A look at the Uganda Martyrs' University farmland

soil survey and land evaluation

S. Dondeyne
June 1995

Uganda Martyrs University — Virtute et Sapientia — Duc Mundum

Ingenieurs zonder grenzen

Institute for Land and Water Management

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Uganda Martyrs' University
PO Box 5498
Kampala
Uganda
Tel. +256-41-26.77.99
Fax. +256-41-26.77.54

Ingenieurs zonder Grenzen
Desguinlei 214
2018 Antwerpen
Belgium
Tel. +32-3-216.09.96
Fax. +32-3-216.06.89

Institute for Land and Water Management — KU Leuven
Vital Decosterstraat 102
3000 Leuven, Belgium
Tel. +32-16-23.13.81
Fax. +32-16-23.06.07

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Summary

The Uganda Martyrs' University, a catholic university founded in 1991, possesses 290 hectares of land for the purpose of developing a farm. A soil survey and land evaluation study of this land and its surroundings, was carried out in order to assess its potential. The soil map — drawn at a 1/10,000 scale — is based on aerial photographs and field observations (7 soil profiles and 35 augerings). The mapping units are defined as a combination of landform units and soil units. The soil units are classified according to the FAO/Unesco classification system.

The university farmland is split into two blocks: a small block of 8 ha, located next to the university campus on the hill top, and a large block of 282 ha located down the Nkozi hill. The most fertile soils are found in the small block. These soils are identified as sandy clay loam *Haplic Ferralsols*, and cover 5.8 ha. The large block covers part of the foot slopes, of the lacustrine terrace and the valley bottom. Soils on the foot slopes are also sandy clay loam *Haplic Ferralsols* but with a very low fertility status. On the lacustrine terrace there are some fertile sandy clay loam *Haplic Acrisols* (35 ha), besides some moderately fertile sandy loam *Gleyic Acrisols* (8 ha). Other parts of the lacustrine terrace are sand or sandy loam *Gleyic Cambisols* (69 ha) having low fertility status. At the fringe of the lacustrine terrace and the valley bottom poorly drained but moderately fertile sandy loam *Dystric Gleysols* (32 ha) occur. The valley bottom — itself 46% of the farmland — is dominated by very poorly drained organic soils. Some 87 ha are *Fibric Histosols* and are essentially occupied by floating papyrus. The other 46 ha are *Terric Histosols* covered by an association of swamp palm trees and papyrus.

For the further development of the farm it is suggested to focus on a few production systems in-line with the current interest and know-how of the staff. This is in first instance poultry production (layers and broilers) and dairy cattle. At least, part of the animal feed can be produced on the university farm by growing cereals and establishing pastures on the *Haplic* and *Gleyic Acrisols*. There is also an interest for bee-keeping and for starting a passion fruit plantation. The passion fruits can be planted on the sandy loam *Gleyic Cambisols*, and would offer plenty of flowers which would be advantages for bee-keeping. The *Dystric Gleysols* can be used for growing vegetables during the dry season.

As presently the poorly drained soils are hardly utilised, there is no pressing need for embarking on irrigation. However, this may change in the future. The *Haplic Acrisols*

are the best suited for surface irrigation. The gross water requirements on these soils were calculated for pasture, citrus, maize, soya bean and groundnut. Out of this list, pasture would be the greatest water consumer, requiring almost 1000 mm/ha/year. Maize will take the highest peak demand, corresponding to 370 m3/ha/application. Pitcher irrigation seems to be promising for applying sub-surface irrigation to the passion fruits.

The expansion of the agricultural activities offers the possibility to start with the processing of farm products particularly for animal feed, passion fruit concentrate or wine, and honey. The own production shall provide a stable supply, which should be supplemented with products purchased from neighbouring farmers and fishermen. This would be advantageous to neighbouring farmers, provided they get a "fair price". These "small scale enterprises" as spin-offs, would provide interesting didactic cases for the students in business administration and developments studies.

It is the author conviction that the present farm has the potential to develop independently. External input would definitely hasten this process but care should then be taken not to overwhelm its own development dynamic.

Preface

If need be, we can do without planes, trains and cars, or without petrol, gas or electricity, but we won't stand long, without drinking or eating. For what we eat, we rely on the land. Plants only grow on suitable soil (*the mother*) provided they get energy from the sun (*the father*), and as long as there is water (*the spirit*). I therefore believe these elements to be the cornerstones of religion, and that we owe a careful use of the land given to us, not only to ourselves, but also to our children as well as to the ancestors. A land evaluation study should help to find the base to achieve this objective.

If there is any merit in this work, it is first and foremost the fruit of four weeks of field work in a pleasant environment. This is both the physical and human environment. Especially, the friendly co-operation of Mr *Esau Galukande*. His high degree of efficiency has been a key to the success of this work. The presence and assistance of Ms *Providence Kayitesi Gatwa* made the field work even more enjoyable. Ms Ir *Kristine Smets* is gratefully acknowledged for her assistance in the digitizing work.

During the preparation phase, I kindly obtained a wealth of data at the Royal Museum for Central Africa (Tervuren, Belgium). Its *Information Centre for Tropical Agro-meteorology*" (Centre d'Informatique appliquée au Développement et à l'Agriculture Tropicale — CIDAT) is acknowledge for providing climatic data on the area, and the *Department of Geology* for making available copies of the geological maps and the accompanying explanatory notes. In Uganda, aerial photographs and topographical maps were kindly provided by the *Lands and Surveys Department* at Entebbe, and additional climatic data by the *Meteorology Department* at Kampala.

Nothing more inspiring than the enthusiasm and seemingly endless energy of Professor Dr *Michel Lejeune*, Vice-Chancellor of the Uganda Martyrs' University. I am also grateful to Professor Dr Ir *Jozef Deckers*, of the Institute for Land and Water Management at KU Leuven for all the comments, suggestions and fruitful discussions. Last but not least, I am grateful to the board of "*Ingenieurs zonder Grenzen*" for entrusting this study to me.

Ir *Stephane Dondeyne*
June 1995, Leuven

1 Introduction

This study was carried in a joint effort by *Ingenieurs zonder Grenzen* (IzG - Engineers without Frontiers) and the *Institute for Land and Water Management* of the Catholic University of Louvain (KU Leuven). IzG is a non-profit organisation founded by the *Royal Flemish Society of Engineers* (Belgium). Its aim is to provide technical assistance through short-term missions by specialised top-level engineers. It supports projects or parts of projects in developing countries which are not financed through the normal development aid channels. It was contacted by the *Uganda Martyrs' University* for technical advise concerning the development of its farm. The *Institute for Land and Water Management* (ILWM) is a research and teaching unit of the Faculty of Agricultural and Applied Biological Science of KU Leuven. The land evaluation unit of ILWM was contacted by the president of IzG for assistance in carrying out the present study.

The *Uganda Martyrs' University* (UMU) is owned by the catholic bishops of Uganda. It is about 82 km south-west of Kampala, along the Kampala-Masaka road and was launched on 24th March 1991. The first academic year started in October 1993. It offers a Bachelor's degree in Ethics and Development Studies, a Bachelor's degree in Business Administration and Management, and various diploma courses in managerial skills.

At present, the Uganda Martyrs' University farm includes a dairy unit, a poultry unit, a vegetable garden and has some 5 acres of arable crops such as sweet potato, cassava and sugar cane. A plantation of cooking bananas (*matoke*) is currently being rehabilitated. Lately, the government of the Republic of Uganda allocated about 300 ha of land to enable the further development of the university farm. With this farm, the university aims:

- to produce enough food for its own consumption
- to have a reliable source of income
- to provide labour opportunities for neighbouring farmers
- to test and introduce new technologies in the area.

This text reports on the characterisation and evaluation of the newly acquired land and its surroundings. The general objectives of this study are to assess the potentials to develop the farmland. Specifically:

- to draw a soil map indicating variations in soil depth, texture, drainage status, and sub-surface characteristics

- to assess the soil suitability of identified mapping units for relevant land uses
- to draw a proposal for optimal land use
- to assess the possibilities for irrigation considering:
  * crop water requirements
  * present water sources, water quality, and soil properties

2 Physical setting

2.1 Location

The Uganda Martyrs' University is based at Nkozi, which is 82 km from Kampala and 2.5 km off of the Kampala-Masaka road. It is located 32° east and almost exactly on the equator. It is roughly 5 km from the shores of lake Victoria (Figure 1). The major part of the university farmland is at the foot of the Nkozi hill and in the Kasemulambo valley.

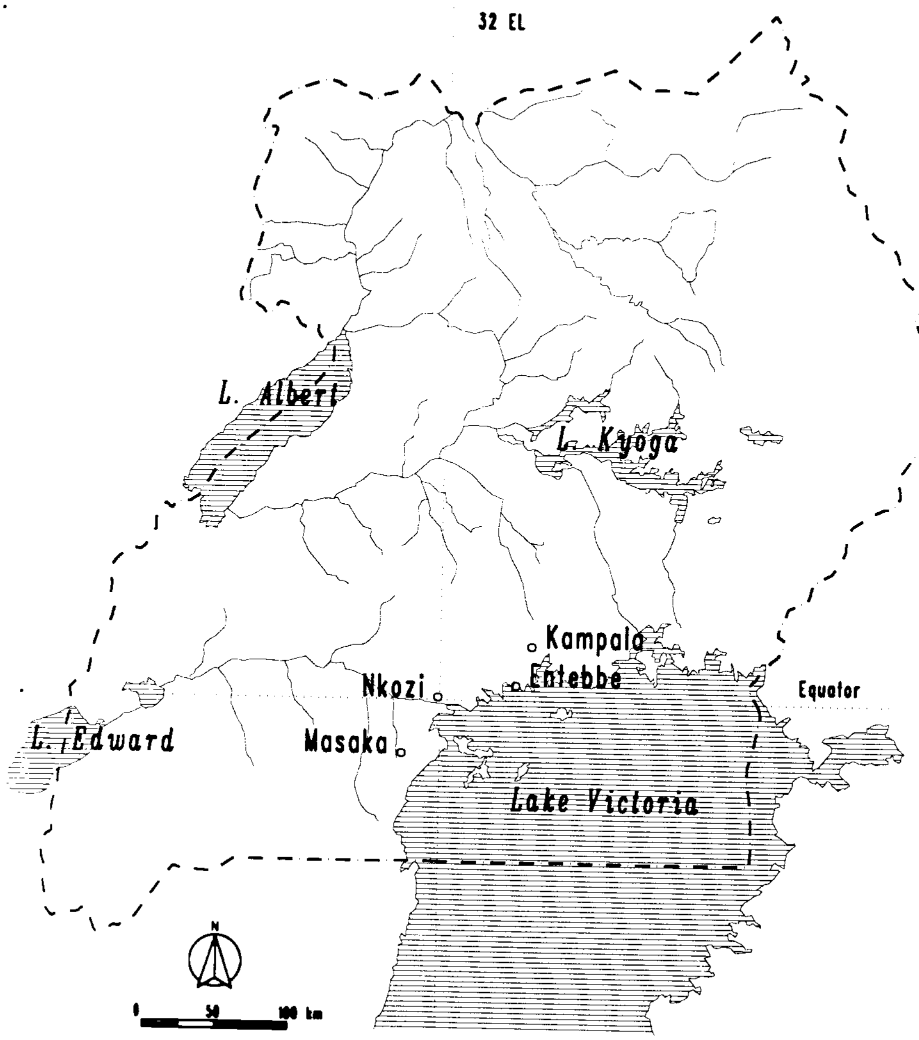


Figure 1 Location of Nkozi, Uganda

2.2 Climate

The climate in the region around Nkozi is marked by a decrease in rainfall away from lake Victoria (Figure 2). As no climatic data are available for Nkozi itself, inferences are made based on data of nearby stations. Annual average precipitation of 29 stations with at least 15 years of observations (30 years on average and between 20 and 25 years as a mode) was used to draw a precipitation map by spatial interpolation (Kriging). From this the average annual precipitation at Nkozi can be estimated to be around 1200 mm.

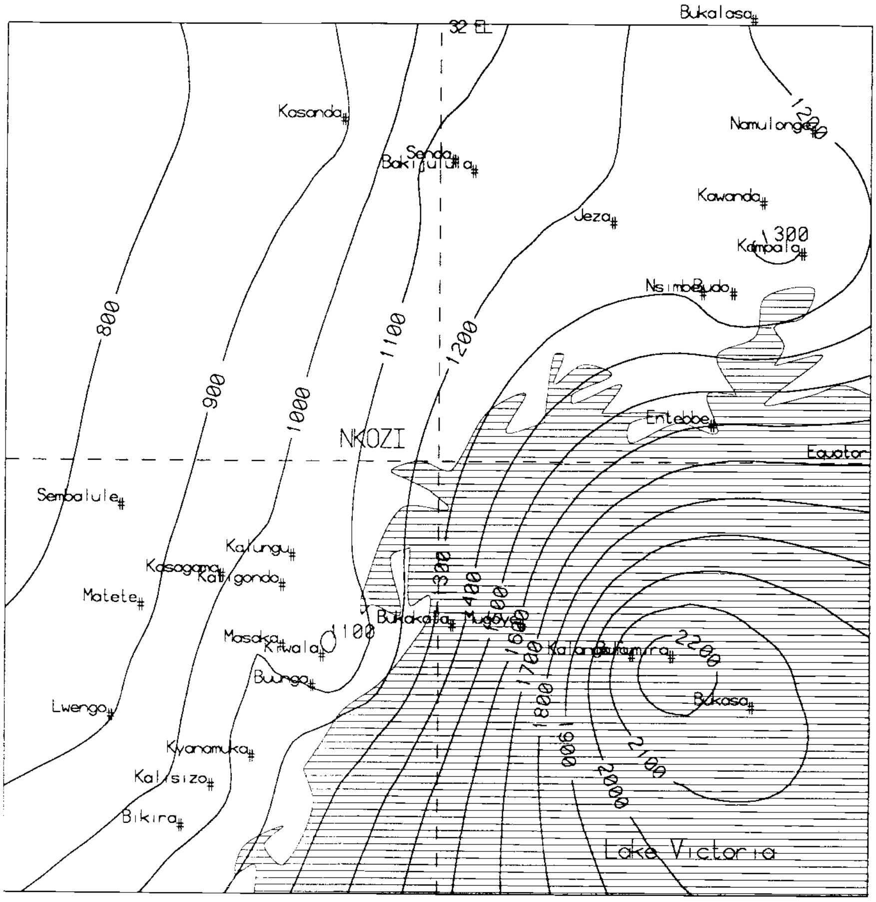


Figure 2 Average annual precipitation pattern around Nkozi (Uganda)

A frequency analysis of the monthly rainfall data recorded during the period 1966-1992, at Katigondo was done. This station falls within the same rainfall zone as Nkozi. The monthly average as well as the 25 and 75% probability range of exceedance are presented in Figure 3. Superimposed on the same graph are average monthly class A pan evaporation rates measured at the Kawanda agricultural station during the years 1969-1975.

The bi-modal rainfall distribution is evident from this data. Two humid periods occur each year: a first from April to May, a second from October to December. The precipitation being less than half the pan evaporation, the months June and July are truly dry. January and February, besides August and September are intermediate.

Temperature, much like evapotranspiration, is less variable over the months as compared to rainfall. The average and maximum-minimum ranges recorded at Kawanda station are presented in Figure 4 (period 1945-1970).

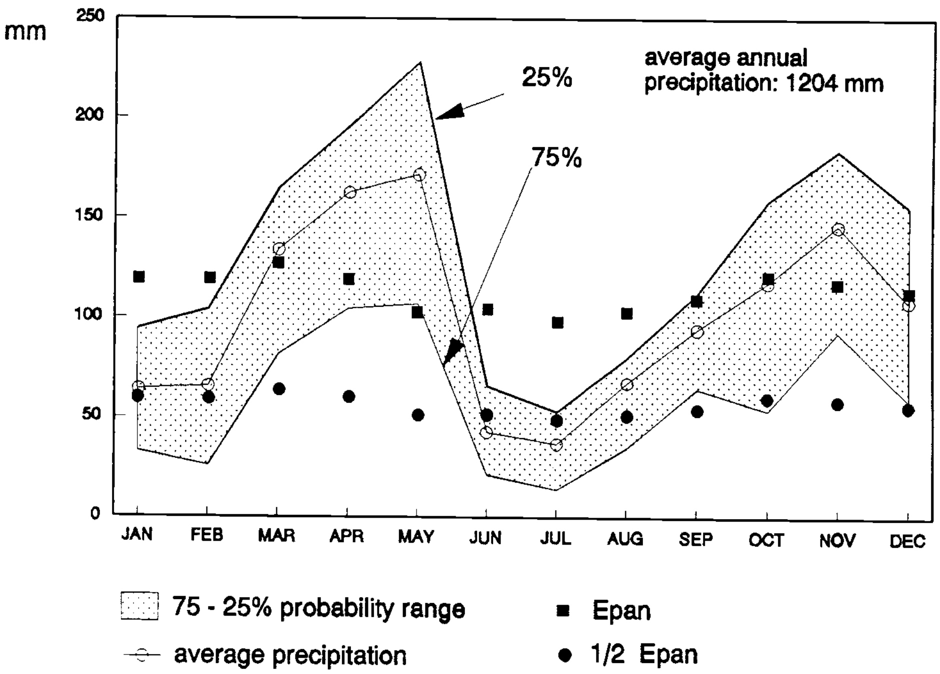


Figure 3 Monthly average rainfall, probability range of exceedance (Katigondo station) and pan evaporation (Kawanda station)

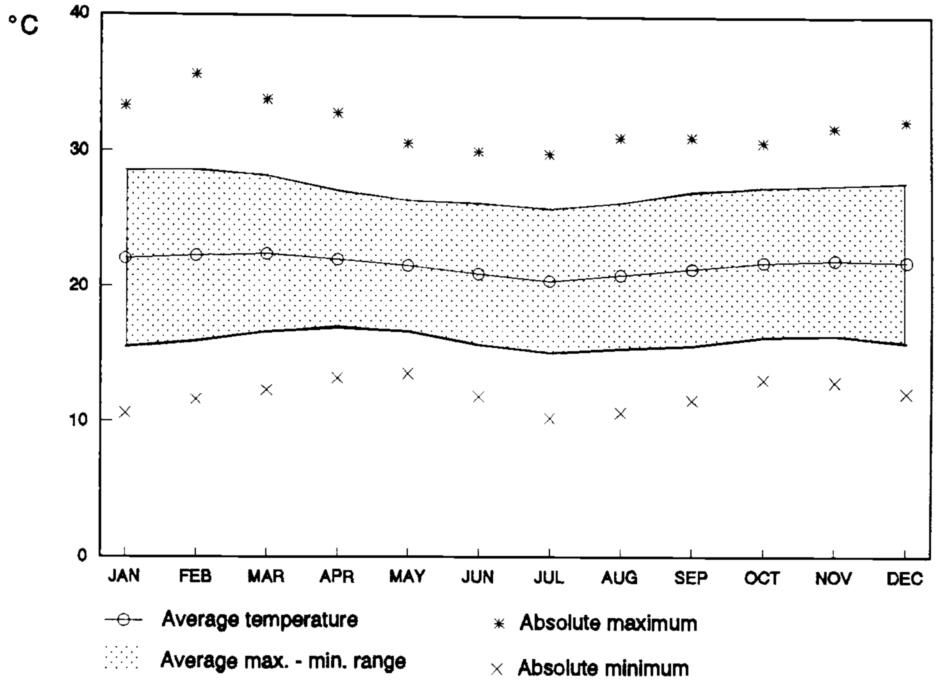


Figure 4 Average and maximum and minimum temperature at Kawanda station

2.3 Geology and geomorphology

The bedrock underlying Nkozi and its surroundings are predominantly muscovite-biotite gneisses (Johnson, 1960; GEOLOGICAL SURVEY OF UGANDA, 1961 & 1962) (Figure 5). These rock formations belong to the *Buganga Series* and date back to the pre-cambrium era. The valleys are partly filled by pleistocene lacustrine deposits from lake Victoria and partly by more recent alluvial deposits.

The landscape around Nkozi is that of an undulating hilly country, going from 1140 to 1250 m asl. Around Nkozi, two types of hills are found. The highest are flat-topped hills with concordant summit levels at about 1300 m (e.g. Kalagala-Nkozi hill and Wasozi hill). They are capped by ferricrite ("laterite[1]") with a relatively steep upper slope passing into a more gentle pediment slope. Another type are conical with a rounded top, as e.g. UMU-Nkozi hill. These hills are slightly steeper near the summit, but their flanks have a more gentle slope. They represent remnants of former flat-topped hills from which the ferricrite cap has degraded and are residues from a mid-tertiary erosion surface.

[1] *laterite* is a term that has been used by different authors to designate such a wide variety of things (going from a reddish soil to ironstone) that it is no longer used in modern soil classification systems.

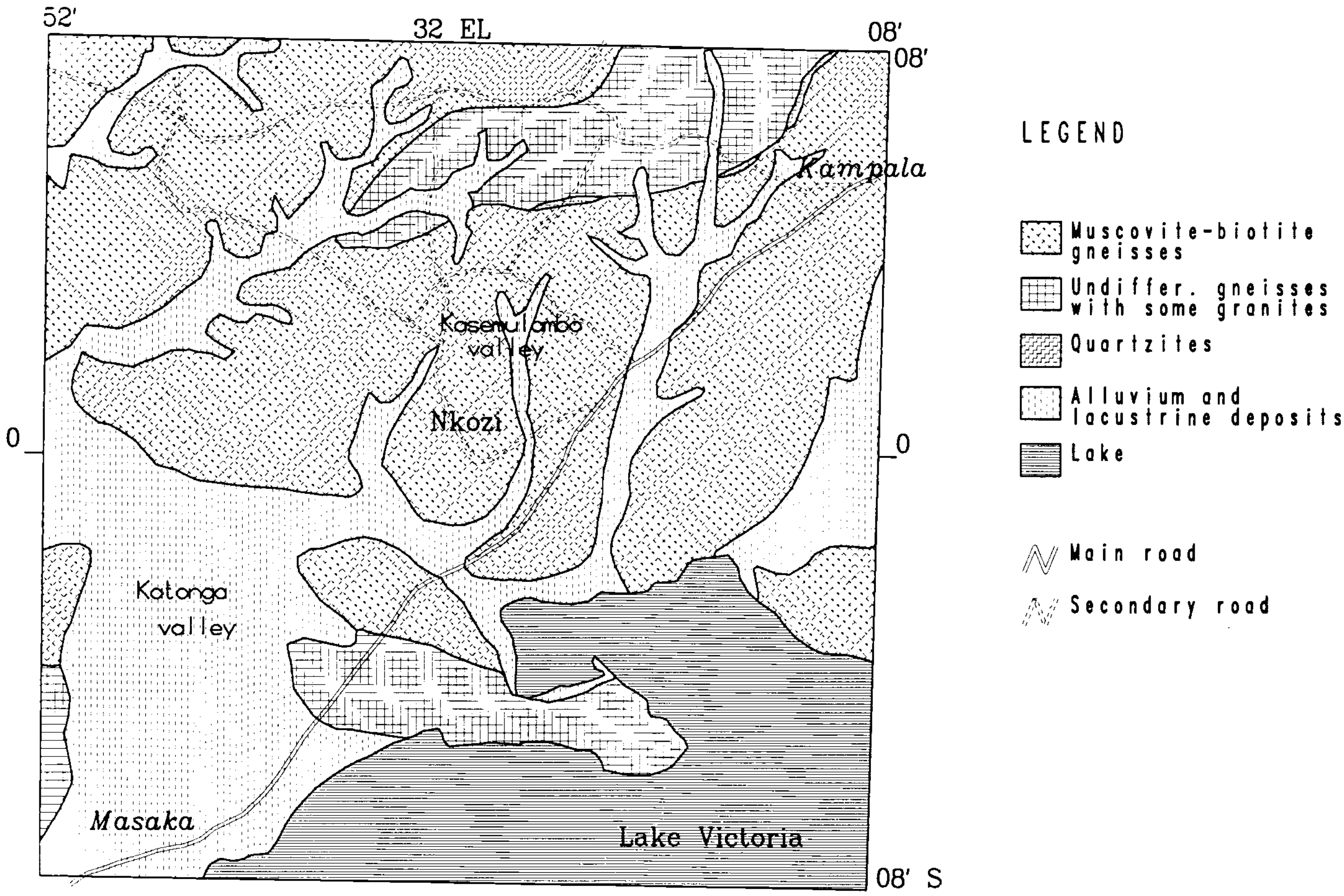


Figure 5 Main geological formations around Nkozi (adapted from: Geological Survey of Uganda, 1961 & 1962)

The surface was incised resulting into a end-tertiary erosion surface appearing as wide terraces. The actual drainage system was subsequently carved out on this end-tertiary erosion surface. The formation of lake Victoria and, subsequent changes in its level, silted up these broad valleys. The pattern of the river system is rectilinear and draining towards lake Victoria. The slope gradient being very low, the discharge of the rivers is equally relatively low. Just around Nkozi, the valleys are arranged north-south, while further to the west they are running north-east to south-west. Sandbars occur in some of the northern tributaries of the Katonge river, as e.g. in the Kasemulambo valley. These sandbars are aligned in an opposite direction to the present drainage (west-east), suggesting a prevailing south-easterly wind at the time of their formation. They were formed when the Katonga valley was part of a bay of lake Victoria.

2.4 Vegetation and land use

Major crops grown in the area are cooking bananas (*matoke*), beer bananas, maize, cassava, sweet potato and groundnuts. Some farmers have soya beans, but observed fields did not look very healthy. Magnesium deficiency was suspected in soya, while symptoms of phosphorus deficiency were often observed with maize (both on presumably *Ferralsols*). For many farmers, coffee (*C. robusta*) is an important cash crop. Popular fruit trees seem to be jackfruit, papaya, mango, besides sweet bananas. Bark-cloth trees are commonly found around the houses.

Natural vegetation seems to have survived on less favourable soils only. On sandy soils a shrub savanna vegetation has been preserved. On some of the clayey soils lemon grass dominates. Papyrus occupies the valley bottoms. Remainders of forest swamps are found on poorly drained mineral soils at the fringes of the valleys.

3 Soils

3.1 Survey procedure and laboratory methods

Two sets of aerial photographs were available during the field study: one from 1955 at an approximate scale of 1/39,000; and one from 1988 at an approximate scale of 1/29,000. The latter however did not cover the whole survey area and was partly shaded by clouds. The map was therefore primarily drafted based on the 1955 photographs. It was subsequently enlarged to 1/10,000 scale. Photographic enlargements of the national topographic maps (original scale 1/50,000) were used as a planimetric base.

After a first reconnaissance walk through the area, a preliminary interpretation of the aerial photographs was made. From this two transect lines were identified along which augerings were made, the location of which were selected according to the landform units (transects A and B). Based on this data, seven representative soil profile pits were identified for detailed analyses. Soil mapping boundaries were later adjusted based on additional augerings (transect C). In total 35 augerings were made.

Soil samples of seven representative profiles were analyzed at the Kawanda Agriculture Research Station on:

- texture (hydrometer method), and presented according to the USDA soil texture classes
- pH(H_2O 1:1) and pH(1N KCl 1:1)
- organic matter (Walkley and Black method)
- total nitrogen (macro Kjeldahl method)
- exchangeable bases and available phosphorus: Ca, Mg, K , Na and P were extracted with ammonium lactate acetic acid. Concentration of Ca, K and P were determined by flame photometry, of Mg and Na by atomic absorption spectrophotometry.
- cation exchange capacity (leaching with sodium acetate, at pH 8.2) and subsequently with ammonium acetate and, determination of the sodium.

At the Institute for Land and Water Management (KU Leuven), analyses were done on 24 core samples for the determination of saturated hydraulic conductivity, bulk density and moisture retention of six profiles (sand table method, pressure membrane method). Apart from one profile (NKZ-2) duplicate samples were taken from the surface horizon

(0-30 cm) and from a subsurface horizon at a depth of around 50 cm. NKZ-2 being a very deep profile single samples were taken at 0-20, 20-40 and 80-100 cm depth.

3.2 Mapping units

The mapping units are delineated through aerial photograph interpretation and field observation. They are defined as a combination of landform units and soil units.

3.2.1 Landform units

The landform units are demarcated on the basis of relief features in relation to the geomorphology (see section 2.2). These units were readily recognised on the aerial photographs. The landform units are:

- hill top;
- summit slope: the slopes towards the conical hill summit;
- hill ridge (erosion surface I);
- intermediate slopes: the slopes between or, at the fringe of the erosional surfaces;
- erosional terrace: the remainder of the end-tertiary erosion surface (erosion surface II);
- foot slopes: at the interface of the erosional surface II and the lacustrine terrace;
- lacustrine terrace;
- slope of the lacustrine terrace: the eroded parts of the lacustrine terrace towards the actual valley bottom;
- valley bottom: the flat part of the valley.

3.2.2 Soil units

The soils units were identified on the basis of the field observations (auger pit and soil profile pits). Soils were classified according to the FAO/Unesco legend (FAO, 1988). The occurrence of the specific soil units is closely related to the geological base and the geomorphology as can be seen in Figure 6 and Figure 7. It should however be noted that the number of observations on the pre-cambrian material is low. This was justified as most of the UMU farmland is located on the lacustrine terrace or on alluvium in the valley. The general characteristics of the various soil units and their location and extend are discussed below. For the exact definitions of the soil units reference is made to FAO (1988). The area of the soil units are presented in Table 1.

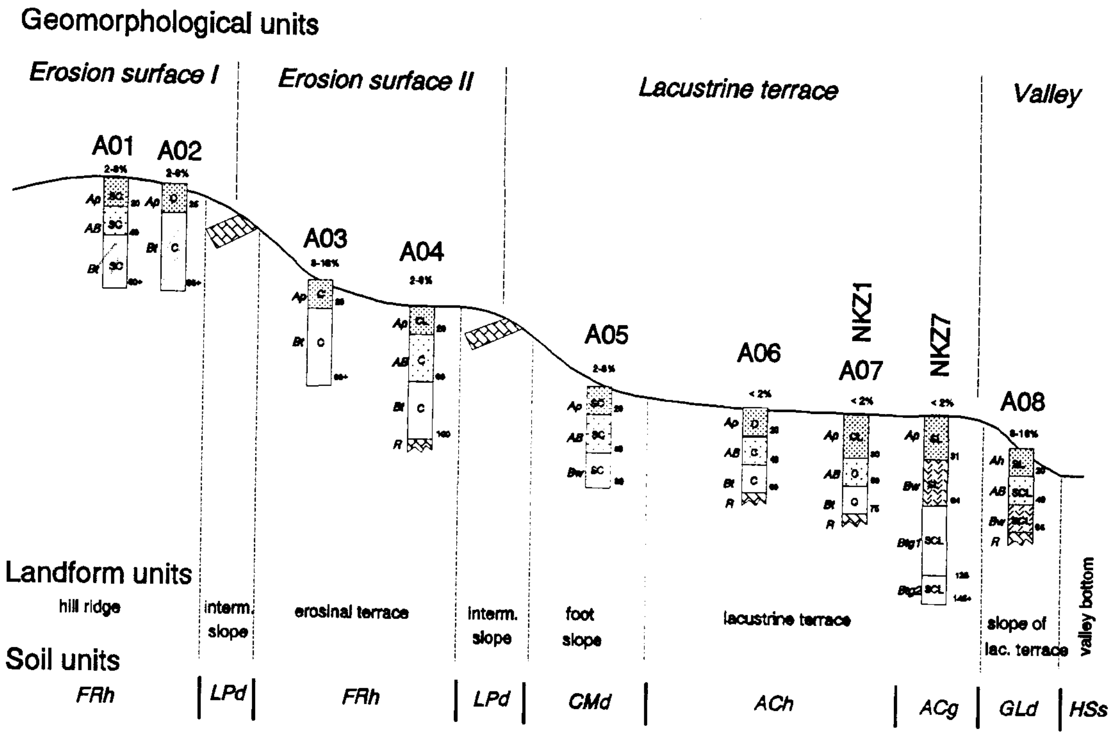


Figure 6 Landform and soil units along transect A

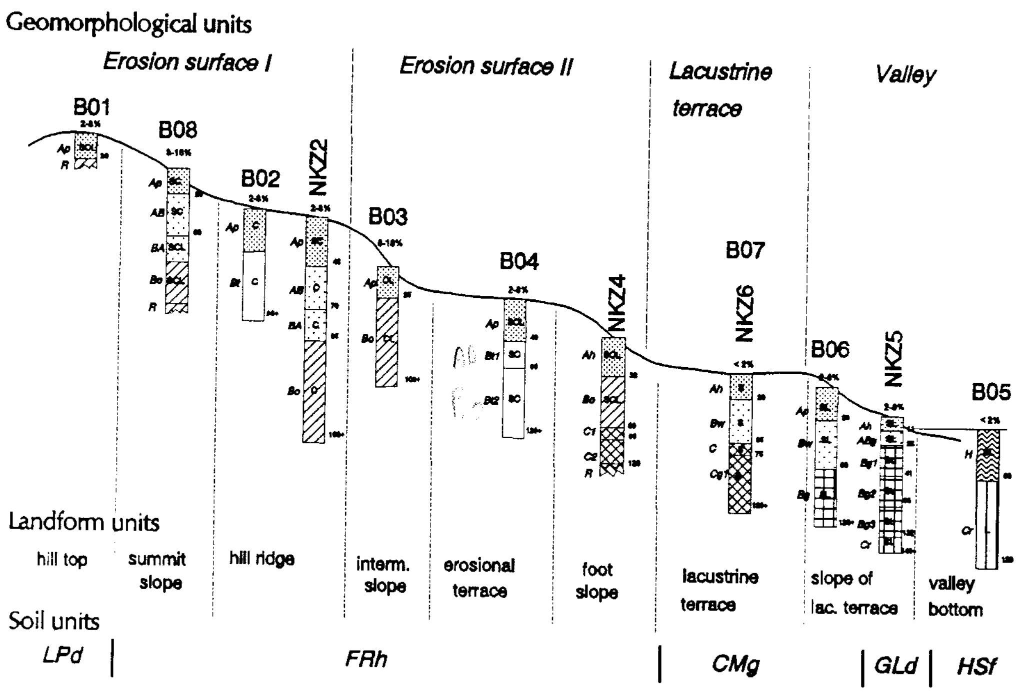


Figure 7 Landform and soil units along transect B

Key: FRh: *Haplic Ferralsols*; LPd: *Dystric Leptosols*; CMd: *Dystric Cambisols*; CMg: *Gleyic Cambisols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; GLd: *Dystric Gleysols*; HSs: *Terric Histisols*; HSf: *Fibric Histosols* *i* *General characteristics and distribution of the soil units*

Dystric Leptosols (LPd) are shallow or very stony soils (less than 30 cm deep) and with a low base saturation. They are found on the top of the UMU-Nkozi hill where they are very gravelly (quartz and ironstone). They are also found on the southern intermediate slopes, underlain by ferricrete. On UMU farmland they are found close to the hill top but occupy less than 1% of the total farmland.

Haplic Ferralsols (FRh) are well drained reddish soils with a strongly weathered sub-surface horizon. This implies that they are rich in kaolinite clay besides iron and aluminium sesquioxides. The surface soil texture is either sandy clay or sandy clay loam. They are found on the old erosional surfaces, as well as on the intermediate slopes. On the lowest parts of which they may be limited in depth by bedrock at about 1 meter. On UMU farmland they are found on the summit slopes, the hill ridge and on foot slopes and represent 5% of the farmland.

Haplic Acrisols (ACh) are well drained acid soils with a sub-surface horizon having a higher clay content than the surface horizon. They are found on the lacustrine terrace (south-east of Nkozi-Kayabwe road). The surface soil texture is sandy clay loam. These soils are limited in depth by underlying quartz bedrock at 70 to 80 cm. They occupy 12% of the farmland.

Gleyic Acrisols (ACg) are imperfectly drained acid soils with a sub-surface horizon having a higher clay content than the surface horizon. They are found on the southern part of the lacustrine terrace. The surface soil texture is predominantly sandy loam. They cover only 2.6% of the farmland.

Dystric Cambisols (CMd) are well drained acid soils, with sub-surface horizons lacking clear accumulation from the surface layers (e.g. of clay). They are found on the southern foot slopes, at the fringe of the pre-cambrium material and the erosional terrace. The surface soil texture is sandy clay. Bedrock may occur at a depth 80 cm. They only represent a small area of the farmland (3 ares).

Gleyic Cambisols (CMg) are imperfectly drained soils with sub-surface horizons lacking clear accumulations from the surface layers (e.g. of clay). They are found on the sandy parts of the lacustrine terrace. Surface soil texture is sand for the largest part of them, and is sandy loam on its slopes in the neighbourhood of the pump house. Covering 24% of the farmland they are the second most important soil unit.

Dystric Gleysols (GLd) are poorly drained soils with a low base saturation. They are found at the fringes of the lacustrine terrace and the valley bottom and often under forest swamp. They cover 11% of the farmland.

Fibric Histosols (HSf) are very poorly drained soils, of raw or weakly decomposed organic materials. They occupy the largest parts of the papyrus swamps. The augerings indicated that they often consist of about one meter of floating organic debris. This is the most common soil unit and covers 30% of the farmland.

Terric Histosols (HSs) are very poorly drained organic soils, of highly decomposed organic materials. They are found in the southern tip of the farmland in the valley bottom. Vegetation consists of an association of papyrus and a swamp palmtree. Mineral soil is found at a depth of 80 cm. They cover 16% of the farmland.

Table 1 Area (ha) of the soil units according to landform units on UMU farmland

Landform units	Soil units[a]									**Total**
	LPd	FRh	ACh	ACg	CMd	CMg	GLd	HSf	HSs	
Hill top	0.16	—	—	—	—	—	—	—	—	0.16
Summit slope	—	2.2	—	—	—	—	—	—	—	2.2
Hill ridge	—	5.8	—	—	—	—	—	—	—	5.8
Foot slope	—	6.8	—	—	0.03	—	—	—	—	6.9
Lacustrine terrace	—	—	34.7	7.6	—	59.8	—	—	—	102.1
Slope of lac. terrace	—	—	—	—	—	9.2	31.9	—	—	41.1
Valley bottom	—	—	—	—	—	—	—	86.5	45.4	132.0
Total	0.16	14.8	34.7	7.6	0.03	69.0	31.9	86.5	45.4	290.1

[a] LPd: *Dystric Leptosols*; FRh: *Haplic Ferralsols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; CMd: *Dystric Cambisols*; CMg: *Gleyic Cambisols*; GLd: *Dystric Gleysols*; HSf: *Fibric Histosols*; HSs: *Terric Histosols*

3.3 Soil properties

3.3.1 *Physical properties*

The physical properties of the seven reference profiles are summarised in Table 2 for the topsoil (the surface horizon) and the subsoil (horizon around 50 cm). The complete data set is presented in Appendix C.1. Rooting depth of the *Haplic Ferralsols* (FRh) is limited on the foot slope (NKZ-4) where it is underlain by ferricrete layer. Quartzite rocks are underlying the *Haplic Acrisols* (ACh), represented by profile NKZ-1. The sandy *Gleyic Cambisols* (CMg), such as profile NKZ-6, had a gravel layer around 75 cm. Infiltration capacity of the clayey soils is reasonably high indicating a well developed soil structure, and is excessively high in the sandy soils (NKZ-6). The soil profiles with sandy loam texture (NKZ-3 and -7) have the highest water storage capacity.

3.3.2 *Chemical properties*

The chemical characteristics([1]) of the studied profiles are presented in Table 3. As a matter of simplification — and analogous to the physical properties — they are summarised for the topsoil (the surface horizon), and the subsoil (horizon around 50 cm). The full data set is given in Appendix C.2.

The soils are all moderately to very acid (pH:H_2O 4.4 - 5.9), except the *Haplic Ferralsols* (FRh) profile located on the hill crest (NKZ-2) which is slightly acid (pH:H_2O 5.9 - 6.5). This profile is located close to the university buildings. Soils in this area have most likely been under cultivation for many years. This seems to have had a positive influence on their chemical fertility status. This soil profile has the highest base saturation and very high phosphorus levels. Phosphorus levels are high (26 ppm) in the topsoil of the *Dystric Gleysols* (NKZ-5), and are medium (6 - 9 ppm) for the *Haplic* and *Gleyic Acrisols* (NKZ-1, NKZ-7). They are very low in the other soils. Calcium values remain low (2.5 - 2.9 cmol+/kg soil) in the *Haplic Ferralsols* on the hill ridge (NKZ-2), but are very low in all the other profiles. Medium levels (1.54 - 1.71 cmol+/kg soil) are found for magnesium in NKZ-1 and NKZ-2, whereas they are low to very low in the other profiles. Again high levels (0.85 - 1.48 cmol+/kg soil) are found in NKZ-2 for potassium and medium levels (0.33 - 0.43 cmol+/kg soil) in NKZ-1 and NKZ-5. Sodium levels are low to very low in all sampled horizons except in the subsoil of NKZ-2.

[1] Results of the nitrogen analyses were found unreliable and are therefore left out of this discussion.

Table 2 Summary of the physical properties of the soil profiles

	Soil units[a]						
	FRh		ACh	ACg	CMg		GLd
Profile	NKZ-2	NKZ-4	NKZ-1	NKZ-7	NKZ-3	NKZ-6	NKZ-5
Rooting depth (cm)	>100	80	69	>100	>100	75	>100
Texture							
Topsoil							
Class[b]	SCL	SCL	SCL	SL	SL	S	SL
%Clay	25	23	27	9	11	5	11
%Silt	12	4	14	18	20	6	16
%Sand	63	73	59	73	69	89	73
Silt/clay ratio	0.48	0.17	0.52	2.00	1.82	1.20	1.45
Subsoil							
Class	SC	SCL	SC	SCL	SL	S	SL
%Clay	45	33	43	25	13	7	19
%Silt	8	6	10	12	20	4	12
%Sand	47	61	47	63	67	89	69
Silt/clay ratio	0.18	0.18	0.23	0.48	1.54	0.57	0.63
Infiltration (Ksat mm/h)							
Topsoil (average ± std)	64	41 ± 6	89 ± 13	140 ± 48	142 ± 6	386 ± 111	—
Subsoil (average ± std)	11	328 ± 180	45	33 ± 6	13 ± 4	976 ± 142	—
Bulk density (g/cm3)							
Topsoil	1.5	1.6	1.4	1.4	1.2	1.5	—
Subsoil	1.4	1.4	1.6	1.6	1.5	1.6	—
Porosity (%Vol.)							
Topsoil	40	38	46	45	51	36	—
Subsoil	43	42	40	35	45	39	—
Storage capacity (%Vol.)							
Topsoil	11	9	12	15	20	9	—
Subsoil	10	10	6	14	19	7	—

[a] FRh: *Haplic Ferralsols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; CMg: *Gleyic Cambisols*; GLd: *Dystric Gleysols*

[b] S sand; SC sandy clay; SL sandy loam; SCL sandy clay loam

Table 3 Summary of the chemical characteristics of the soil profiles

Landform Unit	Soil Unit	Profile[b]	Horizon	pH (H_2O)	pH (KCl)	OM[a] (%)	P (ppm)	Ca	Mg	K	Na	CEC	TEB	BS (%)
								<-----	-----	cmol+/kg soil	-----	-----	----->	
Hill ridge	FRh	NKZ-2	Topsoil	5.9	5.7	4	550	2.5	1.58	0.85	0.04	11.0	5.0	45.2
			Subsoil	6.5	6.0	1.1	26	2.9	1.54	1.48	0.39	7.6	6.3	83.0
Foot slope	FRh	NKZ-4	Topsoil	4.4	4.3	2.1	1	0.2	0.17	0.10	0.08	3.0	0.6	18.3
			Subsoil	4.6	4.3	0.7	0	0.1	0.13	0.05	0.04	0.6	0.3	53.3
Lacustrine terrace	ACh	NKZ-1	Topsoil	5.6	5.2	4.4	6	0.7	1.71	0.33	0.08	9.4	2.8	30.0
			Subsoil	4.9	4.3	2.4	15	0.3	1.58	0.15	0.08	8.4	2.1	25.1
	ACg	NKZ-7	Topsoil	4.9	4.6	2.4	9	0.3	0.38	0.10	0.08	3.6	0.9	23.9
			Subsoil	4.6	4.5	1.1	0	0.1	0.25	0.07	0.04	9.1	0.5	5.1
	CMg	NKZ-3	Topsoil	4.7	4.2	3.7	4	0.3	0.29	0.13	0.04	6.0	0.8	12.7
			Subsoil	4.6	4.3	1.2	0	0.1	0.13	0.07	0.04	3.2	0.3	10.6
Slope of lacustrine terrace	CMg	NKZ-6	Topsoil	4.6	4.5	1.9	3	0.3	0.17	0.18	0.08	5.1	0.7	14.3
			Subsoil	5.9	4.7	0.2	0	0.4	0.17	0.28	0.13	7.4	1.0	13.2
	GLd	NKZ-5	Topsoil	4.7	3.9	7.1	26	0.6	0.38	0.43	0.13	6.6	1.5	23.3
			Subsoil	5.1	5.0	1.2	0	0.1	0.29	0.03	0.00	0.8	0.4	52.5

[a] OM organic matter; CEC cation exchange capacity; TEB total exchangeable bases (Ca+Mg+K+Na); BS base saturation = 100 TEC/CEC

[b] FRh: *Haplic Ferralsols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; CMg: *Gleyic Cambisols*; GLd: *Dystric Gleysols*

4 Land evaluation

In this section, an attempt is made to rank the soil units in terms of suitability for a number of land uses. The list of crops was provided by the farm manager and includes crops which are considered to have a good potential for the development of the farm. All of these crops are to some extend grown in the region, hence the climatic environment can be considered adequate.

4.1 Land qualities

Land qualities are complex attributes of the land which directly influences the land suitability. Land qualities considered here are: texture, rooting depth, chemical fertility, pH and drainage status. Most of these can be interpreted directly from the soil properties. A fertility class was determined by computing a fertility index *FI* as:

$$FI = \sum_{i=1}^{i=n} W_i \; P_i \; BS_i$$

where i is an index for the horizons, and n the number of horizons
W_i is a weight factor for horizon i as a function of its thickness
P_i the corresponding phosphorus content and
BS_i the corresponding base saturation.

The interpretation given to the land qualities is presented in Table 4. As the dominant clays are of the kaolinite type, which have a better workability than other types of clays (e.g. smectite clays), the clayey soils are taken as "medium" textured.

Table 4 Land qualities of the land units

Landform unit	Soil unit[a]	Profile	Texture	Drainage status	Rooting depth	pH	FI	Fertility class
Hill ridge	FRh	NKZ-2	medium	well	deep	5.9	7451	very high
Lacustrine terrace	ACh	NKZ-1	medium	well	moderate	5.6	153	high
Slope of lacustrine terrace	GLd	NKZ-5	light	poorly	deep	4.7	79	moderate
Lacustrine terrace	ACg	NKZ-7	light	well	deep	4.9	69	moderate
Slope of lacustrine terrace	CMg	NKZ-6	light	imperfectly	moderate	4.7	13	low
Lacustrine terrace	CMg	NKZ-3	light	imperfectly	deep	4.7	9	low
Foot slope	FRh	NKZ-4	medium	imperfectly	moderate	4.4	8	low

[a] FRh: *Haplic Ferralsols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; CMg: *Gleyic Cambisols*; GLd: *Dystric Gleysols*

4.2 Crop/soil requirements

The crop/soil requirements derived from literature are presented in Table 5.

Table 5 Soil requirements of envisaged crops for the UMU-farm

Crop	Texture	Minimum rooting depth (cm)	Fertility	pH	Drainage status
Maize	medium	60 - 90	high	5.5 - 7.5	well
Sorghum	heavy to light	60 - 90	medium	4.5 - 8.5	imperfectly
Banana	medium to light	> 90	high	5.5 - 8.0	well
Cassava	medium to light	> 90	medium	5.5 - 6.5	well
Cocoyam	medium to light	> 90	high	5.5 - 6.5	poorly
Irish potato	medium to light	60 - 90	high	4.5 - 6.0	imperfectly
Bean	medium to light	60 - 90	medium	5.5 - 7.5	well
Castor bean	medium to light	60 - 90	high	5.5 - 7.5	well
Groundnut	medium to light	60 - 90	medium	6.0 - 8.0	well
Soya bean	medium to light	60 - 90	medium	5.5 - 7.0	imperfectly
Sunflower	medium to light	60 - 90	medium	6.0 - 7.5	imperfectly
Cabbage	medium	30 - 60	high	6.0 - 7.5	well
Carrot	medium to light	30 - 60	high	6.0 - 7.5	well
Onion	medium	30 - 60	high	6.0 - 7.5	well
Tomato	medium	60 - 90	high	5.0 - 7.0	well
Pasture	heavy to medium	30 - 60	medium	5.0 - 8.0	poorly
Citrus	medium	> 90	high	5.0 - 8.0	well
Papaya	medium	> 90	high	6.0 - 6.5	well
Passion fruit	medium to light	60 - 90	high	5.5 - 7.5	imperfectly
Pineapple	medium to light	60 - 90	medium	5.5 - 6.5	well
Water melon	medium	60 - 90	high	6.5 - 7.5	well

Source: adapted from EUROCONSULT (1989)

4.3 Crop/soil suitability

Crop/soil suitability scores were calculated using the parametric method (Driessen and Konijn, 1992). This was done by attributing a rating (ranging from 1 to 0.5) to each of the land qualities for each crop. When a particular crop/soil requirement is met a rating of 1 was given to that land quality, else a lower rating was given, depending on the limitation. These ratings were multiplied by each other yielding a final score, which was finally used to classify the profiles as in Table 6. Based on this data, a crop/soil suitability map has been drawn (Figure 8).

Table 6 Crop/soil suitability to the reference profiles

Crop	Soil unit[a]/Soil profile						
	FRh		ACh	ACg	CMg		GLd
	NKZ-2	NKZ-4	NKZ-1	NKZ-7	NKZ-3	NKZ-6	NKZ-5
Maize	S1[b]	S3	S1	S3	N2	N2	S3
Sorghum	S1	S3	S1	S1	S2	S2	S2
Banana	S1	N1	S2	S3	N1	N2	N1
Cassava	S1	N1	S2	S2	S3	N1	S3
Cocoyam	S1	N1	S2	S3	S3	N1	N1
Irish potato	S2	N1	S2	S3	S3	S3	S3
Bean	S1	S3	S1	S2	N1	N1	S3
Castor bean	S1	S3	S1	S3	S3	S3	N1
Groundnut	S2	S3	S2	S2	S3	S3	S3
Soya bean	S1	S3	S1	S2	S3	S3	S3
Sunflower	S2	S3	S2	S2	N1	N1	S3
Cabbage	S2	S3	S2	S3	N2	N2	N1
Carrots	S2	S3	S2	S3	S3	S3	N1
Onion	S2	S3	S2	S3	N2	N2	N1
Tomato	S1	S3	S1	S3	N2	N2	N1
Pasture	S1	S3	S1	S2	N2	N2	S3
Citrus	S2	N2	S3	N1	N2	N2	N1
Papaya	S2	N1	S3	S3	N2	N2	N1
Passion fruit	S1	S3	S1	S3	S3	S3	N1
Pineapple	S1	S3	S1	S2	N1	N1	S3
Water melon	S2	S3	S2	S3	N2	N2	N1

[a] FRh: *Haplic Ferralsols*; ACh: *Haplic Acrisols*; ACg: *Gleyic Acrisols*; CMg: *Gleyic Cambisols*; GLd: *Dystric Gleysols*

[b] S1 highly suitable; S2 suitable; S3 moderately suitable; N1 not suitable; N2 highly unsuitable

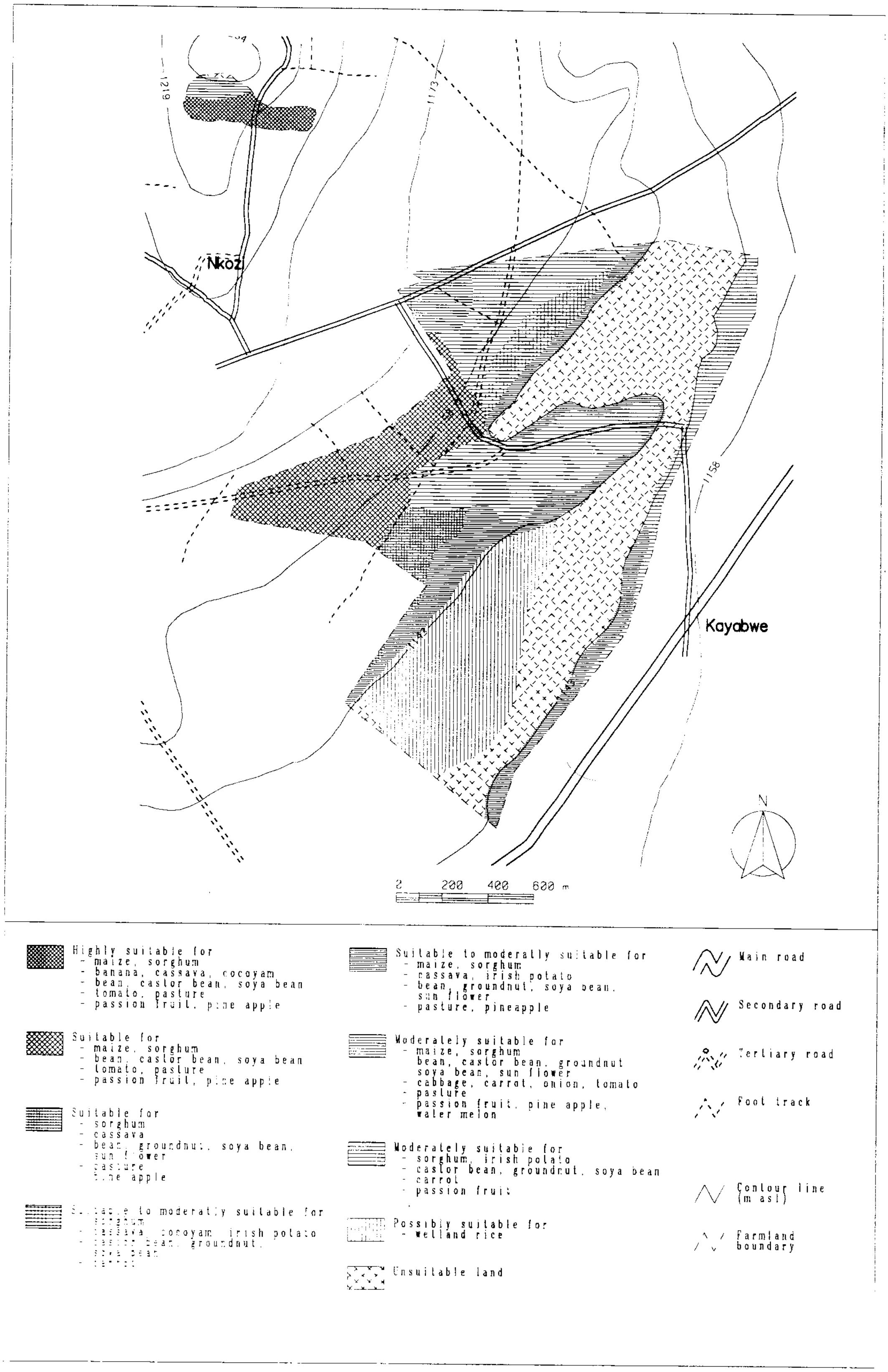


Figure 8 Crop/soil suitability map for the UMU-farm

It should be emphasized that this approach only provides a first approximation. Nevertheless it allows for some interesting observations:

i. The soils identified as *Haplic Ferralsols* (FRh) seem to entail the "best" (NKZ-2) and almost the "worst" (NKZ-4) soils. The former are soils located on the hill ridge, and are indeed most intensively used by the farmers in the area. These soils have probably been enriched as a result of the farming practises. This gives some scope for improving similar soils located at the foot slope, as NKZ-4.

ii. The *Haplic Acrisols* (ACh) and *Gleyic Acrisols* (ACg) rank the second (NKZ-1) and third (NKZ-7) best. The good rating of NKZ-1 is a consequence of its higher fertility status. The main disadvantage of NKZ-1 is its depth limitation. Profile NKZ-7 has a lower fertility status.

iii. The *Gleyic Cambisols* seem only (moderately) suited for less demanding crops as e.g. sorghum, cassava, and castor bean. The good water holding capacity of the sandy loam soils (as NKZ-3) may however give some perspective for improving these soils with appropriate management. This will definitely be more difficult in the sandy ones (as NKZ-6).

iv. The low ratings obtained for the *Dystric Gleysols* is on one hand due to its low fertility status and to the poor drainage condition. In the dry season however these soils are useful for growing vegetables.

v. The *Histosols* have been left out in this discussion, as these peat soils seem to be too problematic. They are extremely poorly drained, in the largest part only consist of floating papyrus. Trying to take this land into cultivation will require expensive drainage works, possibly even poldering, as they may come under the level of lake Victoria. Fish ponds may be a feasible vocation for this land. The *Terric Histosols* may possibly be used for wetland rice cultivation. This would however entail slashing of the papyrus and planting of rice on this peaty soils. Which would be very labour demanding and probably not worth the effort.

4.4 Potential for irrigation

The question was raised whether it would be feasible to embark on irrigation. As the development of an irrigation scheme involves relatively high investments cost, this usually only pays off, in situations where there is :

- drought stress during a part of the year;
- a source with ample water supply;
- relative scarcity of land; and
- good market opportunities for high value crops (e.g. for vegetables).

As discussed in section 2.2, the dry season in Nkozi is rather short: only the months of June and July are really dry. So drought stress will not be that pronounced. Sufficient irrigation water can be taken from the swamps, all depending on available pump capacity. Land may once become a constraint, as the university farm is confined to a limited area, a large part of which is not or marginally suitable for agriculture. Considering development costs, surface irrigation and pitcher irrigation seems to be the most appropriate methods for the UMU farm. Technically, pressurised irrigation may also be feasible on the sandy loam soils (as NKZ-3 and NKZ-7).

i. Surface irrigation. Considering the topography only part of the lacustrine terrace mapped as sandy clay loam *Haplic Acrisols* are suited for surface irrigation. This will require digging out of canals, and the installation of a pump. Other areas on the lacustrine terrace are either to sandy, resulting in high infiltration losses, or have too steep slopes. As indicative values, the gross irrigation requirements for five of the potential crops are presented in Table 7. These calculations were made for the sandy clay loam *Haplic Acrisols* (with NKZ-1 as reference), using the software programme *CROPWAT* (FAO, 1991). The planting date for the arable crops was chosen at the end of the rainy season.

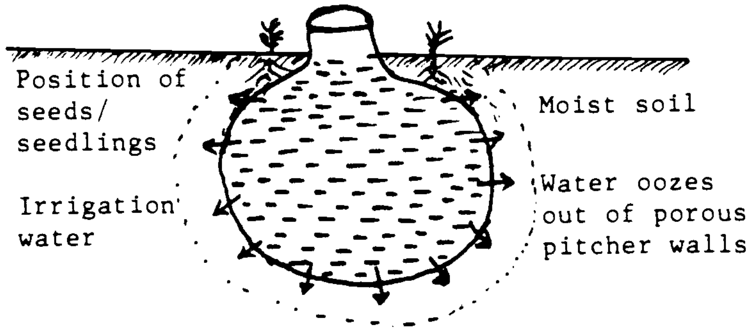
Table 7 Irrigation water requirements at Nkozi for five potential crops

Crop	Planting date	Harvesting date	Gross irrigation requirement (mm/ha/season)	Peak demand (m3/ha/application)
Pasture	1st Mar.	1st Mar.	989	360
Citrus	1st Mar.	1st Mar.	691	270
Maize	14th May	14 Oct.	416	370
Soya bean	14th May	4 Oct.	326	300
Groundnut	14th May	24 Sep.	284	250

Effective rainfall was assumed to be 70% of the average rainfall. Maximum rooting depth is taken as 70 cm, and irrigation intervals are set at once a week. Under these conditions it can be seen that the highest peak demand will be 370 m^3/ha/day for maize([1]). This gives an idea of the required pump capacity. The pump actually supplying the campus would probably not be sufficient for irrigating up to one hectare.

ii. Pitcher irrigation (Figure 9) is a simple and efficient way to provide localised subsurface irrigation, which was developed in India (Chhabra, 1990). It consists of an earthen pot, known as pitcher, which is buried in the soil. Through the pores, the water oozes out and wets the soil in the vicinity of the pitcher. It is particularly fitted for seedlings or for vine crops which are planted at relative large interdistance, as melons and passion fruits. At Nkozi it may particularly be worth to try out this technic either on the clayey *Haplic Acrisols* or on the sandy loam *Gleyic Cambisols.*

[1] Note that basic domestic water needs can be met with 100 litre per person per day. Thus 370 m3 or 370.000 litre, is equivalent to the domestic water demand of 3700 persons.



Source: Chhabra (1990)

Figure 9 Schematic diagram showing functioning of pitcher irrigation

5 Recommendations

5.1 Land-use options

The question rises now on "what to do where" on the farm. A clear-cut answer is not possible without having set the priorities for development of the farm. The objectives, as spelled out in the introduction, of self-reliance in food production and being an income maker, are to some extend conflicting.

Most realistic seems to focus on not more than a few production systems, for which the actual — and possible future — staff is most competent or interested in. At this stage this is clearly the case for the poultry (layers and broilers) and for the dairy cattle. Two other potential activities for which an interest exists, are:

- passion fruit for making juice concentrate or wine; and
- bee keeping.

It can be expected that with the expansion of the university campus, the farmland on the Nkozi hill will largely be taken up for buildings. This will leave only the land on the lacustrine terrace to the farm. A scenario for developing this land could be — as presented in Figure 10:

- to allocate part of the *Haplic* and *Gleyic Acrisols* to produce part of the poultry feed (e.g. maize, sorghum); and
- to establish some good pasture land on part of these soils;
- to develop a passion fruit plantation on the sandy loam *Dystric Cambisols*; which will give a lot of flowers, ideal for honey bees;
- to construct buildings (e.g. poultry houses, stables, etc.) on the poorest soils which are the sandy *Gleyic Cambisols*. Part of this land can also be used as extensive grazing areas, which in the rainy season may provide a good alternative to the pastures on the clayey *Haplic* and *Gleyic Acrisols*;
- to grow vegetables on the *Dystric Gleysols*, during the dry season. As long as there is still ample of this land available, developing irrigation schemes should not have a high priority.

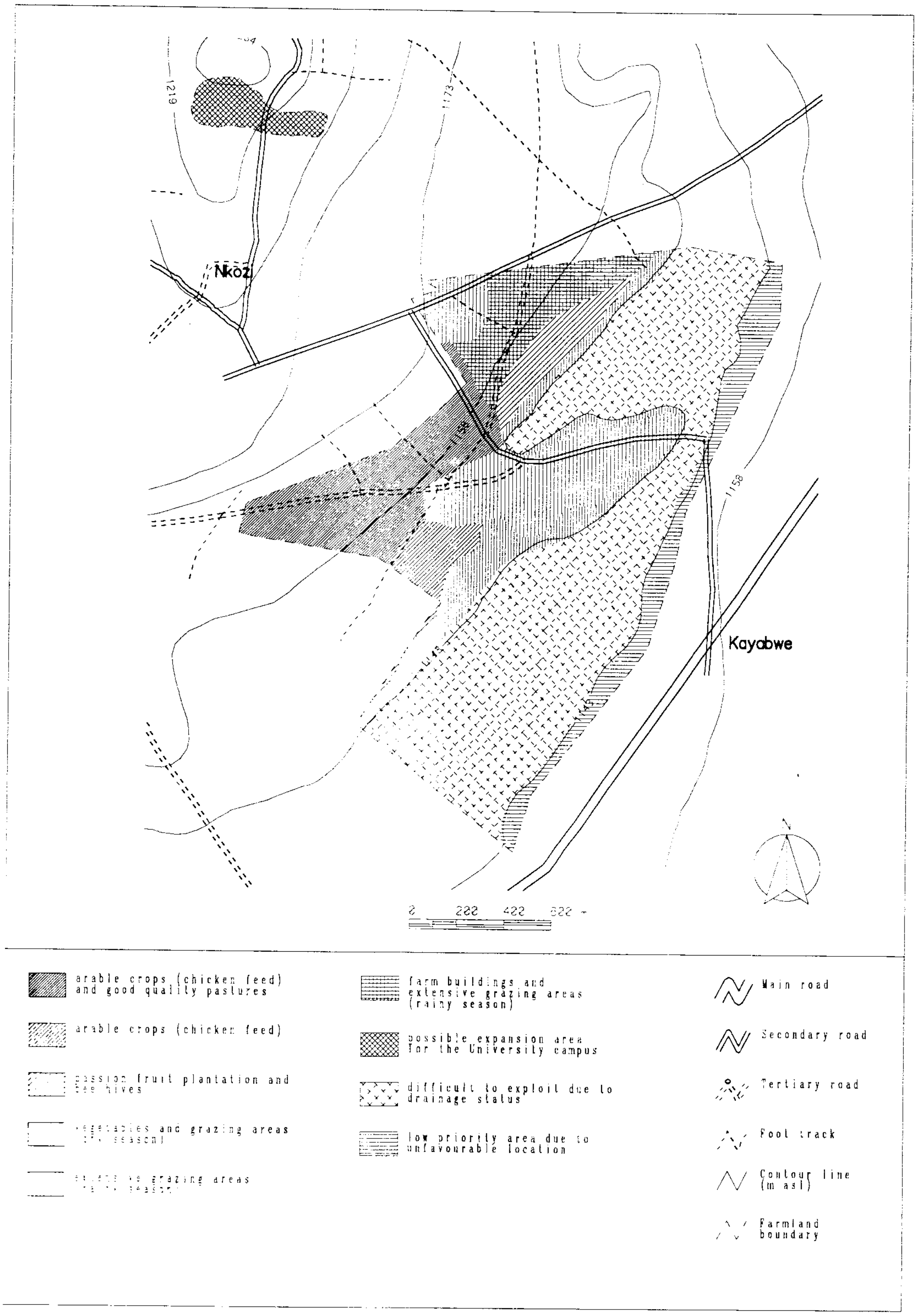


Figure 10 Proposed land-use allocation for the UMU-farm

Complementary to the production, the processing of farm produce, such as chicken feed from the cereals, juice concentrate from passion fruit, or refining of honey, will offer the possibility of starting "small scale enterprises". This would have some attractive points. As has been shown in other parts of the country, the processing of agricultural products can be very profitable. This would provide some real life study grounds for the students in business administration. Besides, neighbouring farmers would benefit from it if they can sell some of their produce at a fair price.

5.2 Soil fertility management

Soil test results — as presented in section 3.3.2 — are a measure of available nutrient contents but do not indicate additions needed to get optimal yields. To answer this question field experiments are required linking the soil test values to the rate of application and yields. Therefore it is suggested that whenever fertilizers are applied, a careful book keeping is done of how much has been applied on which soil, and what the yields were. This will definitely provide the most accurate information basis for estimating appropriate application rates.

Yet, as has been discussed in section 3.3.2, the fertility status of the soils is pretty low. Acidity is pronounced and extractable phosphorus is low. A good policy will therefore be to try to raise the pH between 5.0 and 5.5 by liming. This will reduce the phosphate fixation capacity of the soil, and making phosphorus fertilizers more effective. The total exchangeable bases are low, but so is the cation exchange capacity. The latter can be raised by increasing the organic matter content and by raising the pH, which will again make the application of plant nutrients more effective. As the values for P, Ca, Mg and K were generally low to very low, these will have to be supplied, and given the low CEC, split applications are to be recommended. In order to give some guidelines, approximate nutrient requirements are presented in Table 8. These are based on estimates of the quantities of nutrients removed by these crops, in one growing season for the annual crops, or in one year for the perennials. Needless to say that cattle and poultry manure are most valuable sources of fertilizers.

Table 8 Approximate nutrient requirements by crop

Crop	Range of minimum-maximum nutrient applications in kg/ha		
	N	P_2O_5	K_2O
Maize	60-100	50-100	30- 60
Banana	50- 90	60-100	150-250
Irish potato	50-100	50-100	75-150
Cassava	50- 90	60- 75	80-120
Soya bean	0- 25	35- 60	35- 75
Groundnut	0- 25	50-100	35- 75
Citrus	100-125	60-100	100-200

Source: EUROCONSULT, 1989

5.3 Closing remarks

At present the farm has the potential to develop independently — slowly but surely. The present expertise of the farm manager is definitely good enough to warrant this. Obviously, if an external input would be given, the development may go faster; but great care should be taken not to overwhelm the own development dynamic of the university farm.

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Appendix

A Climatic data

APPENDIX
CLIMATIC DATA

STATION	LAT Deg	Min	LONG E Deg	Min	ALT (m asl)	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN.	Obs. Period begin	end	No of obs years
Kiwala estate	0	20	31	48	1298	52	64	100	120	71	21	17	56	102	115	116	70	904	1937	1964	27
Kitalya prison farm	0	24	32	14	1311	47	44	105	174	132	64	44	81	115	167	117	93	1183	1950	1964	14
Kibibi	0	29	32	4	1219	69	64	149	204	142	59	71	130	110	191	183	105	1477	1956	1964	8
Kawungera	0	27	31	4	1372	35	35	62	80	68	33	40	72	89	125	103	58	800	1944	1964	20
Kawanda agric. stat	0	25	32	32	1196	54	75	119	167	129	69	57	105	104	121	135	83	1218	1939	1970	31
Katigondo W.F.M	0	13	31	44	1310	51	69	113	164	152	44	29	62	90	109	110	88	1081	1914	1964	50
Kasagama	0	12	31	38	1311	33	43	78	104	68	20	35	57	81	81	105	58	763	1940	1964	24
Kasanda	0	33	31	50	1372	35	29	84	110	90	41	42	70	84	109	114	62	870	1949	1964	15
Kampala Kololo hill	0	20	32	36	1312	51	62	113	182	140	75	50	86	101	109	114	97	1180	1931	1954	23
Kalungu	0	10	31	45	1219	49	60	96	162	118	48	27	71	92	100	124	85	1032	1942	1964	22
Kamenyamigo	0	18	31	40	1341	69	57	114	174	111	37	24	56	106	114	107	103	1072	1953	1964	11
Kalisizo	0	33	31	37	1219	59	64	23	175	180	28	25	50	135	84	105	100	1028	1944	1964	20
Kalangala Saza H.C	0	20	32	19	1158	121	146	243	334	324	184	112	109	110	125	185	198	2191	1924	1970	46
Kajansi fish farm	0	13	32	31	1219	81	76	161	231	131	51	67	67	87	109	151	102	1314	1956	1964	8
Jeza estate	0	23	32	17	1219	52	71	127	159	119	72	45	90	117	138	135	91	1216	1948	1964	16
Entebbe airport	0	3	32	27	1155	90	96	177	274	258	102	67	83	80	116	162	119	1624	1914	1970	56
Buunga	0	-23	31	47	1250	49	60	129	214	207	63	31	47	83	77	100	99	1159	1931	1960	29
Butenga	0	-12	31	38	1219	45	61	105	148	107	32	24	69	95	97	97	85	965	1947	1964	17
Butasindirwa	0	36	32	9	1158	63	48	101	146	126	47	50	98	78	95	91	59	1002	1957	1964	7
Bulera	0	30	32	1	1219	49	51	113	158	104	62	38	106	98	130	120	60	1089	1954	1964	10
Bukakata pier	0	-17	32	1	1137	66	86	147	258	251	88	34	56	60	69	125	111	1351	1940	1962	22
Bukalasa agric. stat	0	43	32	31	1128	48	66	130	177	134	78	71	117	130	151	126	81	1309	1921	1970	49
Bukasa	0	-25	32	31	1158	135	143	212	280	273	167	153	140	119	124	212	181	2139	1948	1964	16
Bugema missionary	0	34	32	39	1128	60	54	132	182	126	64	58	110	113	144	129	72	1244	1954	1964	10
Bufumira Sesse isla	0	-20	32	23	1158	137	165	259	343	337	173	115	113	126	125	206	190	2289	1945	1964	19
Budo King's college	0	16	32	29	1311	55	64	119	180	141	72	51	91	111	113	129	92	1218	1913	1964	51
Bombo	0	35	32	32	1280	37	118	118	118	118	118	118	118	118	118	118	118	1335	1923	1927	4
Bowa	0	39	32	28	1219	81	62	182	155	135	98	55	105	135	226	223	133	1590	1962	1964	2
Bikira W.F.M.	0	-37	31	34	1219	63	65	129	178	177	34	22	35	83	98	104	96	1084	1932	1964	32
Bigasa cotton var. tı	0	-1	31	31	1280	41	41	118	120	96	28	31	31	120	141	131	65	963	1960	1963	3
Bakijulula	0	28	32	3	1219	50	72	112	152	112	57	48	103	92	138	126	78	1140	1936	1964	28
Bajo estate	0	31	32	43	1219	69	73	161	201	143	84	61	95	102	159	160	102	1410	1957	1964	7
Kabanyolo univ. farı	0	28	32	37	1219	90	54	189	210	139	102	44	81	117	178	199	135	1538	1961	1964	3
Tondolo (Kanoni)	0	11	31	54	1341	55	72	139	160	85	48	45	71	117	184	184	111	1271	1959	1964	5
Kitovu, St Henry's c	0	-20	31	45	1280	48	85	139	198	181	34	44	53	86	100	131	133	1232	1956	1962	6
Sembalule	0	-5	31	28	1326	46	52	91	120	91	28	22	60	86	93	78	67	834	1942	1963	21
Senda	0	29	32	1	1219	50	65	119	166	117	55	48	104	111	146	121	79	1181	1936	1964	28
Samaliya Kiganja es	0	-17	31	49	1219	56	62	124	207	167	47	38	66	80	94	125	110	1176	1950	1964	14
Nsimbe estate	0	16	32	26	1219	60	76	135	175	135	74	53	105	116	133	141	101	1304	1922	1964	42
Namulonge researc	0	32	32	37	1148	58	70	135	208	131	69	61	86	108	138	143	89	1296	1947	1970	23
Nabbingo	0	17	32	27	1128	63	73	121	155	140	63	49	89	102	104	129	77	1165	1948	1962	14
Mwera	0	18	32	7	1265	93	74	179	173	111	49	33	65	90	162	210	131	1370	1963	1964	1
Mugoye, Sesse islaı	0	-17	32	8	1158	93	100	179	293	242	97	55	62	81	101	152	136	1591	1947	1962	15
Mpanga forest statio	0	12	32	18	1250	94	78	139	171	117	65	52	93	93	166	193	100	1361	1956	1970	14
Matete	0	-15	31	30	1219	50	49	84	117	105	21	17	61	101	90	95	81	871	1942	1964	22
Masaka	0	-19	31	44	1250	55	63	118	187	173	47	38	54	87	105	101	92	1120	1903	1970	67
Lwengo	0	-26	31	27	1311	45	57	103	129	119	20	18	55	77	83	112	76	894	1943	1963	20
Lake Namugabo	0	-21	31	53	1143	68	87	174	239	186	89	36	47	70	95	122	127	1340	1958	1964	6
Kyanamuka	0	-30	31	41	1219	58	69	135	202	205	54	32	41	79	87	100	94	1156	1938	1964	26
max	0	43	32	54	1372	137	165	259	343	337	184	153	140	135	226	223	198	2289	1963	1970	67
min	0	-37	31	1	1128	33	29	23	80	68	20	17	31	60	69	78	58	763	1903	1927	1

Standard A pan Evaporation at Kawanda research station

Average daily (mm)

YEAR	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969	3.1	3.5	3.3	3.8	3.4	4.5	3.4	3.4	3.6	4.1	3.9	3.4
1970	2.7	3.9	3.3	3.9	3.4	3.6	3.1	2.8	3.4	3.3	3.5	3.3
1971	4.4	4.5	4.9	3.8	3.2	3.3	3.0	3.2	3.9	3.9	3.8	3.6
1972	4.2	3.4	4.5	4.0	3.3	3.3	3.5	3.7	3.7	4.1	3.8	4.1
1974	4.4	5.2	3.6	4.0	3.1	3.0	3.1	3.7	3.7	4.2	3.9	4.1
1975	4.4	5.1	5.2	4.5	3.5	3.2	2.9	3.2	3.7	3.7	4.6	3.4
Average monthly (mm)	120	119	128	120	103	105	98	103	110	120	118	113

B Profile descriptions and photographs

Profile:	NKZ-1
Altitude:	1140 m asl
Parent material:	lacustrine deposits
Physiographic position:	lacustrine terrace
Slope of site:	2%
Drainage class:	moderately well drained
Land use/vegetation:	lemon grass, bananas, cassava
Classification:	FAO 1988: *Haplic Acrisols* (ALh)
	Soil Taxonomy 92[1]: *Typic Haplohumults*

Ah *0-18 cm:* brownish black (10YR3/1) moist; sandy clay loam; slightly hard dry, friable moist; slightly sticky and plastic; moderate medium sub-angular blocky structure; few very fine interstitial pores; common very fine to coarse roots; clear smooth boundary.

AB *18-24 cm:* dark brown (10YR3/3) moist; sandy clay loam; slightly hard dry, friable moist; slightly sticky and plastic; moderate fine to medium sub-angular blocky structure; broken moderate thick clay/organic matter cutans; common fine tubular pores; common very fine to coarse roots; clear smooth boundary.

Bt1 *24-43 cm:* yellowish brown (10YR5/6) moist; sandy clay; slightly hard dry, friable moist; slightly sticky and plastic; moderate fine to medium sub-angular blocky structure; continuous moderate thick clay/organic matter cutans; common fine to coarse tubular pores; common very fine to fine roots; clear smooth boundary.

Bt2 *43-69 cm:* yellowish brown (10YR5/8) moist; sandy clay; slightly hard dry, friable moist; slightly sticky and plastic; moderate fine to medium angular blocky structure; broken moderate thick clay/organic matter cutans; few rounded quartz stones and boulders; common fine to coarse tubular pores; common very fine to fine roots; abrupt smooth boundary.

R *≥ 69 cm* Quartz rock

[1] Soil Survey Staff (1992)

NKZ-1

environment

profile

Profile:	NKZ-2
Altitude:	1230 m asl
Parent material:	gneiss
Physiographic position:	hill ridge
Slope of site:	8%
Drainage class:	well drained
Land use/vegetation:	pasture, bananas, vegetables
Classification:	FAO 1988: *Haplic Ferrasol* (FRh)
	Soil Taxonomy 92: *Typic Eutrudox*

Ah *0-48 cm:* dark reddish brown (5YR3/2) moist; sandy clay; very hard dry, friable moist; slightly sticky and plastic; moderate medium sub-angular blocky structure; very few coarse rounded quartz gravel; many very fine tubular pores; many fine roots; abrupt smooth boundary.

AB *48-70 cm:* dark reddish brown (5YR3/4) moist; sandy clay; very hard dry, friable moist; sticky and plastic; moderate medium sub-angular blocky structure; continuous moderate thick clay/organic matter cutans on pores and root channels; many very fine to coarse tubular pores; common fine roots; clear smooth boundary.

BA *70-86 cm:* dark reddish brown (5YR3/6) moist; clay; slightly hard dry, friable moist; sticky and plastic; moderate medium sub-angular blocky structure; continuous moderate thick clay/organic matter cutans on pedfaces and pores; many medium to coarse tubular pores; few very fine roots; abrupt smooth boundary.

Bo *86-160+ cm:* dark reddish brown (5YR3/6) moist; clay; loose dry, friable moist; slightly sticky and plastic; moderate very fine crumb and medium sub-angular block structure; common fine tubular pores; no roots; horizon continuous at least upto 257 cm.

NKZ-2

environment

profile

Profile:	NKZ-3
Altitude:	1140 m asl
Parent material:	lacustrine deposits
Physiographic position:	upper slope of lacustrine terrace
Slope of site:	2%
Drainage class:	imperfectly drained
Land use/vegetation:	cassava, maize, sweet potato, sugar cane
Classification:	FAO 1988: *Gleyic Cambisol* (CMg)
	Soil Taxonomy 92: *Aquic Dystropepts*

Ap *0-20 cm:* dark brown (7.5YR3/3) moist; sandy loam; slightly hard dry, friable moist; slightly sticky and slightly plastic; weak to moderate, fine to medium sub-angular blocky structure; very few very fine tubular pores; many very fine to coarse roots; clear smooth boundary.

Bw *20-50 cm:* brown (7.5YR4/4) moist; sandy loam; slightly hard dry, very friable moist; slightly sticky and slightly plastic; weak to moderate, fine to medium sub-angular blocky structure; many very fine to fine tubular pores; common very fine roots; clear wavy boundary.

Bg1 *50-112 cm:* dull yellowish brown (10YR5/4) moist; abundant coarse prominent clear mottles (10YR5/8); sandy loam; very friable moist; slightly sticky and slightly plastic; weak to moderate, fine to medium sub-angular blocky structure; many fine tubular pores; few very fine roots; abrupt wavy boundary.

Bg2 *112-121 cm:* grayish yellow (2.5Y6/2) moist; common coarse prominent clear mottles (7.5YR4/6); sandy loam and gravel; slightly hard dry, very friable moist; slightly sticky and slightly plastic; no structure; abundant quartz gravel; few very fine interstitial pores; few very fine roots; abrupt wavy boundary.

Bg3 *121-160+ cm:* dull yellowish brown (10YR6/4) moist; abundant coarse prominent clear mottles (7.5YR4/6); sandy loam; slightly hard dry, very friable moist; slightly sticky and slightly plastic; weak to moderate, medium sub-angular blocky structure; few very fine tubular pores; few very fine roots; groundwater at 230 cm.

NKZ-3

environment

profile

Profile:	NKZ-4
Altitude:	1160 m asl
Parent material:	gneiss
Physiographic position:	foot slope
Slope of site:	5%
Drainage class:	well drained
Land use/vegetation:	shrub savanna
Classification:	FAO 1988: *Haplic Ferralsol* (FRh)
	Soil Taxonomy 92: *Lithic Hapludox*

Ah *0-33 cm:* dark reddish brown (5YR3/3) moist; sandy clay loam; very hard dry, very friable moist; slightly sticky and plastic; moderate fine to medium sub-angular blocky structure; common fine tubular pores; common fine roots; clear wavy boundary.

Bo *33-80 cm:* dark reddish brown (5YR3/6) moist; sandy clay loam; hard dry, very friable moist; slightly sticky and plastic; moderate fine to medium sub-angular blocky and very fine crumb structure; common fine tubular pores; common fine roots; abrupt wavy boundary.

C1 *80-88 cm:* reddish brown (5YR4/6) moist; sandy clay & gravel and stones; hard moist; slightly sticky and plastic; no structure; broken moderatly thick clay cutans on pedfaces; abundant coarse rounded quartz gravel and stones; no obvious pores; common very fine roots; abrupt wavy boundary.

C2 *88-120 cm:* reddish brown (5YR4/6) moist; sandy clay & gravel; many coarse prominent clear mottles (7.5YR5/6) ; firm moist; slightly sticky and plastic; no structure; continuous moderate thick clay cutans on ped faces; many rounded quartz gravel; no obvious pores; few very fine roots; abrupt smooth boundary.

R ≥ *120 cm* Quartz rock

NKZ-4

environment

profile

Profile:	NKZ-5
Altitude:	1140 m asl
Parent material:	lacustrine deposits
Physiographic position:	slope of lacustrine terrace (± 25 m from papyrus swamp)
Slope of site:	4%
Drainage class:	poorly drained, ground water at 140 cm
Land use/vegetation:	grassland, eucalyptus and forest thickets
Classification:	FAO 1988: *Dystric Gleysol* (GLd)
	Soil Taxonomy 92: *Typic Hydraquents*

Ah *0-11 cm:* reddish black (2.5YR2/1) moist; common fine prominent clear reddish mottles (2.5YR2/4); sandy loam; friable moist; non sticky and slightly plastic; moderate, fine to medium sub-angular blocky structure; common fine interstitial pores; many medium roots; abrupt wavy boundary.

ABg *11-23 cm:* grayish brown (7.5YR4/2) moist; many fine prominent sharp reddish (5YR3/6) mottles; sandy loam; friable moist; slightly sticky and slightly plastic; moderate, medium sub-angular blocky structure; common fine tubular pores; many medium roots; clear smooth boundary.

Bg1 *23-41 cm:* grayish yellow brown (10YR6/2) moist; many fine prominent clear reddish (5YR4/6) mottles; sandy loam; friable moist; slightly sticky and slightly plastic; moderate medium angular blocky structure; common fine tubular pores; common medium roots; gradual smooth boundary.

Bg2 *41-85 cm:* grayish yellow brown (10YR6/2) moist; abundant coarse prominent sharp yellowish (10YR5/8) mottles; sandy loam; friable moist; non sticky and slightly plastic; moderate medium angular blocky structure; common very fine tubular pores; few fine roots; clear smooth boundary.

Bg3 *85-132 cm:* yellowish brown (10YR5/8) moist; abundant coarse prominent sharp grayish (10YR6/2) mottles; sandy loam; friable moist; non sticky and slightly plastic; moderate medium sub-angular blocky structure; common very fine tubular pores; few fine roots; abrupt smooth boundary.

Cr *132-140 cm:* yellowish grey (2.5Y5/1) moist; abundant coarse prominent sharp olive brown (2.5Y4/4) mottles; sandy loam; friable moist; slightly sticky and slightly plastic; moderate medium angular blocky structure; common very fine tubular pores; few very fine roots; groundwater at 140 cm.

NKZ-5

environment

profile

Profile:	NKZ-6
Altitude:	1160 m asl
Parent material:	lacustrine deposits
Physiographic position:	lacustrine terrace
Slope of site:	2%
Drainage class:	well drained
Land use/vegetation:	shrub savanna
Classification:	FAO 1988: *Gleyic Cambisol* (CMg) Soil Taxonomy 92: *Aquic Dystropepts*

Ah *0-20 cm:* greyish yellow brown (10YR5/2) moist; sand; soft dry, very friable moist; non sticky and non plastic; moderate, medium sub-angular blocky structure; few very fine tubular pores; common very fine roots; gradual wavy boundary.

Bw *20-65 cm:* dull yellowish brown (10YR4/3) moist; sand; soft dry, very friable moist; non sticky and non plastic; weak sub-angular blocky structure; common very fine interstitial and tubular pores; common very fine roots; clear smooth boundary.

CB *65-75 cm:* dull yellowish brown (10YR4/3) moist; loamy sand and gravel; loose dry, loose moist; non sticky and non plastic; no structure; abundant rounded medium to coarse quartz gravel; no obvious pores; common very fine roots; clear smooth boundary.

Cg1 75-103 *cm:* dull yellowish brown (10YR5/3) moist; common coarse prominent clear mottles (5YR3/6); very coarse sand and gravel; loose dry, loose moist; non sticky and non plastic; no structure; common rounded medium to coarse quartz gravel; no obvious pores; few very fine roots; clear irregular boundary.

Cg2 *103-160+ cm:* greyish yellow brown (10YR5/2) moist; common coarse prominent clear reddish mottles (7.5YR4/6); coarse sand; loose dry, loose moist; non sticky and non plastic; no structure; no obvious pores; no roots; groundwater deeper than 230 cm.

NKZ-6

environment

profile

Profile:	NKZ-7
Altitude:	1160 m
Parent material:	lacustrine deposits
Physiographic position:	upper part of slope of lacustrine terrace
Slope class of site:	5%
Drainage class:	imperfectly drained
Land use/vegetation:	grass fallow, cassava
Classification:	FAO 1988: *Gleyic Acrisol* (ACg)
	Soil Taxonomy 92: *Aquic Haplohumults*

Ap *0-31 cm:* brownish black (7.5YR2/2) moist; sandy loam; slightly hard dry, friable moist; non sticky and slightly plastic; moderate, fine to medium sub-angular blocky structure; few fine tubular pores; common very fine to fine roots; clear smooth boundary.

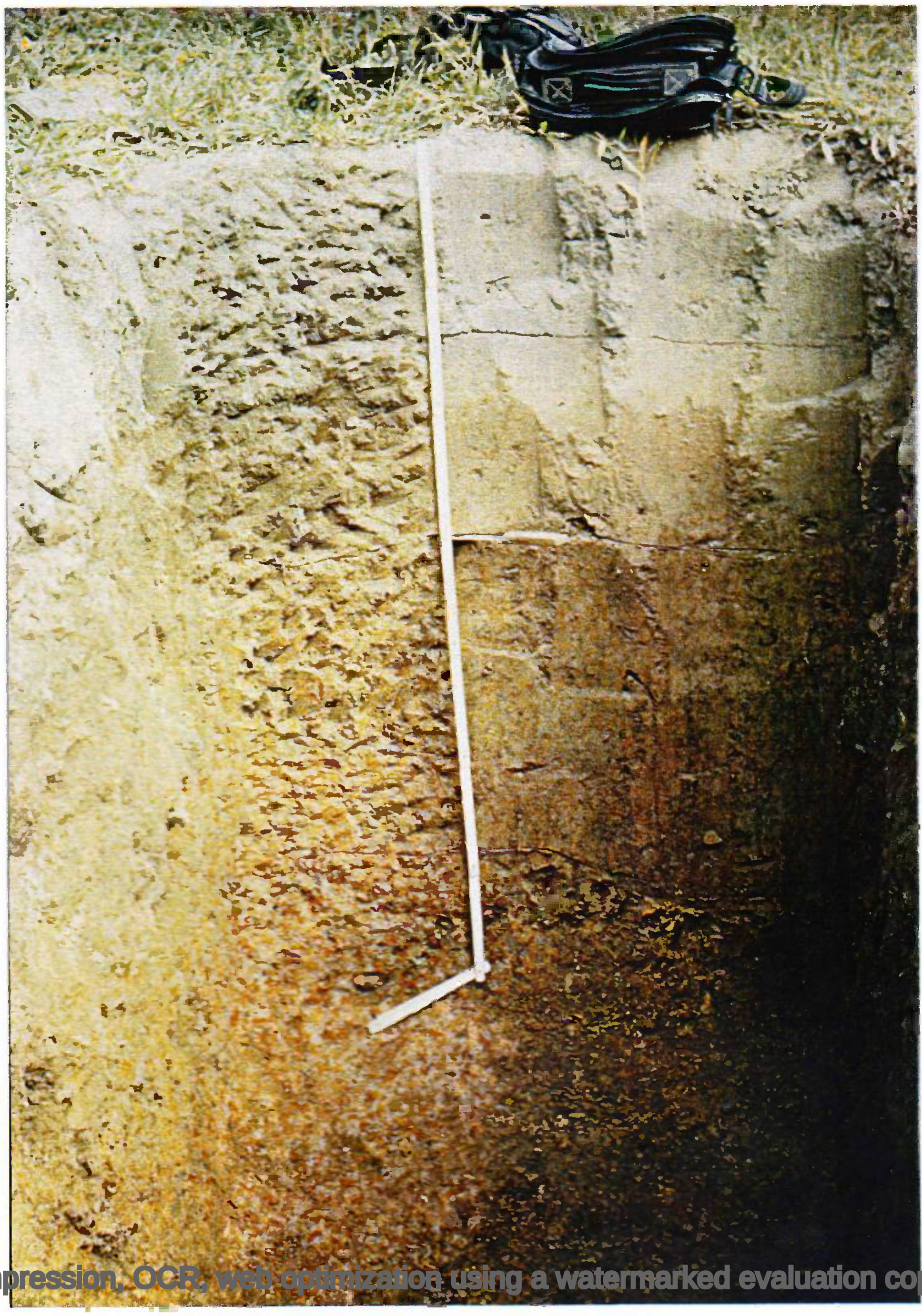
Bw *31-64 cm:* brown (7.5YR4/3) moist; sandy loam; very friable moist; slightly sticky and slightly plastic; weak, fine to medium sub-angular blocky structure; many fine tubular pores; common fine roots; clear smooth boundary.

Btg1 *64-125 cm:* dull yellowish brown (10YR5/4) moist; sandy clay loam; abundant coarse prominent diffuse mottles (7.5YR5/8); clay loam; very hard dry, friable moist; slightly sticky and plastic; moderate, medium angular blocky structure; broken moderate thick clay/organic matter cutans on pore faces; many fine to medium tubular pores; few very fine to fine roots; clear wavy boundary.

Btg2 *125-145+ cm:* dull yellowish brown (10YR5/4) moist; sandy clay loam; abundant coarse prominent diffuse reddish brown (2.5YR4/8) mottles; clay loam; very hard dry, friable moist; slightly sticky and plastic; moderate, fine to medium angular blocky structure; broken moderate thick clay/organic matter cutans on ped and pore faces; continuous moderate thick clay/organic matter cutans; very few rounded quartz stones; many fine to medium tubular pores; no roots.

NKZ-7

environment



profile

C Soil analytical data

C.1 *Physical soil properties*

ANNEX
PHYSICAL PROPERTIES

Profile	Sample Nr	Horizon	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Class	BD (g/cm3)	Ksat (mm/h)	Water Content (% Vol) SAT	FC	WP	AWC
Nkz1	11	Ah	0 - 18	27	14	59	SCL	1.42 - 1.43	76 - 102	45.0 - 47.6	30.4 - 31.1	20.7 - 21.0	9.44 - 10.40
	12	AB	18 - 24	27	14	59	SCL	- -	- -	- -	- -	- -	- -
	13	Bt1	24 - 43	39	14	47	SC	1.52 - 1.57	4 - 46	39.1 - 41.8	27.0 - 29.0	20.0 - 24.9	4.08 - 7.04
	14	Bt2	43 - 69	43	10	47	SC	- -	- -	- -	- -	- -	- -
Nkz2	21.1	Ap1	0 - 40	25	12	63	SCL	- 1.49	- 64	- 40.5	- 22.1	- 14.4	- 7.73
	21.2	Ap2	40 - 48	27	14	59	SCL	- -	- -	- -	- -	- -	- -
	22	AB	48 - 70	45	8	47	SC	- 1.47	- 104	- 42.9	- 28.1	- 21.8	- 6.28
	23	BA	70 - 86	51	6	43	C	- -	- -	- -	- -	- -	- -
	24	Bo	86 - 160	51	4	45	C	- 1.42	- 11	- 43.1	- 26.0	- 18.8	- 7.16
Nkz3	31	Ap	0 - 20	11	20	69	SL	1.22 - 1.25	136 - 148	48.5 - 53.4	23.4 - 24.5	8.6 - 8.9	14.81 - 15.62
	32	Bw	20 - 50	13	20	67	SL	1.51 - 1.53	9 - 17	44.3 - 45.6	23.2 - 23.6	9.9 - 10.5	13.06 - 13.33
	33	Bg1	50 - 112	15	14	71	SL	- -	- -	- -	- -	- -	- -
Nkz4	41	Ah	0 - 33	23	4	73	SCL	1.60 - 1.63	34 - 47	36.7 - 38.4	19.0 - 19.4	11.5 - 13.4	6.04 - 7.51
	42	Bo	33 - 80	33	6	61	SCL	1.31 - 1.52	147 - 508	39.8 - 44.9	19.6 - 22.6	12.1 - 15.9	6.70 - 7.50
Nkz5	51	Ah	0 - 11	11	16	73	SL	- -	- -	- -	- -	- -	- -
	52	ABg	11 - 23	13	18	69	SL	- -	- -	- -	- -	- -	- -
	53	Bg1	23 - 41	15	16	69	SL	- -	- -	- -	- -	- -	- -
	54	Bg2	41 - 85	19	12	69	SL	- -	- -	- -	- -	- -	- -
Nkz6	61	Ah	0 - 20	5	6	89	S	1.51 - 1.55	275 - 497	35.6 - 37.3	11.0 - 11.2	3.9 - 4.3	6.71 - 7.34
	62	Bw	20 - 65	7	4	89	S	1.54 - 1.55	825 - 1109	38.7 - 39.1	9.4 - 9.8	3.4 - 4.2	5.63 - 6.02
Nkz7	71	Ap	0 - 31	9	18	73	SL	1.33 - 1.43	92 - 188	43.5 - 47.4	18.6 - 20.0	7.0 - 7.0	11.59 - 12.96
	72	Bw	31 - 64	11	16	73	SL	1.62 - 1.63	27 - 39	34.7 - 35.8	18.6 - 18.9	8.0 - 8.3	10.62 - 10.65
	73	Bg1	64 - 125	25	12	63	SCL	- -	- -	- -	- -	- -	- -
	74	Bg2	125 - 145	29	10	61	SCL	- -	- -	- -	- -	- -	- -

Legend

BD: bulk density
Ksat: satured hydraulic conductivity
SAT: at saturation (pF 0)
FC: at field capacity (pF 2.3)
WP: at wilting point (pF 4.2)
AWC: available water content (FC-WP)

C.2 *Chemical soil properties*

ANNEX
CHEMICAL PROPERTIES

Profile	Sample Nr	Horizon	Depth (cm)	pH (H2O)	pH (KCl)	OM (%)	N (%)	P (ppm)	Ca	Mg	K	Na	TEB	CEC	BS (%)
									<------------------		(cmol+/kg soil)			------------------>	
Nkz1	11	Ah	0 - 18	5.6	5.2	4.4	0.0112	6	0.7	1.71	0.33	0.08	2.82	9.4	25.6
	12	AB	18 - 24	5.9	4.5	3.3	0.0112	1	0.4	1.00	0.17	0.08	1.65	5.5	25.5
	13	Bt1	24 - 43	4.9	4.3	2.4	0.0252	15	0.3	1.58	0.15	0.08	2.11	8.4	22.4
	14	Bt2	43 - 69	4.9	4.2	2	0.0196	0	0.3	1.58	0.15	0.08	2.11	3.8	49.5
Nkz2	21.1	Ap1	0 - 40	5.9	5.7	4	0.0476	550	2.5	1.58	0.85	0.04	4.97	11.0	37.1
	21.2	Ap2	40 - 48	6.5	4.6	2.9	0.4200	450	2.5	1.67	0.90	0.04	5.11	15.7	26.6
	22	AB	48 - 70	6.5	6.0	1.1	0.0266	26	2.9	1.54	1.48	0.39	6.31	7.6	58.4
	23	BA	70 - 86	6.6	5.8	1.2	0.0140	8	3.1	1.46	1.58	0.47	6.61	2.6	175.4
	24	Bo	86 - 160	5.2	4.6	1.9	0.0168	4	2.7	0.66	1.28	0.35	4.99	6.6	50.9
Nkz3	31	Ap	0 - 20	4.7	4.2	3.7	0.0322	4	0.3	0.29	0.13	0.04	0.76	6.0	9.8
	32	Bw	20 - 50	4.6	4.3	1.2	0.0294	0	0.1	0.13	0.07	0.04	0.34	3.2	7.2
	33	Bg1	50 - 112	4.5	4.2	1.4	0.0112	0	0.1	0.21	0.05	0.04	0.4	3.6	8.6
Nkz4	41	Ah	0 - 33	4.4	4.3	2.1	0.0210	1	0.2	0.17	0.10	0.08	0.55	3.0	12.3
	42	Bo	33 - 80	4.6	4.3	0.7	0.1106	0	0.1	0.13	0.05	0.04	0.32	0.6	38.3
Nkz5	51	Ah	0 - 11	4.7	3.9	7.1	0.0140	26	0.6	0.38	0.43	0.13	1.54	6.6	14.8
	52	ABg	11 - 23	4.9	4.1	2.3	0.0364	0	0.2	0.17	1.40	0.13	1.9	18.0	2.1
	53	Bg1	23 - 41	5.0	4.4	1.8	0.0112	0	0.1	0.21	0.05	0.04	0.4	1.8	17.2
	54	Bg2	41 - 85	5.1	5.0	1.2	0.0112	0	0.1	0.29	0.03	0.00	0.42	0.8	48.7
Nkz6	61	Ah	0 - 20	4.6	4.5	1.9	0.0168	3	0.3	0.17	0.18	0.08	0.73	5.1	9.2
	62	Bw	20 - 65	5.9	4.7	0.2	0.0196	0	0.4	0.17	0.28	0.13	0.98	7.4	7.7
Nkz7	71	Ap	0 - 31	4.9	4.6	2.4	0.0210	9	0.3	0.38	0.10	0.08	0.86	3.6	18.9
	72	Bw	31 - 64	4.6	4.5	1.1	0.0112	0	0.1	0.25	0.07	0.04	0.46	9.1	3.8
	73	Bg1	64 - 125	4.6	4.2	1.5	0.0056	2	0.2	0.50	0.07	0.04	0.81	3.0	23.3
	74	Bg2	125 - 145	4.7	4.2	1.4	0.0266	0	0.2	0.33	0.07	0.08	0.68	2.6	20.4

D Auger register

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
A01	hill ridge	2-8%	1190	cassava, maize	00-20 20-40 40-80	Ap AB Bt	SC SC SC	7.5YR3/2 brownish black 5YR3/4 dark reddish brown 5YR3/6 dark reddish brown
A02	hill ridge	2-8%	1190	banana, eggplant, papaya, sugarcane	00-25 25-65	Ap Bt	C C	5YR3/2 dark reddish brown 5YR3/6 dark reddish brown
A03	intermediate slope	8-16%	1185	coffee, banana, sweet potato, maize	00-20 20-80	Ap Bt	C' C	7.5YR2/2 brownish black 5YR3/6 dark reddish brown
A04	erosional terrace	2-8%	1170	banana	00-20 20-60 60-100 100	Ap AB Bt R	CL C C —	7.5YR3/2 brownish black 7.5YR3/2 brownish black 7.5YR4/4 dark brown —
A05	lower slope	2-8%	1160	cassava, coffee, banana, sweet potato, maize	00-20 20-50 50-80	Ap AB Bw	SC SC SC	10YR3/3 dark brown 10YR3/4 dark brown 7.5YR4/6 brown

* C: clay
SC: sandy clay
SCL: sandy clay loam
CL: clay loam
L: loam
SiL: silt loam
Si: silt
LS: loamy sand
SL: sandy loam
S: sand
.': gravel
(GW): groundwater

(continued)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
A06	lacustrine terrace	< 2%	1150	cassava, banana	00-20 20-40 40-60 60	Ap AB Bt R	C C C —	10YR2/3 brownish black 10YR4/3 dull yellowish brown 10YR5/6 yellowish brown —
A07	lacustrine terrace	< 2%	1150	lemon grass	00-30 30-50 50-75 75	Ah Bt1 Bt2 R	SCL SCL SC —	2.5Y3/2 brownish black 10YR5/6 yellowish brown 10YR6/6 yellowish brown —
A08	slope of lacustrine terrace	8-16%	1145	grassland	00-20 20-40 40-65 65	Ah AB Bw R	SL SCL SCL —	10YR3/1 brownish black 10YR3/3 dark brown 10YR4/3 dull yellowish brown —
A09	lacustrine terrace	< 2%	1150	banana	00-30 30-65 65	Ap Bw R	SL SCL —	10YR3/1 brownish black 7.5YR4/6 brown —
B01	hill top	2-8%	1230	poor grassland	00-20 20	A R	SCL’ —	10YR2/1 black —

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(*continued*)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
B02	hill ridge	< 2%	1220	vegetable garden	00-40 40-90	Ap Bt	C C	7.5YR3/2 brownish black 5YR3/6 dark reddish brown
B03	intermediate slope	8-16%	1190	grass bush	00-25 25-100	Ah Bs	CL CL	5YR3/3 dark reddish brown 2.5YR3/6 dark reddish brown
B04	erosional terrace	2-8%	1170	banana, grass, eucalyptus	00-40 40-60 60-120	Ap Bt1 Bt2	SCL SC SC	2.5YR3/3 dark reddish brown 2.5YR3/6 dark reddish brown 2.5YR3/6 dark reddish brown
B05	valley bottom	< 2%	1140	papyrus swamp	00-50 50-120	H Cr	Si SL	7.5Y2/1 black 7.5Y4/1 brownish grey
B06	slope of lacustrine terrace	2-8%	1145	cassava	00-30 30-80 80-120	Ap Bw Bg	SL SL SL	10YR3/3 dark brown 10YR4/4 brown 10YR6/4 dull yellow orange & 10YR5/8 yellowish brown
B07	lacustrine terrace	< 2%	1170	grass and shrubs	00-20 20-70 70	Ah Bw C	S S S'	10YR3/2 brownish black 7.5YR3/3 dark brown —

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(continued)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
B08	summit slope	2-8%	1225	pasture	00-20	Ap	SC	5YR3/2 dark reddish brown
					20-60	AB	SC	5YR3/4 dark reddish brown
					60-80	BA	SCL	5YR3/6 dark reddish brown
					80-120	Bs	SCL	5YR3/6 dark reddish brown
					120	R	—	—
C01	slope of lacustrine terrace	< 2%	1145	grass fallow	00-30	Ap	SL	10YR3/1 brownish black
					30-60	Bw	SL	10YR4/3 dull yellowish brown
					60-120	Bg	SL	10YR5/4 dull yellowish brown & 10YR4/6 brown
C02	slope of lacustrine terrace	2-8%	1140	grass and swamp forest	00-25	Ah	SL	10YR3/1 brownish black & 5YR2/4 v. dark red. brown
					25-45	Bg1	SL	5YR4/1 brownish grey & 5YR3/4 dark red. brown
					45-65	Bg2	SL	10YR5/2 grayish yel. brown & 7.5YR4/6 brown
					65-120	Bg3/Cr	SL	2.5Y6/1 yellowish grey & 10YR5/6 yellowish brown

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(continued)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
C03	lacustrine terrace	< 2%	1150	fallow, maize, sweet potato	00-20	Ap	SCL	10YR3/1 brownish black
					20-40	AB	SCL	10YR3/2 brownish black
					40-80	Bw1	SCL	10YR4/3 dull yellowish brown
					80-120	Bw2	SCL	10YR5/4 dull yellowish brown
C04	valley bottom	< 2%	1140	swamp forest	00-05	Ah	SiL	10YR2/2 brownish black
					05-35	Bg	CL	2.5Y 3/1 brownish black
					35-50	Cr	SL	2.5Y 4/1 yellowish grey
C05	slope of lacustrine terrace	2-8%	1142	fallow, sweet potato, maize, cassava	00-50	Ap	SL	7.5YR2/2 brownish black
					50-80	Bg	SL	10YR5/4 dull yellowish brown & 5YR4/6 reddish brown
					80-120	C	LS'	10YR7/3 dull yellowish orange
C06	slope of lacustrine terrace	2-8%	1150	sweet potato	00-20	Ah	SL	10YR4/1 brownish grey
					20-50	Bw	SL	2.5Y6/3 dull yellow
					50-100	Bg (GW)	LS	2.5Y6/3 dull yellow
C07	valley bottom	< 2%	1140	papyrus and swamp palmtrees	00-30	H1 (GW)	—	—
					30-80	H2	—	—
					80-100	Cr	SCL	—

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(*continued*)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
C08	valley bottom	< 2%	1140	swamp forest	00-25 (GW) 25-120	Ah Bg	CL SC	*dark brown* *grey & reddish mottles*
C09	valley bottom	< 2%	1140	short papyrus	00-40 40-80 80	H (GW) *water* Cr	— — SCL	— — —
C10	valley bottom	< 2%	1140	short papyrus	00-120	H (loose)	—	—
C11	valley bottom	< 2%	1140	tall papyrus	00-120	H (consis.)	—	—
C12	lacustrine terrace	< 2%	1150	shrub savanna	00-20 20-50 50	Ah Bw C	SL SL gravel	7.5YR4/2 grayish brown 7.5YR3/4 dark brown —
C13	lacustrine terrace	< 2%	1150	ploughed field	00-20 20-80 >80	Ah Bw C/R	SL SL gravel	7.5YR4/2 grayish brown 7.5YR3/4 dark brown —
C14	lacustrine terrace	< 2%	1150	cassava	00-20 20-40 40-60 60-80 >80	Ap AB Bt1 Bt2 R	SCL SCL SCL SCL —	10YR2/2 brownish black 10YR3/3 dark brownish 10YR4/4 brown 10YR5/8 yellowish brown —

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(continued)

No	Landform unit	Slope class	Elevation (m)	Vegetation/ Land use	Depth (cm)	Horizon	Texture*	Colour
C15	lacustrine terrace	< 2%	1150	poor looking coffee	00-20	Ap	SCL	10YR2/2 brownish black
					20-40	AB	SCL	10YR3/3 dark brownish
					40-60	Bw1	SCL	10YR4/4 brown
					60-70	Bw2/Bt	SCL	10YR5/8 yellowish brown
					>70	R	—	—
C16	lacustrine terrace	< 2%	1150	poor looking coffee	00-20	Ap	SCL	10YR3/3 dark brownish
					20-40	AB	SCL	10YR4/4 brown
					40-60	Bw	SCL	10YR4/6 brown
					>60	R	—	—
C17	lacustrine terrace	< 2%	1150	coffee	00-20	Ap	SCL	7.5YR3/3 dark brown
					20-40	AB	SCL	7.5YR3/4 dark brown
					40-60	Bt1	SCL	7.5YR5/6 bright brown
					60-80	Bt2	SCL	7.5YR5/8 bright brown
					>80	R	—	—
C18	lacustrine terrace	< 2%	1150	cassava	00-35	Ap	SL	10YR3/2 brownish black
					35-80	Bw	SL	10YR4/3 dull yellowish brown
					>80	P.	—	—

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(continued)