated, ca not be recommended.
The major limiting factors are the high pH and in most parts the high sodium levels in the soils. Under rainfed conditions moisture stress is an additional constraint.
When irrigated the only unit considered moderately suitable is unit S1c mainly as sodicity is less severe and occurs deeper in the profile. Proper management however will be required to prevent salinization and further sodification of the soils when practising irrigation.

Table 5 The suitability and constraints of the mapping units for rainfed seedbeans

Mapping unit	Suitability for rainfed seedbeans	Constraints
Ss (340 ha)	Unsuitable	- lack of moisture in most years - high sodicity - alkaline soil reaction - unfavourable Mg/K balance - low available phosphorus levels in places - very low total nitrogen level
Sl (930 ha)	Unsuitable	- lack of moisture in most years - high sodicity - alkaline soil reaction - unfavourable Mg/K balance - low available phosphorus levels in places - very low total nitrogen levels in places
Slc (210 ha)	Marginal	- lack of moisture in most years - high sodicity in places - alkaline soil reaction
R (20 ha)	No data available	

Table 6 The suitability and constraints of the mapping units for irrigated seedbeans

Mapping unit	Suitability for irrigated seedbeans	Constraints
Ss (340 ha)	Marginal	- high sodicity - alkaline soil reaction - unfavourable Mg/K balance - low available phosphorus levels in places - very low total nitrogen levels
Sl (930 ha)	Marginal	- high sodicity - alkaline soil reaction - unfavourable Mg/K balance - low available phosphorus levels in places - very low total nitrogen levels in places
Slc (210 ha)	Moderate	- high sodicity in places - alkaline soil reaction
R (20 ha)	No data available	

6 MANAGEMENT REQUIREMENTS

6.1 Management requirements for the cultivation of seedbeans under rainfed conditions

Mapping unit Slc is the only unit which is considered to be (marginally) suitable for the cultivation of seedbeans under rainfed conditions. In years with a reasonable rainfall reasonable yields may be expected. There is a need for a more detailed mapping of this mapping unit to map out sodic spots so that these can be omitted. In alluvial areas as this, soil properties tend to differ over very short distances. As the Mg/K ratio is rather low, which is not favourable to the crop, it is advised to apply some magnesium fertilizer.

6.2 Management requirements for the cultivation of seedbeans under irrigated conditions

The only area considered to be (moderately) suitable for irrigated cropping of seedbeans, is mapping unit Slc.
Like stated above, a detailed mapping of the unit is recommendable as to define precisely the problem areas (sodic spots).

If irrigation is practised, in most cases this implicates a rise of the ground watertable which in its turn leads to a higher capillary rise. Because of the high evaporation salts will accumulate near the surface.

In order to prevent a rise of the water table in the first place, care has to be taken that the drainage capacity of the irrigated area is good. This can be done either by artificial means or by reducing the amount of irrigated water.

On the other hand a surplus of water (leaching requirement) has to be applied to wash out salts and sodium from the rooting zone. The fact that the irrigation water itself contains considerable amounts of salts and sodium as well, makes the practice a very risky undertaking.

The water of the Temi will have the lowest concentrations of salts and

sodium during the rainy season but this is not the time that irrigation will be practised. It is after the rains that the need for irrigation water will be highest.
The construction of a water basin to collect river water in the rainy season, in order to obtain a maximal dilution, might be a change for the better. Continuous monitoring of salinity and alkalinity will be necessary after each crop.
A satisfactory yield of beans can only be expected if ESP values in the soil remain below 10, and ECe is below 4 mS/cm.

As Mg/K ratios in the soils of unit Slc are rather low and the more as the potassium contents of the irrigation water are high, magnesium-fertilizer should be applied to avoid magnesium deficiencies.

The low nitrogen contents may limit optimal yields. Simple, comparative trials with nitrogen fertilizers may be done to examine this. In the case of proven nitrogen deficiency, low rates of nitrogen fertilizer are recommended at planting.
Due to the high pH values a zinc deficiency may occur, leading to a poor pod-set.

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Annex 1

Analytical procedures followed

The soil samples were air-dried crushed in a mortar and passed through a 2 mm sieve. Determinations are performed on the fine earth fraction and results are reported on that basis.

The analytical methods are described in detail in report M7 of the National Soil Service (1987) of which a brief summary follows :

- particle size analysis: pipette method (clay and fine silt fractions) and USDA standard sieves (sand fractions) after destruction of the organic matter and using sodium hexametaphosphate as dispersing agent.
- organic carbon: Walkley and Black; wet acid-dichromate digestion and $FeSO_4$ titration.
- total nitrogen: semi-micro Kjeldahl digestion followed by ammonium distillation and titration with sulphuric acid.
- pH: potentiometrically using a combined glass-calomel electrode in a 1:2.5 suspension of H_2O and KCl.
- exchangeable cations: displacement with 1 M NH_4OAc at pH 7 and determination of K and Na by EDTA titration.
- cation exchange capacity: NH_4 saturation with NH_4OAc at pH 7 or Na saturation with NaOAc at pH 8.2 (the latter for soils with pH above 7.4)
- available phosphorus: Olsen extraction with 0.5 M $NaHCO_3$ solution and colorimetric determination of the extracted P, in soils with pH above 7.

Annex 2

Analytical data of the composite topsoil samples (0-20 cm)

Mapping unit	Sample no.	PH (H_2O)	Organic matter (%)	Total nitrogen (%)	Available phosphorus (mg/kg)	CEC	Exchangeable bases Ca	Mg	K	Na
						(meq/100 g soil)				
Ss	6	7.5	1.94	0.07	9	9.9	5.6	1.6	1.83	0.80
	7	7.4	2.61	0.09	5	12.4	7.6	1.7	3.26	0.84
Sl	1	7.8	2.55	0.15	3	31.3	14.9	5.9	6.93	1.91
	2	7.6	3.03	0.14	3	22.2	11.1	2.8	5.51	1.14
	3	7.5	3.96	0.14	9	28.2	14.0	5.0	7.85	2.00
	4	7.4	2.89	0.12	7	22.9	11.8	3.9	5.82	1.41
	5	7.8	2.75	0.09	6	20.0	15.2	6.1	5.51	1.24
	13	7.2	2.55	0.08	3	28.7	10.1	6.5	6.32	1.52
	14	7.4	2.41	0.08	4	29.8	12.8	5.9	3.54	1.52
	15	7.1	3.56	0.13	3	38.2	16.4	5.5	9.07	1.22
	16	7.9	2.61	0.09	10	36.5	12.1	6.8	5.91	1.45
	17	7.8	2.55	0.10	16	33.6	15.3	7.5	6.73	1.01
	18	7.6	2.96	0.10	7	27.3	12.4	5.8	7.34	1.00
Slc	19	8.2	3.82	0.20	23	38.3	22.4	8.0	5.50	2.00
	20	8.1	2.96	0.14	33	45.9	18.0	8.7	6.27	2.17
R	No chemical data available									

Profile No UP1 Mapping unit S1

General information on site and soil

Location: Umoja Estate. Parent material: Volcanic ashes. Landform: Sedimentary plain. Relief: Flat. Slope of site: 0-1%. Elevation: 930 m.

Soil: Very deep, well drained, brown loamy soil with a very weak structure.

Description: The profile was described on 06-04-87 by F. van der Wal, Mr. Lesika, J.D.J. Mbogoni, P.H. Silayo, R. Kimaro and A. Brom.

Soil profile description

A 0 - 23 cm	very dark grayish brown (10YR 3/2, moist and 10YR 5/3, dry); sandy loam; very weak, medium, subangular blocky and granular; soft when dry, very friable when moist, non-sticky non-plastic when wet; porous; abundant sisal roots; gradual and smooth to
AC 23 - 48 cm	dark brown (10YR 3/3, moist and 10YR 5/3, dry); sandy loam very weak, medium, subangular blocky and granular; soft when dry, very friable when moist, non-sticky and non-plastic when wet; porous; gradual and smooth to
C1 48 - 122 cm	dark brown (10YR 3/3, moist and 10YR 5/5, dry); sandy loam to loamy sand; very weak, medium subangular blocky soft when dry, very friable when moist, non-sticky and non-plastic when wet; porous; rounded gravels; gradual and smooth to
C2 122 - 170 cm+	very dark grayish brown (10YR 3/2, moist and 10YR 5/2, dry); loamy sandy; single grain; loose when dry, very friable when moist, non-sticky and non-plastic when wet; porous; rounded gravels.

Soil classification:

FAO/Unesco : Eutric Fluvisol, sodic phase

Soil Taxonomy: Andic Fluventic Ustropept

Analytical data

Horizon		A	AC	C1	C1	C2
Depth (cm)		0-23	25-45	50-70	80-120	125-170
Texture:						
clay	%	5	4	3	2	tr
fine silt	%	12	12	11	10	9
coarse silt	%	21	18	17	16	18
very fine sand	%	18	16	19	20	21
fine sand	%	26	32	32	36	35
medium sand	%	14	15	15	13	14
coarse sand	%	3	3	3	3	3
very coarse sand	%	1	tr	tr	tr	tr
Textural class		sl	sl	sl	ls	ls
pH water 1:2.5		8.0	7.4	7.6	8.6	9.5
pH KCl 1:2.5		7.0	5.6	5.9	7.2	7.8
EC µS/cm 1:2.5		235	105	84	215	300
Organic carbon	%	1.48	0.86	0.46	0.20	0.12
Avail. P Olsen	mg/kg	7	2	1	2	1
CEC NaOAc	me/100 g	29.5	25.7	24.8	27.0	25.8
exch. Ca	"	14.7	11.8	11.0	15.6	11.2
exch. Mg	"	10.0	2.8	3.7	2.4	7.7
exch. K	"	5.71	9.58	6.57	6.83	4.08
exch. Na	"	1.04	2.95	3.22	2.95	4.26
Bulk density (g/cm^3)		1.09	1.17	1.25		
Soil moisture retention:						
pF 2.0	(vol%)	41.0	38.6	40.2		
pF 2.4	"	24.6	24.1	25.5		
pF 3.0	"	16.9	16.2	16.4		
pF 4.2	"	10.0	9.8	16.0		

Profile No UP2

Mapping unit Ss

General information on site and soil

Location: Umoja Estate, western part. Parent material: Volcanic ashes. Landform: sedimentary plain. Relief: Flat. Slope of site: 0-1%. Elevation: 945 m.

Soil: Very deep, well drained, brown, stratified, dominantly sandy soil which is very weakly structured to massive.

Description: The profile was described on 06-04-87 by A.J. Brom, P.H. Silayo, N.R. Lesika and R. Kimaro.

Soil profile description

A11 0 - 16 cm	very dark grayish brown (10YR 3/2 moist); loamy sandy; very weak, fine and medium subangular blocky; very friable when moist, non-sticky non-plastic when wet; gradual and smooth to
A12 16 - 31 cm	very dark gray (10YR 3/1, moist and 2.5Y 3/2, dry); loamy sand; single grain; non-sticky and non-plastic when wet; clear and wavy to
AC 31 - 53 cm	very dark grayish brown (2.5Y 3/2, moist and 2.5Y 4/2, dry); loamy sand; massive, cemented; common very fine and fine pores; gradual and smooth to
C11 53 - 87 cm	very dark grayish brown (2.5Y 3/2, moist and 2.5Y 4/2, dry); sandy loam; cemented, massive; common fine and very fine pores; clear and smooth to
C12 87 - 99 cm	dark grayish brown (2.5Y 4/2, moist and 2.5Y 6/2, dry); sandy loam; cemented, massive; slightly sticky and plastic when wet; clear to abrupt and smooth to
C13 99 - 112 cm	dark grayish brown (2.5Y 4/2, moist and 2.5Y 5/2, dry); sandy loam; massive; slightly sticky and plastic; abrupt and smooth to
C21 112 - 120 cm	very dark grayish brown (10YR 3/2, moist and 10YR 5/3, dry); silty clay; weak, medium and fine, subangular blocky; friable when moist, very sticky and plastic when wet; very porous; calcareous; clear and smooth to
C22 120 - 167 cm	very dark grayish brown (10YR 3/2, most and 10YR 4/3, dry); silty clay loam; weak, medium and fine, subangular blocky; very friable when moist; sticky and plastic when wet, calcareous; clear and smooth to
C3 167+cm	very dark brown (10YR 2/2, moist and 10YR 4/2, dry); sand; single grain.

Soil classification

FAO/Unesco : eutric Fluvisol, sodic phase

Soil Taxonomy : Andic Fluventic Ustropept

Analytical data

Horizon Depth (cm)		A11 0-15	A12 16-30	AC 32-50	C11 55-85	C13 100-112	C22 125-160
Texture:							
clay	%	1	1	tr.	1	1	13
fine silt	%	8	5	10	33	12	18
coarse silt	%	18	13	15	30	17	20
very fine sand	%	15	9	11	23	14	29
fine sand	%	30	30	19	6	24	17
medium sand	%	19	28	22	4	19	2
coarse sand	%	8	12	17	2	10	tr
very coarse	%	1	2	6	1	3	1
Textural class		ls	ls	ls	sl	ls/sl	l
pH water 1:2.5		8.0	8.2	8.1	9.1	8.1	9.4
pH KCl 1:2.5		7.0	6.2	6.3	7.6	6.3	7.8
EC µS/cm 1:2.5		135	66	56	235	08	820
Organic carbon	%	1.78	0.83	0.59	0.44	0.36	0.28
Avail. P Olsen	mg/kg	10	6	4	2	2	13
CEC NaOAc	me/100 g	20.0	14.0	10.5	17.1	17.3	32.3
exch. Ca	"	10.5	4.4	4.0	7.7	3.7	9.3
exch. Mg	"	3.2	1.3	0.8	1.9	2.0	4.0
exch. K	"	3.77	6.12	2.19	3.97	3.97	5.25
exch. Na	"	1.27	1.91	2.43	5.65	3.39	11.74

Profile No. UP3

Mapping unit Ss

General information on site and soil

Location: Umoja Estate, western block. Parent material: Volcanic ashes.
Landform: Sedimentary plain. Relief: Almost flat. Slope of site: 1%.
Elevation: 940 m.

Soil: Very deep, well drained, brown, dominantly sandy soil with a very weak structure.

Description: The profile was described on 06-04-87 by R. Kimaro, A.J. Brom, P.H. Silayo and N.R. Lesika.

Soil profile description:

A 0 - 24 cm	very dark grayish brown (10YR 3/2, moist); loamy sand; very weak granular; loose when dry, loose when moist; non-sticky and non-plastic when wet; porous; gradual and smooth to
AC 24 - 68 cm	dark brown (10YR 3/3, most); loamy sand, very weak, granular; loose when dry, loose when moist, non-sticky and non-plastic when wet; porous; gradual to clear and smooth to
C1 68 - 112 cm	very dark grayish brown (2.5Y 3/2, moist); loamy sand; very weak granular; loose when dry, loose when moist, non-sticky and non-plastic when wet; porous; gradual and smooth to
C2 112 - 157+ cm	dark grayish brown (2.5Y 4/2, moist); sandy loam; very weak to loose, granular; loose when dry, loose when moist, non-sticky and non-plastic when wet; porous; clear and smooth.

Soil classification:

FAO/Unesco : eutric Fluvisol, sodic phase

Soil Taxonomy : Andic Fluventic Ustropept

Analytical data

Horizon		A	AC	C1	C2
Depth (cm)		0-20	25-65	70-112	112-142
Texture:					
clay	%	2	2	1	tr.
fine silt	%	5	7	5	9
coarse silt	%	14	13	12	22
very fine sand	%	13	20	16	31
fine sand	%	33	38	25	30
medium sand	%	24	16	37	7
coarse sand	%	7	4	4	1
very coarse sand	%	2	tr.	tr.	tr.
Textural class		ls	ls	ls	sl
pH water 1.2.5		8.1	7.6	8.0	9.0
pH KCl 1:2.5		6.8	5.6	6.1	7.4
EC µS/cm 1:2.5		220	65	73	190
Organic carbon		1.55	0.82	0.53	0.42
Avail. P Olsen mg.kg		6	2	1	1
CEC NaOAc me/100 g		35.9	17.9	18.0	17.5
exch. Ca	"	11.6	8.0	7.6	6.8
exch. Mg	"	8.3	1.8	1.9	2.3
exch. K	"	4.97	2.85	5.50	3.67
exch. Na	"	1.35	4.87	3.48	1.91

Profile No. UP4

Mapping unit S1c

General information on site and soil

Location: Umoja farm, close to manager's house. Parent material: Volcanic ash. Landform: Sedimentary plain. Relief: Almost flat. Slope of site: 0-1%. Elevation: 920 m.

Soil: Very deep, well drained, brown, stratified, dominantly loamy soil with a favourable structure.

Description: The profile was described on 06-04-87 by R. Kimaro, A.J. Brom, P.H. Silayo and N.R. Lesika.

Soil profile description:

A
0 - 18 cm
very dark grayish brown (10YR 3/2, moist and 10YR 4/2, dry); clay loam; moderately strong, medium, subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; many fine and very fine, common medium pores; clear and wavy to

AC
18 - 32 cm
dark grayish brown (10YR 4/2, moist and 10YR 5/3, dry); silty loam; moderate, medium and coarse, subangular and angular blocky; slihtly hard when dry, friable when moist, sticky and plastic when wet; many fine and very fine, common medium pores; pores; broken, thin cutans; gradual and smooth to

C1
32 - 54 cm
dark brown (10YR 4/3, moist); loam; moderate, medium and coarse, subangular blocky; slightly hard when dry, non-sticky and slightly plastic when wet; common fine and very fine, many medium pores; broken, thin cutans; clear and wavy to

C2
54 - 88 cm
very dark grayish brown (2.5Y 3/2, moist); sand; moderately weak, medium and coarse angular blocky; slightly hard when dry, non-sticky and slightly plastic when wet; common fine and very fine, common medium pores; very abrupt and iregular to

C3
88 - 172 cm
black (5Y 2.5/2, moist and 10Y 4/1, dry); sand; loose, single grain; loose when dry, loose when moist, non-sticky and non-plastic when wet; rounded gravels; abrupt and wavy to

C4
172 - 187
dark olive gray (5Y 3/2, moist); clay loam; massive; non-sticky and non-plastic when wet; fine gravel

Soil classification

FAO/Unesco : eutric Fluvisol, sodic phase

Soil Taxonomy : Andic Fluventic Ustropept

Analytical data

Horizon / Depth (cm)		A 0-10	AC 20-30	C1 35-50	C2 55-80	C3 90-150
Texture						
clay	%	30	25	18	2	tr
fine silt	%	29	33	1	4	23
coarse silt	%	21	19	48	16	5
very fine sand	%	7	8	15	39	5
fine sand	%	8	9	14	36	29
medium sand	%	3	4	3	2	29
coarse sand	%	2	2	1	1	21
very coarse sand	%	tr.	tr.	tr.	tr.	8
Textural class		cl	sil	l	s	s
pH water 1:2.5		7.9	8.0	8.0	8.3	7.8
pH KCl 1:2.5		6.2	6.3	6.4	6.3	5.8
EC µS/cm 1:2.5		250	200	155	82	65
Organic carbon	%	2.44	2.07	1.44	0.38	0.21
Avail. P Olsen	mg/kg	27	18	8	3	2
CEC NaOAc	me/100 g	43.6	41.9	44.4	29.6	48.7
exch. Ca	"	22.0	23.7	22.6	6.5	4.8
exch. Mg	"	5.6	8.3	9.3	2.0	0.4
exch. K	"	8.41	7.90	3.46	3.67	2.75
exch. Na	"	3.56	2.61	5.22	2.00	1.56
Bulk density (g/cm³)		0.82		1.00	1.13	
Soil moisture retention:						
pF 2.0	(vol%)	38.7		45.1	35.7	
pF 2.4	"	32.9		40.7	28.3	
pF 3.0	"	28.7		34.6	9.4	
pF 4.2	"	25.9		18.6	5.4	

Profile No. UP5

Mapping unit S1

General information on site and soil

Location: Umoja farm, fallow area (to be irrigated) Parent material: Volcanic ashes. Landform: Sedimentary plain. Relief: Flat. Slope of site: 0-1%. Elevation:

Soil: Very deep, well drained, brown, loamy soil with a very weak structure.

Description: The profile was described on 06-04-87 by A.J. Brom, P.H. Silayo, R. Kimaro and N.R. Lesika.

Soil profile description:

A
0 - 20 cm — very dark grayish brown (10YR 3/2, moist); sandy loam; very weak, medium, subangular blocky and granular; soft when dry, friable when moist, non-sticky and non-plastic when wet; common to many fine and very fine, common medium pores; gradual and smooth to

AC
20 - 36 cm — dark brown (10YR 4/3, moist and 10YR 5/3, dry); silty loam; very weak, medium and fine subangular blocky; loose when dry, very friable to loose when moist, non-sticky and non-plastic when wet; common to many fine and very fine, common medium pores; gradual and smooth to

C1
36 - 80 cm — dark brown (10YR 4/3, moist and 10YR 5/3, dry); loam; very weak, fine subangular blocky; loose to slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; common to many fine and very fine, common medium pores; gradual and smooth to

C21
80 - 102 cm — dark grayish brown (2.5Y 4/2, moist and 10YR 5/3, dry); silty loam; very weak, fine, subangular slightly hard when dry, very friable to loose when moist, non-sticky and non-plastic when wet; porous; calcareous; gradual and smooth to

C22
102 - 124 cm — light olive brown (2.5Y 5/3, moist and 10YR 6/3, dry); silty loam; weak, medium and coarse subangular blocky and grains; slightly hard when dry, friable when moist, non-sticky and non-plastic when wet; calcareous.

Soil classification

FAO/Unesco : eutric Fluvisol, sodic phase

Soil Taxonomy: Andic Fluventic Ustropept

Analytical data

Horizon		A	AC	C1	C21	C22
Depth (Cm)		0-20	20-35	40-70	85-100	105-120
Texture						
clay	%	10	9	14	10	5
fine silt	%	1	1	28	32	40
coarse silt	%	34	54	17	24	17
very fine sand	%	22	16	9	10	8
fine sand	%	27	14	18	10	9
medium sand	%	4	4	12	7	7
coarse sand	%	1	1	2	7	10
very coarse sand	%	1	1	tr.	tr.	4
Textural class		sl	sil	l	sil	sil
pH water	1:2.5	8.0	8.2	8.4	9.2	9.4
pH KCl	1:2.5	6.4	6.3	6.3	7.2	7.2
EC mS/cm	1:2.5	130	105	130	420	540
Organic Carbon		1.08	0.87	0.73	0.69	0.57
Avail. P Olsen	mg/kg	16	8	4	3	2
CEC NaOAc	me/100 g	44.4	40.0	40.0	59.2	50.5
exch. Ca	"	17.6	22.7	19.5	24.0	20.5
exch. Mg	"	3.5	2.6	5.0	4.1	1.3
exch. K	"	10.61	9.07	5.81	9.07	9.58
exch. Na	"	3.30	2.27	6.26	14.26	15.31
Bulk density (g/cm^3)		0.98	0.86	0.91	0.82	
Soil moisture retention:						
pF 2.3	(vol%)	35.3	48.2	48.9	49.2	
pF 2.4	"	28.9	41.3	39.9	42.6	
pF 3.0	"	22.5	28.1	28.8	31.0	
pF 4.2	"	12.9	16.0	17.2	14.3	

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