# THE SOILS OF NYANTJA ESTATE AND THEIR POTENTIAL FOR TEA CULTIVATION

-ZAIRE-

VOLUME I

MAIN REPORT

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## SUMMARY AND CONCLUSIONS

This report presents the results of a detailed soil survey (scale 1:15,000) of Nyantja Tea Estate carried out for Plantations du Kivu. The purposes of the study were to evaluate the soil conditions, in particular the soil fertility status, with respect to tea cultivation. Moreover the study should indicate suitable areas for new tea and fuelwood plantings and give fertilizer recommendations for the immature and mature tea crop.
Nyantja Estate is located in the Kivu Region (Walungu Zone), approx. 53 km ESE of Bukavu. The estate covers approx. 638.5 ha of which in 1989 253.3 ha was used for tea production, 39 ha being abandoned. Other areas are used for fuelwood or are under bush-fallow.

**CLIMATE**
Rainfall is variable and in 22 years a maximum of 1867 mm and a minimum of 1027 mm per year has been recorded; the average is 1438 mm per year. Except for an annual irregularity in rain there is a variation within the estate. Some divisions receive more rain than others.
Temperatures fluctuates only little at Nyantja Estate. The average temperature is around 20 °C, the mean maximum temperature is around 31°C, the mean minimum between 6 and 11°C.

**GEOLOGY AND PHYSIOGRAPHY**
The Estate is located in a undulating to rolling volcanic area which have been dissected by several streams and rivers. The soils of Nyantja Estate are derived from basalt albeit locally schists and quartz rich rock must have given rise to the soils.
Altitude is varying from 1670 m in the south of Nyantja Division to over 1850 m in the Kakono Division. The overall drainage pattern is in a northly direction with flat alluvial fans in the south (Kakono) and deeply incised river streams in the north (Nyantja).
Slopes vary from 1 to 30%, towards the valleys locally up to 60 %.
The soils show a relation with the landform in which they occur, a so called physiographic relation,

**GENERAL SOIL CHARACTERISTICS**
Based on physiography three soil units have been recognized:
(i) The soils of the **Crests** (97.5 ha) are well drained. The textures are generally sandy clay and slightly increasing with depth. In the subsoil kaolinite is often present. The soils are very deep and have moderately thick or thin topsoils. Very locally the soils are shallow with bedrock and/or gravelly layers within 50 cm depth.

(ii) The soils of the **Slopes** (92.1 ha) are well drained and have clayey textures. There is a significant increase with depth. Locally the soils have dense subsurface structures. The soils are very deep and have thin topsoils albeit the footslopes have generally moderately thick or thick topsoils. In a very few areas the soils are shallow.
The soils are liable to erosion and a protective soil cover is therefore essential.

(iii) The soils of the **Valley** bottoms (63.7 ha) are moderately well to imperfectly drained. It was observed that valley bottoms in the south being generally better drained than in the north of the estate. The depth of groundwater in the valleys of Kakono was found below 120 cm while in Nyantja Division the depth of groundwater is generally at 60 to 80 cm. Water management is a major issue for good tea production of these soils.
The soil textures are varying from sandy clay to heavy clay though the latter is more common in this unit. The soils have often uncomposed organic materials or peaty layers in the profile. The soils are generally deep though the high water table restrict deep-rooting. Topsoils are moderately thick.

**SOIL FERTILITY**
The **soil reactions** of Nduba and Bukombe Divisions are generally favourable for tea cultivation. Other well drained soils have moderate soil reactions except for Kakono where the soil reactions are unfavourable. All valley soils have unfavourable (extremely acid) soil reactions.
**Organic matter** contents of all soils are favourable for tea cultivation. The C/N ratios are moderate in the well drained soils of most divisions excluding the soils in Bukombe and Bitesse which have favourable ratios. All valley soils have unfavourable (too high) ratios indicating low availability of nitrogen.
Exchangeable **magnesium** levels are variable per soil unit and per division. Most soils have moderate levels, unfavourable levels have not been recorded. The soils of the crests in Nyantja and Nduba Division have favourable levels.
Though most soils are not very well supplied with this element the high levels of potassium avoid magnesium deficiencies.
**Potassium** levels are favourable in all soils except the soils of the crests and slopes in Bukombe Division which have unfavourable levels. In the soils of Bukombe potassium fertilization is required to avoid deficiencies.
The **cation exchange capacity** (CEC) is moderate in most well drained soils, the soils of the valleys have generally favourable CEC's. The soils of the crests in Biamba Division have unfavourable CEC's. The general conclusion is that fertilizers should not be given in heavy doses in order to avoid leaching of nutrients to deeper ground.
The available **phosphorus** levels are unfavourable in most soils. Only the soils of Kakono Division have moderate or favourable levels of this element. Also the soils of the slopes and the valleys in Nyantja and Biamba Division are moderately well supplied with phosphorus. All other soils have

too low levels for tea cultivation.
The **aluminium** saturation of the entire Nyantja and Lushondo Divisions reaches moderate levels. An increase of the available aluminium of the soils due to for instance the use of acidifying fertilizers must be considered as a disadvantage.
The soils of Nduba, Bukombe and Bitesse divisions have favourable aluminium saturation levels. The soils of the crest in Biamba Division and all soils of Kakono Division have unfavourable aluminium saturation levels by which aluminium toxicity and nutrient imbalances are likely to occur.

**LAND EVALUATION FOR MATURE TEA**
In the land evaluation as made in this report the actual growing conditions are matched with the tea requirements. This has resulted in a relative scale of potential for the mature the areas:
Areas with a **High Potential** **(120.8 hectares)**
Half of the presently productive tea areas has a high potential for high yields. The areas with a high potential are located in the divisions Nyantja, Nduba and Bukombe. Nearly half of this high potential areas are located in Nduba. The soils in the Bukombe division have also a high potential though the shade trees ought to be removed and this should be compensated with fertilization. About one third of the high potential areas is located in Nyantja Division. Although many of these soils have a moderate fertility they are close to the factory and have favourable physical properties.
It should be borne in mind that high yields can only be obtained with adequate fertilizing and management standards.

Areas with a **Moderate Potential** **(76.2 hectares)**
About one third of the presently productive tea area at Nyantja Estate has soils with a moderate potential for high yields. These areas are all tea soils in the Biamba and Lushondo Division and further the valley soils of Nyantja, Nduba, Bukombe and the slopes of Bitesse.
The tea soils of Biamba and Lushondo division have low to very low levels of nutrients and require heavy dressings of fertilizer for optimal tea yields.
The valley soils of the above mentioned areas have adverse drainage conditions for tea cultivation.

Areas with a **Low Potential** **(56.3 hectares)**
Kakono Division has a low potential for tea cultivation. All soils in this division have a low to very low fertility and about 40 hectares have an impeded soil drainage. Moreover this division is located about 25 km away from the factory which considerably increases the costs of production (transport of tea, fertilizers etc.)

**LAND EVALUATION FOR IMMATURE TEA**
In the land evaluation for new tea plantings the soil conditions of the fallow areas are matched with the growing

requirements of the tea. This has resulted in three suitability classes, as follows:

Suitable Areas (31 hectares)
Suitable areas are found in the most northern part of field 1 and between field 3 and 14 of Nyantja Division (3 hectares). Although the fertility is poor the soils have favourable physical properties and are situated nearby the factory.
In Lushondo Division about 2 hectares is suitable for tea cultivation, situated in north of field 7 and in field 5 and 9. Suitable soils in Nduba Division are found between field 8 and 10 and the flat area east of field 5.
All these soils have favourable physical properties but initially fertilizing is essential for a good establishment of the new tea plantings.

Moderately Suitable Areas ( hectares)
Moderately suitable areas are considered the 20 hectares of thin fuelwood land north of field 10 and the boundary with Biamba, and downslope at the western part of field 5 in Nduba Division. In the former area

Unsuitable Areas (45 hectares)
Absolutely unsuitable for tea cultivation is the western part of Lushondo Division (28 ha) and the southern part of Bukombe Division (14 ha). Also the southern part of field 1 in Nyantja Division is unsuitable.
These areas are unsuitable as consequence of the shallow soils. In these soils the rooting depth is restricted by gravelly layers or bedrock within 80 cm depth resulting in a insufficient rooting volume for the tea.

**RECOMMENDATIONS**
The following recommendations are discussed.

(i) Soil fertility management for tea:
Application rates of a maximum of 150, 200 and 250 kg nitrogen per hectare per year for resp. low, moderate and high potential areas.
The annual increase should not incline 25 kg N/ha per year.
Fertilizer should be given in split applications in resp. October/November and March.
Urea is not a suitable fertilizer for the tea at Nyantja Estate.
Sulphate of Ammonia may be considered for Nduba and Bukombe Divisions though in combination with phosphorus applications.
After severe hailstorms supplementary dressings of nitrogen and phosphorus are required.

(ii) General soil management:
Cultivation with 'le trident' should be avoided.
Prunings should be left to rot and decompose.
New tea plantings should be made on the contour.
Artificial high waterways may increase the productivity of the valley bottom soils.

(iii) Miscellaneous:
Shade trees should gradually be removed on all well drained soils accompanied with nitrogen fertilization.
Shade reduction in Kakono Division should occur on an empirical base.
Soil sampling for regular monitoring of the soil fertility status and to adjust the fertilizing scheme is recommended.
More fuelwood should be planted to cope with an increasing tea production in the future.

# 1 INTRODUCTION

## 1.1 Inducement and Purpose of the Study

As part of the rehabilitation program of Nyantja Estate the Plantations du Kivu management decided to conduct a detailed soil survey of the estate. The objectives of the survey were to evaluate the productive area of Nyantja Estate with respect to tea and fuelwood cultivation, the study should indicate detailed fertilizer requirements for the tea crop. At last the survey should recognize suitable areas for new tea and fuelwood plantings.

## 1.2 Location Study Area

Nyantja Estate is located in the Kivu Region (Walungu Zone), approx. 53 km ESE of Bukavu (see figure 1). The Estate covers 638.5 ha of which in 1989 253.3 ha was used for tea production, 39 ha being abandoned. Other areas are used for fuelwood or are under bush-fallow.

## 1.3 Organization

Field work took place in July and Augustus 1989 by Mr. A.E. Hartemink, soil surveyor of The Chillington Corporation London.
Soil samples collected during the survey were analyzed by the Laboratoire de Pedologie Inera-Mulungu under the supervision of Mr. L. Lubanga MSc.
Map Drawing and word processing was done by Mr. A.E. Hartemink.
Some of the final estate maps were drawn by Mr. S.V. Assenga of the National Soil Service Project Mlingano, Tanzania.

## 1.4 About this Report

The soil survey report of Nyantja Estate is split in two volumes; Volume I (main report) contains the interpretation and conclusions of the survey. It is given in a reader's friendly way thus in non-technical terms. Volume II presents all technical data like soil analysis results, production and climate records. Volume II contains also the soil and area maps in order to allow the reader to look at the maps while reading through this main report.
The main report firstly presents an environmental description of Nyantja Estate e.g. climate, geology, and drainage and physiography. Most of these data have been collected at the estate and give an impression of the environmental growing conditions. Chapter 3 contains an interpretation of the available production records. It includes information about the teacrop of the estate. In the fourth section the soils of Nyantja Estate are described in detail. The soils are in general described in the sections 'soil fertility' and 'major soil units'. This is followed by detailed soil descriptions of each division.

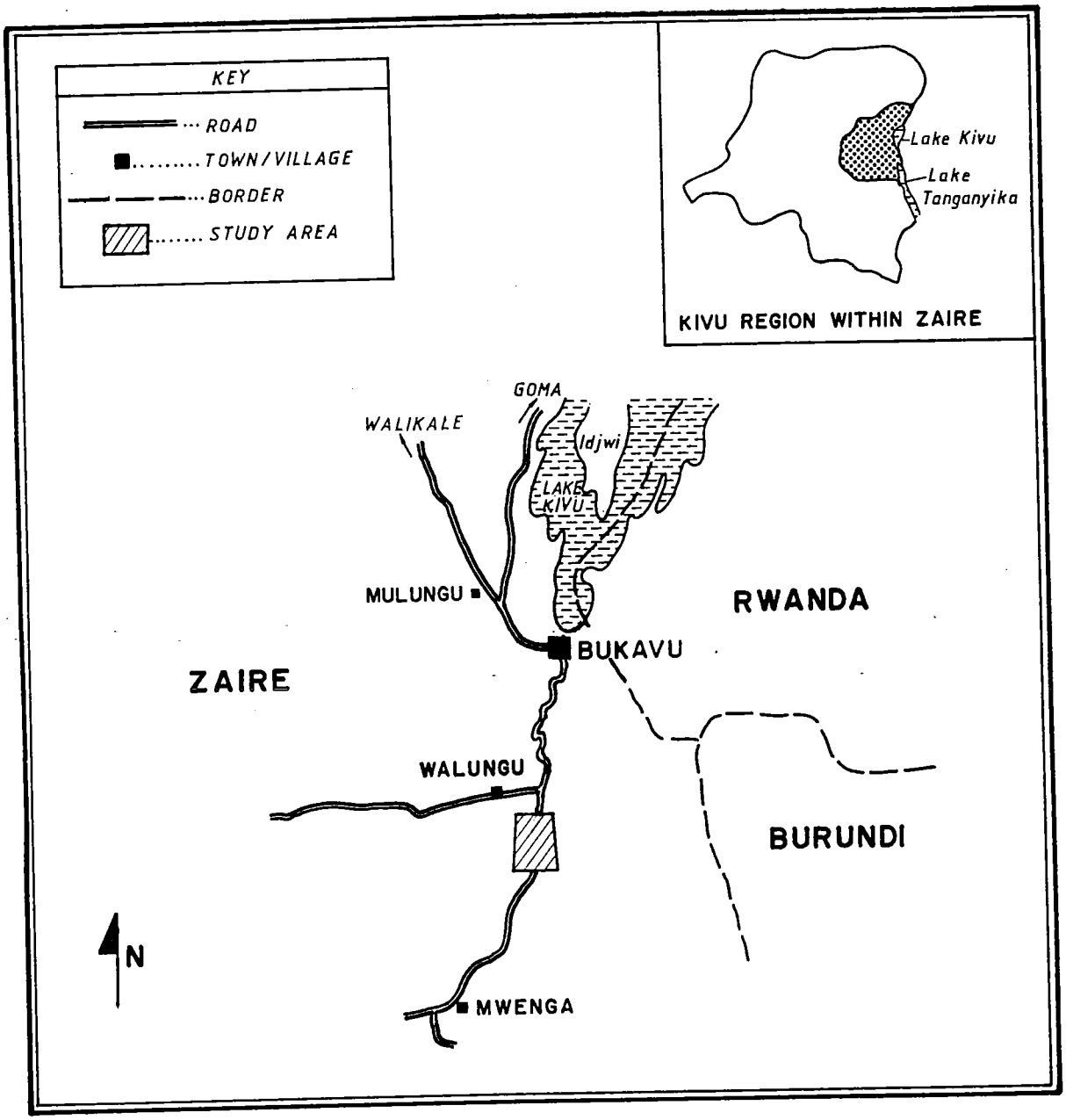



FIG.1 LOCATION STUDY AREA
(NOT TO SCALE)

In the fifth section the requirements of the tea crop are given. The overall evaluation with respect to tea cultivation is made in chapter 6 where the actual growing conditions are matched with the tea requirements. Hereafter recommendations on soil and crop management follow including detailed advises for fertilizer applications.

## 1.5 Acknowledgements

The surveyor wishes to acknowledge Mr. J. van Haarsten who provided his car and who was very helpful during the fieldwork, and Mr. and Mrs. MacLeod for their great hospitality. Moreover the kind assistance of Mr. F. Lufungulo who provided useful information during fieldwork. Furthermore the cooperation of the Inera Research Station for their soil analysis is gratefully acknowledged.

## 2 THE ENVIRONMENT

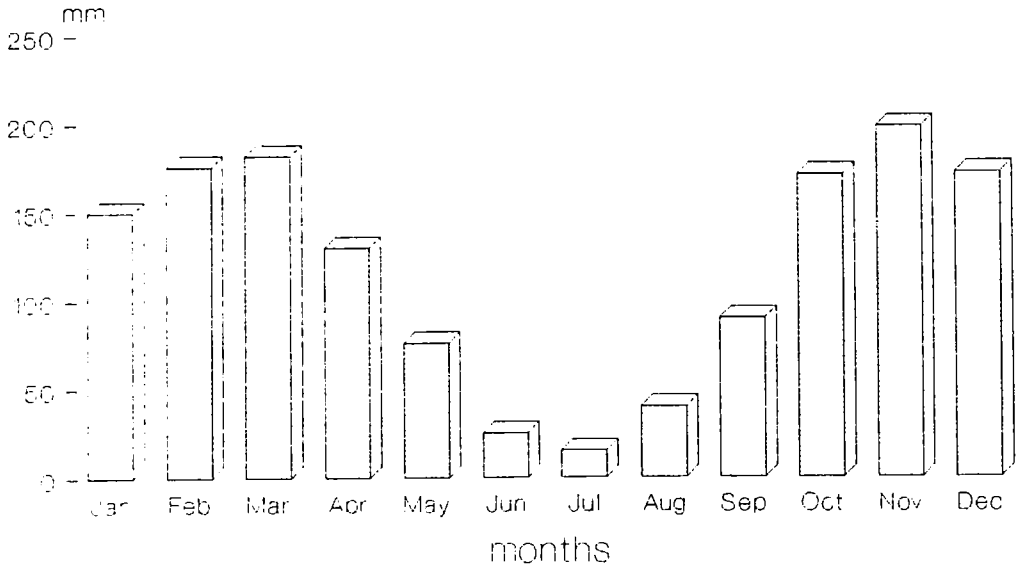
### 2.1 Climate

Few climatological data were available for the area and no other data from surrounding areas could be traced. The records have been collected near the manager's house at an altitude of approximate 1700 m. This site may however not be representative for all divisions surveyed.
All available climate records are presented in Volume II of this report. This section only deals with an interpretation and summary of the records.

#### 2.1.1 Precipitation

From an AHT report of 1964 the monthly rainfall records have been obtained covering the period 1954-1963. Since 1977 rain is recorded again which make a total of 22 years. The long term yearly average is 1438 mm. From 22 years of records figures as low as 1027 mm and as high 1867 mm per year have been recorded. Except from this yearly irregularity there is likely to exist a variation between the divisions. Some divisions receive probably more rain than others.
The average monthly rainfall is presented in figure 2.

Figure 2 Average Monthly Rainfall of Nyantja Estate




22 years average from the periods 1954-1963 and 1977-1988/89

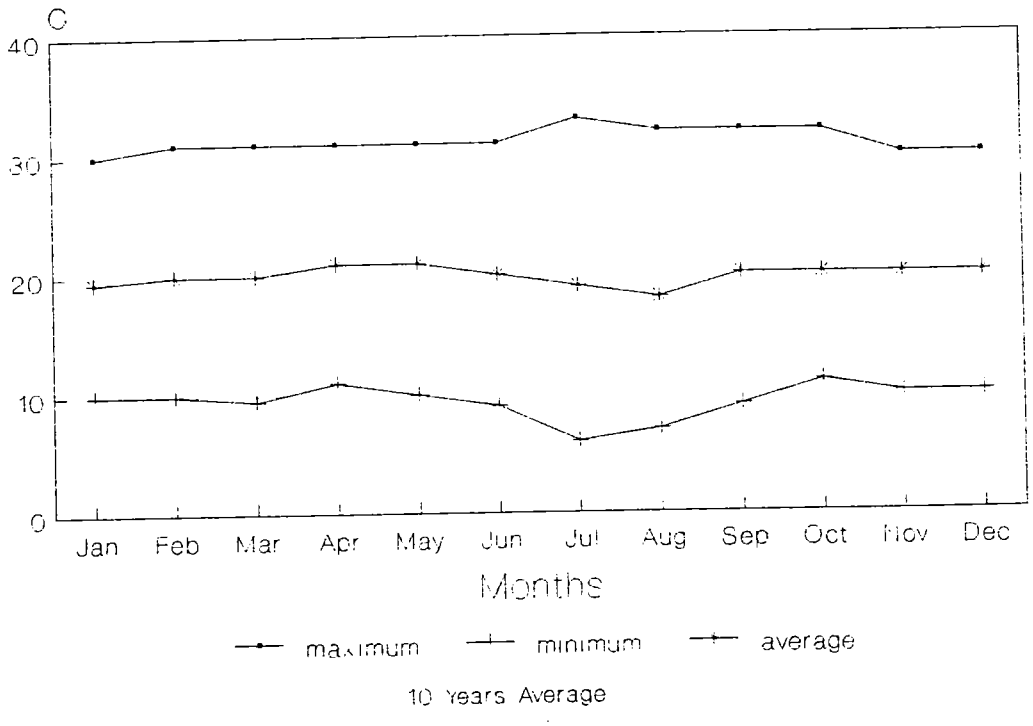
There is a very distinct period from May to August with an average monthly rainfall below 75 mm. This dry period starts at the end of April and may extend up to end of September. In the other months rainfall is on average around 175 mm.
In the half year April to September approximate one quarter of the total annual rain precipitates while in the half year October to March three-quarter of the total annual rain precipitates.
In despite of the low rainfall figures during July and Augustus, the tea seems not to suffer excessively from water stress. At first the plant tends to have a kind of natural recess in which grow is limited and hence the water demand is rather low. Secondly, dew is commonly observed which may contribute to the water availability of the tea plant during the drier season. However, if monthly averages drop below 50 mm it is expected that crop production suffers severely.

Hailstorms have been reported in Nduba Division and some other divisions. The frequency of the hailstorms and caused damaged to the tea is unknown.

### 2.1.2 Temperature

Temperature data are available from April 1977 till April 1981 and from March 1984 till June 1989. The maximum, minimum and average temperatures per month are presented in figure 3.

Figure 3 Maximum, Minimum and Average Temperature of Nyantja Estate



The following temperature pattern may be noticed through the year: A very constant temperature over the period November to February after which the average minimum temperature gradually decreases to about 7°C in July, and at the same time an increase of the average maximum temperature. During this period when the mean maximum temperature may exceed 30°C, it is often accompanied by humidities so low that a cessation of active development in inevitable for the tea plant.

### 2.1.3 Sunshine

Sunshine has been recorded very shortly covering the period March 1984 till January 1986 and from June 1986 till September 1986.
The data are presented in table 1.

**Table 1 Sunshine Records Nyantja Estate in Hours, Average Number of Days per Month and Average Hours/Day per Month**

| Month | Maximum | Minimum | Mean | Days | Hours/day |
|---|---|---|---|---|---|
| Jan | 143 | 124 | 134 | 31 | 4.5 |
| Feb | - | - | 84 | 27 | 3.1 |
| Mar | 154 | 66 | 110 | 22 | 5.0 |
| Apr | 170 | 125 | 148 | 30 | 4.9 |
| May | 242 | 190 | 216 | 31 | 7.0 |
| Jun | 253 | 176 | 207 | 30 | 6.9 |
| Jul | 235 | 150 | 201 | 31 | 6.5 |
| Aug | 213 | 167 | 195 | 31 | 6.3 |
| Sep | 148 | 90 | 118 | 28 | 4.2 |
| Oct | 156 | 128 | 143 | 31 | 4.6 |
| Nov | 139 | 94 | 117 | 30 | 3.9 |
| Dec | 146 | 138 | 142 | 30 | 4.7 |

From the sunshine records can be seen that the number of hours sunshine per day are largest in the dry month May as it is less cloudy. Generally can be concluded that the hours of sunshine are indirectly proportional to the monthly precipitation.

### 2.1.4 Humidity

Humidity has been recorded from April 1977 till April 1981.
The data are presented in table 2 on the following page.
The table illustrates the little fluctuations in humidity throughout the year. The average humidity is the highest in the months November to January (±65 %), the lowest humidity is from Augustus to October with average values of less than 60%.
It must be borne in mind that humidity may often be higher than as given here; it was frequently observed that there were dewdrops on the tea in the early morning. This implicates a humidity of over 100 % and is caused by the drop in temperature during the night. This may particularly occur during the dry season due to the high difference between the

day and night temperatures. Though shade trees may reduce these temperature fluctuations it was however observed that dew was formed under the shade.

**Table 2 Humidity data of Nyantja Estate in %.**

| Month | Maximum 6.00h | Minimum 12.00h | Average |
|---|---|---|---|
| Jan | 91 | 32 | 66 |
| Feb | 93 | 23 | 61 |
| Mar | 94 | 30 | 63 |
| Apr | 93 | 35 | 65 |
| May | 92 | 32 | 64 |
| Jun | 93 | 33 | 63 |
| Jul | 95 | 27 | 61 |
| Aug | 94 | 24 | 56 |
| Sep | 93 | 22 | 59 |
| Oct | 93 | 22 | 58 |
| Nov | 92 | 34 | 64 |
| Dec | 92 | 37 | 65 |

## 2.2 Geomorphology and Geology

A geological survey of the area could not be traced. Therefore some of the information as given here has been collected in the field by the present writer.

The eastern part of Africa contains a serie of rift valleys that are known collectively as the East African Rift Valley System. The whole system is in the form of a number of interlocked troughs in which lie most of the major lakes of East Africa. On either sides and on the floors of the rifts are hundreds of volcanoes, most of them now extinct. The Nyantja area is located in the western rift of the East African Rift Valley. Lake Kivu and Lake Tanganyika are part of the western rift.

The parent material in the Nyantja area consists of magmatic or volcanic rocks (basalt). The basalt rock is able to release some nutrients by weathering though must be realized that weathering tend to occur very slowly on this type of rock. Regarding the generally very deep red soils which are formed sedentary (in situ), the soils must be very old and hence highly weathered.
In some small patches a indubitably other parent material must have given rise to the soils. Schists or sedimentary rock with quartz veins were found and it is likely that these were uplifted or uncovered with magma during the tectonic activity in the area. This however could not be mapped.

## 2.3 Physiography and Drainage

Nyantja Estate is located at an altitude varying from 1670 m in the south of the Nyantja Division to over 1850 m in the

Kakono Division. Bukombe, Nyantja and Lushondo are at an altitude of approx. 1700 m while most of the tea at Nduba and Bitesse is found at an altitude of 1760 to 1790 m.
The overall drainage pattern is in a northly direction with flat alluvial fans in the south (Kakono) and deeply incised river streams in the north (Nyantja). Slopes do generally not exceed 30 % though in the fallow area of Bukombe a slope of more than 60 % was measured.

## 3 NYANTJA ESTATE

### 3.1 General

Nyantja Estate covers a total area of approximately 638.5 hectares. The Estate is divided in 7 divisions of which the most remote division is approximately 25 km away from the factory. The basic data of each division is presented in the following table.

**Table 3 Landuse at Nyantja Estate in Hectares per Division***

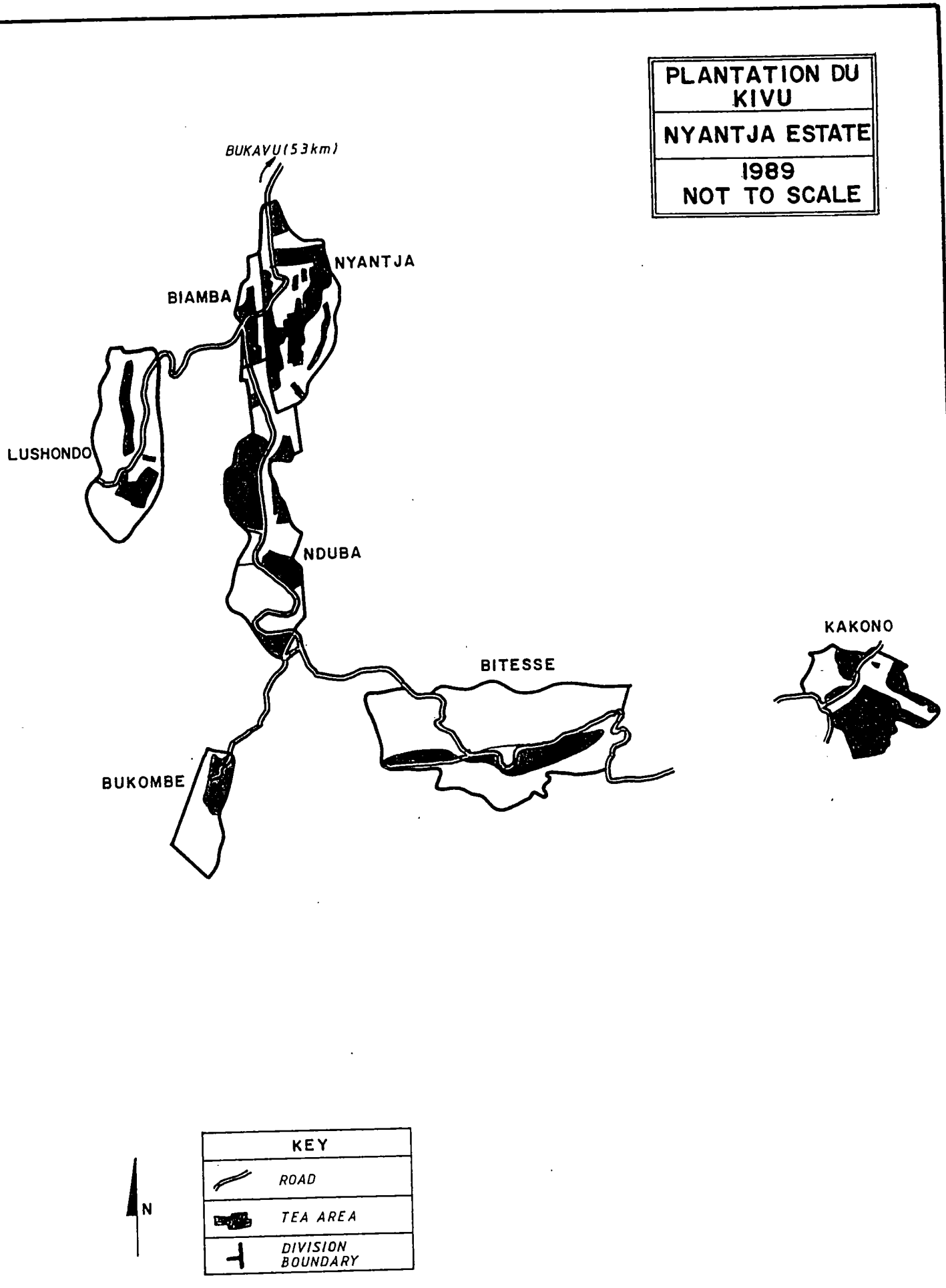
| Division | ha tea production | ha tea abandoned | ha fuelwood | ha fallow | ha swamps/ roads etc. | ha total | kms from factory |
|---|---|---|---|---|---|---|---|
| Nyantja | 60.2 | 0 | 5.0 | 6.0 | 13.8 | 85.0 | 0 |
| Biamba | 16.0 | 0 | 23.0 | 0 | 1.7 | 40.7 | 3 |
| Lushondo | 31.5 | 0 | 0.5 | 30.0 | 2.6 | 64.6 | 7 |
| Nduba | 56.2 | 4.0 | 123.0 | 0 | 2.3 | 185.5 | 7 |
| Bukombe | 22.1 | 0 | 0 | 14.0 | 0.5 | 36.6 | 11 |
| Bitesse | 11.0 | 29.0 | 4.0 | 91.0 | 2.5 | 137.5 | 11 |
| Kakono | 56.3 | 6.0 | 19.0 | 0 | 7.3 | 88.6 | 25 |
| Total | 253.3 | 39.0 | 179.5 | 141.0 | 25.7 | 638.5 | |

(* - During the time of the survey the accurate extent of some divisions was unknown)

At the time of the survey about 253.3 hectare was in production, 39.0 hectares have been abandoned. The 29 hectares which have been abandoned in Bitesse Division are due to a shortage of pluckers. While the 10 hectares in Nduba and Kakono Division are abandoned as consequence of poor yields.
So in total there is 292.3 hectares of mature tea at Nyantja Estate. There is no immature tea or a nursery.

Most of the tea is obtained from seedlings, and have been planted in the fifties. Only in some fields clones are planted: BB35 which is probably bred at Inera Mulungu is planted in field 13, 16, 17 and 18 of Nyantja Division and field 6 and 8 of Nduba Division. The clone JG365 has been planted in field 14 of Nyantja Division. In field 5 of Nduba Division clone TRI6/10 of the Tea Research Institute in Kericho (Kenya) is planted. According to the writer's information, there has never been any systematic research and monitoring of the tea clones and their production at Nyantja Estate.
An overview of varieties and their extent is given in Annex V (Volume II).

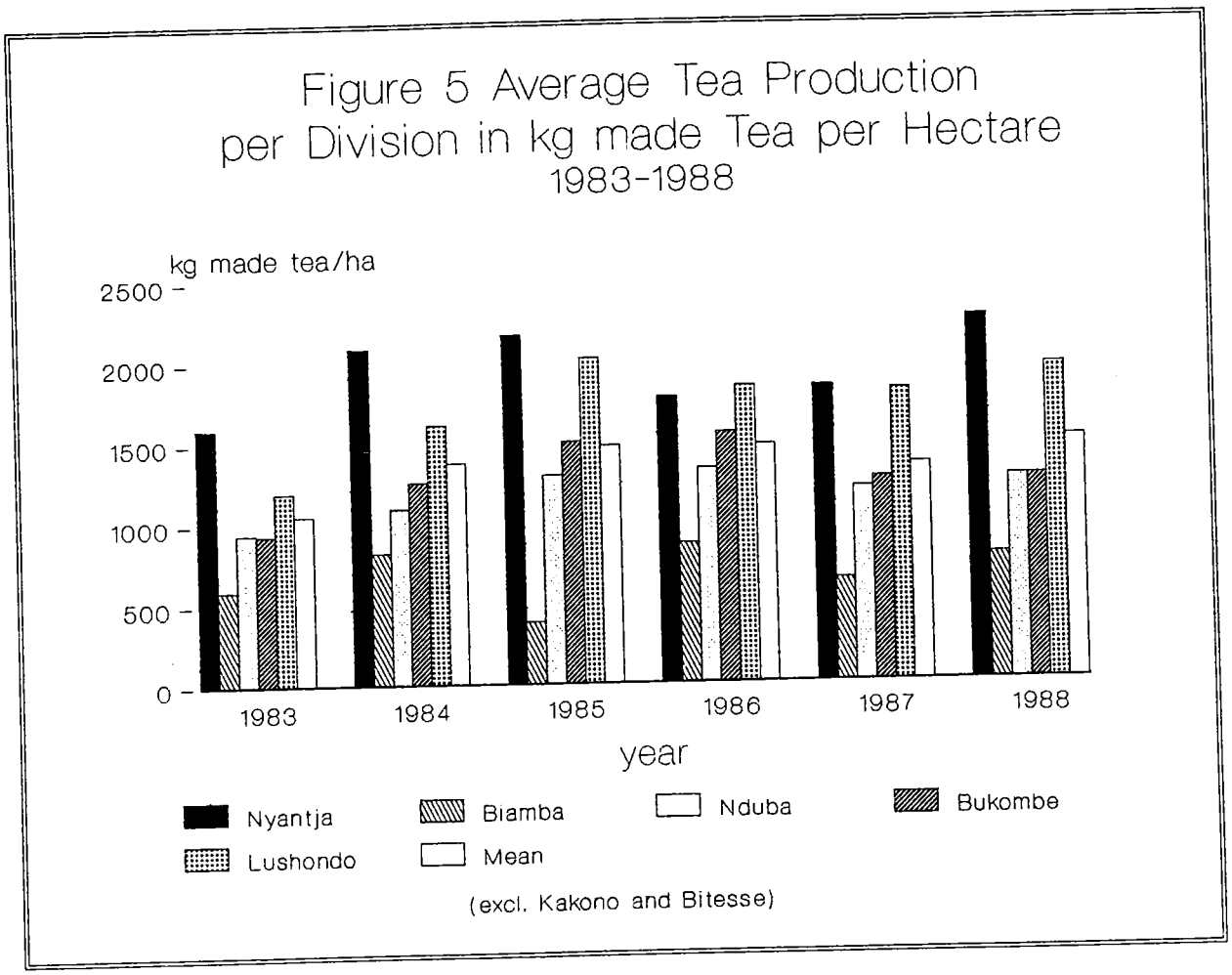
On the next page an overview map of Nyantja Estate is presented indicating the approximate tea areas.


PLANTATION DU KIVU
NYANTJA ESTATE
1989
NOT TO SCALE
BUKAVU (53km)
NYANTJA
BIAMBA
LUSHONDO
NDUBA
BITESSE
KAKONO
BUKOMBE
N
KEY
ROAD
TEA AREA
DIVISION BOUNDARY

## 3.2 Tea

### 3.2.1 Divisions and Production

At present (1989) about 253.3 ha of tea is in production, 39 ha is abandoned. The production in kg made tea per hectare of each division is presented in the following figure:




The best producing division in kg made tea per hectare is Nyantja Division. In the period 1983-1988 the production has consistently been between 1500 and 2000 kg made tea per hectare which is high. This is particular high if the fact is taken in account that fertilization has stopped in 1985/86. The highest records of production of Nyantja Division were recorded in fields 1 and 12 where in 1985 yields were over 3000 kg made tea per hectare. This is probably due to favourable weather conditions and adequate fertilization. It demonstrates however indisputable the potential for tea cultivation in the area. In other years there were quite a number of fields which produced between 2500 and 3000 kg of made tea per hectare and most fields produced between 2000 and 2500 kg of tea. The mean production of Nyantja Division is about one and a half times the average estate production in kg made tea per hectare.

The second best yielding division is Lushondo where production has increased to a constant average annual yield of over 1500 kg made tea per hectare. In 1985 field 7 and 8 produced incidentally over 3000 kg of made tea per hectare. Most fields produce on average above the estate average.
Below average are Bukombe and Nduba Division which produce about the same yield per hectare (between 1000 and 1500 kg made tea per hectare. The lowest average yields are obtained from Biamba Division which produces far below the average of Nyantja Estate.

Figure 6, on the next page, shows the extent in percentages of each area in relation to the total production in percentages as calculated by the production mean of 1986-1988. The following can be remarked:

(i) Nyantja Division comprises about one quarter of the total productive tea area, but about one-third of the total tea production is obtained from this division.

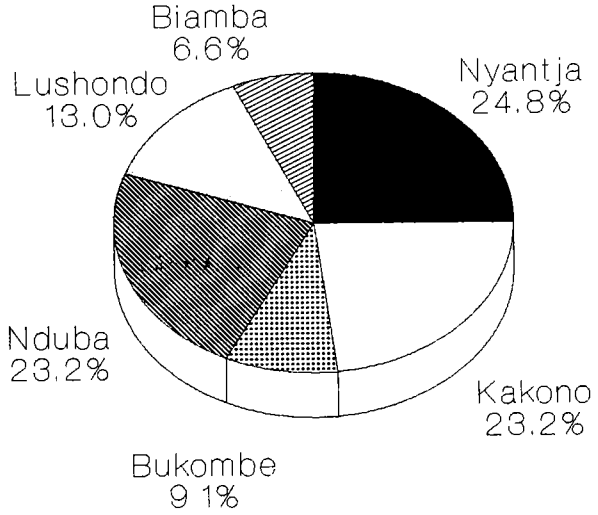
(ii) Nyantja and Lushondo Divisions take care of about half of the production while the two divisions comprise less than 40% of the total productive tea area.

(iii)Kakono and Biamba comprise nearly 30% of the total tea area while the production of these two area is less than a quarter of the total.

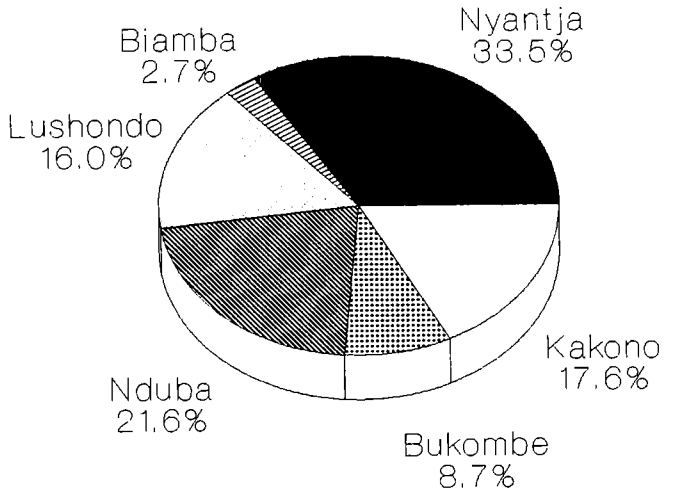
(iv) Nduba and Bukombe Divisions produce about the average and hence their extent is directly proportionally to their production.

The ratio extent/production is of great economical importance i.e. the production costs per hectare are considered the same for a low or a high yielding field while the benefits may differ largely.

# Fig. 6 Divisions and their Production at Nyantja Estate*




% of total tea area




% of total production**

* -excl. Bitesse

** -production mean 1986-1988

### 3.2.2 Tea and Shade

There are areas at Nyantja Estate which are fairly heavy shaded. This is particular the case in the Bukombe and Kakono Divisions. It has however been proven that shade does influence the production largely and that with good management shade reduces the production making sunlight the most limiting factor. On the other hand shade trees do have quite a number of advantages; they stabilize the climate by reducing wind velocity and avoid large temperature fluctuations, suppress weedgrowth and evaporation by a mulch layer, the roots may break open stiff clay layers which could before not be penetrated by the tea roots.
The impact of shade trees on the teaproduction at Nyantja Estate depends on climate, soil properties and management and according to present writer is an uniform policy regarding shade reduction at Nyantja Estate difficult to give. A rather hypothetical attempt has been made to correlate some diagnostic factors. The results are given in table 4.

**Table 4 Hypothetical Relation between Soil Drainage, Shade and Nitrogen Fertilization regarding Tea Production at Nyantja Estate.**

| Growing Condition | Some Production Determining Factors | | |
|---|---|---|---|
| | light | water | nitrogen |
| **Well drained soils** | | | |
| -shade, no nitrogen | - | + | ± |
| -shade, nitrogen | - | + | + |
| -no shade, no nitrogen | + | + | - |
| -no shade, nitrogen | + | + | + |
| **Imperfectly drained soils** | | | |
| -shade, no nitrogen | ± | + | - |
| -shade, nitrogen | - | ± | + |
| -no shade, no nitrogen | + | - | ± |
| -no shade, nitrogen | + | - | + |

KEY
- = limiting production
± = uncertain, intermediate
+ = not limiting production

It should be borne in mind that there are only a few

ecologically production determining factors assessed and that others are considered as not limiting (dry spells, lack of pluckers etc.). Albeit this table clearly indicates that the impact of shade (or microclimate) on production does vary with soil properties (drainage), and management (nitrogen fertilization). The following may be concluded:

Nitrogen fertilization on well drained soils which are heavy shaded is a waste as the tea plants are not able to extract the nitrogen from the soil solution and hence it will leach to deeper ground. Reducing the shade to acceptable levels, leaving only windbreaks, will definitely has a production increasing effect if fertilization becomes a standard management practice. Without fertilizer N, the effect of shade is to increase yields compared with the crop from unshaded tea.
This theory is considered most relevant for the soils on the crests and slopes of the Bukombe Division.

Nitrogen fertilization on imperfectly drained soils which are heavy shaded will have a very low recovery. It is expected that nitrogen is not the limiting factor but sunlight and the water availability to the tea plants do largely influence the production. Reducing the shade will tend to lead to water stress even in the growing (or rainy) seasons as the wind will increase the evapotranspiration. Moreover the thick mulch layer will be easily decomposed once radiation increases which will incline the evaporation. On the other hand this may give a nutrient boost to the tea crop. The plants will give a strong reaction on the nutrient boost and radiation increase, discovering however soon that they are too shallow rooted and hence water stress occurs. Reducing shade in such imperfectly drained soils is therefore hazardous.
One could consider shade reduction and maintaining an artificial high water table placing vertical boards in the ditches. This has been seen in surrounding tea estates of Nyantja Estate.
This theory is most relevant for the shaded valley areas of the Kakono Division.

### 3.3 Fuelwood

In total there is approximately 179.5 hectares of fuelwood cultivated. About 70% of the total fuelwood area is located in Nduba Division. The species cultivated are Eucalyptus grandis and Cupressus spp (Cypres). There is about 23 ha of mature Eucalyptus, mainly found in Kakono and Bitesse. Most of the fuelwood areas are very young and constitute often of regenerated Eucalyptus trees.
Fuelwood replanting may be essential if tea production is going to be increased. Areas suited will be discussed in chapter 6.

# 4 THE SOILS OF NYANTJA ESTATE

In this section the soils of Nyantja Estate will be described. The description is made in general with the parameters as given in Annex III (Volume II).

## 4.1 Study Approach and Methods

### 4.1.1 Data Collection

In order to correlate the soil physical and soil fertility data with other ecological parameters, all climate and production records were collected. These are presented in Volume II of this report and a summary is presented in the previous section. The data were kindly collected in cooperation with Mr. Lufungulo.

### 4.1.2 Map Preparation

As there were no maps available from Nyantja Estate the land registry maps of 1989 (1:5,000) were reduced to a scale of 1:15,000 which were then used as base maps. Hereafter the fields and roads were sketched on the maps in combination with several field checks. These were the best maps which could de made and as aerial photographs were lacking a proper map on scale could not be made. On the base maps which was made for every division, the soil maps were drawn. The soil maps are made of the whole plantation while the extent as given hereafter is of the productive tea area during the time of the survey. The extent of the soil units has been made by an accurate estimation of the soil units per field of which the extent was known. In other words the survey area has an extent of 638.5 hectare (the Chillington property) while the soil units area is 253.3 hectare (the productive tea area).

### 4.1.3 Fieldwork

In the field, augerhole observations (for general soil characterization e.g. texture, soil depth, structure) and soil pit descriptions (for detailed study) were made at sites selected according to the physiography.
Field work included the description of 62 augerholes to a depth of 200 cm (depth of bedrock and groundwater permitting) and the detailed study of 3 soil profile pits to depths varying from 120 to 200 cm; 10 soil samples were collected from the soil pits. Forty-nine composite soil samples from 00-25 cm depth were collected of selected fields covering all soil types in all divisions. The composite topsoil samples were taken of 20 randomized spots. Each samples covers approximately one acre. Furthermore numerous leaf samples have been taken of which however the laboratory results have never been obtained from Inera Mulungu.
The soils are described according to the Guidelines for soil profile description (FAO, 1977). Colours are moist colours according to the Munsell Colour Chart (1975).

## 4.2 Previous work

In 1958 Mons. A. Pecrot conducted a soil survey of the Kivu Region. According to map of this survey the soils are deep, red and clayey upland, and grey to brown with clay textures in the valleys. The upland soils have been classified as Rhodic Ultisols. The present study more or less confirms this general description.
In 1964 AHT conducted a reconnaissance survey of the Nyantja area. The soils are described as: 'deep, brown or red loam or loamy sand with a low pH. The tea does not suffer from drought stress in the dry season as consequence of the very deep soils. Erosion is said to occur and erosion control is considered important'. Furthermore the report remarks the valley soils in which tea is cultivated: 'With good (water) management these soils tend to give higher yields than the upland soils'.
The fertility of the soils was evaluated through some soil samples and the interpretation was as follows: 'The soils are very acid; phosphate and potassium levels are very low; magnesium could not be traced. Borium levels are however high and the soils are moderate provided with manganese'. The present study confirms the low pH and phosphate levels. The very low levels of potassium and the absence of magnesium must however be disputed, the levels found by the present survey were resp. high and moderate or low.
The results of the AHT soil analysis are given in Annex VI (see Volume II), and as no detailed locations are given these data are not further considered in this study.

## 4.3 Distribution of the Major Soil Units

The soils of Nyantja Estate show a strong relation with the landform in which they occur, a so-called physiographic relation. Based on this relation three soil units have been formed: the Crests, the Slopes and the Valleys. A general description of the units is given hereafter.

**(i) The Crests**, occurring as stretched ridges or nearly flat plateaus between the major drainage ways in most of the divisions. Most of the flat plateaus are found in the Nyantja and Nduba Division.
The soils are well drained. The textures are generally sandy clay and slightly increasing with depth. In the subsoil kaolinite is often present. The soils are very deep and have moderately thick or thin topsoils. Very locally the soils are shallow with bedrock and/or gravelly layers within 50 cm depth.

**(ii) The Slopes.** This unit has characteristic convex to straight slopes, towards the valleys the slopes become steeper and more concave (footslopes). The drainage is generally good though it may be a little excessive on steep slopes as consequence of (subsurface) runoff or soil crusts impeding infiltration. The footslopes which are often included in this soil association, have generally an impeded drainage.
The soil textures are clayey. There is a significant increase

with depth. Locally the soils have dense subsurface structures. The soils are very deep and have thin topsoils albeit the footslopes have generally moderately thick or thick topsoils. In a very few areas the soils are shallow.
The soils are liable to erosion and a protective soil cover is therefore essential.

**(iii) The Valleys**, are moderately well to imperfectly drained. It was observed that valley bottoms in the south being generally better drained than in the north of the estate. Though being only some measurements (and in the dry season), the depth of groundwater in the valleys of Kakono (field 1,3,4,5 & 6) was found below 120 cm while in Nyantja Division (field 9,10,11 & 12) the depth of groundwater generally occurred at 60 to 80 cm. The valleys in Lushondo and Bukombe take intermediate positions. Rooting depth was found to be directly proportional with the depth of groundwater. In the wet season depth of groundwater is less and some soils may be flooded or have a constantly saturated topsoil which is an very adverse growing condition for most crops.
Water management may therefore be a major issue for good tea production of these soils.
The soil textures are varying from sandy clay to heavy clay though the latter is more common in this unit. The soils have often uncomposed organic materials or peaty layers in the profile. The soils are generally deep though the high water table restrict deep-rooting. Topsoils are moderately thick.

The overall distribution is presented in the following table.

**Table 5 Distribution of Major Soil Units of Total Productive Tea Area.**

| | ha | % |
|---|---|---|
| Crests | 97.5 | 39 |
| Slopes | 92.1 | 36 |
| Valleys and Footslopes | 63.7 | 25 |
| Total | 253.3 | 100 |

Representative profiles of each soil unit are given in Annex I (volume II).

### 4.4 General Soil Fertility Status

In this section the fertility status will be evaluated in general terms. The following parameters are used: soil reaction (pH), organic matter (org. C x 1,72), Carbon/Nitrogen ratio (C/N), exchangeable bases (Ca = Calcium, Mg = Magnesium and K = Potassium), Cation Exchange Capacity (CEC), available phosphorus (P), and the aluminium saturation (Al %).
The fertility status will be discussed per division in the section 4.5 till 4.11. The implications of the soil fertility

for tea cultivation is given in resp. chapter 6 and 7.

The soils with the lowest **soil reactions** (pH) are found in Nyantja, Lushondo and Kakono Division. In the former two the pH may have decreased as consequence of continuous cropping and may have been accelerated by the use of acidifying fertilizers as Sulphate of Ammonia. In the Kakono Division the soils are extremely acid due to the reducing circumstances (waterlogging, high groundwater table). In Nduba and the Bukombe Divisions the soil reactions are commonly higher.
Nearly all soils have a very high **organic matter** content. The C/N ratio indicating the ability of the organic matter to release nitrogen when mineralizing is favourable on soils of the crests and slopes. Only the soils of Biamba Division and most of the valley soils throughout the estate have unfavourable ratios which may cause nitrogen deficiencies. In all soils the total available nitrogen is however not sufficient to cover the needs of a high yielding teacrop.
Most soils of Nyantja Division have low **calcium** levels. The lowest levels are found in the valley soils of Kakono. Only the soils of Nduba Division have moderate levels.
**Magnesium** levels are generally low to moderate, in some fields of Biamba and Lushondo very low levels are recorded.
Most soils are fairly well supplied with **potassium**. The soils of Lushondo are poorly supplied with this element.
The capacity of the soils to retain nutrients (**CEC**) is moderately. The soils of the crests in the Biamba Division however, have a low capacity to retain nutrients and hence leaching of nutrients after fertilization may be expected. The soils in the valleys have generally a high CEC.
The **base saturation** indicating the saturation of the CEC by the exchangeable bases (Ca, Mg K and Na) are low for most soils. The soils of the crests and in the valleys at Lushondo Division have the lowest values. Only few soils have moderate base saturation levels.
Except for some soils in Nyantja and Kakono Divisions, all soils have low available **phosphorus** levels. This problem is accelerated as most soils are strongly acid i.e. in acid soils phosphorus is precipitated into compounds of low solubility which are unavailable for plant growth. The lower the pH, the higher the phosphorus fixation.
The **aluminium saturation** indicating the percentage of the CEC occupied by aluminium is moderate in the soils of Nyantja and some soils of Lushondo Division. High (toxic) levels are found in the soils of the crests in Biamba and in all soils of the Kakono Division. The soils of Nduba, Bukombe and Bitesse Divisions have low levels.

## 4.5 The Soils of Nyantja Division

The productive tea area in Nyantja Division is about 60.2 hectares. The distribution of the soil units of this tea area is shown in the table on the next page.

Table 6 Distribution of Major Soil Units of the Productive Tea Area in Nyantja Division

| | ha | % |
|---|---|---|
| Crests | 33.2 | 55 |
| Slopes | 11.4 | 19 |
| Valleys and Footslopes | 15.6 | 26 |
| Total | 60.2 | 100 |

Soils of the Crests

More than half of the tea in Nyantja Division is cultivated on flat or nearly flat crests. Extended flat areas are field 13 and 14 and the eastern part of Nyantja Division. The soils of the crests are very deep and have a good internal drainage. The soils have dark reddish brown, thin or moderately thick topsoils and clayey textures. In the northern part of field 1, the soils have bedrock within 75 cm depth and hence the tea is performing poorly.

The fertility of the soils is low. Organic matter and potassium levels are generally high, phosphorus and nitrogen levels are low. Soils with the poorest fertility are in field 6 and the best soils within this unit are in field 1, 2 and 14.

Soils of the Slopes

One-fifth of the total productive tea is cultivated on slopes with gradients up to 20%. extensive parts of this unit are in field 3, 4, 7 and 8. The soils of this unit are well to somewhat excessively drained and have sandy clay textures. The soils are very deep and the topsoils are thin. Colours are dark reddish brown and the subsoil may locally have dense subsurface structures.

The fertility of this unit is low. The soil reactions are extremely acid. Organic matter and potassium levels are high. Magnesium, nitrogen and phosphorus levels are low or very low. Aluminium levels are locally high reaching toxic levels (field 3, 6 and 8).

Soils of the Valleys and Footslopes

Some 16 hectares of tea in Nyantja Division is cultivated in the valley bottoms. Extensive parts are in field 1, 3, 9, 11 and 12. This unit is characterized by moderately well to imperfectly drained soils. The soils have generally heavy clay textures and may have peat layers at irregular depths. The topsoils are moderately thick and have dark brown or dark greyish brown colours. Manganese concretions and mottles are commonly. The depth of groundwater is fluctuating but is mostly found within 80 cm.

The soils have a very low fertility and soil reactions are extremely acid. Only potassium levels are high. All other nutrient levels are low or very low.

## 4.6 The Soils of Biamba Division

The soil unit distribution of Biamba Division is presented in

the following table.

**Table 7 Distribution of Major Soil Units of the Productive Tea Area in Biamba Division**

| | ha | % |
|---|---|---|
| Crests | 3.2 | 20 |
| Slopes | 12.8 | 80 |
| Valleys and Footslopes | 0 | 0 |
| Total | 16.0 | 100 |

Soils of the Crests
About 20 % (3.2 hectare) of the productive tea in Biamba Division is cultivated on flat or nearly flat crests. The soils are very deep and are well drained. The topsoil is thin. Colours are dark reddish brown throughout the profile. Locally the soils have dense subsurface structures.
The fertility is very low with extremely acid soil reactions. Organic matter and potassium levels are high. Magnesium tend to be nearly absent in this soil. Nitrogen and phosphorus levels are very low. The available aluminium levels are high reaching toxic levels.
Soils of the Slopes
This unit covers about 12.8 (80%) hectare of Biamba Division. These soils resemble physically almost the soils on the crests in Biamba Division, but colours tend to be more yellow towards dark brown in the topsoil and dark reddish brown in the subsoil.
The overall fertility of the soils is very low. The soils have extremely acid soil reactions and the low levels of exchangeable bases. The availability of nitrogen is low. Organic matter and phosphorus levels are resp. high and moderate.

### 4.7 The Soils of Nduba Division

More than half of the productive tea in Nduba Division is grown on crests as can be seen from the following table.

**Table 8 Distribution of Major Soil Units of the Productive Tea Area in Nduba Division.**

| | ha | % |
|---|---|---|
| Crests | 30.9 | 55 |
| Slopes | 24.7 | 44 |
| Valleys and Footslopes | 0.6 | 1 |
| Total | 56.2 | 100 |

Soils of the Crests

The soils of the crests cover the whole area west of the road to Bukombe Division. The soils are very deep and well drained. Colours are very dusky red. The moderately thick topsoils have sandy clay textures. Subsoils have a higher clay content (kaolinite). The soils are less sticky and stiff as in Nyantja and Biamba Division.

The fertility of the soils on the crests in Nduba Division is moderate. The soil reaction is strongly acid but most soils of Nduba Division have the highest pH of the whole estate. Organic matter and potassium levels are high. The C/N ratio is moderate, total nitrogen and available phosphorus levels are low.

Soils of the Slopes

The soils of the slopes have dark reddish brown colours and clayey textures in the topsoil. The soils are very deep, topsoils are moderately thick. The subsoil is more kaolinitic with dark reddish brown colours.

The fertility of the soil is moderate. The pH is strongly acid and the soils have very high organic matter levels. Except for the very low exchangeable magnesium levels of field 3, the soils have moderate exchangeable bases levels. Phosphorus levels are low.

Soils of the Valleys and Footslopes

Only 0.6 hectare in Nduba Division is cultivated in the valley bottoms. The soils are imperfectly drained.

No samples for analysis were taken.

## 4.8 The Soils of Lushondo Division

The distribution of the units is presented in the following table after which a description of each units follows:

**Table 9 Distribution of Major Soil Units of the Productive Tea Area in Lushondo Division.**

| | ha | % |
|---|---|---|
| Crests | 11.5 | 37 |
| Slopes | 13.8 | 44 |
| Valleys and Footslopes | 6.2 | 19 |
| Total | 31.5 | 100 |

Soils of the Crests

About 11.5 hectares of the total productive tea area in Lushondo Division is located on crests position. The soils are very deep and have dark reddish brown colours. Both top- and subsoil are clayey, texture is increasing with depth. The topsoil is thin. As can be seen on the soil map (see Volume II) west of the stream through field 7, the soils on the crests are shallow with gravelly bedrock within 50 cm. These soils have been planted with Cypres which grew poorly.

The fertility of the crests soils is low. The soils have an extremely acid soil reaction (pH) and low to very low levels

of exchangeable bases. Phosphorus an d nitrogen levels are low. The aluminium saturation of the CEC, reaches moderate levels.

Soils of the Slopes

Sloping productive land covers about 44% (13.8 ha) of Lushondo Division. The soils are very deep and have very dusky red top- and subsoils. The topsoils are thin. Textures are clayey and increasing with depth.

West of the stream and south of field 7 the sloping land is shallow and bedrock is found within 50 cm depth. This land has previous been under Cypres which grew very poorly as consequence of the adverse rooting conditions.

The fertility of the sloping tea-land in Lushondo Division is very low. The soil reaction is extremely acid. Organic matter levels are very high. Exchangeable bases, nitrogen and phosphorus levels are low to very low. The aluminium saturation levels are moderate.

Soils of the Valleys and Footslopes

Approximate 20% of the tea at Lushondo Division is cultivated in the valley bottoms. Field 8, 9 and 10 are completely within this unit. The soils are moderately well drained at the footslopes and imperfectly drained in the centre of the valley bottom. The colours of the topsoils are dark brown, subsoil colours are grey black with many red mottles. The topsoils are moderately thick. The subsoil have locally peat layers. Groundwater levels are deeper than 120 cm in the dry seasons.

The soils have extremely acid soil reactions. The organic matter levels are very high. The C/N ratios are unfavourable and nitrogen levels are very low. Potassium levels are high but other exchangeable bases levels are low to very low. Phosphorus levels are low. Summarized can be said that the soils in the valley bottoms of Lushondo Division have a very low fertility status.

## 4.9 The Soils of Bukombe Division

The soil unit distribution of Bukombe Division is given in the following table:

**Table 10 Distribution of Major Soil Units of the Productive Tea Area in Bukombe Division.**

| | ha | % |
|---|---|---|
| Crests | 12.7 | 57 |
| Slopes | 7.9 | 36 |
| Valleys and Footslopes | 1.5 | 7 |
| Total | 22.1 | 100 |

Soils of the Crests

The soils of the flat or nearly flat crests cover about 57% (12.7 ha) of the total productive tea area in Bukombe Division. Field 3, 5, 8 and 9 are within this unit. The soils

are very deep, well drained and have dark red topsoils and dusky red subsoils. The topsoils are thin and covered with a Grevillea leaf litter mulch. The textures are clayey and increasing with depth.
The fertility of the soils is moderate. The soils have very strongly acid soil reactions and high organic matter contents. Exchangeable potassium levels are high, calcium and magnesium levels are low. Phosphorus and nitrogen levels are low. The available aluminium is low.

Soils of the Slopes

The sloping land of Bukombe Division covers nearly 8 hectare (or 36%). The soils are well drained and are generally very deep (> 120 cm). The thin topsoils have dark reddish brown colours and clayey textures. The subsoils have an slightly heavier texture (more clay) and dusky red colours.
The fertility of the soils is moderate. The soil reactions are very strongly acid, levels of organic matter and potassium are high. The C/N ratio is favourable though absolute nitrogen levels are low. Phosphorus levels are low. The aluminium saturation levels are low.

Soils of the Valleys and Footslopes

The valley bottom land of the Bukombe Division has an impeded drainage. The soils are generally deep with thin topsoils. Textures vary from peaty to heavy clay.
No samples for analysis were taken of this unit.

## 4.10 The Soils of Bitesse Division

The productive in Bitesse Division is only grown on sloping land as can be seen form the following table.

**Table 11 Distribution of Major Soil Units of the Productive Tea Area in Bitesse Division.**

| | ha | % |
|---|---|---|
| Crests | 0 | 0 |
| Slopes | 11 | 100 |
| Valleys and Footslopes | 0 | 0 |
| Total | 11 | 100 |

Soils of the Slopes

The thin topsoils have dusky red to dark reddish brown colours and dusky red subsoils. The textures are clayey and increasing with depth. Locally the topsoils are very thin and less than 10 cm. The soils are well to somewhat excessively drained and are generally very deep.
The fertility of the soils of Bitesse Division is low. The soil reactions are very strongly acid. Organic matter and potassium levels are low. The phosphorus levels are low. In field 3 aluminum saturation levels has reached high levels.

## 4.11 The Soils of Kakono Division

The distribution of the soil units is given in the next table.

**Table 12 Distribution of Major Soil Units of the Productive Tea Area in Kakono Division.**

| | ha | % |
|---|---|---|
| Crests | 6.0 | 11 |
| Slopes | 10.5 | 18 |
| Valleys and Footslopes | 39.8 | 71 |
| Total | 56.3 | 100 |

Soils of the Crests

The soils of the crests cover about 6 hectare (or 11%) of the total productive tea area in Kakono. The moderately thick topsoils have dusky red colours and clayey textures. The dusky red subsoils have an increasing clay content.
The fertility of these soils is low. The pH is extremely acid. Organic matter and potassium levels are high. Exchangeable bases and nitrogen levels are low. The available phosphorus levels are low. Exchangeable aluminium levels reaches high values and the aluminium saturation of the CEC is accordingly.

Soils of the Slopes

Sloping land covers about 10.5 hectare of the total productive tea area in Kakono Division. The soils have dark reddish brown colours throughout the profile. The moderately thick topsoils have clayey textures and are covered with a thick mulch (± 5 cm) of Grevillea leaf litter. The subsoils, which may locally be (probably rudimentary) mottled, have clay textures with greater depth.
No samples for analysis were taken.

Soils of the Valleys

About three quarter of the Kakono tea is grown on moderately well to imperfectly drained soils. These soils which have moderately thick topsoils with a thick mulch layer (of Grevillea leaves) have groundwater at an average depth of 120 cm being deeper than the levels of the valley bottom lands in the other divisions of Nyantja Estate. An artificial drainage pattern of many ditches and three natural streams, drain the whole southern part of the division (field 1 - 6) The soils have olive brown colours in the topsoil and very dark gray colours in the heavy mottled subsoils. Textures are clayey throughout the profile. Locally many uncomposed woodpieces are accumulated at irregular depths.
The fertility of the valley soils is low to very low. The pH is extremely acid and in this unit the lowest values of the whole estate are recorded (as low as pH H2O 3.2). Organic matter levels are very high. POtassium levels are very high in all sampled soils of this unit. Calcium and magnesium levels are low to moderate. The C/N ratio is unfavourable and the absolute amounts if nitrogen are very low. The available phosphorus levels are high and the highest recorded in the estate.

# 5 TEA REQUIREMENTS

In this section the environmental requirements for tea cultivation are given. The nutrient requirements of tea are emphasized e.g. soil acidity, major nutrients like NPK and minor nutrients. At last some fertilizers will be discussed which are suitable for tea fertilization.

## 5.1 General Tea Requirements

The Mulungu Research Station summarized optimal growing conditions for tea in South-Kivu at an altitude of approx. 2000 m with a total annual rainfall varying from 1500-2500 mm. Though it is stated that 1500 to 1600 mm is sufficient, if not too hot. The temperature should not drop under 5 °C or exceed 35 °C. Soils should preferably be deeper than 150 cm. Further the Mulungu Station states that tea in South-Kivu has generally a good reaction on nitrogen and phosphorus fertilization.
An optimal tea crop production requires sunshine exceeding 5 hours per day, i.e. ± 1800 hours per year, but tea is able to grow in areas with a daily sunshine of 3-4 hours per day.
Tea crop is particularly sensitive to impeded drainage; any flooded unit is unsuitable for tea cultivation. An imperfect drainage is already a severe limitation for tea cultivation because it promotes some diseases and squeezes the root development. Tea soils should be well drained to ensure oxygen availability and promote a deep rooting.

## 5.2 Mineral Requirements of Tea

### 5.2.1 Soil Acidity

First of all, tea requires an acid soil. Some authors propose optimum pH values around 5.4 - 5.6 (pH water), but it is generally admitted that tea can grow successfully on soils with pH values between 4 and 5.8. Nevertheless, attention must be paid to soil pH, because increasing soil acidity may:

- -induce deficiencies, mainly of potassium and phosphorus, sometimes magnesium and molybdenum,
- -increase losses due to leaching and reduce the efficiency of fertilizer application,
- -produce excessive amounts of manganese and lead to either Mn toxicity or Mn/Mg antagonisms; this chiefly depends on soil type (original Mn content) and drainage conditions,
- -increase availability of zinc and copper while reducing availability of molybdenum.

However, liming of tea soils is not recommended: calcium applications may hinder the uptake of potassium, if the latter is in short supply. Moreover, the tea plant accumulates significant amounts of aluminium and manganese, nutrients that become unavailable above pH values around 5.6-5.8.
Soil acidity is therefore one of the main tea requirements but should be kept within acceptable limits that guarantee the availability of all essential elements for tea in correct balance.

### 5.2.2 Major Nutrients

**Nitrogen** is the most important nutrient for a high yielding tea crop since it is cultivated for its leaf production. It is estimated that 50 kgs of nitrogen are removed per 1000 kgs of made tea.
A nitrogen shortage is a highly limiting factor for high yields. An application of around 90 kg/ha, per year is considered as the minimum. For high yields, doses of around 200 - 250 kg N/ha per year are often recommended. Sulphate of ammonia has been the common tea fertilizer. Unfortunately, repeated applications of SA over many years reduces the pH of the soil faster than some other N-fertilizers. Where pH is too low, it is recommended to apply another form such as a compound fertilizer NPK 25-5-5 or 20-10-10 in order to avoid P and/or K-deficiencies.

**Phosphorus** may become deficient where mulching (pruned stalks and leaves) is not a common practice. Also the availability of phosphorus can be depressed by soil phosphorus fixation processes in relation to soil acidity. In acid conditions exchangeable aluminium and phosphate anions precipitate into compounds of low solubility: the lower the pH the higher the exch. aluminium levels and the larger the phosphorus fixation (e.g. in highly weathered soils).
If necessary phosphorus can be supplied with NPK fertilizers. First of all, phosphorus availability should be guaranteed for young plants since this element stimulates new wood and root formation. Concerning mature tea, phosphate applications increase the capability of the tea plant to respond to nitrogen. At least 8 kg of $P_2O_5$ (3.5 kg of P) are removed per 1000 kg made tea. Where no NPK fertilizer is used an application of 30 kg of $P_2O_5$ (13 kg of P) can be given per hectare per year.

**Potassium** has appeared to be very important in many experiments and various areas. Potassium deficiencies are rather common in tea and generally due to one or more of the following factors:
-<u>Excessive soil acidity</u>: The Tea Research Institute of East Africa recommends a potash applications where soil pH is below 5.8; continuous cropping without application of potassium will eventually cause deficiency of this element: this is often the case after continuous applications of SA alone on tea soils for a number of years.
-<u>Nutrient antagonisms</u>:the use of calcium fertilizers such as CAN (Calcium Ammonium Nitrate) or single super phosphate is likely to hinder the potassium uptake while an excess of N often induces K/N imbalances.
The amount of potash applied depends on the severity of the deficiency and could in some cases, be over 200 kg $K_2O$ per ha per year.

**Magnesium** deficiency generally occurs on poor acid highly weathered and leached soils. The symptoms of Mg deficiency consist of a bright yellow colour of mature leaves with a dark inverted "V" along the mid-rib.
Magnesium deficiency symptoms may also be associated with

relative excess of manganese and a poor root development induced by a lack of potassium. In the last case the application of potash will promote the uptake of magnesium and hence the magnesium deficiency symptoms will disappear.

**Sulphur** is an essential element for tea. On mature tea, sulphur deficiencies have seldom been reported since Sulphate of Ammonia is often use to fertilize tea soils. In soils high in calcium, sulphur must be used for new plantings and mixed with the soil in the planting hole. In this case Aluminium Sulphate is preferably used.

### 5.2.3 Minor Nutrients

The tea plant accumulates **aluminium and manganese.** The role played by aluminium is not very well known but a few authors consider that this element contributes to the health and vigor of the tea bush. As pointed out above, aluminium is generally available in tea soils because of their acidity. When the pH is too high (above 6) it is necessary to apply aluminium sulphate in the planting hole. Depending on the manganese content in the parent material excessive amounts of exchangeable manganese are associated with low soil pH and the manganese availability increases with increasing acidity of soil. Manganese toxicity can develop in poor drainage conditions and hinder magnesium uptake.

The availability of **zinc and copper** normally covers the tea requirements because soil acidity promotes it. Nevertheless, a substantial supply of these elements might be necessary in cases where the soils are developed in parent materials that are originally poor in zinc or copper. Foliar applications of zinc sulphate (± 20 kg/ha) and copper sulphate (± 5 kg/ha) correct zinc and copper deficiency respectively.

## 5.3 Suitable Fertilizers

Presently there are no fertilizers available in the south Kivu Region of Zaire. Therefore fertilizer proposals as given hereafter are based on the types of fertilizers available on the world market and which are recommended for tea fertilization.

The table on the following page correlates some soil properties and suitable fertilizers. The following fertilizers may be considered for fertilization schemes at Nyantja Estate:

Sulphate of Ammonia
The best type of nitrogenous fertilizer for high yielding tea is sulphate of ammonia (SA) which is the most efficient in terms of crop yields and economic return. However continuous applications of SA acidify the soil which has serious consequences as discussed in 5.2.1.

**Table 13 Correlation of Soil Properties and Fertilizers**

| soil properties | fertilizer |
|---|---|
| moderately acid or acid with favourable levels of P and K | Sulphate of Ammonia (20.5% N) |
| acid or strongly acid with favourable levels of P and K | NPK 25-5-5 (25% N) |
| acid or strongly acid with unfavourable levels of P and/or K | NPK 20-10-10 (20% N) |

NPK 25-5-5
The compound NPK fertilizer 25-5-5 is commonly advised by TRI (Kericho) for tea fertilizing. It is a concentrated fertilizer and should be used on soils below pH 5.8.

NPK 20-10-10
A fertilizer with a higher content of phosphorus and potassium is NPK 20-10-10. Consequently the N-content per kilogram fertilizer is lower than that of 25-5-5. This fertilizer is advised on soils which have relatively poor levels of P and K.

Although there are more fertilizers suitable this list is deliberately made short to facilitate the choices for importing.

# 6 LAND EVALUATION FOR TEA AND FUELWOOD

## 6.1 Introduction

In this chapter the evaluation of the Nyantja lands with respect to tea and fuelwood cultivation is made. Firstly the parameters will be discussed which are used in the evaluation. The parameters selected are considered relevant for the determination of the potential of the Nyantja lands for high tea yields. For each parameters a relative scale in terms of favourable/unfavourable for tea cultivation has been developed. This scale is the key in the evaluation as the actual conditions are matched with the tea requirements via this scale.
At last a word on the selection of parameters:
- Available water calculations could unfortunately not be made due to the lack of ring sample analysis facilities and the lack of evapotranspiration data.
- Erosion hazard is not considered in the evaluation of the mature tea status as tea has generally a sufficient groundcover. It is only considered for new plantings of tea and fuelwood.

## 6.2 Evaluation Parameters

A brief discussion of each evaluation parameter follows hereafter:

Soil Fertility
The following parameters have been used: soil reaction (pH), organic matter (org. C x 1,72), Carbon/Nitrogen ratio (C/N), exchangeable bases (Mg = Magnesium and K = Potassium), Cation Exchange Capacity (CEC), available phosphorus (P), and the aluminium saturation (Al %).
The parameter has been determined by the analysis of composite topsoil samples.

Soil Physics
With soil physics is meant here the soil depth and the soil drainage class.
The soil depth is dependent from the depth to bedrock or gravelly layers or the depth to groundwater. Soil depth is an important parameter determining the rooting conditions.
The soil depth is determined by soil auger.
The soil drainage class which has also been determined by soil auger, indicates the oxygen availability of the roots and is closely linked with soil depth. The colour and abundance of mottles, and the depth of groundwater are important for determination.

Distance to the Factory
The distance of a division to the factory determines greatly the potential. A division with a great distance has a lower potential than a division nearby the factory. This parameter becomes less important once the estate is rehabilitated.

## 6.3 Mature Tea

### 6.3.1 Soil Fertility Appraisal

In table 14 the soil fertility status of the sampled soil units of Nyantja Estate is matched with the requirements of the tea crop.

**Table 14 Appraisal of Present Soil Fertility Status with Respect to Tea Cultivation at Nyantja Estate**

| Division | Soil Unit | pH | OM | C/N | Mg | K | CEC | P | Al% |
|---|---|---|---|---|---|---|---|---|---|
| Nyantja | crest | ± | + | + | + | + | ± | - | ± |
| | slopes | ± | + | ± | ± | + | ± | ± | ± |
| | valleys | - | + | - | + | + | + | ± | ± |
| Biamba | crests | ± | + | - | ± | + | - | - | - |
| | slopes | ± | + | - | ± | + | ± | ± | ± |
| Nduba | crest | + | + | ± | + | + | ± | - | + |
| | slopes | + | + | + | ± | + | + | - | + |
| | valleys | no samples taken | | | | | | | |
| Lushondo | crests | ± | + | ± | ± | - | ± | - | ± |
| | slopes | ± | + | ± | ± | - | ± | - | ± |
| | valleys | - | + | - | ± | + | + | - | ± |
| Bukombe | crests | + | + | + | ± | + | ± | - | + |
| | slopes | + | + | + | ± | + | ± | - | + |
| | valleys | no samples taken | | | | | | | |
| Bitesse | slopes | ± | + | + | ± | + | ± | - | + |
| Kakono | crests | - | + | + | ± | + | ± | + | - |
| | slopes | no samples taken | | | | | | | |
| | valleys | - | + | - | ± | + | ± | ± | - |

| KEY | |
|---|---|
| pH = pH water<br>OM = organic matter<br>C/N = carbon/nitrogen ratio<br>Mg = exch. magnesium<br>K = exch. potassium<br>CEC = Cation Exchange Capacity<br>P = available phosphorus<br>Al% = aluminium saturation of CEC | + = favourable<br>± = intermediate<br>- = unfavourable |

From this table can be seen that the soil reactions of Nduba and Bukombe Divisions are generally favourable for tea cultivation. Other well drained soils have moderate soil reactions except for Kakono where the soil reactions are unfavourable. All valley soils have unfavourable (extremely acid) soil reactions.

**Organic matter** contents of all soils are favourable for tea cultivation. The C/N ratios are moderate in the well drained soils of most divisions excluding the soils in Bukombe and Bitesse which have favourable ratios. All valley soils have unfavourable (too high) ratios indicating low availability of nitrogen.
Exchangeable **magnesium** levels are variable per soil unit and per division. Most soils have moderate levels, unfavourable levels have not been recorded. The soils of the crests in Nyantja and Nduba Division have favourable levels.
Though most soils are not very well supplied with this element the high levels of potassium probably avoid magnesium deficiencies.
**Potassium** levels are favourable in all soils except the soils of the crests and slopes in Bukombe Division which have unfavourable levels. In the soils of Bukombe potassium fertilization is required to avoid deficiencies.
The **cation exchange capacity** (CEC) is moderate in most well drained soils, the soils of the valleys have generally favourable CEC's. The soils of the crests in Biamba Division have unfavourable CEC's. The general conclusion is that fertilizers should not be given in heavy doses in order to avoid leaching of nutrients to deeper ground.
The available **phosphorus** levels are unfavourable in most soils. Only the soils of Kakono Division have moderate or favourable levels of this element. Also the soils of the slopes and the valleys in Nyantja and Biamba Division are moderately well supplied with phosphorus. All other soils have too low levels for tea cultivation.
The **aluminium** saturation of the soils of the entire Nyantja and Lushondo Divisions reaches moderate levels. An increase of the available aluminium of the soils due to for instance the use of acidifying fertilizers must be considered as a disadvantage. The soils of Nduba, Bukombe and Bitesse divisions have favourable aluminium saturation levels. The soils of the crest in Biamba Division and all soils of Kakono Division have unfavourable aluminium saturation levels by which aluminium toxicity and nutrient imbalances are likely to occur.

### 6.3.2 Overview

In the following table (next page) the selected parameters for the evaluation of the Nyantja lands are matched with the tea requirements. The evaluation results in a relative classification in terms of high, moderate or low potential for high tea production. This means that for the rehabilitation of the estate the management should scope first of all on the high potential areas where little inputs are required to obtain high yields. After a steady income and the relatively quick return of the high potential areas the management may scope on the moderate and low potential areas where relatively more inputs are required to secure optimal production.

**Table 15 Appraisal of the Soil Units of Nyantja Estate with Respect to Tea Cultivation**

| Division | soil Unit | soil fertil. | soil physics | distance factory | potential | extent in ha. |
|---|---|---|---|---|---|---|
| Nyantja | crest | ± | + | + | high | 33.2 |
| | slopes | ± | + | + | high | 11.4 |
| | valleys | - | ± | + | moderate | 15.6 |
| Biamba | crests | - | + | + | moderate | 3.2 |
| | slopes | - | + | + | moderate | 12.8 |
| Nduba | crest | + | + | ± | high | 30.9 |
| | slopes | + | + | ± | high | 24.7 |
| | valleys | nd | ± | ± | moderate | 0.6 |
| Lushondo | crests | ± | + | ± | moderate | 11.5 |
| | slopes | - | + | ± | moderate | 13.8 |
| | valleys | - | ± | ± | moderate | 6.2 |
| Bukombe | crests | + | + | ± | high | 12.7 |
| | slopes | + | + | ± | high | 7.9 |
| | valleys | nd | ± | ± | moderate | 1.5 |
| Bitesse | slopes | ± | + | ± | moderate | 11.0 |
| Kakono | crests | - | + | - | low | 6.0 |
| | slopes | nd | + | - | low | 10.5 |
| | valleys | - | ± | - | low | 39.8 |

(nd = not determined)

| KEY |
|---|
| + = favourable<br>± = intermediate<br>- = unfavourable |

Areas with a High Potential (120.8 hectares)
Half of the presently productive tea areas has a high potential for high yields. The areas with a high potential are located in the divisions Nyantja, Nduba and Bukombe. Nearly half of this high potential areas are located in Nduba where only fertilization is required to obtain high yields. The soils in the Bukombe division have also a high potential though the shade trees ought to be removed and this should be compensated with fertilization as discussed in section 3.2.2. About one third of the high potential areas is located in Nyantja Division. Although many of these soils have a moderate fertility they are close to the factory and have favourable physical properties.
It should be borne in mind that high yields can only be obtained with adequate fertilizing and management standards.

Areas with a Moderate Potential (76.2 hectares)
About one third of the presently productive tea area has soils with a moderate potential for high yields. These areas are all tea soils in the Biamba and Lushondo Division and further the valley soils of Nyantja, Nduba, Bukombe and the slopes of Bitesse.
The tea soils of Biamba and Lushondo division have low to very low levels of nutrients and require heavy dressings of

fertilizer for optimal tea yields.
The valley soils of the above mentioned areas have adverse drainage conditions for tea cultivation.

Areas with a Low Potential (56.3 hectares)
Kakono Division has a low potential for tea cultivation. All soils in this division have a low to very low fertility and about 40 hectares have an impeded soil drainage. Moreover this division is located about 25 km away from the factory which considerably increases the costs of production (transport of tea, fertilizers etc.)

### 6.4 New Tea Plantings

It is the aim of the Plantation du Kivu Management to increase the tea acreage with about 100 hectares to 350 hectares which is said to be more economically.
Areas available and suitable for new plantings will be discussed in this section.

#### 6.4.1 Available Areas for New Tea Plantings

In Volume II the maps of each division are presented. The acreage and boundaries on the soil map present the approximate Chillington property. If these maps are compared with the mature tea areas than can be seen that less than half of the total estate area is planted with tea. Remaining areas are under fuelwood or are bush fallow. Hereafter a brief discussion on the fallow areas follows.

Nyantja and Biamba Division
Fallow areas in Nyantja cover about 6 hectare. The areas are found west of field 1 and between field 2 and 14. Further there are no areas available for any extension of tea or fuelwood in both divisions.
Nduba Division
In Nduba Division no direct fallow areas are available. However, there are areas where the fuelwood stand is very thin and which could be totally cleared for new tea plantings. These areas are located between field 8 and 10 and the flat areas east of the road through field 5, in total about 26 hectares. Further there is about 20 hectares of thinned and regenerated fuelwood between field 10 and the boundary with Biamba Division, south of field 1 and downslope at the eastern part of field 5.
Lushondo Division
In the Lushondo Division there is about 30 hectares of fallow land mainly located in the western part of the division which has previously been under Cypres for fuelwood. About 2 hectares of fallow land is located north of field 9, and in field 5 and 7.
Bukombe Division
There is about 14 hectares of fallow land in the Bukombe Division. This is found in the southern part.
Bitesse Division
There is about 91 hectare of fallow land in the southern part

of Bitesse. The availability is except from the adverse sloping conditions, discussable as some of the land has been taken by squatters whom are not very eager to leave.
Kakono Division
No land available for new plantings.

An overview of available areas is given below:

**Table 16 Overview of Available Areas for New Tea Plantings**

| Division | hectare fallow | location |
|---|---|---|
| Nyantja | 6.0 | west of field 1, between field 2 and 14 |
| Biamba | 0 | |
| Nduba | 26.0 | thinned fuelwood areas between field 8 and 10, flat area east of field 5 |
| | 20.0 | north of field 10 and the boundary with Biamba, south of field 1, downslope at the western part of field 5 |
| Lushondo | 28.0 | western part of the division |
| | 2.0 | north of field 9, in field 5 and 7 |
| Bukombe | 14.0 | southern part of the division |
| Bitesse | 91.0 | south of field 3 |
| Kakono | 0 | |
| Total | 187.0* | |

(* - This is 46 hectares more as given in table 3 due to the fact there is 46 hectares of Nduba Division included which is actually not fallow but under thinned half generated fuelwood trees)

### 6.4.2 Suitable Areas for New Tea Plantings

The here made evaluation of the suitable areas for new tea plantings is rather pragmatic. The principle areas available for new plantings have been recognized in the previous section. The soil properties and distance to the factory are matched with the tea requirements as given in section 5.
A brief discussion in terms of unsuitable/moderately suitable/suitable is given below:

Suitable Areas (31 hectares)
Suitable areas are found in the most northern part of field 1 and between field 3 and 14 of Nyantja Division (3 hectares). Although the fertility is not high the soils have favourable physical properties and are situated nearby the factory.
In Lushondo Division about 2 hectares is suitable for tea cultivation, situated in north of field 7 and in field 5 and 9. Suitable soils in Nduba Division are found between field 8 and 10 and the flat area east of field 5.
All these soils have favourable physical properties but initially fertilizing, particular phosphorus, is essential for a good establishment of the new tea plantings.

Moderately Suitable Areas ( hectares)
Moderately suitable areas are considered the 20 hectares of thin fuelwood land north of field 10 and the boundary with Biamba, south of field 1 and downslope at the western part of field 5 in Nduba Division. Erosion hazard and the land clearing costs make these lands only moderate suitable for new tea plantings.

Unsuitable Areas (45 hectares)
Absolutely unsuitable for tea cultivation is the western part of Lushondo Division (28 ha) and the southern part of Bukombe Division (14 ha). Also the southern part of field 1 in Nyantja Division is unsuitable.
These areas are unsuitable as consequence of the shallow soils. In these soils the rooting depth is restricted by gravelly layers or bedrock within 80 cm depth resulting in a insufficient rooting volume for the tea.

**Table 17 Overview of Suitable Areas for New Tea Plantings**

| Class | Division | Location | Extent | Limitation(s) |
|---|---|---|---|---|
| Suitable | Nyantja | NW of field 1 | 1 ha | soil fertility |
| | | between field 2 and 14 | | |
| | Nduba | between field 8 10, flat area west of field 5 | 26 ha | |
| | Lushondo | N of field 9, in field 5 and 7 | 2 ha | |
| Moderately Suitable | Nduba | N of field 10 | total 20 ha | thick bush and many trees |
| | | S of field 1 | | erosion hazard |
| | | downslope W of field 5 | | erosion hazard |
| | Bitesse | S of field 3 | 91 ha | erosion hazard, slope |
| Unsuitable | Nyantja | SW of field 1 | 3 ha | limited soil depth and adverse rooting conditions |
| | Lushondo | SW part | 28 ha | id. |
| | Bukombe | S part | 14 ha | id. |

(N = north, E = east, S = south, W = west)

If all suitable areas are planted the expansion of the estate is about 31 hectares. Another 29 hectares could be gained with pruning the abandoned fields in Nduba, Bitesse and Kakono Divisions. In case of Nduba only heavy dressings of fertilization is required to take the abandoned fields back in

production. The abandoned fields in Bitesse and Kakono may be hindered by shortage of pluckers.
Nonetheless the increase of the tea areas may be about 60 hectares (29 + 31) above the presently productive area of 253.3 hectare. This brings the total suitable tea area at Nyantja Estate about 313.3 hectare. An extension to about 350 hectares is possible when the moderately suitable areas are planted though it is recommended to rehabilitate the mature area first and then plant the suitable land. Planting the moderately suitable land could be considered in a later stage of the rehabilitation program.

### 6.5 Expansion of Fuelwood Areas

The areas which have been classified in the previous section as moderately suitable or unsuitable for tea cultivation, are primary suitable for fuelwood. Although the following should be kept in mind: The stony and shallow areas in Nyantja (N of field 1), south of Bukombe and in the south west of Lushondo may be considered for planting but growth will be retarded. This is illustrated by the Cypres fuelwood areas which have been in the south of Lushondo. The trees planted on stony and shallow soils reached a thickness of only 20 cm in more than 30 years. Planting such soils is therefore not recommendable.

The area considered most suitable for fuelwood planting is situated in Bitesse, south of field 3. About 91 hectare is fallow in this division though some hectares have been claimed by squatters. The land is sloping which enlarges the hazard for erosion when planting the trees. The soils are generally deep and have favourable physical properties for tree planting. There is already one field of Eucalyptus planted. Planting these areas may also avoid that the more land is taken by squatters.
Other areas suitable for fuelwood plantings are west of field 5 in Nduba Division. Here the soils are deep but great care should be taken to avoid erosion.

## 7 RECOMMENDATIONS

In this section recommendations on soil and crop management are made. Firstly the soil fertility management will be discussed for the mature and immature tea followed by some recommendations on general soil management. At last some miscellaneous recommendations are made.

### 7.1 Soil Fertility Management for Tea

#### 7.1.1 Mature Tea

- The mature tea of Nyantja Estate requires fertilizer applications for good yields. As the fertilizing program at Nyantja Estate has stopped in the mid eighties, initially the application rate may be higher to restore the depletion of soil fertility which have taken place in the past years. Fertilization increases should however not be made to quickly as tea takes some time to adjust to higher nutritional levels. Regardless of this fact the following table gives a proposal for fertilizer application rates at Nyantja Estate.

**Table 18 Fertilizer Proposal for the Mature Tea Fields of Nyantja Estate**

| Division | Soil Unit* | Approximate Fields** | Type of Fertilizer | Kg/Ha/Year |
|---|---|---|---|---|
| Nyantja | crests | 2,5,6,13,14 15,16,17,18 | NPK 20-10-10 | 250 kg N |
| | slopes | 3,4,7,8 | NPK 25-5-5 | 250 kg N |
| | valleys | 1,9,10,11,12 | NPK 25-5-5 | 250 kg N |
| Biamba | crest | 2,4 | NPK 20-10-10 | 200 kg N |
| | slopes | 1,3 | NPK 25-5-5 | 200 kg N |
| Nduba | crests | 4,5,6,8,10 | NPK 20-10-10 | 250 kg N |
| | slopes | 1,2,3,7,9 | NPK 20-10-10 | 250 kg N |
| Lushondo | crests | 5,6 | NPK 20-10-10 | 200 kg N |
| | slopes | 1,2,3,4 | NPK 20-10-10 | 200 kg N |
| | valleys | 7,8,9,10 | NPK 20-10-10 | 200 kg N |
| Bukombe | crests | 3,5,8,9 | NPK 20-10-10 | 250 kg N |
| | slopes | 1,2,4,6,7 | NPK 20-10-10 | 250 kg N |
| Bitesse | slopes | 1,2,3 | NPK 20-10-10 | 200 kg N |
| Kakono | slopes | 7,8 | NPK 25-5-5 | 150 kg N |
| | valleys | 1,2,3,4,5,6 | NPK 25-5-5 | 150 kg N |

* - For unsampled soil units, fertilization levels as given are based on similar soils in other divisions

** - Although there are many fields with two or three soil units, there is only one rate of fertilizer application given per field.

- It should be borne in mind that the fertilizer proposal is approximate and that types and quantities are dependent on yield levels and the climate. Nevertheless is recommended that the soils classified with a high potential receive annually about 250 kg N per ha. This is equivalent to about 1250 kg NPK 20-10-10 or 1000 kg NPK 25-5-5. For soils with a moderate potential it is recommended to apply about 200 kg of nitrogen annually which is equivalent to 1000 kg NPK 20-10-10 or 800 kg NPK 25-5-5. Low potential soils should receive annually about 150 kg of nitrogen which is equivalent 750 kg NPK 20-10-10 or 600 kg NPK 25-5-5.

- Soil analysis should indicate whether in this approximate fertilizing scheme one can shift from NPK 20-10-10 with relatively more P and K to NPK 25-5-5 which is cheaper in terms of kg nitrogen. Also regarding the fact that with NPK 20-10-10 too much K is applied as many soils of Nyantja Estate have favourable levels of this nutrient.

- The annual increase of fertilizer applications should not increase 25 kg Nitrogen per hectare as tea takes time to adjust to higher nutritional levels. This implicates that it will take 6, 8 and 10 years to reach the fertilizer regimes of resp. 150, 200 and 250 kg nitrogen per hectare.

- The best time of application is shortly after the rains have started in October or November. With the onset of the rainy period the soils produces a sort of natural nitrogen flush. This is not sufficient to cover the further needs of the tea plants. It is not recommended to apply fertilizer shortly before heavy rains are expected as it may physically be washed away from the soil.

- It is recommended to split the fertilizer applications in two dressings, one in November after the commencement of the rains and one in February/March. This is particular relevant after a few years of the adoption of the fertilizer schemes when application rates reach 100 kg N per hectare or more.

- Urea is not a suitable fertilizer for tea fertilizing at Nyantja Estate. As the fertilizer is broadcast over the surface mulch of leaf litter and rotted prunings, there would be the risks of N-losses due to volatilization. Moreover urea ash a pH decreasing effect which is unfavourable for most soils.

- One may consider applying Sulphate of Ammonia on the soils of Nduba and Bukombe Division as the soil reactions are generally favourable and this fertilizer is cheaper in terms of kg nitrogen. Repeated applications however, increase the soil acidity and induce nutrient deficiencies. Additional applications of phosphorus are however required.

- After severe hailstorms which can do considerable damage to tea, the bushes should be skiffed (or pruned) to below the level of maximum damage and a supplementary dressing of nitrogen and phosphorus fertilizer should be applied. Application rates should be up to 44 kg nitrogen and 110 kg

single superphosphate. Both the skiffing and the application of fertilizers should be completed within two weeks of the hailstorm.

### 7.1.2 Young Tea

- For young tea nitrogen and phosphorus application is strongly recommended. In the planting hole 15 g P2O5 should be applied. Suitable fertilizers are ground rock phosphate or triple super phosphate. Three to six months after planting 50 kg NPK 20-10-10 per hectare is recommended. The fertilizer should be applied in a ring around the young tea plant.
For high yield clones it is recommended to increase the above mentioned rates with 50%.

## 7.2 General Soil Management

- Cultivation with a hoe ('le trident') between the tea rows in order to break crusts and improve the infiltration should be avoided. Tea has many roots at rather shallow depth and these roots will be seriously damaged when the topsoil is tilled. It is recommended to leave the prunings to rot in order to get a mulch layer which will avoid the formation of crusts.

- New tea plantings on sloping land should be on the contour as the soils on the slopes of Nyantja Estate are fairly erodible. In young tea plantings with an insufficient cover of the tea branches and without mulch layer on the surface, erosion is considerable and the fertile topsoil is easily lost.

- The valley soils have an impeded drainage which implicates a high groundwater table during the rainy season. In the drier seasons the tea plants discover however soon that they are shallow rooted and a serious cessation of leafgrowth or drought stress are likely to occur. Therefore it is recommended to place vertical boards in the drainage ways and streams at the end of rainy seasons in order to keep an artificial and reasonably high water table. This will avoid cessation of growth in the drier seasons and improve production of these soils.

## 7.3 Miscellaneous

- The elimination of shade trees in all well drained areas (crests and slopes) is recommended. It has been proven that the removal of shade may double yields in combination with fertilization. As consequence of the shade removal radiation increases, which will lead to an acceleration of the mulch decomposion, and initially the nitrogen requirements may be covered but after this decomposion the tea plant requires N-fertilization to avoid deficiencies.
It is recommended to kill off the trees rather gradually in order to let the tea crop adjust to the new microclimate.

- Shade reduction in the moderately well drained and imperfectly drained soils of Kakono Division should be done with care and on an empirical base.

- Soil sampling for regular monitoring of the fertility status is recommended for all productive tea areas of Nyantja Estate. Furthermore it is recommended to investigate in detail the fertility status of new areas in which tea is going to be planted.

- Tea prunings should not be removed from the field but should be left to rot and decompose slowly. The so formed mulch layer protects the soil against erosion after the pruning and contains nutrients, particular P, for the regrowth of the tea-bush.

- In order to cope with the increasing tea production in the future it is required to increase the fuelwood areas. Suitable areas to be planted are in the south of Bitesse Division and west of field 5 in Nduba Division. Application of phosphorus in the planting hole to establish a good root system is recommended.

## GLOSSARY

**Aerial photograph** - A photograph of the earth's surface taken from airborne equipment.

**Alluvium** - Fine material such as sand, silt or clay that has been deposited on land by streams.

**Base saturation** - The extent to which the absorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminium; expressed as a percentage of the total cation exchange capacity.

**Cation exchange capacity** - The total of exchangeable cations that a soil can absorb; expressed in milli-equivalents per 100 grams of soil; Abbr. CEC.

**Clay** - As a soil separate, the mineral soil particles less than 0.002 millimeters in diameter; as a soil textural class; soil material that is 40 percent or more clay, less than 45 percent sand and less than 40 percent silt. Heavy clay has more than 60 percent clay.

**Crust** - A soil-surface layer, ranging in thickness from a few millimeters to a few tens of millimeters, that is much more compact, hard, and brittle when dry, then the material immediately beneath it.

**Depth, soil** - Depth of the soil to the underlying substratum (i.e. the C horizon or R horizon). Also called solum depth or true soil depth.

**Drainage, soil** - Refers to the rate of water removal from the soil by free flow. The following classes of drainage were identified at Nyantja Estate:

**well drained** Water is removed from the soil readily but not rapidly. Well drained soils are sometimes called freely drained soils. Well drained soils are free or nearly free of mottles.

**moderately well drained** Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. The soils have slowly permeable layer within or immediately beneath the solum.

**imperfectly drained** Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Somewhat poorly drained soils are also called imperfectly drained soils. They commonly have a high water table or additions of water through seepage or a combination of these conditions. These soils are mottled in the B and C horizons.

**Footslope** - The relatively gently sloping, slightly concave to straight slope component of an erosional slope that is at the base of the backslope component

**Gravel** - Pieces rock or mineral material with diameter between 0.2 and 7.5 cm.

**Gravelly soil** - A soil having 35 to 60 percent by volume of gravel.

**Horizon, soil** - A layer of soil, approximately parallel to the surface which has distinct characteristics produced by soil forming processes. The master horizons in a soil profile are: A horizon (layer with maximum accumulation of organic matter), B horizon (layer with maximum clay formation), C horizon (unconsolidated material showing the original structure and arrangement of the parent rock) and R horizon (non or only slightly weathered, indurated rock).

**Land evaluation** - Interpretation of soils, topography and climate for land management purposes and for land use planning.

**Leaching** - The removal of soluble materials from soils or other material by percolating water.

**Mottled** - Irregularly marked with spots of different colours that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage.

**Munsell colour notation** - A system for designating colour by degrees of three simple variables - **hue**, **value** and **chroma**. For example, a notation of 2.5YR3/6 is a colour that has a hue of 2.5YR, a value of 3, and a chroma of 6.

**Organic matter** - A general term for plant and animal material, in or on the soil, in all stages of decomposition.

**Parent material** - The horizon of soft, weathered rock or partly weathered soil material from which the soil has formed has formed; the C horizon in a profile.

**Profile, soil** - A vertical section of the soil through all its horizons and extending into the parent material. See also Horizon.

**Reaction, soil** - The degree of acidity or alkalinity of a soil expressed in pH values. Degrees of acidity or alkalinity are given in Annex III.

**Sand** - Individual rock or mineral fragments of soil having a diameter between 0.05 and 2.0 millimeters. Soil of sand texture contains 85 percent or more sand and not more than 10 percent clay.

**Sedentary** - refers to soils which are derived form the weathering products of the underlying rock (also used: in situ)

**Stone** - A piece of rock or mineral material with a diameter between 7.5 and 25 cm.

**Structure** - The arrangement of primary soil particles into compound particles or clusters that are separated from adjoining aggregates and have properties unlike those of an

equal mass of unaggregated primary soil particles.

**Subsoil** - Technically the B horizon; roughly, the part in the profile below plow depth.

**Texture, soil** - The relative proportions of sand, silt and clay particles in a mass of soil. The basic textural classes in order of increasing proportions of fine particles are: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay and clay.

**Topsoil** - The soil ordinarily moved by tillage or its equivalent in uncultivated soil, about 20 cm in thickness; the plough layer.

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**NOTES**

# THE SOILS OF NYANTJA ESTATE AND THEIR POTENTIAL FOR TEA CULTIVATION

-ZAIRE-

VOLUME II

## ANNEXES, MAPS AND RECORDS

A.E. HARTEMINK

1991

# VOLUME II ANNEXES, MAPS AND RECORDS

## ANNEXES



## MAPS



## CLIMATE RECORDS



## PRODUCTION RECORDS

VOLUME II

# ANNEXES

## NYANTJA ESTATE

Annex I Soil Profile Descriptions

Profile no. 1

Location: Nyantja Estate, Nyantja Division. Fallow area opposite of field no. 1, five meters west of the main road to the factory.
Landform: Crest
Parent material: Basalt
Elevation: approx. 1680 m above mean sealevel.
Landuse: fallow, some shrubs and grass (Hyparhaennia), previous cinchona land.
Soil: Very deep, well drained soil with a thick, very dark reddish brown clay topsoil over a dark reddish brown clay subsoil.
Description: The profile was described on 21-07-1989 by A.E. Hartemink.

Profile Description:

Ah 00-31/38 cm: Very dark reddish brown (5YR 2/4) moist; clay; moderate, very fine to medium granular subangular blocky; hard when dry, friable when moist, sticky and plastic when wet; many very fine to fine, common medium pores; roots in all sizes; broken and gradual to:

Bws1 31/38-90 cm: Dark reddish brown (2.5YR 3/4) moist; clay; moderate to weak medium angular blocky; hard when dry, firm when moist, very sticky and plastic when wet; many very fine pores, few medium pores; few mediumm, many very fine and fine roots; diffuse and smooth to:

Bws2 90->200 cm: Dark reddish brown (2.5YR 3/4) moist; clay; moderate to weak, medium to coarse angular to subangular blocky, some coarse prismas; slightly firm when moist, very sticky and plastic when wet; very few, very small quartz fragments; many very fine pores; few very fine roots.

Remark: Some termite activity at > 120 cm

Analytical data

| Horizon | Ah | Bws1 | Bws2 | Bws2 |
|---|---|---|---|---|
| Depth (cm) | 00-20 | 50-70 | 100-120 | 150-170 |
| pH water 1 : 2.5 | 4.6 | 5.0 | 4.9 | 5.0 |
| pH KCl 1 : 2.5 | 3.9 | 3.7 | 3.8 | 3.8 |
| Organic C % | 1.9 | 0.2 | 0.3 | 0.2 |
| C/N ratio | 11 | 4 | 6 | 7 |
| Avail. P Bray I mg/kg | 6.7 | 1.8 | 0.9 | 2.3 |
| CEC NH4OAc me/100 g | 8.1 | 9.6 | 8.5 | 2.8 |
| exch. Ca '' | 3.8 | 1.6 | 1.8 | 1.6 |
| exch. Mg '' | 1.0 | 1.4 | 0.6 | 0.4 |
| exch. K '' | 0.87 | 0.77 | 0.46 | 0.23 |
| exch. Na '' | 0.05 | 0.08 | 0.09 | 0.10 |
| Base saturation % | 71 | 40 | 35 | 83 |
| exch. Al me/100 g | 2.00 | 0.80 | 1.60 | 0.84 |
| exch. Al % | 25 | 8 | 19 | 30 |

Profile no. 2

Location: Nyantja Estate, Biamba Division. Block no. 1, approx. 15 m north of the road to Nyantja.
Landform: slope
Parent material: basalt
Slope gradient: Profile is located midslope (± 15 %) with convex shape.
Elevation: approx. 1700 m above mean sealevel.
Landuse: Tea, not performing very well, deficiency diseases observed. Prolific weed growth.
Soil: Very deep, well drained, thick, dark reddish brown clay topsoil over a dusky red, clay subsoil.
Description: The profile was described on 27-07-1989 by A.E. Hartemink.

Profile Description:

Ah 00-16 cm — Very dark reddish brown (2.5YR 2/4) moist,(2.5YR 3/3, dry); clay; moderate, very fine to medium granular subangular blocky; 00-02 cm hard clay crust; hard when dry, slightly firm when moist, sticky and plastic when wet; many pores in all sizes; many (grass) roots in all sizes; gradual and smooth to:

AB 16-30 cm — Weak red (2.5Yr 4/2) moist; clay; moderate, fine to medium, angular blocky; hard when dry, firm when moist, sticky and plastic when wet; common medium and many very fine and fine pores; common very fine and fine, few medium sized roots; diffuse and smooth to:

Bws1 30-50 cm — Dusky red (10R 3.5/4) moist; clay; moderate to weak subangular blocky; friable when moist, sticky and plastic when wet; common fine, few medium pores; few fine roots; very few cutans observed; diffuse and smooth to:

Bws2 >50-200 cm — Dusky red (10R 3.5/4) moist; clay; moderate, medium subangular blocky; friable when moist, very sticky and plastic when wet; common fine and few medium pores; very few fine roots.

Analytical data

| Horizon | Ah | Bws1 | Bws2 |
|---|---|---|---|
| Depth (cm) | 00-20 | 30-50 | 100-120 |
| pH water 1 : 2.5 | 4.2 | 4.4 | 4.9 |
| pH KCl 1 : 2.5 | 3.6 | 3.8 | 3.8 |
| Organic C % | 0.7 | 0.9 | 0.5 |
| Avail. P Bray I mg/kg | 2.3 | 0.6 | 1.1 |
| CEC NH4OAc me/100 g | 6.4 | 6.2 | 7.0 |
| exch. Ca " | 1.2 | 1.1 | 2.5 |
| exch. Mg " | 0.3 | 0.2 | 0.4 |
| exch. K " | 0.33 | 0.56 | 0.33 |
| exch. Na " | 0.13 | 0.10 | 0.21 |
| Base saturation % | 30 | 32 | 49 |
| exch. Al me/100 g | 3.12 | 2.32 | 0.72 |
| exch. Al % CEC | 49 | 37 | 10 |

Profile no. 3

Location: Nyantja Estate, Nyantja Division, block no. 11, 5 m east of the main road.
Parent material: basalt with some alluvial deposits
Slope gradient: Profile is located in a valley, sloping slightly south.
Elevation: approx. 1690 m above mean sealevel.
Landuse: Tea, not very well performing.
Soil: Moderately deep, imperfectly drained soil with a black, clay topsoil over a very dark grey, clay subsoil. Groundwater at 70 cm.
Description: The profile was described on 29-07-1989 by A.E. Hartemink.

Profile Description:

Ah 00-26 cm — Black (10YR 2/1) moist; clay; strong, medium, granular and subangular blocky; friable when moist; slightly sticky and slightly plastic when wet; many pores in all sizes; common, very fine and fine, few medium sized roots; abrupt and irregular to:

ACg 26-52 cm — Black (10YR 1.7/1) moist; clay; moderate, medium subangular blocky; slightly firm when moist,sticky and plastic when wet; common fine to medium red iron mottles;common pores in all sizes; many fine, common medium roots, many roots in pipes of subsurface runoff; smooth and irregular to:

Cg > 52 cm — Very dark grey (5Y 3/1) moist; clay almost structureless; very firm when moist, very sticky and very plastic when wet; many, medium red mottles increasing with depth; very few fine pores; very few fine roots.

Groundwater at approx. 70 cm depth (dry season)

Remark: Pipe erosion as consequence of subsurface runoff at 30 to 50 cm depth

Analytical data

| Horizon | Ah | ACg | Cg |
|---|---|---|---|
| Depth (cm) | 00-20 | 30-50 | 50-70 |
| pH water 1 : 2.5 | 4.4 | 4.2 | 4.5 |
| pH KCl 1 : 2.5 | 3.5 | 3.3 | 3.2 |
| Organic C % | 5.6 | 3.3 | 3.6 |
| C/N | 14 | 9 | 13 |
| Avail. P Bray I mg/kg | 41.0 | 60.0 | 22.0 |
| CEC NH4OAc me/100 g | 13.4 | 19.8 | 17.8 |
| exch. Ca " | 2.4 | 1.4 | 2.8 |
| exch. Mg " | 0.7 | 0.6 | 0.9 |
| exch. K " | 0.31 | 0.13 | 0.15 |
| exch. Na " | 0.21 | 0.10 | 0.10 |
| Base saturation % | 27 | 11 | 22 |
| exch. Al me/100 g | 0.40 | 1.12 | 4.40 |
| exch. Al % CEC | 3 | 6 | 25 |

Annex II Analytical Data of Composite Topsoil Samples Taken in the Productive Tea Areas of Nyantja Estate

| Division | Field | Soil Unit | Depth cm | pH H2O | pH KCl | Org.C % | C/N | exch.base me/100g Ca | Mg | K | Na | CEC me/100g | Base sat.% | P mg/kg | exch. Al me/100g | Al% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nyantja | 1 | crest | 00-20 | 4.9 | 4.1 | 3.1 | 11 | 4.0 | 7.4 | 1.25 | 0.08 | 13.4 | 50 | 8.6 | 2.40 | 18 |
| | 2 | crest | 00-20 | 4.8 | 4.2 | 5.7 | 10 | 3.2 | 1.8 | 2.33 | 0.06 | 20.8 | 31 | 7.0 | 3.60 | 17 |
| | 5 | crest | 00-20 | 4.6 | 4.0 | 4.7 | 11 | 2.2 | 1.2 | 1.12 | 0.05 | 21.4 | 21 | 3.2 | 5.68 | 27 |
| | 6 | crest | 00-20 | 4.2 | 3.8 | 4.4 | 11 | 2.3 | 0.2 | 2.02 | 0.10 | 22.8 | 20 | 10.5 | 7.60 | 33 |
| | 13 | crest | 00-20 | 4.7 | 4.2 | 5.4 | 10 | 3.4 | 3.8 | 0.92 | 0.09 | 21.5 | 38 | 4.4 | 4.56 | 21 |
| | 14 | crest | 00-20 | 4.8 | 4.2 | 5.8 | 11 | 4.6 | 2.4 | 0.97 | 0.10 | 17.0 | 47 | 4.4 | 3.52 | 21 |
| | 18 | crest | 00-20 | 4.6 | 3,9 | 3,4 | 13 | 3,6 | 1,8 | 0,92 | 0.11 | 16.6 | 38 | 12.1 | 5.44 | 33 |
| | 1 | slope | 00-20 | 4.9 | 4.2 | 4.5 | 12 | 5.6 | 3.4 | 0.84 | 0.09 | 12.4 | 48 | 12.6 | 2.80 | 23 |
| | 3 | slope | 00-20 | 4.5 | 3.7 | 4.1 | 14 | 1.4 | tr. | 0.51 | 0.11 | 18.0 | 18 | 9.0 | 6.80 | 38 |
| | 6 | valley | 00-20 | 4.5 | 3.9 | 4.0 | 13 | 2.4 | 2.4 | 0.64 | 0.06 | 14.4 | 38 | 15.6 | 5.20 | 36 |
| | 8 | slope | 00-20 | 4.4 | 3.9 | 3.9 | 14 | 1.4 | 0.2 | 0.38 | 0.06 | 18.0 | 11 | 15.6 | 6.56 | 36 |
| | 17 | slope | 00-20 | 4.8 | 3.9 | 2.8 | 11 | 4.2 | 7.6 | 2.56 | 0.06 | 16.8 | 50 | 21.6 | 2.72 | 16 |
| | 9 | valley | 00-20 | 4.9 | 3.6 | 1.9 | 19 | 1.6 | 0.8 | 0.39 | 0.06 | 43.4 | 7 | 13.5 | 11.68 | 27 |
| | 12 | slope | 00-20 | 4.3 | 3.8 | 4.6 | 15 | 1.4 | 0.2 | 0.46 | 0.21 | 19.6 | 12 | 4.6 | 5.24 | 26 |
| Biamba | 4 | crest | 00-20 | 4.5 | 4.0 | 5.7 | 32 | 1.4 | tr. | 0.66 | 0.13 | 8.3 | 26 | 3.0 | 4.00 | 48 |
| | | | 30-50 | 4.6 | 4.2 | 1.5 | 25 | 1.1 | 0.1 | 0.12 | 0.08 | 8.0 | 18 | 1.2 | 1.80 | 23 |
| | 1 | slope | 00-20 | 4.5 | 4.0 | 4.2 | 16 | 1.8 | 0.8 | 0.89 | 0.05 | 19.4 | 18 | 17.5 | 4.40 | 23 |
| | 3 | slope | 00-20 | 4.5 | 3.9 | 4.7 | 18 | 1.0 | 0.2 | 0.46 | 0.15 | 14.8 | 12 | 6.4 | 4.72 | 32 |
| Nduba | 4 | crest | 00-20 | 4.9 | 4.2 | 7.4 | 19 | 3.5 | 0.7 | 0.76 | 0.06 | 24.8 | 20 | 3.1 | 1.52 | 6 |
| | 5 | crest | 00-20 | 5.2 | 4.5 | 6.2 | 29 | 4.0 | 0.6 | 1.02 | 0.05 | 25.2 | 23 | 4.2 | 1.76 | 7 |
| | | | 30-50 | 5.2 | 4.5 | 1.5 | 12 | 2.0 | 0.4 | 1.38 | 0.03 | 10.0 | 38 | 2.3 | 0.84 | 8 |
| | 6 | crest | 00-20 | 5.0 | 4.4 | 7.1 | 18 | 4.4 | 0.2 | 0.30 | 0.05 | 26.4 | 19 | 3.0 | 1.36 | 5 |
| | 6 | crest | 00-20 | 5.2 | 4.2 | 5.9 | 11 | 3.0 | 0.8 | 0.97 | 0.01 | 15.9 | 30 | 4.6 | 1.60 | 10 |
| | 8 | crest | 00-20 | 5.4 | 4.3 | 5.6 | 26 | 2.5 | 0.7 | 1.02 | 0.05 | 20.2 | 21 | 4.4 | 1.36 | 7 |
| | *a | crest | 00-20 | 4.8 | 4.2 | 6.3 | 11 | 2.8 | 1.2 | 0.66 | 0.09 | 15.0 | 32 | 2.3 | 3.60 | 24 |
| | 1 | slope | 00-20 | 5.0 | 4.2 | 8.0 | 11 | 4.1 | 1.1 | 0.71 | 0.06 | 28.2 | 21 | 3.3 | 2.80 | 10 |
| | 3 | slope | 00-20 | 5.2 | 4.6 | 7.0 | 13 | 5.8 | tr. | 1.23 | 0.06 | 24.2 | 29 | 3.8 | 1.76 | 7 |
| | *b | slope | 00-20 | 4.8 | 4.0 | 6.6 | 13 | 1.8 | 0.4 | 0.77 | 0.06 | 14.4 | 21 | 3.1 | 2.56 | 18 |

tr. = traces
*a = sample taken at the fallow area between block n. 8 and 10
*b = sample taken at fallow/bush area opposite of the main road through block no.5

Annex II (Continued)

| Division | Field | Soil Unit | Depth cm | pH H2O | pH KCl | Org.C % | C/N | exch.base me/100g Ca | Mg | K | Na | CEC me/100g | Base sat.% | P mg/kg | exch. Al me/100g | Al% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bukombe | 2 | crest | 00-20 | 4.7 | 4.0 | 4.8 | 12 | 2.4 | 0.4 | 0.26 | 0.06 | 16.5 | 19 | 3.3 | 2.2 | 13 |
| | 8 | crest | 00-20 | 5.0 | 4.1 | 7.0 | 11 | 2.6 | 0.4 | 1.38 | 0.09 | 17.9 | 25 | 3.5 | 2.8 | 16 |
| | | | 30-50 | 5.1 | 4.4 | 1.1 | 10 | 4.4 | 1.0 | 0.31 | 0.11 | 9.6 | 61 | 2.3 | 1.3 | 14 |
| | 7 | slope | 00-20 | 4.9 | 4.2 | 5.7 | 12 | 2.8 | 1.0 | 0.66 | 0.08 | 15.6 | 29 | 3.0 | 1.8 | 12 |
| Bitesse | 1 | slope | 00-20 | 4.9 | 3.9 | 4.7 | 12 | 2.0 | 0.4 | 1.94 | 0.11 | 13.4 | 33 | 4.4 | 2.0 | 15 |
| | 2 | slope | 00-20 | 4.8 | 4.2 | 5.3 | 10 | 1.6 | 0.4 | 0.97 | 0.15 | 16.2 | 20 | 3.3 | 1.4 | 9 |
| | 2 | slope | 00-20 | 4.6 | 3.9 | 6.6 | 11 | 2.0 | 0.8 | 1.99 | 0.22 | 15.1 | 33 | 3.6 | 4.0 | 26 |
| | 3 | slope | 00-20 | 4.5 | 3.8 | 3.9 | 15 | 1.2 | 0.4 | 0.46 | 0.10 | 9.8 | 22 | 6.0 | 4.6 | 46 |
| Lushondo | 5 | crest | 00-20 | 4.6 | 3.8 | 4.8 | 15 | 2.0 | 0.2 | 0.10 | 0.06 | 20.4 | 12 | 5.5 | 4.8 | 24 |
| | | | 30-50 | 4.8 | 4.0 | 0.7 | 12 | 1.2 | 0.1 | 0.02 | 0.05 | 10.0 | 14 | 1.1 | 2.7 | 27 |
| | 4 | slope | 00-20 | 4.5 | 4.0 | 6.4 | 10 | 2.0 | 0.2 | 0.02 | 0.05 | 28.2 | 15 | 3.3 | 4.5 | 16 |
| | 3 | slope | 00-20 | 4.2 | 3.8 | 5.9 | 16 | 1.5 | 0.3 | 3.17 | 0.04 | 20.8 | 24 | 7.8 | 6.4 | 31 |
| | 7 | valley | 00-20 | 3.9 | 3.5 | 5.9 | 43 | 1.4 | 0.2 | 1.93 | 0.05 | 29.6 | 12 | 6.8 | 8.4 | 28 |
| | 8 | valley | 00-20 | 4.4 | 3.8 | 7.3 | 60 | 2.0 | 0.3 | 0.76 | 0.05 | 29.4 | 11 | 3.0 | 5.4 | 18 |
| | 9 | valley | 00-20 | 4.2 | 3.6 | 10.0 | 15 | 3.9 | 0.5 | 0.92 | 0.08 | 32.8 | 16 | 5.6 | 4.4 | 13 |
| Kakono | 8 | crest | 00-20 | 4.4 | 3.6 | 3.3 | 11 | 3.0 | 0.6 | 1.28 | 0.09 | 12.7 | 39 | 22.5 | 6.4 | 50 |
| | 1 | valley | 00-20 | 3.3 | 2.9 | 8.5 | 10 | 1.4 | 1.6 | 2.05 | 0.12 | 22.1 | 23 | 15.3 | 11.6 | 52 |
| | 2 | valley | 00-20 | 4.3 | 3.5 | 4.0 | 12 | 1.8 | 0.6 | 1.18 | 0.06 | 12.4 | 29 | 19.3 | 4.8 | 38 |
| | 3 | valley | 00-20 | 3.2 | 2.9 | 3.7 | 14 | 1.4 | 0.4 | 1.53 | 0.04 | 11.2 | 30 | 20.0 | 7.2 | 33 |
| | 5 | valley | 00-20 | 4.4 | 3.4 | 2.2 | 16 | 2.4 | 0.6 | 0.56 | 0.06 | 6.4 | 57 | 30.5 | 3.4 | 53 |
| | 6 | valley | 00-20 | 3.4 | 3.0 | 9.0 | 32 | 2.0 | 0.6 | 1.23 | 0.11 | 21.3 | 18 | 25.0 | 11.8 | 55 |

tr. = traces

ANNEX III Keys to Soil Depth, Soil Reaction Classes and General Ratings of Soil Fertility Parameters used in this Study for the General Description of the Soil Units

| thickness topsoil cm | | thickness solum cm | |
|---|---|---|---|
| very thin | <10 | very shallow | <25 |
| thin | 10-20 | shallow | 25-50 |
| mod. thick | 20-30 | mod. deep | 50-80 |
| thick | 30-40 | deep | 80-120 |
| very thick | >40 | very deep | >120 |

| soil reaction (pH-water) | | | |
|---|---|---|---|
| extremely acid | <4.5 | neutral | 6.7-7.3 |
| v. strongly acid | 4.5-5.0 | mildly alkaline | 7.4-7.8 |
| strongly acid | 5.1-5.5 | mod. alkaline | 7.9-8.4 |
| mod. acid | 5.6-6.0 | strongly alkaline | 8.5-9.0 |
| slightly acid | 6.1-6.6 | v.strongly alkaline | >9.0 |

| | v. low | low | mod | high | v.high |
|---|---|---|---|---|---|
| % organic matter | <1 | 1-2 | 2-4 | 4-6 | >6 |
| C/N | | <10 | 10-15 | >15 | |
| CEC me/100g | <6 | 6-12 | 12-25 | 25-40 | >40 |
| exch. Ca me/100g | <2 | 2-5 | 5-10 | 10-20 | >20 |
| exch. Mg me/100g | <0.3 | 0.3-1 | 1-3 | 3-6 | >6 |
| exch. K me/100g | <0.1 | 0.1-0.2 | 0.2-0.4 | 0.4-0.8 | >0.8 |
| % base saturation | <20 | 20-40 | 40-60 | 60-80 | >80 |
| % Al saturation | | <20 | 20-40 | 40-60 | >60 |
| avail. P (Bray I) | | <7 | 7-20 | >20 | |

## Annex IV Field Measurements of pH

For the pH measurements about 20 g soil was taken and 50 ml of destilled water was added. After twenty minutes of shaking the pH was measured in the solution.
It is experienced that field measurements are often higher than the pH found in the soil laboratory in despite of the same method applied.

| division | blockno. | position | depth (cm) | pH |
|---|---|---|---|---|
| Nyantja | 1 | slope | 00-25 | 5.3 |
| | 2 | crest | 00-25 | 5.0 |
| | 2 | slope | 00-25 | 4.4 |
| | | | 30-50 | 4.1 |
| | 2 | valley | 00-25 | 4.0 |
| | | | 30-50 | 4.1 |
| | 3 | slope | 00-25 | 4.4 |
| | 4 | slope | 00-25 | 4.1 |
| | | | 30-50 | 4.4 |
| | 5 | crest | 00-25 | 4.8 |
| | 6 | crest | 00-25 | 4.3 |
| | 6 | slope | 00-25 | 4.7 |
| | | | 30-50 | 4.4 |
| | 8 | slope | 00-20 | 4.2 |
| | | very steep | 30-50 | 4.3 |
| | | | 130-150 | 4.4 |
| | 8 | slope | 00-25 | 4.4 |
| | 9 | valley | 00-25 | 3.8? |
| | 11 | valley | 00-25 | 4.6 |
| | 12 | slope | 00-25 | 4.5 |
| | 13 | crest | 00-25 | 4.6 |
| | 14 | crest | 00-25 | 4.9 |
| | 17 | slope | 00-25 | 5.1 |
| | 18 | crest | 00-25 | 4.8 |

Annex IV Field Measurements of pH (continued)

| division | blockno. | position | depth (cm) | pH |
|---|---|---|---|---|
| Biamba | 1 | slope | 00-25 | 4.6 |
| | 3 | slope | 00-25 | 4.5 |
| | 4 | crest | 00-25 | 4.7 |
| | | | 30-50 | 4.7 |
| Lushondo | 3 | slope | 00-25 | 4.5 |
| | 4 | slope | 00-25 | 4.7 |
| | 5 | crest | 00-25 | 4.8 |
| | | | 30-50 | 4.6 |
| | 7 | valley | 00-25 | 4.2 |
| | 8 | valley | 00-25 | 4.7 |
| | 9 | valley | 00-25 | 4.6 |
| Nduba | 1 | slope | 00-25 | 5.0 |
| | 3 | slope | 00-25 | 5.1 |
| | 4 | crest | 00-25 | 4.8 |
| | 5 | crest | 00-25 | 5.3 |
| | | | 30-50 | 5.3 |
| | 6 | crest | 00-25 | 5.2 |
| | 8 | crest | 00-25 | 5.3 |
| Bukombe | 2 | slope | 00-25 | 5.0 |
| | 8 | crest | 00-25 | 4.9 |
| | | | 30-50 | 4.7 |
| Bitesse | 1 | slope | 00-25 | 5.0 |
| | 2 | slope | 00-25 | 4.9 |
| | 2 | slope | 00-25 | 4.8 |

Annex IV Field Measurements of pH (continued)

| division | blockno. | position | depth (cm) | pH |
|---|---|---|---|---|
| Kakono | 1 | valley | 00-25 | 3.6 |
| | 2 | slope | 00-25 | 4.7 |
| | 5 | valley | 00-25 | 4.6 |
| | 6 | valley | 00-25 | 3.8 |
| | 8 | slope | 00-25 | 4.7 |
| Fuelwood and fallow areas: | | | | |
| Nyantja | 1 | crest(fallow) | 00-25 | 5.1 |
| Nduba | 6 | abandoned tea | 00-25 | 5.4 |
| | opp. no. 5 | | 00-25 | 4.8 |
| | between no. 8 & 10 | | 00-25 | 5.0 |
| Bitesse | 3 | abandoned tea | 00-25 | 4.6 |

ANNEX V Field Extents and Tea Varieties per Division

| division | field | hectares | tea variety | year planted |
|---|---|---|---|---|
| Nyantja | 1 | 3.0 | seedlings | 1987 |
| | 2 | 4.7 | seedlings | 1968 & 1988 |
| | 3 | 4.5 | seedlings | 1956/57 |
| | 4 | 4.0 | seedlings | 1957/58 |
| | 5 | 3.0 | seedlings | 1957/58 |
| | 6 | 2.0 | seedlings | 1955/56 |
| | 7 | 3.3 | seedlings | 1959/60 |
| | 8 | 1.0 | seedlings | 1955/56 |
| | 9 | 4.7 | seedlings | 1956/57 |
| | 10 | 3.5 | seedlings | 1959/60 |
| | 11 | 3.5 | seedlings | 1959/60 |
| | 12 | 0.9 | seedlings | 1973 |
| | 13 | 6.0 | BB35 | 1974 |
| | 14 | 7.0 | JG365 | 1976 |
| | 15 | 1.0 | mixture of var. | 1978 |
| | 16 | 2.2 | BB35 | 1978 |
| | 17 | 3.0 | BB35 | 1979 |
| | 18 | 3.0 | BB35 | 1980 |
| | Total | 60.3 ha | | |
| Biamba | 1 | 5.8 | seedlings | 1958/59 |
| | 2 | 2.0 | seedlings | 1958/59 |
| | 3 | 7.0 | seedlings | 1958/58 |
| | 4 | 1.2 | seedlings | 1957/58 |
| | Total | 16.0 ha | | |
| Lushondo | 1 | 3.5 | seedlings | 1959/60 |
| | 2 | 4.5 | seedlings | 1959/60 |
| | 3 | 3.0 | seedlings | 1959/60 |
| | 4 | 5.0 | seedlings | 1959/60 |
| | 5 | 4.0 | seedlings | 1960/61 |
| | 6 | 5.0 | seedlings | 1960/61 |
| | 7 | 1.0 | seedlings | 1960/61 |
| | 8 | 2.0 | seedlings | 1960/61 |
| | 9 | 3.0 | seedlings | 1960/61 |
| | 10 | 0.5 | seedlings | 1978 |
| | Total | 31.5 ha | | |

ANNEX V Field Extents and Tea Varieties per Division
(continued)

| division | Field | hectares | tea variety | year planted |
|---|---|---|---|---|
| Nduba | 1 | 6.0 | seedlings | 1956/57 |
| | 2 | 1.2 | seedlings | 1956/57 |
| | 3 | 8.1 | seedlings | 1956/57 |
| | 4 | 3.1 | seedlings | 1956/57 |
| | 5 | 9.7 | Tri 6/10 | 1957/58? |
| | 6 | 10.0 | seedlings/BB35 | 1957/58 |
| | 7 | 4.0 | seedlings | 1957/58 |
| | 8 | 6.0 | BB35 | 1960/61? |
| | 9 | 6.0 | seedlings | 1957/58 |
| | 10 | 2.1 | seedlings | 1974/75 |
| | Total | 56.2 ha | | |
| Bukombe | 1 | 1.8 | seedlings | 1957/58 |
| | 2 | 3.0 | seedlings | 1957/58 |
| | 3 | 2.5 | seedlings | 1957/58 |
| | 4 | 1.8 | seedlings | 1957/58 |
| | 5 | 2.5 | seedlings | 1958/59 |
| | 6 | 2.0 | seedlings | 1958/59 |
| | 7 | 3.0 | seedlings | 1958/59 |
| | 8 | 2.3 | seedlings | 1958/59 |
| | 9 | 3.2 | seedlings | 1958/59 |
| | Total | 22.1 ha | | |
| Bitesse | 1 | 11.0 | seedlings | |
| | 2 | 15.0 | seedlings | unknown |
| | 3 | 14.0 | seedlings | |
| | Total | 40.0 ha | | |
| Kakono | 1 | 4.3 | seedlings | |
| | 2 | 10.5 | seedlings | |
| | 3 | 6.0 | seedlings | |
| | 4 | 7.5 | seedlings | unknown |
| | 5 | 7.5 | seedlings | |
| | 6 | 6.5 | seedlings | |
| | 7 | 7.0 | seedlings | |
| | 8 | 7.0 | seedlings | |
| | Total | 56.3 ha | | |

ANNEX VI Soil Analysis Results AHT 1964

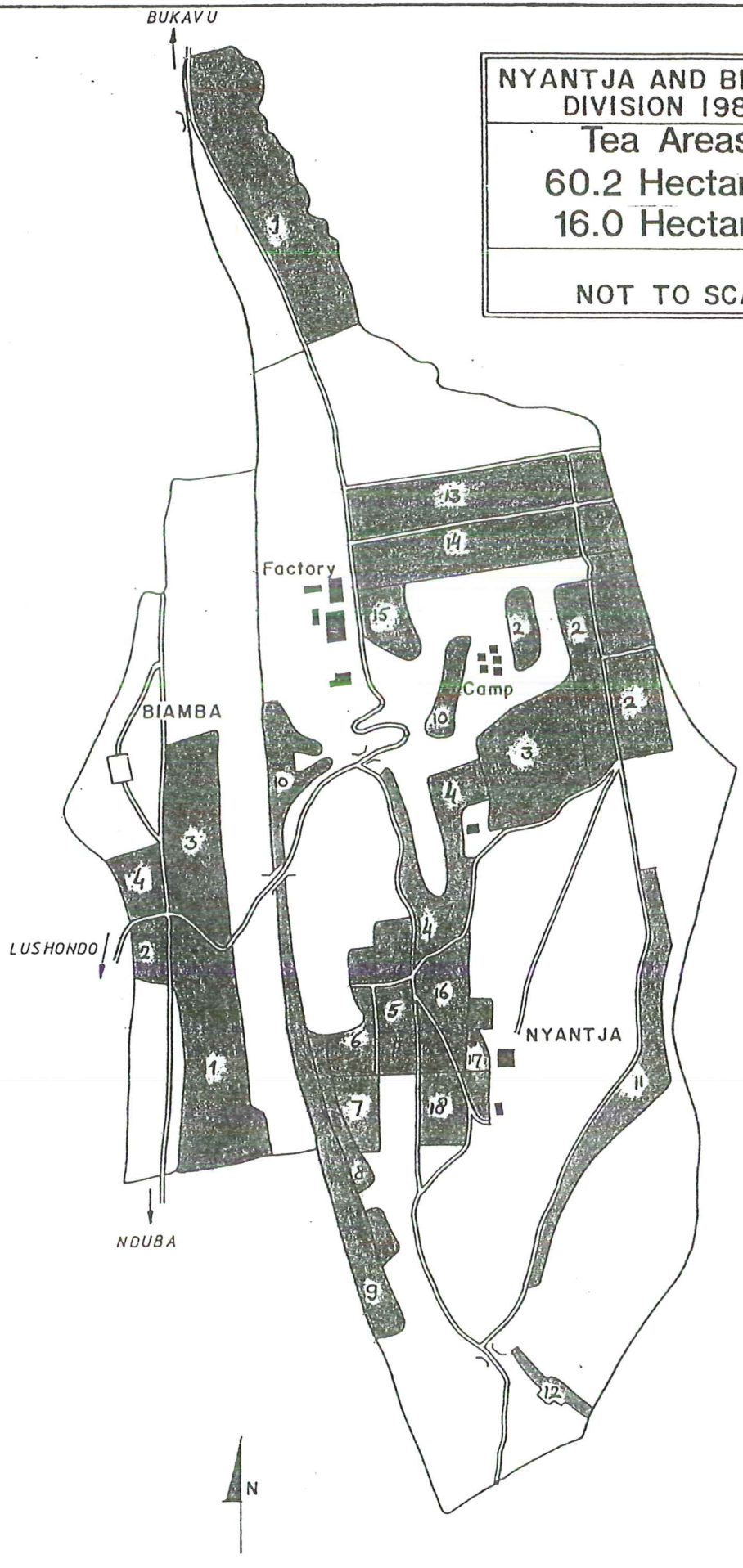
| | pH KCl | %N | P205 | K20 mg/100g | Mg | Ca meq/100 | Bor ppm | Mn ppm | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Division Nyantja | 4.1 | 0.32 | 0.1 | 12.0 | 3.3 | - | - | - | Universitat Gottingen |
| | 4.9 | - | 6.5 | 1.0 | 1.2 | 0.0 | - | - | Scott Agric. Lab. Nairobi |
| Kakono | 4.1 | - | 0 | 8 | 0 | - | 4.3 | 208 | Augustenburg Germany |
| | 3.5 | - | - | 5 | 0 | - | 1.8 | 7 | " " |
| Nyantja | 4.2 | - | 1 | 6 | 0 | - | 1.9 | 108 | |
| | 3.9 | - | 2 | 8 | 0 | - | 4.3 | 26 | " " |

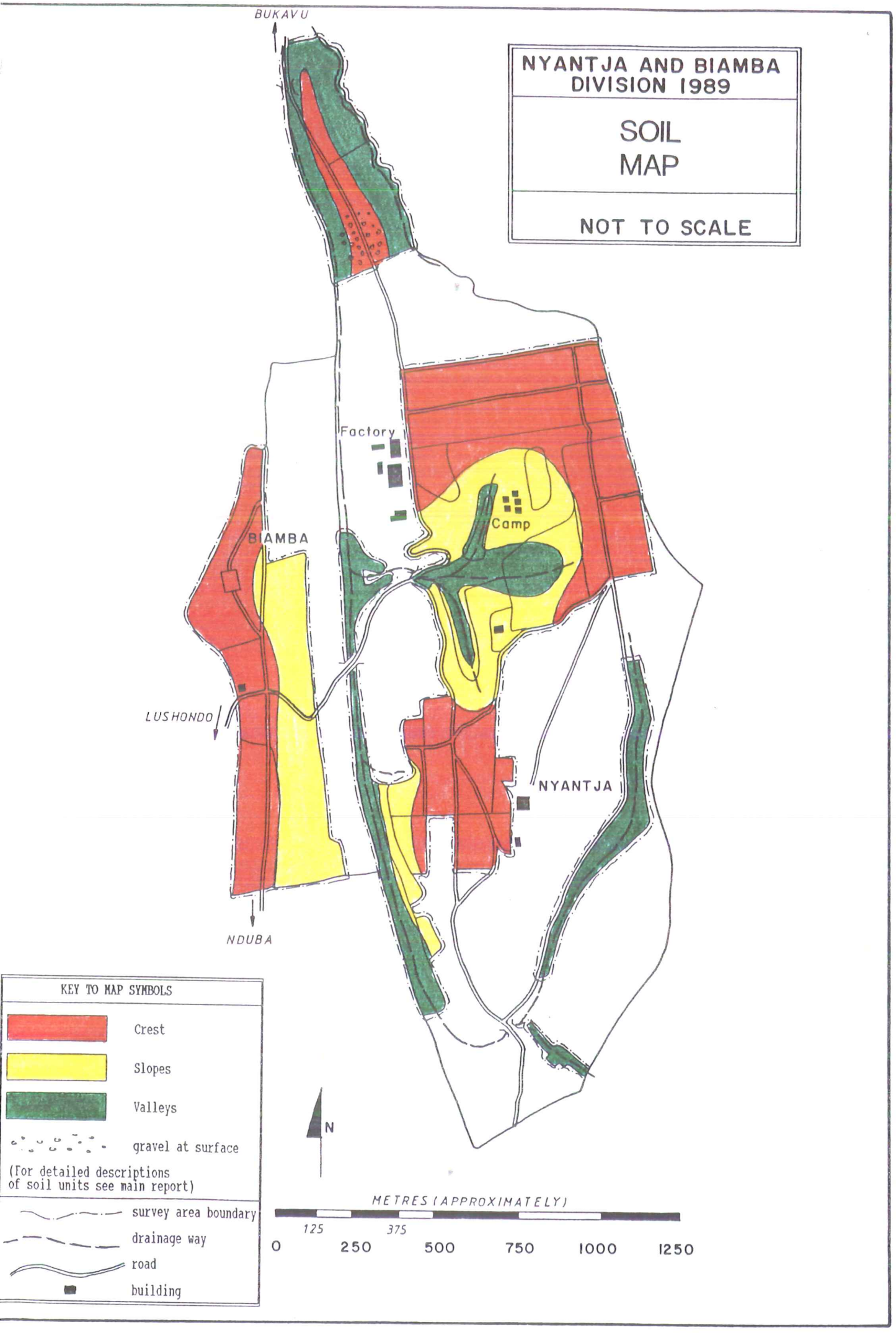
For interpretation see 4.2 in Volume I (Previous Work)

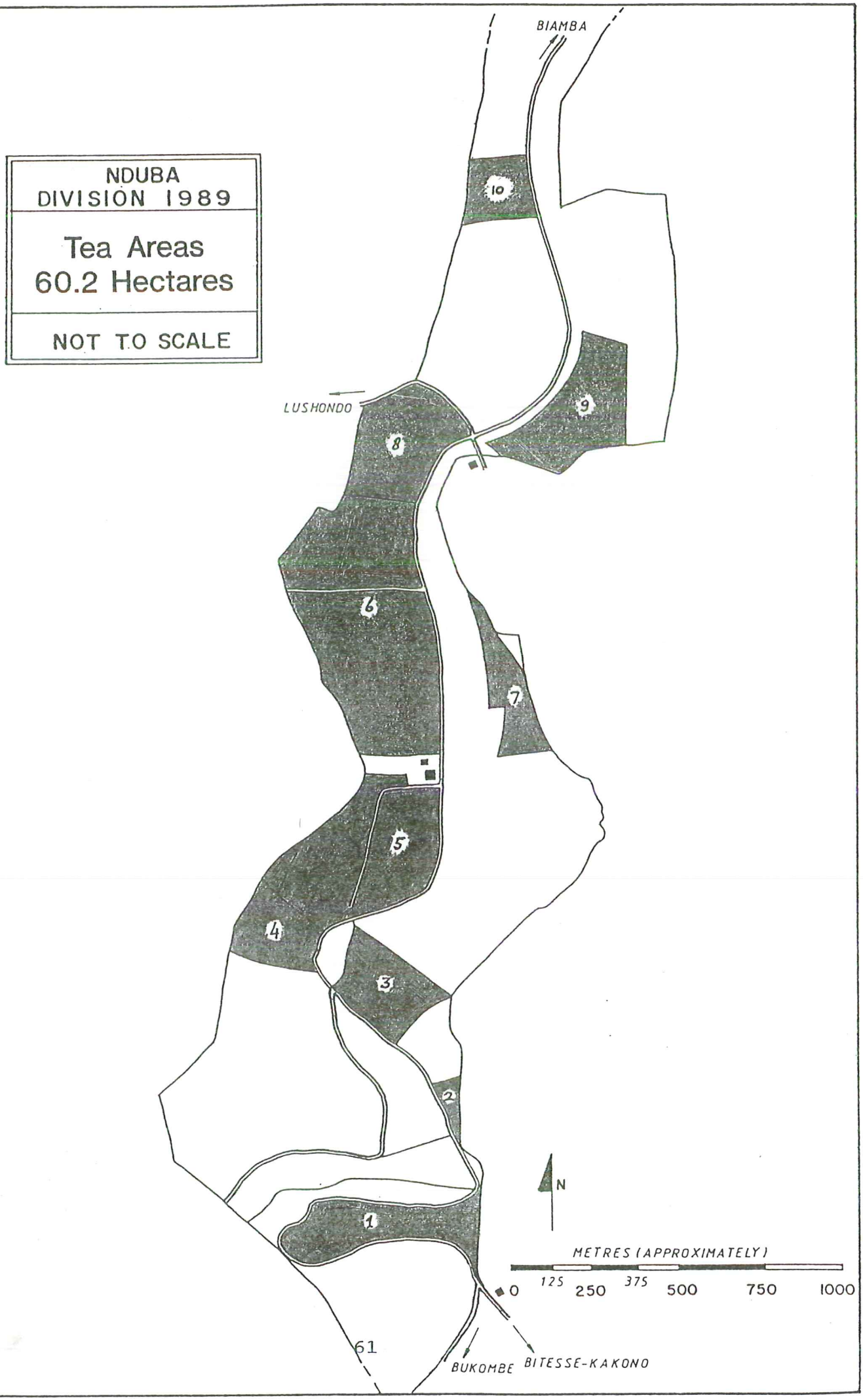
VOLUME II

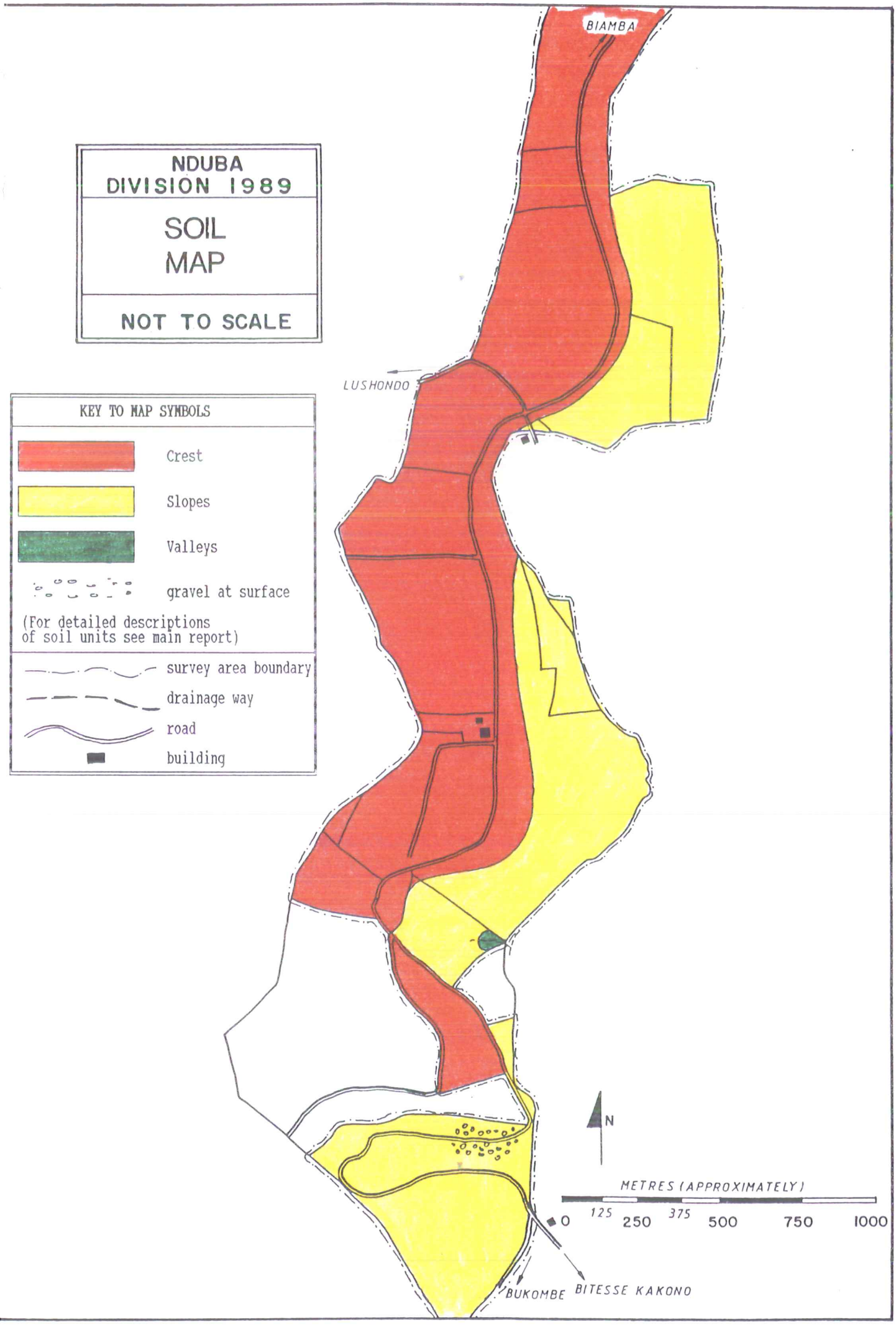
# MAPS

## NYANTJA ESTATE


BUKAVU
NYANTJA AND BIAMBA
DIVISION 1989
Tea Areas
60.2 Hectares
16.0 Hectares
NOT TO SCALE
Factory
Camp
BIAMBA
LUSHONDO
NDUBA
NYANTJA
N
METRES (APPROXIMATELY)
0
125
250
375
500
750
1000
1250


BUKAVU
NYANTJA AND BIAMBA DIVISION 1989
SOIL MAP
NOT TO SCALE
Factory
Camp
BIAMBA
LUSHONDO
NYANTJA
NDUBA
KEY TO MAP SYMBOLS
Crest
Slopes
Valleys
gravel at surface
(For detailed descriptions of soil units see main report)
survey area boundary
drainage way
road
building
N
METRES (APPROXIMATELY)
0
125
250
375
500
750
1000
1250

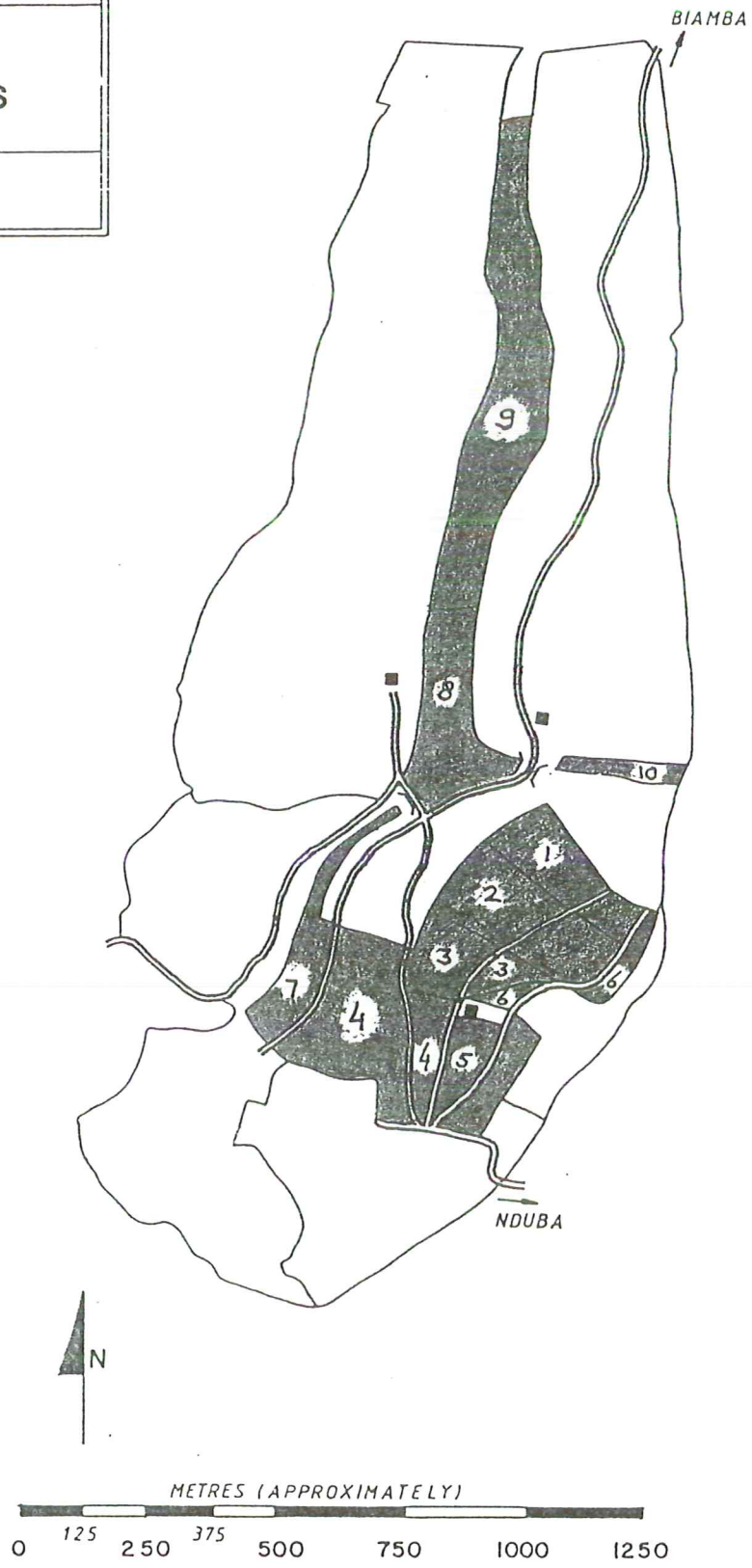

NDUBA
DIVISION 1989
Tea Areas
60.2 Hectares
NOT TO SCALE
BIAMBA
LUSHONDO
BUKOMBE
BITESSE-KAKONO
1
2
3
4
5
6
7
8
9
10
N
METRES (APPROXIMATELY)
0
125
250
375
500
750
1000


NDUBA
DIVISION 1989
SOIL
MAP
NOT TO SCALE
KEY TO MAP SYMBOLS
Crest
Slopes
Valleys
gravel at surface
(For detailed descriptions
of soil units see main report)
survey area boundary
drainage way
road
building
BIAMBA
LUSHONDO
BUKOMBE
BITESSE KAKONO
N
METRES (APPROXIMATELY)
0
125
250
375
500
750
1000

LUSHONDO
DIVISION 1989

# Tea Areas
# 31.5 Hectares

NOT TO SCALE



# LUSHONDO
## DIVISION 1989

# SOIL MAP

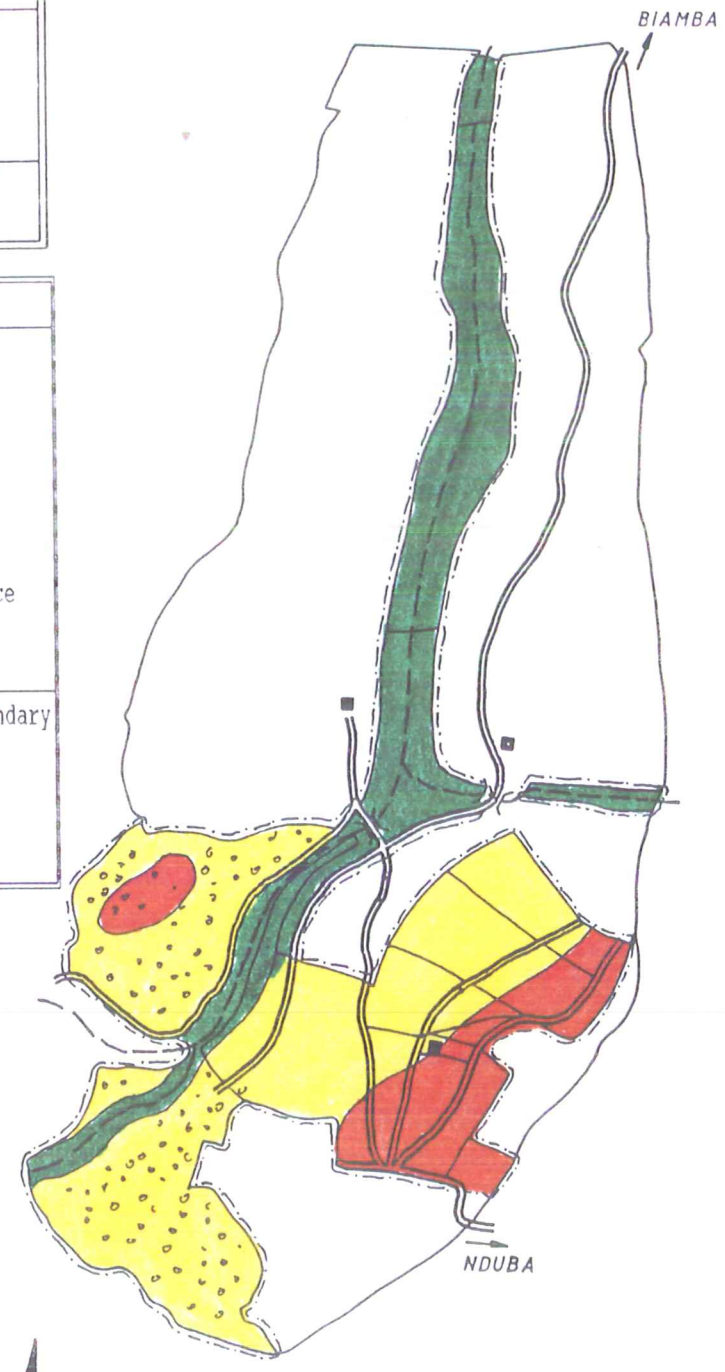
NOT TO SCALE

KEY TO MAP SYMBOLS

- Crest
- Slopes
- Valleys
- gravel at surface

(For detailed descriptions of soil units see main report)

- survey area boundary
- drainage way
- road
- building





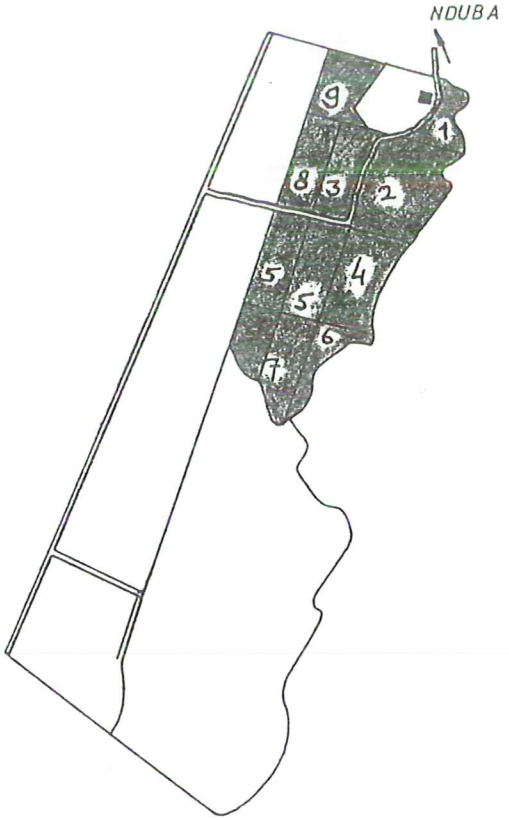
METRES (APPROXIMATELY)

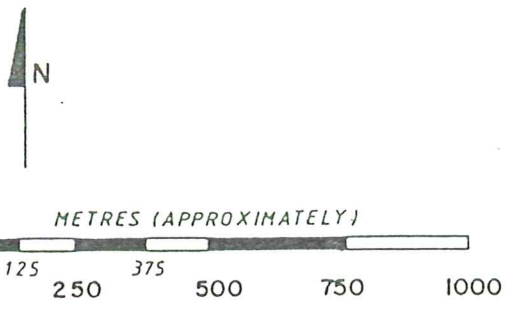
0 125 250 375 500 750 1000 1250

BUKOMBE
DIVISION 1989

# Tea Areas
# 22.1 Hectares

NOT TO SCALE

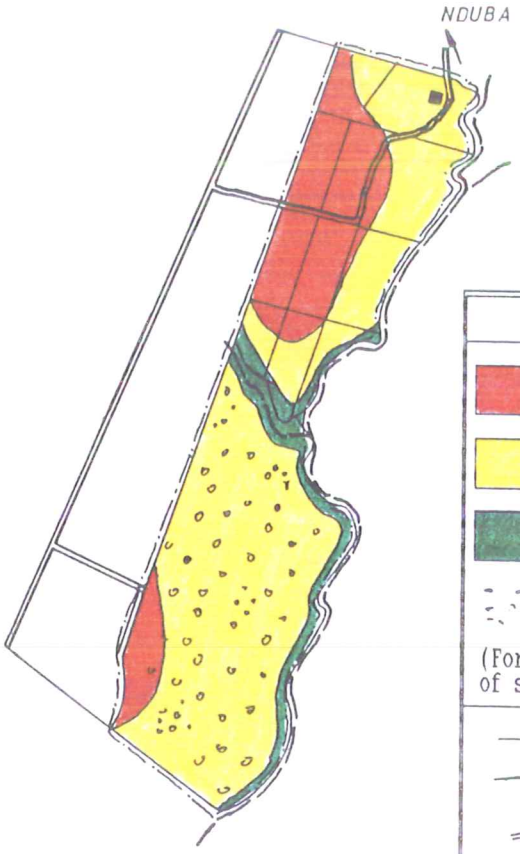


# BUKOMBE
## DIVISION 1989

# SOIL MAP

NOT TO SCALE




KEY TO MAP SYMBOLS

- Crest
- Slopes
- Valleys
- gravel at surface

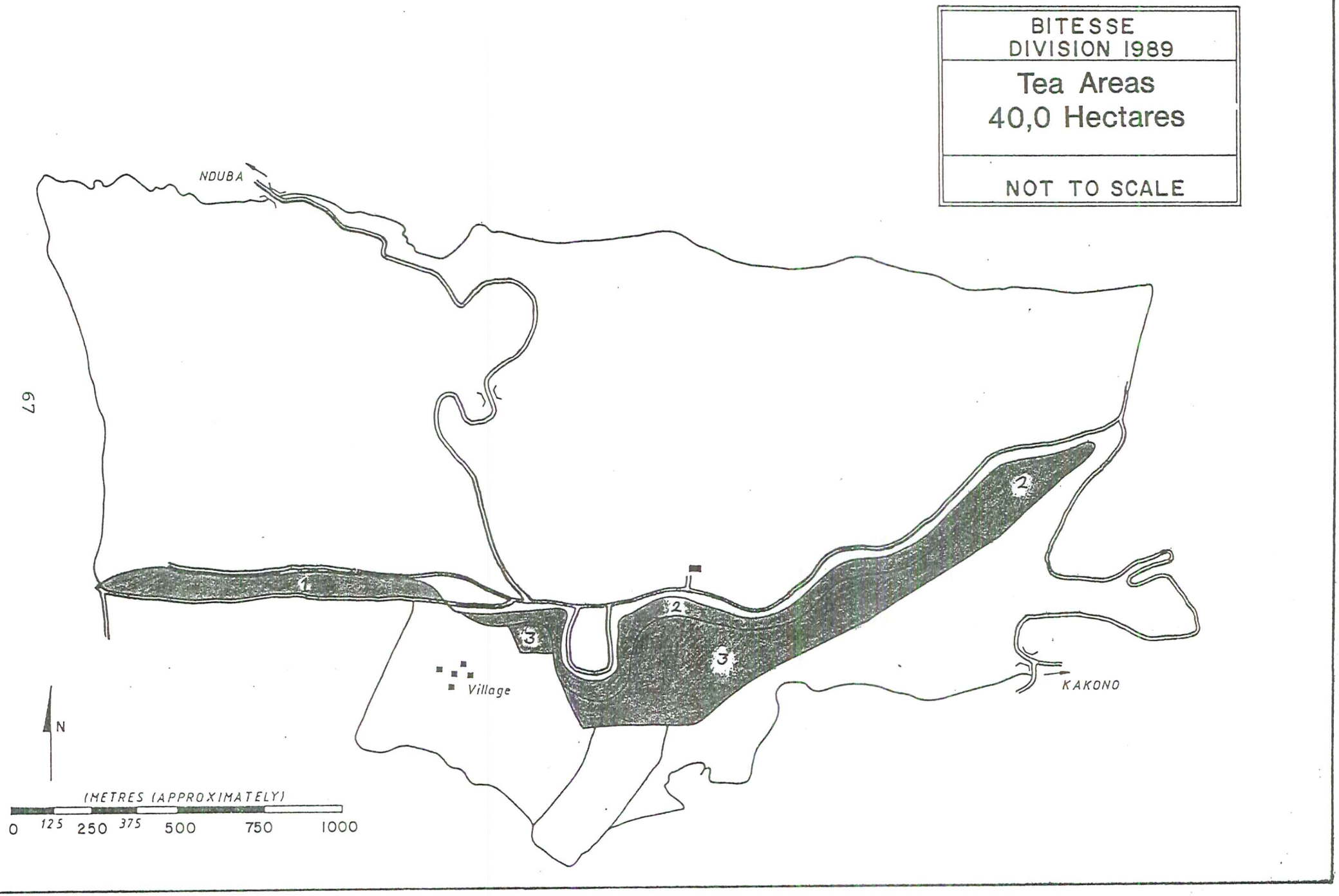
(For detailed descriptions of soil units see main report)

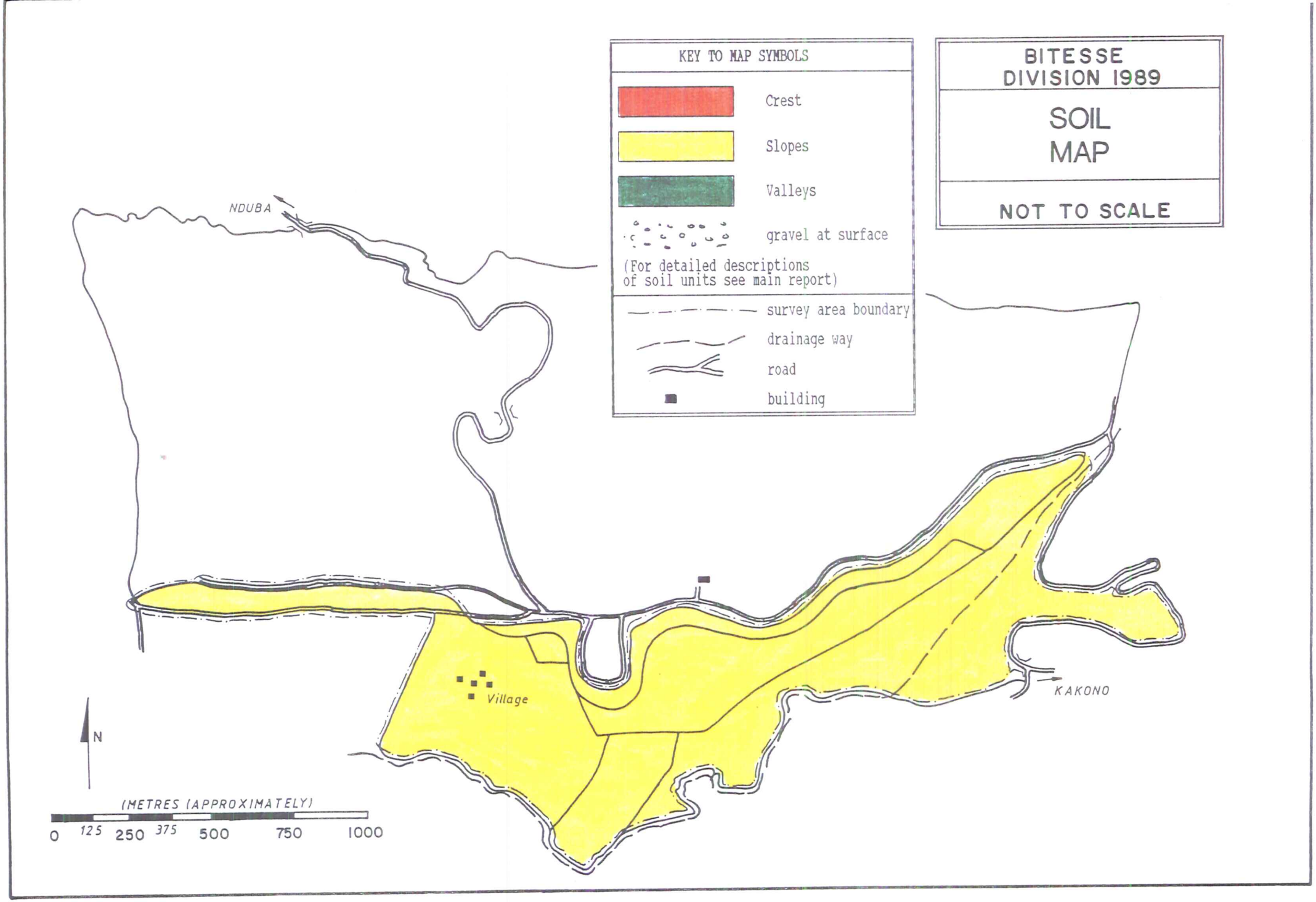
- survey area boundary
- drainage way
- road
- building

N

METRES (APPROXIMATELY)

0 125 250 375 500 750 1000

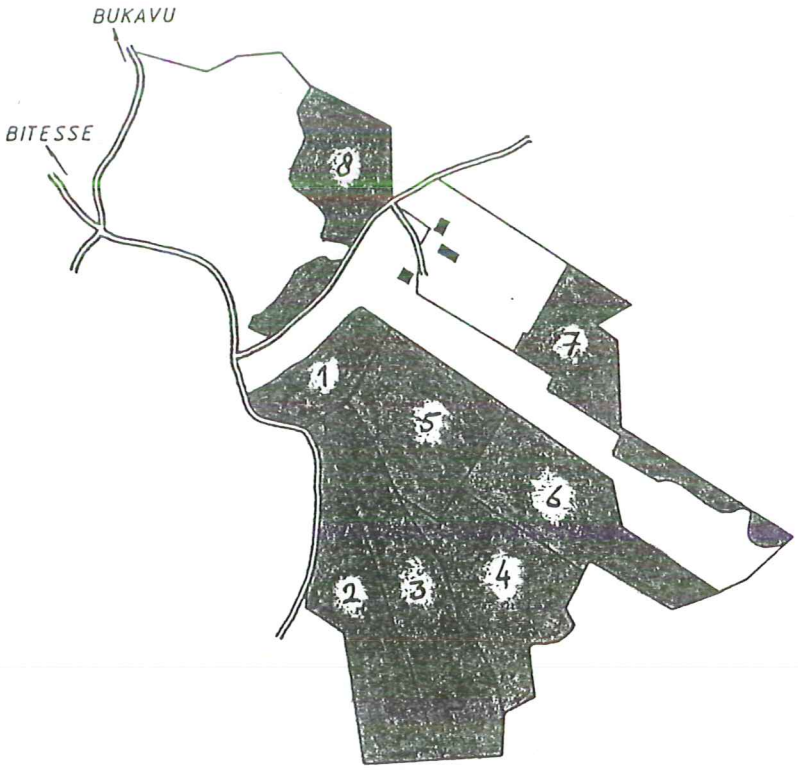

BITESSE
DIVISION 1989
Tea Areas
40,0 Hectares
NOT TO SCALE
NDUBA
KAKONO
Village
1
2
3
2
3
N
(METRES (APPROXIMATELY)
0 125 250 375 500 750 1000


KEY TO MAP SYMBOLS
Crest
Slopes
Valleys
gravel at surface
(For detailed descriptions of soil units see main report)
survey area boundary
drainage way
road
building
BITESSE DIVISION 1989
SOIL MAP
NOT TO SCALE
NDUBA
Village
KAKONO
N
(METRES (APPROXIMATELY)
0 125 250 375 500 750 1000

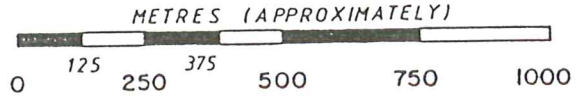
KAKONO
DIVISION 1989

# Tea Areas
# 59.3 Hectares

NOT TO SCALE



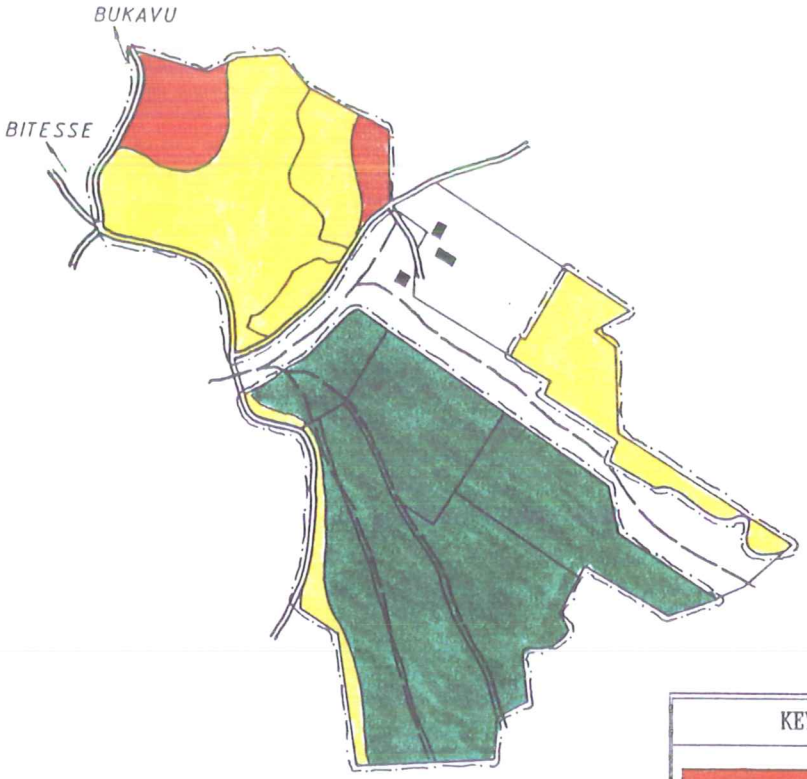




KAKONO
DIVISION 1989

# SOIL MAP

NOT TO SCALE




KEY TO MAP SYMBOLS

- Crest
- Slopes
- Valleys
- gravel at surface

(For detailed descriptions of soil units see main report)

- survey area boundary
- drainage way
- road
- building

N

METRES (APPROXIMATELY)

0 125 250 375 500 750 1000

VOLUME II

# RECORDS

NYANTJA ESTATE

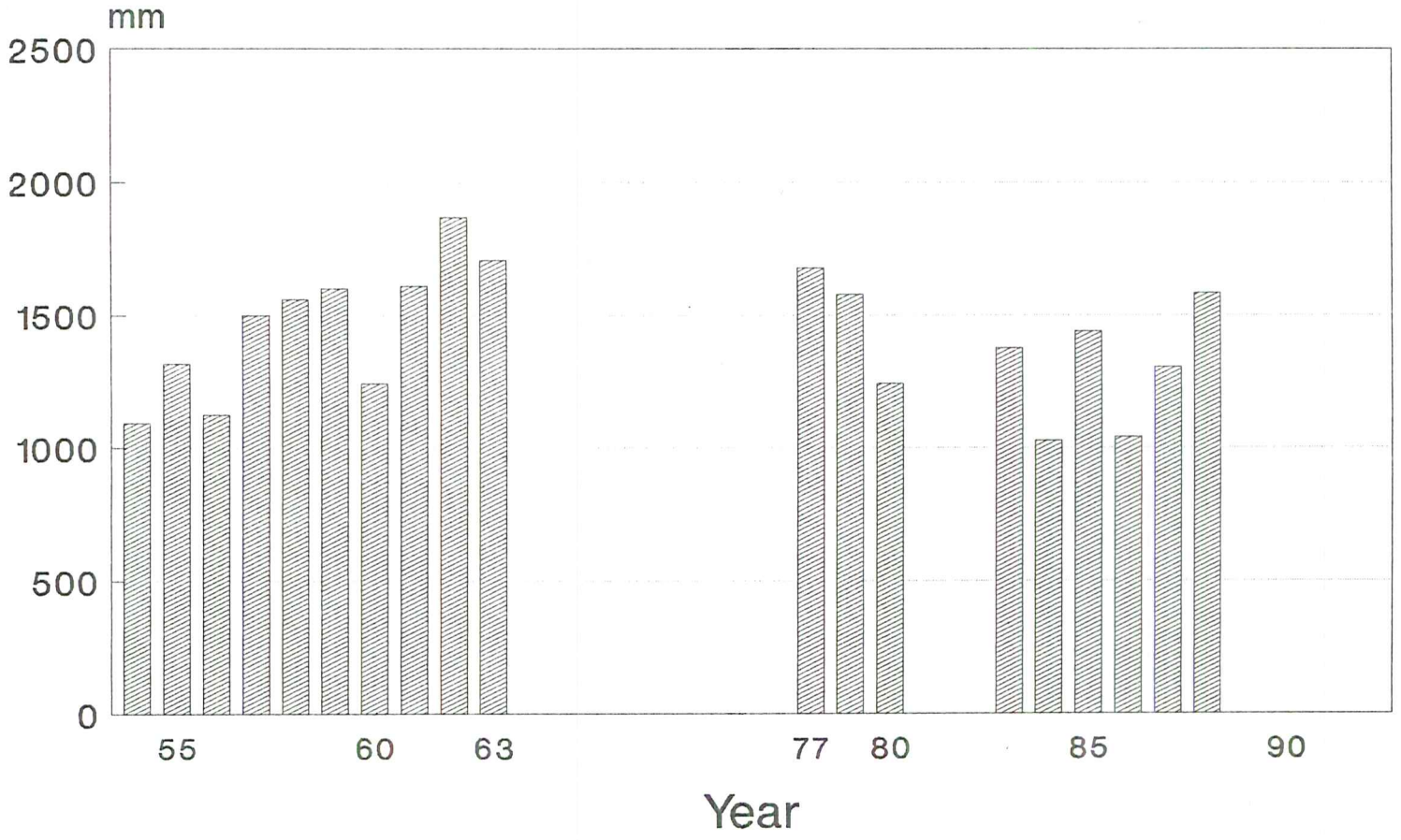
# CLIMATE RECORDS
# NYANTJA ESTATE
ZAIRE

**RAINFALL** (in mm)

| year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1954 | 126 | 105 | 101 | 107 | 70 | 53 | 32 | 0 | 54 | 116 | 93 | 236 | 1093 |
| 1955 | 56 | 249 | 203 | 195 | 12 | 12 | 55 | 22 | 121 | 148 | 66 | 176 | 1315 |
| 1956 | 84 | 42 | 162 | 158 | 100 | 2 | 1 | 28 | 72 | 204 | 178 | 93 | 1124 |
| 1957 | 119 | 220 | 211 | 173 | 95 | 48 | 0 | 9 | 45 | 184 | 108 | 286 | 1498 |
| 1958 | 186 | 269 | 212 | 112 | 136 | 10 | 7 | 15 | 178 | 151 | 170 | 115 | 1561 |
| 1959 | 169 | 213 | 166 | 88 | 105 | 15 | 2 | 41 | 100 | 318 | 165 | 220 | 1601 |
| 1960 | 197 | 211 | 127 | 93 | 17 | 10 | 10 | 66 | 36 | 147 | 212 | 116 | 1242 |
| 1961 | 149 | 346 | 143 | 141 | 23 | 7 | 18 | 19 | 94 | 114 | 343 | 212 | 1609 |
| 1962 | 279 | 127 | 322 | 110 | 120 | 49 | 23 | 94 | 107 | 256 | 179 | 201 | 1867 |
| 1963 | 174 | 240 | 178 | 254 | 201 | 36 | 28 | 17 | 107 | 180 | 278 | 115 | 1707 |
| 1977 | - | - | - | 95 | 91 | 54 | 18 | 89 | 71 | 108 | 230 | 104 | |
| 1978 | 131 | 242 | 211 | 86 | 61 | 33 | 0 | 88 | 115 | 218 | 270 | 223 | 1678 |
| 1979 | 92 | 221 | 205 | 133 | 152 | 20 | 4 | 29 | 11 | 159 | 316 | 206 | 1579 |
| 1980 | 92 | 103 | 147 | 78 | 115 | 18 | 0 | 0 | 127 | 160 | 228 | 173 | 1241 |
| 1981 | 212 | 95 | 194 | 121 | - | - | - | - | - | - | - | - | |
| 1982 | - | - | - | - | - | - | - | - | 143 | 207 | 324 | 184 | |
| 1983 | 150 | 190 | 128 | 130 | 57 | 13 | 15 | 80 | 69 | 243 | 104 | 196 | 1375 |
| 1984 | 107 | 130 | 99 | 89 | 13 | 3 | 36 | 40 | 43 | 159 | 165 | 143 | 1027 |
| 1985 | 185 | 181 | 256 | 198 | 31 | 24 | 10 | 4 | 82 | 123 | 164 | 179 | 1437 |
| 1986 | 136 | 133 | 170 | 135 | 15 | 24 | 3 | 5 | 23 | 116 | 114 | 167 | 1041 |
| 1987 | 112 | 89 | 160 | 130 | 25 | 23 | 0 | 4 | 182 | 204 | 276 | 98 | 1303 |
| 1988 | 214 | 179 | 223 | 171 | 57 | 12 | 38 | 151 | 112 | 79 | 180 | 166 | 1582 |
| 1989 | 182 | 121 | 197 | 70 | 91 | 24 | | | | | | | |
| 1990 | | | | | | | | | | | | | |
| 1991 | | | | | | | | | | | | | |
| 1992 | | | | | | | | | | | | | |

- = NOT RECORDED

# Total Annual Rainfall of Nyantja Estate

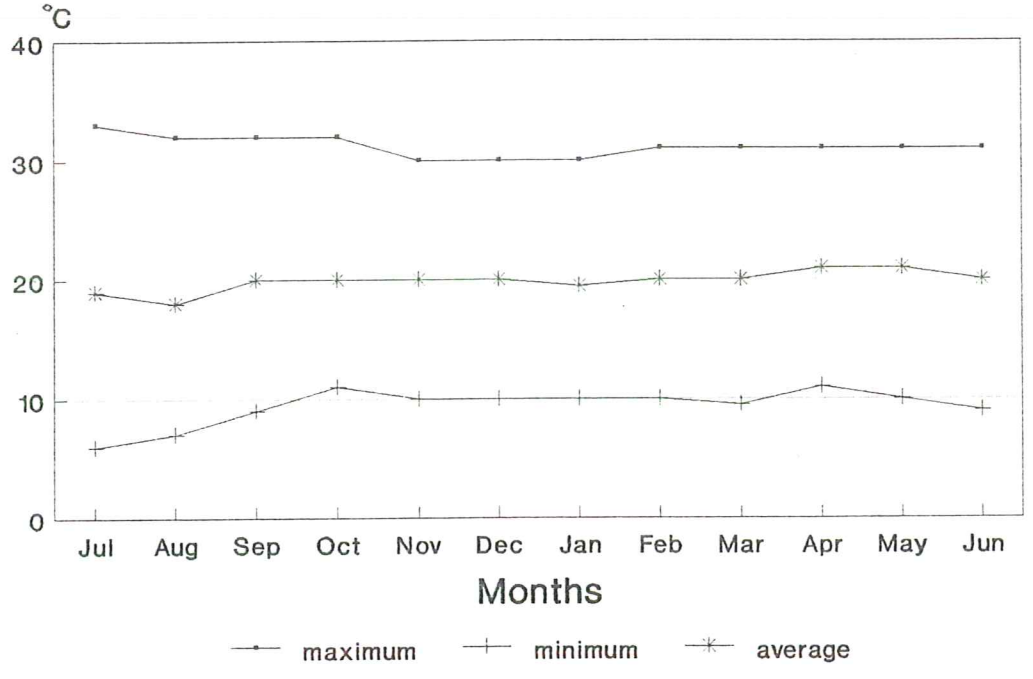


**TEMPERATURE** (IN °C)

\+ = maximium  - = minimum

| year | Jan + | Jan - | Feb + | Feb - | Mar + | Mar - | Apr + | Apr - | May + | May - | Jun + | Jun - | Jul + | Jul - | Aug + | Aug - | Sep + | Sep - | Oct + | Oct - | Nov + | Nov - | Dec + | Dec - |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | ----no records--- | | | | | | 22 | 14 | 22 | 14 | 22 | 12 | 23 | 11 | 22 | 11 | 23 | 11 | 24 | 13 | 21 | 12 | 23 | 12 |
| 1978 | 24 | 12 | 27 | 10 | 25 | 10 | 26 | 11 | 27 | 11 | 24 | 10 | 25 | 6 | 30 | 7 | 30 | 11 | 30 | 13 | 29 | 12 | 29 | 12 |
| 1979 | 30 | 15 | 30 | 14 | 31 | 14 | 29 | 15 | 28 | 14 | 29 | 15 | 29 | 11 | 31 | 10 | 35 | 11 | 32 | 12 | 30 | 14 | 30 | 14 |
| 1980 | 30 | 15 | 31 | 13 | 30 | 11 | 30 | 15 | 30 | 15 | 29 | 13 | 30 | 12 | 31 | 11 | 32 | 13 | 31 | 12 | 30 | 14 | 30 | 15 |
| 1981 | 29 | 12 | 30 | 13 | 31 | 13 | 30 | 14 | -No temperature recorded till march 1984 ------ | | | | | | | | | | | | | | | |
| 1984 | ---------- | | | | 28 | 11 | 30 | 12 | 31 | 13 | 30 | 13 | 30 | 10 | 31 | 9 | 30 | 9 | 28 | 11 | 27 | 11 | 26 | 10 |
| 1985 | 28 | 10 | 27 | 11 | 29 | 11 | 28 | 12 | 30 | 12 | 31 | 9 | 33 | 9 | 32 | 10 | 29 | 11 | 28 | 12 | 27 | 11 | 27 | 11 |
| 1986 | 27 | 11 | ----no records--------- | | | | | | | | 30 | 11 | 29 | 9 | 31 | 8 | 30 | 10 | 29 | 11 | 26 | 11 | 26 | 10 |
| 1987 | 27 | 12 | 29 | 12 | 30 | 11 | 31 | 11 | 31 | 10 | 31 | 14 | 32 | 11 | 30 | 10 | 31 | 11 | 28 | 11 | 28 | 12 | 28 | 11 |
| 1988 | 28 | 11 | 28 | 11 | 29 | 12 | 30 | 11 | 30 | 13 | 31 | 11 | 30 | 9 | 30 | 10 | 29 | 11 | 28 | 11 | 28 | 10 | 27 | 11 |
| 1989 | 25 | 10 | 27 | 10 | 28 | 10 | 29 | 12 | 28 | 14 | 31 | 9 | | | | | | | | | | | | |
| 1990 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1991 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1992 | | | | | | | | | | | | | | | | | | | | | | | | |

# Maximum, Minimum and Average Temperature of Nyantja Estate

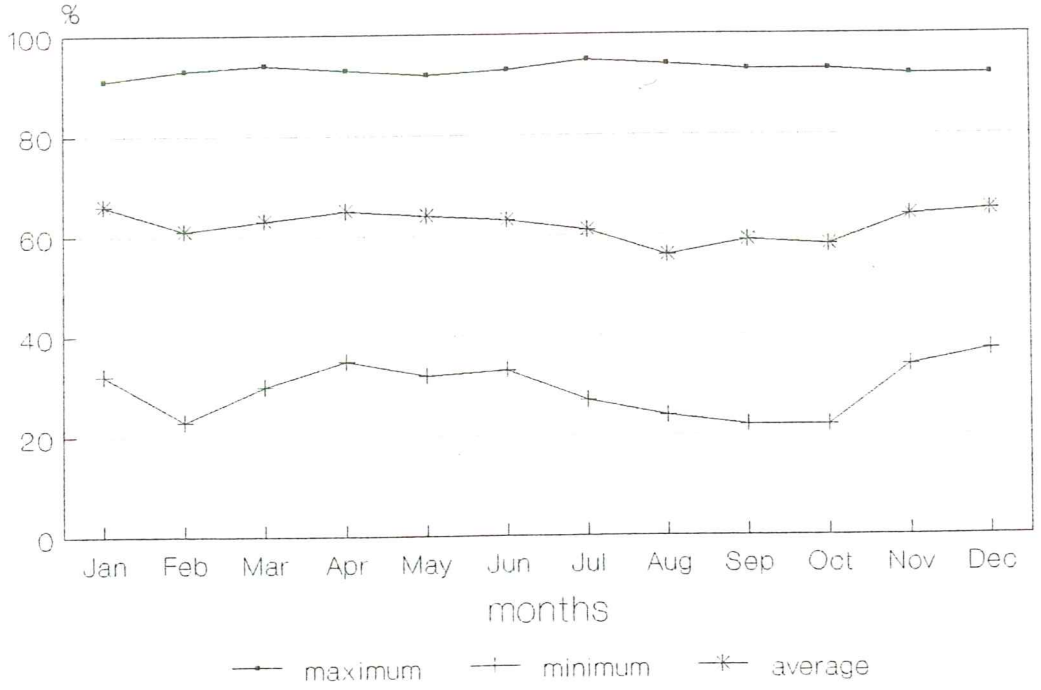



10 Years Average

**HUMIDITY (IN %)**

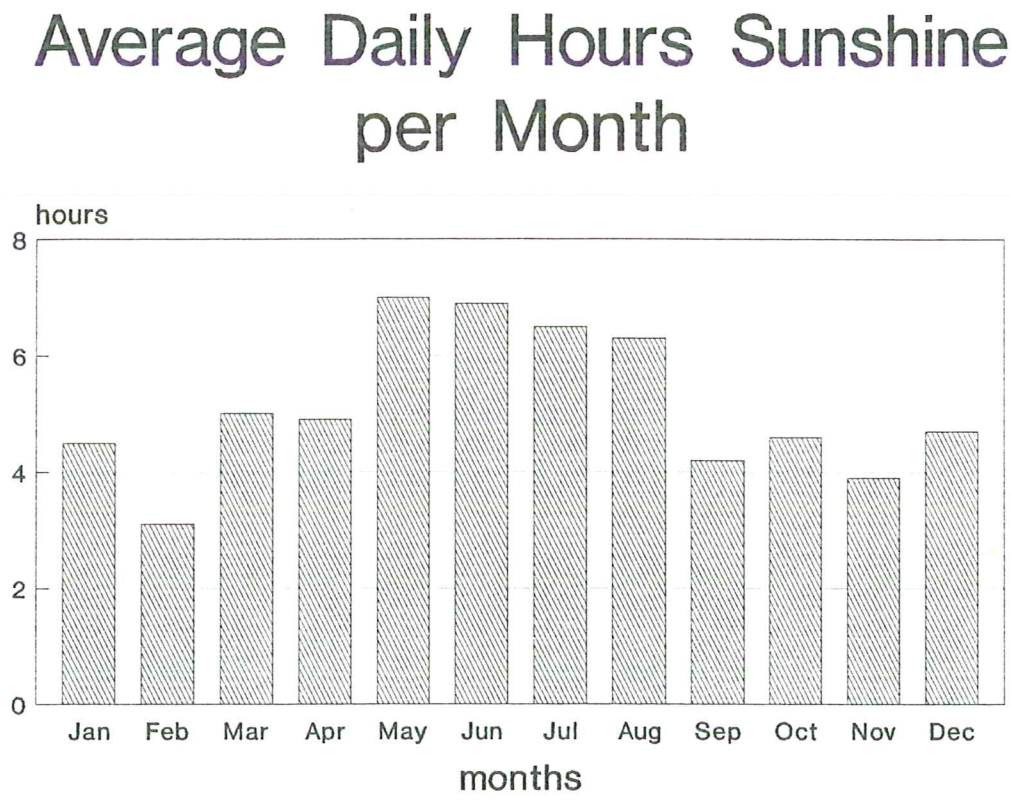
| | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|
| Jan maximum | - | 91 | 91 | 91 | 91 |
| minimum | - | - | 33 | 33 | 32 |
| Feb maximum | - | 92 | 91 | 93 | 91 |
| minimum | - | 33 | 35 | 28 | 23 |
| Mar maximum | - | 94 | 92 | 92 | 91 |
| minimum | - | 37 | 30 | 32 | 35 |
| Apr maximum | 89 | 93 | 91 | 91 | 91 |
| minimum | - | 36 | 39 | 40 | 35 |
| May maximum | 87 | 92 | 91 | 91 | - |
| minimum | - | 32 | 41 | 39 | - |
| Jun maximum | 90 | 93 | 92 | 93 | - |
| minimum | - | 35 | 33 | 34 | - |
| Jul maximum | 90 | 93 | 95 | 94 | - |
| minimum | - | 29 | 30 | 27 | - |
| Aug maximum | 91 | 93 | 94 | 94 | - |
| minimum | - | 24 | 26 | 27 | - |
| Sep maximum | 93 | 92 | 93 | 93 | - |
| minimum | - | 26 | 22 | 26 | - |
| Oct maximum | 93 | 92 | 92 | 92 | - |
| minimum | - | 27 | 22 | 25 | - |
| Nov maximum | 91 | 92 | 92 | 92 | - |
| minimum | - | 40 | 34 | 35 | - |
| Dec maximum | 91 | 91 | 92 | 92 | - |
| minimum | - | 37 | 41 | 39 | - |

# Maximum, Minimum and Average Monthly Humidity of Nyantja Estate



**SUNSHINE** (in Hours)

| Month | Maximum | Minimum | Mean | Days Sunshine | Hours/Day |
|---|---|---|---|---|---|
| Jan | 143 | 124 | 134 | 31 | 4.5 |
| Feb | - | - | 84 | 27 | 3.1 |
| Mar | 154 | 66 | 110 | 22 | 5.0 |
| Apr | 170 | 125 | 148 | 30 | 4.9 |
| May | 242 | 190 | 216 | 31 | 7.0 |
| Jun | 253 | 176 | 207 | 30 | 6.9 |
| Jul | 235 | 150 | 201 | 31 | 6.5 |
| Aug | 213 | 167 | 195 | 31 | 6.3 |
| Sep | 148 | 90 | 118 | 28 | 4.2 |
| Oct | 156 | 128 | 143 | 31 | 4.6 |
| Nov | 139 | 94 | 117 | 30 | 3.9 |
| Dec | 146 | 138 | 142 | 30 | 4.7 |



# PRODUCTION RECORDS

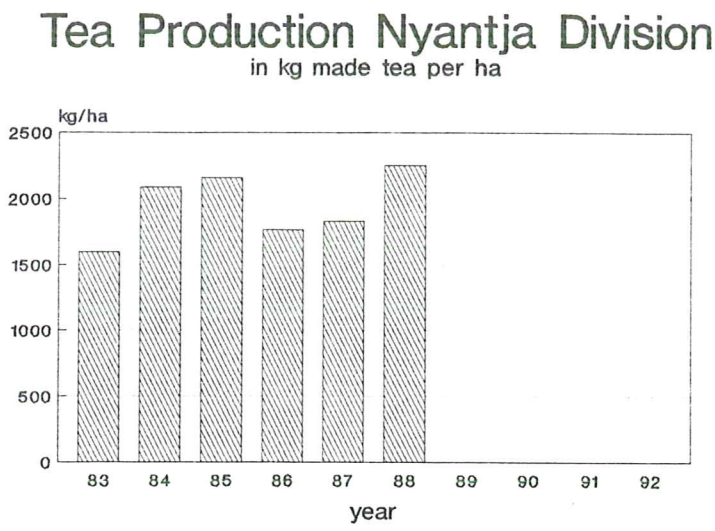
## NYANTJA ESTATE

ZAIRE

**PRODUCTION OF NYANTJA DIVISION IN KG MADE TEA PER HA**

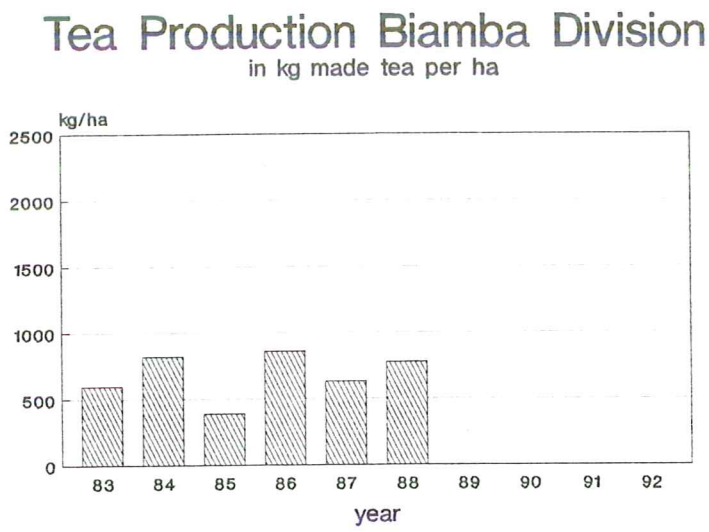
* = pruned

| Year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2878 | 2324* | 3156 | 2445 | 1833 | 3010 | | | | |
| 2 | 2076 | 2130 | 1997 | 1289* | 2001 | 2111 | | | | |
| 3 | 1831 | 1834 | 1553* | 1720 | 1708 | 1362 | | | | |
| 4 | 2050 | 2096 | 1482* | 2056 | 2025 | 2075 | | | | |
| 5 | 1330* | 2529 | 2584 | 1421* | 2106 | 2157 | | | | |
| 6 | 954* | 2263 | 2174 | 1392 | 1541 | 2783 | | | | |
| 7 | 1310 | 1010* | 1895 | 1244 | 1132 | 1434 | | | | |
| 8 | 2792 | 1536 | 1956* | 2408 | 2550 | 2960 | | | | |
| 9 | 440* | 2450 | 2294 | 1267* | 1716 | 1979 | | | | |
| 10 | 660* | 2150 | 1858 | 1195* | 1616 | 1469 | | | | |
| 11 | 1653 | 1479* | 2719 | 2070 | 1307 | 2407 | | | | |
| 12 | 1204* | 3188 | 3486 | 2541* | 1594 | 3001 | | | | |
| 13 | 2334 | 2887 | 2441* | 1758 | 2793 | 3346 | | | | |
| 14 | 2379* | 2900 | 2573* | 1914 | 2580 | 3082 | | | | |
| 15 | 2332 | 2148 | 2427 | 2564 | 2532 | 3512 | | | | |
| 16 | 1135* | 2111 | 2328 | 1483 | 1505 | 1391 | | | | |
| 17 | 488 | 933 | 938* | ? | 958 | 1006 | | | | |
| 18 | 899 | 1642 | 1046 | 1295 | 1394 | 1434 | | | | |
| mean | 1597 | 2089 | 2162 | 1768 | 1827 | 2251 | | | | |



**PRODUCTION OF BIAMBA DIVISION IN KG MADE TEA PER HA**
* = pruned

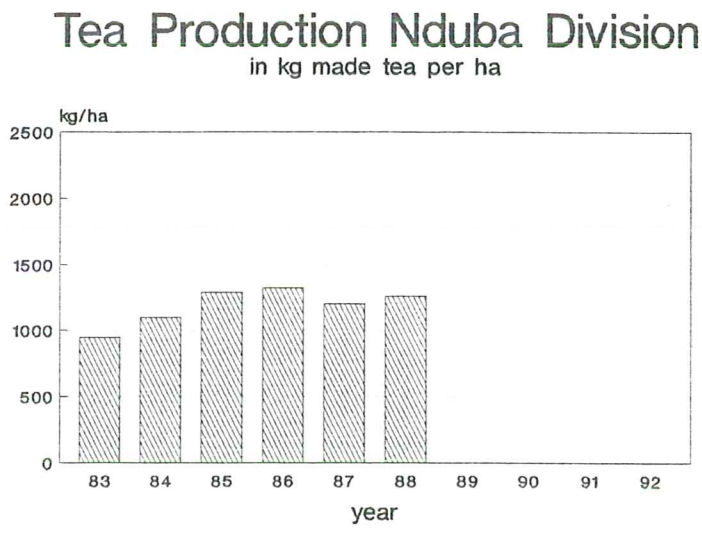
| Year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 291 | 1036 | 725 | 509 | 393 | 594 | | | | |
| 2 | 427 | 757* | 250 | 876 | 650 | 906 | | | | |
| 3 | 716 | 712 | 75* | 579 | 432 | 219 | | | | |
| 4 | 948 | 787* | 500 | 1483 | 1053 | 1393 | | | | |
| mean | 596 | 823 | 388 | 862 | 632 | 778 | | | | |



**PRODUCTION OF NDUBA DIVISION IN KG MADE TEA PER HA**

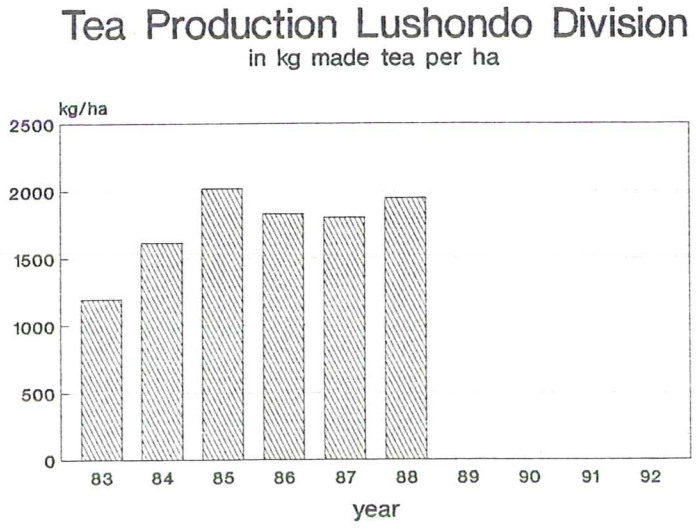
* = pruned

| year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1106 | 965 | 1221* | 1353 | 1075 | 1056 | | | | |
| 2 | 1337 | 1100 | 1533* | 2166 | 1538 | 1877 | | | | |
| 3 | 758 | 1090 | 908 | 706* | 1171 | 1097 | | | | |
| 4 | 1466 | 1277 | 1269* | 1699 | 1599 | 1515 | | | | |
| 5 | 940 | 1328 | 1632 | 1571 | 1121 | 1866 | | | | |
| 6 | 361 | 1214 | 1293 | 1704 | 1348 | 1061 | | | | |
| 7 | 646 | 695* | 1155 | 1092 | 1228 | 1128 | | | | |
| 8 | 876 | 998* | 1229 | 1010 | 659 | 607 | | | | |
| 9 | 426 | 1053 | 1431 | 737 | 963 | 1283 | | | | |
| 10 | 1545 | 1263 | 1241 | 1210 | 1297 | 1131 | | | | |
| mean | 946 | 1097 | 1291 | 1325 | 1200 | 1262 | | | | |



**PRODUCTION OF LUSHONDO DIVISION IN KG MADE TEA PER HA**
* = pruned

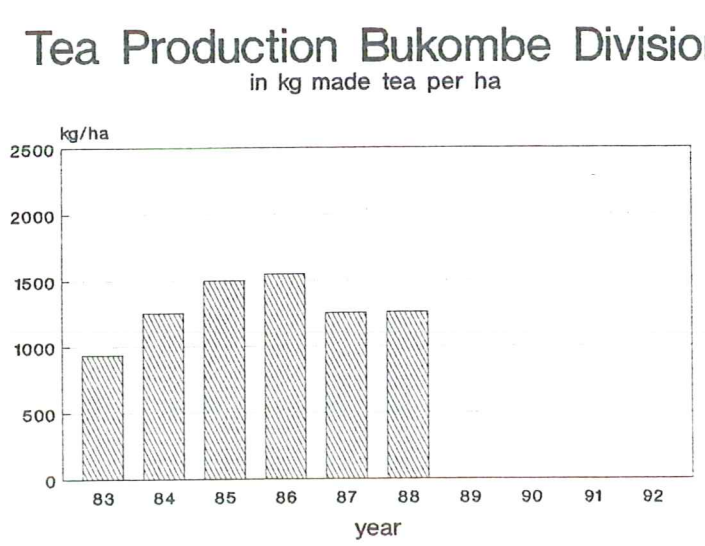
| year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1146 | 991* | 1309 | 1615 | 1550 | 1534 | | | | |
| 2 | 1198 | 1188 | 1032* | 1602 | 1209 | 1199 | | | | |
| 3 | 1482 | 1294 | 1461* | 1643 | 1243 | 1112 | | | | |
| 4 | 1357 | 1409 | 1393 | 1722 | 1277 | 2279 | | | | |
| 5 | 1103 | 1584* | 2375 | 2135 | 2109 | 1761 | | | | |
| 6 | 1007 | 1527 | 1665 | 1080* | 1760 | 1872 | | | | |
| 7 | 2079 | 2836 | 3009 | 2066* | 3089 | 3071 | | | | |
| 8 | 1339 | 1724 | 3091 | 2315 | 2564 | 1909 | | | | |
| 9 | 356 | 1905 | 2800 | 2246 | 1531 | 2727 | | | | |
| 10 | 907 | 1672 | 2014 | 1876 | 1702 | 2007 | | | | |
| mean | 1197 | 1613 | 2015 | 1830 | 1803 | 1947 | | | | |



**PRODUCTION OF BUKOMBE DIVISION IN KG MADE TEA PER HA**

* = pruned

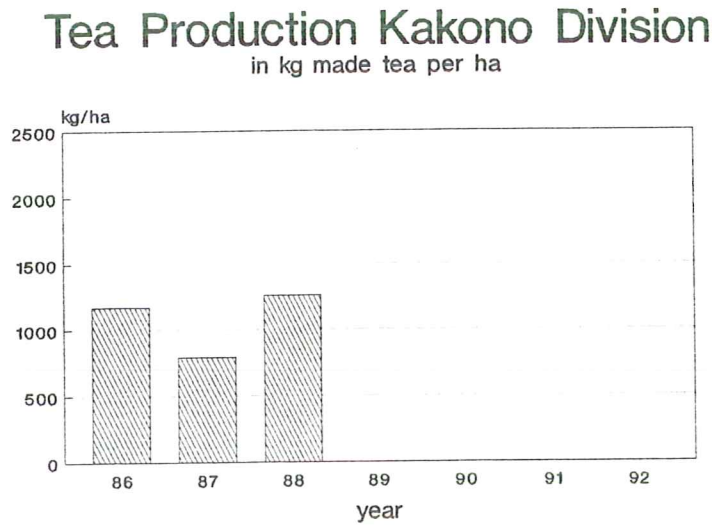
| year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1216 | 1414* | 1335 | 2980 | 1370 | 1003 | | | | |
| 2 | 192* | 1139 | 1741 | 1919 | 1112 | 1504 | | | | |
| 3 | 1211 | 801 | 1202* | 1280 | 1189 | 776 | | | | |
| 4 | 366 | 1770 | 1620 | 1159 | 1570 | 1153 | | | | |
| 5 | 1097 | 1010 | 881* | 1341 | 1280 | 1268 | | | | |
| 6 | 1036 | 1294 | 1369 | 1044* | 1285 | 1172 | | | | |
| 7 | 1170 | 1253* | 2129 | 1649 | 916 | 1537 | | | | |
| 8 | 1257 | 1205* | 1914 | 1457 | 1102 | 1597 | | | | |
| 9 | 902 | 1422 | 1295* | 1085 | 1492 | 1336 | | | | |
| mean | 939 | 1256 | 1498 | 1546 | 1257 | 1259 | | | | |



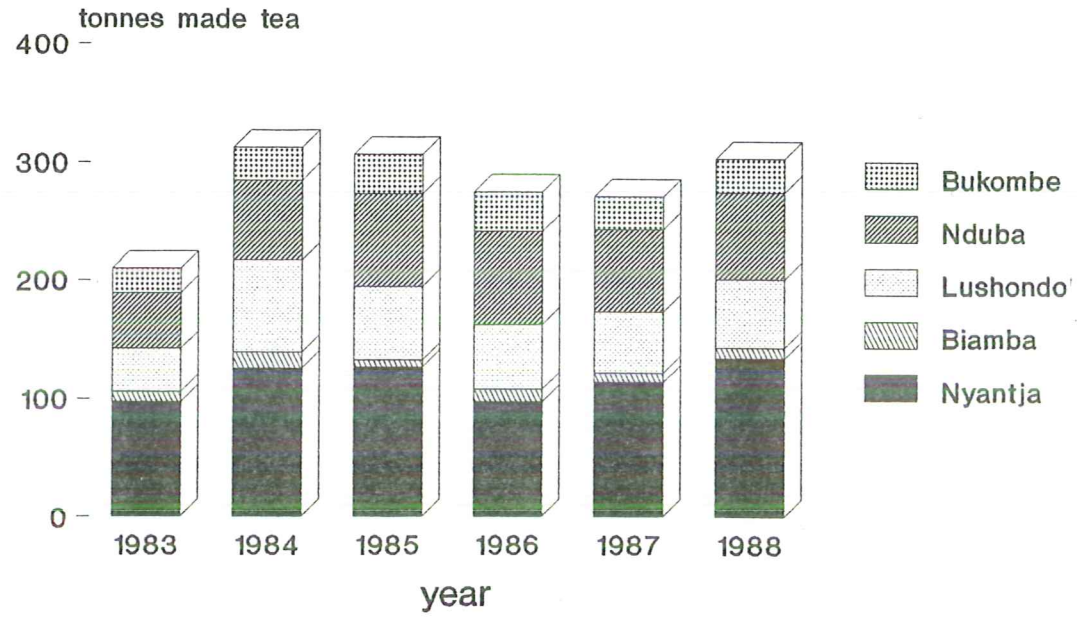
**PRODUCTION OF KAKONO DIVISION IN KG MADE TEA PER HA**

* = pruned

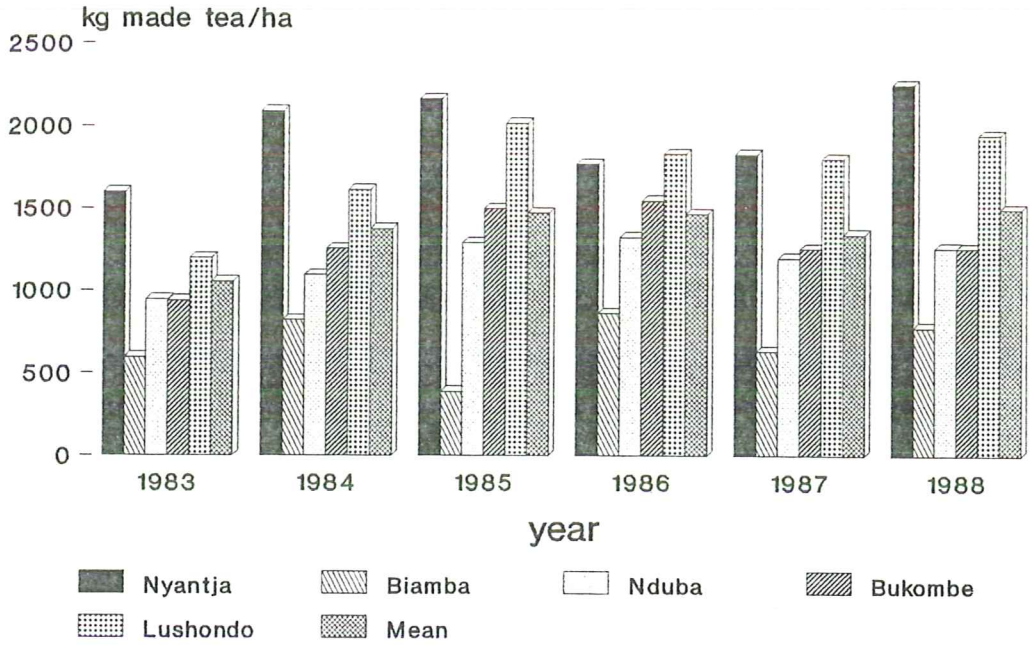
| year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|
| 1 | 1284 | 786 | 1467 | | | | |
| 2 | 1339 | 692 | 1225 | | | | |
| 3 | 1603 | 944 | 1739 | | | | |
| 4 | 1325 | 888 | 1082 | | | | |
| 5 | 1782 | 550 | 2240 | | | | |
| 6 | 674 | 1069 | 588 | | | | |
| 7 | 646 | 602 | 872 | | | | |
| 8 | 733 | 793 | 867 | | | | |
| mean | 1173 | 791 | 1260 | | | | |



# Tea Production at Nyantja Estate in Tonnes Made Tea
*1983-1988*




# Average Tea Production per Division in kg made tea per ha
*1983-1988*




(excl. Kakono and Bitesse)