Land Resource Study

28 Forestry development prospects in the Imatong Central Forest Reserve, Southern Sudan Volume 2 Main Report

Land Resources Division, Ministry of Overseas Development

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Volume 2

Main Report

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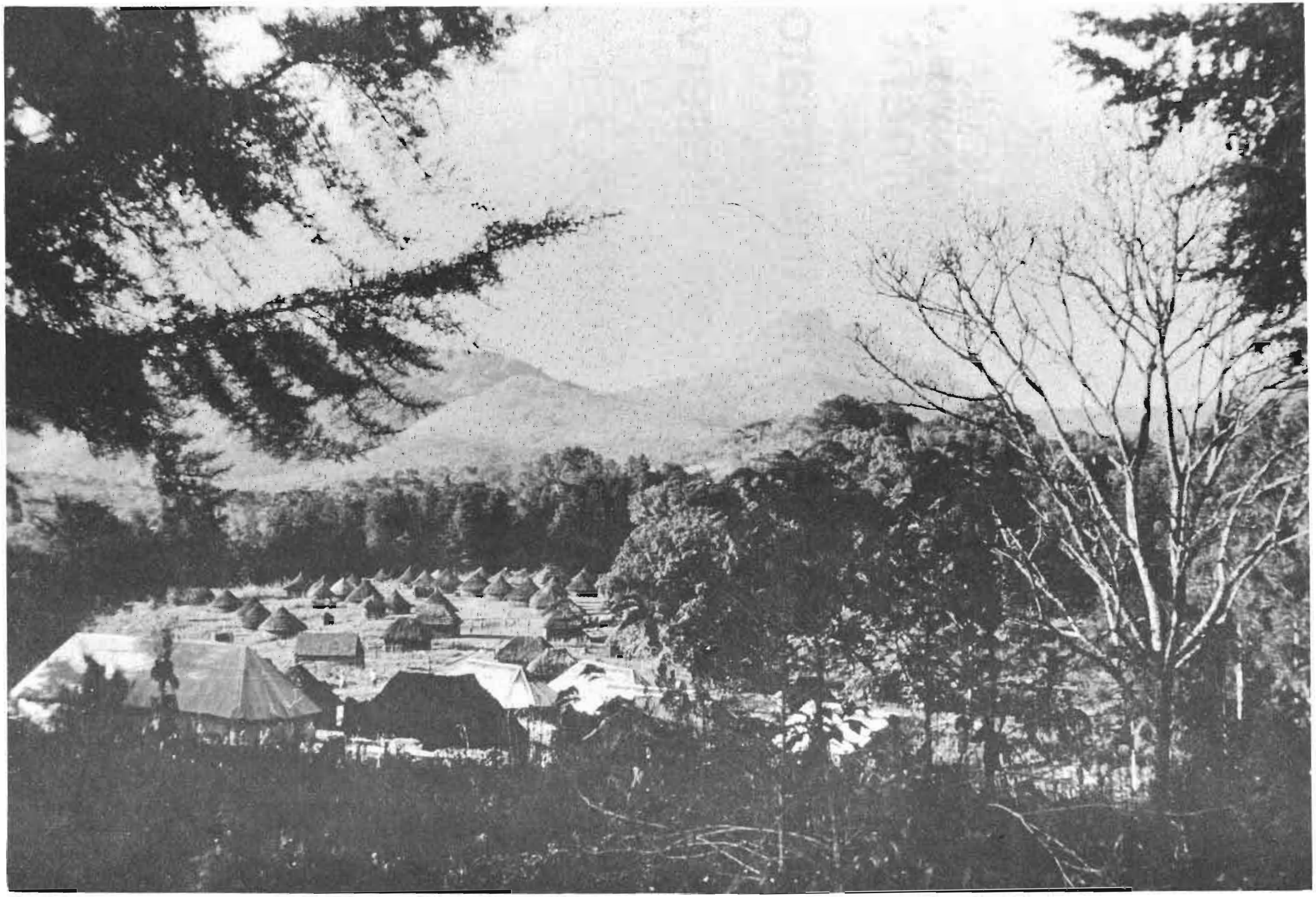

Gilo forest camp and *Cupressus* plantation with the peak of Garia (3,009 m) in the background

Land Resources Division

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Volume 2

Main Report

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NOTICE TO READERS

This study is presented in two volumes: Volume 1, Summary, and Volume 2, Main Report.

The Summary is intended to give a rapid oversight of the contents of the Main Report.

The Main Report describes the background to the study, records the soil survey and forest inventory data collected during the mission and comments upon the possibilities for forestry development. More detailed records on specialist aspects of the study are included in the appendixes at the end of the report.

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ABSTRACT

An area of nearly 10 000 ha has been demarcated in the Ngairigi and Upper Kinyeti Basins for the development of softwood plantations. Some 6 000 ha of the area selected has been designated Class 1 land, having no or only minor limitations for plantation development. An enumeration of 490.8 ha of existing plantations has revealed a standing volume of 127 000 m^3. Recommendations are made for clear felling 274.8 ha, which can be expected to yield about 84 900 m^3, for thinning 152.2 ha, which would yield about 9 800 m^3, for pruning 99.4 ha and for weeding, cleaning and beating up 60.0 ha. Of the area selected for plantation development, 6 405.6 ha are covered by vegetation types containing merchantable timber species. These types include *Croton* – *Macaranga* – *Albizia* forest, *Olea* – *Podocarpus* closed forest, *Podocarpus* – *Syzygium* open forest and *Podocarpus* – *Dombeya* open forest and together they contain about 841 500 m^3 of timber of which 186 000 m^3 is *Podocarpus* and 203 600 m^3 is established hardwoods.

An enumeration of the Talanga forest showed that there was a standing volume of about 258 500 m^3 over some 2 135.7 ha, and this would keep the Katire sawmill supplied with timber for between 5 and 11 years, depending upon the area over which it proved possible to extract economically.

RESUMÉ

Une superficie de près de 10 000 ha a été délimitée dans les Bassins de Ngairigi et de l'Upper Kinyeti pour l'aménagement de plantations d'arbres résineux. Sur cette superficie, quelque 6 000 ha ont été désignés comme terres de 1ère classe, n'offrant aucune limitation à l'aménagement de plantations, ou au plus des limitations mineures. Un inventaire de 490,8 ha dans les plantations qui existent déjà a révélé un volume de bois sur pied de 127 100 m^3. La coupe à blanc étoc de 274,8 ha, produisant quelque 84 900 m^3, l'éclaircie de 152,2 ha, produisant 9 800 m^3, l'émondage de quelque 99,4 ha et le nettoiement et la mise en état de 60 ha ont été recommandés. Sur la superficie choisie pour l'aménagemènt de plantations, 6 405,6 ha sont couverts de types de végétation comprenant des espèces commerciales de bois. Ceux-ci comprennent notamment une forêt de *Croton-Macaranga-Albizia*, une forêt fermée de *Olea* – *Podocarpus*, une forêt claire de *Podocarpus* – *Dombeya* et une forêt claire de *Podocarpus* – *Syzygium*, et représentent un total de quelque 841 500 m^3 de bois dont 186 000 m^3 de *Podocarpus* et 203 600 m^3 d'arbres feuillus déjà établis.

Un inventaire de la forêt de Talanga a démontré qu'il y avait un volume sur pied de quelque 258 500 m^3 sur une superficie de 2 135,7 ha, ce qui suffirait pour fournir en bois la scierie de Katire pendant une période de 5 à 11 ans, selon la superficie sur laquelle il serait possible d'exploiter le bois d'une manière économique.

KEYWORDS

Africa, Sudan, south; soil description, soil survey, soil mapping, soil analysis, soil classification, streamflow gauging, afforestation, *Albizia,* basal area assessment, *Cupressus, Eucalyptus,* forest classification, forest enumeration, forest inventory, forest mapping, forest mensuration, forestry (general), forest sampling, forest site quality, forest stocking (potential crop), forest thinning (artificial regeneration), forest yield, hardwood species, *Khaya, Chlorophora, Maesopsis, Pinus,* plantation (forest), softwood species, stand density, stand description, stand height assessment, stand species composition, stand volume table, stand yield prediction, stocking density, tree growth rate, tree increment, tree volume measurement, wood use.

Parts 1-8

Part 1

Introduction

PREFACE

This report has been prepared as part of a programme of studies undertaken in response to a request by the Government of the Democratic Republic of the Sudan for assistance in developing the Imatong Central Forest Reserve. It is issued with the permission of the Sudanese Government and covers the selection of accessible areas within the forest reserve suitable for the establishment of 10 000 ha of softwood plantations, the assessment of the forest likely to be cleared during the establishment of the new plantations, the assessment of the existing softwood plantations and the assessment of forest areas suitable for exploitation by the Katire sawmill. The fieldwork was undertaken between January and April 1976 and data processing and mapping were continued throughout the remainder of 1976.

An interim report was issued in May 1976 (Jenkin *et al.*, 1976). It was confined to the preliminary assessment of that part of the fieldwork programme designed to select the accessible areas suitable for softwood plantation development, to assess the forest on land likely to be cleared in such development and to assess the existing softwood plantations.

TEAM COMPOSITION

The team comprised R N Jenkin (project manager and soils), W J Howard (forestry), P Thomas (soils), T M B Abell (forestry) and G C Deane (forestry).

ACKNOWLEDGEMENTS

The authors are conscious of the assistance given by the Director of Agriculture, Dr D Bassiouni, by the Head of the Forestry Department, Sayed Kamal Badi, and their staffs. They wish to especially thank Mr Peter M Rusum, Conservator of Forests in Juba, who acted as Liaison Officer for the project, and Mr Eluzai G Ali, Forest Officer, who was responsible for arrangements in the Gilo area.

The authors are indebted to the forest enumeration team leaders Paterno Fatis, Anjelo Jada, Vittorino Legge, Wilson Nathan and Alfred Odibo and to the soil survey team leaders Joseph Kenyi and Claudio Lobwaku.

The authors enjoyed the congenial company of and obtained considerable support from the Directorate of Overseas Surveys (DOS) party, Messrs A T Jones, R J Brown and G Woods, who provided the ground control for mapping associated with this project. They are grateful to Mr Jones, leader of the survey party at Gilo, Mr R A Bardua, leader of the DOS party in Kenya, and Mr I T Logan, Regional Survey Officer in the British High Commission in Nairobi, for their help in provisioning the project from Kenya, and wish to especially thank Mrs Jones for so effectively controlling the domestic arrangements.

The team are indebted to the Norwegian Church Relief Mission at Torit for providing a postal service through their Nairobi office.

The assistance of Dr R L Johnson of the Institute of Geological Sciences, London, who identified and described 17 rock specimens collected during the fieldwork, is acknowledged.

The botanical collections made during the forest enumeration were identified by Dr G E Wickens of the Royal Botanic Gardens, Kew, and Mr P Adlard of the Commonwealth Forestry Institute, Oxford, provided computing facilities.

Finally, thanks are due to our colleagues in the Directorate of Overseas Surveys and in the Land Resources Division who supplied the support needed for the compilation of maps, analysis of soil samples and the preparation of this report.

ORIGIN OF PROJECT

Following the re-establishment of peaceful conditions in the Southern Region, FAO mounted a mission to consider reactivation of forestry production in Southern Sudan. This led later in 1973 to the production of a plan for a forestry sub-project in the Imatong Central Forest Reserve by Draper, an FAO/IBRD Cooperative Programme consultant. In 1974, following a visit to the area by the British Ministry of Overseas Development's (ODM's) Forestry Adviser, the Southern Regional Authorities asked ODM for help in developing the reserve, and a pre-appraisal mission organised jointly by the Commonwealth Development Corporation (CDC), ODM and the Sudanese Government visited the area in November 1975. It was that mission which prepared the detailed terms of reference for the present study.

TERMS OF REFERENCE

The detailed terms of reference are set out in Dorward *et al.* (1976). They are restated here in a summarised form omitting detailed procedural instructions, which will be considered later under the heading 'Procedure'.

1. Inventory of existing plantations

    i. To produce a 1:10 000 scale map of the stands established between 1941 and 1975 recording both species and age

    ii. To assess quantitatively the stocking (number of trees/ha and basal area/ha) and total exploitable volume/ha by size classes in the stands established between 1941 and 1965 and to prepare general volume tables for the principal species

    iii. To assess the condition of all stands planted between 1941 and 1975 and to recommend silvicultural treatments, where appropriate, and to draw up an order of priority for their exploitation over a 15-year period.

2. Soil assessment for plantation development

    i. To produce a geomorphological map of the Imatong Central Forest Reserve incorporating an outline forest land classification related to the geomorphic units

    ii. To produce, within the more restricted area being mapped topographically by the Directorate of Overseas Surveys, a slope analysis map showing a suitable qualitative grouping of slopes within the 30^{o} threshold limit for plantation development

iv. To examine in detail the soils of selected sites within the present softwood plantations to relate tree growth to soil conditions

v. To identify by soil survey appropriate to a mapping scale of 1:50 000 a minimum area of 10 000 ha of land suitable for softwood plantation development.

3. Inventory of indigenous forest

i. To produce by airphoto interpretation (AP1), within the Upper Kinyeti and Ngairigi Basins, in adjacent parts of the Ateppi Basin and on the Imatong Mountains (east), a 1:50 000 scale forest type map taking account of those types (c2-5) differentiated by Jackson (1956) and such other types as the study may indicate to be present

ii. To undertake an intensive inventory of the unexploited forest in the Upper Kinyeti and Ngairigi Basins, in adjacent parts of the Ateppi Basin and on the Imatong Mountains (east) on land likely to be cleared in the development of softwood plantations, the results being expressed by forest type and by species and timber species group as mean volume/ha and reliable minimum estimate (RME) for trees larger than 20, 30 and 40 cm dbh, the aim being a sample error of less than 20% with a confidence limit of 95% (97.5% for the RME) for timber species groups, and to produce volume tables for the principal species and for the timber species groups

iii. To determine by API of forest types in the Talanga area and in adjacent accessible forest on the top and eastern flank of the Acholi Mountains the areas of exploited and unexploited forest

iv. To undertake an inventory of the unexploited forest in the Talanga area and in the adjacent accessible forest on the top and eastern flank of the Acholi Mountains, the results being expressed by forest type and by species and timber species group as mean volume/ha and RME for trees larger than 30, 40 and 50 cm dbh, the aim being a sample error of less than 20% with a confidence limit of 95% (97.5% for the RME) for timber species groups, to undertake sub-sampling to determine the status of regeneration and to produce volume tables for the principal species and timber species groups

v. To assess by API and, if time permits, to make a reconnaissance survey, of the remaining forest of the Ateppi Basin and Lomwaga Uplands.

4. Stream flow assessment

To undertake stream flow measurements on both the Kinyeti and Ngairigi.

The terms of reference also required that the outline results of the plantation assessment and of the inventory of the indigenous forest on the land deemed suitable for development of softwood plantations should be made available to the Commonwealth Development Corporation by the end of May 1976.

PROCEDURE

The constraints that timing and the availability of personnel placed upon the operation of the project were such that the work could not always be undertaken in the normal sequence. For instance the primary geomorphological airphoto interpretation (API), necessary for the selection of areas for semi-detailed soil survey and for forest inventory in the Upper Kinyeti and Ngairigi Basins, was not completed in advance of the start of the fieldwork. Similarly the investigation of the soils in relation to the growth of the present softwood plantations could not be completed in advance of the start of the fieldwork aimed at finding further areas suitable for plantation development. Nevertheless to facilitate reference between this and the previous section, the order followed is the same as that used under 'Terms of reference'.

1. Inventory of existing plantations

Mapping

Initial working maps were prepared from two prints (numbers 145 and 146 film number 153A SU3) of the 1975 air photography which were enlarged two times to 1:10 000 scale to provide a convenient photographic base. All stands were visited and sketch maps indicating compartment boundaries prepared. By combination of the sketch maps and stereoscopic examination of the air photography it was possible to draw accurately the compartment boundaries onto the photographic base. The pines have a darker tone than the cypress on the photography and the lines of *Eucalyptus* stand out very distinctly. For the older stands, Compartments 1-18, the information on the existing plantation map was incorporated. Tracings from the annotated photographs provided working maps at approximately 1:10 000 scale.

In the latter part of 1976 the above information was plotted onto the 1:10 000 base map prepared by the Directorate of Overseas Surveys.

Quantitative assessment

Sampling method The extent of each stratum to be sampled was determined by examination of the 1:10 000 airphoto enlargements combined with field reconnaissance of the compartments. The existing plantation map was found to be of only limited value for this exercise, since it detailed only the earlier plantings and did not fully indicate changes in species within individual compartments.

In most cases strata corresponded directly with single compartments; however, there were instances where several compartments could be considered together as a single stratum, or conversely, sub-compartments had to be recognised.

Random number coordinates were used to position the individual sampling points within each stratum, the points being located by pacing from a pre-selected starting point, usually a corner of a compartment or some such easily located position.

Sampling by discrete plots was used initially. Subsequently point sampling was used to augment the results obtained from the plots and to increase the precision of results obtained.

Circular or square plots of 150, 200 or 250 m^2 were used, plot size being selected to give between 15 and 20 trees in each plot. Circular plots were normally used, but occasionally, where planting lines were distinct, square plots were used to save time. Plot size and shape were kept constant within a single stratum.

A pilot sample of between two and ten plots per stratum was enumerated, the size of sample being dependent on stratum size and a visual impression of variability. Five plots were most frequently used in the pilot sample.

The breast height overbark diameter (dbh to the nearest cm) of every living tree, indigenous regrowth excepted, was recorded together with the top height of the two tallest trees. For the tree with the mean plot diameter, the top height, the timber height (to 10 cm diameter when visible), base diameter and mid-log diameter were measured by relascope to enable the mean tree volume to be calculated. Notes on the slope, aspect, ground vegetation and the state of the crop were also completed at the same time.

From the pilot sample an indication was obtained of the variability within the stratum together with the sampling error. Basal area, being closely correlated with volume, was chosen as the most suitable parameter for estimation of the sampling error.

This initial sampling intensity revealed that apart from a few uniform compartments (for example 4, 8 and 49), there was considerable variability in the basal area within a stratum, producing sampling errors in the range of 30-60%. Analysis of variance on the stocking per hectare showed even greater variability.

It was decided that the most efficient way of increasing the precision of the estimate of basal area was to make random basal area sweeps using a Spiegel relascope. A target sampling error of 20% was chosen because the large number of points required for a higher precision in such variable conditions was impracticable.

The number of sweeps necessary to achieve a sampling error of 20% was calculated using the equation:

$$N = \left[\left(\frac{E}{20} \right)^2 \times n \right] - n$$

where N is the number of additional plots required, E is the original sampling error % and n is the number of plots in the pilot sample.

Using the data collected from the basal area sweeps a new analysis of variance was computed giving new estimates of the mean basal area per hectare, confidence limits and sampling error.

Computation of results. The basal area/ha, mean dbh, stocking/ha and mean top height were calculated from the data collected in the pilot sample plots in each compartment. The plot basal area was calculated by converting the mid point of the 5 cm dbh class to a basal area, multiplying this value by the number of stems in that class and adding the results for all the classes. Similarly the plot volumes were calculated using size class volumes obtained from the volume tables, multiplied by the frequency.

Analysis of variance on the plot volumes in each compartment showed volume to be equally as variable as the other parameters. In order to improve volume estimates it was necessary to take advantage of the increased precision in the basal area estimate. A linear regression model of the relationship between plot basal area and plot volume (on a per hectare basis) for the pilot samples in *Cupressus* compartments was tested, and an equation for the relationship with a coefficient of determination of 0.96 was obtained.

The relationship between volume and basal area in *Cupressus* stands is given by:

$$y = 9.71x + 28.3$$

where y = plot volume (m^3/ha) and x = plot basal area (m^2/ha).

The mean volume per hectare for each *Cupressus* compartment was then calculated by substituting the mean basal area (obtained from the pilot sample and basal area sweeps) for x in the regression equation. The mean volumes for *Pinus radiata* compartments were calculated from the same regression, but as there was insufficient data for a similar volume/basal area regression for the other species, their volume could only be calculated on the pilot sample data, and wide confidence limits for the volume per hectare had to be accepted.

In order to obtain a reliable minimum estimate (RME) for volume in *Cupressus* stands, the RME for the basal area was used in the regression equation, and the corresponding volume was calculated. However in view of this derived method of obtaining the volume it was considered appropriate to use the lower confidence limit for the regression result as the RME volume. The method of calculating the RME volume is shown in Figure 1.

Volume tables. It was initially intended that volume tables for the main plantation species would be constructed from the estimates of volume of the mean diameter tree measured within each sample plot of the pilot sample. It was soon evident that with *Cupressus* in particular there would be great difficulty in accurately assessing timber height and indeed mid-log diameter, due to heavy branching. It was therefore decided that the volume table for *Cupressus* should be constructed from the direct measurement of felled trees.

A total of 113 *Cupressus,* of which approximately 75% were felled, the remainder being windblown, were measured for volume. The trees were selected to give a reasonable representation of all the diameter classes encountered in the plantation (see Appendix 1).

Overbark diameters were recorded at the stump, at breast height (1.3 m), 2 m, 4 m and subsequently at 2 m intervals up to timber height, which was taken to be the position at which the diameter was 10 cm. Total height and timber height were also recorded. From this data the volume was calculated by application of Smalian's formula, namely:

$$\text{Volume} = \frac{A_1 + A_2}{2} \times L$$

where A_1 and A_2 are the areas at the end of each log and L is the length of the log.

A graph of dbh against tree volume to 10 cm top height diameter was drawn and subsequently straight line regression was calculated.

In the case of the pines it was decided that the data obtained from calculation of the mean tree volumes was not sufficient on which to base a local volume table. However, it was realised that because of the limited area planted to pines, a full programme of fellings similar to that used for the construction of the *Cupressus* volume table was not warranted. Instead it was decided that for *P. patula, P. kesiya* and *P. caribaea* the Tanzanian Standard Volume Table for *Pinus patula* (Ackhurst and Micski, 1971) could be used. It was found that the mean tree volumes for all the above species fitted satisfactorily to the regression used for the construction of these tables.

Pinus radiata volumes were found to be best represented by the local *Cupressus* volume table.

The standing volume of the one area of *Eucalyptus saligna* (Compartment 46) was calculated directly from the mean tree volumes.

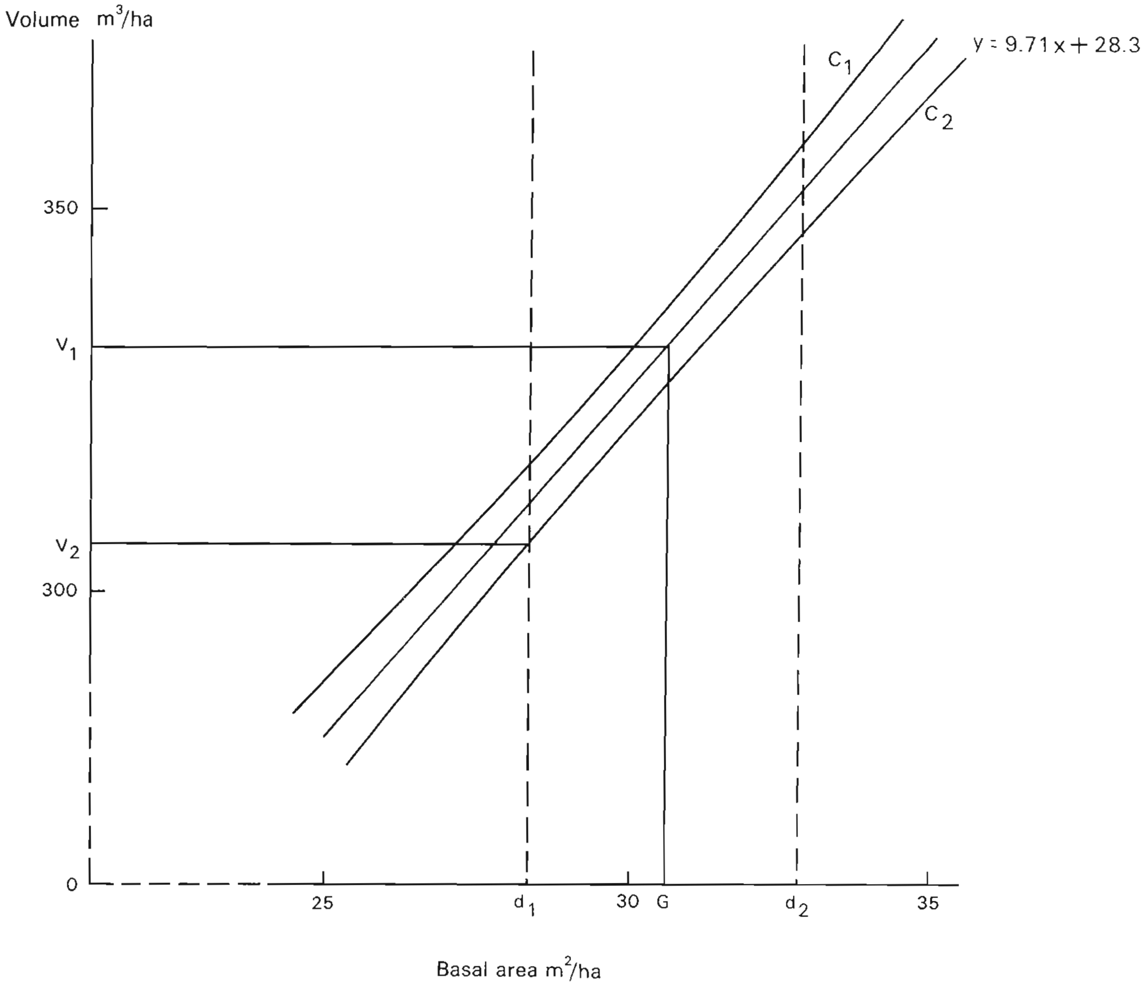
Qualitative assessment

This assessment was made by inspection in the field, account being taken of the data collected in the quantitative assessment.

2. Soil assessment for plantation development

Terrain analysis mapping

The mapping was undertaken using airphoto interpretation (API) of the 1:40 000 scale 1975 photography. In addition to the data obtained from the semi-detailed soil survey undertaken in the Upper Kinyeti and Ngairigi Basins, field data were also used from the reconnaissance traverses in the Ateppi Basin, the Imatong Mountains and in the Kipia Uplands.



V1	Mean volume for basal area G
V2	RME volume
d_1 d_2	95% confidence limits for basal area
C_1 C_2	95% confidence limits for the regression

FIGURE 1 Calculation of RME volume using the regression of basal area against volume for pilot sample plots in *Cupressus* compartments

Slope analysis mapping

API of the 1:40 000 scale photography, supported by data gathered during the fieldwork undertaken in connection with the 1:50 000 soil mapping, was used to produce the slope analysis map. Five slope categories, 0-1, 2-5, 6-20, 21-30 and over 30°, were recognised.

Soil conditions and plantation growth

In addition to observations made and soil pits described and sampled as part of a free range soil survey of the existing plantations, the soils were examined and classified at 185 of the plots enumerated during the sampling of the plantations.

Identification of land suitable for softwood plantation development

The 1:50 000 scale soil mapping was undertaken in areas of the Upper Kinyeti and Ngairigi Basins which seemed from the slope map to have a potential for softwood plantation development. Soils were augered to a depth of 150 cm, described and classified at every fifth plot down the forest inventory lines, giving an average prospection density of 1:25 ha. At least one soil pit, from which samples were collected for analysis, was dug in each forest inventory block, giving a sampling density of about 1:400 ha. Depth of soil, if less than 1 m, was recorded at each plot in the forest inventory lines, giving an average coverage of 1:5 ha. In addition soil data were gathered from two lines cut through areas which had already been exploited for timber and were not included therefore in the forest inventory.

To minimise the mapping requirements it was decided to plot the terrain analysis, slope analysis and soil survey on the same 1:50 000 base maps.

3. Inventory of indigenous forest

Forest type mapping in Upper Kinyeti and Ngairigi Basins

A forest type map at 1:25 000 scale was compiled following airphoto interpretation (API) of the 1:20 000 and 1:40 000 scale 1975 photography. Field data collected during the enumeration were used to check and amend the interpretation. The base for the 1:25 000 map was derived from the 1:50 000 base map compiled by the Directorate of Overseas Surveys. For the interim report (Jenkin *et al.*, 1976) a 1:20 000 map was prepared on a base compiled from a laydown of the 1:20 000 airphoto prints corrected using ground survey data supplied by the DOS field party. This was done after it was discovered that distortion in the 1:20 000 and 1:50 000 scale print laydowns (PLD) made plotting of the inventory blocks impossible.

Inventory of the Upper Kinyeti and Ngairigi Basins

Sampling method The inventory covered land slopes of less than 30° that had a forest cover in the Ngairigi and Upper Kinyeti Basins. Following API of the 1:20 000 scale photography it was possible to exclude from the enumeration those areas of forest which had been disturbed. After a few days of field reconnaissance a design for the layout of the inventory blocks was finalised. Assessment was made by line transects using the method outlined by Dawkins (1958). The sampling framework consisted of 16 blocks with base lines 2 000 m wide. Within each block two transects were cut 20 m wide and ranging in length from 2 000 to 3 000 m. The blocks were laid out using ridge tops as base lines, to make access and the identification of the starting points of transects easy. The blocks are arranged in a semi-circle around Gilo; Blocks 1 to 5 fall in the Ngairigi Basin, 6 to 16 cover the Upper Kinyeti Basin and Blocks 18 and 19 fall partly in the Ateppi Basin. Originally 19 blocks were selected for enumeration but, shortly after the start of the fieldwork, the initial geomorphological API was completed and three blocks (8, 14 and 15), none of which had at the time been enumerated, were discarded because they contained significant tracts of land with slopes over 30°. All trees over 20 cm dbh within the transects were measured.

Some of the species listed by Dorward *et al.* (1976) were not recorded during the survey and the timber species groups were amended to:

A. Species established on the timber market: *Podocarpus milanjianus, Croton macrostachys, Fagara macrophylla, Ocotea kenyensis, Olea* spp., *Pygeum africanum.*

   Two species of *Olea, O. hochstetteri* and *O. welwitschii,* could not be distinguished by the field teams on the characteristics given in Dale and Greenway (1961). As a result they have been booked as *Olea* spp. Subsequently identification at the Royal Botanic Gardens, Kew confirmed that the species most frequently met with is *Olea hochstetteri.*

B. Species potentially utilisable for timber: *Dombeya goetzenii, Macaranga kilimandsharica, Syzygium guineense, Teclea nobilis.*

   The common species, *Syzygium guineense* subsp. *afromontanum* has been placed in the potentially utilisable group in the volume summaries. Initially it was identified as *S. guineense* by referring to von Breitenbach (1963). Specimens were identified later at Kew Herbarium.

C. Species of no use for timber: *Bersama abyssinica, Ochna holstii.*

   Species unknown to the enumeration teams were also included in this group, which is collectively referred to as 'others' in this report.

A number of botanical specimens were collected in order to confirm the species identification; the specimens were sent to the Royal Botanic Gardens, Kew, for identification. A species list, including authorities, showing those species identified at Kew as well as those originally identified by Jackson (1956) is included in Table 34 in Part 5.

As there was no element of allowance for defective or partially defective trees in the volume tables defect was recorded by putting the letter 'B' after the diameter class for trees that were less than 50% usable and 'C' for trees that were useless for timber. When the volumes of these trees were worked out the volume table value was reduced by 50% and 100% in the case of 'B' and 'C' respectively. It was however difficult to maintain consistent booking of defective logs between the forest rangers in charge of the inventory teams.

Volume tables. Volume tables for individual species and timber species groups were prepared in order to convert diameter measurements along the enumeration lines into overbark timber volumes. Subsequently these timber volumes per plot were used to calculate reliable minimum estimates (RMEs) of timber volumes/ha for the forest inventory area.

Every fifth plot along the cut lines was used for volume measurement. Within these plots, the dbh of each tree was measured using a diameter tape, and the timber height, log top diameter and log middle diameter were measured using a Spiegel relascope. Only sound trees were measured in this manner, so that the volume tables could be prepared without large variations in volume occurring.

Species were grouped, for the purposes of the volume table calculations, both on the basis of merchantability as specified by Dorward *et al.* (1976) and of observed characteristics. *Podocarpus, Olea* spp., *Croton* and *Syzygium* were treated individually and *Pygeum, Ocotea* and *Fagara,* by virtue of their bole-shape similarity were placed together. The potentially merchantable species *(Dombeya, Macaranga* and *Teclea)* were treated as a group and the unidentified species, together with those of unknown commercial value, were placed in a final group.

Sufficient data were collected to give a minimum sample of 100 trees for each group. The timber volumes of the trees in these samples were calculated using Newton's formula, in which,

$$\text{Volume} = \frac{(a_1 + 4a_2 + a_3)}{6} \times L$$

where a_1, a_2 and a_3 are respectively the breast-height, mid log and log top cross-sectional areas and L is the timber length of the tree.

For the preliminary report (Jenkin *et al.*, 1976) a simple linear regression model was used because of the difficulty of performing more complex calculations under field conditions. Subsequently the data was recalculated using the VOLTAB computer programme at the Commonwealth Forestry Institute, Oxford.

Determination of exploited and unexploited forest in the Talanga area

Because the past exploitation of the forest in the Talanga area has been restricted to the larger specimens of only a few timber species, canopy disturbance has been minimal and it was found to be impossible to distinguish on the 1:20 000 photography between exploited and unexploited forest. It was possible however to differentiate between a number of forest types and these were mapped at 1:50 000 scale.

Inventory of the Talanga area

Sampling method. A lower priority had been assigned to this inventory by Dorward *et al.* (1976). In the time available it was not possible to undertake the full inventory programme envisaged by Dorward *et al.* (1976) and a reduced programme was devised accordingly. From the airphoto interpretation it was apparent that the Talanga area consisted of lowland high forest surrounded by lower montane forest on the Acholi Mountains and lowland low forest in Kinyeti Valley. As the lowland low forest did not appear to be of high commercial value and some information was already available on the lower montane forest from the inventory in the Upper Kinyeti and Ngairigi Basins, it was decided to confine the inventory in the Talanga area to the lowland high forest areas.

In view of the relatively small area of lowland high forest, it was considered inappropriate to use the method outlined by Dawkins (1958) because there would have been insufficient blocks for any meaningful analysis of variance calculation. Instead the inventory area was treated as a single unit, transect lines were located within it at random and standard analysis of variance techniques were used.

Four transects, varying in length between 3 000 and 3 750 m, were laid out perpendicular to a base line about 3 000 m long which extended roughly south-west from the final loading point on the extraction road linking Talanga with Katire. The sampling intensity was thus about 3%.

Although senior project staff established the start points of the transects on the ground, because of shortage of time they were unable to supervise the line cutting and booking. However, the enumeration teams were given written instructions and had been using very similar methods in the Upper Kinyeti and Ngairigi Basin inventory. The principal differences with which the enumeration teams had to contend were in species, in measuring only trees above 30 cm dbh and in the use of a modified Biltmore Stick (Meyer, 1953) to measure diameters of trees with large buttresses.

Although it had been intended to use the timber species groups specified by Dorward *et al.* (1976), the inability of the enumeration teams to distinguish consistently more than four of the merchantable hardwoods, *Chlorophora excelsa, Khaya grandifoliola, Celtis* spp. and *Maesopsis eminii,* made this impossible. It has been necessary therefore to present the results for only two groups, one comprising the four species named above and the other group including all other species. This latter group is known to contain some established merchantable hardwoods as well as species belonging to the potentially utilisable group and species of no known timber value.

In view of the lack of consistency in recording log defect, this factor has had to be ignored in computing the results.

Volume tables. Time permitted the collection of data for only one general volume table covering all the species encountered in the Talanga area. The data was collected in much the same way as in the enumeration of the Upper Kinyeti and Ngairigi Basins, except that trees were selected from all plots rather than every fifth plot because of the relatively small number of trees in the sample area. The volumes of trees measured were calculated using Newton's formula as before.

A sample of 104 sound trees from a wide range of diameter classes was collected and the results fed into the VOLTAB computer programme at the Commonwealth Forestry Institute, Oxford.

Airphoto interpretation (API) of forest in the Ateppi Basin and Lomwaga Uplands

Following the completion of the fieldwork and the issue of the preliminary report (Jenkin *et al.*, 1976) API of the 1:20 000 scale 1975 photography was completed and a 1:50 000 map showing forest types throughout the whole forest reserve was compiled. It was not possible to undertake a field reconnaissance of the Ateppi Basin and Lomwaga Uplands during the fieldwork phase of the project.

4. Stream flow assessment

Although the station at which Hasek (1963) collected river gauging data on the Kinyeti near Katire was located, it was not possible to make satisfactory arrangements for the collection of further data from this station. Temporary stations were set up on the Kinyeti and Ngairigi Rivers between Gilo and Katire. However the one on the Kinyeti was destroyed by vandals and the data collected from the other was only fragmentary because of the difficulty of obtaining regular measurements when fuel supplies for transport were so limited.

Part 2
The environment

Physical background

LOCATION

The Imatong Central Forest Reserve lies on the Sudan-Uganda border, about 190 km south-east of Juba, between latitudes 3° 45′ and 4° 10′N and longitudes 32° 30′ and 33° 10′ E. Its location in relation to the rest of the Sudan is shown in Text Map 1.

The Reserve, which includes most of the Imatong and Acholi Mountain Ranges, covers an area of about 1 032 km^2 and its general geography is illustrated in Text Map 2.

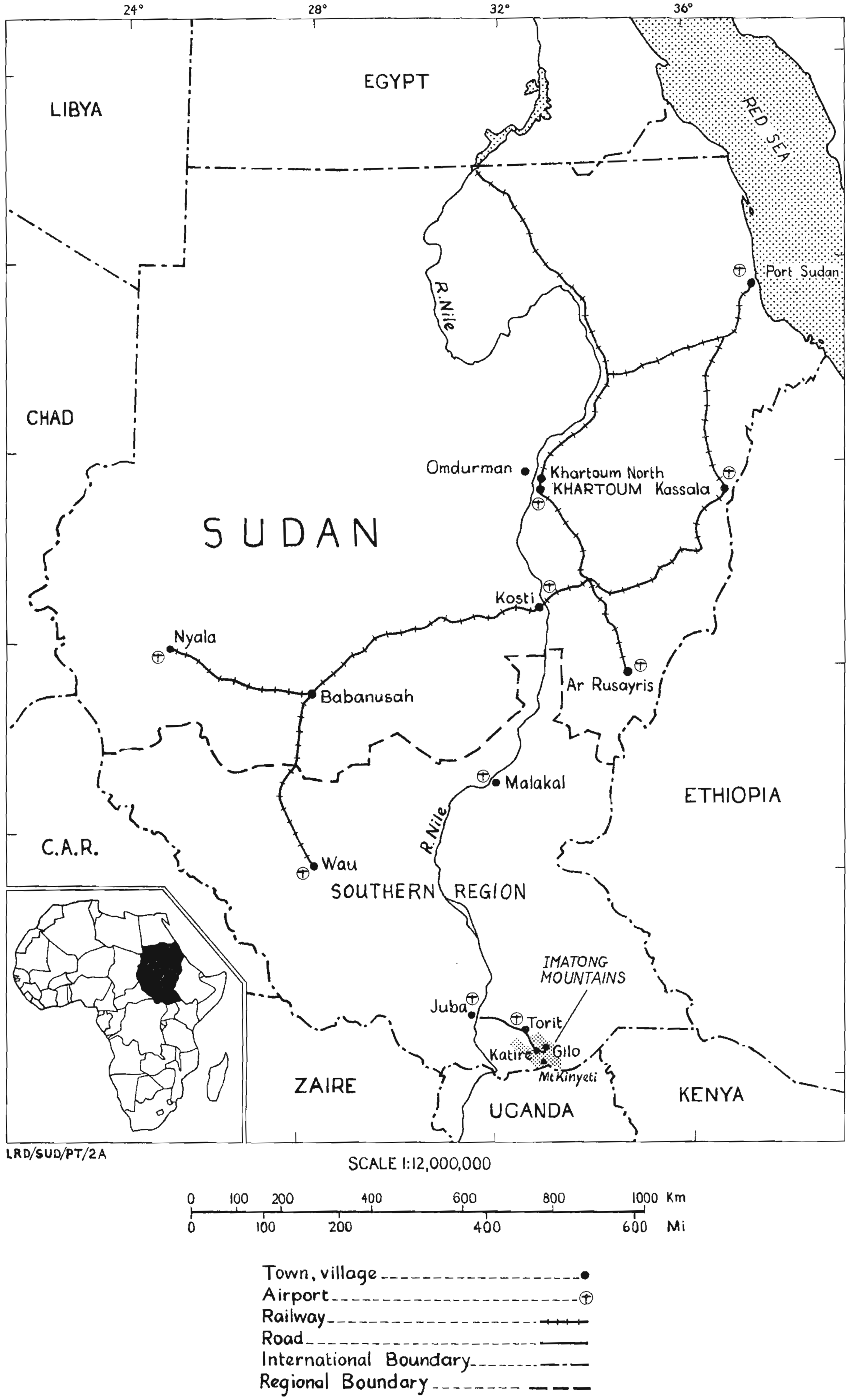
CLIMATE

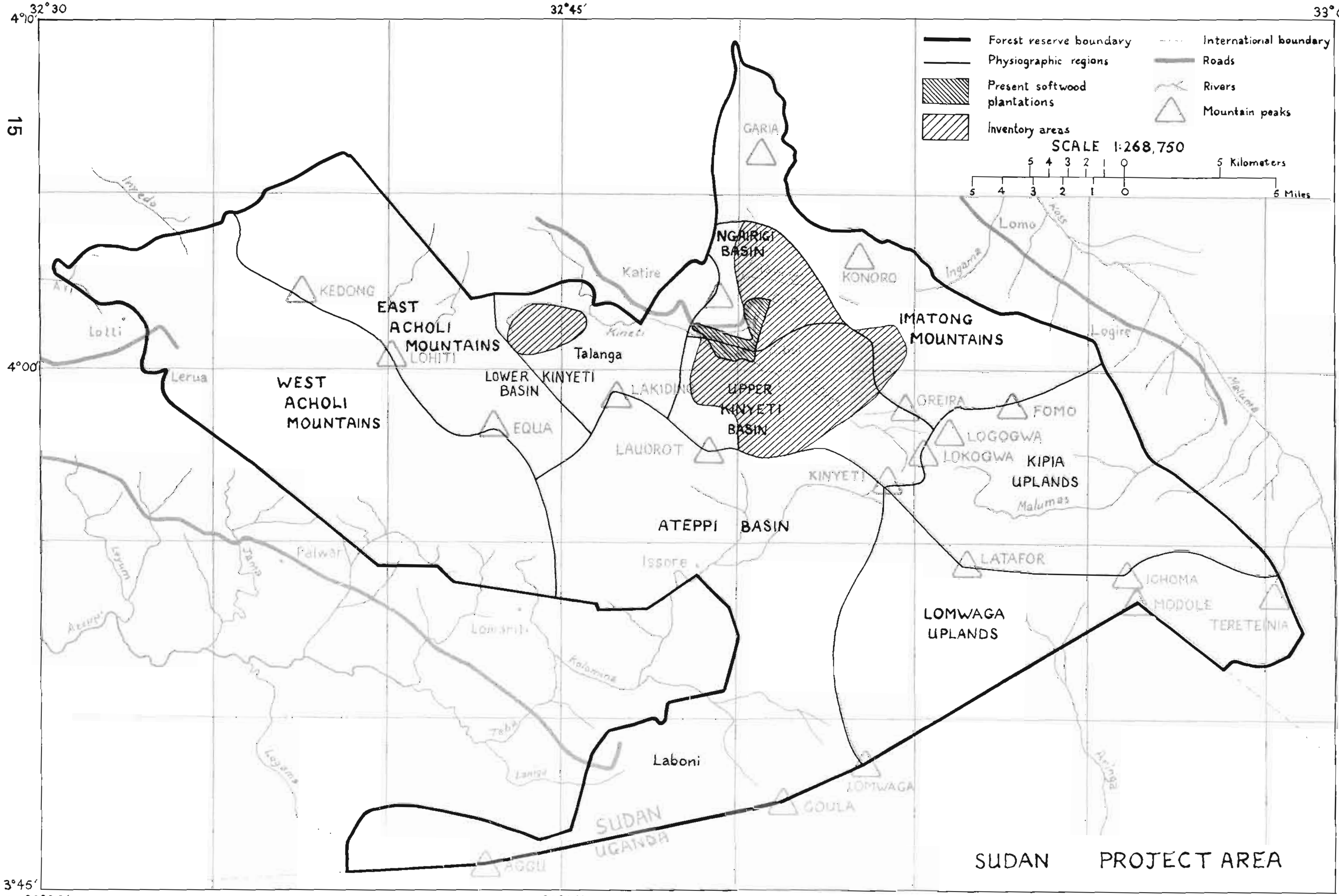
The climate of the project area, which is warm sub-tropical at the lower altitudes and temperate at the higher altitudes, contrasts strongly with the dry tropical climate of the surrounding plains. Within the project area the patterns of rainfall, temperature and wind reflect the alignment and amplitude of the topography.

Rainfall

Jackson (1956) has estimated the annual rainfall of the surrounding plains to vary from less than 800 mm on the east and north-east to about 1 000 mm on the western plains. In contrast the rainfall in the project area is considerably greater, and increases with altitude though possibly, in common with other parts of East Africa, it may decrease again above 2 000-2 500 m. The increase at lower altitudes is clearly seen in Table 11, which presents the rainfall data for Katire and Gilo, the latter station having the highest recorded mean annual rainfall in the Sudan, 2 261 mm. Subsequent figures quoted by Dorward *et al.* (1976) for Gilo, indicate the mean annual rainfall for the station has fallen more recently to 1 984 mm. Rainfall records are no longer kept at Gilo. Although Talanga is only a short distance from Katire, the rainfall is believed to be substantially higher at the former station. This view is supported by limited data available; in 1962 annual rainfall at Talanga was 29% greater than at Katire.

The wet season generally starts in late March or early April and lasts until October or November, with a reduction in rainfall in June in about one year out of every two corresponding with the interval between the 'long' and the 'short' rains further south. There is considerable variation from year to year in the start and finish of the rains, and consequently the months of February to April and September to November show the greatest variation in monthly rainfall.


24°
28°
32°
36°
24°
20°
16°
12°
8°
4°
EGYPT
LIBYA
RED SEA
R. Nile
Port Sudan
CHAD
Omdurman
Khartoum North
KHARTOUM
Kassala
SUDAN
Kosti
Nyala
Babanusah
Ar Rusayris
Malakal
ETHIOPIA
R. Nile
C.A.R.
Wau
SOUTHERN REGION
IMATONG MOUNTAINS
Juba
Torit
Katire
Gilo
Mt Kinyeti
ZAIRE
UGANDA
KENYA
LRD/SUD/PT/2A
SCALE 1:12,000,000
0 100 200 400 600 800 1000 Km
0 100 200 400 600 Mi
Town, village
Airport
Railway
Road
International Boundary
Regional Boundary



TEXT MAP 2

LRD/SUD/RNJ/7

TABLE 11 Rainfall data for Katire and Gilo, mm

Data	J	F	M	A	M	J	J	A	S	O	N	D	Year
Katire*													
Mean	8	17	72	134	192	167	208	247	201	152	72	24	1 494
Min	0	0	7	49	36	77	74	151	44	15	0	0	975
Max	90	80	254	245	579	372	427	406	470	365	404	94	2 201
Gilo+													
Mean	4	21	114	231	288	307	376	337	309	190	58	28	2 261
Min	0	13	7	110	203	87	136	41	6	100	0	0	1 514
Max	18	59	320	347	482	428	875	432	472	413	160	146	2 777

Source : Katire data : derived from data supplied by Sudan Meteorological Office; Gilo data : Jackson (1956)

* Data for 35 years (1941-75). + Data for 10 years (1946-55)

The length and severity of the dry season vary from year to year and have a considerable effect upon the incidence of bush fires. In some years there may be only two really dry months, while in others drought conditions may continue for up to 5 months. Jackson (1956) cites the particularly bad fires which coincided with lack of rain recorded at Gilo between December 1945 and 20 March 1946. Fortunately the effects of drought are tempered at all altitudes by the occurrence of dew, which is abundant in the dry season, and at higher altitudes, above 2 300 m, by the occurrence of mist.

Temperature

The only station for which temperature records exist is Katire. The data for this station is given in Table 12.

TABLE 12 Mean daily maximum and minimum temperatures at Katire, °C

Data	J	F	M	A	M	J	J	A	S	O	N	D
Max °C	33.9	34.2	33.5	32.3	30.4	29.5	28.6	28.3	28.8	30.6	31.7	32.9
Min °C	16.9	16.8	17.4	17.7	17.1	16.6	16.5	15.9	16.6	15.7	14.9	14.9

Source: Jackson (1956)

The hottest temperatures generally occur in the period January to March, before the onset of the rains, and the coldest nights usually occur in November and December. Dorward *et al.* (1976) suggest that at Gilo and at higher altitudes daily maxima higher than 30°C are uncommon. Whitehouse (1931) recorded the noon temperature during the dry season on the summit of Kinyeti as 7°C, and Jackson (1956) indicates that above 2 500 m frosts have been observed, generally on clear, still nights in the dry season, usually confined to frost hollows.

Winds

Regionally, south-easterly winds predominate, but the mountainous topography exerts considerable local influence upon both wind strength and direction. A major feature of the area during the dry season are the strong katabatic winds which blow down the valleys for about an hour after sunset. Strong and gusty winds occur during thunderstorms and can cause windthrow in plantations which have been left unthinned.

TOPOGRAPHY AND GEOLOGY

The Imatong Mountains System is the highest and most extensive of a number of similar areas which occur along the frontier zone with Uganda (Whitehouse, 1931). These form conspicuous highland features rising from the extensive plains of the region. They are formed by crystalline basement rocks, which rise through the Tertiary and Quaternary unconsolidated deposits (Whiteman, 1971) of the lowlands.

The Imatong Mountains system is formed predominantly by acid metamorphic rocks, mainly gneisses, probably of the Waitian Group (Stephens, 1976). The rock types have been described by Johnson (1976) as follows:

'The leucocratic gneiss is a medium-grained weakly foliated rock which in thin section can be seen to comprise a granular mosaic of quartzite and perthite which makes up about 90% of the rock with hypersthene as the predominant accessory material. Lesser amounts of biotite, sillimanite, opaque minerals and zircon are also present.

The augen gneiss is, in hand specimen, a mesotypic medium-grained quartz-feldspar-hornblende gneiss. The augen are quartzo-feldspathic aggregates rather than single crystals but the dark minerals are confined to the groundmass which ranges from medium to very fine grained. In thin section the feldspar is seen to be largely andesine; the potash feldspar is largely confined to antiperthitic intergrowths. In addition to the brown horneblende the groundmass contains garnet, biotite and hypersthene and lesser amounts of zircon and opaque minerals.

The quartz-rich leucocratic gneiss is a variation of the leucocratic gneiss described above. Apart from the greater abundance of quartz the quartz-perthite mosaic is similar. Accessory minerals include garnet, hypersthene, biotite and opaque minerals.'

Johnson (1976) remarks on the mineralogical and chemical similarities of the rocks, varying in the main only by their quartz and dark mineral contents, and concludes that the occurrence of economic mineral deposits in the area is unlikely.

The rocks are strongly faulted and sheared, and the topography is largely tectonically controlled, although the quartz-rich leucocratic gneiss, being more resistant to denudation, forms many of the main ridges. Both the general strike and faulting are north-west to south-east, and the long western arms, known as the Imatong and Acholi Mountains respectively, follow this trend. A secondary series of faults can be discerned running at right angles to this main structural alignment and runs from north-east to south-west. The Imatong and Acholi Mountains are separated by the Kinyeti Valley (Plate 1), the long detrital slopes of which suggest trough faulting.

The 2 400, 1 800 and 1 300 m levels are represented by a series of broad platforms, the first being extensive in the Kipia (Plate 2) and Lomwaga Uplands and where the higher ground marks the watershed between the Upper Kinyeti and Ngairigi Basins (particularly in the Dumusum-Bushbuck Ridge area). The second level at 1 800 m occupies the flatter land of the Ngairigi (Plate 3) and Upper Kinyeti (Plate 4) Basins; while the lowest level occurs as a continuous belt of land in the Ateppi Basin (Plate 5) between Issore and Lomariti. Colluvial deposits are locally important as basin infillings on these platforms, particularly in the Ngairigi Basin, the Kipia Uplands and the Issore and Lomariti areas. These deposits are marked by rolling hills.

The land above, between and below these levels is sometimes rugged and rocky, ranging from the domed rocky summit of Mount Kinyeti (Plate 6), which forms the highest point at 3 827 m (Whitehouse, 1931), the conspicuous and typical inselberg feature of Garia (3 009 m) and the long sharp rocky ridges of Bushbuck Ridge and Dumusum, to the often sheer rock faces and detrital slopes of the escarpments. An important general feature of the landscape, however, is that, with the exception of the escarpments and precipices flanking the main mountain and ridge crests, gradients are rarely steep (over 30^{o}) but of considerable length; slopes of over 1 km rising steadily through over 400 m are common.

Figure 2 illustrates the general physiography of the survey area.

The three country rock types occur with little variation, apart from local quartz veining, over extensive areas. Leucocratic gneisses are the most widespread, underlying much of the Upper Kinyeti, Ngairigi and Ateppi Basins. The augen gneisses form the Imatong Mountains, while the quartz-rich leucocratic gneisses form the Kinyeti-Ateppi watershed to the south and west and the ridge running north from

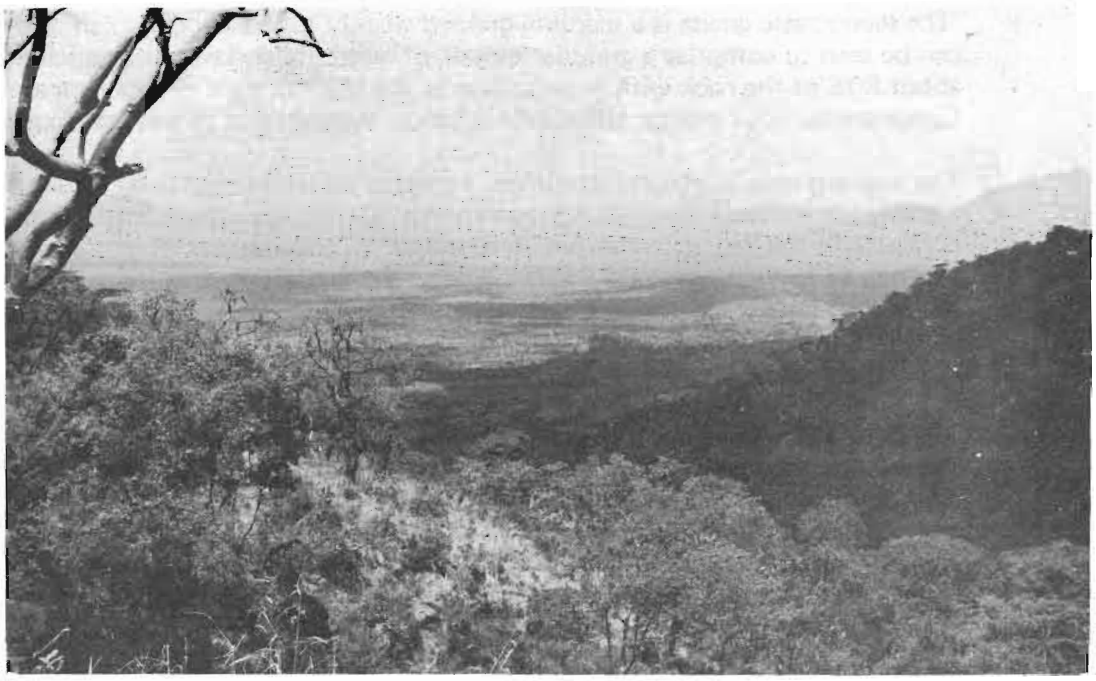


PLATE 1 Western view of the Kinyeti Valley from Gilo. Imatong and Acholi Mountains to the north and south respectively in background

PLATE 2 Kipia Uplands which form the highest platform at 2,400 m, viewed from the west. The pale-toned woodland is *Gnidia-Hypericum-Hagenia* low woodland

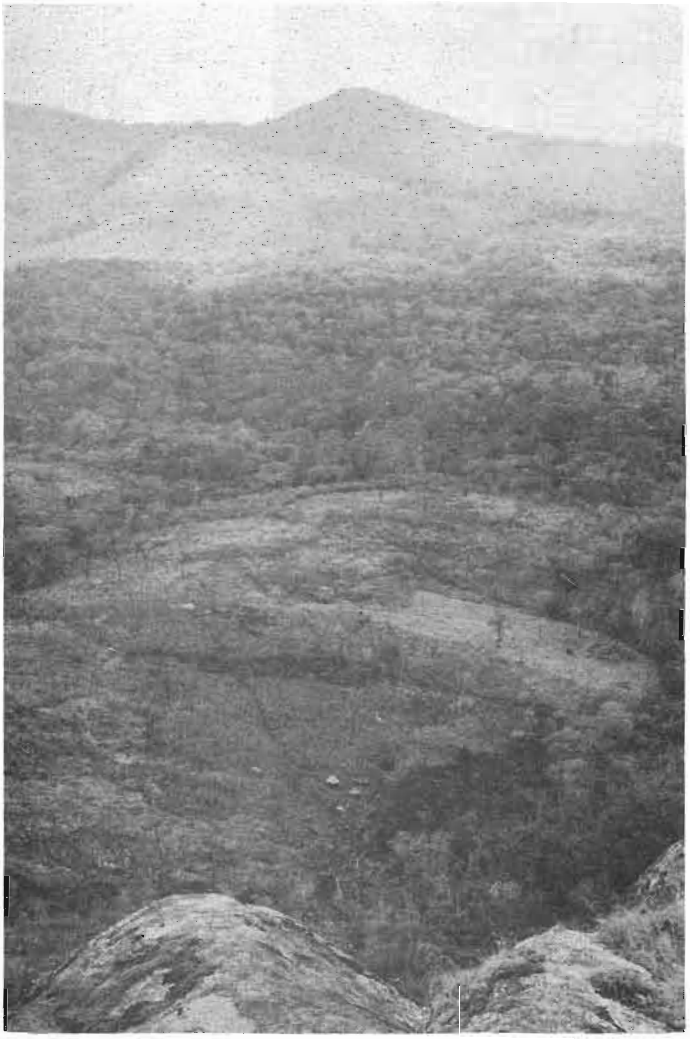


PLATE 3
Ngairigi Basin, which forms part of the 1,800 m platform, viewed from the south

PLATE 4 Upper Kinyeti Basin viewed from Dumusum Ridge to the west. Note the long forested slopes

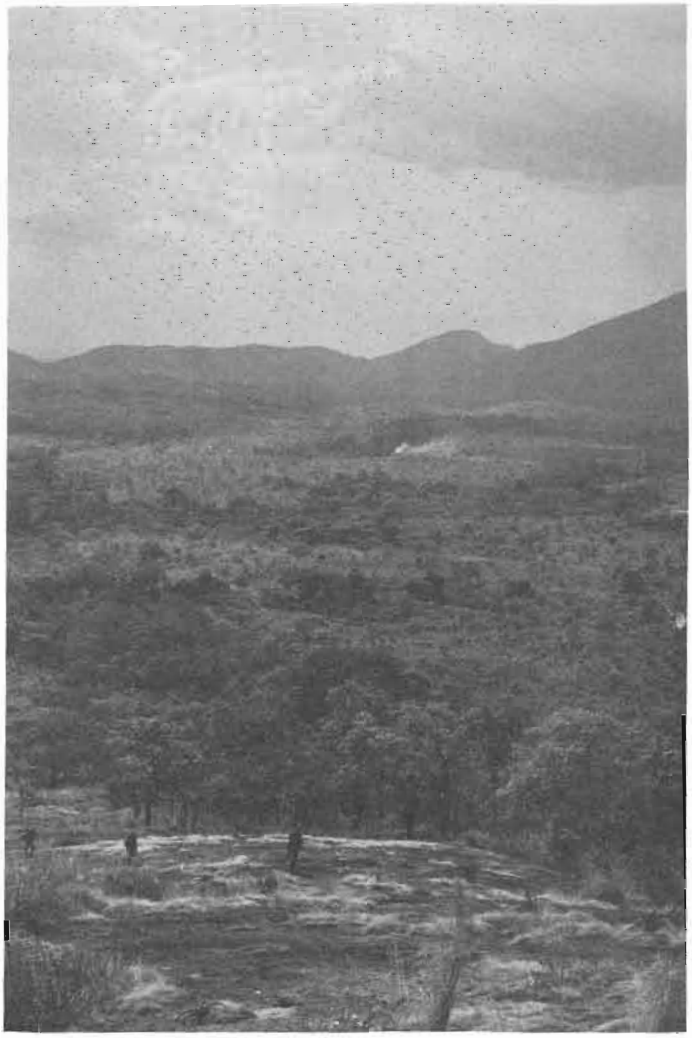
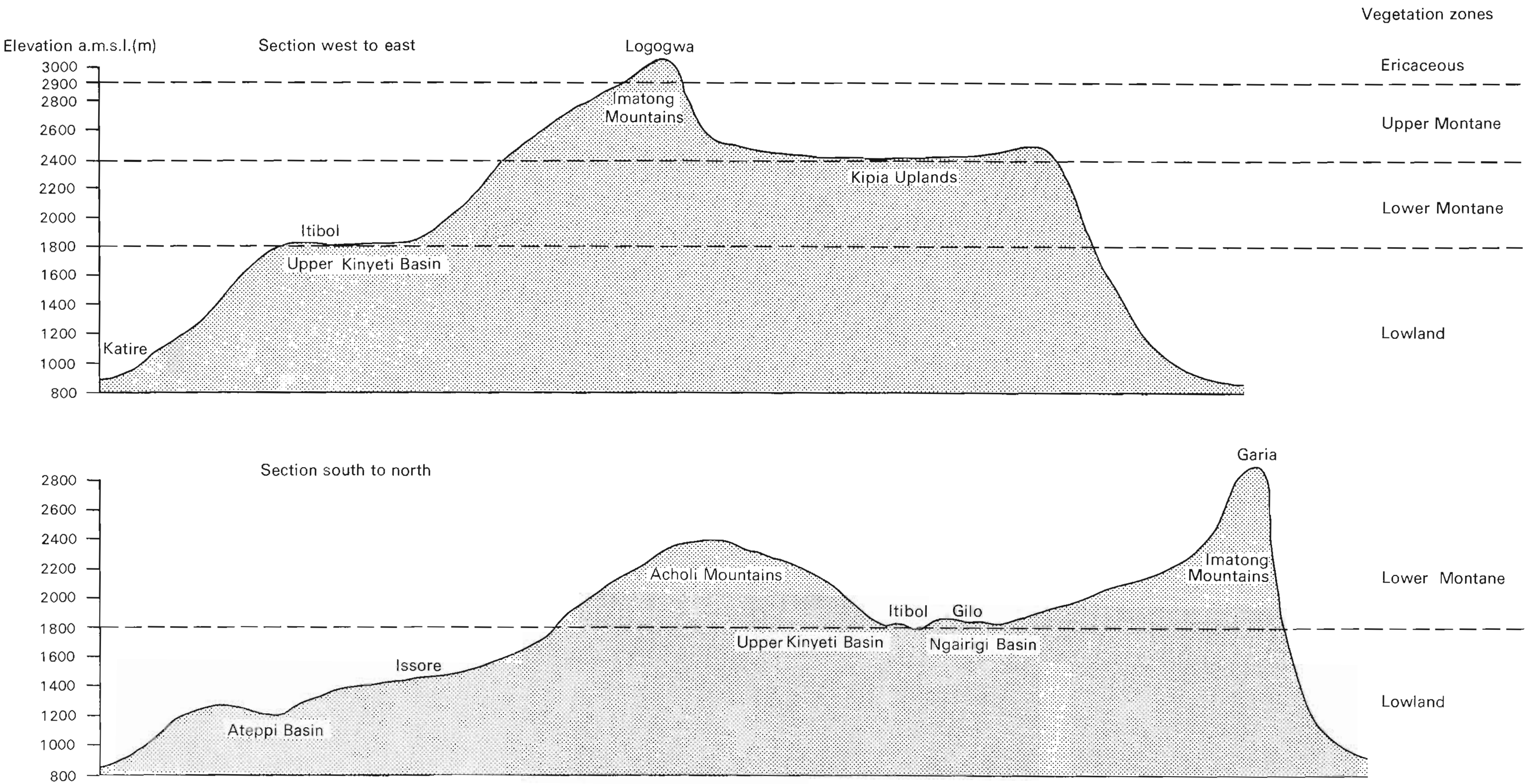


PLATE 5
Ateppi Basin, which marks the 1,300 m platform, viewed from the west

PLATE 6 View to the north from the summit of Mount Kinyeti (3,827 m). Note the domed rocky summit and the peak of Garia (3,009 m) in the distance



Scales: horizontal 1:172000
vertical 1:40000

FIGURE 2 Semi-schematic landscape profiles

FIGURE 2

Mount Kinyeti to Konoro. This ridge forms the divide between the Kinyeti River system, which flows to the west, and the Malumas, which drains the Kipia Uplands to the east. Much of the Kipia Uplands, together with the Lomwaga Uplands to the south, is also underlain by quartz-rich leucocratic gneisses.

HYDROLOGY

The Kinyeti, into which the Ngairigi flows, is the largest river in the Reserve. However the catchment of the Ateppi River, which drains the south-western slopes of the Acholi Mountains, is more extensive than that of the Kinyeti. Other important streams with perennial flow include the Malumas, which drains the Kipia Uplands, and the Ayi and Iyedo which flow from the western side of the Acholi Mountains. Most of the streams rise in a zone which lies between 1 800 and 2 700 m altitude. Flow is usually gentle over the 2 400 and 1 800 m platforms, after which the water courses are marked by rapid flow, with cascades and waterfalls until the plains are reached at about 900 m. In the Acholi Mountains relatively gentle stream flow is restricted in parts to the 1 300 m platform.

Some further records of gauge plate readings for the station on the Kinyeti about 3 km south of Katire were obtained from the monthly reports of the Assistant Conservator of Forests (East Circle); this data has been incorporated with that collected by Hasek (1963) and is summarised in Table 13.

TABLE 13 Gauge plate readings in metres on the Kinyeti River near Katire

Record	J	F	M	A	M	J	J	A	S	O	N	D
Mean monthly	1.49	1.43	1.47	1.64	1.67	1.69	1.77	2.00	1.94	1.93	1.85	1.69
Mean max.	1.62	1.76	1.84	1.95	1.96	1.89	1.99	2.33	2.70	2.50	2.19	2.02
Mean min.	1.32	1.29	1.24	1.24	1.42	1.44	1.59	1.37	1.70	1.61	1.59	1.46

Source: March 1960 - February 1963 : Hasek (1963)
March 1963 - June 1965 : Monthly Reports, ACF (East Circle)

As the gauge plate is well downstream of Katire, the discharge that is available to power the sawmill will be less than that associated with data given in Table 13.

SOILS

The soils are described in detail in Part 4. Though varying from skeletal soils amongst rock exposures on the hills to deeply developed soils on the footslopes and river basins, they are notable in having well developed dark humus-rich surface horizons, which may extend to depths below 1 m. In the deeper soils these dark horizons usually overlie medium to fine textured subsoils, which are generally amongst the reddest to be found. Other characteristic features are their very friable and porous nature which gives rise to extremely rapid internal drainage. The red subsoils sometimes overlie a weathering rock mantle, and this is marked by a distinct mottled clay layer which includes weathering fragments of feldspar. The soils in general appear to be inherently fertile, but most of the plant nutrients are associated with the organic-rich topsoils.

VEGETATION

The Imatong Mountains are covered with montane forest in which the botanical composition and structure vary with elevation, climate, soil conditions and land use. The vegetation has been described by Jackson (1956) who identified five major vegetation zones, four of which occur inside the Reserve. Table 14 summarises the vegetation communities that fall in the different zones identified on the vegetation map (Maps 4 a and b). The relationship between vegetation zones and elevation are illustrated in Figure 2. Although the top of Garia in the section south to north exceeds 2 400 m elevation, because it is a rock outcrop with no vegetation, no distinction between Higher (Upper) and Lower Montane Zones has been made.

Detailed forest inventory was carried out in the Upper Kinyeti and Ngairigi Basins in the Lower Montane Zone and in the high forest Talanga area in the Lowland Zone; the results of these inventories are given in Part 6.

In the Upper Kinyeti and Ngairigi Basins four vegetation types containing commercial timber have been identified (hereafter these four vegetation types are referred to as forest types).

Croton-Macaranga-Albizia forest This is secondary forest dominated by *Croton macrostachys, Macaranga kilimandsharica* and *Albizia gummifera,* which occurs in areas near Gilo and Itibol that have been farmed in the past.

TABLE 14 Vegetation types by zone and structure

Structure	Vegetation zones			
	Lowland <1 800 m	Lower Montane 1 800 - 2 400 m	Higher Montane 2 400 - 2 900 m	Ericaceous >2 900 m
Grassland or wooded grassland	Wooded grassland	*Loudetia* grassland	*Exotheca* grassland *Carex* sedge swamp grassland	*Erica* thicket
Woodland	*Albizia-Terminalia* woodland	*Hagenia* woodland	*Gnidia-Hypericum-Hagenia* woodland	
Thicket or low forest	*Khaya-Cola* low forest	*Vernonia* shrub thicket	*Olea-Podocarpus* pole forest/ thicket	
Forest	*Khaya-Chlorophora* high forest	*Croton-Macaranga-Albizia* forest *Olea-Podocarpus* closed forest *Podocarpus-Syzygium* open forest	*Podocarpus-Dombeya* open forest	

The mean stocking of this forest is 82 m^3/ha of which 15 m^3/ha is *Croton.*

Olea-Podocarpus closed forest This has a mean total stocking of 177 m^3/ha of which 60 m^3/ha is *Podocarpus milanjianus,* and 40 m^3/ha is *Olea* spp. (mostly *O. hochstetteri*). Although there is a higher volume of *Podocarpus* there are many more *Olea* trees per hectare.

Podocarpus-Syzygium open forest This forest is similar in species composition to the closed forest, the main difference being that the open forest contains a higher proportion of mature and overmature trees and a dearth of small-size trees. Although the mean total volume of the open forest appears high (132 m^3/ha) it is likely that a high proportion of the trees will be only partially merchantable. The volumes of *Podocarpus, Syzygium* and *Olea* are 37, 31 and 24 m^3/ha, respectively.

Podocarpus-Dombeya open forest At an elevation of about 2 400 m the forest becomes more open and species of the Higher Montane Zone are found. Where the type occurs on the steep slopes rising up to the Kipia Uplands the forest should not be exploited for fear of erosion.

In the Lowland Zone, the Talanga forest contains *Chlorophora excelsa, Khaya grandifoliola, Celtis* spp. and *Maesopsis eminii.* The mean total volume is 142 m^3/ha of which 26 m^3/ha are accounted for by the four merchantable hardwoods mentioned above.

WILDLIFE

Bushbuck browsing the *Hypoestes* ground layer are a common sight in the *Podocarpus-Syzygium* open forest and Colobus monkeys are common in the forest trees, where they eat the fruits, particularly the *Olea* berries.

Signs of elephants can frequently be seen and it is likely that they move nearer to Gilo in the wet season. The elephant's small relative, the rock hyrax, is also common and was frequently hunted by the inventory teams. Other animals that occur in the forest are duikers, bush-pig and buffalo.

Bushbuck eat the bark of *Olea hochstetteri* and *Allophyllus abyssinicus* and enter the plantations to similarly damage the bark of *Eucalyptus saligna.* Jackson (1956) reports that elephant damage the forest vegetation, but no severe damage was seen by any of the foresters in the team.

At the weekend, hunting parties armed with bows and arrows and spears leave Katire to hunt in the reserve. Large hunting camps were found in the forest. Although the hunters have no rifles they hunt in such large numbers that they are bound to deplete the game. They also tend to collect too much meat and waste some because they are unable to carry it back to Katire.

The greatest concentration of game appears to be in the Kipia Uplands, with elephant, buffalo, bushbuck, pig, hyena and leopard being the most notable. This area is visited periodically by hunting parties from Issore.

Social background

SETTLEMENT AND POPULATION

In 1974 the population of the Torit District totalled 107 636 (Rusum, 1976). The 1974 census records a population composed of seven tribes, two of which, the Acholi and Latuka live in the vicinity of the Imatong Central Forest Reserve (see Table 15).

Reliable population data are not available for Katire, the main village in the area, or for the two villages in the forest reserve, Gilo and Itibol. Similarly no records are available for the numerous small settlements around the eastern and western boundaries of the reserve. Estimates of population were collected from local records by the pre-appraisal mission team (Dorward *et al.*, 1976), and reproduced in Table 16. It is considered that these considerably underestimate the population, because non-tax-payers and those unknown to the Forest Department are excluded.

TABLE 15 Population in the Torit District

Tribe	Population
Acholi	17 247
Lango	20 118
Latuka	38 876
Lokoro	8 606
Lokoya	3 650
Lopit	10 908
Madi	8 231
Total	107 636

TABLE 16 Population data for Katire, Gilo and Itibol

Location	Males	Females	Children	Total
Katire	508	1 037	2 067	3 612
Gilo	70	n.a.	n.a.	200
Itibol	88	76	169	333

n.a. = not available
Source: Katire: tax rolls; Gilo and Itibol: Forest Department records

Although a comparison of the numbers employed by the Forest Department (674, as quoted by Dorward *et al.* (1976)), with the population data given in Table 16 suggests that there is no surplus of male labour in the area, there is good reason to believe, from the experience of the present mission in recruiting extra daily paid labour, that many of those currently engaged in agriculture and hunting would readily accept any offer of employment. Furthermore, there is evidence, from applications for employment on the present mission from people residing outside the project area, to suggest that labour would migrate into the area from other parts of the Torit District.

ADMINISTRATION

Administrative control of the Torit District is exercised by a Local Government Inspector, who resides in Torit and is directly responsible to the Assistant Commissioner for the whole of Eastern Equatoria, who also has his office in Torit. There are five elected warranted councils in the Torit District, Torit Bur, Kiala, Ikotos, Magwi and Loa, the first of which covers the Katire area. Although composed mostly of elected members, Torit Bur Council is chaired by the Local Government Inspector, who has the right to set aside council decisions when he considers they are not in the best interests of the people. Another civil servant, an executive officer, serves as Secretary to the Council. The Council levies a poll-tax as well as taxes on livestock, markets, businesses and profits and is responsible for social and welfare services, including the maintenance of minor roads, education and medical care.

There is also a system for the administration of customary laws under the control of tribal chiefs. The tribal chief in Katire, Kuintino Ali, presides over the tribal court, at which land disputes, minor personal quarrels and customary law marriage problems are resolved. More serious disputes and criminal offences are heard at the court in Torit, where the Local Government Inspector has delegated authority to act as judge.

COMMUNICATIONS

The project area is reached from Juba by road via Torit, a distance of 190 km. For its whole length the road is of earth and broken stone construction, and is in a poor state of repair, as recorded by Dorward *et al.* (1976). Towards the end of the fieldwork regrading and in places resurfacing with murram had commenced from the Nimule turn off towards Torit, but the worst stretches remain untouched. Dorward *et al.* (1976) have indicated that plans exist for improving the Juba-Torit section during 1976, and have recommended the upgrading of the Torit-Katire road. They have similarly indicated the need to improve the present roads connecting Katire with Itibol and Gilo, which currently will take only vehicles below about 3-ton weight.

There is a regular, daily bus (lorry) service connecting Torit with Juba. This service also carries the mail. There is no service between Torit and Katire.

Police check points, at which all vehicles are obliged to report, are operated at Juba, Torit and Katire; non-residents are obliged to obtain travel permits to proceed beyond Juba.

Because of the poor supply of most commodities available in the Southern Sudan, the ease with which freight can be brought to Juba from the Northern Sudan and from the neighbouring countries is of major importance. Road transport between Juba and the North is restricted to the dry season, and most freight is carried either on the daily air service connecting Khartoum and Juba (Boeing 737 or 707) or by steamer and barge along the Nile. Two freight companies, Interfreight (Kenya) Ltd and Trans Expo (Kenya) Ltd, operate road freight services to and from Nairobi along the only available route through Uganda.

Although Juba airport receives only a few flights each day, it operates throughout the 24-hours, has a tarmac landing strip, and has international status, though customs and immigration officials are not on duty at the airport at all times and normally have to be called to the airport when international flights land. Although light aircraft charter flights from Nairobi are frequent, there are no regular scheduled flights operating between Juba and Nairobi.

The nearest airstrip to the project area is that at Torit. It is an all weather earth strip, capable of taking aircraft up to the size of the Fokker Friendship, used by Sudan Airways, but is not served by regular domestic flights. Any incoming or outgoing international flights are obliged to clear customs and immigration at Juba.

At Torit there is a post office offering full postal and telegraphic services, and although a post office is planned for Katire, no such facilities yet exist in the project area. In addition to the post office in Torit, radio contact with Juba is also maintained by the Police and by the Norwegian Church Relief Mission.

PUBLIC SERVICES

The main regional hospital is in Juba, but there is a small hospital in Torit, in addition to which there are a doctor and two nurses from the 'Save the Children Fund' and a doctor at the Norwegian Church Relief Mission also stationed at Torit. At Katire there is a dispensary. No specific transport is available for transporting patients needing hospital treatment to Torit, transport being dependent upon the Forest Department having a vehicle and fuel available. With a major sawmill, two subsidiary mills and the attendant field operations in the area transport should be available at all times to convey injured personnel to hospital in Torit.

There is only one primary school in the area and this is in Katire. There are five teachers and about 400 pupils, including some children who daily make the 3-4 hour return journey on foot from Gilo and Itibol. Pupils attend the school at Katire for 6 years, and in their final year sit the entrance examination for the junior secondary school at Torit. After 3 years at the junior secondary school at Torit and a further examination successful students are admitted to the senior secondary school at Juba, from which after 3 years they can emerge with qualifications equivalent to the old Cambridge School Certificate.

In Torit there is a piped water supply, but in Katire piped water is available to only a few houses, however a good all the year round water supply is available from the River Kinyeti. At Gilo water is piped to a single point at the entrance to the village, but at Itibol the supply is rudimentary, there being a single water hole about 0.4 km from the nearest house and this becomes partly inaccessible during the wet season.

There is no public electricity supply either at Torit or in the project area. However in Katire the River Kinyeti, which powers the Katire sawmill, also from about 17.30 h, when the sawmill is not operating, drives a small 33 Kw generator from which electricity is supplied to the staff houses, the police station, the offices and the furniture workshop. The generator is now functioning again, new brushes having been fitted since the visit of Dorward *et al.* (1976).

Forestry background

TIMBER MARKET

In 1973/4 about 70 000 m^3 of timber were used in the Sudan, of which nearly 55 000 had to be imported (Dorward *et al.* 1976). Draper (1973) has estimated the volume of railway sleepers used at about 11 000 m^3/year and Dorward *et al.* (1976) consider that 80% of the remaining timber used is accounted for by softwoods. The latter authors estimate the demand for softwood timber in 25 years time at 100 000 m^3/year, of which 80% will be used in northern Sudan and 20% in the south.

The *Podocarpus* in the natural forest and the existing softwood plantations in the Imatong Central Forest Reserve are the principal sources of softwood timber in the Sudan at the present time.

Dorward *et al.* (1976) indicated that the Forest Department considered the demand for building poles was considerable and this,together with the possibility of sales for fuel wood and charcoal, would provide a ready market for thinnings from the proposed plantations.

Most, if not all,the sawmills in the Southern Sudan are run by Government; the prices of timber are set in relation to both the cost of production and to import prices. Government prices for a variety of local timber products are given in Table 17.

TABLE 17 Sale prices of forest produce from the Southern Region, Sudan

Produce	Location and specifications	Price LS per unit specified
Sawn timber	At mill	48.80/m^3
	At depot (Juba, Wai Aweil)	53.68/m^3
Sleepers	Sudan Railway	60.30/m^3
	Sudan Gezira Board	68.75/m^3
Poles	Medium grade (3½-8 in mid-length diam)	0.65/pole
	Light grade (up to 3½ in mid-length diam)	0.45/pole
Firewood	Main towns, Southern Sudan	1.20/m^3
	Districts, Southern Sudan	1.00/m^3
Charcoal	Equatoria: Juba	0.80/bag
	Districts	0.60/bag
	Bahr el Ghazal: Wau	0.50/bag

Source: Dorward *et al.* (1976)

It is estimated that the current price of imported Scandinavian softwood is about LS 170/m^3.

Due to the scarcity of fuel and vehicles on the roads in the Southern Region it is difficult to obtain a free market price for haulage. To transport timber from the southern border of the Sudan to the north will undoubtedly be expensive. Two factors can be set against the high transport cost; first the import substitution of providing home grown softwoods will save foreign exchange; second the timber can be shipped by barge from Juba, hopefully at relatively cheap rates, because most of the flow of goods is from north to south and many barges go downstream empty. Dorward *et al.* (1976) have estimated likely haulage costs.

RESERVATION

Since the early 1930s the Sudan Forestry Department has had an interest in the Imatong Mountains. In 1940, due to the acute shortage of timber brought about by the second world war, a road was constructed from Katire to Gilo and *Podocarpus* timber was exploited. The plantation was started a year later in 1941. The forest Reserve was legally gazetted as a Central Forest Reserve under LRO No. 11 of 1952 in the legislation supplement to the Sudan Government Gazette No. 840, dated 15 March 1952.

PLANTATION HISTORY

The history of plantation establishment falls into three periods:

1. 1941-54 Trial plantings and early establishment of cypress in the Gilo Range
2. 1955-64 Establishment of cypress and pines in the Dumusum and Itibol Ranges
3. 1965-76 Neglect during the disturbances; new planting north of Gilo on cleared forest sites.

The period 1941-54

In the first few years of planting (1941-3), a range of species was tried including *Cupressus lusitanica, Juniperus procera, Eucalyptus grandis, Podocarpus gracilor, Callitris calcarata* and *Olea* spp. After this planting was mainly of *Cupressus lusitanica,* which was established all over the northern Gilo block of the plantations.

The period 1955-64

In this period a wider range of pines was tried on the Dumusum and Itibol Ranges, because the cypress suffered from drought crack in severe dry seasons (Leuchars *et al.*, 1954). It was feared that the cracks in the stem would lead to insect or fungal attack and spoil the quality of the timber. The main species tried were *Pinus patula, P. radiata* and *P. kesiya. P. patula* was particularly successful on steep slopes over shallow soils.

The period 1965-76

From 1965 to 1972 no new planting or silvicultural treatment of the established plantations was carried out, due to the disturbances. Many of the plantations established in the previous period, particularly compartments in the Dumusum Range, are only partially stocked due to neglect at this time. In the period since 1972, when peace was restored, the main activity has been clearing and planting of forest north and west of Gilo labour camp. No thinning, pruning or cleaning of young regrowth has taken place.

Part 3

The existing plantations and their management

INTRODUCTION

The existing plantations cover an area of 490.8 ha and are located within three ranges. The Gilo Range, centred around Gilo Village, contains the oldest planting and consists mainly of *Cupressus lusitanica* planted between 1941 and 1950 (Plate 7). The Dumusum Range planted between 1954 and 1965 lies to the south of Gilo and is planted with *Cupressus* and *Pinus radiata*. The Itibol Range lies along the road from Itibol sawmill to Katire and is situated south west of Gilo. In this range a variety of pines have been tried as well as cypress; *P. patula, P. radiata, P. kesiya* and *P. caribaea*. Most of the planting appears to have been done between 1951 and 1965.

The oldest Gilo compartments of cypress are now 26-33 years old and are ready to clear fell. Some thinning has been carried out in the old compartments, but younger compartments in the Dumusum and Itibol Ranges have not been thinned and are now suffering from severe windblow; the latter have been neglected for so long that if they are thinned now the remaining trees will almost certainly blow over. It is also unlikely that further thinning in the mature compartments around Gilo is justified, because the remaining trees may blow over and are unlikely to respond by putting on increment; their crowns are greatly reduced by underthinning and the bole timber will have large knots because the trees have not been high-pruned. A major problem for management is deciding which compartments can be left without risk of blowing over and which compartments should be clear felled as soon as possible because they are unstable. In the section entitled 'Prescriptions for the silvicultural management of the plantations' solutions to the problem are suggested. These include indications of which compartments will respond to thinning and which compartments require weeding and beating up.

AREA AND AGE CLASSES OF THE PLANTATIONS

In Table 18 the compartments are classified by species, age class and area (see also Map 1). The total area of the plantations is 490.8 ha; 3.4 has been clear felled and a further 60.2 ha comprises the partially stocked stands. Most of the partially stocked stands lie in the Dumusum Range and the central part of the Itibol Range. About 40% of the fully stocked stands were established in the 8 years to 1951. These compartments are primarily in the Gilo Range and are virtually all *Cupressus lisitanica.* A further 40% of the fully stocked stands were established between 1951 and 1961 in the Dumusum and Itibol Ranges. Of this figure, 60% were *Cupressus* and 40% *Pinus* spp. (mainly *P. patula* and *P. radiata*). It is within this age group that the bulk of the partially stocked compartments are found, much being *P. radiata* in the Dumusum Range.

In the last 15 years only 20% of the total has been planted, 12% in the last 4 years. This latest planting is primarily *C. lusitanica* with some *P. patula* used for beating up.

PLATE 7
The unthinned unbrashed *Cupressus* plantation in Compartment 9. The trees are standing close together and have a high volume

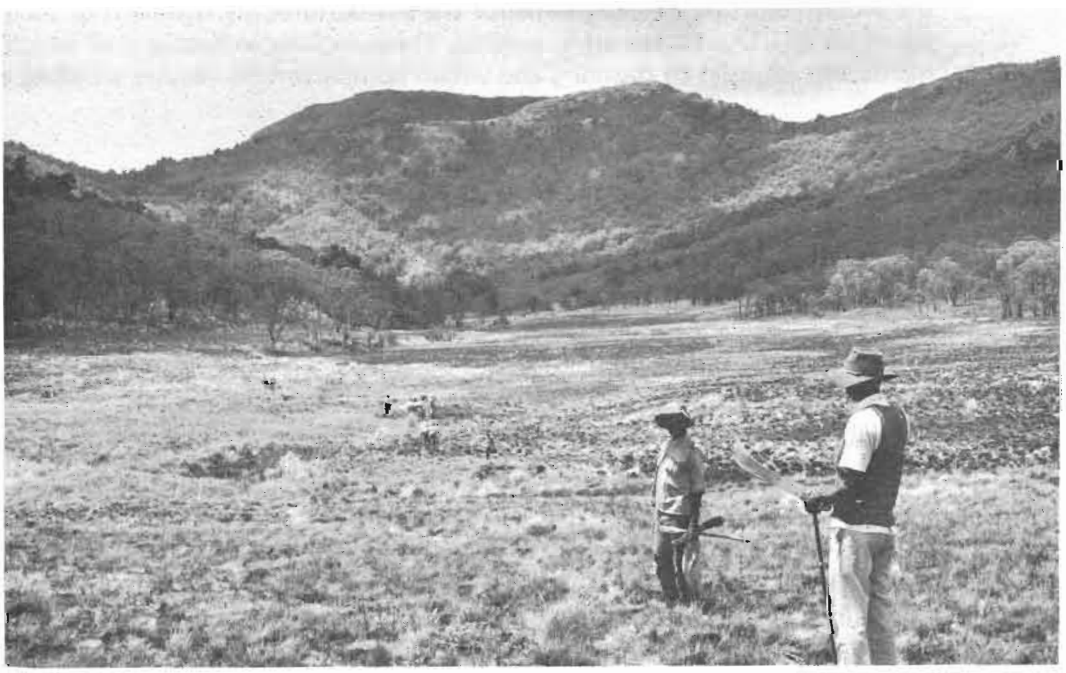


PLATE 8 View in the Kipia Uplands, with the peat deposits of Landform Unit J marked by *Exotheca* grassland in the foreground and *Carex* sedge swamp grassland in the middle and extending down the valley

TABLE 18 Species, age classes and areas of the plantation

Species	Age class years	Compartment number	Area, ha	
			Fully stocked	Partially stocked
Cupressus	25+	2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 15, 28, 29, 73*, 75, 76	162.8	2.9
	15-24	18, 20, 21, 24, 34, 36*, 39, 41, 52, 53, 56, 58, 66, 69, 70, 71	106.7	7.2
	5-14	23*, 35, 47	28.8	8.9
	0-4	27, 43, 44, 45, 78	40.5	
	All ages		338.8	19.0
Cupressus and *Pinus* spp.	25+	10 (*P. radiata*)	3.1	–
	15-24	49 (*P. kesiya*), 55* (*P. patula*)	3.2	3.7
	5-14		–	–
	0-4		–	–
	All ages		6.3	3.7
Pinus radiata	25+	30	7.7	–
	15-24	31*, 32*, 40, 59, 63, 64, 74	13.1	20.3
	5-14		–	–
	0-4		–	–
	All ages		20.8	20.3
Pinus patula	25+	77	0.5	–
	15-24	22, 25*, 33*, 51, 54, 57, 67, 72	26.2	11.2
	5-14	26, 42, 65, 68*	5.2	6.0
	0-4		–	–
	All ages		31.9	17.2
Pinus kesiya	25+		–	–
	15-24	60	7.2	–
	5-14		–	–
	0-4		–	–
	All ages		7.2	0.0
Mixed *Pinus* spp.	25+		–	–
	15-24	50	4.2	–
	5-14	61, 62	2.0	–
	0-4		–	–
	All ages		6.2	0.0
Other spp.	25+		–	–
	15-24	46 (*Eucalyptus*), 48 (*Podocarpus*)	3.7	–
	5-14	37 (*Acacia*), 38 (coppiced *Eucalyptus*)	4.0	–
	0-4		–	–
	All ages		7.7	0.0
All species	25+		174.1	2.9
	15-24		164.3	42.4
	5-14		40.0	14.9
	0-4		40.5	0.0
	All ages		418.9	60.2

* Partially stocked compartments

N.B. Compartment 1 (unstocked) and the narrow breaks of *Eucalyptus* between compartments are not included in this table.

PLANTATION VOLUME AND GROWTH MEASUREMENTS

The standing volumes of the different species are given by age and size classes in Table 19. *Cupressus* has a total volume of 108 091 m^3 or 85% of the total volume in the plantations. The compartments that are over 25 years old contain a standing volume of 69 489 m^3, 59 134 m^3 of which has a mean diameter of between 25 and 34 cm dbh.

TABLE 19 **Total volumes in the compartments by age class and size class**

Species	Age class years	Diameter class cm	Compartment	Total RME vol* m3	Total vol. age class m3	Total vol. species m3
Cupressus	25+	20-24	28, 73	6 351		
		25-29	8, 9, 11, 12, 15, 76	31 799		
		30-24	4, 5, 6, 7, 29, 75	27 335		
		35-39	2 (part)	3 010		
		40-44	3	994	69 489	
	15-24	5-9	41	130		
		10-14	56	925		
		15-19	20, 36, 39, 52, 66, 69, 70	15 128		
		20-24	18, 21, 24, 34, 53, 58, 71	18 315	34 498	
	5-14	15-19	35	4 104	4 104	108 091
Pinus radiata	25+	30-34	30	1 540	1 540	
	15-24	10-14	32	329		
		15-19	31, 40, 63, 64	3 694		
		20-24	59, 74	1 314	5 337	6 877
Pinus patula	25+	15-19	77	216	216	
	15-24	15-19	22, 54, 68	2 947		
		20-24	57, 67, 72	2 480		
		25-29	33, 51	1 242	6 669	6 885
Pinus kesiya	15-24	20-24	60	1 238	1 238	1 238
Cupressus and pine mixture	25+	20-24	10	648	648	
	15-24	20-24	49	925		
		25-29	55	322	1 247	1 895
Pine mixtures	15-24	20-24	50	777	777	777
Podocarpus	25+	15-19	2 (part)	127		
		20-24	2 (part)	163	290	
	15-24	5-9	48	8	8	298
*Eucalyptus***	15-24	40-44	46	943	943	943
Juniperus †	25+	not sampled	2 (part)	100†	100	100
Total all species	25+	undifferentiated		100		
		15-19		343		
		20-24		7 162		
		25-29		31 799		
		30-34		28 875		
		35-39		3 010		
		40-44		994	72 283	
	15-24	5-9		138		
		10-14		1 254		
		15-19		21 769		
		20-24		25 049		
		25-29		1 564		
		30-34		0		
		35-39		0		
		40-44		943	50 717	
	5-14	15-19		4 104	4 104	127 104

* For those compartments where RME volume/ha could not be calculated, mean volume/ha values have been used

† Estimate only

** Volumes of *Eucalyptus* breaks between compartments not included

The pines have a standing volume of nearly 18 000 m^3 of which 6 877 m^3 is *P. radiata* and 6 885 m^3 is *P. patula.* Records of the dates of planting of the pines are unreliable but it is likely that most of the compartments are between 15 and 24 years old. The *P. radiata* is either overmature and windblown or the compartments are understocked through lack of weeding. All will have to be clear felled as a first or second priority. The *P. patula,* on the other hand, is more resistant to windblow than the *Cupressus.* The volume is evenly distributed between the size classes. It is from the *Pinus patula* compartments that useful increment can be realised in the intermediate period after the overmature and unstable *Cupressus* has been felled, and before the young plantations mature.

Details of the growth performance of the species can be found in Table 20 which gives the ages, area, mean diameter, top height, basal area, volume and stocking for all compartments.

TABLE 20 Species, age, area, mean diameter, top height, basal area, mean volume and stocking of the compartments

Compartment	Age years	Area ha	Mean dbh cm	Mean top height m	Mean basal area m^2/ha	Error %	Mean volume m^3/ha	Stocking stems/ha
Cupressus lusitanica								
2	33	5.3	35.7	29	66.4	16	673	608
3	32	2.0	41.7	32	57.8	16	589	410
4	29	9.9	32.2	32	52.4	10	537	616
5	28	21.2	33.5	28	62.8	14	638	590
6	28	4.1	34.4	30	56.8	13	580	616
7	27	4.5	30.5	30	49.5	15	508	640
8	27	21.2	25.8	28	68.7	15	727	1 180
9	27	6.0	27.2	26	36.7	15	385	675
11	26	11.0	29.2	29	48.3	16	498	728
12	26	11.8	27.0	24	43.0	17	442	716
15	25	22.3	29.7	26	35.2	15	376	424
18	22	10.4	23.3	23	42.9	11	445	930
20	16	7.2	19.3	22	34.5	12	363	947
21	19	6.0	24.0	19	39.3	14	409	880
24	15	8.6	20.4	17	17.8	32	201	700
28	25	18.4	23.2	24	36.2	18	380	904
29	25	12.8	30.0	28	34.1	17	360	620
34	15-20	6.0	20.4	19	35.3	10	371	1 053
35	12-15	17.1	19.0	16	26.9	15	286	859
36	15-20	7.2	19.1	–	4.6	–	47	178
39	16	11.1	18.0	20	36.7	16	385	1 031
41	16	0.6	9.5	–	46.4	–	216	6 100
52	15	5.3	19.5	20	40.6	15	436	1 253
53	20-25	1.3	23.1	27	46.7	15	504	1 093
56	15	3.2	13.3	19	31.1	12	331	1 684
58	20	24.0	22.5	24	35.5	17	384	883
66	15	12.9	17.3	24	42.1	14	429	1 617
69	20	1.2	18.7	23	38.5	18	402	1 067
70	15-20	6.9	19.9	22	29.3	15	313	855
71	15-20	2.0	20.4	23	42.7	17	443	930
73	25	2.9	24.5	25	28.4	28	304	400
75	26	9.0	30.8	25	38.7	15	404	410
76	28	1.7	28.8	31	58.0	13	592	734
Pinus radiata								
30	26	7.7	31.3	30	29.1	35	311	369
31	15	11.4	–	–	–	–	–	–
32	15	8.9	–	–	–	–	–	–
40	20-25	0.2	15.9	27	31.1	–	300	1 425
59	20	6.0	22.7	25	21.9	19	215	530
63	20	4.7	15.1	26	30.0	15	320	1 427
64	15-20	0.9	15.7	22	13.8	–	158	800
74	20-25	1.3	21.3	24	23.0	13	251	480
Pinus patula								
22	16	12.9	17.8	19	36.0	11	287	1 400
25	16	6.9	–	–	–	–	–	–
26	10	2.1	–	–	–	–	–	–
33	15	4.3	27.2	20	19.5	–	141	300
51	20-25	3.6	25.1	27	38.8	14	434	792
54	12-15	0.5	17.5	19	32.3	11	210	1 220
57	20	4.4	22.0	26	35.1	13	292	774
67	20	4.3	22.1	26	29.9	19	323	654
68	12	6.0	17.0	15	1.8	–	11	80
72	15-20	0.5	19.6	23	20.4	32	181	520
77	26	0.5	19.4	30	31.2	20	432	933
Pinus kesiya								
60	15	7.2	19.7	20	31.2	14	282	1 050
Cupressus and pine mixtures								
10	27	3.1	23.7	27	22.2	14	244	427
49	15	3.2	21.2	20	39.0	15	350	974
55	22	3.7	28.4	26	9.0	–	87	117

TABLE 20 (Continued)

Compartment	Age years	Area ha	Mean dbh cm	Mean top height m	Mean basal area m^2/ha	Error %	Mean volume m^3/ha	Stocking stems/ha
Pine mixtures								
50	22	4.2	22.4	25	31.8	27	392	772
61	7	1.7	–	–	–	–	–	–
Podocarpus spp.								
2 (part)	33	0.8	15.5	18	24.5	–	159	1 220
2 (part)	33	0.4	21.7	25	65.4	–	408	1 575
48	22	0.8	9.4	9	9.5	–	10	1 334
Eucalyptus saligna								
38	–	1.5	–	–	–	–	–	–
46	15	2.9	45.5	40	22.3	–	325	133
Other species								
* 2 (part)	33	0.4	–	–	–	–	(250)	–
+ 37	21	2.5	–	–	–	–	–	–

* Juniper, not sampled, volume is an estimate only
\+ Wattle (*Acacia molissima*)

The oldest compartments of *Cupressus* are now 27 to 33 years old. These have mean diameters of from 25 to 42 cm, top heights of 28-32 m and mean volumes of 500-730 m^3/ha. The compartments of known age lie in the middle of the Quality Class II site index curve for *Cupressus* grown in Kenya (Dyson, 1962). The mean annual increment based on the 12 oldest *Cupressus* compartments is 19.3 m^3/ha/year. It is the severe underthinning that has led to windblow, for instance in Compartments 28 and 58.

In Appendix 2, details are given of the results of a stem analysis of *Cupressus*. The study was based on one single mature tree only and therefore extrapolation of the growth figures to complete stands is not possible. However the study did indicate that maximum current annual increment (0.052 m^3/year) was approached at around 15 years and that maximum mean annual increment was realised at about 27-28 years at a value of 0.037 m^3/year.

The growth and performance of *P. radiata* cannot be judged from the results obtained in the compartments given in Table 20. Due to lack of weeding in the early years and lack of thinning, the stocking of the compartments is often low. The diameter and height increment rival that of *Cupressus* and this species should not be discounted because of the results presented here.

The *P. patula* has grown very well, particularly on stony shallow soils (Plate 9) unsuited to *Cupressus*. The mean annual increment varies from 13 to 19 m^3/ha/year with a mean of 15 m^3/ha/year based on seven compartments. Although this figure is only an estimate, because the ages of the compartments are not known with certainty, it gives an idea of the species capability.

P. kesiya has not been widely planted but Compartment 60, the largest single block of this species, has been growing well with a mean annual increment of almost 19 m^3/ha/year at age 15 years.

The *Eucalyptus saligna* fire and wind breaks are characterised by massive, vigorous trees and Compartment 46 is equally impressive. Diameter and height after 15 years (estimated) are 45 cm and 40 m respectively. Mean volume per hectare was roughly estimated to be 325 m^3, stocking being 133 stems/ha. Diameter increment in the early years was high because the trees were planted wide apart (7 x 7 m). Normally with closer spacing (necessitated by high weeding costs) the initial increment would not have been so great.

PLATE 9 Very shallow soil of the Sahue Series supporting *Pinus patula*

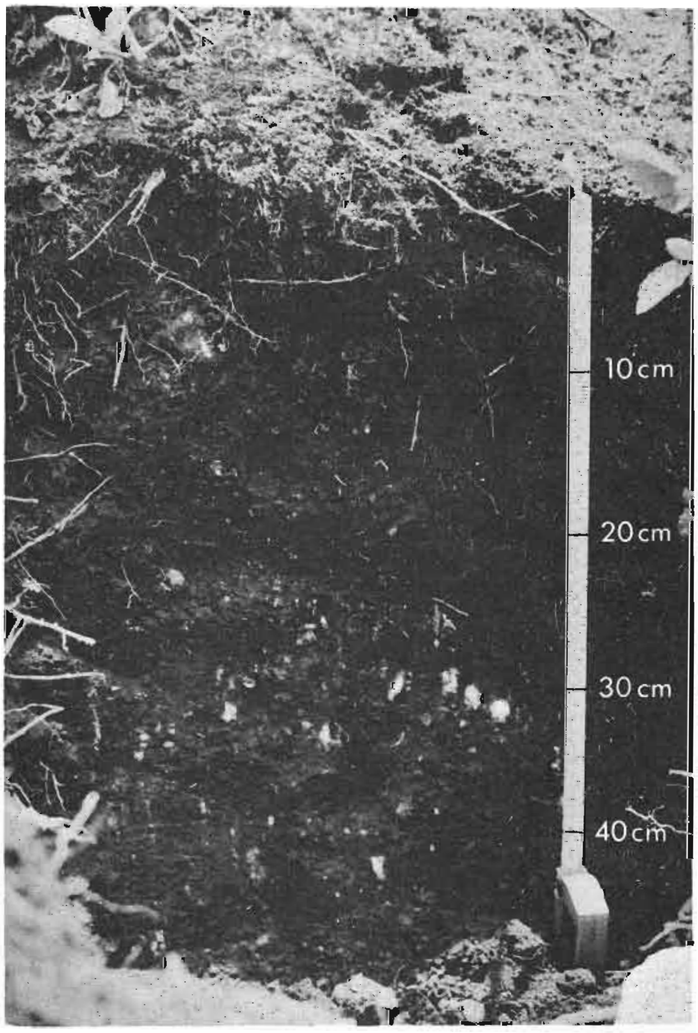


PLATE 10
Sahue Series; note the rock rubble at base

PRESCRIPTIONS FOR THE SILVICULTURAL MANAGEMENT OF THE PLANTATIONS

Silvicultural management of the present plantations involves three operations, namely:

1. Compartments to be clear felled either as soon as possible (priority 1) or within a few years (priority 2)

2. Compartments to be retained, thinned and pruned as required (again priorities 1 and 2)

3. Young compartments still requiring weeding, clearing and possibly partial replanting.

In the case of the latter two operations only those immediately required can be detailed, e.g. the extent of the next thinning operation. It would be impractical to itemise the entire management programme for each compartment, but it is recommended that those compartments being retained are thinned according to the schedule given in Appendix 4.

Clear felling

The preponderance of compartments at or approaching maturity, together with the presence of unstable or inadequately stocked semi-mature stands, has led to the conclusion that over half of the total plantation area should be clear felled. Of this area 97.5 ha is considered to be priority 1 for felling. These compartments are regarded as potentially unstable having already extensive areas of windblow and should be felled as soon as possible, preferably within the first 3 years of the commencement of the project.

The remaining 177.4 ha is regarded as priority 2, comprising compartments regarded as relatively stable, which can be left until the priority 1 areas have been dealt with.

Tables 21 and 22 detail the compartments to be clear felled under priority 1 and priority 2 respectively. Reliable minimum estimates (at 97.5% confidence level) of the volumes on a per hectare and a total compartment basis are given.

TABLE 21 Priority 1 compartments to be cleared for replanting

Compartment	Age years	Species	Area ha	Present RME vol. m^3/ha†	Present total RME vol. m^3	Remarks
12 (part)	26	*Cupressus*	5.1	359	1 831	Priority 1 for eastern section, which is overgrown, and has scattered windblow. Priority 2 for western section around Observation Hill. Latter section should be felled as unit with Comp. 8
15	24	*Cupressus*	22.3	315	7 025	Patchy windblow throughout compartment
28	25	*Cupressus*	18.4	310	5 704	Priority 1 for most of compartment especially for section close to Itibol where there is extensive windblow
29	25	*Cupressus* and a little *Pinus radiata*	12.8	298	3 814	Patchy, windblown crop
30	(26)*	Mainly *Pinus radiata* and *P patula*	7.7	200	1 540	Open, windblown crop
36	(15-20)	Mainly *Cupressus* also *P. patula*	7.2	(47)	(338)	Patchy crop, areas of extensive windblow
58	(20)	*Cupressus*	24.0	322	7 728	There has been extensive windblow in this compartment. Regarded as too liable to further windblow if thinned. Replant with pines

* Ages in brackets are estimates
† Volumes in brackets are based on mean values and not the RME volume

TABLE 22 Priority 2 compartments to be cleared for replanting

Compartment	Age years	Species	Area ha	Present RME vol. m³/ha†	Present total RME vol. m³ †	Remarks
1	–	–	3.4	–	–	Compartment already clear felled
2	33	*Podocarpus gracilior* *Podocarpus milanjianus* *Juniperus procera* *Cupressus*	0.4 0.8 0.4 5.3	(408) (159) (250) 568	(163) (127) (100) 3 010	Crop stable, no windblow. Overstocked but further thinning not worthwhile
3	32	*Cupressus*	2.0	497	994	Standing at an acceptable final stocking
5	28	*Cupressus*	21.2	550	11 660	Volume figures do not include *E. saligna* windbreaks
6	28	*Cupressus* and *P. radiata*	4.1	502	2 058	Overstocked, but further thinning not worthwhile
7	27	*Cupressus*	4.5	430	1 935	Excellent compartment, slightly over-stocked but further thinning not worthwhile
8	27	*Cupressus*	21.2	617	13 080	Variable stocking and quality; further thinning not worthwhile
9	27	*Cupressus*	6.0	328	1 968	Patchy compartment
10	27	*P. radiata* and *Cupressus*	3.1	209	648	Some windblow. Limited access
11	26	*Cupressus*	11.0	420	4 620	NW section has fairly extensive windblow; the greater part of compartment is stable
12 (part)	26	*Cupressus*	6.7	359	2 405	Western section around Observation Hill is priority 2; to be felled as a unit with Comp. 8. See priority 1 table (Table 21)
23	<10	Mainly *Cupressus*	8.9	nil	nil	Failed compartment; area should be cleared and replanted with pine
25	(16)*	*P. patula*	6.9	nil	nil	Failed compartment; area should be cleared and replanted
31	(15)	Mainly *P. radiata*	11.4	(195)	(2 223)	Completely neglected compartments, overgrown by indigenous trees
32	(15)	Mainly *P. radiata*	8.9	(37)	(329)	
33	(15)	Mainly *P. patula*	4.3	(141)	(606)	
40	(20-25)	*P. radiata*	0.2	(300)	(60)	
46	(15)	*E. saligna*	2.9	(325)	(943)	
50	22	*Pinus* spp. *Podocarpus* *Cupressus*	4.2	185	777	
55	22	*P. patula* *Cupressus*	3.7	(87)	(322)	Patchy area of very low stocking
57	(20)	*P. patula*	4.4	(292)	(1 285)	
59B	(20)	*P. radiata*	3.7	172	637	59A, adjacent to 54 and 56 to be thinned and maintained
63	(20)	*P. radiata*	4.7	270	1 269	
68	(12)	*P. patula*	6.0	(11)	(66)	Very poorly stocked compartment (80 stem/ha)
69	(20)	*Cupressus*	1.2	331	397	Unthinned compartment, partially windblown, clear fell with Comp. 68
72	(15-20)	*P. patula*	0.5	(181)	(90)	
73	(25)	*Cupressus*	2.9	223	647	
74	(20-25)	*P. radiata*	1.3	217	282	
75	26	*Cupressus*	9.0	344	3 096	
76	28	*Cupressus*	1.7	512	870	
77	26	*P. patula*	0.5	(432)	(216)	

* Ages in brackets are estimates
† Volumes in brackets are based on mean values and not the RME volume

The volumes in brackets are means for those areas insufficiently sampled for a RME value to be quoted. The figures relate to levels at time of sampling and allowance for growth will have to be made at time of felling.

Table 26 summarises the total volume figures from which it can be seen that 27 980 m^3 can be expected from priority 1 areas and a further 56 883 m^3 from priority 2 compartments. Of the grand total of 84 863 m^3 86% is composed of *Cupressus*.

Thinning and pruning

Almost without exception it can be stated that the plantations are at present over-stocked and underpruned, and all the semi-mature compartments being retained will require thinning as soon as possible. As in the case of compartments designated for clear felling, priorities 1 and 2 are recognised for thinning and pruning.

The past neglect and overstocking has resulted in a general instability of the plantations particularly with the shallow-rooted *Cupressus*. Future thinning, especially the first thinning, will have to be light – a 25% removal being the maximum that can be recommended in the potentially unstable compartments.

Tables 23 and 24 detail the thinning and pruning programme and indicate the estimated volumes to be obtained from the thinnings and the standing volumes of the main crop following thinning. These figures are all based on 1976 volumes. With the single exception of Compartment 41 it is assumed that all thinnings will be selective. The thinning volume figures include a 15% reduction which was made to allow for the inevitable higher proportion of small sized timber removed during a selective thinning. No allowances were made for possible losses or damage during skidding. The volume of timber removed in thinning was calculated by

$$\frac{\text{RME in m}^3\text{/ha x area in ha x stems removed}}{\text{Original number of stems}} \times 0.85$$

Compartment 4, although fully mature, has been included within those compartments to be thinned since it is recommended that it be retained as a temporary seed stand. It will require heavy thinning to encourage maximum fruiting on the selected seed bearers.

Weeding, cleaning and beating up

Table 25 gives details of those areas requiring weeding or cleaning. Possible beating up may be required in the most recently planted areas and it is suggested that a survival count is made.

There has been only limited planting within recent years, there being some 37.1 ha only of plantations of age 3 years or less. The quality of weeding within those areas is generally poor and it is likely that the highly variable stocking seen in many of the plantations of age 10-20 years could be attributed to early losses as a result of poor weeding and failure to beat up.

Spot weeding for the first three seasons should be generally sufficient for future *Cupressus* and pine plantings.

All operations

Table 26 gives a summary of areas for which silvicultural operations have been prescribed and summarises the volumes of timber which would be produced thereby (see also Map 2).

TABLE 23 **Compartments to be thinned and maintained, priority 1**

Comp.	Age years	Species	Area ha	Thinning prescription stems/ha	RME of vol. of thinnings m^3†	RME of main crop vol after thinning m^3†	Pruning prescription	Remarks
4	29	*Cupressus*	9.9	616 to 200	571	4 201	No pruning required	Recommended that this compartment be retained as a seed stand for as long as required
18	22	*Cupressus* and *Pinus patula*	10.4	930 to 700	861	3 237	Further pruning of limited value	Severe slope, careful thinning necessary to avoid heavy windblow
20	(16-20)*	*Cupressus*	7.2	947 to 700	601	1 703	Nil. Further pruning of limited value	Some windblow in this compartment, careful opening of canopy required
21	(20)	*Cupressus*	6.0	880 to 650	469	1 643	Prune to 2.2 m prior to thinning	25% canopy opening, a moderately exposed site
22	(16)	*P. patula*	12.9	1 400 to 1 050	831	1 994	Prune to 2.2 m prior to first thinning	25% opening. Highly exposed site. High pruning of doubtful value for such a poor site
24	(15)	*Cupressus*	8.6	700 to 500	297	924	Prune to 2.2 m prior to thinning, but following cleaning	Dense regrowth of indigenous species. Compartment requires cleaning prior to thinning
34	(15-20)	*Cupressus*	6.0	1 050 to 750	453	1 413	Prune to 2.2 m prior to thinning	High pruning of limited value at this age
35	(12-15)	*Cupressus*	17.1	860 to 650	852	3 252	Prune to 2.2 m prior to first thinning. Prune better 300 stem/ha to 6 m or half height after thinning	Slope of up to 18°, light thinning only recommended at this stage
39	(16)	*Cupressus*	11.1	1 030 to 750	826	2 748	Prune to 2.2 m prior to thinning	A good compartment, but high pruning of limited value at this stage
41	(16)	*Cupressus*	0.6	6 000 to 1 500 line thinning removing alternate lines	(83)	(47)	Prune to 2.2 m following thinning	Close planted (1 x 1 m) trial area. To be line thinned and brought into Compartment 39 as soon as possible
51	(20-25)	*P. patula*	3.6	790 to 500	388	854	Further pruning of no value	
52	(15)	*Cupressus*	5.3	1 253 to 900	459	1 460	Prune to 2.2 m prior to thinning	Slope around 16°, thinning directly to 750 stems/ha might create windblow
53	(20-25)	*Cupressus*	1.3	1 093 to 750	148	408	nil	
54 + 65	(12-15)	*P. patula*	3.1	1 220 to 750	18	38	Prune to 2.2 m prior to thinning. Prune better 300 stems/ha to 6 m after thinning	Compartments 54 and 65 regarded as belonging to the same statum
56	(15)	*Cupressus*	3.2	1 684 to 1 250	203	722	Prune to 2.2 m prior to thinning. Prune better 300 stems/ha to 6 m after thinning	Slope 20°, careful opening of the crop will be essential
60	(15)	*P. kesiya*	7.2	1 050 to 750	301	940	Prune to 2.2 m prior to thinning. Prune better 300 stems/ha to 6 m after thinning.	

* Ages in brackets are estimates
† Volumes in brackets are derived from the mean values and not the RME.

TABLE 23 (Continued)

Comp.	Age years	Species	Area ha	Thinning prescription stems/ha	RME of vol. of thinnings m^3	RME of main crop vol. after thinning m^3	Pruning prescription	Remarks
66	(15)	*Cupressus*	12.9	1 617 to 1 250	918	3 842	Prune better 300 stems/ha to 6 m following first thinning	Windblow extensive along W edge. Gradual opening essential
70	(15-20)	*Cupressus*	6.9	855 to 700	283	1 552	nil	To be thinned along with Compartment 71
71	(15-20)	*Cupressus*	2.0	930 to 700	154	580	nil	Gradual opening essential to prevent windblow

TABLE 24 Compartments to be thinned and maintained, priority 2

Comp.	Age years	Species	Area ha	Thinning prescription stems/ha	RME of vol. of thinnings m^3 †	RME of main crop vol. after thinning m^3 †	Pruning prescription	Remarks
26	10	*Cupressus*	2.1	Thin to 750	not sampled	not sampled	Prune to 2.2 m	
45	10	*Cupressus*	1.3	Thin to 750	not sampled	not sampled	Half compartment has been pruned to 2.2 m, prune remainder prior to thinning. High prune better 300 stem/ ha to ½ height after thinning	
48	22	*Podocarpus*	0.8	1 334 to 750	(3)	(5)		Compartment of limited value, could be clear felled with Comp. 28
49	(15)*	*Cupressus* and *P. kesiya*	3.2	974 to 750	180	745		
59A	(20)	*P. radiata*	2.3	530 to 300	381	651		This section of Compartment 59 to be thinned and retained until Compartments 54 and 56 are regarded as stable after thinning
61	(7)	*Pinus* spp.	1.7	–	not sampled	not sampled	Prune to 2.2 m	
62	(12)	*P. caribaea*	0.3	Thin to 750	not sampled	not sampled	Prune to 2.2 m prior to thinning	
64	(15-20)	*P. radiata*	0.9	800 to 500	(45)	(97)	nil	A poor area, but to be maintained to avoid extending windblow within Comp. 66
67	(20)	*P. Patula*	4.3	654 to 300	508	597	nil	To be retained until Comp. 66 is regarded as stable following thinning

* Ages in brackets are estimates
† Volumes in brackets are derived from the mean values and not the RME

TABLE 25 Areas requiring weeding, cleaning or beating up

Compartment	Age years	Species	Area ha	Treatment required
24	(15)*	*Cupressus*	8.6	Heavy regrowth of indigenous species within this area. Compartment to be cleaned prior to first thinning and pruning
27	3	*Cupressus*	21.1	One further weeding and a check to be made for possible beating up
42	8	*P. patula*	0.5	Cleaning required
43	3	*Cupressus*	2.6	One further weeding and a check to be made for possible beating up
44	5	*Cupressus*	2.1	Cleaning required
47	8	*Cupressus and Acacla*	11.7	Extensive cleaning required
78	1-3	*Cupressus*	13.4	One or two further weedings required plus need for possible beating up

* estimate

TABLE 26 Summary of prescriptions

Operation	Species	Area ha	RME total vol. removed (1976 levels), m^3
Clear felling, priority 1	Mainly *Cupressus*	89.8	26 440
	Other species	7.7	1 540
	Total	97.5	27 980
Clear felling, priority 2	Mainly *Cupressus*	105.7	46 740
	Other species	71.7	10 143
	Total	177.4	56 883
Thinning, priority 1	Mainly *Cupressus*	108.5	7 178
	Other species	26.8	1 538
	Total	135.3	8 716
Thinning, priority 2	Mainly *Cupressus*	6.6	180*
	Other species	10.3	937*
	Total	16.9	1 117
Pruning	Mainly *Cupressus*	74.2	–
	Other species	25.2	–
	Total	99.4	–
Weeding, cleaning, beating up	Mainly *Cupressus*	59.5	–
	Other species	0.5	--
	Total	60.0	–

* Slight underestimate, since volume figures not available for some small young areas

CHOICE OF SPECIES

As already indicated, the bulk of the early planting consisted of *Cupressus lusitanica,* and this was followed by a period of planting both *C. lusitanica* and *Pinus* spp.

The very limited records available refer mainly to *Cupressus lusitanica* Miller but also *C. lindleyi* Klotsch. To a much lesser extent reference is made to *C. benthamii* Endl. and *C. macrocarpa* Hartw. *C. lindleyi* and *C. benthamii* are now generally recognised to be varieties of the single species *C. lusitanica* though some botanists still prefer to give them specific status. No *C. macrocarpa* was definitely identified during the inventory and if planted at all must have been restricted to small research plots. Although in a few instances possible varietal differences did seem evident within the *Cupressus* compartments these differences were of no practical value and the entire *Cupressus* plantings were simply regarded as *C. lusitanica (sensu lato).*

In the oldest *Cupressus* compartments there is a considerable variation in stem quality, from 60 cm trees of excellent form, to equally large trees with severe defects such as persistent branches at ground level (e.g. Compartment 76), drought crack and buttress formation.

In the middle aged compartments (age 15-24 years) there is a contrast between areas where the lack of management has resulted in failure and areas where the plantations have grown well in spite of neglect. In some *Cupressus* stands there is severe windblow whilst in other more sheltered compartments, there are many stems over 30 cm dbh in 20 year old stands that are still at their original 2 x 1 m spacing (e.g. Compartment 71).

C. lusitanica is suited to the area and its continued use in future plantings is recommended. It is a species with a shallow rooting habit which makes it liable to windthrow when planted on steep or exposed sites, and it is strongly suggested that this species be reserved for the more moderate slopes and less exposed areas. *Pinus patula,* on the other hand, has shown itself to be very windfirm even when growing on shallow soils near ridge tops, and it should be used for replanting those sites where windthrow of *Cupressus* has been a problem.. At present seed is collected locally and there is no apparent selection of seed from elite trees. In order to improve the phenotype of future plantations, it is recommended that selected *C. lusitanica* seed from Kenyan seed orchards* be purchased. However such seed is expensive and usually only obtainable in small quantities. It would therefore be desirable to set aside an area as a seed stand. Compartment 4, following heavy thinning, would be an obvious choice, augmented if necessary with selected seed trees from Compartments 3 and 6.

Taking account of the past neglect the *Cupressus* appeared to be generally healthy except for some stem crack.

In East Africa some damage is caused by cypress canker, *Rhynchosphaeria cupressi* Natrass, Booth and Sutton, though *C. lusitanica* is more resistant than other *Cupressus* species. The principal pest of *C. lusitanica* in East Africa is the cerambycid *Oemida gahani* Distant. which appears to be associated with conditions similar to those around Gilo (Browne, 1968). No evidence of the presence of this insect was noted during field work; however since damage is restricted to the heartwood it is not until milling that the larvae tunnels are revealed.

Oemida gains access into healthy *Cupressus* by pruning and extraction scars. To minimise the amount of scar tissue, silvicultural practice in Kenya concentrates on very early pruning of the crop.

Pinus patula Schlechtend. and Cham. has grown well and would be recommended for further planting. As mentioned previously it has demonstrated its ability to grow on exposed and steep sites without windthrow and would be particularly suited to such areas. Again improved seed should be obtained from outside; Malawi** as well as Kenya could be approached. Seed trees should be selected from within those *P. patula* compartments being retained – especially Compartments 41 and 67 – in case outside supplies of seed prove to be insufficient.

Two of the other pines planted in the past, namely *P. radiata* D. Don. and *P. kesiya* Royle ex Gordon, have grown satisfactorily and could be considered as secondary species if in the future, diversification from *Cupressus* and *P. patula* is thought to be desirable. Red band needle cast, *Dothistroma pini* Hulbary, might be a problem with *P. radiata* during wetter years (Dyson, 1962 b; Browne, 1968).

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Eucalypts have generally been successful, particularly the *E. saligna* Sm. fire and wind breaks and Compartment 46 close to Itibol sawmill. Consideration should certainly be given to a eucalypt working circle, possibly partly managed under the coppice system, to provide construction and transmission poles together with medium grade saw timber. *E. saligna* and the virtually identical *E. grandis* Hill ex Maiden. would be obvious choices but there are many others that could be considered e.g. *E. cloeziana* F. Muell. and *E. deglupta* Bl.

Part 4

Site selection

LANDFORM UNITS

The general pattern of landform has been described in Part 2. In this more detailed study of landform a total of 14 units have been recognised. Their more important characteristics are given in Table 27, and their distribution is shown on Maps 3a-b. Figure 3 illustrates their main features.

TABLE 27 The main characteristics of the landform units

Unit	Feature	Parent material	Relief m	Slope range		Drainage type
				Slope °	Extent %	
A	Escarpments	Leucocratic and augen gneiss	>150	>30	>50	Parallel
B	Hills			6-20 >30 21-30	>50 10-50 <10	Rectangular
C				>30 21-30	>50 <10	Trellis
D				6-20 21-30 >30	>50 10-50 <10	Complex
E			30-150	21-30 6-20 >30	>50 10-50 <10	Rectangular
F				6-20 21-30	>50 10-50	
G	Valleys			6-20 21-30 >30	>50 <10 <10	Dendritic
H				6-20 21-30	>50 <10	
I	Hills	Quartz-rich leucocratic gneiss		21-30 6-20	>50 <10	Rectangular
J		Colluvium and Peat		6-20 1- 5 <1	>50 10-50 <10	Trellis
K	Valleys	Colluvium		>30 21-30 6-20	>50 <10 <10	Parallel
L				6-20 21-30	>50 10-50	Dendritic
M			< 30	6-20 21-30 1- 5	>50 <10 <10	
N	Plains			1- 5 6-20 <1	>50 <10 <10	Rectangular

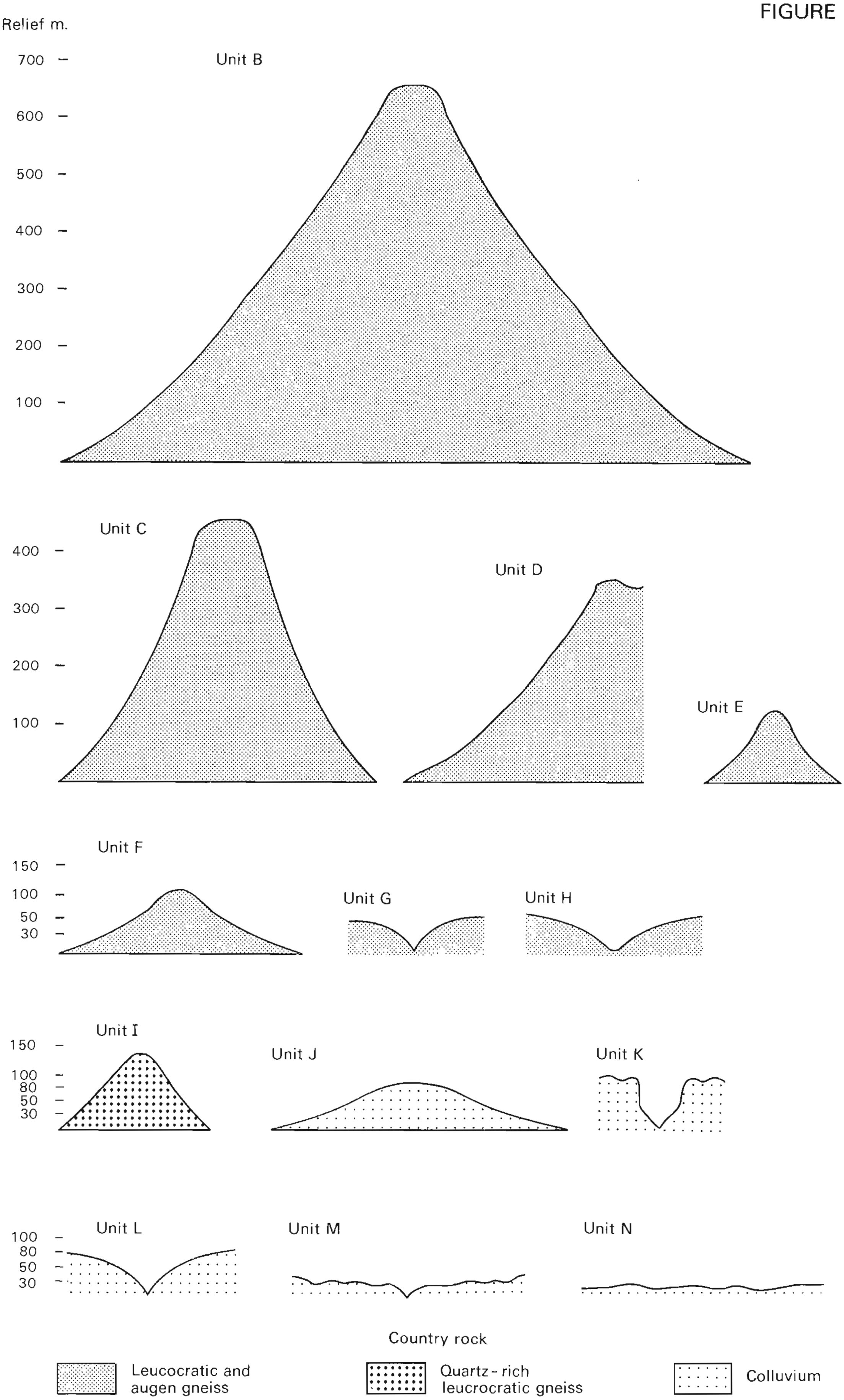


FIGURE 3 Landform unit profiles

LAD/SUD/RNJ/BC

Prepared by Land Resources Division 1976

Unit A

The escarpments are probably the most spectacular features of the landscape, being particularly prominent in the north-east, where the forest reserve is bounded for about 40 km by a precipitous scarp rising sheer to heights varying from 1 000 m to 1 500 m above the adjoining plain. Similar, but less extensive areas flank the Imatong Mountains near Katire and also mark the abrupt boundary of the Acholi Mountains near Lotti and Palwar. The escarpments are formed by cliffs, interspersed by deep clefts which mark the courses of streams falling onto the adjoining plains. The less precipitous slopes are commonly formed by bouldery colluvial detritus.

Unit B

This comprises the main mountain and hill areas of the Acholi Mountains, the Kipia and Lomwaga Uplands and parts of the Upper Kinyeti and Ateppi Basins and, as such, is by far the most extensive unit. The landscape is characterised by long moderate (6-20^{o}) to strong (21-30^{o}) slopes; the western flank of Mount Kinyeti (Plate 18), for example, rises in excess of 1 000 m over a distance of 4 to 5 km. A typical toposequence would include a rocky domed summit area flanked by steep ($>$ 30^{o}), sometimes precipitous with cliffs, usually relatively short boulder-strewn upper slopes. These merge fairly abruptly with less steep (generally in the 21-30^{o} range) but longer middle slopes. The middle slopes are also bouldery, but the rubble content gradually diminishes with gradient as they merge into the long, but still locally rubbly, moderate (6-20^{o}) footslopes. The rivers and streams draining these mountains and hills follow a distinct rectangular pattern, generally following the NW-SE and NE-SW faulting.

Unit C

Although of limited extent and recognised only in the Imatong Mountains, this landform occupies particularly prominent features in the area, marking the conspicuous peaks of Garia and Konoro. Garia is outstanding rising bare and precipitously, its southern face vertically from its strongly sloping, rubbly, footslopes.

Unit D

This unit comprises a number of conspicuous scarp features in the Upper Kinyeti and Ateppi Basins and, in particular forms the periphery of the 2 400 m platform found in the former. The scarp slopes, although rarely steep, are long and can be of high local relief. The western flank of Bushbuck Ridge, for example, rises unbroken almost 500 m over a distance of about 2.5 km. Two distinct zones can be recognised; an undulating rock-free summit area marking the platform surface, and a moderately to strongly sloping flanking slope. The junction of the two zones is usually marked by a discontinuous lip of bare rock which marks the scarp edge. The upper slopes are long, strongly sloping (21-30^{o}) and frequently bouldery, while the middle and lower slopes are usually boulder-free and more gentle. This general pattern, however, is sometimes disrupted by local stream incision resulting in the drainage courses on middle and lower slopes being marked by strongly sloping boulder-strewn sides. These streams flowing down the scarp slopes run on roughly parallel courses, but in their catchments on the platform surface their alignment appears to be controlled by regional fault trends, giving rise to an overall and distinctive trellis drainage pattern.

Unit E

Of limited extent and restricted to the Imatong Mountains and the eastern edge of the Lomwaga Uplands, this landform is characterised by rock-capped hills of moderate relief. Slopes of between 21 and 30^{o} are dominant, typically occupying the upper and middle slopes and generally associated with boulders and stones, while the footslopes are gentler, ranging between 6 and 20^{o} and usually boulder and stone-free. A distinctive feature of this landform is the short, sharp and steep rocky slope which marks the junction of the upper slope and summit zones.

Unit F

This landform occurs as well rounded hills of generally moderate relief and, again, marked by rocky summit areas. Steep slopes are absent and, apart from some localised areas immediately below the limit of the rock outcrops where slopes can be in the 21-30° range, slopes are generally moderate (6-20°). The rock rubble content tends to decrease with slope, but boulders and stones may sometimes be encountered even on the lower footslopes. This unit is of very limited extent, being only recognised in the Gilo area and in the Acholi Mountains near Palwar.

Unit G

Relatively broad valley tracts on the 2 400 m platform in the Upper Kinyeti Basin and on the 1 300 m platform along the Teba River in the Ateppi Basin mark this unit. It consists of a series of rounded interfluves marked by a dendritic drainage pattern, and with a local relief rarely in excess of 50 m. Rock outcrops are generally absent, and a typical toposequence would consist of a gently sloping crest of relatively small extent, flanked by moderate (6-20°) slopes. The stream courses are generally incised and, accordingly, marked by steeper slopes, i.e. in the 21-30° range.

Unit H

Except for the strongly (21-30°) sloping lower slopes this unit is similar to Unit G. It appears, however, to be far more extensive, occurring throughout the Ateppi Basin and many parts of the Acholi Mountains.

Unit I

Shearing, generally at a low angle, of quartzite in the Kipia Uplands has resulted in conspicuous long broken ridges of moderate relief, generally in the 100-150 m range, the disorderly alignment of which gives rise to the complex stream pattern of that region. Slopes are uniformly strongly sloping (21-30°) and frequently planar. Quartzite, being very resistant to denudation, outcrops frequently in summit areas, and rock material is usually present close to the land surface.

Unit J

Even though highly resistant to denudation, the faulting and uplifting of the quartz-rich leucocratic gneiss in the Kipia Uplands has resulted in a number of localised basins marked by colluvial infilling of highly siliceous materials. These mark the most subdued relief of the Kipia Uplands, probably giving rise to the earlier, but misleading, term 'plateau' being used. This distinctive land unit consists of moderately sloping (6-20°) hills, normally capped by a loose quartz-conglomerate, which rise some 50 to 80 m from the adjoining valley tracts. The valley bottoms, even though conspicuous, being marked by well defined low marshy vegetation, are rarely wider than 250 m. They follow a distinctive trellis drainage pattern, and are filled with peat deposits which may be developed on slopes of up to 5° (Plate 8).

Unit K

The effect of trough faulting is well marked near Gilo, where the Ngairigi River follows a well defined fault zone, cutting through a thickness of over 80 m of boulder detritus which is exposed along the sides of a steep-sided valley. The steep, in parts precipitous, bouldery slopes are capped by a slightly dissected, undulating, somewhat bouldery, summit area. This probably represents an earlier land surface related to Unit M, which is described below.

Unit L

This is closely related to Unit K both in location and mode of formation. The trough faulting at the head of the Kinyeti Plain and consequent detrital infilling has resulted in the formation of the long, sometimes bouldery colluvial slope which marks the base of the valley below Itibol. This feature, although rising through an altitudinal range of about 500 m has an average gradient of around only 8° and, in general moderate slopes, i.e. in the 6-20° range predominate. The course of the Kinyeti River, however, is deeply incised, and marked by strong (21-30°) flanking slopes. Smaller, relics, of this unit occur adjoining the Ngairigi River near Gilo.

Unit M

This unit is restricted to the platforms which mark the colluvial deposits of the Ngairigi (Plate 11) and Ateppi Basins. The deposits are essentially fine textured and non-bouldery, and a number of streams have cut into these deposits in a typically dendritic pattern; in some cases exposing the gneiss, which is the country rock. The stream incisions are rarely more than 20 m deep and are usually marked by slopes of between 21 and 30°. The interfluve areas are characterised by their undulating nature, with gradients never in excess of 20°, and low relief, normally in the 20-30 m range.

Unit N

The zone of redeposited colluvial material marking the footslopes of the main mountain mass marks a well defined piedmont. Gradients are normally gentle (1-5° range) and long, but frequently incised by drainage channels.

SLOPE ANALYSIS

From the description of the landform units a general appraisal of the suitability of each of the units for forest plantation development was made and this is presented in the legend of Maps 3a-b. From the descriptions, however, it can be seen that most of the landform units, although having a recurring pattern of topography, outcropping rocks, etc., can vary from site to site, particularly in factors which are significant for plantation development and management. Thus taking Unit D, for example, its undulating boulder-free platform surface together with its moderately sloping, also non-bouldery, middle and lower slopes would be easier to develop than the strongly sloping and bouldery middle slopes; while no planting could be contemplated for the rocky summit areas.

With these factors in mind a slope analysis was undertaken for the part of the reserve which was to be topographically mapped at the scale of 1:50 000. The slope classes are given in Table 28.

TABLE 28 Slope classes

Slope class	Slope °
1 Steeply sloping	>30
2 Strongly sloping	21-30
3 Moderately sloping	6-20
4 Gently sloping	1- 5
5 Flat	<1

The slope of a site may represent a limitation to softwood plantation development. Class 1 represents a severe limitation, Class 2 a moderate limitation, while Classes 3 to 5 represent no limitations as far as development is concerned.

The slope classes are shown on Maps 3a-b as the arabic numeral immediately following the letter assigning the landform unit. Hence, for example, B2 indicates strongly sloping land of Unit B.

Areas of outcropping rock occurring within the boundary of the projected 1:50 000 scale topographic mapping area are also shown. This is depicted outside the soil survey area (see text below), by the lower case letter 'r' following the numeral for the slope class. For example, B1r indicates Landform Unit B, with steep rocky slopes. The prospects for developing such land for forest plantations would be nil.

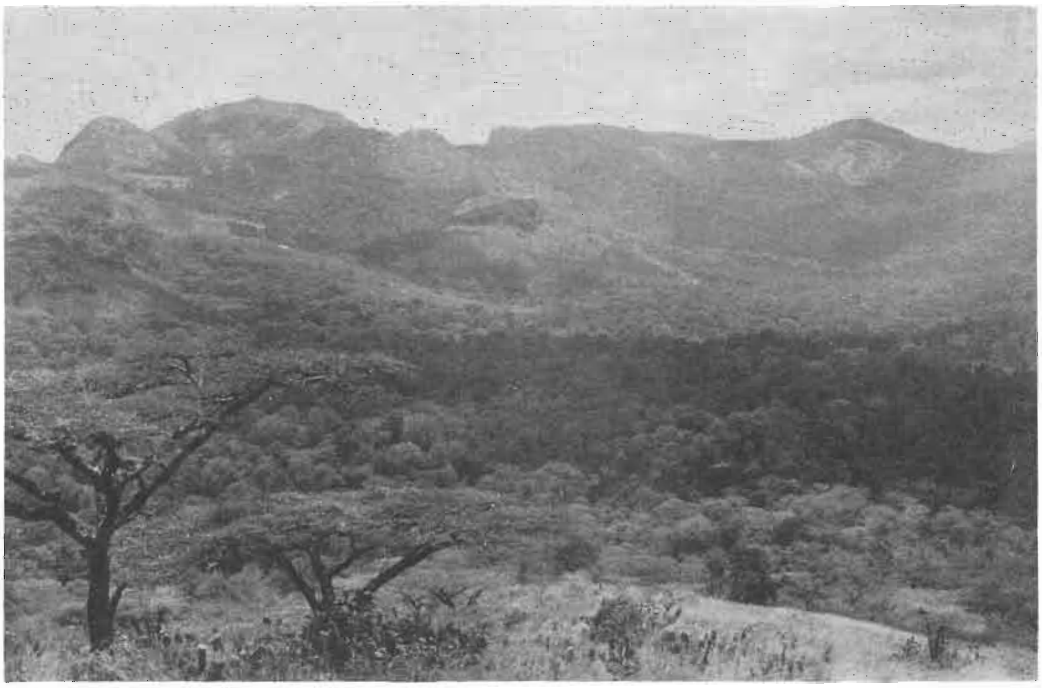


PLATE 11 Ngairigi Basin from the north with low rolling terrain marking Landform Unit M. *Loudetia* grassland in the fore-ground with occasional *Acacia abyssinica* trees

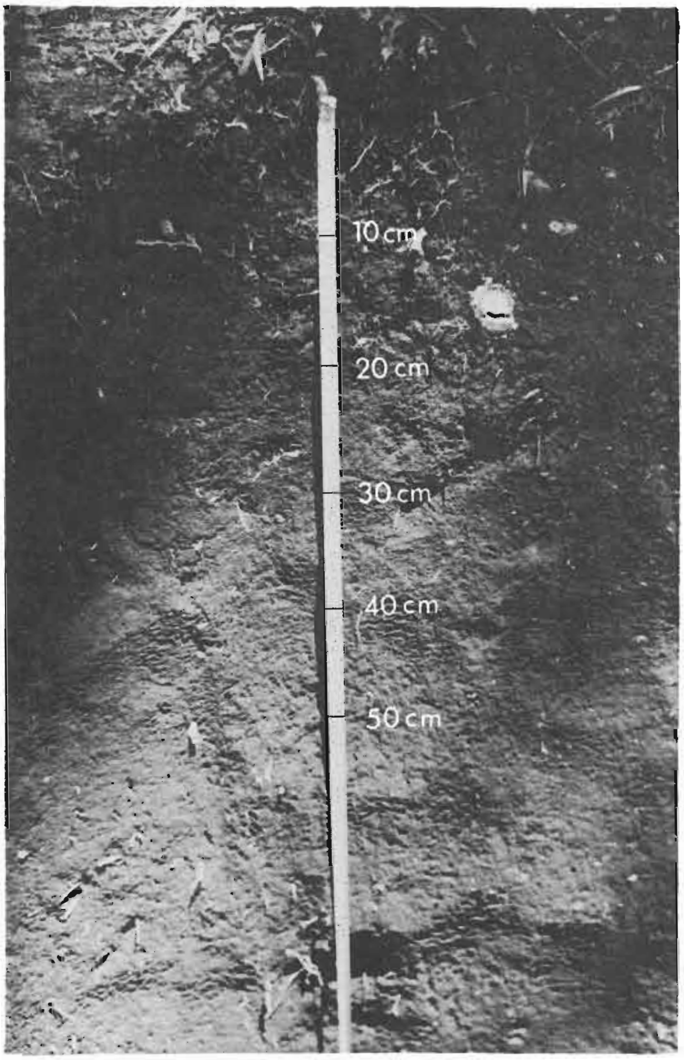


PLATE 12
Ngairigi Series, probably the most common soil; note its depth and homogeniety

SOILS

General

The general uniformity of the soils is recorded in Part 2. This uniformity can be directly attributed to three factors: first the occurrence of only a limited range of parent materials, secondly the high stability of the soils and, thirdly, animal activity.

Even though three main types of country rock have been recognised, i.e. leucocratic gneiss, augen gneiss and quartz-rich leucocratic gneiss, the leucocratic gneiss and the augen gneiss are mineralogically similar and their weathering products give rise to soils which are indistinguishable. Therefore, as far as pedogenesis is concerned, these two types of gneiss can be grouped as one.

The absence of landslide scars and other evidence of mass downward movement, which can be related to present times, is a notable feature of the general landscape, especially on the long mountain slopes. Except for a few locations, slopes appear to be stable. This can be directly attributed to the slope detritus being within its angle of rest and, also, to the homogeneity, porosity and friability of the soil mantle giving rise to a high level of resistance to erosion. Hence, with such a stable regolith, the processes which are responsible for soil formation vary little from site to site, thus contributing to the high degree of general uniformity found in the soils.

Another characteristic feature of the soils is the thick, dark coloured, humus-rich, very porous and friable upper horizons. They may extend to below 1 m, and can be directly attributed to the very high level of termite activity. As a result, the rate of turnover of the surface organic residues, mainly leaf litter, and its incorporation with mineral particles in the sub-surface horizons is high. This continuous soil-mixing largely occludes the influence of other soil differentiating processes, thus contributing to the general homogeneity of these soils.

Although having many features in common the soils, in addition to showing differences reflecting their derivation from on the one hand leucocratic and augen gneisses and on the other quartz-rich leucocratic gneiss, also exhibit other important differences. These can be related to physiographic factors, and attributed to the previous history of down-slope movement of colluvial material. Hence, a typical toposequence would show country rock exposed on summit sites flanked by boulder-strewn shallow soils on strongly sloping to steep upper slopes. The depth of soil increases down the slope while the boulder and stone content decreases. Hence the upper slopes tend to be characterised by shallow and bouldery soils, while the soils on the middle and lower slopes are usually deep and frequently non-bouldery.

Soil classification

With the identification of a number of similarities and differences in their properties, it has been possible to devise a soil classification, the highest categories of which are differentiated according to the units defined in the soil map of the world (FAO, 1974). These are further divided, according to parent material and other soil differentiae, into soil series. An outline of the soil units, parent materials and soil series is given in Table 29. The symbols used in Maps 3a-b to portray soil series are also given in this table.

TABLE 29 **The soil units, parent materials and soil series**

Soil unit	Parent material	Soil series	Symbol on Maps 3a-b
Dystric Histosols	Peat	Mulumas	–
Lithosols	Leucocratic and augen gneiss	Garia	–
Fluvisols	Alluvium	Sasai	–
Humic Cambisols	Quartz-rich leucocratic gneiss	Kinyeti	–
	Siliceous colluvium	Otolo	–
	Leucocratic and augen gneiss	Lohocho	a
		Dumusum	b
		Sahue	c
Humic Nitosols		Nabakin	d
		Gilo	e
		Lokotulu	f
		Ngairigi	g
		Itibol	h
		Konoro	i
		Oreira	j
Humic Acrisols	Siliceous colluvium	Kipia	–

The following gives an account of the main properties of the soil units and series. Reference is made to descriptions of representative soil profiles which are given in Appendix 7. The principal difference recognised between the series are those of texture, the presence or absence of coarse fragments and large differences in colour (United States Department of Agriculture Soil Conservation Service, 1970).

Dystric Histosols

These are soils consisting of peat, which is 40 cm or more thick. One series has been established: Mulumas Series.

Mulumas Series This is restricted to the Kipia Uplands, and its occurrence is an integral part of Landform Unit J. The swampy condition and water-logging of the valley bottoms, coupled with extremely acid groundwater draining from the quartz-rich catchment areas has resulted in the accumulation of the peat. The peat extends to below 1 m, and is derived mainly from non-woody material, generally grass and sedge vegetation and is therefore amorphous. The suitability of such a soil for forest plantation is low. Profile 1 is a typical member of the series. The very high organic matter content is shown by the figure for loss on ignition. Soil reaction is strongly acid. The cation exchange capacity (CEC) is very high due to the high organic matter content; the same applies for nitrogen and carbon. The exchangeable cations vary; with very high potassium, medium magnesium and low calcium. Available phosphorus is very high due to the organic matter content.

Lithosols

These are soils which are 'limited in depth by continuous coherent hard rock within 10 cm of the surface' (FAO, 1974). Again, only one series has been recognised: Garia Series.

Garia Series Profile 2 is typically representative of the series. It consists of a thin layer of closely admixed humus and mineral material overlying abruptly, without a weathering zone, fresh compact rock. A high organic matter content is shown by the figure for carbon, the same applies for nitrogen. The pH is within the acid range. A moderate level of exchangeable bases is indicated, with a high value for exchangeable potassium and medium values for magnesium and calcium. The CEC is high, partly reflecting the high organic matter content. Available phosphorus is unusually high. The data for the trace elements show nothing unusual. These soils occur adjacent to all rock exposures, and have been described as such on Landform Units A, B, C, D, E, F and I. Their shallow nature severely restricts root development and, accordingly, they are not suited for plantation development.

Fluvisols

Even though alluvial deposits of significant extent are rare, localised tracts may be found adjacent to the larger stream courses. These are, however, never extensive enough to be mapped at the scale of 1:50 000. Fluvisols are developed from such deposits. They are characterised by a lack of diagnostic horizons apart from some accumulation of humus in the surface horizon. One series is recognised: Sasai Series.

Sasai Series This occurs on low terraces which are subject to periodic flash-flooding and, therefore, receives fresh material at regular intervals. The soil consists of a relatively thin, dark surface horizon over a sandy, bouldery deposit, with evidence of a seasonal water table at depth. Even though these soils afford an adequate substratum for root development, their water retention capacity is low which might result in some drought stress for exotic tree species. The description of a representative soil is given under Profile 3. This is an acid to strongly acid soil, with a slight depression of pH in the second horizon, followed by a small increase below. The CEC is low; largely reflecting the low organic matter and clay contents. There is a slight accumulation of organic matter at the surface, which is marked by medium levels of nitrogen and exchangeable potassium, magnesium and calcium; otherwise low to very low levels occur. Available phosphorus follows an unusual distribution pattern; occurring at a medium level at the surface and increasing to very high levels below. The trace elements occur at normal levels, except for low manganese in the subsurface horizons.

Humic Cambisols

These are relatively young soils which lack evidence of soil development except for some structural aggregation. Evidence of clay movement is lacking and the sandy loamy textures which predominate, together with the presence of weatherable rock material, testify to their juvenile nature. These then are essentially shallow to moderately shallow soils with bedrock or boulders occurring within 150 cm of the surface. Humic Cambisols differ from other Cambisols by the presence of the well developed, dark, humus-rich horizons, which in the soils described during the survey, usually extend throughout the solum. Five series have been defined: Kinyeti, Otolo, Lohocho, Dumusum and Sahue Series.

Kinyeti Series These are essentially shallow soils overlying quartz-rich leucocratic gneiss within 50 cm of the surface. They have medium to coarse textures and occur in localised pockets, amongst bare rock exposures, on Landform Unit I. Soils of this series have also been located on Landform Unit B marking the localised occurrence of quartz-rich leucocratic gneiss. Profile 4 is a description of a typical profile. A high organic matter content is shown by the data for organic carbon and the very high levels of nitrogen. The CEC is very high due to the organic matter content. Available phosphorus in the surface horizon is very high, below which horizon it decreases to medium concentrations. The pH also decreases with depth, from acid to strongly acid down the profile; and a similar trend can be discerned for exchangeable potassium, magnesium and calcium which decrease from high to medium values. The shallow nature of these soils precludes their use for forest plantations.

Otolo Series The quartz-conglomerate beds of Landform Unit J described in the Kipia Uplands give rise to these distinctive soils. Profile 5 is a typical representative, the soil consisting of a dark, loamy, weakly structured horizon overlying at a shallow depth a layered colluvial deposit. By far the greatest proportion of the plant nutrients are retained in the thick surface horizon which has medium levels of organic carbon, exchangeable potassium, magnesium and calcium, and total nitrogen. Although available phosphorus decreases slowly with depth, medium concentrations are maintained throughout the profile. Soil reaction is strongly acid, except in the lowest horizon where it increases to pH 6.0. The CEC is low except in the surface horizon, where it is high. Although being derived from highly siliceous material the nutrient status of these soils appear adequate for forest plantation development, especially with pines.

Lohocho Series Profile 6 is a typical representative of this series. These are distinctively red (hues in the 10 R to 2.5 YR range), loamy soils, with dominant boulders of gneiss occurring at moderately shallow depths, i.e. between 50 and 150 cm. The surface horizon has an acid reaction but below this the pH decreases to very acid levels. The base saturation is high near the surface, with potassium, magnesium and calcium at high levels, and decreases to very low in sub-surface horizons; there is a corresponding increase in magnesium and calcium, but potassium remains at medium levels. The topsoil is well supplied with nitrogen. The CEC varies from high near the surface to medium in the subsoil. The data for the trace elements show nothing unusual. Their distribution is widespread, occurring on bouldery slopes described on Landform Units B, D, E, F, G and L. Although generally suited for forest plantation development, their bouldery nature may limit the growth of some species.

Dumusum Series Soils of this series have similar characteristics to those of the Lohocho Series described above. They differ, however, in having coarse textures, ranging from sand to sandy loam. A description of a typical representative is given under Profile 8. The organic matter content, although high to medium, does not reach the high levels suggested by the blackness of the soil. Both carbon and nitrogen are high in the surface horizon and decrease to medium in the lower horizon. The CEC varies, largely dependent on the organic matter content, decreasing with depth but remaining with medium levels. The exchangeable cations also decrease with depth, with high levels of potassium, magnesium and calcium in the top horizon, but with magnesium and calcium decreasing to very low and potassium to medium levels. Soil reaction in the surface horizon is acid and strongly acid below. Their occurrence is restricted to the bouldery sites described on Landform Units B, D, F, G and K. As for the Lohocho Series, their suitability for exotic softwoods would be moderate; but their low water retention capacity due to coarse texture might give rise to drought stress particularly in predominantly water-shedding sites on summits and upper slope areas.

Sahue Series This is the third soil series of the Humic Cambisols derived from leucocratic and augen gneiss. It differs mainly from the other two, Lohocho and Dumusum Series, however, in colour, which is predominantly reddish brown with a hue of 5 YR. Rock is usually encountered at shallow depths, i.e. around or above 50 cm (Plate 10). Descriptions of those typical profiles are given in Appendix 7. Profiles 9 and 11 occur under *Olea-Podocarpus* forest and Profile 10 in a *Pinus patula* stand. Both forest soils have a medium content of organic matter with nitrogen being high in the surface horizon. The reaction is strongly acid to acid and the levels of exchangeable cations appear to be adequate for most plant growth. This is also indicated by the data for available phosphorus. The CEC varies from very high to high with depth. A distinctive feature of Profile 10, which occurs in a plantation, is that many of the lowest values are recorded in the second horizon. This may be due to the increase in nutrient mobility induced by the pine vegetation. Most of the nutrients, however, appear to be stored in the surface horizon which has medium levels of exchangeable potassium, magnesium and calcium, nitrogen and organic carbon, and a very high level of available phosphorus. Below the surface horizon these decrease to low to very low levels, except for calcium and available phosphorus which, after the initial decrease in the second horizon, increase to medium to high levels respectively in the third horizon. Soils of this series have been mapped as occurring amongst the rock outcrops described on Landform Units B, D, E, F and G. Their shallow nature would limit prospects for development except for, perhaps, pines.

Humic Nitosols

These constitute the deep, friable, strongly coloured soils which are so conspicuous in the area. Most are coloured red (hues 10 R to 2.5 YR), others reddish brown (hue 5 YR). Brown coloured soils (hues 7.5 YR to 10 YR) are relatively rare. Textures vary from clay to loam, never coarser. Below the dark, humus-rich horizons, there is usually a slight increase in clay content, but this is rarely significant. There is some evidence of clay translocation, particularly at depth, but the continuous turnover of the soils material as the result of the termite activity tends to minimise its effect. Many of these soils appear to be associated with older and more stable geomorphic features and also an advanced stage of weathering in that some subsurface horizons contain only small amounts of water-dispersible clay, have low base saturation figures and some very low values when the CEC is calculated on the basis of clay rather than fine earth content.

These then are deep, friable, strongly coloured soils, with thick, dark, surface horizons having medium to fine textures and showing very little, usually less than 20%, increase in clay content with depth. Seven series, all derived from leucocratic or augen gneiss are recognised: Nabakin, Gilo, Lokotulu, Ngairigi, Itibol, Konoro and the Oreira Series. Some, however, are also formed on deep, colluvial infillings derived from this rock. These deposits differ little in physical properties from those overlying gneiss *in situ.* Hence some representatives, particularly of the Nabakin and Ngairigi Series, may occur in both locations.

Nabakin Series Soils of this series are distinguished from other Humic Nitosols by their fine textures, which may vary from clay loam to clay. These are essentially red soils, with a hue of either 10 R or 2.5 YR. Profile 12 describes a typical representative. The dark surface horizons extend to a depth of 70 cm. Textures are fine and there is little increase in clay content below the humus-rich zone, although the presence of cutans indicate some movement of clay in the profile. The high porosity and strong but very fine structural aggregation which extends to a depth of 102 cm marks the zone of termite activity. The soil is developed on a fine grained deposit, while Profile 13 overlies weathering rock material. This soil also has the characteristics described above, but the presence of feldspar at depth marks the uppermost zone of the weathering rock mantle. Profile 12 also illustrates the degree to which organic matter can be dispersed to depth; organic carbon remaining above 1 per cent throughout, and total nitrogen varying from high to medium levels down to a depth as great as 70 cm. The base saturation figures show that the soil is very strongly leached, and this is verified by the low figures given for the exchangeable bases and the medium figures for the CEC below the surface horizon. The surface horizon contains most of the nutrients, with high levels of exchangeable potassium, magnesium and calcium, and available phosphorus. The available phosphorus increases with depth. Soil reaction varies from acid in the surface horizon to strongly acid below. The figures for chromium, copper, manganese and zinc all fall within the normal range. The soils of this series have a widespread distribution and have been mapped on moderately sloping sites on Landform Units F, G, H, K, L and M. They are considered to be very suited for plantation development.

Gilo Series Soils of this series are distinguished morphologically from those of the Nabakin Series by their medium textures, which may vary from loam to sandy clay loam. A typical representative is described under Profile 15. The base saturation figures show that the soil is very strongly leached; very low figures being recorded for the subsoil. The medium to high figures for the topsoil reflect its importance for nutrient retention. This is associated with the high organic matter content and high levels of exchangeable bases in which the exchange complex is dominated by calcium, although high levels are recorded for potassium and magnesium. The topsoil also contains high to very high levels of nitrogen and medium to high levels of organic carbon. The CEC is very high due to the high organic matter content. Available phosphorus occurs at medium levels throughout. Soil reaction varies from acid in the topsoil to strongly acid below. They have been mapped on Landform Unit G with the Nabakin Series. They also occur on Landform Unit L. The prospects for forestry development on these soils are also good.

Lokotulu Series Colour is used to differentiate these from the Gilo Series. These are essentially reddish brown soils with a hue of 5 YR. A description is given under Profile 16. The laboratory data show that the soil has a high nutrient status, but with the main nutrients tied-up with organic matter in the surface epipedons. An exception is shown by the figures for available phosphorus which increases from medium amounts in the top 60 cm to a very high level below. This can probably be explained by phosphates being released by the weathering of alumino-silicate minerals. Soil reaction decreases slowly with depth, from acid in the surface horizon to strongly acid below 60 cm. They are of very limited extent and have been found on Landform Unit E but they cover too small an area to be mapped. These soils are also considered to be very suitable for plantation development.

Ngairigi Series (Plate 12) This is probably the most common soil in the area and seven profiles (Nos. 17 to 23) are described in Appendix 7. It frequently occurs in association with the Nabakin Series, which it closely resembles. It differs from that series by the presence of a medium textured topsoil, finer than a sandy loam and coarser than a clay loam. Clay content variation can be higher than that normally accepted for Nitosols (within 20% of maximum value), and this is illustrated by Profiles 19, 21, 22 and 23. Unusually low figures for CEC/100 gm clay are recorded in Profile 22. Profile 17 describes a typical representative which illustrates particularly well the influence that the surface organic matter has on nutrient retention; all the major nutrients in the top horizon are at medium to high levels but below decrease to low and to very low except for nitrogen and available phosphorus, the former occurring at a medium concentration in the second horizon and the latter increasing from high to very high at depth. The soil is very strongly leached and the reaction varies from acid at the surface to strongly acid below. The CEC appears to be largely dependent on the organic matter content, decreasing from high to very low with depth. Chromium, copper, manganese and zinc occur at normal levels. These soils have been mapped extensively on the moderate slopes described on Landform Units B, E, F, G, H, K, L and M. These rank amongst the best soils for forest plantations.

Itibol Series The presence of a reddish brown topsoil (hue 5 YR) as compared to a red (hues 10 R to 2.5 YR) to a depth of around 50 cm, distinguishes this series from the Ngairigi Series. A typical representative is Profile 24. The surface horizons have higher CEC, exchangeable cations, base saturation, available phosphorus, total nitrogen and organic carbon values than the subsurface horizons. The values vary from medium to high in the topsoil to low to very low in the subsoil with the exception of available phosphorus which remains unusually high. The nutrient status is clearly linked with the organic matter content. An acid reaction is recorded for the surface horizon and strongly acid below. The range of clay distribution is somewhat higher than normal for Nitosols. On comparing this profile with Profile 17 (Ngairigi Series) it can be seen that, apart from this difference in colour, the soils are very similar. They are also closely related in the field, occurring in association on the moderate slopes of Landform Unit G. The Itibol Series is mapped only on this landform unit but it also occurs locally on Landform Unit E. It also has a high potential for plantation development.

Konoro Series Again colour is used to distinguish this soil; it is similar to the Itibol Series except for the reddish brown colour which in this case extends throughout the profile. A typical profile is described under that of Profile 26. This shows atypically, for Nitosols, high range of clay distribution and low activity of the clay fraction (CEC/100 gm clay). Compared to other soils analysed during the survey pH values are unusually high, being near neutral in the surface horizon, but decreasing to acid in the subsoil. The values given for the exchangeable cations are unusual in that they are maintained at medium levels at depth from high to very high in the surface horizon. The total nitrogen content is high in the topsoil, but follows the usual trend to very low at depth. The available phosphorus content is medium throughout. The CEC is largely dependent on the organic matter content, being very high at the surface to very low below. A low degree of leaching is exemplified by the high base saturation figures. In all the data shows that this soil has an unusually high plant nutrient status. It has been mapped with the Lohocho Series on Landform Unit E but also occurs on Landform Unit D and sometimes on F. These soils are also highly recommended for development.

Oreira Series These are essentially brown soils with a hue of 7.5 YR or 10 YR. Variegated mottling in the subsoil, showing evidence of sesquioxide accumulation, also distinguishes these soils from the other Humic Nitosols. Otherwise, in profile morphology they are similar to the Ngairigi, Itibol and Konoro Series, with loamy topsoils and clayey subsoils. Differences in clay content can be somewhat higher than normal for Nitosols. Profile 28 is representative. The base saturation figures show that the soil is very strongly leached with very low figures being recorded in the subsoil. The high figure recorded for the surface horizon is an indication of the importance of the topsoil for nutrient retention. This is in itself associated with the medium to high organic matter content and the high levels of exchangeable bases in which the exchange complex is dominated by calcium, although high levels are recorded for magnesium and medium for potassium. The topsoil also contains medium to high levels of nitrogen and organic carbon. The CEC is very high and largely dependent on the organic matter content. Available phosphorus increases from medium values in the topsoil to high and to very high values below. Soil reaction is strongly acid throughout. Soils of the Oreira Series are of very restricted extent and have been mapped on some moderate slopes of Landform Unit G only in association with the Ngairigi Series. Again, these are highly recommended for development.

Humic Acrisols

These are soils which show a marked increase in texture with depth which can be directly attributed to the translocation of clay. Though present, the dark, humus-rich surface horizons rarely extend below 30 cm. They are developed on colluvial material derived from quartz-rich leucocratic gneiss and base saturation values can be expected to be well below 50%. One series, Kipia Series, has been recognised.

Kipia Series Soils of this series are of very limited extent, having been recognised only on the moderate slopes of Landform Unit J of the Kipia Uplands. A typical representative is described in Profile 30. Dark surface horizons extend to 30 cm overlying the mineral subsoil. This consists of loam but rapidly becomes heavier in texture with depth to a sandy clay. The presence of cutans testify to the movement of clay through the solum. The mobilisation and concentration of sesquioxides and manganese is shown by the variegated mottling and discrete nodules which occur in the subsoil. The data show that most of the plant nutrients are retained in the thin surface horizon in which available phosphorus is very high, exchangeable potassium, magnesium and calcium is high, and nitrogen and organic carbon are at medium levels. The CEC is also high. Below the surface horizon the levels of the nutrients decrease from low to very low with the exception of available phosphorus which increases to very high at depth. The reaction profile is irregular, varying from acid in the topsoil to strongly acid below, with a slight increase in pH at depth to bring the levels up to within the acid range. The data for trace elements show nothing unusual. Although the nutrient status of these soils is relatively low they can be recommended for plantation, although successful development might depend on a judicious choice of species adapted for such soil conditions.

LAND SUITABILITY AND THE IDENTIFICATION OF LAND FOR PLANTATION DEVELOPMENT

The boundary of the area which has been soil surveyed is shown on Maps 3a and 3b. The mapping units are based on various combinations of landform, slope class and soil series. The soil series are distinguished by lower case letters, the first of which designates the dominant soil, the subordinate soils, if they occur, occupying more than 20% of the area, are indicated by a second letter. The letter for associated soils, i.e. those covering less than 20% of the area, is enclosed by brackets. For example, L3dg(a) indicates Landform Unit L with moderate slopes; Nabakin Series dominant, Ngairigi Series subordinate and Lohocho Series associated.

TABLE 30 The soil mapping units, their limitations, suitability for plantation development and areas

Soil mapping unit	Limitations		Suitability class	Area ha
	Slope	Soil		
B1ra	Very serious	Very serious	3	166
B1rb	Very serious	Very serious	3	366
B3ag	Minor	Serious	2	405
B3rc	Minor	Very serious	3	16
D1rb	Very serious	Very serious	3	99
D2a	Serious	Serious	2	190
D2ra	Serious	Very serious	3	83
D3rb	Minor	Very serious	3	34
D3r(c)	Minor	Very serious	3	32
E1ra	Very serious	Very serious	3	186
E2a	Serious	Serious	2	12
E2ae	Serious	Serious	2	136
E2ai	Serious	Serious	2	45
E2r	Serious	Very serious	3	12
E2r(c)	Serious	Very serious	3	67
E3a	Minor	Serious	2	22
E3ag	Minor	Serious	2	97
E3ai	Minor	Serious	2	308
E3g	Minor	None	1	20
E3ga	Minor	Minor	1	115
E3rc	Minor	Very serious	3	28
F2rag	Serious	Very serious	3	46
F2ar	Serious	Serious	2	41
F3ad	Minor	Serious	2	281
F3gd	Minor	None	1	136
F3r	Minor	Very serious	3	28
F3rb	Minor	Very serious	3	12
G1a	Very serious	Serious	3	8
G1ra	Very serious	Very serious	3	73
G1rc	Very serious	Very serious	3	73
G2a	Serious	Serious	2	848
G2ae	Serious	Serious	2	6
G2ag	Serious	Serious	2	14
G2ah	Serious	Serious	2	320
G2ar	Serious	Serious	2	18
G2b	Serious	Serious	2	30
G2rb	Serious	Very serious	3	30
G2rc	Serious	Very serious	3	36
G2rd	Serious	Very serious	3	30
G3a	Minor	Serious	2	289
G3ad	Minor	Serious	2	61
G3ag	Minor	Serious	2	324
G3dg	Minor	None	1	2 469
G3gd	Minor	None	1	73
G3gh(a)	Minor	None	1	449
G3g(j)	Minor	None	1	160
G3r	Minor	Very serious	3	14
G3r(a)	Minor	Very serious	3	18
G3ra	Minor	Very serious	3	10
G3ra(d)	Minor	Very serious	3	265
G3rc	Minor	Very serious	3	16
H3dg	Minor	None	1	478
K1bg	Very serious	Serious	3	113
K1rd	Very serious	Very serious	3	24
K3gb	Minor	None	1	20
L2a(r)	Serious	Serious	2	287
L2ar	Serious	Serious	2	38
L2gd	Serious	None	2	43
L2gd(a)	Serious	None	2	26
L3dg(a)	Minor	None	1	1 004
L3gd	Minor	None	1	109
M3gd	Minor	None	1	884
M3r	Minor	Very serious	3	8
M4d	None	None	1	55

A comparison of growth rates of *Cupressus,* using top height, basal area and volume as parameters, with the soils data collected during the plantation inventory has not revealed any evidence of differences in growth between plots growing on the Sahue, Lohocho, Nabakin and Ngairigi Soil Series. Insufficient data was available to carry out similar comparisons involving *Pinus* spp. It is unlikely however that any difference would be found in the case of the pines if none was found with cypress. On the evidence available to date therefore there is no evidence to support the choice of any one of the above soil series rather than another for growing pines or cypress except that it would be prudent to avoid planting cypress on the shallower soils where, because of their shallower rooting habit, they would be likely to be more prone to windthrow.

The suitability of each of the soil series for softwoods has been noted, the limitation imposed by slope has been discussed and the general development potential of the landform units indicated. From this information it is possible to devise a system of classification, relating to suitability for softwoods, which can be used to identify the area suited to plantation development. Table 30 gives the soil mapping units which occur in the soil survey area, together with the nature and degree of limitation due to slope and soil factors which occur, and the suitability class in respect of forest plantation development.

The three suitability classes are defined as follows:

Class 1 No or only minor limitations for development; suited for a wide range of softwood species

Class 2 At least one serious limitation which does not preclude development. Success would depend upon the selection of species suited for bouldery soils, or a relatively high management input to overcome the effect of strong slopes, or both

Class 3 At least one very serious limitation, which precludes development.

Table 31 gives the extent of the three classes.

TABLE 31 Areas of suitability classes

Class	Area ha
1	5 972
2	3 841
3	1 893

Thus it can be seen that a total of 9 813 ha have been identified for development of softwood plantations. From Map 5 it can be seen that it occurs as a contiguous block of land covering most of the Ngairigi and Upper Kinyeti Basins, with a relatively small area extending into the catchment of the Ateppi River south of Itibol.

Part 5

Vegetation

INTRODUCTION

The Imatong Mountains are covered with forest, woodland and grassland that reflect differences in elevation, climate, soil conditions and past land use. Jackson (1956) defined five major zones of elevation and climate; four of these fall within the forest reserve boundary and have been used in this report:

1. Lowland Zone and the transition to Montane Zone between 1 000 and 1 800 m

2. The Lower Montane Zone 1 800-2 400 m

3. The Higher Montane Zone 2 400-2 900 m

4. The Ericaceous Zone above 2 900 m.

Although the fieldwork touched on all the zones, the forest inventory was concentrated in the Lower Montane Zone extending up to the edge of the Higher Montane Zone. Time did not permit botanical collecting in the Talanga forest situated in the Lowland Zone. The description of the vegetation communities outside the Lower Montane Zone rely heavily on the work of Jackson (1956). The relation between the landscape and the zones was illustrated in Figure 2 in Part 2.

The communities that have been mapped (Maps 4a and b) are listed together with the areas they cover in Table 32. The terms used in describing the structure of the vegetation follow those recommended by Pratt *et al.* (1966).

The areas given in Table 32 do not include 1 277 ha of cultivated land within the reserve and 1 143 ha of plantations including the *Cupressus* and pine plantations at Gilo and the *Cedrela* and teak plantations around Katire.

LOWLAND ZONE AND TRANSITION TO MONTANE ZONE, 1 000-1 800 m

Wooded grassland (Type 1a)

Outside the reserve the vegetation has been reduced by bush fallow cultivation to wooded grassland. Inside the reserve seral stages of the succession from wooded grassland through woodland to forest are found. Bush fires sweep up the scarp slopes accelerated by convection currents. The effect has been to reduce the vegetation on the escarpment to wooded grassland with occasional tongues of forest in valleys extending down from the summit. Wooded grassland is found on the plains on the southern boundary of the reserve covering large areas in the Ateppi Basin.

TABLE 32 Vegetation types in the Imatong Central Forest Reserve

Vegetation zone	Vegetation type	Map symbol	Area ha
Lowland Zone and transition	Wooded grassland	1a	15 057
	Albizia-Terminalia woodland	1b	8 774
	Khaya-Cola low forest	1c	5 263
	Khaya-Chlorophora high forest	1d	3 974
Lower Montane Zone	*Loudetia* grassland	2a	4 114
	Hagenia woodland	2b	1 469
	Vernonia shrub thicket	2c	8 806
	Croton-Macaranga-Albizia forest	2d	19 019
	Olea-Podocarpus closed forest	2e	4 387
	Podocarpus-Syzygium open forest	2f	12 359
	Oxytenanthera bamboo thicket	2g	1 459
Higher Montane Zone	*Exotheca* grassland	3a	656
	Carex sedge swamp grassland	3b	200
	Gnidia-Hypericum-Hagenia woodland	3c	1 862
	Olea-Podocarpus pole forest/thicket	3d	4 808
	Podocarpus-Domeya open forest	3e	8 399
Ericaceous Zone	*Erica* thicket	4a	154

In the wetter areas to the south and west of the mountain range the trees are economic farm trees that have been preserved in the farmland such as *Vitex doniana.* To the North-east where the climate is drier and the soil is heavy clay the dominant tree genus is *Acacia, A. seyal* in the north replaced by thorn scrub further south with trees like *A. raddiana, A. mellifera, Albizia sericocephala, Terminalia spinosa* and *Commiphora* spp.

The dominant grasses in the plains and on the sides of the escarpment are *Hyparrhenia cymbaria* and *Beckeropsis uniseta* with *Hyparrhenia dissoluta* on shallower soils and *Loudetia arundinacea* on very stony places. *Acacia abyssinica* is found from about 1 500 m to the top of the escarpment.

Albizia — Terminalia woodland (1b)

At the foot of the western and southern slopes of the mountains and in the Kinyeti Valley woodland occurs reaching a height of 15 m with a canopy closure of 50-100%. Common species are as follows (where f = frequent, c = common, o = occasional, r = rare, l = local, + recorded but no information as to abundance).

Larger trees, up to approximately 15 m in height

Albizia zygia (f)
Terminalia glaucescens (f)
Vitex doniana (f)
Lannea kerstingii (o)
Ficus glumosa var. *glaberrima* (l)
Acacia sieberiana (l)

Smaller trees, generally 2-5 m high

Combretum binderanum (c)
Stereospermum kunthianum (c)
Grewia mollis (c)
Acacia seyal var. *multijuga* (f, l, c)
Bridelia scleroneuroides (c)
Annona chrysophylla (f)
Dombeya quinqueseta (f)
Piliostigma thonningii (f)

Nauclea latifolia (f)
Hymenocardia acida (o)
Ziziphus abyssinica (+)
Lonchocarpus laxiflorus (o)
Vernonia amygdalina (o, l, f)
Maytenus senegalensis (o)

Shrubs

Securinega virosa (f)
Pseudomussaenda flava (o)
Acalypha ornata (o)

Common grasses

Panicum maximum
Hyparrhenia cymbaria
Beckeropsis uniseta

Khaya-Cola low forest (1c)

The first forest community in the succession from cleared farmland to forest is a dense thicket of climbers, forest grasses and forbs through which grow the pioneer forest species.

The lianes are: *Paullinia pinnata, Cardiospermum halicacabum, Culcasia scandens, Landolphia comorensis* var. *floride* and *Phyllanthus muellerianus.* The pioneer trees that grow through the climbers and forbs are:- *Khaya grandifoliola, Cola cordifolia, Bridelia ferruginea* var. *orientalis, Phyllanthus discoideus* and *Spathodea campanulata.*

The type occurs on the fringe of the Talanga forest and along section of the southern boundary of the Reserve.

Khaya-Chlorophora high forest (1d)

As Jackson (1956) has indicated the area in which closed forest still survives is small, (3 974 ha), though there are signs that it is, at present, increasing. Apart from gallery forests, the only forests of any appreciable extent remaining are at Talanga in the Kinyeti valley, and Lotti on the west side of the hills, and Laboni on the southern edge of the reserve. These three forests are, on the whole, very similar in floristic composition, as can be seen from Table 33 which lists the species recorded from the mature parts of the forests, excluding the forest edge and species confined to streams and swampy places. In the compilation of Table 33 the lists of Leuchars *et al.* (1954) for Lotti and Talanga have been used with additions.

Jackson (1956) has described the forest as follows:
'The four main storeys distinguished in these forests are:

Dominants (canopy trees) usually 30 to 50 m high, generally with straight, relatively slender stems, often without branches for 20 to 25 m, and frequently with buttresses. This layer is fairly continuous except where it has been disturbed by felling or windfall.

Second storey trees, from 15 to 30 m high, usually not so straight, more copiously branched, and with less tendency to form buttresses. This layer is not continuous as a rule.

A layer of *evergreen shrubs,* 4 to 6 m high, among which are a few small trees up to 8 or 10 m high. This layer is very dense and has numerous lianes and semi-scandent shrubs among it.

Ground layer, usually sparse, and often completely absent. It consists of grasses and herbs, together with a few low shrubs which rarely exceed 1 m in height.

The lists are not complete, and further collection will probably increase the number of species common to all three areas.'

TABLE 33 Tree species recorded from Talanga, Lotti and Laboni forests

	Talanga	Lotti	Laboni
Dominants 30-50 m			
Celtis zenkeri Engl.	c	c	c
C. soyauxii Engl.	f	o	—
Chrysophyllum albidum G. Don	c	c	c
Khaya grandifoliola C. DC.	c	c	f
Chlorophora excelsa (Welw.) Benth. and Hook f.	f	f	o
Chrysophyllum sp. nov. ?*	f	f	o
Cola cordifolia (Cav.) R. Br.	f	o	f
Mildbraediodendron excelsum Harms	f	f	r
Aningeria altissima (A. Chev.) Aubr. and Pellegr.	f	o	o
Antiaris toxicaria (Rumph. ex Pers.) Lesch.	f	o	o
Schrebera macrantha Gilg and Schellenb.	f	o	r
Majidea fosteri (Sprague) Radlk.	o	o	o
Cordia holstii Guerke	r	o	f
Erythrophleum guineense G. Don	f	r	r
Klainedoxa gabonensis Pierre	f	f	—
Bosquiea phoberos Baill.	f	+	—
Alstonia boonei De Wild.	o	o	—
Entandrophragma angolensis (Welw.) C. DC.	o	o	—
Parinari excelsa (Sabine) Hiern	o	o	—
Pycnanthus angolensis (Welw.) Exell	r	o	—
Canarium schweinfurthii Engl.	r	r	—
Ricinodendron heudelotii (Baill.) Peirre ex Pax	r	r	—
Ekebergia senegalensis Juss.	r	+	—
Ficus mucosa Welw. ex Ficalho	+	+	—
Casearia engleri Gilg	—	+	—
Fagaropsis angolensis (Engl.) Dale	—	+	—
Dialium bipindensis Harms	—	+	—
Mimusops bagshawei S. Moore	o	—	—
Mimusops sp.	—	+	—
Second storey trees 15-30 m			
Melanodiscus sp. nov.✝	c	c	f
Strombosia grandifolia Hook. f.	f	l,c	f
Aphania senegalensis (Juss.) Radlk.	f	+	c
Celtis brownii Rendle	f	o	o
Blighia unijugata Bak.	o	+	r
Funtumia elastica (Preuss) Stapf	r	+	l,c
Morus lactea (Sim.) Mildbr.	r	+	+
Tetrapleura tetraptera Taub.	r	l	+
Irvingia gabonensis Baill.	f	f	—
Myrianthus arboreus Beauv	o	f	—
Craibea utilis M B. Moss	o	f	—
Teclea nobilis Del.	f	o	—
Chrysophyllum natalense Sond	o	o	—
Premna angolensis Guerke	o	o	—
Bersama abyssinica Fres.	o	—	o
Teclea grandifolia Engl.	f	+	—
Lychnodiscus cerospermus Radlk.	f	+	—
Pachystela brevipes (Bak.) Engl.	f	+	—
Drypetes sp. ? *D. ugandensis* (Rendle) Hutch.	f	+	—
Albizia grandibracteata Taub.	o,l,f	+	—
Parkia filicoidea Welw.	r	o	—
Vitex sp✝✝	r	r	—
Fagara sp. ? *F. melanacantha* (Planch.) Engl.	r	r	—
Trichilia splendida A. Chev	r	+	—
Cassipourea ruwenzoriensis (Engl.) Alston	+	+	—
Ficus capensis Taub.	+	+	—
F. exasperata Vahl	o,l,f	—	—
Trichilia prieuriana A. Jus	o	—	—
Garcinia buchananii Bak.	o	—	—
Zanha golungensis Hiern	o	—	—
Gelonium procerum Prain	o	—	—

*Eggeling and Dale (1951), p. 394. ✝ Ibid., p. 381. ✝✝ Identified at Kew as *V. amboniensis* Guerke but appears to be distinct.

Note: c = common, f = frequent, o = occasional, r = rare, l = local, + = recorded, but no information as to abundance Source : Jackson, 1956

LOWER MONTANE ZONE, 1 800-2 400 m

Loudetia grassland (Type 2a)

Structure and characteristic species

A grassland consisting largely of the perennial tussock grass *Loudetia arundinacea* occurs on rocky hills (Plate 14). The grass grows to a height of 1-1.5 m. Occasional *Acacia abyssinica* trees occur and the shrub *Protea gaguedi* is found.

Ecology and distribution

The grassland occurs at the tops of hills where the soil is shallow (Plate 14); on slightly deeper soils a wide range of grasses are found including *Hyparrhenia cymbaria* and *Andropogon* sp. possibly *A. schirensis. Loudetia* grassland can be recognised on the aerial photographs by its very pale almost white tone. This grassland occurs along the north-east edge of the Imatong Mountains and in the Ateppi Basin. Throughout the Reserve small grass-covered hills occur: The total area of this type is 4 114 ha.

Hagenia woodland (2b)

Structure and characteristic specias

A woodland dominated by *Hagenia abyssinica* occurs at the forest edge (Plate 14) and over rocky hill tops. The light upper canopy forms at a height of 5-8 m with a grass layer beneath. *H. abyssinica* is usually dominant but may be replaced by *Nuxia congesta* and *Maesa lanceolata.* Other common shrubs are *Faurea speciosa, Gnidia glauca* and *Hypericum revolutum.*

Ecology and distribution

Hagenia woodland is an intermediate stage in the development of forest from grassland. *Podocarpus* and *Olea* are fire resistant to a certain extent and regenerate in the centre of thickets of shrubs. The woodland can be identified on aerial photographs by the grey tone (paler than forest) and slight texture caused by the *Hagenia* tree crowns. *Hagenia* woodland never covers large areas occuring often as a collar of woodland around grassy hill tops. It occurs more frequently in the Imatong Mountains and Upper Kinyeti Basin than in the Acholi Mountains and Ateppi Basin. The total area is 1 469 ha.

Vernonia shrub thicket (2c)

Structure and characteristic species

Vernonia shrub thicket is a dense tangle of shrubs, climbers and forbs that invade a farm after it has been abandoned (Plate 13). The description also includes natural clearings in the forest. The species composition of the community is shown in Table 34. Although no shrub is dominant the common shrubs are: *Vernonia ampla, Dombeya geotzenii, Croton macrostachys, Macaranga kilimandsharica and Nuxia congesta.*

Ecology and distribution

This is the first stage in colonisation of an abandoned farm reverting to forest. The *Croton, Macaranga* and *Dombeya* grow quickly smothering the grasses and forbs and leading into forest Type 2d,*Croton-Macaranga-Albizia* forest.*Vernonia* shrub thicket occurs around the existing softwood plantation at the edge of the forest near the escarpment in the north, in the Ateppi Basin and on the Acholi Mountains covering an area of 8 806 ha.

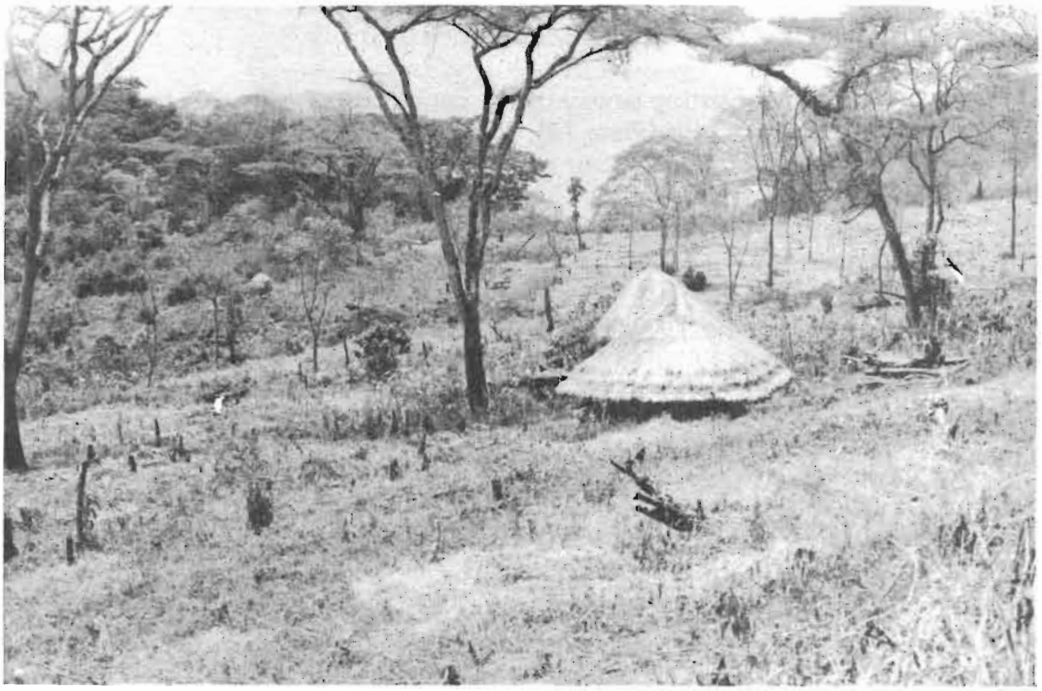


PLATE 13 Farmland in the foreground under *Acacia abyssinica* trees. In the middle of the picture on the left is *Vernonia* shrub thicket and beyond it is *Croton-Macaranga-Albizia* secondary forest

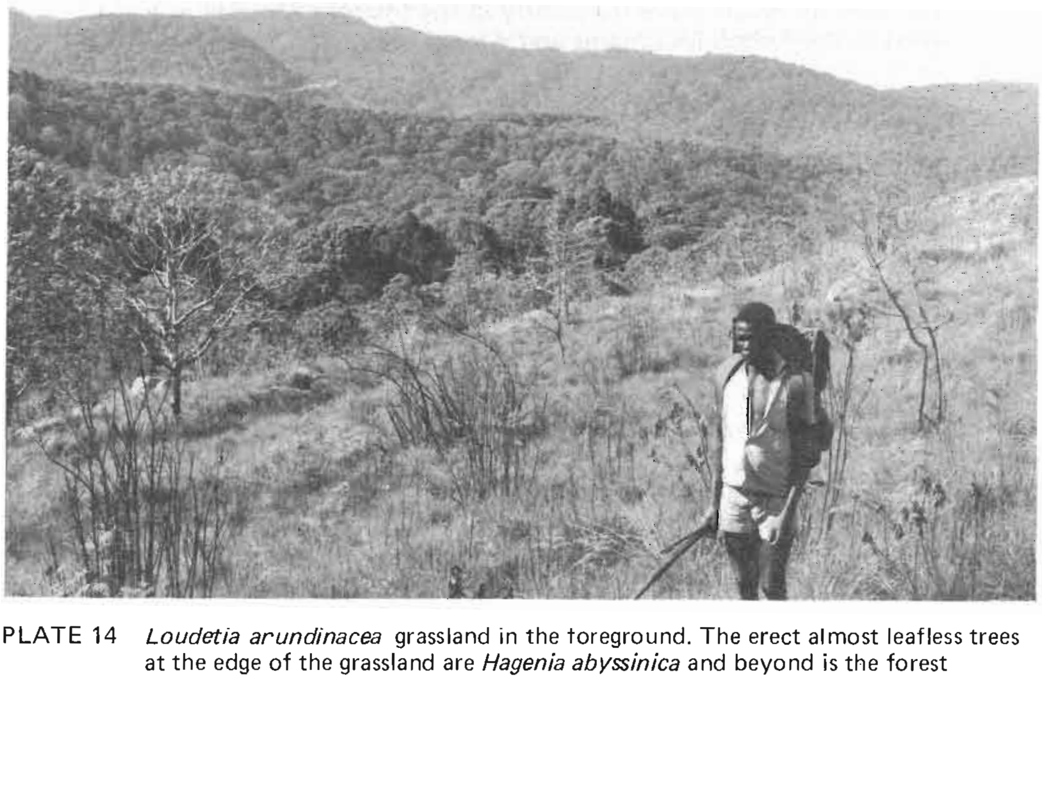


PLATE 14 *Loudetia arundinacea* grassland in the foreground. The erect almost leafless trees at the edge of the grassland are *Hagenia abyssinica* and beyond is the forest

TABLE 34 Species composition of the vegetation types in the Lower Montane Forest Zone

Species	*Loudetia* grassland	*Hagenia* woodland	*Vernonia* shrub thicket	*Croton-Macaranga-Albizia* forest	*Olea-Podocarpus* closed forest	*Podocarpus-Syzygium* open forest
Forest trees						
Podocarpus milanjianus Rendle		o (poles)		o	a	a
Olea hochstetteri Bak.		o (poles)		c	a	a
Syzygium guineense (Willd.) DC. subsp. *afromontanum* F. White				o	a	a
Pygeum africanum Hook. F (=*Prunus africana* Hook.f.) Kalkman				c	c	c
Ocotea kenyensis (Chiov.) Robyns & Wilcz.				o	o	o
Teclea nobilis Del.				+	o	o
Ochna holstii Engl.					o	o
Afrocrania volkensii (Harms) Hutch.						+
Ilex mitis (L.) Radlk.					o	
Ekebergia capensis Sparrm. (=*E. rueppelliana* (Fresen) A. Rich.)					+	
Apodytes dimideata E. mey. ex Benth.					+	
Bersama abyssinica Fresen.					+	c
Croton macrostachys Hochst. ex A. Rich.			c (shrub)	c	c	c
Macaranga kilimandsharica Pax			c (shrub)	c	o	o
Albizia gummifera (J. F. Gmel.) C.A.Sm.			o	o (a locally)		
Dombeya goetzenii K. Schum.		o	c (shrub)	+	o	o
Allophyllus abyssinicus (Hochst.) Radlk.				o		
Fagara macrophylla Engl.				o	o	+
Polyscias ferruginea (Hiern) Harms			o	o		
Celtis africana Lam. f.				o		
Trichilia volkensii Guerke					+	
Forest shrubs						
Galiniera coffeoides Del.		o		a	c	c
Grumilea sp.				a	c	
Ouratea densiflora de Wild. & Th. Dur.				o	o	
Maytenus undatus (Thunb.)Blakelock					c	a
Cassipourea malosana (Bak.) Alston					o	c
Acanthus eminens C.B.Cl.					a	c
Crateva adansonii DC.				o	o	
Discopodium penninervium Hochst.					c	+
Clausena anisata (Willd.) Hook. f. ex Benth.				o		
Piper guineense Schumach. & Thonn.				o		
Turraea holstii Gürke				o		
Vernonia ampla O. Hoffm.		o	a	o		
Woodland/grassland trees and shrubs						
Hagenia abyssinica J. F. Gmel.		a				
Acacia abyssinica Hochst. ex Benth. subsp. *calophylla* Brenan			c (shrub)			
Nuxia congesta R. Br. ex Fresen.	o	c	c			
Maesa lanceolata Forsk.	o	c	c			
Hypericum revolutum Vahl	o	c				
Faurea speciosa Welw.	o	c				
Gnidia glauca (Fresen.) Gilg.		c				
Halleria lucida L.		o				
Protea gaguedi J.F. Gmel	c					
Hymenodictyon floribundum (Hochst & Steud.) B. L. Robinson.	o					

Note: a = abundant, c = common, o = occasional, + = present

TABLE 34 (Continued)

Species	*Loudetia* grassland	*Hagenia* woodland	*Vernonia* shrub thicket	*Croton-Macaranga-Albizia* forest	*Olea-Podocarpus* closed forest	*Podocarpus-Syzygium* open forest
Grasses and forbs						
Oplismenus hirtellus (L.) Beauv.				c	c	
Pseudobromus sylvaticus K. Schum.				o	o	
Setaria chevalieri			c			
Melinis sp.			c	o		
Panicum sp. (IM 78)			c	o		
Triumfetta macrophylla K. Schum.			c			
Lobelia gibberoa Hemsl.		o	c			
Helictotrichum elongatum (A. Rich.) C. E. Hubbard		o				
Hypoestes forskalei (Vahl) Soland ex Roem. & Schultes		o			c	a
Isoglossa cf. *somaliensis* Lind.					c	a
Mimulopsis sp.					c	
Loudetia arundinacea (Hochst. ex A. Rich) Steud. var. *trichantha* C. E. Hubbard	a					
Hyparrhenia cymbaria (Linn.) Stanf		o	c			
Beckeropsis uniseta (Nees) K. Schum		c	c			
Pteridium aquilinum (L.) Kuhn	o	o	c			
Emilia sagittata DC.	o					
Tephrosia atroviolacea Bak f.		o				
Climbers						
Sericostachys scandens Gilg & Lopv			o	c	o	
Combretum paniculatum Vent. subsp. *paniculatum*				c	c	
Urena hypselodendron (Hochst. ex A. Rich.) Wedd.			o		c	
Todalia asiatica (L) Lam.						o
Cissampelos rigidifolia (Engl) Diels			o			
Periploca linearifolia Dill. and Rich.			o	o		
Lantana mearnsii Mold.		o	o			
Clerodendron johnstonii Oliv.			o			
Mucuna pruriens (L) DC.			o			
Rubus steudneri Schweinf.			o	o		

Note: a = abundant, c = common, o = occasional, + = present

Croton-Macaranga-Albizia forest (2d)

This forest type includes Jackson's (1956) *Albizia* woodland, but is essentially a forest and not a woodland (Plate 16).

Structure and characteristic species

The upper storey of trees reaches a height of 20-25 m. The canopy may be closed or open; when it is open the ground layer consists of a dense thicket of grasses, forbs, shrubs and climbers; when the canopy is closed the understorey is absent and the ground layer consists of a carpet of forest grasses: *Oplismenus hirtellus, Brachypodium flexum* and *Pseudobromus silvaticus.*

The characteristic species are *Croton macrostachys, Macaranga kilimandsharica* and *Albizia gummifera.* The *Macaranga* often grows in clumps, three or four shoots from one stool, providing a dense shade, whereas *Croton* invariably grows in the open. Details of the species composition are given in Table 34 and the volume density of the timber species is illustrated in Figure 5 in Part 6.

Ecology and distribution

Plate 13 shows the stages in the succession from farmland to *Croton-Macaranga-Albizia* (Type 2d). In the foreground is farmland, in the middle left is *Vernonia* thicket (Type 2c) and in the background Type 2d.

The species of the next seral stage *Olea, Podocarpus* and *Syzygium* occur as small trees in this community.

Forest Type 2d covers an area of 19 019 ha occuring in limited areas in the Ngairigi and Upper Kinyeti Basins and extensive areas in the Ateppi Basin, West and East Acholi Mountains.

Olea-Podocarpus closed forest (2e)

This forest type includes what Jackson (1956) refers to as 'forest climax with *Podocarpus, Olea* and *Syzygium'.*

Structure and characteristic species

The canopy is closed and the trees reach a height of 25-30 m. The ground layer may be a light grass cover or may be dense and 2 m high. The trees are straight-boled and stand close together with a shrub layer that is discontinuous or absent (see Plate 15).

The dominant species in the upper canopy are *Olea* spp., *Podocarpus milanjianus* and *Syzygium guineense.* Species that occur less frequently are *Pygeum africanum, Croton macrostachys, Teclea nobilis* and *Ocotea kenyensis.* Details of the species composition are given in Table 34 and the volume density of the timber species is illustrated in Figure 5 in Part 6.

In the understorey and shrub layer the common species are young *Olea, Podocarpus* and *Teclea* and shrubs that do not grow into the upper canopy such as *Grumilea* sp., *Galiniera coffeoides* and *Maytenus undatus.*

Ecology and distribution

In contrast to forest Type 2d the emergent trees in this type are typical climax trees with a high surface area of leaves produced by a many branched crown with steeply ascending branches and small leaves. Species with this kind of crown pattern are *Olea* spp., *Syzygium guineense* and *Pygeum africanum.*

The closed forest occurs on steep slopes, ridge tops and surrounds clearings in the forest. Where it occurs at the forest edge old *Hagenia abyssinica* and *Acacia abyssinica* can be found, indicating that this forest can be the next stage in the succession after woodland. *Olea-Podocarpus* closed forest occurs throughout the Ngairigi and Upper Kinyeti Basins and occupies about 30% of the enumerated blocks. This type is not common in the Lomwaga Uplands, Ateppi Basin or Acholi Mountains. It covers an area of 4 387 ha.

Podocarpus-Syzygium open forest (2f)

The large overmature trees of *Podocarpus, Syzygium, Olea* and *Pygeum* are widely spaced and an understorey and shrub layer are absent. A dense layer of forbs cover the ground giving this the appearance of open parkland (see Plate 17). The type conforms to Jackson's (1956) description of 'broken forest post-climax'.

Structure and characteristic species

The widely-spaced trees, 30 m in height have a canopy closure of 50 to 90%. The type has been distinguished on the aerial photographs by the deep shadows occurring between the crowns of the emergent trees. Shrubs and understorey trees are rare or absent and occasionally the trees are draped in climbers.

PLATE 15 *Olea-Podocarpus* closed forest showing the clean boles and lack of shrub layer

PLATE 16
Croton-Macaranga-Albizia forest is often difficult to penetrate. Here the line was cut through the middle of a strangling fig tree

Podocarpus and *Syzygium* are the commonest trees often reaching diameters of over 100 cm. Less frequent are *Olea, Pygeum* and *Croton.* The stand table (Table 47 in Part 6) shows a quite different size class distribution in this forest type compared with 2e (Table 46). In the open forest *Podocarpus, Syzygium* and *Olea* have from one to three trees in each diameter class up to the 90 cm dbh class, whereas in 2e the number of trees falls from about eight in the 20 cm dbh class to one in the 90 cm dbh class. The open forest has 84 trees/ha compared with the closed forest which has 145 trees/ha.

In the gaps smaller trees sometimes occur, notably *Bersama abyssinica* and *Dombeya goetzenii.* Often the ground is covered with a thick mat 1.0-1.5 m high of *Hypoestes forskalei, Isoglossa* cf. *somaliensis* or *Mimulopsis* sp. Details of the species composition are given in Table 34 and the volume density of the timber species is illustrated in Figure 5 in Part 6.

Ecology and distribution

Open forest occurs at an elevation of 2 200 to 2 400 m and tends to occur on the gently sloping valley sides and bottoms. The open forest probably develops from closed forest by windblow and is maintained by browsing animals and the thick mat of ground vegetation. The succession is discussed in greater detail in the next section. Open forest covers 12 359 ha of the whole reserve and about 40% of the enumerated area. This type has a widespread distribution in the forest reserve covering extensive areas in the Lomwaga Uplands, Ateppi Basin and East Acholi Mountains.

Oxytenanthera bamboo thicket (2g)

Structure and characteristic species

Pure stands of the bamboo *Oxytenanthera abyssinica* grow in clumps to a height of 7-10 m mostly with a closed canopy. The pattern on the aerial photographs is distinctive with a very even tone, broken up in the middle where the older bamboo survive as individual clumps. The montane bamboo *Arundinaria alpina* has been identified on the aerial photographs in only one limited area and was never met with in the field work.

Ecology and distribution

It is not known whether the bamboo has any particular site preference. The photographs show it to grow on all topographic positions.

Vidal-Hall (1952) reports that *Oxytenanthera* in Equatoria Province generally does not die off after seeding every seven years, but some clumps flower annually and continue to flourish. He suggests that clumps die off when they become overmature and overcrowded. The gregarious habit of bamboo is perhaps more easily explained when it is remembered that it is a grass and grows like a perennial tussock grass, except that it reaches tree size. Extensive areas of bamboo are confined to the Laboni and Issore areas in the Ateppi Basin, where it covers 1 459 ha.

HIGHER MONTANE ZONE, 2 400-2 900 m

The Higher Montane Zone is confined to the Kipia and Lomwaga Uplands.

Exotheca grassland (Type 3a)

This type of vegetation covers an area of 656 ha in the Kipia Upland including boggy areas. It has short grasses 50-100 cm high mixed with herbs; *Bulbostylis atrosanguinens,* a wire-leaved, tussock-forming sedge, is dominant over wide areas. Common grasses are:- *Exotheca abyssinica, Setaria sphacelata* and *Digitaria uniflumis.* Plate 8 shows *Exotheca* grassland in the foreground.

Carex sedge swamp grassland (3b)

Swampy areas underlain by the peat deposits of the Malumas soil series have a grassland vegetation clearly distinguishable on the aerial photographs. The type, which covers an area of 200 ha, is confined to valley bottoms in the Kipia Uplands. Common sedges are *Carex steudneri, C. fischeri, Juncus dregeanus, Eriocaulon* sp., *Scirpus cormymbosus* and *Utricularia tribracteata.* In Plate 8 *Carex* sedge swamp grassland occurs in the low-lying land in the centre of the picture.

Gnidia-Hypericum-Hagenia low woodland (3c)

Jackson (1956) has described this as a transition from grassland to *Podocarpus* forest at high elevation. The common trees are *Gnidia glauca, Hypericum revolutum* and *Hagenia abyssinica.* The trees reach a height of 8 m and 50-70% canopy cover. The ground is covered by a dense layer of grasses and forbs in which the dominant species are *Exotheca abyssinica* and *Cyperus derreilema.* A detailed species list is to be found in Table 35.

This community is found on the Kipia Uplands surrounding the *Exotheca* grassland possibly where soil drainage is slightly better (Plate 2). The total area is 1 862 ha.

Olea-Podocarpus pole forest/thicket (3d)

At high elevations and on exposed sites at slightly lower elevations a dense pole-forest occurs, in which the trees reach a height of 12-15 m and a diameter of 20-30 cm. The predominant trees are *Olea* spp. and *Podocarpus milanjianus* with occasional *Olinia rochetiana, Rapanea neurophylla* and *Dombeya goetzenii.* There are no shrubs and the ground is carpeted with grass and sedge. A detailed species list is to be found in Table 35.

This community is probably the climax vegetation on exposed sites, but develops into pure *Podocarpus* forest in sheltered situations. The type is confined to the Kipia and Lomwaga Uplands and covers an area of 4 808 ha.

Podocarpus-Dombeya open forest (3e)

The canopy is open with large isolated *Podocarpus* standing in a lower intermittent storey of *Domeya.* The *Podocarpus* reach a height of 20-25 m and the canopy closure ranges from 50 to 80%.

The *Podocarpus* has the highest volume and the *Dombeya* has a volume greatly reduced by allowance for defect since many of the trees are heavily branched and hollow. The stocking of *Olea* spp. is high because of the inclusion of ridge top forest consisting of a pure *Olea-Podocarpus* pole forest in strips on ridges too narrow to map separately. *Rapanea rhododendroides* and *Hagenia abyssinica* are also common. In the shrub layer common and occasional species are *Galiniera coffeoides, Hypericum revolutum* and *Lobelia giberroa.* The ground layer is dominated by *Cyperus derreilema* with occasional *Pteridium* and *Hypoestes forskalei.*

Jackson (1956) describes it as a seral stage towards the pure *Podocarpus milanjianus* high montane forest climax(Plate 18). The type is common on the steep often boulder strewn slopes rising to the Kipia Uplands and occurs on the Kipia and Lomwaga Uplands covering an area of 8 399 ha.

TABLE 35 Species composition of the vegetation types in the Upper Montane and Ericaceous Zones

Species	*Exotheca* grassland	*Carex* sedge swamp grassland	*Gnidia-Hypericum Hagenia* woodland	*Olea-Podocarpus* pole forest/thicket	*Podocarpus-Dombeya* open forest	*Erica* thicket
Trees						
Podocarpus milanjianus Rendle				c	a	
Olea hochstetteri Bak. Hook. f.				a	c	
Olinia rochetiana A. Juss.				c	o	
Syzygium guineense (Willd.) DC. subsp *afromontanum* F.White				o	c	
Afrocrania volkensii (Harms) Hutch					r	
Dombeya goetzenii K Schum				o	a	
Rapanea neurophylla (Gilg) Mez					o	
Rapanea rhododendroides Mez, l.c.			c(al)		c	
Hagenia abyssinica J F Gmel					o	
Teclea nobilis Del.				o	o	
Shrubs						
Galiniera coffeoides Del					a	
Hypericum revolutum Vahl			c	o	c	c
Lobelia giberroa Hemsl			o		c	
Gnidia glauca (Fresen) Gilg.			c			c
Tephrosia atroviolacea Bak f			c			
Erica arborea L						a
Myrica salicifolia Hochst ex A.Rich.						a
Anthospermum usambarense K. Schum.						o
Senecio myriocephalus Sch.Bip. ex A.Rich						o
Alchemilla argyrophylla Oliv.subsp.*argyrophylla*						o
Crassula pentandra (Royle ex Edgw) Schoul var *phyturus*						o
Erlangea imatongensis M.R.Taylor						o
Blaeria breviflora Engl.						o
Smithia volkensii Taub.						
Forbs, grasses and sedges						
Bidens mossii Schaeff (syn *Coreopsis tripartita* M.B.Moss)	a					
Moraea diversifolia Baker	o					
Hypoxis urceolata Nel	o					
Delphinium leroyei Franch.	o					
Athrixia rosmarinifolia (Sch.Bip.) Oliv. and Hiern	o					
Justicia whytei S Moore	o					
Hebenstreita dentata L	o					
Lactuca capensis Thunb	o					
Polygala abyssinica R Br ex Fres	o					
Sopubia ramosa Hochst	o					
Exotheca abyssinica (A Rich) Anderss	c		c			c

Note: a = abundant, c = common, o = occasional, r = rare

TABLE 35 Continued

Species	*Exotheca* grassland	*Carex* sedge swamp grassland	*Gnidia-Hypericum* *Hagenia* woodland	*Olea-Podocarpus* pole forest/thicket	*Podocarpus-Dombeya* open forest	*Erica* thicket
Forbs, grasses and sedges Cont.						
Bulbostylis atrosanguineus	a					
Digitaria uniglumis (A Rich) Stapf	c					
Setaria sphacelata (Shumach) Stapf and Hubbard	c					
Micromeria biflora Benth	o					
Rhamphicarpa tenuisecta Standley	o					
Lotus corniculatus L	o					
Plectranthus schimperi Vatke	o					
Geranium šimense Hochst ex A Rich	o					
Carex steudneri Boek		c				
Carex fischeri K Schum		c				
Juncus dregeanus Kunth		o				
Ericaulon spp		o				
Scirpus corymbosus Rottb		o				
Utricularia tribracteata Hochst ex A Rich		o				
Lathyrus hygrophilus Taub		o				
Hypericum peplidifolium A Rich		o				
Carduus sp		o				
Gunnera perpensa L		o				
Setaria strata Hack		o				
Impatiens hochstetteri Warb		o	o			
Ranunculus oreophytus L		o				
Veronica abyssinica Fres			o			
Viola eminii (Engl) Fries			o			
Cyperus derreilema Steud			a	o	c	c
Brachypodium flexum Nees			o			
Brachypodium simplex Nees			c	a		
Streblochaete longiarista (A Rich) Pilg			c			
Agrostis kilimandscharica Mez			c			
Enrharta erecta Lam var *abyssinica* (Hochst) Pilg			c			
Bromus runnsoroensis K Schum			c			
Coleus grandicalyx E A Bruce						o
Carex cf *cuprea* (Kuk) Nelmes				o		
Hypoestes forskalei (Vahl) Soland ex Roem and Schultes					c	
Pteridium aquilinum (L Kuhn)					o	
Micromeria punctata (R Br) Benth var *purtschelleri*					o	
Calamintha simensis Benth					o	
Helichrysum schimperi (Sch.Bip.ex A.Rich.) Moeser					o	

Note: a = abundant, c = common, o = occasional

TABLE 35 Continued

Species	*Exotheca* grassland	*Carex* sedge swamp grassland	*Gnidia-Hypericum Hagenia* woodland	*Olea-Podocarpus* pole forest/thicket	*Podocarpus-Dombeya* open forest	*Erica* thicket
Forbs, grasses and sedges Cont.						
Monechma bracteatum Hochst					o	
Adenocarpus manii Hook F					o	
Bromus runssoroensis K Schum			c			
Climbers						
Urena hypselodendron (Hochst ex A Rich) Wedd					o	
Rubus steudneri Schweinf			o		c	

Note: a = abundant c = common o = occasional

ERICACEOUS ZONE, OVER 2 900 m

Jackson writes: 'This zone is found at the summit of Mount Kinyeti, above the line of *Podocarpus* forest at 2 900 to 3 000 m. Some of its characteristic species occur rather lower on exposed rocky peaks, indicating that exposure rather than altitude alone may be the chief factor producing this type of vegetation in the Imatongs.

Certain life-forms are very characteristic of this zone such as ericoid shrubs; wiry, often aromatic herbs; and plants with white hoary leaves. All these characters seem to be adaptions to the intense insolation and high rates of transpiration found at high altitudes near the equator.'

Erica thicket (Type 4a)

The vegetation grows in a thicket 2.5-3 m high dominated usually by *Erica arborea,* associated shrubs are *Rapanea neurophylla, Hypericum revolutum, Gnidia glauca* and *Myrica salicifolia.* Forbs include *Senecio myriocephalus, Coleus grandicalyx, Helichrysum schimperi, Alchemilla argyrophylla* and the sedge *Cyperus derreilema.* This community occurs in the foreground of Plate 18. It is not widespread being confined to the summit of Mount Kinyeti and one other isolated peak, covering an area of 154 ha.

AFFINITIES TO VEGETATION OF NEIGHBOURING COUNTRIES

The vegetation comprises three major elements; in the plains, below 1 800 m, the forest vegetation consists almost entirely of species belonging to the Guineao-Congolian Phytogeographical Region whereas the woodland and wooded grassland belongs to the Sudano-Zambezian Region. Above 1 800 m the vegetation belongs to the Afro-Montane Region with a very small representation of the Afro-Alpine Region at the top of Mount Kinyeti (Chapman and White, 1970, Hedberg, 1951).

Forest of the plains

The outliers of forest at Talanga, Lotti and Laboni have been compared with forest in Uganda by Dawkins, who reported that out of a total of 154 identified species all were to be found in Uganda (Leuchars *et al.,* 1954). Jackson (1956), comparing the lowland forest with the Budongo rain forest in Uganda described by Eggeling (1947), states that it strongly resembles the mixed forest seral stage. The Talanga forest resembles the forest that lies along the northern edge of the forest zone in Nigeria. The only notable

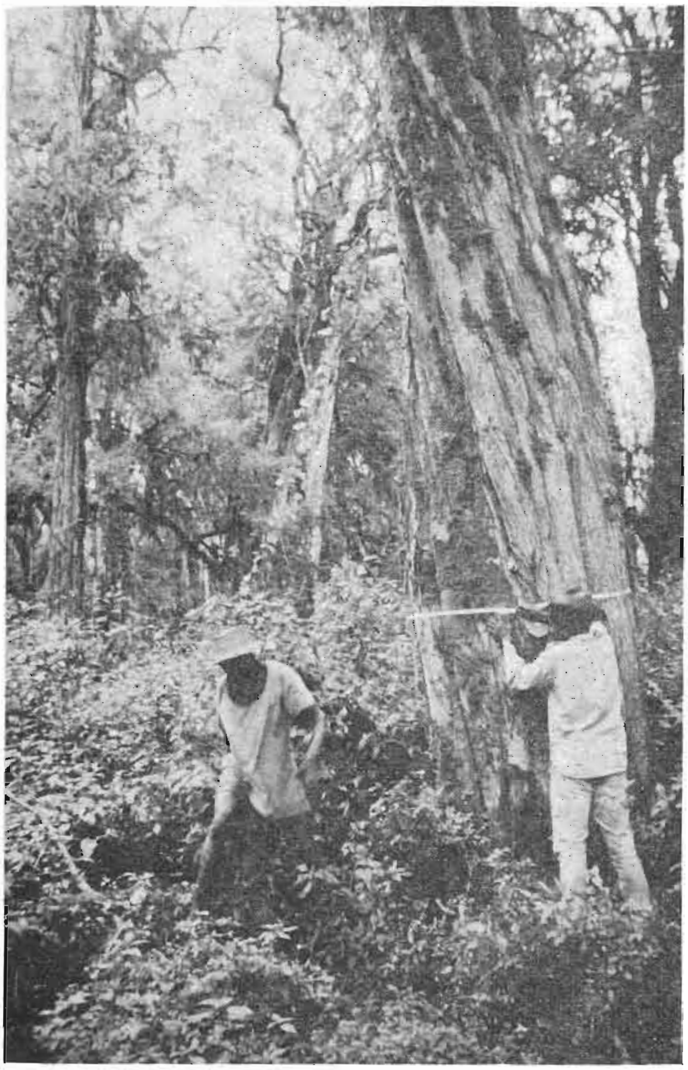


PLATE 17
Measuring a large *Podocarpus milanjianus* tree in the vegetation type *Podocarpus*-*Syzygium* open forest. The man on the left has struggled through the tall *Isoglossa* herb layer

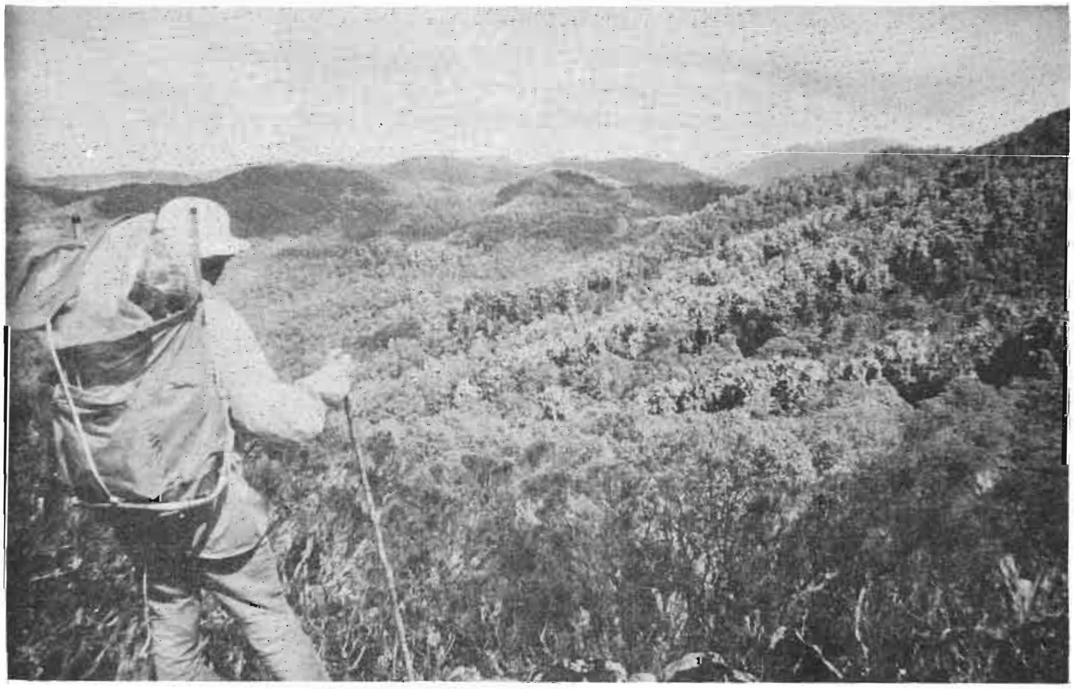


PLATE 18 On the path to Mount Kinyeti looking at a pure stand of *Podocarpus* on Landform Unit B. The *Podocarpus* looks white because it is covered with lichen. The line of shrubs in the foreground is *Erica arborea*

absentees from the upper storey of the Talanga forest are *Triplochiton scleroxylon* and *Aubrevillea kerstingii.*

Lower and Higher Montane Zones

Vegetation types that correspond to the *Croton-Macaranga-Albizia* forest, the *Olea-Podocarpus* closed forest and the *Podocarpus-Syzygium* open forest can be found at similar elevations on the chain of mountains that extended southwards through East Africa and to the north-east in Ethiopia. Elements of all three Imatong forest types mentioned above occur in the Pygeum moist montane forest described by Langdale-Brown *et al.* (1964) for Uganda. The similarities can be found both in the species composition and in the structure. In the Upper Montane Zone *Gnidia-Hypericum-Hagenia* woodland corresponds to the *Hagenia-Rapanea* moist montane forest in Uganda. The *Podocarpus-Dombeya* open forest has many features in common with the *Juniperus-Podocarpus* dry montane forest of Uganda, particularly in the open structure and in the species composition of the understorey and ground layer. The absence of *Juniperus* in the Imatongs may be due to the fact that the climate is wetter.

The Lower Montane Zone forest types have certain similarities with types described by von Breitenbach (1963) for Ethiopia, although close comparison is difficult because von Breitenbach's descriptions are brief. The *Celtis* forest and *Polyscias* forest in Ethiopia in the semi-humid lower highland forest zone resemble *Croton-Macaranga-Albizia* forest and *Olea-Podocarpus* forest although the *Celtis* is a different species *(C. kraussiana)* and the climax forest of which these are the pioneering stages, is *Podocarpus gracilior* and not *P. milanjianus* as in the Imatongs.

In the Upper Montane Zone the *Gnidia-Hypericum-Hagenia* woodland of the Imatongs corresponds to the *Hagenia* thicket described by von Breitenbach as occurring in the semi-humid mountain woodland zone in Ethiopia.

Ericaceous Zone

The *Erica* thicket and associated low moorland vegetation of the Imatongs has broadly similar species composition and appearance to the communities described by Coe (1967) on Mount Kenya and Hedberg (1964) on several mountains in East Africa.

Jackson (1956) makes the point that the domiant vegetation recorded from other mountains in East Africa often corresponds to seral stages and not the climax in the Imatongs. 'This may be because the effect of human interference has been less intense or less prolonged in the Imatongs or it may be due to climatic factors.'

FOREST SUCCESSION

The succession from farmland to forest in the Lower Montane Zone goes via *Vernonia* shrub thicket through *Croton-Macaranga-Albizia* forest to the *Olea-Podocarpus* closed forest as illustrated in the accompanying diagram. The succession only advances from *Hagenia* woodland to forest if fire is excluded for a few years. The *Podocarpus-Syzgium* open forest certainly looks like an overmature stage of the *Podocarpus-Olea* forest. The lack of small sizes in the stand table show that *Olea, Podocarpus* and *Syzygium* are not regenerating in the open forest. Succession is illustrated in Figure 4.

Logan (1946) ascribes the open nature of the *Podocarpus* montane forest in Ethiopia to cultivation and grazing, but cultivation and grazing except by wild animals have not occurred in the Imatongs for many years. Unthinned *Cupressus* plantations that have suffered from windblow look very like the open forest with large heavily branched *Cupressus* standing widely spaced in a dense ground layer. It seems possible that the trees in the unthinned plantation or the densely stocked *Olea-Podocarpus* closed forest lose their anchorage when heavy rain saturates the loose structured top soil. In the strong winds that accompany storms the trees blow over easily. Fallen trees are a feature of the *Podocarpus-Syzygium* open forest. Regeneration is prevented by the thick mat of moist non-inflammable *Hypoestes* and *Isoglossa* that cover the ground. Seedlings of *Podocarpus, Olea* or *Syzygium* have difficulty in penetrating this mat, which is heavily grazed by bushbuck *(Tragelaphus scriptus dodingae).* It seems likely that any tree seedling that did penetrate the ground vegetation would be browsed by the bushbuck. It looks as if, before the forest can regenerate, fire has to enter and the vegetation develop through *Vernonia* shrub thicket or *Hagenia* woodland to *Olea-Popocarpus* closed forest.

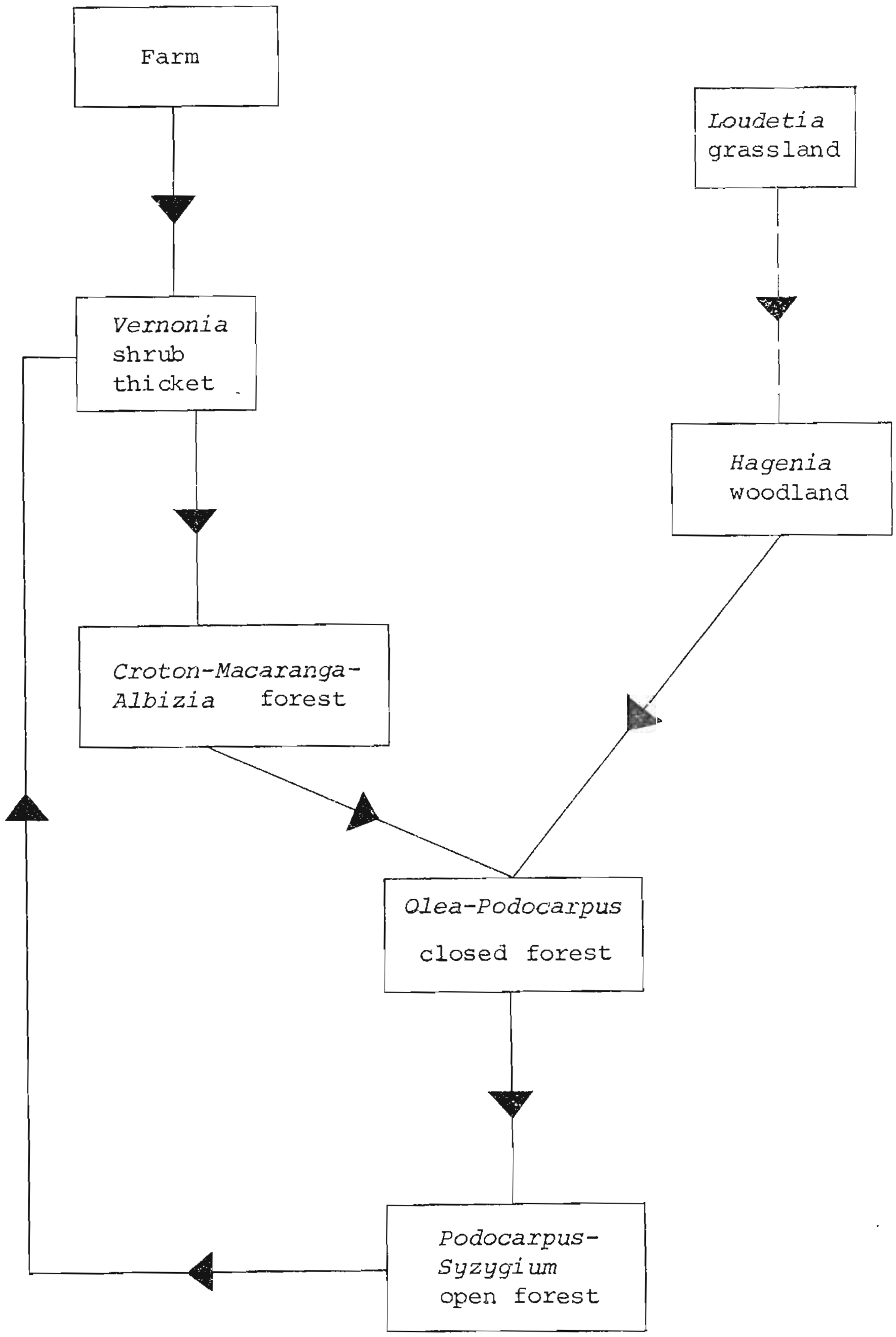


FIGURE 4 Forest succession in the Lower Montane Zone

Part 6

Forest inventory of selected areas

INTRODUCTION

In this part of the report the results are presented from inventories covering two areas within the forest reserve; firstly the Upper Kinyeti and Ngairigi Basins and secondly the Talanga area. The inventory of the former area was confined to unexploited forest areas on land under 30° slope which might be developed for softwood plantations. The latter area was at a lower elevation and was enumerated to determine if there was sufficient timber to keep the sawmill at Katire fully supplied.

INVENTORY OF THE NGAIRIGI AND UPPER KINYETI BASINS

Area of vegetation types

The Lower Montane and Higher Montane vegetation communities which occur within the Ngairigi and Upper Kinyeti Basins have been described in Part 5. The areas which each of the types listed below covers within the inventory blocks is given in Table 36.

- 2a *Loudetia* grassland
- 2b *Hagenia* woodland
- 2c *Vernonia* shrub thicket
- 2d *Croton-Macaranga-Albizia* forest
- 2e *Olea-Podocarpus* closed forest
- 2f *Podocarpus-Syzygium* open forest
- 3e *Podocarpus-Dombeya* open forest

Of the vegetation communities occurring within the inventory area, volume data are presented for only four, namely 2d, 2e, 2f and 3e. (These four vegetation communities are forested and are referred to as forest types).

There was a small overlap between Blocks 2 and 5 and the correction to the areas which this necessitated is included in Table 36.

Volumes

The most outstanding feature of the results is the very high volumes per unit area in the four forest types. The reliable minimum estimates (RME) of the total stocking for Types 2e and 2f are 161 and 117 m^3/ha respectively. Of these volumes a high proportion is made up of *Podocarpus* and hardwoods already known on the timber market such as *Olea, Croton* and *Pygeum.* In Type 2e the mean RME for *Podocarpus* is 56 m^3/ha and for the hardwoods is 45 m^3/ha. In Type 2f the mean RME for *Podocarpus* is 31 m^3/ha and for hardwoods is 35 m^3/ha. This means that a high proportion of the total volume is utilisable.

TABLE 36 Area of vegetation types within blocks, ha

Block no.	Vegetation types							Total
	2a	2b	2c	2d*	2e*	2f*	3e*	
1	–	–	53.6	341.8	3.0	25.3	–	423.7
2	25.3	7.1	6.1	167.9	165.9	58.7	–	431.0
3	4.0	–	10.1	104.2	20.2	262.1	–	400.6
4	2.0	13.2	–	43.5	215.5	56.6	–	330.8
5	17.2	4.0	–	12.1	83.0	265.1	–	381.4
6	11.1	13.2	–	–	112.3	135.6	–	272.2
7	12.1	5.1	–	–	136.6	156.8	–	310.6
9	11.1	10.1	–	–	43.5	193.3	–	258.0
10	5.1	2.0	–	–	88.0	193.2	–	288.3
11	15.2	2.0	–	–	159.9	165.9	–	343.0
12	2.0	9.1	9.1	–	45.5	161.9	103.2	330.8
13	–	3.0	–	–	63.7	14.2	180.1	261.0
16	6.1	19.2	–	–	221.5	169.0	19.2	435.0
17	–	13.2	–	1.0	198.3	300.5	–	513.0
18	31.4	2.0	6.1	241.7	56.7	207.4	–	545.3
19	3.0	15.2	–	–	155.8	3.0	172.0	349.0
Total	145.6	118.4	85.0	912.2	1 769.4	2 368.6	474.5	5 873.7
Less overlap between 2 and 5		–1.0		–2.0	–33.4	–2.0		–38.4
Total	145.6	117.4	85.0	910.2	1 736.0	2 366.6	474.5	5 835.3

* Referred to as forest types

The RMEs of total volume are to be found in Table 37.

TABLE 37 Reliable minimum estimates † (RME) of total volume in the enumerated area for the four forest types, m^3

Timber species/group	Min. dbh cm	Type 2d	Type 2e	Type 2f	Type 3e
Podocarpus	20	(3 500)	97 000	73 600	9 900
	30	(3 500)	93 000	72 400	9 300
	40	(3 500)	85 400	68 400	7 800
Hardwoods	20	19 200	78 100	81 900	7 100
	30	17 800	73 600	80 000	7 300*
	40	14 200	66 300	76 200	6 500
Potential hardwoods	20	3 500	69 300	71 500	(6 400)
	30	3 500	66 300	69 100	(5 700)
	40	3 800*	62 100	64 400	(4 900)
Others	20	9 300	19 300	24 600	(4 000)
	30	9 300	16 300	22 000	(3 400)
	40	6 800	11 800	17 500	(2 600)
All groups total	20	67 000	280 200	277 800	35 000
	30	62 700	266 300	269 800	35 000
	40	52 300	240 600	252 500	31 200

† Where RME is negative (or less than 0.5 m^3/ha) the mean volume/ha for the sampled area has been used and the volume is given in brackets
* Anomalous figures due to smaller variance in larger diameter classes.

Type 2d contains a high volume of established hardwoods particularly *Croton*, but it only contains a small quantity of *Podocarpus*. From the sawmiller's point of view Type 2e has the highest potential. The RME of total volume in this type is 280 200 m^3 of which 97 000 m^3 is *Podocarpus* and 78 100 m^3 is established hardwoods. The trees are comparatively small and less likely to be defective in this type compared with Type 2f (see section on log defect). Type 2f contains an RME of total volume of 277 800 m^3 of which *Podocarpus* makes up 73 600 m^3 and the established hardwoods 81 900 m^3. As has been mentioned in the description of the forest types the size class distribution in this type has a high proportion of large trees and relatively few small trees. The large trees are generally overmature and likely to be defective.
Type 3e although it contains 9 900 m^3 of *Podocarpus* has a relatively low stocking. It should have a low priority for timber exploitation.

Sampling error

Tables 38, 39 and 40 give the sampling errors and mean RMEs for the timber species groups.

TABLE 38 **RME of timber volume/ha for all trees over 20 cm dbh, m^3/ha**

Timber species group	Type 2d		Type 2e		Type 2f		Type 3e	
	Sampling error %	RME*	Sampling error %	RME	Sampling error %	RME	Sampling error %	RME*
Podocarpus	116	(3.9)	9	55.9	16	31.1	39	20.8
Hardwoods	48	21.1	12	45.0	19	34.6	40	15.0
Potentially utilisable	74	3.9	22	39.9	20	30.2	105	(13.4)
Others	58	10.2	12	11.1	29	10.4	113	(8.4)
Total	17	73.6	8	161.4	11	117.4	8	73.8

*Where RME is negative (or less than 0.5 m^3/ha) the mean volume/ha for the sampled area is given in brackets

TABLE 39 **RME of timber volume/ha for all trees over 30 cm dbh, m^3/ha**

Timber species group	Type 2d		Type 2e		Type 2f		Type 3e	
	Sampling error %	RME*	Sampling error %	RME	Sampling error %	RME	Sampling error %	RME*
Podocarpus	116	(3.9)	9	53.6	16	30.6	40	19.6
Hardwoods	49	19.6	13	42.4	19	33.8	36	15.4+
Potentially utilisable	72	3.8	22	38.2	21	29.2	109	(12.1)
Others	62	10.2	13	9.4	30	9.3	118	(7.2)
Total	17	68.9	8	153.4	11	114.0	3	73.7

+ Anomalous figure due to smaller variance in over 30 cm dbh class * See Table 38

TABLE 40 **RME of timber volume/ha for all trees over 40 cm dbh, m^3/ha**

Timber species group	Type 2d		Type 2e		Type 2f		Type 3e	
	Sampling error%	RME*	Sampling error %	RME	Sampling error %	RME	Sampling error %	RME
Podocarpus	117	(3.8)	9	49.2	17	28.9	47	16.4
Hardwoods	55	15.6	13	38.2	19	32.2	39	13.7
Potentially utilisable	62	4.2+	23	35.8	22	27.2	127	(10.4)
Others	68	7.5	16	6.8	35	7.4	121	(5.5)
Total	21	57.5	9	138.6	12	106.7	5	65.8

+ Anomalous figure due to smaller variance in over 40 cm dbh class * See Table 38

In the forest types that are important for commercial logging, Types 2e and 2f, the sampling error for all species groups is for trees over 20 cm dbh 8% and 11% respectively. In both types the sampling errors for individual species groups are 20% or below for all the groups except for potentially utilisable species in 2e (22%) and for 'others' in 2f/(29%).

In Type 2d the sampling error for all species groups for trees over 20 cm dbh is 17%, but all the individual groups have sampling errors above 20%. This is because the type is not widespread and occurs at the edge of forest. When it occurs in only one line in a block no variance can be calculated for that block, severely limiting the number of samples included in the final variance calculation.

The sampling error for Type 3e is 8% for all species groups for trees over 20 cm dbh but well above 20% for the individual groups. The area sampled was small and only occurred in three blocks extensively. It was separated from 2f, because it does have a different mean volume and occupies a distinct ecological zone.

Defective logs

An indication of the number of defective logs recorded in the survey is given in Table 41. The table has been compiled from a study of a few lines in each forest type where the booking was closely supervised. *Syzygium, Dombeya* and *Macaranga* are the species most prone to defect. *Podocarpus, Olea* and *Croton* are rarely defective in any of the forest types. Types 2f and 3e have more defective logs than 2d and 2e. This shows in the greater proportion of useless logs in 2f and 3e. The high proportion of defect in 'Others' is due to the fact that many understorey shrubs are branched from the ground and useless for timber.

TABLE 41 **Proportion of defective logs in sample lines in the forest types, %**

Species	Type 2d			Type 2e			Type 2f			Type 3e		
	A	B	C	A	B	C	A	B	C	A	B	C
Podocarpus	100	–	–	96	3	1	95	3	2	93	7	–
Croton	92	8	–	100	–	–	100	–	–	–	–	–
Fagara	100	–	–	–	–	–	100	–	–	–	–	–
Ocotea	–	–	–	100	–	–	75	25	–	–	–	–
Olea	100	–	–	92	66	2	87	9	4	92	4	4
Pygeum	88	12	–	100	–	–	86	7	7	78	–	22
Syzygium	57	36	7	73	17	10	74	19	7	70	20	10
Dombeya	–	–	–	55	35	10	65	4	31	42	23	35
Macaranga	–	–	–	50	17	33	78	11	11	–	–	–
Teclea	71	29	–	77	17	6	–	–	–	94	–	6
Others	70	11	19	73	23	4	61	12	27	56	10	34

A= usable B= 50% usable C= useless
–= less than 1% or insufficient data available

Volumes of the individual species

Tables 42, 43 and 44 give the volumes of the individual species in each forest type for all trees over 20 cm dbh (see also Figure 5). The total volumes have been obtained from the mean volume for the species in the sampled area. It should be noted that the means and the totals are not reliable minimum estimates. Reliable minimum estimates have been worked out only for the species groups.

From the tables it can be seen that *Podocarpus, Olea* and *Syzygium* are the species with the largest mean volumes in Types 2e and 2f. *Croton* is common in Type 2d. *Fagara* and *Ocotea* never have high volumes.

TABLE 42 **Mean volumes (m^3/ha) and total volumes (m^3) by forest types of trees over 20 cm dbh in the enumerated area**

Species	Type 2d		Type 2e		Type 2f		Type 3e	
	Mean	Total	Mean	Total	Mean	Total	Mean	Total
Softwood								
Podocarpus milanjianus	4.8	4 400	60.2	104 500	37.0	87 600	36.4	17 300
Hardwoods								
Croton macrostachys	14.9	13 600	4.6	8 000	7.5	17 700	0.4	200
Fagara macrophylla	2.6	2 400	0.9	1 600	1.0	2 400	0.0	0
Ocotea kenyensis	1.7	1 500	3.2	5 600	4.2	9 900	0.6	300
Olea spp.	11.1	10 100	40.2	69 800	24.4	57 700	20.8	9 900
Pygeum africanum	7.4	6 700	4.9	8 500	6.6	15 600	2.4	1 100
Total	37.7	34 300	53.8	93 400	43.7	103 400	24.2	11 500
Potential hardwoods								
Dombeya goetzenii	1.1	1 000	1.3	2 300	1.7	4 000	4.6	2 200
Macaranga kilimandsharica	8.6	7 800	1.7	3 000	1.6	3 800	0.2	100
Syzygium guineense	4.9	4 500	43.6	75 700	30.7	72 700	9.4	4 500
Teclea nobilis	0.5	500	3.6	6 200	3.4	8 000	2.8	1 300
Total	15.1	13 700	50.2	87 100	37.4	88 500	17.0	8 100
Other species	24.4	22 200	12.7	22 000	14.3	33 800	8.6	4 100
Total	82.0	74 600	176.9	307 100	132.4	313 300	86.2	40 900

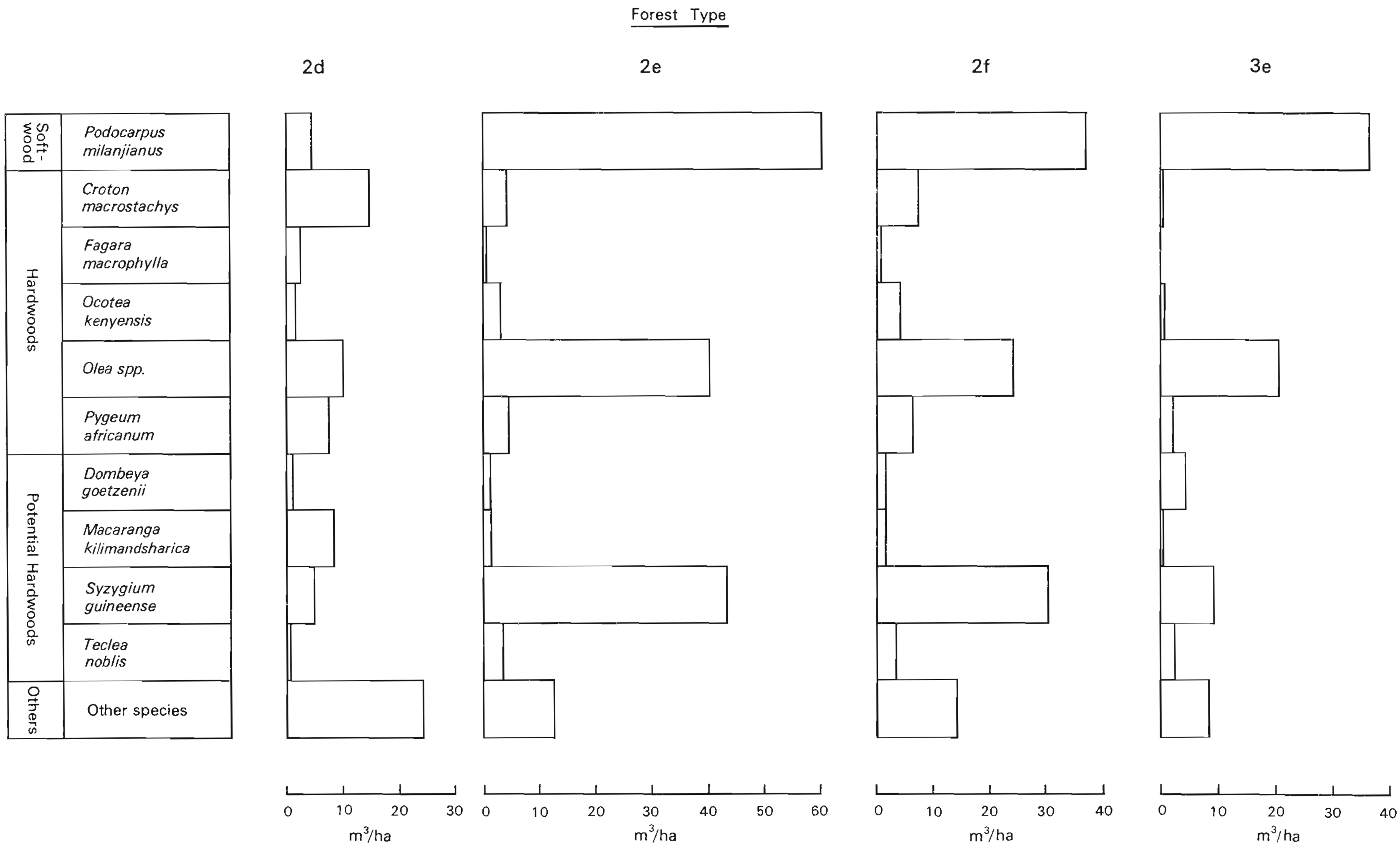


FIGURE 5 Comparison of mean volumes of the enumerated species in each forest type (m^3/ha) for all trees over 20cm d.b.h.

FIGURE 5

LRD/SUD/RNJ/8E

Prepared by Land Resources Division 1976

TABLE 43 Mean volumes (m^3/ha) and total volumes (m^3) by forest types of trees over 30 cm dbh in the enumerated area

Species	Type 2d		Type 2e		Type 2f		Type 3e	
	Mean	Total	Mean	Total	Mean	Total	Mean	Total
Softwood								
Podocarpus milanjianus	4.7	4 300	58.1	100 900	36.4	86 100	35.3	16 700
Hardwoods								
Croton macrostachys	14.4	13 100	4.3	7 500	7.3	17 300	0.4	200
Fagara macrophylla	2.4	2 200	0.9	1 600	0.9	2 100	0.0	0
Ocotea kenyensis	1.7	1 500	3.1	5 400	4.2	9 900	0.6	300
Olea spp.	10.4	9 500	37.8	65 600	23.8	56 300	20.0	9 500
Pygeum africanum	7.3	6 600	5.2	9 000	6.6	15 600	2.4	1 100
Total	36.2	32 900	51.3	89 100	42.8	30 300	23.4	11 100
Potential hardwoods								
Dombeya goetzenii	1.0	900	1.3	2 300	1.7	4 000	4.2	2 000
Macaranga kilimandsharica	7.8	7 100	1.6	2 800	1.6	3 800	0.2	100
Syzygium guineense	4.8	4 400	43.1	74 800	30.5	72 200	9.4	4 500
Teclea nobilis	0.4	400	2.4	4 200	2.7	6 400	2.1	1 000
Total	14.0	12 700	48.4	84 000	36.5	86 400	15.9	7 500
Other species	22.1	20 100	10.9	18 900	13.1	31 000	7.3	3 500
Total	77.0	70 100	168.7	292 900	128.8	304 800	81.9	38 900

TABLE 44 Mean volumes (m^3/ha) and total volumes (m^3) by forest type of trees over 40 cm dbh in the enumerated area

Species	Type 2d		Type 2e		Type 2f		Type 3d	
	Mean	Total	Mean	Total	Mean	Total	Mean	Total
Softwoods								
Podocarpus milanjianus	4.6	4 200	53.6	93 000	34.5	81 600	33.1	15 700
Hardwoods								
Croton macrostachys	12.5	11 400	4.2	7 300	6.9	16 300	0.4	200
Fagara macrophylla	2.3	2 100	0.8	1 400	0.9	2 100	0.0	0
Ocotea kenyensis	1.7	1 500	2.9	5 000	3.9	9 200	0.5	300
Olea spp.	9.7	8 800	33.8	58 700	22.4	53 000	18.5	8 800
Pygeum africanum	7.1	6 500	4.8	8 300	6.4	15 100	2.4	1 100
Total	33.3	30 300	46.5	80 700	40.5	95 800	21.8	10 300
Potential hardwoods								
Dombeya goetzenii	0.8	700	1.0	1 700	1.4	3 300	3.4	1 600
Macaranga kilimandsharica	6.0	5 500	1.3	2 300	1.4	3 300	0.2	100
Syzygium guineense	4.3	3 900	41.8	7 300	29.8	70 500	9.2	4 400
Teclea nobilis	0.3	300	1.5	2 600	1.8	4 300	1.3	600
Total	11.4	10 400	45.6	79 200	34.4	81 400	14.1	6 700
Other species	19.1	17 400	8.1	1 400	11.1	26 300	5.5	2 600
Total	68.4	62 300	153.8	267 000	120 5	285 200	74.5	3 500

Stand tables

Tables 45, 46,47 and 48 show the total number of trees recorded and the number of trees per hectare (mean) for the size classes from 20 cm dbh to 150 cm dbh (2 to 15+ in the tables).

In the *Olea-Podocarpus* closed forest (Type 2e) the mean stem frequency for *Olea* and *Podocarpus* is 10/ha and 8/ha, respectively, in the 20 cm dbh class falling by even steps to 1/ha in the 90 cm dbh class. In the *Podocarpus-Syzygium* open forest (Type 2f) the mean stem frequency for *Podocarpus, Syzygium* and *Olea* is not greater in the smaller diameter classes than in the larger ones. This suggests that, in the open forest, there is not the recruitment of smaller trees and that the open forest is not regenerating. The total number of stems per hectare is 145 for Type 2e, and 84 for Type 2f.

TABLE 45 **Stand table for *Croton-Macaranga-Albizia* forest (Type 2d)**

Species	Total /mean	Size class 2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Softwoods															
Podocarpus	T	3	3	5	3		7	3	1	2		1			
	M	<1	<1	<1	<1		<1	<1	<1	<1		<1			
Hardwoods															
Croton	T	35	47	45	30	17	5	4	2	1					
	M	2	3	3	2	1	<1	<1	<1	<1					
Fagara	T	16	3	6	7	1	2		1	2					1
	M	1	<1	<1	<1	<1	<1		<1	<1					<1
Ocotea	T				2	1			2	1		1			
	M				<1	<1			<1	<1		<1			
Olea	T	49	21	21	10	7	6	2	1	2	4	1		1	1
	M	3	1	1	1	<1	<1	<1	<1	<1	<1	<1		<1	<1
Pygeum	T	2	6	3	8	5	2	3	1	1	2				
	M	<1	<1	<1	1	<1	<1	<1	<1	<1	<1				
Total	T	102	77	75	57	31	15	9	7	7	6	2		1	2
	M	6	5	5	4	2	1	1	<1	<1	<1	<1		<1	<1
Potential hardwoods															
Dombeya	T	19	20	7	1	1		1	1						
	M	1	1	<1	<1	<1		<1	<1						
Macaranga	T	75	83	65	34	9	5	1							
	M	5	5	4	2	1	<1	<1							
Syzygium	T	15	23	13	5	7	1	7	2	3	2	3			
	M	1	2	1	<1	<1	<1	<1	<1	<1	<1	<1			
Teclea	T	7	5	3	3										
	M	<1	<1	<1	<1										
Total	T	116	131	90	43	17	6	9	3	3	2	3			
	M	7	8	6	3	1	<1	1	<1	<1	<1	<1			
Other species	T	263	135	76	44	18	22	9	2	5	3	1		1	3
	M	17	9	5	3	1	1	1	<1	<1	<1	<1		<1	<1
Total	T	484	346	246	147	66	50	30	13	17	11	7		2	5
	M	31	22	16	9	4	3	2	1	1	1	<1		<1	<1

TABLE 46 **Stand table for *Olea-Podocarpus* closed forest (Type 2e)**

Species	Total /mean	Size class 2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Softwoods															
Podocarpus	T	381	369	305	243	198	143	101	52	26	12	9	6	1	3
	M	8	7	6	5	4	3	2	1	1	<1	<1	<1	<1	<1
Hardwoods															
Croton	T	9	21	26	21	12	10	6	5	2	1	2			
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			
Fagara	T		3		1	2	1	2	2		1		1		
	M		<1		<1	<1	<1	<1	<1		<1		<1		
Ocotea	T	21	5	13	7	3	4	6	7	2	1	1	3		
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Olea	T	495	408	307	222	147	87	64	33	18	11	10	1		4
	M	10	8	6	4	3	2	1	1	<1	<1	<1	<1		<1
Pygeum	T	7	11	15	11	17	10	5	3	8	1	2	2	1	2
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total	T	532	448	361	262	181	111	83	50	30	15	15	7	1	6
	M	11	9	7	5	4	2	2	1	1	<1	<1	<1	<1	<1

(Table continued over page)

TABLE 46 (continued)

Species	Total /mean	Size class 2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Potential hardwoods															
Dombeya	T	16	43	11	22	6	3	3	1						
	M	<1	1	<1	<1	<1	<1	<1	<1						
Macaranga	T	29	37	29	15	13	1	3	3	1					
	M	1	1	1	<1	<1	<1	<1	<1	<1					
Syzygium	T	142	182	187	165	127	105	100	83	54	28	33	23	11	18
	M	3	4	4	3	3	2	2	2	1	1	1	<1	<1	<1
Teclea	T	264	121	49	14	8	1	1							
	M	5	2	1	<1	<1	<1	<1							
Total	T	451	383	276	216	154	110	107	87	55	28	33	23	11	18
	M	9	8	6	4	3	2	2	2	1	1	1	<1	<1	<1
Other species	T	571	361	181	70	38	12	13	4	3	2	2	3		3
	M	11	7	4	1	1	<1	<1	<1	<1	<1	<1	<1		<1
Total	T	1 935	1 561	1 123	791	571	376	304	193	114	57	59	39	12	30
	M	39	31	23	16	12	8	6	4	2	1	1	1	<1	1

TABLE 47 Stand table for *Podocarpus-Syzygium* open forest (Type 2f)

Species	Total /mean	Size class 2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Softwoods															
Podocarpus	T	124	172	180	127	110	93	73	54	28	18	16	3	3	5
	M	2	3	3	2	2	2	1	1	1	<1	<1	<1	<1	<1
Hardwoods															
Croton	T	37	36	48	36	36	26	18	5		1	1			
	M	1	1	1	1	1	1	<1	<1		<1	<1			
Fagara	T	5	2	6	3	6	2	1	1	2	1				
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1				
Ocotea	T	15	24	17	17	14	6	8	5	5	2	3	1	1	
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Olea	T	170	171	139	116	87	58	59	34	26	12	7	3	2	3
	M	3	3	2	2	1	1	1	1	1	<1	<1	<1	<1	<1
Pygeum	T	7	16	13	15	14	14	6	6	13	5	6	2		6
	M	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1
Total	T	234	249	223	187	157	106	92	51	46	21	17	6	3	9
	M	4	4	4	3	3	2	2	1	1	<1	<1	<1	<1	<1
Potential hardwoods															
Dombeya	T	22	37	48	25	11	6		1	1					
	M	<1	1	1	<1	<1	<1		<1	<1					
Macaranga	T	22	23	27	18	8	5	5	2		2				
	M	<1	<1	<1	<1	<1	<1	<1	<1		<1				
Syzygium	T	67	101	108	105	109	84	88	62	46	36	35	22	9	20
	M	1	2	2	2	2	1	1	1	1	1	1	<1	<1	<1
Teclea	T	205	139	59	31	19	4	3	1						
	M	3	2	1	1	<1	<1	<1	<1						
Total	T	316	300	242	179	147	99	96	66	47	38	35	22	9	20
	M	5	5	4	3	2	2	2	1	1	1	1	<1	<1	<1
Other species	T	468	336	168	68	50	18	9	16	11	6	4	4	4	10
	M	8	6	3	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total	T	1 142	1 057	813	561	464	316	270	187	132	83	72	35	19	44
	M	19	17	13	9	8	5	4	3	2	1	1	1	<1	1

TABLE 48 **Stand table for *Podocarpus-Dombeya* open forest (Type 3e)**

Species	Total /mean	Size class													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Softwoods															
Podocarpus	T	47	43	34	27	22	23	15	10	8		4	4		1
	M	4	4	3	2	2	2	1	1	1		<1	<1		<1
Hardwoods															
Croton	T				1		1								
	M				<1		<1								
Fagara	T														
	M														
Ocotea	T	2	2	1			2								
	M	<1	<1	<1			<1								
Olea	T	57	48	37	25	20	18	17	8	3	2		1		
	M	5	4	3	2	2	2	1	1	<1	<1		<1		
Pygeum	T	1		3	1		1	3	1		1	2	2		
	M	<1		<1	<1		<1	<1	<1		<1	<1	<1		
Total	T	60	50	41	27	20	22	20	9	3	3	2	3		
	M	5	4	4	2	2	2	2	1	<1	<1	<1	<1		
Potential hardwoods															
Dombeya	T	45	53	41	28	13	3	2	2						
	M	4	6	4	2	1	<1	<1	<1						
Macaranga	T		2	1	1										
	M		<1	<1	<1										
Syzygium	T	31	26	2	5	3	1	6	4	1	1	6	3		1
	M	<1	1	<1	<1	<1	<1	1	<1	<1	<1	1	<1		<1
Teclea	T	38	22	11	4	1	1	1							
	M	3	2	1	<1	<1	<1	<1							
Total	T	84	83	65	38	17	5	9	6	1	1	6	3		1
	M	7	7	6	3	1	<1	1	1	<1	<1	1	<1		<1
Other species	T	109	64	34	18	12	4	4	4	1	1				
	M	9	6	3	2	1	<1	<1	<1	<1	<1				
Total	T	300	240	174	110	71	54	48	29	13	5	12	10		2
	M	25	21	15	9	6	5	4	2	1	<1	1	1		<1

INVENTORY OF THE TALANGA AREA

Area of forest types

Neither the fieldwork nor airphoto interpretation (API) revealed any significant differences in forest type within the inventory area, which lay entirely within the Lowland Zone high forest. Known areas of exploitation could not be distinguished from the photographs.

The boundary between the Lowland Zone high forest and the surrounding vegetation types was established using API. The total area of the Talanga forest is 2 135.7 ha, of which 1 098.7 ha were enumerated.

Volumes

The mean total volume of timber/ha in the Lowland Zone high forest is very similar to that of Forest Type 2f in the Upper Kinyeti and Ngairigi Basins. The RME of volume for all species over 30 cm dbh is 128 m^3/ha. However only 20% of this (25.6 m^3/ha) is accounted for by the four named species that are established on the timber market. An attempt to break down the 'other' volume is made in a later section.

The RMEs of total volume in the enumerated area are given in Table 49.

TABLE 49 Reliable minimum estimates (RME) of total volume in the enumerated area of the Talanga forest

Timber species group	Min.dbh cm	RME total vol., m^3*
Identified merchantable hardwoods	30	(28 100)
	40	(26 800)
	50	(25 160)
Others	30	105 900
	40	97 500
	50	88 000
All groups total	30	140 500
	40	129 300
	50	119 600

*Where RME is negative (or less than 0.5 m^3/ha) the mean volume/ha for the sampled area is given in brackets

There is only a 15% fall in total volume when the girth limit is raised from 30 cm to 50 cm dbh. This reflects the size class distribution, which, like Forest Type 2f, contains a relatively high proportion of large trees but few small trees. It also reflects the fact that the largest trees have very high volumes, and constitute a high proportion of the total volume. Some individual trees of around 30 m^3 were measured for the volume table, and Jackson (1956) has noted that, for *Chlorophora excelsa,* trunks containing over 1 000 ft^3 (28.3 m^3) of timber have been felled.

Sampling error

Table 50 gives the sampling errors and mean RMEs for the timber species groups.

TABLE 50 Sampling errors per cent and reliable minimum estimates (RME) of timber volumes/ha for all trees over 30, 40 and 50 cm dbh, m^3/ha

Timber species group	Minimum diameter					
	30 cm		40 cm		50 cm	
	Error %	RME*	Error %	RME*	Error %	RME*
Identified merchantable hardwoods	108.1	(25.56)	113.5	(24.43)	116.6	(22.90)
Others	17.8	95.46	17.8	88.77	18.7	80.10
All groups total	9.7	127.91	11.1	117.69	12.0	108.84

*Where RME is negative the mean volume/ha for the sampled area is given in brackets

Despite the small number of samples (four lines) the sampling error of the total volumes are very low (10-12%). This would suggest that the forest is either fairly undisturbed, or, more likely, large areas of Talanga have been exploited at about the same intensity.

The sampling errors of the identified hardwoods are very high as a result of a low mean volume and great variability of the volume of each species within each line.

Defective logs

No records of defect were made, and so it is impossible to give a quantitative indication of defect. However, on the basis of observation, rather than measurement, it seems that despite the very large size of some trees the forest does not have the 'over-mature' appearance of Forest Type 2f; and fewer trees are probably defective.

Many trees had large buttresses, some extending to 5 m from the ground. The diameters of these trees were measured above the buttress and the buttress volume was excluded as useless.

Volumes of individual species

Table 51 gives the volumes of individual species and the species groups. The mean total volumes have been calculated by adding up the mean volumes of species; they are not therefore reliable minimum estimate values.

TABLE 51 **Mean volumes (m^3/ha) and total volumes (m^3) of all trees over 30, 40 and 50 cm dbh in the enumerated area of the Talanga forest**

Species/timber species group	Minimum diameter					
	30 cm		40 cm		50 cm	
	Mean	Total	Mean	Total	Mean	Total
Chlorophora	7.7	8 500	7.2	7 900	7.1	7 800
Khaya	6.0	6 600	5.8	6 400	5.5	6 000
Celtis spp.	10.2	11 200	9.9	10 900	9.0	9 900
Maesopsis	1.5	1 600	1.4	1 500	1.3	1 400
Total identified merchantable hardwoods	25.6	28 000	24.4	26 800	22.9	25 200
Others	116.2	127 700	108.2	118 900	98.7	108 400
All groups total	141.7	155 700	132.6	145 700	121.6	133 600

The volumes of the four named merchantable hardwoods are relatively small, but represent about one stem/ha of each species.

The greatest volume is in the undifferentiated 'others' class.

A general idea of the species composition and the timber properties of the species included as 'others' is given in Table 52. The frequency of occurrence has been obtained from Jackson (1956) and the timber properties are indicated by numbers as follows:

1. Species established on the timber market: as defined in the terms of reference
2. Potentially utilisable species for the timber market
3. Species that could be used for the local market and in local workshops.
4. Species with no known uses, and those for high grade charcoal and firewood
5. Species for which no details regarding timber properties are available.

The bulk of the canopy trees fall into timber groups 1 and 2, and most of the rest are in 3. A few do not appear in the references consulted. Most of the second storey trees are in groups 2 and 3, although several do not have any known uses.

On the basis of the information in Table 52 it is possible to conjecture that trees over 50 cm dbh in the 'others' category are likely to be 30-50 m high and in the upper canopy. It is likely that a high proportion of the volume of trees over 50 cm dbh will be utilisable for timber. Unfortunately it is not possible to give a precise estimate for this 'high proportion' of utilisable timber species, because of the problem of identification. But, if only 50% of the 'others' volume for trees over 50 cm dbh is utilisable, this will amount to 40 m^3/ha. Therefore a total utilisable volume of around 65 m^3/ha for the Talanga high forest could be expected (based on RME values).

TABLE 52 The frequency, timber species group and main uses of species recorded from Talanga

Species	Frequency*	Timber species group+	Main use	Ref. **
Canopy trees,30-50 m				
Chrysophyllum albidum	c	2	Constructional timber	1, 4
Aningeria altissima	f	1	Construction & veneers	1, 4
Antiaris toxicaria	f	1	Softwood substitute	2, 3
Bosquiea phoberos	f	2	Furniture	1
Erythrophleum guineense	f	2	Rough construction - flooring	2
Klainedoxa gabonensis	f	2	Piles, sleepers, stair treads	1
Mildbraediodendron excelsum	f	2	'A timber of great possibilities'	1
Schrebera macrantha	f	3	Carpentry and firewood	1
Cola cordifolia	f	4	Firewood	1
Chrysophyllum sp.nov.	f	5	—	—
Entandrophragma angolense	o	1	Joinery & veneers	2, 3
Alstonia boonei	o	2	Rough carpentry	2
Parinari excelsa	o	2	Rough construction	2
Majidea fosteri	o	5	—	—
Mimusops bagshawei	o	5	—	—
Canarium schweinfurthii	r	2	Interior work (mahogany substitute)	2
Ekebergia senegalensis	r	2	Interior carpentry	1, 5
Cordia holstii	r	3	Cabinet work	1, 5
Pycnanthus angolensis	r	3	Plywood packing	2, 1
Ricinodendron heudelotii	r	3	Balsa substitute	2, 3
Second story trees, 15-30 m				
Melanodiscus sp. nov.	c	5	—	—
Aphania senegalensis	f	2	Joinery, turnery (resembles walnut)	1, 5
Irvingia gabonensis	f	2	Building posts, planking	1, 4
Teclea grandifolia	f	2	Tool handles, inlays	1, 5
Teclea nobilis	f	2	Tool handles, inlays	1, 5
Drypetes ugandensis	f	3	Building poles	1
Pachystela brevipes	f	3	Seats, mortars, pestles	1, 5
Strombosia grandifolia	f	3	Resembles boxwood	1, 5
Celtis brownii	f	4	—	—
Lychnodiscus cerospermus	f	5	—	—
Albizia grandibracteata	o,1.f.	4	—	—
Blighia unijugata	o	3	Piles, sleepers	1, 5
Garcinia buchananii	o	3	Furniture	1, 5
Zanha golungensis	o	3	Furniture	1
Bersama abyssinica	o	4	—	—
Myrianthus arboreus	o	4	—	—
Premna angolensis	o	4	—	—
Trichilia prieuriana	o	4	High grade charcoal	1
Chrysophyllum natalense	o	5	—	—
Craibia utilis	o	5	—	—
Gelonium procerum	o	5	—	—
Fagara sp.	r	2	Construction & carpentry	1, 5
Morus lactea	r	3	Joinery, cabinets, flooring	1, 5
Tetrapleura tetraptera	r	3	Carpentry	1, 4
Vitex sp.	r	3	Interior and low strength uses	1, 5
Funtumia elastica	r	4	—	—
Parkia filicoidea	r	4	—	—
Trichilia splendida	r	5	—	—

* Frequency: c = common, f = frequent, o = occasional, o.l.f. = occasional, locally frequent, r = rare

\+ Timber species groups: 1. Established on the timber market, 2. Potentially utilisable for timber, 3. Small scale local use, 4. No known use, except firewood and charcoal, 5. No information located

** References: 1. Eggeling W J and Dale I R (1951). 2. Forest Products Research Laboratory (1956). 3. Jay B L A (1950). 4. Keay R W J, Onochie C F A and Stanfield D P (1960, 1964). 5. Dale I R and Greenway P J (1961).

Stand tables

Table 53 shows the total number of trees measured and the number of trees/ha for the size classes from 30 cm dbh to 150 cm dbh and larger, in the enumerated area.

The distribution of number of trees per size class is very similar to Forest Type 2f, except that there are fewer trees in the smaller size classes. There are 43 trees/ha over 30 cm dbh compared with 66 for 2f and 107 for 2e. There are, on average, six stems/ha of the four named species.

TABLE 53 Stand table for Talanga high forest

Species/timber species group	Total/ mean	Size class													All classes
		3	4	5	6	7	8	9	10	11	12	13	14	15+	
Chlorophora	T	1	2	2	5	–	7	1	2	2	–	–	–	1	26
	M	<1	<1	<1	<1	–	<1	<1	<1	<1	–	–	–	<1	1
Khaya	T	9	7	4	–	3	2	–	2	5	1	–	–	3	36
	M	<1	<1	<1	–	<1	<1	–	<1	<1	<1	–	–	<1	1
Celtis	T	11	20	21	5	10	5	4	3	1	–	–	–	1	84
		<1	1	1	<1	<1	<1	<1	<1	<1	–	–	–	<1	3
Maesopsis	T	4	3	2	4	–	1	–	1	–	–	–	–	–	15
	M	<1	<1	<1	<1	–	<1	–	<1	–	–	–	–	–	1
Total identified merchantable hardwoods	T	28	32	29	14	13	15	5	8	8	1	–	–	8	161
	M	1	1	1	1	<1	1	<1	<1	<1	<1	–	–	<1	6
Others	T	316	207	120	67	64	45	44	24	15	26	15	9	31	983
	M	12	8	4	2	2	2	2	1	1	1	1	1	1	37
All groups total	T	344	239	149	81	77	60	49	32	23	27	15	9	39	1 144
	M	13	9	6	3	3	2	2	1	1	1	1	1	1	43

Part 7

Development possibilities

UPPER KINYETI AND NGAIRIGI BASINS AND IMATONG MOUNTAINS (PART)

Soil survey

Taking into account landform, slope and soils, the units of land mapped were classified according to their suitability for development of softwood plantations. The suitability classes were defined as follows:

Class 1 No or only minor limitations for development; suited for a wide range of softwood species

Class 2 At least one serious limitation which does not preclude development. Success would depend upon the selection of species suited for bouldery soils, or a relatively high management input to overcome the effect of strong slopes, or both

Class 3 At least one very serious limitation, which precludes development.

Table 54 shows the areas covered by each class in the Ngairigi and Upper Kinyeti Basins. From this it can be seen that a total of 9 813 ha have been identified for development of softwood plantations. The area identified is shown on Map 5.

TABLE 54 Areas of land suitable for softwood plantation development

Suitability class	Area, ha
1	5 972
2	3 841
3	1 893

Part of the land designated as suitable for plantation development is already under existing plantations, composed mostly of softwood species, but there is also an area of hardwoods, principal amongst which is *Cedrela toona*. This latter species covers 166.9 ha.

Existing softwood plantations

The plantations cover an area of 490.8 ha and have a standing volume of 127 104 m^3 of which 108 091 m^3 is *Cupressus.* Other softwood species include *Pinus radiata, P. patula* and *P. kesiya,* which contribute about 18 000 m^3. A summary of the species, age, area and reliable minimum estimate (RME) of total volume are given in Table 55.

TABLE 55 Summary of species, age class, area and reliable minimum estimate (RME) of total volume in the plantations

Species	Age class years	Area ha	Total volume RME, m^3
Cupressus	25+	165.7	69 489
	15-24	113.9	34 498
	5-14	37.7	4 104
	0-4	40.5	–
Pinus radiata	25+	7.7	1 540
	15-24	33.4	5 337
Pinus patula	25+	0.5	216
	15-24	37.4	6 669
	5-14	11.2	–
Pinus kesiya	15-24	7.2	1 238
Mixed compartments *Cupressus*, pines and other species	25+	3.1	1 038
	15-24	14.1	2 975
	5-14	6.0	–
Total		479.1*	127 104*

* Area and volume of *Eucalyptus* breaks between compartments not included.

Many of the compartments have not been managed during the disturbances and are now underthinned and liable to windthrow. Recommendations as to which compartments should be felled without delay and which are stable and can stand for a few years are given in Table 21 and 22 in Part 3 and a summary of silvicultural prescriptions is given in Table 56. The prescriptions are given as first and second priorities for felling and thinning. It is recommended that the first priority fellings are completed within 3 years. They involve the clear felling of 97.5 ha, which will realise a volume of 27 980 m^3 of which 26 440 m^3 is *Cupressus*. Detailed prescriptions for thinning, pruning and other treatment are given in Table 23-25 in Part 3. The first priority thinning will cover 135.3 ha and realise 8 716 m^3. Pruning covering 99.4 ha and weeding, cleaning and beating up of young plantations covering an area of 60.0 ha are recommended.

TABLE 56 Summary of prescriptions in the plantations

Operation	Species	Area ha	RME total vol. removed 1976 levels, m^3
Clear felling priority 1	Mainly *Cupressus*	89.8	26 440
	Other species	7.7	1 540
	Total	97.5	27 980
Clear felling priority 2	Mainly *Cupressus*	105.7	46.740
	Other species	71.7	10 143
	Total	177.4	56 883
Thinning priority 1	Mainly *Cupressus*	108.5	7 178
	Other species	26.8	1 538
	Total	135.3	8 716
Thinning priority 2	Mainly *Cupressus*	6.6	180
	Other species	10.3	937
	Total	16.9	1 117
Pruning	Mainly *Cupressus*	74.2	–
	Other species	25.2	–
	Total	99.4	–
Weeding, cleaning and beating up	Mainly *Cupressus*	59.5	–
	Other species	0.5	–
	Total	60.0	–

Forest inventory of the indigenous forest

Of the 9 813 ha suitable for the development of softwood plantations, apart from the 657.7 ha which are already under plantations, 7 406.3 ha are covered by forest types containing merchantable timber and 1 749.0 ha are covered by exploited forest or vegetation types containing no or little merchantable timber. *Croton-Macarange-Albizia* forest (Type 2d) contains a high proportion of secondary species like *Croton* and only small quantities of *Podocarpus* and *Olea.* The RME of mean volume is 74m^3/ha of which the established hardwoods account for 21 m^3/ha. *Olea Podocarpus* closed forest (Type 2e) is the climax forest containing *Podocarpus* (RME of the mean volume, 56 m^3/ha) and established hardwoods (RME of the mean volume, 45 m^3/ha); it has an RME of mean volume for all species groups of 161 m^3/ha. *Podocarpus-Syzygium* open forest (Type 2f) is overmature forest in which the measured merchantable volume may not be realised because the trees have begun to rot. In this type the RME of the mean volume for *Podocarpus,* established hardwoods and all species groups are 31, 35 and 117 m^3/ha, respectively *Podocarpus-Dombeya* open forest (Type 3e), is a transitional type to montane forest of high elevation. The RMEs of mean volume for *Podocarpus,* established hardwoods and all species groups are 20, 15 and 74 m^3/ha, respectively. Only part of the *Podocarpus-Dombeya* open forest can be considered exploitable because much of it occurs on steep land.

Table 57 gives the area covered by each of the productive forest types found on the land demarcated as suitable for plantation development (see Map 5). Also included in the table are volume estimates based on the reliable minimum estimates obtained within the enumerated area.

TABLE 57 Area and standing volumes of timber of natural forest on land suitable for softwood plantation development

Forest type	Area ha	Total RME vol., m^3*		
		Podocarpus	Hardwoods	All species
2d	2 055.5	(8 000)	43 400	151 300
2e	1 944.5	108 700	87 500	313 800
2f	2 868.3	89 200	99 200	336 700
3e	538.0	11 200	8 100	39 700

*Where RME is negative (or less than 0.5 m^3/ha) the mean volume/ha for the sampled area is given in brackets.

It is intended that the natural forest that is suitable for exploitation in the Upper Kinyeti and Ngairigi Basins will be replaced by softwood plantations. Recommendations about methods of natural regeneration are therefore unnecessary.

Access

The Ngairigi and Upper Kinyeti Basins form more or less level platforms of land at elevations of 1 800 m and 2 400 m respectively. They are separated by a steep scarp slope that lies on a north-east to south-west axis running through Bushbuck Ridge and Dumusum Ridge.

Access to the Ngairigi Basin presents no problem, because it is at the same elevation as Gilo and Itibol. The existing footpath from Gilo northwards to Garia peak and Imatong Village crosses the Ngairigi stream once in the middle of Block 1 and maintains a level gradient through the forest area. It could be used as an extraction road alignment. Similarly the footpath from south of Itibol to Issore follows the contour and could be used as a road alignment for timber extraction from Blocks 17 and 18.

Access to the Upper Kinyeti catchment is difficult because of the steep scarp slope between Bushbuck Ridge and Dumusum Ridge. There are two alternative road alignments up this scarp slope, one following the existing footpath from Itibol to Mount Kinyeti and the other going from the South-east corner of Block 5 to Bock 7.

TALANGA AREA

Forest inventory of the indigenous forest

The total volume of the identified merchantable hardwoods in the enumerated area (1 098.7 ha) has been estimated at 28 000 m^3 and of other species the RME is 105 900 m^3 (see Table 58). If we assume that 50% of the others can be used (see Part 6) the estimated total volume is 81 000 m^3.

TABLE 58 Reliable minimum estimates (RME) of total volume in the enumerated area of the Talanga forest

Timber species group	Min dbh, cm	Total RME vol., m^3*
Indentified merchantable hardwoods	30	(28 100)
	40	(26 800)
	50	(25 160
Others	30	105 900
	40	97 500
	50	88 000
All groups total	30	140 500
	40	129 300
	50	119 600

*Where RME is negative (or less than 0.5 m^3/ha) the mean vol/ha for the sampled area has been used and the volume is given in brackets.

Extrapolation of the volume data from the enumerated area to the whole area (2 135.7 ha) of the Talanga forest (see Map 5) reveals that the standing volumes are probably of the order of 54 600 m^3 of merchantable hardwoods and 203 900 m^3 of unidentified species. If we assume that 50% of the unidentified species can be used (see Part 6) the likely total standing volume of timber is 156 550 m^3.

If the sawmill at Katire were rehabilitated and adequate fuel and vehicles to bring the logs into the mill were available, at least 160 logs per month could be sawn. Assuming an average log volume of 7 m^3 the yearly input of logs is 13 440 m^3 (160 x 7 x 12). If only the identified hardwoods are sawn up there is enough timber in the enumerated forest to last approximately 2 years.

If the identified hardwoods and 50% of the others are sawn up there is enough timber in the enumerated forest to last 5 years.

The Katire sawmill could be supplied from the enumerated forest for approximately 5 years. After this, supplies could come from the fringe of forest outside the enumerated area, but not from the scarp slope, which is too steep for logging. The Acholi East Mountains are accessible by a route up the scarp slope.
The area of forest on the top of the Mountains is limited and would involve considerable road building. The Katire sawmill could thus be supplied from the Talanga forest for between 5 and 11 years, depending upon how much of the whole area can be economically logged.

Access

Talanga forest lies 6 km west of Katire; present access is along the main Torit road for 1 km and then along an all-season earth road to the edge of the forest. This is of a similar quality to other roads in the area as far as the final loading area that is currently being used. Within the forest the track deteriorates very rapidly and after a few days of rain in April it was so deeply rutted as to make it impassable to wheeled vehicles. The very deep, soft soils could not support the vehicles using the road.

The southern and western parts of the Talanga forest rise steeply and extraction roads are likely to be very expensive, and some form of skyline logging may be preferable.

On the basis of airphoto interpretation the quality and extent of montane forest around Talanga does not justify the expense of constructing a road for extraction up the scarp face.

Regeneration

The Talanga forest should not be felled without regenerating it. The type of regeneration that is undertaken will depend on a variety of factors, e.g. finance and staff available, etc. The options available are:

1. Clearance of the land and establishment of plantations of teak or another introduced species

2. Line planting or group planting of indigenous or shade bearing introduced species

3. Natural regeneration by tropical shelterwood or other systems

Clearance of land and establishment of plantations

Teak and *Cedrela toona* grow well at Katire. Either of these species could be established and would grow much faster than they do at Katire. Against the advantage of fast growth has to be set the high cost of clearing forest unless the taungya method is used.

Line or group planting

This represents a good compromise solution between clearing the land completely and relying on natural regeneration. A possible approach might be to plant groups of indigenous or shade-bearing exotics in the gaps where the big trees have been felled. Indigenous *Khaya* and *Chlorophora* could be used or introduced *Terminalia* or *Triplochiton.*

Natural regeneration

Natural regeneration by the tropical shelterwood system could be adopted but the results could not be assured. For success the method requires a good knowledge of the silviculture of the major species and skilled field staff.

It is recommended that the regeneration of the Talanga forest is undertaken after more field study of the problems and some experiments into alternative approaches have been undertaken.

Part or all of the Talanga forest was, at one time, designated as a nature reserve, although exploitation of the forest seems to have continued for a long time. The forest could be partially conserved by felling on a high girth limit (50 cm dbh) and using natural regeneration. There are three outliers of lowland forest remaining in the Imatong reserve at Talanga, Lotti and Laboni. We recommend that one of these is kept as a strict nature reserve in which no felling is permitted. As both Talanga and Lotti have sawmills sited near them it would seem wise to conserve Laboni.

ACHOLI MOUNTAINS, ATEPPI BASIN, LOMWAGA AND KIPIA UPLANDS

The softwood plantation development proposed for the Upper Kinyeti and Ngairigi Basins covers an area of approximately 10 000 ha or 8% of the total area of the reserve. Although it is not necessary to develop the whole reserve at one time it is useful to have an overall idea of how it should be used. We recommend that the reserve remains as a nature reserve: in coming to this decision we have been influenced by the following factors:-

1. Distribution of the forest types
2. The rare flora
3. The abundant wildlife
4. The reserve may become fragmented by development

Distribution of the forest types

Logging of the forest will only be commercially viable where there is a high proportion of the *Olea-Podocarpus* closed forest (Type 2e) and the *Podocarpus-Syzygium* open forest (Type 2f). The *Croton-Macaranga-Albizia* forest (Type 2d) has a low stocking and contains a high proportion of light hardwoods, which are useful timbers, but not so valuable as the *Podocarpus, Olea, Pygeum* and *Ocotea.* Therefore it would not be worth exploiting the *Croton-Macaranga-Albizia* forest on its own. A study of Map 4a and b shows that the best concentration of forest Types 2e and 2f occur in the area proposed for plantation development. Small patches of good forest occur in the Lomwaga Uplands and on the West Acholi Mountains, but the construction of logging roads to either of these places would be expensive, bearing in mind the limited timber resource there.

Rare flora

The flora is rare and relatively unknown. Eleven of the 95 specimens collected in the course of the survey were first records for the Royal Botanical Gardens, Kew. The arguments for preserving examples of vegetation are well known; as a gene pool for known cultivated species, for the development of drugs and chemicals from plants and for the development of new food plants. The Imatongs form a link in the chain of mountains having an Afro-Montane flora, that extends from East Africa to Ethiopia. The Imatongs have some of the best preserved *Podocarpus* forest in East Africa, because the forest has been relatively undisturbed by man (see Part 5). The lowland forest at Talanga, Lotti and Laboni are among the few surviving relicts of high forest remaining in the lowlands of the Sudan.

Abundant wildlife

Game is abundant in the Reserve and includes many species. In many game reserves and national parks it has taken 15-20 years to build up the game populations to the levels that exist in the Imatongs now. The game, particularly the bushbuck, could be managed and culled at intervals to supply meat to neighbouring villages. The harassment and uncontrolled exploitation of the game that goes on at present is likely to result in excessive and wasteful depletion of the stock over a short period of time. Once herd size has been drastically reduced recovery to present level could take a long time.

Reserve fragmented by development

Because of its high rainfall and elevation the reserve has a development potential for a variety of purposes. We recommend that any alternative proposals for development are integrated with the proposal for plantation development at Gilo. The purpose of this is to obtain economies in overheads for the developments and to avoid fragmentation of the reserve into a number of little autonomous development schemes.

Keeping the reserve as a conservation area involves no immediate action except to control hunting by the local population and to either realign the reserve boundary near Issore or to expel the people who are farming there inside the reserve.

Part 8
References

ACKHURST P W & MICSKI J (1971) Tanzania standard volume for *Pinus patula.* Ministry of Natural Resources and Tourism, Forestry Division, Tanzania.

von BREITENBACH F (1963) The indigenous trees of Ethiopia. Addis Ababa : Ethiopian Forestry Association.

BROWNE F G (1968) Pests and diseases of forest plantation trees : an annotated list of the principal species occurring in the British Commonwealth. Oxford : Clarendon Press and Oxford University Press.

CARROLL D M & HILL I D (1968) Draft recommendations for soil profile descriptions. London : Ministry of Overseas Development, Land Resources Division Miscellaneous Report 61.

CHAPMAN J D & WHITE F (1970) The evergreen forests of Malawi. Commonwealth Forestry Institute University of Oxford.

COE M J (1967) The ecology of the alpine zone of Mount Kenya. The Hague : Dr W Junk.

DALE I R & GREENWAY P J (1961) Kenya trees and shrubs. Nairobi, Kenya : Buchanan's Kenya Estates Limited.

DAWKINS H C (1958) The management of Natural Tropical High-Forest with special reference to Uganda. *Imperial Forestry Institute Paper* 34.

DORWARD F S, LEWIS M L M, HENRY P W T, STOBBS A R, STAFFORD D W, AGAR P L, RAWLINGS B R, BADI K & JODA S (1976) Imatong Forestry Project, Sudan; Pre-appraisal Mission Report. Commonwealth Development Corporation and Ministry of Overseas Development, London.

DRAPER S A (1973) Southern Region. Imatong forestry project. A request of the Government of the Sudan to the World Bank/IDA for a loan to finance a forestry project. Sudan : The Government.

DYSON W G (1962) Notes on the silviculture of cypress grown for timber in Kenya. Kenya Forest Department Tech. Note 84.

DYSON W G (1962b) *Pinus radiata* — Interim report and instructions. Nairobi, Kenya : Forest Department Technical Note 86.

EGGELING W J (1947) Observations on the ecology of the Budongo rain forest, Uganda. Journal of Ecology 34 1,20-87.

EGGELING W J & DALE I R (1951) The indigenous trees of the Uganda Protectorate Entebbe, Uganda : Government Printer

FOOD AND AGRICULTURAL ORGANIZATION (1974) Soil map of the world. Legend. Vol. 1. Paris : FAO/UNESCO.

FOREST PRODUCTS RESEARCH LABORATORY (1956) A Handbook of hardwoods. London : HMSO.

HASEK V C (1963) Internal Final Report on sawmilling, research and training in the Sudan. Khartoum, Sudan : Department of Forestry.

HEDBERG O (1951) Vegetation belts of the East African Mountains. Svensk Botanisk Tidskrift 45, 140-201.

HEDBERG O (1964) Features of Afroalpine plant ecology. Uppsala : Acta Phyto-geographica Suecica, 49.

JACKSON J K (1956) The vegetation of the Imatong Mountains, Sudan. Journal of Ecology, 44, 341-374.

JACKSON J K (1960) The introduction of exotic trees into the Sudan. *Sudan Silva* 1, 14-30.

JACKSON J K (1960) The Imatong Mountains Forest Reserve. *Sudan Silva* 1, 15-19.

JAY B A (1950) Timbers of West Africa. High Wycombe : Timber Research and Development Association.

JENKIN R N, HOWARD W J, THOMAS P, ABELL T M & DEANE G C (1976) Interim report on forestry development prospects in the Upper Kinyeti and Ngairigi Basins, Imatong Central Forest Reserve, Sudan, London : Ministry of Overseas Development Land Resources Division. Land Resource Report no. 14.

JOHNSON R L (1976) Imatong rock samples. Report filed under 1006/71/d, dated 30 April 1976. Institute of Geological Sciences, London.

KEAY R W J, ONOCHIE C F A & STANFIELD D P (1960/64) Nigerian Trees. Volumes I & II. Ibadan, Nigeria : Department of Forest Research.

LANGDALE-BROWN I, OSMASTON H A & WILSON J G (1964) The vegetation of Uganda and its bearing on land use. Government of Uganda.

LEUCHARS D, SWABEY C & DAWKINS H C (1954) Notes on a visit to the Imatong Mountains, Southern Sudan. Technical Note 6 Uganda Forest Department.

LOGAN W E M (1946) An introduction to the forests of Central and Southern Ethiopia. University of Oxford. Imperial Forestry Institute Paper no. 24.

MEYER H A (1953) Forest Mensuration. Pennsylvania, USA : Penns Valley Publishers Inc.

MINISTRY OF OVERSEAS DEVELOPMENT (1974) The Democratic Republic of the Sudan and adjacent areas. Geological Map. 1:2 000 000 scale. London.

PRATT D J, GREENWAY P J & GWYNNE M D (1966) A classification of East African rangeland. Journal of Applied Ecology, 369-382.

RUSUM P M (1976) Private communication; Ministry of natural resources, Forestry Department, Juba, Sudan.

STEPHENS E A (1976) Private communication. Institute of Geological Sciences, London.

SUDAN GOVERNMENT (1952) The Central Forest Ordinance 1932 – Equatoria Province Order (1952 LRO no. 11). Khartoum, Sudan : Government Gazette 840, Supplement 3.

TOTHILL A H (1955) Aims in the Imatongs. Empire Forestry Review. 34, 173-176.

TURNER J F & VERHAGEN J (1960) Igneous and metamorphic petrology. 2nd edition. New York, Toronto, London : McGraw-Hill Book Company Inc.

UNITED STATES DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE (1970) Soil taxonomy of the national co-operative soil survey. Selected chapters from this unedited text. Soil Survey, Soil Conservation Service, United States Department of Agriculture. Washington DC USA.

VIDAL-HALL M P (1952) The sylviculture and regeneration of the forest types of the Equatoria and Bahr el Ghazal Provinces. Forestry Memoir 4, Ministry of Agriculture, Sudan Government Khartoum.

WHITEHOUSE G T (1931) The Langia-Acholi Mountain Region of the Sudan-Uganda borderland. Geographical Journal. Feb.

WHITEMAN A J (1971) The geology of the Sudan Republic. Oxford : Clarendon Press.

Appendixes 1-7

Appendix 1

Volume tables for plantation species

LOCAL VOLUME TABLE FOR *CUPRESSUS LUSITANICA*

Range of data

A total of 113 trees were assessed for volume in order to calculate the regression of overbark merchantable volume on overbark diameter breast height (dbh). The diameter distribution of sample trees is given in Table 59.

Table 59 Overbark diameter distribution of sample trees

Dbh cm	No. of trees	Dbh cm	No. of trees
10	2	30	4
11	3	31	3
12	4	32	1
13	4	33	1
14	3	34	2
15	8	35	1
16	7	36	2
17	4	37	1
18	9	38	2
19	3	39	0
20	11	40	2
21	7	41	0
22	4	42	1
23	3	43	1
24	4	44	0
25	1	45	0
26	4	46	0
27	2	47	0
28	7	48	1
29	1	49	0

Regression calculation

The regression of merchantable volume (10 cm top diameter) on overbark breast height diameter (dbh) was found to have a good straight line fit; the equation being calculated as

$$V = 0.04448\ D - 0.53573$$

where V = overbark volume in m^3 to 10 cm top diameter and D = breast height overbark diameter in cm.

The correlation coefficient for the regression was calculated to be 0.96 and the corresponding value of r^2, was therefore 0.93 indicating that 93% of the variation of the dependent variable could be explained by the regression equation. This degree of fit is illustrated in Figure 6.

Volume table

Table 60 is a one-way volume table derived from the above regression.

Table 60 Merchantable overbark volume table for *Cupressus lusitanica*

Dbh cm	Volume m^3	Dbh cm	Volume m^3
15	0.131	33	0.932
16	0.176	34	0.976
17	0.220	35	1.020
18	0.265	36	1.065
19	0.309	37	1.110
20	0.354	38	1.154
21	0.398	39	1.199
22	0.443	40	1.243
23	0.487	41	1.288
24	0.532	42	1.332
25	0.576	43	1.377
26	0.621	44	1.421
27	0.665	45	1.466
28	0.710	46	1.510
29	0.754	47	1.555
30	0.800	48	1.599
31	0.843	49	1.644
32	0.888	50	1.688

TANZANIA STANDARD VOLUME TABLE FOR *PINUS PATULA*

An extract from the volume table for *Pinus patula* constructed by Ackhurst and Micski (1971) in Tanzania is presented in Table 61.

Table 61 Merchantable overbark volume table by height class for *Pinus patula*, m^3

Dbh cm	Height class, m					
	5	10	15	20	25	30
15	0.036	0.074	0.113	0.153	0.193	0.234
16	0.042	0.087	0.133	0.180	0.227	0.275
17	0.049	0.100	0.153	0.207	0.262	0.317
18	0.055	0.114	0.175	0.236	0.298	0.361
19	0.062	0.128	0.196	0.265	0.335	0.406
20	0.069	0.143	0.218	0.295	0.373	0.452
21	0.076	0.158	0.241	0.326	0.412	0.499
22	0.084	0.173	0.264	0.357	0.452	0.547
23	0.091	0.188	0.288	0.390	0.492	0.596
24	0.099	0.204	0.312	0.422	0.534	0.646
25	0.107	0.220	0.337	0.456	0.576	0.698
26	0.115	0.237	0.363	0.490	0.620	0.750
27	0.123	0.254	0.389	0.525	0.664	0.804
28	0.131	0.271	0.415	0.561	0.709	0.858
29	0.140	0.289	0.442	0.598	0.755	0.914
30	0.149	0.307	0.470	0.635	0.803	0.972
31	0.157	0.326	0.498	0.673	0.851	1.030
32	0.167	0.344	0.527	0.712	0.900	1.089
33	0.176	0.364	0.556	0.752	0.950	1.150
34	0.185	0.383	0.586	0.792	1.001	1.212
35	0.195	0.403	0.617	0.834	1.054	1.275
36	0.205	0.424	0.648	0.876	1.107	1.340
37	0.215	0.444	0.680	0.919	1.161	1.406
38	0.225	0.465	0.712	0.963	1.216	1.472
39	0.235	0.487	0.745	1.007	1.273	1.541
40	0.246	0.509	0.775	1.052	1.330	1.610
41	0.257	0.531	0.813	1.099	1.388	1.681
42	0.268	0.554	0.847	1.146	1.448	1.752
43	0.279	0.577	0.883	1.193	1.508	1.826
44	0.290	0.601	0.919	1.242	1.569	1.900
45	0.302	0.624	0.955	1.291	1.632	1.975
46	0.314	0.649	0.992	1.342	1.695	2.052
47	0.326	0.673	1.030	1.393	1.759	2.130
48	0.338	0.698	1.068	1.444	1.825	2.209
49	0.350	0.724	1.107	1.497	1.892	2.290
50	0.362	0.750	1.147	1.550	1.989	2.371

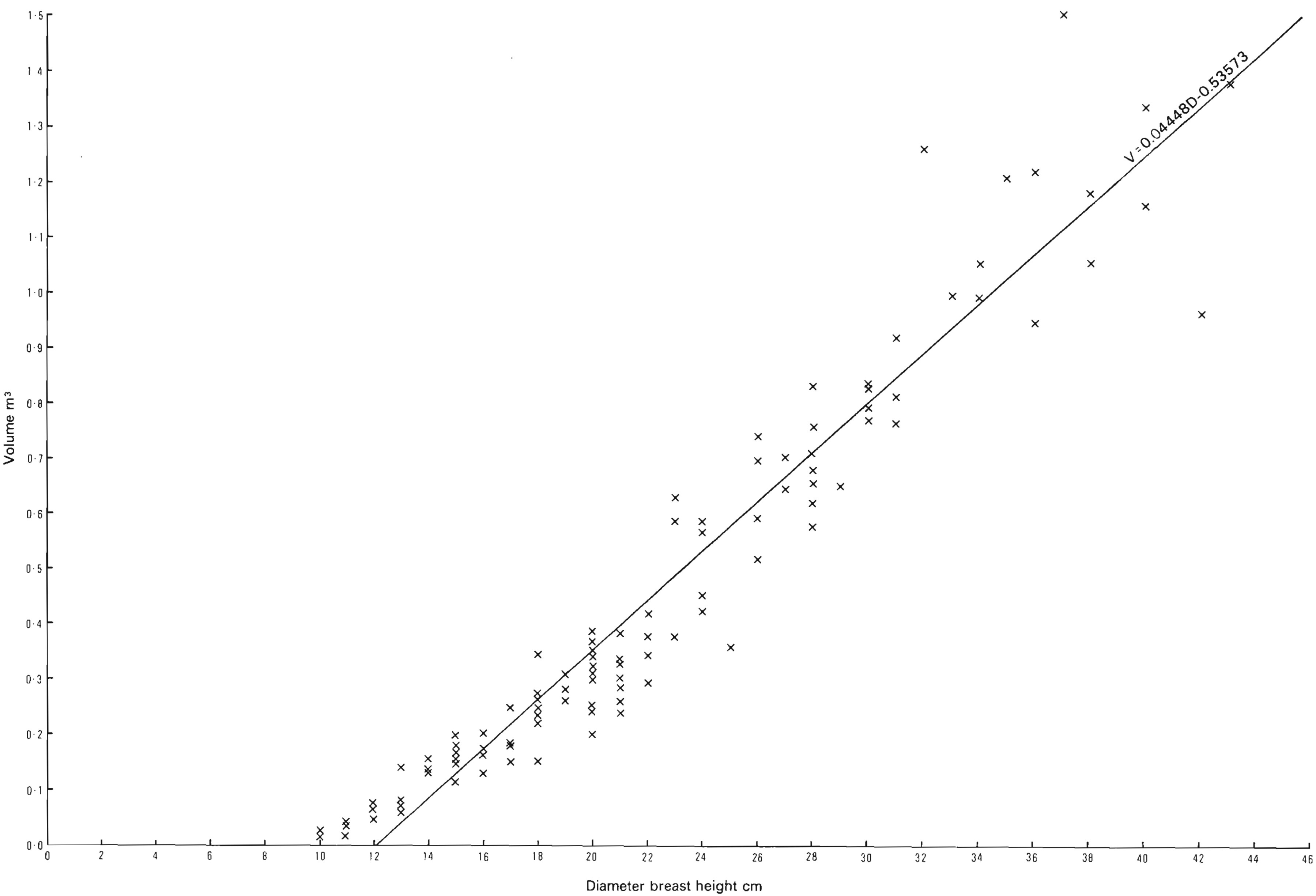


FIGURE 6 Volume/diameter regression line for *Cupressus*

LRD/SUD/RNJ/8F

Prepared by Land Resources Division 1976

The volume table for *Pinus patula* was constructed by Ackhurst and Micski (1971) using the equation

$$\log_{10}V = -4.11086 + 1.7316 \log_{10}D + 1.0483 \log_{10}H$$

where V = total volume in m^3, D = diameter breast height in cm, and H = total height in m.

Merchantable overbark volume to a 10 cm top diameter was derived by multiplying the total volume by a conversion factor F,

where $F = 0.9897 - 5.4384\, e^{-0.5555\, D}$

Appendix 2

Stem analysis for Cupressus

GENERAL

Stem analysis is a technique whereby a 'picture' of the past growth of a single tree in graphical and quantitative terms can be derived. In a well managed forest enterprise growth parameters are derived from regularly monitored sample plots. In a situation such as exists in the Imatong Central Forest Reserve, where no intermediate growth figures are available for the mature plantations, with coniferous species stem analysis is the only method of obtaining such figures.

For the results to apply to a complete stratum it would be necessary to fell and examine a number of trees. Because of the short time available for fieldwork it was possible to examine only one tree in the present study, therefore the results only give an indication of the kind of growth rate being attained in the plantations and they should not be extrapolated to apply to complete compartments.

PROCEDURE

A dominant, well-formed tree of *Cupressus lusitanica* in Compartment 6 (age 27-28 years) was felled as close to the ground as possible. After snedding total height and timber height (to 10 cm top diameter) were recorded. Discs, 2-3 cm thick, were then removed at the stump, at breast height, at 3 m, at 6 m and at 3 m intervals up to timber height. Growth rings were found to be clear and the interpretation was not complicated by the presence of false rings.

Two diameters at right angles to one another and passing through the growth centre were drawn on one side of each disc. Working from the outside towards the centre, the points at which the diameters crossed the 27th, 22nd and each previous 5-year growth ring were marked. The two diameters corresponding to ages 2, 7, 12, 17, 22 and 27 years were then measured and the means of the two diameters were used in subsequent volume calculations. Total tree volumes at the above ages were calculated using Smalian's formula

$$\text{Tree volume} = \frac{A_1 + A_2}{2} \times L$$

where A_1 and A_2 are the areas at each end of a log and L is the length of the log, i.e. 3 m.

The top section was regarded as a cone in which

$$\text{Volume} = \frac{\pi}{3} r^2 L_1$$

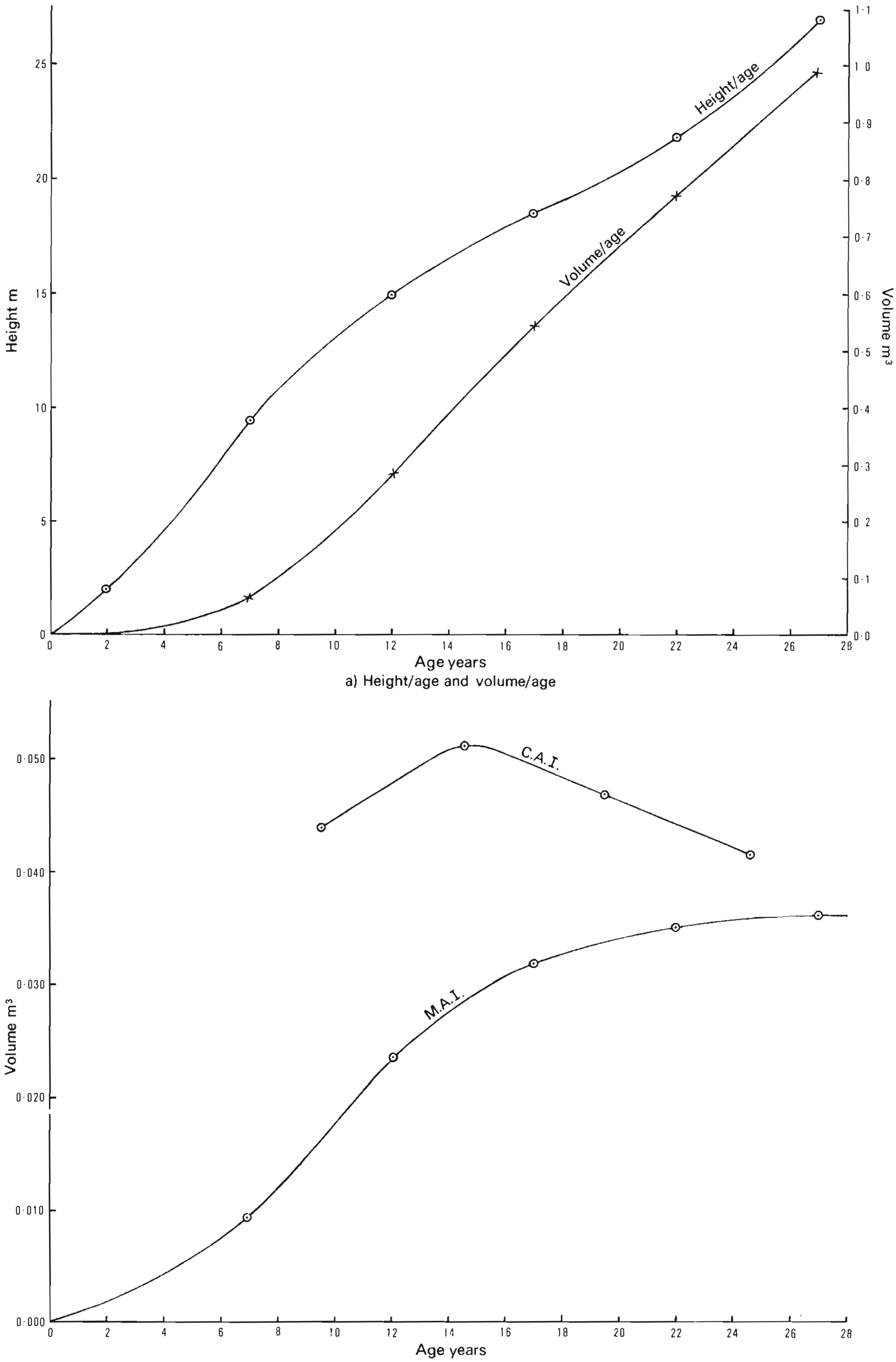
Where r = 5 cm, and L_1 = total height – timber height

Graphs illustrating the relationship between age and height, total tree volume and volume increment (mean annual increment and current annual increment) were constructed (see Figure 7), together with a diagram (Figure 8) illustrating the development of diameter throughout the length of the tree with age.

RESULTS

At felling the diameter breast height was 36.5 cm and total overbark volume was calculated to be 1.094 m^3, merchantable volume to 10 cm top was 1.080 m^3, conforming very closely to the *Cupressus* volume table. Underbark volume was 0.983 m^3 and the bark percentage was therefore 11%.

The current annual increment declined after reaching a maximum value of about 0.052 m^3/a at 14-15 years. The mean annual increment appears to reach its peak value of about 0.037 m^3/a at about age 28 years.



a) Height/age and volume/age

b) Current annual increment/age and mean annual increment/age

FIGURE 7 Relationship of height, volume, current annual increment and mean annual increment with age for *Cupressus*

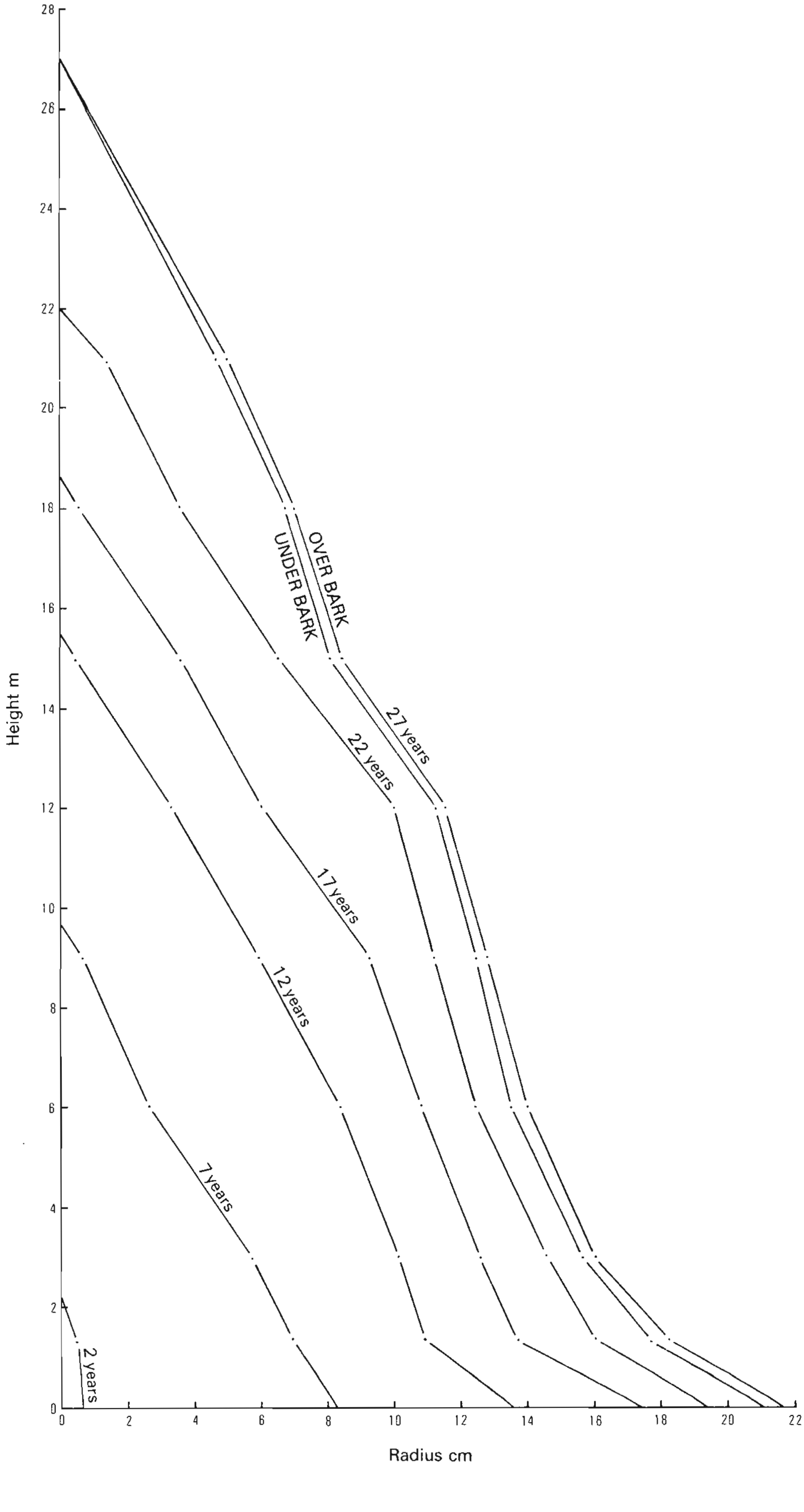


FIGURE 8 Stem analysis of 27-year-old *Cupressus lusitanica* showing radial and height development at 2, 7, 12, 17, 22 and 27 years

LRD/SUD/RNJ/8H

Prepared by Land Resources Division 1976

Appendix 3

Compartment descriptions

Compartment 1

Planted	1941
Area	3.4 ha
Species	Majority of this compartment has been clear felled. Small areas of Eucalypts, *Podocarpus* and *Juniperus procera* to the south of the track
Site	Main NW aspect; 8-10^{o} slope; some woody regrowth and variable forb/herb layer; Lohocho and Ngairigi Soil Series
Stand	Most of this compartment (formerly *C. lusitanica*) has been clear felled and now covered with indigenous regrowth
Recommendation	To be replanted. Eucalypts, *Podocarpus* and Juniper to be left as amenity plantings

Compartment 2

Planted	1943
Area	6.9 ha
Species	1. *C. lusitanica* 2. *Podocarpus milanjianus* 3. *P. gracilior* and 4. *Juniparus procera* planted in separate blocks

Diam. breast ht.	1. 35.7 ± 3.5 cm	2. 15.5 cm	3. 21.7 cm	4. n.s.
Mean top ht.	1. 29.2 m	2. 18.0 m	3. 24.5 m	4. n.s.
Stems/ha	1. 608 ± 151	2. 1 200	3. 1 575	4. n.s.
Basal area	1. 66.4 ± 10.3 m^2/ha	2. 24.5 m^2/ha	3. 65.4 m^2/ha	4. n.s.
RME volume	1. 568 m^3/ha	2. 159 m^3/ha*	3. 408 m^3/ha*	4. 250 m^3/ha*

Site	N aspect; 10^{o} slope; medium dense forb/herb layer; Lohocho, Ngairigi and Nabakin Soil Series
Stand	1. A good mature crop, overstocked and partly pruned; boles tend to be fluted and some stem crack is evident 2. Stem form generally good but marked tendency towards early forking 3. Stem form fair, some persistent dead branches and a tendency towards early forking 4. Highly overstocked, excellent straight stems
Recommendation	Clear felling, priority 2; if possible *Podocarpus* and *Juniperus* could be retained as a conservation area

n.s. not sampled * mean volume ** estimate only RME = reliable minimum estimate

Compartment 3

Planted	1944-6
Area	2.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	41.7 ± 5.8 cm
Mean top ht.	31.8 m
Stems/ha	410 ± 267
Basal area	57.8 ± 9.1 m^2/ha
RME volume	497 m^3/ha
Site	NW aspect; 8° slope; variable ground cover but mainly low, medium-dense herbaceous layer; Lohocho, Sahue and Ngairigi Soil Series
Stand	Generally good stem form, some high pruning has been carried out; standing at an acceptable final stocking
Recommendation	Clear felling, priority 2

Compartment 4

Planted	1947
Area	9.9 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	32.2 ± 3.8 cm
Mean top ht.	31.6 m
Stems/ha	616 ± 115
Basal area	52.4 ± 5.2 m^2/ha
RME volume	482 m^3/ha
Site	N aspect; 10° slope; no ground cover; Lohocho and Ngairigi Soil Series
Stand	Excellent mature crop, stem form generally very good; overstocked
Recommendation	To be retained as a temporary seed stand. A heavy thinning to about 200 stems/ha to be carried out following careful selection of the seed trees

Compartment 5

Planted	1948
Area	21.2 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	33.5 ± 4.6 cm
Mean top ht.	27.5 m
Stems/ha	590 ± 184
Basal area	62.8 ± 8.6 m^2/ha
RME volume	550 m^3/ha
Site	W to NE aspect; 15-25° slope; ground cover variable from absent to very thick herbaceous layer; Gilo, Nabakin and Ngairigi Soil Series
Stand	Extremely variable compartment, stocking somewhat irregular; western half of compartment is dissected by three *Eucalyptus saligna* windbreaks, two to three trees wide; there is a small area of *E. tereticornis* at the SE end of the compartment which is showing signs of severe leader dieback
Recommendation	Clear felling, priority 2

Compartment 6

Planted	1948
Area	4.1 ha
Species	Mainly *C. lusitanica,* some *Pinus radiata* intermixed
Diam. breast ht.	34.4 ± 9.2 cm
Mean top ht.	29.5 m
Stems/ha	616 ± 215
Basal area	56.8 ± 7.5 m^2/ha
RME volume	502 m^3/ha
Site	N aspect; 15° slope; very little ground vegetation; Lohocho and Ngairigi Soil Series
Stand	Form of the *Cupressus* generally good; an especially fine stand adjacent to the rest house; persistent dead branching and stem crack has spoilt many trees however
Recommendation	Clear felling, priority 2

Compartment 7

Planted	1949
Area	4.5 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	30.5 ± 1.0 cm
Mean top ht.	30.0 m
Stems/ha	640 ± 357
Basal area	49.5 ± 7.6 m^2/ha
RME volume	430 m^3/ha
Site	N aspect; 15° slope; no ground vegetation; Lohocho, Ngairigi and Nabakin Soil Series
Stand	An extremely fine stand. Crop has been high pruned to around 6 m. Slightly overstocked but further thinning considered not worthwhile
Recommendation	Clear felling, priority 2

Compartment 8

Planted	1949
Area	21.2 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	25.8 ± 2.1 cm
Mean top ht.	28.1 m
Stems/ha	1 180 ± 190
Basal area	68.7 ± 10.3 m^2/ha
RME volume	617 m^3/ha
Site	N aspect; 13° slope; no ground vegetation; Ngairigi, Nabakin and Lohocho Soil Series
Stand	Variable compartment in both stocking and quality of the crop. Western half has been more intensively thinned and is generally excellent. However whole compartment is grossly overstocked.
Recommendation	Clear felling, priority 2

Compartment 9

Planted	1949
Area	6.0 ha
Species	*Cupressus lusitanica*
Diam breast ht.	27.2 ± 6.3 cm
Mean top ht.	26.0 m
Stems/ha	675 ± 103
Basal area	36.7 ± 5.4 m^2/ha
RME volume	328 m^3/ha
Site	NE to E aspect; 13^o slope; light woody ground vegetation; Ngairigi and Nabakin Soil Series
Stand	Extremely patchy compartment, stocking being very irregular. A little wind blow, but not at a serious level. Stem form of the crop fair
Recommendation	Clear felling, priority 2

Compartment 10

Planted	1949
Area	3.1 ha
Species	*Pinus radiata* and *Cupressus lusitanica*
Diam. breast ht.	23.7 ± 6.5 cm
Mean top ht.	27.0 m
Stems/ha	427 ± 58
Basal area	22.2 ± 3.2 m^2/ha
RME volume	209 m^3/ha
Site	SE aspect; 18^o slope; little ground cover as a result of recent fire; Lohocho and Gilo Soil Series
Stand	Fairly extensive wind damage resulting in stem snap and partial windblow. Access is poor to this compartment
Recommendation	Clear felling, priority 2

Compartment 11

Planted	1950
Area	11.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	29.2 ± 4.1 cm
Mean top ht.	28.8 m
Stems/ha	728 ± 267
Basal area	48.3 ± 7.5 m^2/ha
RME volume	420 m^3/ha
Site	W aspect; 11^o average slope; variable ground vegetation, sparse to dense, woody growth of 2 m; Gilo Soil Series.
Stand	There is some windblow in this compartment, particularly in the NW corner, but majority of the compartment can be regarded as stable
Recommendation	Clear felling, priority 2

Compartment 12

Planted	1950
Area	11.8 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	27.0 ± 3.3 cm
Mean top ht.	23.7 m
Stems/ha	716 ± 254
Basal area	43.0 ± 7.2 m^2/ha
RME volume	359 m^3/ha
Site	Both E and W aspects; 28° average slope, but over 35° in places; Lohocho and Nabakin Soil Series. Considered in two parts for stand description and management purposes
Stand	Eastern half: moderate slopes but fairly extensive windblow and prolific regrowth of indigenous species. Western half: extends along the western edge of Observation Hill and is characterised by extremely severe slopes and rocky outcrops, but windblow is surprisingly limited. However the edge of the compartment adjacent to the road is extensively indented as a result of the crop completely failing at an early stage. Stem form generally good, branching light though the crop has been left unthinned and unpruned. The dense stocking is reduced in areas by the presence of rock outcrops.
Recommendation	Eastern half: clear felling, priority 1 Western half: clear felling at same time as Compartment 8, priority 2

Compartments 13 & 14

The boundaries of the original Compartments 13 and 14 have been altered and renumbered as Compartments 28 & 29 respectively

Compartment 15

Planted	1951
Area	22.3 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	29.7 ± 5.6 cm
Mean top ht.	25.7 m
Stems/ha	424 ± 240
Basal area	35.2 ± 5.2 m^2/ha
RME volume	315 m^3/ha
Site	NW aspect; 13° average slope; ground cover mainly light; Ngairigi, Nabakin and Lohocho soil series
Stand	Fairly extensive windblow throughout this compartment. The crop has rather heavy branching
Recommendation	Clear felling, priority 1

Compartments 16 & 17

The boundaries of the original Compartments 16 have been altered and renumbered Compartments 75 and 76. The original Compartment 17 does not exist

Compartment 18

Planted	1954
Area	10.4 ha
Species	*Cupressus lusitanica* and *Pinus patula*
Diam. breast ht.	23.3 ± 4.5 cm
Mean top ht.	22.9 m
Stems/ha	930 ± 370
Basal area	42.9 ± 4.9 m^2/ha
RME volume	394 m^3/ha
Site	NW aspect; 27° slope; no ground vegetation; Ngairigi, Sahue and Lohocho Soil Series
Stand	The compartment is mainly *Cupressus,* but a belt of *Pinus patula* has been planted adjacent to a section of Observation Hill. *Cupressus* has excellent stem form and light branching. Unthinned but stocking variable. Appears to have been pruned to about 2 m. No windblow
Recommendation	Thinning to 700 stems/ha removing 25% of the standing crop, priority 1

Compartment 19

This compartment is now included within Compartment 28 along with the original Compartment 14

Compartment 20

Planted	c. 1956-60
Area	7.2 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	19.3 ± 2.8 cm
Mean top ht.	21.5 m
Stems/ha	947 ± 252
Basal area	34.5 ± 4.0 m^2/ha
RME volume	320 m^3/ha
Site	W aspect; 15° average slope; no ground vegetation; Gilo, Lohocho and Ngairigi Soil Series
Stand	A variable crop in both form and stocking. Patchy windblow throughout this compartment
Recommendation	Thinning to 700 stems/ha removing 25% of the standing crop, priority 1

Compartment 21

Planted	c. 1957
Area	6.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	24.0 ± 3.9 cm 18.9 m 880 ± 5.6 39.3 ± 5.6 m^2/ha 352 m^3/ha
Site	SW aspect; 15^o slope; no ground vegetation; Lohocho and Gilo Soil Series
Stand	An unthinned, unpruned crop of *Cupressus.* Form generally fair, a little windblow (less than 5%). Crop open in parts as a result of natural thinning and early losses
Recommendation	Pruning to 2.2 m to assist with access for marking and thinning to around 650 stems/ha removing 25% of the standing crop, priority 1

Compartment 22

Planted	c. 1960
Area	12.9 ha
Species	*Pinus patula*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	17.8 ± 2.2 cm 18.7 m 1 400 ± 462 36.0 ± 3.8 m^2/ha 219 m^3/ha
Site	SW aspect; 20^o slope; no ground vegetation; Sahue, Lohocho and Ngairigi Soil Series
Stand	Compartment in three distinct blocks. Highly exposed site with rock outcrops in parts, but no windblow. Stocking very variable but crop has not been thinned or pruned. Stem form generally good but spoilt by persistent dead branches
Recommendation	Careful thinning to around 1 050 stems/ha removing 25% of standing crop. To be pruned to 2.2 m prior to thinning, priority 1

Compartment 23

Planted	c. 1966
Area	8.9 ha
Species	*Cupressus lusitanica*
Site	S aspect; slope not measured; dense woody regrowth; Lohocho Soil Series
Stand	Failed compartment
Recommendation	To be cleared and replanted with *Pinus* sp. because of exposed nature of the site

Compartment 24

Planted	c. 1961
Area	8.6 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	20.4 ± 1.9 cm
Mean top ht.	16.8 m
Stems/ha	700 ± 204
Basal area	17.8 ± 5.6 m^2/ha
RME volume	142 m^3/ha
Site	S aspect; 5^o slope; no ground vegetation; Ngairigi and Nabakin Soil Series
Stand	Stocking very irregular and extensive regrowth of indigenous tree species
Recommendation	Compartment requires cleaning and a light thinning to 500 stems/ha. Pruning to 2.2 m will also be required prior to thinning. Priority 1

Compartment 25

Planted	c. 1960
Area	6.9 ha
Species	*Pinus patula*
Site	SW aspect; slope not assessed; extensive woody regrowth and thicket, dense in places, restricting access; Lohocho Soil Series
Stand	Mainly a failed compartment
Recommendation	Clearing and replanting

Compartment 26

Planted	c. 1966
Area	2.1 ha
Species	*Pinus patula*
Site	SW aspect; slope not measured; herb and forb regrowth
Stand	Compartment considered too young for sampling. Lohocho and Nabakin Soil Series
Recommendation	Pruning to 2.2 m as a low priority

Compartment 27

Planted	c. 1973
Area	21.1 ha
Species	*Cupressus lusitanica*
Site	S aspect; slope not measured; variable herb and forb growth; Lohocho, Nabakin and Ngairigi Soil Series
Stand	Recently planted compartment, weeding has been neglected
Recommendation	Compartment should be given one further weeding (poorly weeded at time of inspection) and a survival count made with a view to possibly beating up

Compartment 28

Planted	1951
Area	18.4 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	23.2 $\pm$ 1.9 cm
Mean top ht.	23.9 m
Stems/ha	904 $\pm$ 250
Basal area	36.2 $\pm$ 6.7 m^2/ha
RME volume	310 m^3/ha
Site	N aspect; 15^o slope; no ground vegetation over most of the compartment; Sahue, Nabakin and Ngairigi Soil Series
Stand	Originally planted at 1.5 x 1.5 m, unthinned but stocking irregular as a result of early losses. Scattered windblow throughout the compartment, severe in the area close to Itibol
Recommendation	Clear felling, priority 1

Compartment 29

Planted	1951
Area	12.8 ha
Species	*Cupressus lusitanica* plus some *Pinus radiata*
Diam. breast ht.	30.0 $\pm$ 4.2 cm
Mean top ht.	27.5 m
Stems/ha	620 $\pm$ 131
Basal area	34.1 $\pm$ 5.9 m^2/ha
RME volume	298 m^3/ha
Site	N aspect; 10^o slope; dense herb/grass layer, in places 1-2 m tall; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Crop over mature, with dead trees becoming evident. Scattered windblow
Recommendation	Clear felling, priority 1

Compartment 30

Planted	c. 1950
Area	7.7 ha
Species	Mainly *Pinus radiata* plus *Pinus patula*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	31.3 ± 3.7 cm 30.0 m 369 ± 126 29.1 ± 10.6 m^2/ha 200 m^3/ha
Site	Mainly N aspect; 8^o slope; dense ground vegetation of up to 2 m, restricting access in several areas; Nabakin and Ngairigi Soil Series
Stand	Mature crop, rather open in places. Many trees leaning and a tendency to form coarse branching
Recommendation	Clear felling, priority 1

Compartment 31

Planted	c. 1961
Area	11.4 ha
Species	*Pinus radiata*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	18.4 cm 22 m 675 20.6 m^2/ha* 195 m^3/ha*
Site	NE aspect; 10^o slope; dense woody regrowth throughout the compartment; Ngairigi Soil Series
Stand	This compartment has suffered severely from a complete lack of general maintenance and was only partly sampled. The crop is completely overgrown with woody regrowth which severely restricts access. The stocking and form of the crop is variable
Recommendation	Clearing and replanting, priority 2

Compartment 32

Planted	c. 1961 (est.)
Area	8.9 ha
Species	Mainly *Pinus radiata*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	12.6 cm 20 m 350 4.7 m^2/ha* 37 m^3/ha*
Site	NE aspect; 10^o slope; dense woody regrowth; Nabakin Soil Series
Stand	As for Compartment 31; namely completely overgrown by regrowth and the stocking of pine is very poor
Recommendation	Clearing and replanting, priority 2

* mean

Compartment 33

Planted	c. 1961
Area	4.3 ha
Species	Mainly *Pinus patula*
Diam. breast ht.	27.2 cm
Mean top ht.	19.5 m
Stems/ha	300
Basal area	19.5 m^2/ha*
RME volume	141 m^3/ha*
Site	NE aspect; 10^o slope; dense woody regrowth; Nabakin Soil Series
Stand	Suffering from complete neglect with dense regrowth of indigenous trees. However there are several excellent pine but their stocking is insufficient
Recommendation	Clearing along with Compartments 31 and 32 and replanting, priority 2

Compartment 34

Planted	c. 1956-61
Area	6.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	20.4 $\pm$ 2.2 cm
Mean top ht.	18.6 m
Stems/ha	1 053 $\pm$ 433
Basal area	35.3 $\pm$ 5.7 m^2/ha
RME volume	311 m^3/ha
Site	W aspect; 11^o slope; no ground vegetation; Lohocho, Nabakin and Ngairigi Soil Series
Stand	A reasonable unthinned crop. Stem form variable, there are several stems with butt sweep and varying degrees of sinuosity but should make a good crop following thinning. The crop has not been pruned
Recommendation	Pruning to 2.2 m and thinning to an average stocking of 750 stems/ha, priority 1. High pruning is unlikely to be worthwhile at this stage.

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* mean

Compartment 35

Planted	c. 1961-64
Area	17.1 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	19.0 ± 0.9 cm
Mean top ht.	15.7 m
Stems/ha	859 ± 87
Basal area	26.9 ± 4.0 m^2/ha
RME volume	240 m^3/ha
Site	E aspect; 15° slope; no ground vegetation, but there are unplanted areas where indigenous trees and associated ground vegetation do occur; Lohocho Soil Series
Stand	Mainly a dense unthinned crop, but there are open patches associated with rock outcrops. Stem form variable, many sinuous trees often with rather course branching, but should make an acceptable crop following thinning
Recommendation	Pruning to 2.2 m followed by thinning to an average stocking of 650 stems/ha (25% reduction), priority 1. High pruning should be worthwhile and it is recommended that the better 300 stems/ha are pruned to 6 m

Compartment 36

Planted	c. 1956-61
Area	7.2 ha
Species	Mainly *Cupressus lusitanica,* also *Pinus patula*
Diam. breast ht.	19.1 cm
Mean top ht.	not measured
Stems/ha	178
Basal area	4.63 m^2/ha*
RME volume	47 m^3/ha*
Site	An indefinite windblow area sampled by transect; Lohocho, Nabakin and Ngairigi Soil Series
Stand	
Recommendation	Clearing and replanting, priority 1

Compartment 37

Planted	c. 1955+
Area	2.5 ha
Species	*Acacia mollissima*
Site	Almost flat site; patches of dense forbs and shrubs; Nabakin Soil Series
Stand	A small area of open *Acacia* considered to be of little value or interest and consequently was not sampled
Recommendation	Leave or fell as required

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* mean

Compartment 38

Planted	not determined
Area	1.5 ha
Species	*Eucalyptus* sp.
Site	Almost flat site; no ground vegetation; Nabakin Soil Series
Stand	A small dense stand of *Eucalyptus* coppice. No measurements were made
Recommendation	Leave or fell as required

Compartment 39

Planted	c. 1960
Area	11.1 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	18.0 ± 1.6 cm
Mean top ht	20.3 m
Stems/ha	1 031 ± 386
Basal area	36.7 ± 6.0 m^2/ha
RME volume	322 m^3/ha
Site	NE aspect; 12° slope; ground vegetation nil or sparse; Lohocho, Ngairigi and Nabakin Soil Series
Stand	An unthinned well stocked compartment. Form generally good and should make an excellent compartment following thinning
Recommendation	Pruning to 2.2 m and thinning to an average stocking of 750 stems/ha, priority 1. High pruning of doubtful value at this age

Compartment 40

Planted	c. 1951-56
Area	0.2 ha
Species	*Pinus radiata*
Diam. breast ht.	15.8 cm
Mean top ht	27.3 m
Stems/ha	1 425
Basal area	31.1 m^2/ha*
RME volume	300 m^3/ha*
Site	E aspect; 10° slope; grass, sedge and herb layer of 0.5-1.5 m, access not restricted; Ngairigi Soil Series
Stand	Planted at 2 x 2 m and has not been thinned or pruned. Trees are badly leaning
Recommendation	Clear felling and replanting, priority 2

* mean

Compartment 41

Planted	c. 1960
Area	0.6 ha
Species	*Cupressus lusitanica*
Diam. breast ht	9.5 cm
Mean top ht.	16 m
Stems/ha	6 100
Basal area	46.4 m^2/ha*
RME volume	216 m^3/ha*
Site	Located on crest of a small hill, slope being 5^o in all directions; no ground vegetation; Ngairigi Soil Series
Stand	A small plot that has been close planted (1 x 1 m) and left unthinned; presumed to be an abandoned research area
Recommendation	Line thinning, removing alternate lines at right angles to reduce stocking to 1 500 stems/ha and thereafter to manage it as part of Compartment 39, as soon as it is brought to a comparable stocking. Prune to 2.2 m, priority 1

Compartment 42

Planted	1968 or later
Area	0.5 ha
Species	*Pinus patula*
Site	NW aspect; slope not measured; some regrowth; Lohocho Soil Series
Stand	Considered too young to be assessed
Recommendation	Cleaning operation will be required

Compartment 43

Planted	c. 1973
Area	2.6 ha
Species	*Cupressus lusitanica*
Site	S aspect; slope not measured; variable herb/forb regrowth; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Recently planted area
Recommendation	One further weeding required, followed by a survival count to indicate the need for a possible beating up

* mean

Compartment 44

Planted	c. 1971
Area	2.1 ha
Species	*Cupressus lusitanica*
Site	N aspect; slope not measured; extensive growth of weeds; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Too young for assessment
Recommendation	Cleaning and weeding operations are required

Compartment 45

Planted	c. 1966
Area	1.3 ha
Species	*Cupressus lusitanica*
Site	N aspect; slope not measured; no ground vegetation; Nabakin and Ngairigi Soil Series
Stand	Unthinned but part has been pruned to about 2 m. At an insufficient age and size for sampling
Recommendation	Completion of pruning and thinning to 750 stems/ha, priority 2

Compartment 46

Planted	c. 1961
Area	2.9 ha
Species	*Eucalyptus saligna*
Diam. breast ht.	45.5 cm
Mean top ht.	40 m
Stems/ha	133
Basal area	22.3 m^2/ha*
RME volume	325 m^3/ha*
Site	NE aspect; 10^o slope; dense ground vegetation of shrubs and creepers of 2-3 m high; Lohocho and Ngairigi Soil Series
Stand	The crop was planted at an espacement of 7 x 7 m, but some gaps have developed. The crowns have responded to the available growing space, and the crop is now fully mature
Recommendation	Clear felling, priority 2

* mean

Compartment 47

Planted	1968+ (est.)
Area	11.7 ha
Species	*Cupressus lusitanica* plus *Acacia mollissima*
Site	S aspect; slope not measured; extensive weed regrowth; Ngairigi and Nabakin Soil Series
Stand	Too young for sampling. Stocking appeared to be reasonable and should be a useful compartment
Recommendation	Cleaning operation in the near future to remove woody regrowth

Compartment 48

Planted	1954
Area	0.8 ha
Species	*Podocarpus milanjianus*
Diam. breast ht Mean top ht. Stems/ha Basal area RME volume	9.4 cm 9.3 m 1 334 9.5 m^2/ha* 10 m^3/ha*
Site	SW aspect; slope moderate but not measured; no ground vegetation; Ngairigi and Nabakin Soil Series
Stand	Well stocked, even stand of young *Podocarpus*
Recommendation	If maintained, this compartment should be thinned to 750 stems/ha. It is however of limited value and could well be clear felled along with Compartment 28

Compartment 49

Planted	c. 1961
Area	3.2 ha
Species	*Cupressus lusitanica* and *Pinus kesiya*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	21.2 $\pm$ 2.9 cm 20.4 m 974 $\pm$ 266 39.0 $\pm$ 5.8 m^2/ha 289 m^3/ha
Site	S aspect; 15^o slope; no ground vegetation; Ngairigi Soil Series
Stand	Made up of two sub-compartments; an area of pure *Cupressus* and an area of *Pinus kesiya/Cupressus* mixture, *P. kesiya* being the predominant species. The form of *P. kesiya* is average for unimproved stock of this species, namely rather sinuous and severe butt sweep
Recommendation	Should make an acceptable crop following thinning to 750 stems/ha, priority 2

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* mean

Compartment 50

Planted	1954
Area	4.2 ha
Species	*Pinus patula, P. radiata, P. caribaea, Podocarpus* sp. and *Cupressus lusitanica*
Diam. breast ht.	22.4 ± 6.6 cm*
Mean top ht.	25.2 m*
Stems/ha	772 ± 252*
Basal area	31.8 ± 8.6 m^2/ha*
RME volume	185 m^3/ha*
Site	W aspect; 20° slope; comprises mainly the original Compartment 20, though the boundaries have been amended; Lohocho and Nabakin Soil Series
Stand	Variable, overstocked area, but some excellent pine
Recommendation	Clear felling, priority 2

* Figures relate to the pines and *Cupressus* only

Compartment 51

Planted	c. 1951-56
Area	3.6 ha
Species	*Pinus patula*
Diam. breast ht	25.1 ± 2.2 cm
Mean top ht.	26.5 m
Stems/ha	792 ± 300
Basal area	38.8 ± 5.4 m^2/ha
RME volume	345 m^3/ha
Site	W aspect; 10° slope; minimal ground vegetation; Lohocho, Sahue and Ngairigi Soil Series
Stand	An overstocked semi-mature stand
Recommendation	Should make a reasonable crop following thinning to 500 stems/ha, priority 1. Considered too late to high prune

Compartment 52

Planted	c. 1961
Area	5.3 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	19.5 ± 4.3 cm
Mean top ht.	19.5 m
Stems/ha	1 253 ± 368
Basal area	40.6 ± 6.1 m^2/ha
RME volume	362 m^3/ha
Site	SW aspect; 16° slope; ground vegetation mostly absent; Lohocho, Sahue and Ngairigi Soil Series
Stand	Grossly overstocked compartment, some patchy windblow
Recommendation	Pruning to 2.2 m prior to thinning to about 900 stems/ha, priority 1

Compartment 53

Planted	1951-56
Area	1.3 ha
Species	*Cupressus lusitanica*
Diam. breast ht Mean top ht Stems/ha Basal area RME volume	23.1 ± 5.7 cm 26.5 m 1 093 ± 313 46.7 ± 7.0 m^2/ha 428 m^3/ha
Site	Mainly NW aspect; 16° slope; no ground vegetation; Lohocho, Sahue, Nabakin and Ngairigi Soil Series
Stand	Overstocked, but otherwise a good crop. A little windblow evident.
Recommendation	Thinning to 750 stems/ha, priority 1. Further pruning would not be worthwhile

Compartment 54

Planted	1961-64 (est.)
Area	0.5 ha
Species	*Pinus patula*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	17.5 ± 3.4 cm 18.5 m 1 220 ± 671 32.3 ± 3.7 m^2/ha 111 m^3/ha
Site	NE aspect; 15° slope; No ground vegetation, but a deep needle litter; Lohocho and Ngairigi Soil Series
Stand	Compartment is in two separate sections, separated by Compartment 59(A) – *Pinus radiata.* In addition Compartment 65 is regarded as belonging to the same stratum as Compartment 54. Crop is unthinned *Pinus patula* at an espacement of 2 x 2 m. Form is good but diameter growth has been reduced by lack of thinning
Recommendation	Thinning to give an average stocking of 750 stems/ha, followed by high pruning to 6 m on the better 300 stems/ha, priority 1

Compartment 55

Planted	1954
Area	3.7 ha
Species	Mainly *Pinus patula,* some *Cupressus lusitanica*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	28.4 cm 26 m 117 9 m^2/ha* 87 m^3/ha*
Site	W aspect; slope not measured; heavy woody regrowth; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Open, partially stocked compartment and could only be sampled adequately by a transect
Recommendation	Clear felling, priority 2

*mean

Compartment 56

Planted	1961 (est.)
Area	3.2 ha
Species	*Cupressus lusitanica*
Diam. breat ht. Mean top ht. Stems/ha Basal area RME volume	13.3 ± 2.0 cm 18.5 m 1 684 ± 630 31.1 ± 3.9 m^2/ha 289 m^3/ha
Site	NE aspect; 25° slope; no ground vegetation; Lohocho and Ngairigi Soil Series
Stand	Unthinned crop, though stocking is irregular with some patches of windblow. Form generally good and branching light
Recommendation	Pruning to 2.2 m prior to thinning to 1 250 stems/ha, priority 1. High pruning to 6 m on the better 300 stems/ha to be carried out following thinning. Thinning must be restricted to 25% at this stage if extensive windblow is to be avoided

Compartment 57

Planted	1956 (est.)
Area	4.4 ha
Species	*Pinus patula*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	22.0 ± 7.0 cm 26 m 774 ± 600 35.1 ± 4.7 m^2/ha 292 m^3/ha
Site	Mainly W aspect; 18° slope; ground vegetation mainly sparse, but in places where the canopy is open there is regrowth of *Albizia* sp. etc.; Lohocho and Ngairigi Soil Series
Stand	Dominants have good form
Recommendation	Crop could be thinned and maintained. However, since it is intended to clear fell all surrounding compartments, it is recommended that, for ease of management, this area be clear felled at the same time, priority 2

* mean

Compartment 58

Planted	c. 1956
Area	24.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	22.5 ± 1.7 cm 24.2 m 883 ± 215 35.5 ± 6.0 m^2/ha 322 m^3/ha
Site	Various aspects; 16° slope; ground vegetation very limited; Lohocho, Ngairigi and Gilo Soil Series
Stand	Original espacement appears to have been 4 x 1 m; the crop has not been thinned. This compartment is the one most affected by windblow, probably the result of the combination of fairly severe slopes and the irregular espacement used
Recommendation	Although the crop is reasonable in parts, it is considered that any thinning would promote further windblow. It is recommended, therefore, that the compartment should be clear felled and replanted with pine, priority 1

Compart 59

Planted	c. 1956
Area	6.0 ha
Species	*Pinus radiata*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	22.7 ± 5.1 cm 24.8 m 530 ± 223 21.9 ± 4.2 m^2/ha 172 m^3/ha
Site	N to NE aspect; 10° slope; ground vegetation generally sparse; Lohocho and Ngairigi Soil Series
Stand	Unthinned stand, though stocking is fairly open in parts. Considered in two sections A (2.3 ha) and B (3.7 ha) for management purposes. Section A lies between the two parts of Compartment 54, and B is situated to the West of Compartment 54 and is located both sides of the road
Recommendation	A: thinning to an average stocking of 300 steam/ha, priority 2, and maintenance for as long as is required to protect Compartments 54 and 56 from possible windblow. B: clear felling, priority 2

Compartment 60

Planted	c. 1961
Area	7.2 ha
Species	*Pinus kesiya*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	19.7 ± 2.1 cm 19.5 m 1 050 ± 444 31.2 ± 9.4 m^2/ha 172 m^3/ha
Site	Mainly NW aspect; 11° slope; no ground vegetation, but thick litter layer; Nabakin and Ngairigi Soil Series
Stand	Unthinned and unpruned crop. Growth has been vigorous but the stem form is typical of unimproved *P. kesiya,* namely rather sinuous with severe butt sweep, but a sufficient number of acceptable trees to make a final crop
Recommendation	Firstly, pruning to 2.2 m, followed by a thinning to 750 stems/ha, priority 1. High pruning of the better 300 stems/ha to 6 m should follow the thinning operations

Compartment 61

Planted	c. 1969
Area	1.7 ha
Species	*Pinus* spp.
Site	Almost flat site; light herb and forb regrowth; Ngairigi and Nabakin Soil Series
Stand	Too young for sampling
Recommendation	Pruning to 2.2 m priority 2

Compartment 62

Planted	c. 1964
Area	0.3 ha
Species	*Pinus caribaea*
Site	N aspect; slope not measured; no ground vegetation; Ngairigi and Nabakin Soil Series
Stand	This small trial plot was not sampled. Growth was seen however to be vigorous and form is good
Recommendation	Pruning to 2.2 m and then thinned to an average stocking of 750 stems/ha, priority 2

Compartment 63

Planted	c. 1956
Area	4.7 ha
Species	*Pinus radiata*
Diam. breast ht.	15.1 ± 2.2 cm
Mean top ht.	25.7 m
Stems/ha	1 427 ± 526
Basal area	30.0 ± 4.6 m^2/ha
RME volume	270 m^3/ha
Site	N aspect; 13° slope; ground vegetation sparse or absent; Lohocho and Ngairigi Soil Series
Stand	Crop has not been thinned or pruned, and except for some dominants, is generally of poor form. There has been a lot of stem snap in this compartment, together with scattered windblow. Branching tends to be coarse
Recommendation	Clear felling, priority 2

Compartment 64

Planted	1956-61 (est.)
Area	0.9 ha
Species	*Pinus radiata*
Diam. breast ht.	15.7 cm
Mean top ht.	22 m
Stems/ha	800
Basal area	13.8 m^2/ha*
RME volume	158 m^3/ha*
Site	NW aspect, 16° slope; light herb layer, no restriction to access Lohocho and Ngairigi Soil Series
Stand	Very poor, patchy crop of little value
Recommendation	To be thinned and maintained, priority 2. Clear felling might well result in the initiation of windblow in the adjacent areas of Compartment 66

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* mean

Compartment 65

Planted	1961-64 (est.)
Area	2.6 ha
Species	*Pinus patula*
Diam. breat ht.	*
Mean top ht.	*
Stems/ha	*
Basal area	*
RME volume	*
Site	Located around a small hill and therefore has several aspects; 15° slope; no ground vegetation, but deep needle litter; Lohocho and Ngairigi Soil Series
Stand	*Unthinned crop, considered to belong to the same stratum as Compartment 54; the growth parameters for the latter compartment therefore apply
Recommendation	Thinning to 750 stems/ha following pruning to 2.2 m, priority 1. After thinning the better 300 stems/ha should be pruned to 6 m

Compartment 66

Planted	1961 (est.)
Area	12.9 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	17.3 ± 1.7 cm
Mean top ht.	24.3 m
Stems/ha	1 617 ± 375
Basal area	42.1 ± 6.1 m^2/ha
RME volume	369 m^3/ha
Site	Compartment runs along a ridge with aspects to both E and W; 12° slope; no ground vegetation; Lohocho and Ngairigi Soil Series
Stand	Unthinned compartment of *Cupressus* originally planted at 2 x 1 m. It has been brashed to about 2 m. There is no windblow within the compartment, but some occurs along the whole of the western boundary of the compartment and particularly towards the northern end
Recommendation	Thinning to 1 250 stems/ha (25% opening of the canopy) at first thinning, priority 1. High pruning to 6 m on the better 300 stems/ha should be worthwhile following the thinning

Compartment 67

Planted	c. 1956
Area	4.3 ha
Species	*Pinus patula*
Diam. breast ht.	22.1 ± 2.9 cm
Mean top ht.	26.4 m
Stems/ha	654 ± 329
Basal area	29.9 ± 5.5 m^2/ha
RME volume	257 m^3/ha
Site	N aspect; 18° slope; ground vegetation is a light herb/grass layer, dense in places, but not restricting access; Lohocho and Ngairigi Soil Series
Stand	There are scattered indigenous trees within this compartment. The crop is overstocked and diameters are very variable. Branching is rather coarse in some individuals. Generally however a good crop with no windblow
Recommendation	Compartment should be retained and thinned to an average stocking of 300 stems/ha, priority 2. If it were to be clear felled immediately,windblow within Compartment 66 would be extended

Compartment 68

Planted	c. 1964
Area	6.0 ha
Species	*Pinus patula*
Diam. breast ht.	17 cm
Mean top ht.	14.5 m
Stems/ha	80
Basal area	1.8 m^2/ha*
RME volume	11 m^3/ha*
Site	NW aspect; 12° slope; dense indigenous tree regrowth; Lohocho, Ngairigi and Nabakin Soil Series
Stand	A poorly stocked compartment of no value
Recommendation	Clear felling and replanting, priority 2

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* mean

Compartment 69

Planted	c. 1956
Area	1.2 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	18.7 cm
Mean top ht.	23 m
Stems/ha	1 067
Basal area	38.5 ± 6.8 m^2/ha
RME volume	331 m^3/ha
Site	W aspect; 13° slope; no ground vegetation; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Unthinned crop, planted at 2 x 1 m, though some natural thinning has taken place. Patchy windblow
Recommendation	Clear felling together with Compartment 68, priority 2

Compartment 70

Planted	c. 1956-61
Area	6.9 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	19.9 ± 3.0 cm
Mean top ht.	21.6 m
Stems/ha	855 ± 263
Basal area	29.3 ± 4.4 m^2/ha
RME volume	266 m^3/ha
Site	This compartment is composed of three adjacent blocks, S and N aspect; 17° slope; no ground vegetation; Lohocho Soil Series
Stand	An unthinned crop originally planted at 2 x 2 m and 2 x 1 m; stocking is irregular however as a result of rock outcrops. Growth and form of crop generally good. Very little windblow
Recommendation	Thinning to an average stocking of 700 stems/ha together with Compartment 71, priority 1

Compartment 71

Planted	1956-61
Area	2.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	20.4 ± 1.2 cm
Mean top ht.	23.2 m
Stems/ha	930 ± 510
Basal area	42.7 ± 7.4 m^2/ha
RME volume	367 m^3/ha
Site	This compartment is composed of two adjacent blocks, mainly S aspect; 16° slope; no ground vegetation; Lohocho, Ngairigi and Nabakin Soil Series
Stand	Planted at 2 x 1 m and unthinned. No complete windblow, but many trees are badly leaning
Recommendation	Thinning to 700 stems/ha, priority 1

Compartment 72

Planted	1956-61
Area	0.5 ha
Species	*Pinus patula*
Diam. breast ht.	19.6 cm
Mean top ht.	23 m
Stems/ha	520
Basal area	20.4 $\pm$ 6.5 m^2/ha
RME volume	181 m^3/ha*
Site	SW aspect; 24^o slope; ground cover of herbs up to 50 cm; Nabakin Soil Series
Stand	A very small, unthinned stand of *P. patula*
Recommendation	Clear felling, but considered to be of low priority

Compartment 73

Planted	c. 1951
Area	2.9 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	24.5 cm
Mean top ht.	24.5 m
Stems/ha	400
Basal area	28.4 $\pm$ 7.9 m^2/ha
RME volume	223 m^3/ha
Site	W aspect; 10^o slope; Sahue Soil Series
Stand	Very patchy compartment which was problably much larger when originally planted but has been encroached by indigenous regrowth. The compartment is considered to be too poor for any salvage treatments
Recommendation	Clear felling, priority 2

Compartment 74

Planted	c. 1951-56
Area	1.3 ha
Species	*Pinus radiata*
Diam. breast ht.	21.3 cm
Mean top ht.	23.5 m
Stems/ha	480
Basal area	23.0 $\pm$ 3.1 m^2/ha
RME volume	217 m^3/ha
Site	SW aspect; 20^o slope; ground cover of dense ferns and shrubs, extensive indigenous regrowth; Nabakin Soil Series
Stand	A very patchy crop that has suffered from lack of management
Recommendation	Clear felling, priority 2

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* mean

Compartment 75

Planted	1950
Area	9.0 ha
Species	*Cupressus lusitanica*
Diam. breast ht	30.8 ± 5.9 cm
Mean top ht	25 m
Stems/ha	410 ± 211
Basal area	38.7 ± 5.6 m^2/ha
RME volume	344 m^3/ha
Site	S aspect; 30° slope; variable ground cover, being almost absent in established plantation area, but dense herb/grass and shrubs in windblow sections, prolific *Cupressus* regeneration in open area; Lohocho Soil Series. Formerly part of the old Compartment 16
Stand	A compartment of very variable stocking, which is best considered in two halves. The western half has suffered from extensive windblow and is open. The eastern half, situated in fairly rocky terrain, is supporting a more uniform crop which is less affected by windblow
Recommendation	Clear felling, priority 2

Compartment 76

Planted	1948
Area	1.7 ha
Species	*Cupressus lusitanica*
Diam. breast ht.	28.8 ± 10.7 cm
Mean top ht.	31 m
Stems/ha	734 ± 459
Basal area	58.0 ± 7.8 m^2/ha
RME volume	512 m^3/ha
Site	SE aspect; 20° slope; no ground vegetation; Lohocho and Ngairigi Soil Series. Formerly part of the old compartment 16
Stand	Overstocked, mature crop with very heavy branching. The suppressed trees are either dead or dying
Recommendation	Clear felling, priority 2

Compartment 77

Planted	1950
Area	0.5 ha
Species	*Pinus patula*
Diam. breast ht. Mean top ht. Stems/ha Basal area RME volume	19.4 cm 30 m 933 31.2 $\pm$ 6.2 m^2/ha 432 m^3/ha*
Site	E aspect. 12^o slope; sparse ground cover, however some indigenous tree regeneration; Lohocho Soil Series
Stand	A very small stand situated on a rocky site with shallow soils. Dominant trees have shown good growth and form
Recommendation	Clear felling, priority 2

Compartment 78

Planted	1973-75
Area	13.4 ha
Species	*Cupressus lusitanica*
Site	N aspect; slope not measured; herb and forb regrowth; Lohocho and Ngairigi Soil Series
Stand	Young crop of *Cupressus* which appears to have been replanted several times, age being estimated at 1-3 years
Recommendation	This crop will require one or two further weedings and a survival count should be made to establish the need for further beating up

* mean

Appendix 4

Thinning and pruning schedules

Table 62 is meant only as a guide, since it is somewhat unrealistic to specify management prescriptions until a better idea is known of firstly, market requirements in terms of size and quality and secondly, the growth rates of well managed plantations.

The schedule is based to a limited extent on East African experience (Dyson, 1962). The pruning prescription is designed to produce an 8-9 m log with the knotty core restricted to less than 10 cm diameter. It is possible that the demand for knot-free timber will be insufficient to cover the extra premium required for such timber, in which case the pruning prescriptions would be reduced. Assumed planting distance is 2.58 x 2.58 m (1 500/ha).

TABLE 62 Thinning and pruning schedules for *Cupressus lusitanica* and *Pinus patula*

Operation	Mean top height m	Approx age years	Thinning	Pruning
1st pruning	7-8	5		To 2.2 m all trees
1st thinning	10	7	1 500 to 750/ha leaving better 3 trees per 6 planting spots	
2nd pruning	10	7		To ½ height + 1 m on better 500/ha
3rd pruning	13	10		To ½ height + 1 m on better 500/ha
2nd thinning	15-16	12	750 to 500/ha leaving better 2 trees per 6 planting spots	
4th pruning	16	12		To ½ height + 1 m on better 300/ha
3rd thinning	20	17	500 to 300/ha leaving better 1 tree per 5 planting spots	
Clear fell		25-28		

Appendix 5

Volume tables for indigenous species

VOLUME TABLES FOR INDIGENOUS SPECIES IN NGAIRIGI AND UPPER KINYETI BASINS

Table 63 is a one way volume table giving the standing overbark merchantable volume in m^3 for a sound tree. Volumes (V in m^3) were derived from diameters (D in cm) at breast height or above any buttresses using the following regression formulae.

Podocarpus	$\log_e V = 2.16067 \log_e D - 8.16533$	$(r^2 = 0.889)$
Olea	$\log_e V = 2.20105 \log_e D - 8.50113$	$(r^2 = 0.885)$
Syzygium	$\log_e V = 2.21096 \log_e D - 8.76832$	$(r^2 = 0.874)$
Croton	$\frac{V}{D^2} = 0.00063773 - \frac{0.136815}{D^2}$	

Which simplifies for calculation purposes to

$$V = 0.00063773\ D^2 - 0.136815$$

Pygeum, Fagara and *Ocotea*	$\log_e V = 2.1204 \log_e D - 8.11199$	$(r^2 = 0.886)$
Dombeya, Macaranga and *Teclea*	$\log_e V = 2.04577 \log_e D - 8.09396$	$(r^2 = 0.729)$
Other species	$\log_e V = 2.32414 \log_e D - 8.76832$	$(r^2 = 0.844)$

In Table 63 volumes are given for each diameter class. Diameter class 8 for example would apply to all trees of size 80-89 cm, and a value of D = 85 is used in the equations to derive V.

Figure 9 shows the degree of fit of the *Podocarpus* data collected.

TABLE 63 Merchantable overbark volume table for species in the Ngairigi and Upper Kinyeti Basins, m^3

Diameter class o.b., cm	*Podocarpus*	*Olea*	*Syzygium*	*Croton*	*Pygeum Fagara Ocotea*	Potential *Dombeya Macaranga Teclea*	Others
2	0.298	0.243	0.192	0.262	0.276	0.221	0.208
3	0.621	0.509	0.406	0.644	0.564	0.443	0.455
4	1.061	0.885	0.703	1.155	0.960	0.736	0.816
5	1.637	1.376	1.096	1.792	1.470	1.110	1.301
6	2.350	1.988	1.586	2.558	2.095	1.562	1.918

TABLE 63 (Continued)

Diameter class o.b., cm	*Podocarpus*	*Olea*	*Syzygium*	*Croton*	*Pygeum Fagara Ocotea*	Potential *Dombeya Macaranga Teclea*	Others
7	3.200	2.723	2.176	3.450	2.837	2.093	2.675
8	4.055	3.587	2.870	4.471	3.699	2.704	3.578
9	5.334	4.582	3.670	5.619	4.683	3.395	4.633
10	6.622	5.711	4.580	6.894	5.791	4.167	5.847
11	8.061	6.978	5.599	8.297	7.023		7.224
12	9.650	8.383	6.732	9.828	8.381		8.768
13	11.400	9.931	7.982	11.486	9.866		10.486
14	13.300	11.622	9.348	13.271	11.481		12.380
15	15.361	13.460	10.830	15.185	13.224		14.456
16	17.580	15.446	12.440		15.099		16.716
17	19.970	17.581	14.170		17.106		19.166
18	22.500	19.869	16.010		19.245		21.808
19	25.220	22.310	18.000		21.517		24.647
20	28.100	24.906	20.100		23.924		27.685

A total of 888 trees were measured for the construction of the volume tables (Table 63). The number of trees assessed for each diameter class are shown in Table 64.

TABLE 64 **Number of trees assessed for construction of volume tables for species in the Ngairigi and Upper Kinyeti Basins**

Diameter class o.b., cm	*Podocarpus*	*Olea*	*Syzygium*	*Croton*	*Pygeum Fagara Ocotea*	*Dombeya Macaranga Teclea*	Others
2	18	29	5	14	8	21	21
3	35	20	17	18	21	30	29
4	37	17	15	23	14	26	22
5	27	22	13	19	18	16	12
6	33	14	11	11	12	3	10
7	22	19	11	12	13	3	2
8	19	10	12	3	4	0	3
9	13	11	8	3	3	1	3
10	6	1	2	0	7	0	0
11	4	0	3	1	5	0	0
12	0	1	1	0	1	0	0
13	1	1	2	0	0	0	1
14	1	0	3	0	2	0	0
15	0	1	1	0	3	0	0
16	1	0	0	0	1	0	0
17	0	0	0	0	1	0	0
18	0	0	0	0	0	0	1
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
Total	217	146	104	104	113	100	104

VOLUME TABLE FOR INDIGENOUS SPECIES IN TALANGA AREA

Table 65 is a one way volume table giving the standing overbark merchantable volume in m^3 for a sound tree. It is derived from the following regression equation:

$$\frac{V}{D^2} = 0.000678058 - \frac{0.13738}{D^2} \quad \text{simplifying to } V = 0.000678058\, D^2 - 0.13738$$

where V = volume in m^3 and D = diameter at breast height (1.3 m) or above buttresses.

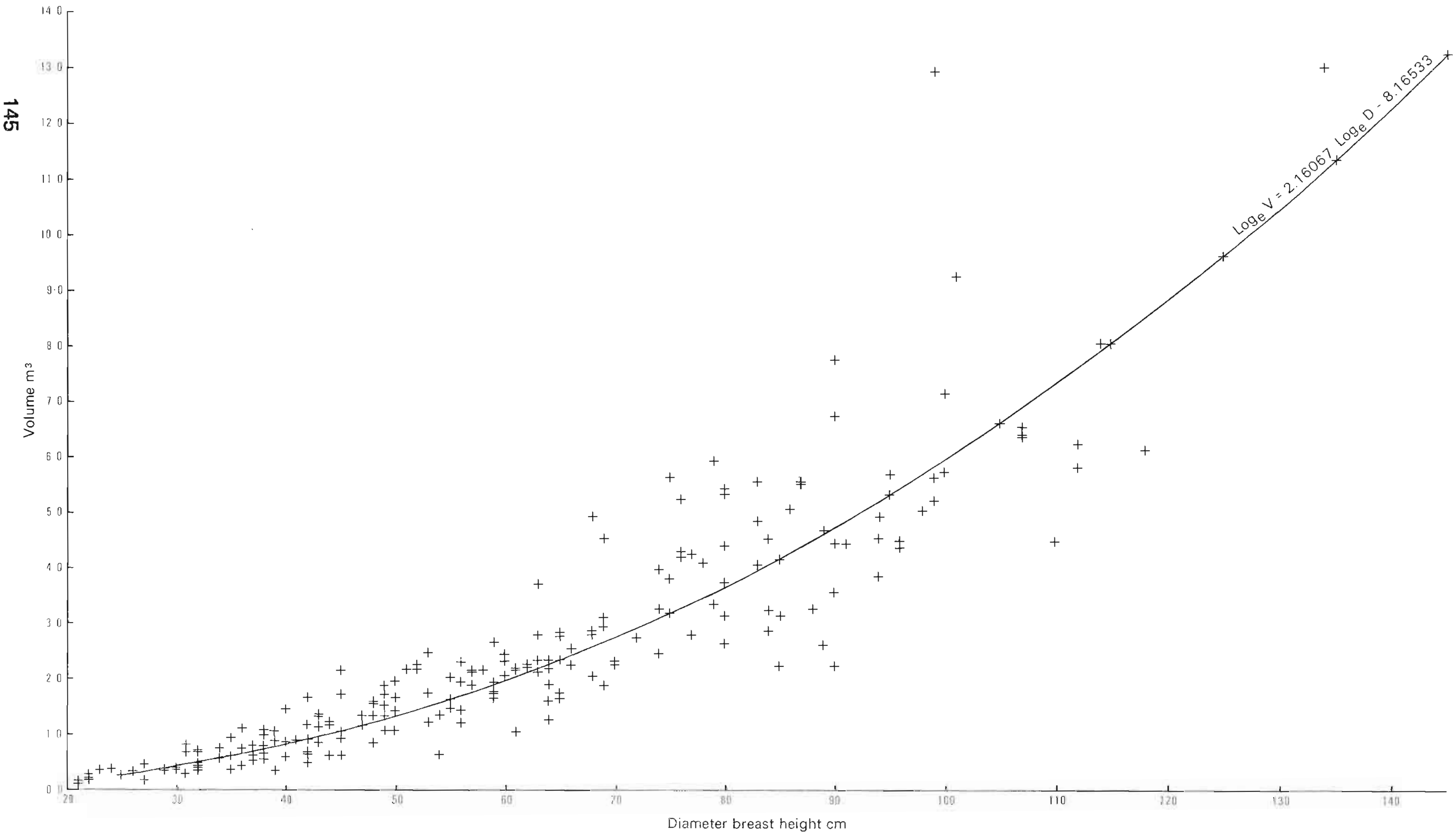

FIGURE 9 Volume/diameter regression line for *Podocarpus milanjianus*

FIGURE 9

Prepared by Land Resources Division 1976

TABLE 65 **General merchantable overbark volume table for all species in the Talanga area**

Diameter class o.b., cm	Volume m^3	Diameter class o.b., cm	Volume m^3	Diameter class o.b., cm	Volume m^3
2	0.286	10	7.338	17	20.628
3	0.693	11	8.830	18	23.069
4	1.236	12	10.457	19	25.646
5	1.914	13	12.220	20	28.358
6	2.727	14	14.119	21	31.206
7	3.677	15	16.153	22	34.189
8	4.762	16	18.323	23	37.308
9	5.982	17	20.628	24	40.565

Table 65 was derived from 105 sample trees, the size distribution of which is given in Table 66.

TABLE 66 **Number of trees assessed for construction of general volume table for species in the Talanga area**

Diameter class o.b., cm	No. of trees	Diameter class o.b., cm	No. of trees	Diameter class o.b., cm	No. of trees
2	1	9	3	16	0
3	11	10	3	17	0
4	12	11	3	18	1
5	14	12	8	19	0
6	15	13	2	20	0
7	17	14	2	21	1
8	10	15	2	22	0

Appendix 6

Field characters of some timber species in the montane forest, Imatong Central Forest Reserve

Slash colour	Leaf shape	Species	Bark	Slash	Leaf description	Flowers and fruit	Frequency and forest type or site
Yellow	Pinnate	*Bersama abyssinica*	Grey, smooth	Soft, thick, flecked and granular. Sapwood white	Leaf 30 cm long, 7-27 leaflets, opposite, up to 10 cm long	Flowers pink, erect raceme 15 cm long. Fruit orange and red in thick capsule 25 mm long	Common 2f
		Fagara macrophylla	Grey, smooth, with large conical thorns	Yellow, soft, thick: strong aromatic smell	Leaf up to 100 cm long, 13-27 leaflets, alternate, with terminal leaflet: base one side rounded, the other cuneate	Flowers, creamy-white, sessile in large terminal panicle	Occasional 2d
	Trifoliate	*Teclea nobilis*	Pale brown rough with corky horizontal lenticels	Yellow flecked with brown, goes black. Sapwood cream	Leaflets narrow-lanceolate 5-15 cm long, leathery	Fruit elliptic red 7 mm long	Common understorey tree
	Simple, broadly ovate	*Croton macrostachys*	Grey, finely fissured in vertical lines	Outer pale brown, inner cream with patches of pink	Broadly ovate 12 cm long with acuminate tip and grey undersides. Sparse canopy	Fruit trilobed capsule 12 mm diameter	Common 2d and 2f
		Dombeya goetzenii		Sometimes yellow/brown. See red/pink slash			
	Simple, broadly elliptic	*Ocotea kenyensis*	Black, deeply flaky	Yellow; goes black on exposure, soft, thick. Cork cambium sharply demarcated	Up to 12 cm long, shiny dark green	Few, small cream-coloured flowers in terminal panicle. Fruit acorn-like 2 cm long	Common/occasional 2e, 2f
	Simple, ovate-elliptic	*Afrocrania volkensii*	Grey, smooth; raised vertical elongated lenticels	Dark red outer bark. Light yellowish brown with thin vertical dark brown lines	Pale green, prominent lateral nerves	Fruit drupe	Rare, beside streams
		Ilex mitis	Grey, smooth	Outer bark green fringe, inner yellow flecked with darker brown	6-7 cm long	Flowers small, white clustered on twig	Rare
	Simple elliptic-lanceolate, small	*Olea hochstetteri*	Grey-white, smooth, occasional broad vertical cracks	Cream-white, mottled with brown	Opposite, 5-9 cm long. Acuminate tip, olive green above, paler beneath	Fruit ellipsoid drupe 1 cm long	Common 2e, 2f
Brown	Pinnate	*Polyscias ferruginea*	Grey-yellow, smooth	Sappy, pale brown, mottled	Leaf up to 120 cm long. 17-29 leaflets, ovate-elliptic, shortly acuminate, 7-18 cm long	Panicle of yellowish flowers	Common 2d
	Bipinnate	*Albizia gummifera*	Grey, smooth	Orange-brown, granular, alternating with paler layer	Pinnae 5-7 pairs. Leaflets 9-16 pairs 0.5 to 1.5 cm long	Flowers, numerous, white with scarlet stamen	Common 2d
	Simple, 3 nerved from base	*Celtis africana*	Greeny grey, smooth	Hard dark brown, flecked with paler brown. Sapwood pinky white	Ovate-lanceolate 4-10 cm long. Apex acuminate	Fruit brown drupe 5 mm diameter	Occasional 2d
	Simple, ovate elliptic	*Syzygium guineense* subsp. *afromontanum*	Grey-brown, peeling off in 10 cm plates. Plank-like buttresses	Pale brown, thin, hard and fibrous	5-8 cm long, opposite, shiny dark green, apex shortly acuminate	Striking mass of white flowers in terminal panicle. Fruit ovoid 10 mm long, blue when ripe	Common 2e, 2f
	Simple, oblong	*Apodytes dimidiata*	Grey, smooth, shallow depressions, long buttresses	Dark red-brown, thick, soft	6-12 cm	Panicle of small white flowers	Rare 2f
Red or pink	Pinnate	*Ekebergia capensis*	Grey, smooth, horizontal shallow depressions	Red with white streaks, brittle. Cream sapwood	Leaf 15-30 cm long. 5-11 leaflets, elliptic to ovate-lanceolate, acuminate at apex, 3-8 cm long	Flowers, white sometimes tinged pink fragrant in axillary panicles. Fruit globose, fleshy 2.5 cm	Rare, forest edge
	Trifoliate	*Allophyllus abyssinicus*	Grey-brown smooth, often nibbled by animals	Pale pink, thin, sweet scent	Leaflets ovate-elliptic 10-20 cm long	Panicle of white flowers	Rare
	Simple, linear oblong	*Podocarpus milanjianus*	Pale-brown to dark brown; cracks in long thin vertical strips	Pink outer, yellow inner. Thin, hard, and fibrous	8 cm long, 5-10 mm wide, pointed tip	Fruit round, 5-10 mm diameter. Attached to red fleshy receptacle	Common 2e, 2f, 3e
	Simple, broadly ovate	*Dombeya goetzenii*	Grey, smooth	Pink, reticulate, stringy	12-35 cm long. Long acuminate tip, cordate at base	Flowers persistent, papery brown petals	Common 2d, 3e
		Macaranga kilimandsharica	Grey, smooth, often many stems from one base	Red, soft, thick and streaky	7-15 cm long. Dense dark green foliage	Fruit, many round capsules 5 mm diameter, covered in yellow glands	Common 2d
	Simple, ovate-lanceolate	*Pygeum africanum*	Dark brown-black, scales off exposing pink-white outer cambium	Pale red, hard, thin, brittle	5-15 cm long. Acuminate at apex. Reddish petiole	Fruit red, glabrous, round, 10 mm diameter	Common 2e, 2f
	Simple, oblong-lanceolate	*Ochna holstii*	Grey, flaky	Red, turns dark red on exposure. Sapwood white	Up to 10 cm long, serrulate margin	Yellow flowers, 6-10 in corymb	Occasional 2e, 2f

Appendix 7

Soil profile descriptions and analyses

DEFINITIONS OF SOIL PARAMETERS

All terms used in soil descriptions are those defined by Carroll and Hill (1968). Colour names and notations are from the Munsell Soil Colour Chart.

METHODS OF SOIL ANALYSIS

Moisture, bulk density and loss on ignition

A known volume of soil is weighed and bulk density (g/ml) is calculated. After heating at 105°C, cooling and re-weighing the % moisture is calculated. The soil is then heated at 500°C, cooled and re-weighed and the loss of weight is computed.

pH

Determinations of pH in 1:5 soil to water ratio and in 1:5 soil to N potassium chloride ratio are carried out automatically using standard stirring and settling times.

Conductivity

Measured in 1:5 soil to water ratio and the reading is corrected to 25°C.

Exchangeable bases

Leaching with neutral ammonium acetate, sodium and potassium are determined by flame photometry on an Auto Analyser and magnesium and calcium by atomic absorption spectroscopy.

Cation exchange capacity (CEC)

Leaching with N potassium chloride at pH 2.5 after removal of excess ammonium acetate, ammonia in the leachate determined colorimetrically by Auto Analyser.

Total nitrogen

A kjeldahl digestion with a selenium catalyst followed by colorimetric determination by Auto Analyser.

Organic carbon

By Walkley and Black's method followed by colorimetric determination using a 'dip' colorimeter.

Total element analysis

Perchloric acid digestion and determination by Auto Analyser.

Phosphorus	Colorimetrically using ascorbic acid as reducing agent.
Potassium	By flame photometry using Li as internal standard.
Magnesium and Calcium	By atomic absorption spectroscopy with Sr as releasing agent.
Trace elements	By atomic absorption spectroscopy.

Available phosphorus

Bray's method 2a.

Mechanical analysis

After pretreatment with hydrogen peroxide to remove organic matter and dispersal in sodium hexametaphosphate solution, the clay (2μ) and silt (50μ-2μ) fractions are determined by settling and pipette sampling; the coarser fractions are separated by sieving.

Water dispersible clay

Dispersion is in water without the addition of a dispersing agent, by end over end shaking for 4 hours, the clay (2μ) being measured by settling and pipette sampling. For the determination of water dispersible clay after removal of organic matter the samples are pretreated with hydrogen peroxide.

PROFILE 1

Soil series	Mulumas
Classification	FAO: Dystric Histosols
Location	On air photo 4/041, Kipia Valley, approximately 300 m south of prominent dark forested area
Elevation	2 490 m
Landform	Physiographic position: on gently sloping valley bottom Landform unit: J Microtopography: low grass/rush hummocks
Slope	5^o
Aspect	SE
Land use	Marsh, with rushes and grass, much grazed by game
Parent material	Peat
Drainage	Very poor
Moisture condition	Moist to surface
Water table	About 25 cm
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
H	0-25	Black (2.5 YR N2/-), moist; amorphous peat; structureless; slightly sticky, plastic consistence; very frequent fine roots. (Peat extends to over 100 cm)

PROFILE 1 LAB. NO. 8451

Characteristic	Horizon (depth in cm)					
	H					
	0-25					
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	10.9 0.37 50					
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.2 4.1 0.09					
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.8 1.2 2.2 4.5					
TEB meq % CEC meq %	8.7 58.8					
Base saturation %	15					
Total N % Organic C %	1.60 20.64					
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	2580 2050 1250 1800					
Available P (Bray) ppm	25.7					
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 2 8 48 42					
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 2

Soil series	Garia
Classification	FAO: Lithosols
Location	At highest point of the Gilo-Lofolung footpath, approximately 1.5 km north-east of the start of Block 3, Line 2
Elevation	1 905 m
Landform	Physiographic position: on lower slope of rocky hill summit Landform unit: E Microtopography: nil
Slope	7°
Aspect	SE
Land use	Bare rock and savanna; much grazed by game

Parent material	Coarse grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	80% cover
Erosion	Moderate sheet

Horizon	Depth cm	
A	0-7	Black (2.5 Y R N2/-), moist; sandy loam; moderate very fine crumb structure; very friable to loose consistence; abundant fine roots; abrupt and wavy boundary.
R	7+	Unweathered coarse grained gneiss

PROFILE 2 LAB. NO. 8445

Characteristic	Horizon (depth in cm)					
	A					
	0-7					
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	2.1 0.73					
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.9 4.7 0.08					
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 1.1 1.4 5.5					
TEB meq % CEC meq %	8.1 25.1					
Base saturation %	32					
Total N % Organic C %	0.75 11.03					
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1240 3200 3400 3800					
Available P (Bray) ppm	78.5					
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 22 34 27 17					
Water dispersible clay % total less OM	 0.8 10.6					
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %	 20 20 360 70 3.4					

PROFILE 3

Soil series	Sasai
Classification	FAO: Dystric Fluvisols
Location	Block 12, Line 1, Plot 15
Elevation	2 165 m
Landform	Physiographic position: on dissected river terrace Landform unit: G (terrace too small to map) Microtopography: dissected, locally gullied by stream abrasion
Slope	3°
Aspect	SW
Land use	C6, <u>Podocarpus-Syzygium</u> open forest
Parent material	Coarse grained bouldery riverine alluvium
Drainage	Imperfect
Moisture condition	Moist
Water table	Absent, but seasonally reaches 75 cm
Surface stones	Absent
Erosion	Locally stream abrasion

Horizon	Depth cm	
A	0-4	Very dark greyish brown (10 YR 3/2), moist; loamy sand; weak fine subangular blocky structure; very friable to loose consistence; frequent fine to medium roots; clear, smooth boundry:
C1	4-75	Dark brown (10 YR 3/3), moist; coarse sand; structureless, single grain; loose consistence; clear, smooth boundary:
C2	75-108	Greyish brown (10 YR 5/2), common fine distinct brown (7.5 YR 4/6) mottles, moist; coarse sand: structureless, single grain; loose consistence; abrupt, irregular boundary:
C3	108+	Boulders (medium grained gneiss).

PROFILE 3 LAB. NO. 8422-24

Characteristic	Horizon (depth in cm)					
	A	C1	C2			
	0-4	4-75	75-108			
Moisture (100-105°C) %	1.0	0.5	0.7			
Bulk density g/ml	1.12	1.38	1.26			
Loss of ignition %						
pH (1:5) soil: water	5.8	5.1	5.7			
pH (1:5) soil: 1N KCl	5.2	4.3	4.4			
Conductivity mmhos	0.09	0.02	0.02			
Exch. Na meq %	0.0	0.0	0.0			
Exch. K meq %	0.4	0.1	0.1			
Exch. Mg meq %	1.8	0.1	0.3			
Exch. Ca meq %	7.0	0.3	0.8			
TEB meq %	9.2	0.5	1.2			
CEC meq %	10.1	2.9	2.9			
Base saturation %	91	17	41			
Total N %	0.27	0.04	0.03			
Organic C %	2.51	0.41	0.30			
Total P ppm	460	320	290			
Total K ppm	950	550	700			
Total Mg ppm	650	250	500			
Total Ca ppm	1400	100	200			
Available P (Bray) ppm	20.6	68.0	38.4			
Mechanical analysis						
2 mm - 250 μ %	23	64	42			
250 μ% - 50 μ %	54	26	42			
50 μ% - 2 μ %	12	6	9			
2 μ%	11	4	7			
Water dispersible clay %						
total	0.2	1.0	1.6			
less OM	6.4	2.0	2.8			
Trace metals						
Copper ppm	10	10	10			
Chromium ppm	20	10	10			
Manganese ppm	390	130	80			
Zinc ppm	50	20	30			
Iron %	1.2	1.0	1.0			

PROFILE 4

Soil series	Kinyeti
Classification	FAO: Humic Cambisols
Location	3 m from pillar on top of Mount Kinyeti
Elevation	3 036 m
Landform	Physiographic position: on rocky convex summit of mountain
	Landform unit: B
	Microtopography: crevice in between boulders and rock outcrops
Slope	10°
Aspect	E
Land use	Rocks with stunted Ericaceae, moss and grasses
Parent material	Leucocratic quartz-gneiss
Drainage	Well drained
Moisture condition	Dry throughout
Water table	Absent
Surface stones/ boulders	95% cover
Erosion	Nil

Horizon	Depth cm	
O	10-0	Dark greyish brown (10 YR 4/2), moist; raw, fine fibrous humus; weak fine crumb structure; soft consistence; very frequent very fine roots; abrupt, smooth boundry:
A	0-27	Very dark brown (10 YR 4/2), moist; very fine sandy loam; structureless; loose; roots as above; abrupt, irregular boundary:
R	27+	Quartzite rock.

Characteristic	Horizon (depth in cm)					
	O	A				
	10-0	0-27				
Moisture (100-105°C)%	5.8	4.5				
Bulk density g/ml	0.58	0.83				
Loss of ignition %						
pH (1:5) soil: water	5.5	5.2				
pH (1:5) soil: 1N KCl	4.4	4.2				
Conductivity mmhos	0.07	0.09				
Exch. Na meq %	0.2	0.1				
Exch. K meq %	0.7	0.4				
Exch. Mg meq %	4.4	2.1				
Exch. Ca meq %	15.8	8.7				
TEB meq %	21.1	11.3				
CEC meq %	55.9	47.6				
Base saturation %	38	24				
Total N %	1.55	1.16				
Organic C %	17.80	10.98				
Total P ppm	1320	1170				
Total K ppm	2350	2050				
Total Mg ppm	3300	2900				
Total Ca ppm	5400	2700				
Available P (Bray) ppm	26.4	12.3				
Mechanical analysis						
2 mm - 250 μ %	19	28				
250 μ% - 50 μ %	18	18				
50 μ% - 2 μ %	39	28				
2 μ%	24	26				
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 5

Soil series	Otolo
Classification	FAO: Humic Cambisols
Location	On air photo 4/041, Kipia Valley, approximately 250 m south-west of prominent dark forested area
Elevation	2 556 m
Landform	Physiographic position: on crest of gently sloping ridge Landform unit: J Microtopography: nil
Slope	5^{o}
Aspect	S
Land use	<u>Hagenia</u> woodland with sparse grass cover, recently burned
Parent material	Colluvial deposit derived from quartz-gneiss
Drainage	Well drained
Moisture condition	Dry throughout
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A	0-40	Dark reddish brown (5 YR 3/2), moist; silty loam; weak fine subangular blocky structure; firm consistence; few fine discontinuous exped pores; few fine and very fine roots; abrupt, smooth boundry:
1C	40-65	Dominant quartz gravel in a matrix of coarse sandy clay loam; with few small, subangular to angular, quartz stones; few fine roots; clear, smooth boundary:
2C	65-85	Brown (7.5 YR 5/4), moist; coarse sandy clay; weak very fine subangular blocky structure; slightly hard consistence; few fine discontinuous exped pores; discontinuous dominant layer of quartz stones; abrupt, clear boundary:
3C	85-125	Deposit consisting of thin light yellow, dark brown and purple sub-horizontal layers; slightly hard; textures as a coarse sandy loam.

PROFILE 5 LAB. NO. 8462-65

Characteristic	Horizon (depth in cm)					
	A	1C	2C	3C		
	0-40	40-65	65-85	85-125		
Moisture (100-105°C)%	3.9	1.8	1.4	0.4		
Bulk density g/ml	0.89	1.09	0.96	0.95		
Loss of ignition %						
pH (1:5) soil: water	5.0	5.1	5.2	6.0		
pH (1:5) soil: 1N KCl	4.2	4.4	4.4	4.7		
Conductivity mmhos	0.05	0.02	0.02	0.02		
Exch. Na meq %	0.0	0.0	0.0	0.1		
Exch. K meq %	0.4	0.1	0.0	0.0		
Exch. Mg meq %	2.3	0.1	0.0	0.0		
Exch. Ca meq %	4.3	0.1	0.2	0.2		
TEB meq %	7.0	0.3	0.2	0.3		
CEC meq %	32.0	8.9	8.1	3.6		
Base saturation %	22	3	3	8		
Total N %	0.48	0.13	0.13	0.03		
Organic C %	8.05	1.75	1.64	0.17		
Total P ppm	1010	800	700	340		
Total K ppm	1300	950	1100	450		
Total Mg ppm	1350	400	550	100		
Total Ca ppm	1200	<100	<100	<100		
Available P (Bray) ppm	12.3	11.2	9.4	6.8		
Mechanical analysis						
2 mm - 250 μ %	20	55	25	24		
250 μ% - 50 μ %	15	13	21	24		
50 μ% - 2 μ %	40	12	20	26		
2 μ%	25	20	34	26		
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 6

Soil series	Lohocho
Classification	FAO: Humic Cambisols
Location	Block 4, Line 1, Plot 15
Elevation	2 020 m
Landform	Physiographic position: on strongly sloping convex middle slope of long scarp
	Landform unit: G
	Microtopography: nil
Slope	23°
Aspect	N
Land use	C5, Olea-Podocarpus closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	10%, boulders dominant locally
Erosion	Nil

Horizon	Depth cm	
A1	0-16	Very dusky red (10 R 2/2), moist; fine sandy loam; strong fine crumb structure; very friable consistence; many fine continuous exped pores; very frequent fine to coarse roots; abrupt, wavy boundry:
A2	16-57	Very dusky red (2.5 YR 2/2), moist; loam; weak fine subangular blocky structure, breaking into strong micro (<1 mm diameter) crumb structure; friable consistence; common fine continuous exped pores; few fine to coarse roots; clear, smooth boundry:
A3	57-70	Dusky red (2.5 YR 3/2), moist; loam; structure, consistence, pores and roots as above; abrupt, irregular boundry:
C	70-95	Decomposing medium grained gneiss; very few medium roots; abrupt, irregular boundary:
C2	95+	Gneiss boulder.

PROFILE 6 LAB. NO. 8396-99

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	C		
	0-16	16-57	57-70	70-95		
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	4.2 0.95	4.1 1.03	3.1 1.16	2.9 1.15		
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.4 4.6 0.09	4.4 4.2 0.04	5.1 4.1 0.02	5.0 4.1 0.03		
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.9 5.1 13.9	0.0 0.4 0.9 1.0	0.0 0.4 0.4 0.2	0.0 0.4 0.5 0.2		
TEB meq % CEC meq %	19.9 35.8	2.3 21.8	1.0 15.6	1.1 15.1		
Base saturation %	56	11	6	7		
Total N % Organic C %	0.70 6.70	0.29 3.62	0.19 2.00	0.18 1.64		
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	860 2900 2850 3600	580 2500 1900 400	550 2750 1800 100	820 2850 1800 <100		
Available P (Bray) ppm	7.2	7.6	14.1	14.6		
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 26 15 27 32	 26 17 24 33	 23 20 23 34	 30 18 19 33		
Water dispersible clay % total less OM	 1.6 15.4	 1.4 4.4	 1.8 5.2	 2.4 6.2		
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %	 30 30 520 60 3.2	 20 30 290 50 3.0	 20 30 270 50 3.0	 20 40 260 60 5.2		

PROFILE 7

Soil series	Lohocho
Classification	FAO: Humic Cambisols
Location	Compartment 8; northern plantation fringe to grass land on summit of Observation Hill
Elevation	1 965 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: F
	Microtopography: irregular, bouldery
Slope	9°
Aspect	SE
Land use	Plantation, *Cupressus*
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	80%
Erosion	Nil

Horizon	Depth cm	
O	9-0	Mat of decomposing *Cupressus* leaves; frequent fine roots; abrupt, smooth boundry:
A	0-20	Dark reddish brown (5 YR 3/2), moist; loam; moderate fine crumb structure; friable consistence; few fine discontinuous exped pores; abundant fine roots; common medium and coarse roots; abrupt, irregular boundary:
C	20+	Boulders of medium grained gneiss.

PROFILE 7 LAB. NO. 8488-89

Characteristic	Horizon (depth in cm)					
	0	A				
	9-0	0-20				
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	2.2 0.47	1.3 0.87				
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.9 5.0 0.10	5.6 4.0 0.04				
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 1.2 5.7 24.8	0.0 0.5 0.7 1.0				
TEB meq % CEC meq %	31.8 44.7	2.2 16.0				
Base saturation %	71	14				
Total N % Organic C %	0.60 16.06	0.24 3.83				
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	580 1900 1750 7200	380 1700 1050 300				
Available P (Bray) ppm	8.9	8.2				
Mechanical analysis 2 mm - 250 µ % 250 µ% - 50 µ % 50 µ% - 2 µ % 2 µ%	 25 13 28 34	 22 15 18 45				
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 8

Soil series	Dumusum
Classification	FAO: Humic Cambisols
Location	Block 16, Line 1, Plot 45
Elevation	2 350 m
Landform	Physiographic position: summit of ridge, close to break of convex slope
	Landform unit: G
	Microtopography: bouldery
Slope	8^{o}
Aspect	W
Land use	*Hagenia* woodland
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Boulders, 50%
Erosion	Nil

Horizon	Depth cm	
A1	0-13	Black (2.5 YR n2/-), moist; loamy sand; moderate fine crumb structure; very friable to loose consistence; many fine continuous exped pores; very frequent fine, medium and coarse roots; clear, smooth boundry:
A2	13-92	Black (2.5 YR N2/-), moist; sandy loam; weak fine crumb structure; consistence and pores as above; frequent subangular stones and boulders (gneiss); frequent fine, medium and coarse roots; abrupt, irregular boundary:
C	92+	Boulders (medium grained gneiss)

PROFILE 8 LAB. NO. 8430-31

Characteristic	Horizon (depth in cm)					
	A1	A2				
	0-13	13-92				
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	4.3 0.78	3.5 1.14				
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.6 4.4 0.06	4.8 4.3 0.03				
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.7 3.2 10.0	0.0 0.3 0.1 0.4				
TEB meq % CEC meq %	13.9 39.4	0.8 18.6				
Base saturation %	35	4				
Total N % Organic C %	0.76 11.11	0.33 5.37				
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	930 1300 1700 2600	620 1150 1150 400				
Available P (Bray) ppm	12.7	7.7				
Mechanical analysis 2 mm - 250 µ % 250 µ% - 50 µ % 50 µ% - 2 µ % 2 µ%	 29 17 31 23	 34 23 28 15				
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 9

Soil series	Sahue
Classification	FAO: Humic Cambisols
Location	Block 4, Line 1, Plot 14
Elevation	2 010 m
Landform	Physiographic position: on strongly sloping locally concave middle slope of a long scarp
	Landform unit: G
	Microtopography: nil
Slope	25°
Aspect	N
Land use	C5, Olea-Podocarpus closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Adjacent to rock outcrop
Erosion	Nil

Horizon	Depth cm	
A1	C-6	Very dusky red (10 R 2/2), moist; very fine sandy loam; weak very fine crumb structure; many fine discontinuous exped pores; very frequent fine to medium roots; abrupt, smooth boundary:
A2	6-40	Dark reddish brown (5 YR 2/2), moist; sandy loam; weak fine subangular blocky structure; friable consistence; few fine discontinuous exped pores; frequent fine to medium roots; abrupt, smooth boundary:
R	40+	Medium grained gneiss

PROFILE 9 LAB. NO. 8394-95

Characteristic	Horizon (depth in cm)					
	A1	A2				
	0-6	6-40				
Moisture (100-105°C)%	7.7	5.3				
Bulk density g/ml	0.77	0.93				
Loss of ignition %						
pH (1:5) soil: water	5.0	5.2				
pH (1:5) soil: 1N KCl	4.1	4.1				
Conductivity mmhos	0.06	0.03				
Exch. Na meq %	0.2	0.1				
Exch. K meq %	0.3	0.3				
Exch. Mg meq %	2.2	1.1				
Exch. Ca meq %	7.0	1.2				
TEB meq %	9.7	2.7				
CEC meq %	46.4	25.3				
Base saturation %	21	11				
Total N %	0.97	0.47				
Organic C %	9.95	4.35				
Total P ppm	910	810				
Total K ppm	2600	3050				
Total Mg ppm	2450	2650				
Total Ca ppm	1800	500				
Available P (Bray) ppm	16.3	8.4				
Mechanical analysis						
2 mm - 250 μ %	17	23				
250 μ% - 50 μ %	10	11				
50 μ% - 2 μ %	44	34				
2 μ%	29	32				
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 10

Soil series	Sahue
Classification	FAO: Humic Cambisols
Location	Compartment 22; approximately 1.7 m east of Gilo resthouse
Elevation	1 875 m
Landform	Physiographic position: immediately below rocky summit of hill, on a moderately sloping concave upper slope
	Landform unit: F
	Microtopography: nil
Slope	15°
Aspect	SE
Land use	Plantation; <u>Pinus patula</u>
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	90%
Erosion	Nil

Horizon	Depth cm	
O1	10-3	Mat of raw pine needles; clear, smooth boundary;
O2	3-0	Layer of decomposing pine needles; few fine roots; clear, smooth boundary:
A1	0-20	Black (2.5 YR N2/-), moist; sandy loam; moderate medium crumb structure; friable to loose consistence; many fine discontinuous exped pores; abundant fine roots; clear, smooth boundary:
A2	20-52	Dark reddish brown (5 YR 2/2), moist; sandy loam; weak medium crumb structure; friable consistence; very few coarse roots; very frequent hard angular stones (gneiss), frequent subangular boulders (gneiss); abrupt, irregular boundary:
R	52+	Decomposing gneiss.

PROFILE 10 LAB. NO. 8476-78

Characteristic	Horizon (depth in cm)					
	02	A1	A2			
	3-0	0-20	20-52			
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	1.6 0.83	1.3 1.13	1.4 1.04			
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.5 4.6 0.07	5.0 4.2 0.02	5.6 4.4 0.04			
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.5 1.2 6.8	0.0 0.2 0.1 0.2	0.0 0.2 0.5 4.3			
TEB meq % CEC meq %	8.5 18.7	0.5 7.9	5.0 13.6			
Base saturation %	46	6	37			
Total N % Organic C %	0.29 4.38	0.21 1.78	0.13 2.70			
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	510 2000 1750 1800	310 1500 1150 200	440 1900 1650 1100			
Available P (Bray) ppm	24.7	8.6	15.0			
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 34 23 28 15	 45 24 20 11	 34 25 23 18			
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 11

Soil series	Sahue
Classification	FAO: Humic Cambisols
Location	Block 13, Line 2, Plot 5
Elevation	2 320 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: E
	Microtopography: nil
Slope	14^o
Aspect	S
Land use	C5, <u>Olea</u>-<u>Podocarpus</u> closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A	0-28	Black (5 YR 2/1), moist; sandy loam; strong fine crumb structure; very friable consistence; many fine continuous exped pores; very frequent fine, medium and coarse roots; abrupt, irregular boundary:
C	28+	White compact subangular boulders (medium grained gneiss).

PROFILE 11 LAB. NO. 8425

Characteristic	Horizon (depth in cm)					
	A					
	0-28					
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	4.2 0.95					
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.8 4.7 0.08					
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 0.6 4.1 13.7					
TEB meq % CEC meq %	18.5 34.0					
Base saturation %	54					
Total N % Organic C %	0.74 9.15					
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	850 2000 2850 3700					
Available P (Bray) ppm	10.7					
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 26 25 33 16					
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 12

Soil series	Nabakin
Classification	FAO: Humic Nitosols
Location	Block 3, Line 1, Plot 15
Elevation	1 780 m
Landform	Physiographic position: on moderately sloping slightly convex middle slope
	Landform unit: M
	Microtopography: nil
Slope	8°
Aspect	SW
Land use	C6, Podocarpus-Syzygium open forest
Parent material	Colluvium
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-4	Very dark grey (5 YR 3/1), moist; clay loam; strong medium crumb structure; very friable consistence; many fine continuous exped pores; very frequent fine, medium and coarse roots; abrupt, smooth boundary:
A2	4-29	Dark reddish grey (10 R 3/1), moist; clay loam; moderate fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; common fine discontinuous exped pores; few fine and medium roots; gradual, smooth boundary:
A3	29-70	Dusky red (2.5 YR 3/2), moist; clay loam; structure, consistence, pores and roots as above; very few subangular medium hard stones (coarse grained gneiss); gradual, smooth boundary:
Bt	70-102	Dark red (10 R 3/6), moist; sandy clay; moderate fine subangular blocky structure, breaking to strong micro crumb structure; friable consistence; patchy cutans; common fine discontinuous exped pores; few fine roots; gradual, smooth boundary:
BtC	102-150	Dark red (10 R 3/6), moist; clay; weak fine subangular blocky structure; firm consistence; few fine discontinuous exped pores; discrete blocks of dark red slightly fissile mudstone (colluvial deposit).

Characteristic	Horizon (depth in cm)					
	A1	A2	AB	Bt	BtC	
	0-4	4-29	29-70	70-102	102-150	
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	6.5 0.87	4.8 0.92	4.4 0.94	4.7 0.93	5.7 0.97	
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.4 4.5 0.16	5.0 4.0 0.04	4.6 4.1 0.03	4.5 4.0 0.02	4.8 3.9 0.02	
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.7 4.2 14.8	0.0 0.3 0.6 1.9	0.0 0.2 0.3 1.2	0.0 0.1 0.2 0.8	0.0 0.1 0.2 0.8	
TEB meq % CEC meq %	19.7 35.8	2.8 23.2	1.7 20.8	1.1 18.2	1.1 16.8	
Base saturation %	55	12	8	6	7	
Total N % Organic C %	0.93 7.75	0.39 3.34	0.26 2.50	0.14 1.50	0.12 1.09	
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1400 2850 3000 3600	1120 2950 2600 600	1020 2850 2600 360	910 2750 2500 200	830 2750 2450 200	
Available P (Bray) ppm	18.0	12.6	18.9	31.1	24.4	
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 9 17 25 49	 9 17 24 50	 8 16 17 59	 6 13 12 69	 5 13 13 69	
Water dispersible clay % total less OM	 1.6 14.6	 1.8 4.8	 2.4 3.6	 2.4 2.8	 3.2 3.6	
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %	 40 40 1500 100 4.1	 40 50 1060 90 5.2	 40 50 600 80 5.6	 50 50 300 80 6.2	 50 50 260 80 6.2	

PROFILE 13

Soil series	Nabakin
Classification	FAO: Humic Nitosols
Location	Block 2, Line 2, Plot 5
Elevation	1 830 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: F
	Microtopography: nil
Slope	11°
Aspect	SE
Land use	C4, <u>Croton</u>-<u>Macaranga</u>-<u>Albizia</u> forest

Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-3	Dusky red (10 R 3/2), moist, fine sandy loam; strong fine crumb structure; loose consistence; very common decomposing leaf litter; very frequent fine roots; abrupt, smooth boundary:
A2	3-10	Dark reddish grey (10 R 3/1), moist; silty clay loam; strong very fine crumb structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; many fine exped pores; frequent fine and medium roots; clear, smooth boundary:
A3	10-38	Dusky red (10 R 3/3), moist; clay loam; moderate very fine subangular blocky structure, breaking to strong micro crumb structure; firm consistence; pores as above; common fine and coarse roots; gradual, smooth boundary:
Bt	38-70	Weak red (10 R 4/3), moist; sandy clay; weak very fine subangular blocky structure, breaking to strong micro crumb structure; firm consistence; patchy thin cutans; fine exped pores; few fine roots; clear, smooth boundary:
Bts	70-150	Dark red (10 R 3/6), common fine distinct red (10 R 5/8) mottles, moist; coarse sandy clay; weak fine subangular blocky structure; firm consistence; patchy thin cutans; common fine exped pores; few medium subangular soft stones (quartzite and feldspar); very few fine roots.

PROFILE 13 LAB. NO. 8384-88

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	Bt	Bts	
	0-3	3-10	10-38	38-70	70-150	
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	7.2 0.70	4.4 0.89	3.5 0.94	2.9 0.96	2.5 1.03	
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.4 4.6 0.14	5.4 4.4 0.07	4.9 4.2 0.03	5.0 4.2 0.02	5.3 4.3 0.02	
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.7 7.4 21.2	0.0 0.5 2.7 7.8	0.0 0.2 0.7 1.4	0.0 0.1 0.4 0.9	0.0 0.0 0.1 0.6	
TEB meq % CEC meq %	29.3 54.5	11.0 27.3	2.3 15.6	1.4 11.9	0.7 6.9	
Base saturation %	54	40	15	12	10	
Total N % Organic C %	1.13 12.70	0.49 5.10	0.21 2.23	0.11 1.26	0.04 0.48	
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1430 1850 2500 360	1290 1900 2000 1800	1210 1750 1950 400	1190 1750 1850 300	2150 1250 850 <100	
Available P (Bray) ppm	13.6	8.1	8.2	13.5	24.0	
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 14 12 52 22	 15 14 24 47	 14 14 22 50	 15 15 23 47	 22 12 16 50	
Water dispersible clay % total less OM	 1.6 16.6	 3.2 7.9	 6.6 6.8	 3.4 4.6	 11.0 7.0	
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %	 30 50 830 90 4.7	 30 50 660 90 5.7	 30 40 440 90 7.1	 40 40 320 90 6.9	 30 50 230 90 7.4	

PROFILE 14

Soil series	Nabakin
Classification	FAO: Humic Nitosols
Location	Block 17, Line 2, Plot 1
Elevation	2 135 m
Landform	Physiographic position: on moderately sloping concave lower slope
	Landform unit: G
	Microtopography: nil
Slope	15°
Aspect	S
Land use	Hagenia woodland

Parent material	Medium grained gneiss and quartzite
Drainage	Well drained
Moisture condition	Dry
Water rable	Absent
Surface stones	Bouldery, 30%
Erosion	Slight sheet and gully erosion

Horizon	Depth cm	
A1	0-22	Dark reddish brown (5 YR 3/2), moist; sandy loam; weak fine subangular blocky structure; friable consistence; few fine discontinuous exped pores; few medium and coarse roots; gradual, smooth boundary:
Bt1	22-60	Dark red (2.5 YR 3/6), moist; gravelly coarse sandy clay; structureless, massive; firm consistence; frequent angular fragments of feldspar, frequent angular fragments of quartz; very few fine roots; clear, smooth boundary:
Bt2	60-120	Dark red (2.5 YR 3/6), moist; sandy clay; weak fine subangular blocky structure; firm consistence; patchy thin cutans with ferro-manganese staining; few fine discontinuous exped pores; few fragments of feldspar and quartz; clear, smooth boundary:
R	120+	Compact decomposing rock material.

PROFILE 14 LAB. NO. 8432-34

Characteristic	Horizon (depth in cm)					
	A1	Bt1	Bt2			
	0-22	22-60	60-120			
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	4.2 0.87	1.3 1.13	1.8 1.05			
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.6 4.8 0.04	5.1 4.3 0.02	5.4 4.3 0.01			
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.0 0.4 3.4 9.2	0.0 0.1 0.1 0.5	0.0 0.1 0.1 0.6			
TEB meq % CEC meq %	13.0 25.4	0.7 7.9	0.8 6.4			
Base saturation %	51	9	13			
Total N % Organic C %	0.42 6.02	0.12 1.50	0.06 0.76			
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	720 1050 1350 200	450 750 600 200	680 1300 850 200			
Available P (Bray) ppm	10.2	6.2	17.9			
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 28 16 17 39	 37 15 10 38	 29 11 11 49			
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 15

Soil series	Gilo
Classification	FAO: Humic Nitosols
Location	Compartment 5; approximately 500 m north-north-east of Gilo resthouse
Elevation	1 780 m
Landform	Physiographic position: on moderately sloping convex upper slope Landform unit: L Microtopography: nil
Slope	10^{o}
Aspect	NE
Land use	Plantation; <u>Cupressus</u>
Parent material	Bouldery colluvium
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	3-0	Raw to partially decomposed leaf litter; frequent fine roots; abrupt, smooth boundary:
A2	0-10	Dusky red (10 YR 3/2), moist; sandy loam; moderate fine subangular blocky structure; friable consistence; many fine discontinuous exped pores; frequent fine and medium roots; clear, smooth boundary:
A3	10-32	Weak red to dusky red (2.5 YR 3.5/2), moist; loam; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; frequent fine and medium roots; clear, smooth boundary:
Bt1	32-48	Dusky red (10 R 3/6), moist; gravelly coarse sandy clay loam; weak fine subangular blocky structure; firm consistence; frequent hard subangular stones (vein quartz and gneiss); few fine roots; clear, smooth boundary:
Bt2	48-150	Red (10 R 4/6), moist; coarse sandy clay loam; weak fine subangular blocky structure; firm consistence; frequent zones of decomposing rock material (mainly quartz, with some decomposing feldspar); very few fine roots.

PROFILE 15 LAB. NO. 8466-70

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	Bt1	Bt2	
	3-0	0-10	10-32	32-48	48-150	
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	4.7 0.58	3.1 0.93	3.8 0.92	2.2 1.14	0.9 1.10	
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.9 5.3 0.08	5.3 4.7 0.05	5.0 4.7 0.03	5.1 4.2 0.02	5.0 4.1 0.02	
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 0.7 5.8 34.8	0.0 0.2 2.4 9.2	0.0 0.1 0.6 0.9	0.0 0.1 0.2 0.1	0.0 0.0 0.2 0.1	
TEB meq % CEC meq %	41.4 58.4	11.8 24.1	1.6 17.5	0.4 13.9	0.3 5.2	
Base saturation %	71	49	9	3	6	
Total N % Organic C %	1.07 18.68	0.50 6.11	0.34 4.07	0.14 1.56	0.05 0.57	
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	990 1750 2100 8600	820 1600 1850 2400	730 1450 1450 300	730 1250 1300 <100	650 1050 950 <100	
Available P (Bray) ppm	13.5	9.5	7.6	9.8	8.6	
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 15 19 31 35	 17 23 20 40	 16 23 20 41	 27 21 18 34	 25 25 14 36	
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 16

Soil series	Lokotulu
Classification	FAO: Humic Nitosols
Location	Block 11, Line 1, Plot 25
Elevation	2 235 m
Landform	Physiographic position: on gentle convex upper slope Landform unit: E Microtopography: nil
Slope	5°
Aspect	SW
Land use	C6, Podocarpus-Syzygium open forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-3	Dark reddish brown (5 YR 3/2), moist; sandy loam; strong medium crumb structure; friable; dominant decomposing leaves (mull); very frequent fine, medium and coarse roots; abrupt, smooth boundary:
A2	3-20	Dark reddish brown (5 YR 3/2), moist; loam; strong medium crumb structure; very friable consistence; many thin discontinuous exped pores; frequent fine and medium roots; gradual, smooth boundary:
A3	20-60	Dark reddish brown (5 YR 3/3), moist; loam; moderate fine subangular blocky structure, breaking into micro (<1 mm diameter) crumb structure; friable consistence; pores as above; few small hard subangular stones (medium grained gneiss); few fine and medium roots; diffuse, smooth boundary:
Bt	60-150	Dark reddish brown (5 YR 3/4), moist; loam; structure, consistence and pores as above.

PROFILE 16 LAB. NO. 8426-29

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	Bt		
	0-3	3-20	20-60	60-150		
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	7.4 0.83	5.5 1.05	4.4 1.06	3.8 1.05		
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.5 4.9 0.13	5.4 4.6 0.05	5.1 4.2 0.03	5.0 4.1 0.02		
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 0.5 4.4 28.2	0.1 0.3 2.1 12.3	0.0 0.1 0.2 1.4	0.0 0.1 0.2 0.8		
TEB meq % CEC meq %	33.2 48.0	14.8 27.5	1.7 20.6	1.1 14.8		
Base saturation %	69	54	8	7		
Total N % Organic C %	0.96 11.11	0.63 5.73	0.23 3.20	0.11 1.83		
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1120 2050 2550 6800	1000 2200 2500 2900	670 1450 1650 400	660 1750 1750 200		
Available P (Bray) ppm	14.8	9.4	14.4	21.2		
Mechanical analysis 2 mm - 250 µ % 250 µ% - 50 µ % 50 µ% - 2 µ % 2 µ%	 12 24 23 41	 13 28 21 38	 13 29 24 34	 12 25 17 46		
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 17

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Block 1, Line 1, Plot 10
Elevation	1 770 m
Landform	Physiographic position: on moderately sloping convex slope immediately above an incised strong lower slope Landform unit: F Microtopography: nil
Slope	12°
Aspect	N
Land use	C4, Croton-Macaranga-Albizia forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water rable	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-18	Very dusky red (2.5 YR 2/2), moist; strong fine crumb structure; very friable consistence; many fine exped pores; very frequent fine and coarse roots; gradual, smooth boundary:
A2	18-52	Dusky red to dark reddish brown (2.5 YR 3/3), moist; loam; weak very fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; many fine exped pores; few, fine roots; gradual, smooth boundary:
Bt1	52-80	Red (2.5 YR 3/6), moist; clay loam; structure, consistence and pores as above; very few fine roots; clear, smooth boundary:
Bt2	80-150	Dusky red (10 R 3/3), moist; sandy clay; moderate fine subangular blocky structure; firm consistence; broken moderately thick cutans; few fine exped pores; few small fragments of decomposing rock (feldspathic ?); very few fine roots.

PROFILE 17 LAB. NO. 8380-83

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt1	Bt2		
	0-18	18-52	52-80	80-150		
Moisture (100-105°C)%	6.4	4.5	3.7	3.7		
Bulk density g/ml	0.79	0.96	1.02	1.00		
Loss of ignition %						
pH (1:5) soil: water	5.5	4.4	4.4	4.8		
pH (1:5) soil: 1N KCl	4.7	4.1	4.1	3.9		
Conductivity mmhos	0.09	0.03	0.02	0.02		
Exch. Na meq %	0.0	0.0	0.0	0.0		
Exch. K meq %	0.9	0.2	0.1	0.2		
Exch. Mg meq %	5.9	0.3	0.2	0.2		
Exch. Ca meq %	13.5	0.5	0.3	0.2		
TEB meq %	20.3	1.0	0.6	0.6		
CEC meq %	35.7	18.2	14.6	14.4		
Base saturation %	57	6	4	4		
Total N %	0.79	0.27	0.14	0.09		
Organic C %	6.91	2.27	1.10	0.82		
Total P ppm	1310	1040	900	870		
Total K ppm	3150	3250	3100	2900		
Total Mg ppm	3000	2300	2050	1850		
Total Ca ppm	3400	200	200	<100		
Available P (Bray) ppm	13.6	18.0	24.9	15.3		
Mechanical analysis						
2 mm - 250 µ %	17	14	13	15		
250 µ% - 50 µ %	12	13	14	11		
50 µ% - 2 µ %	29	21	23	14		
2 µ%	42	52	50	60		
Water dispersible clay %						
total	1.8	2.6	3.9	6.0		
less OM	18.0	7.8	4.2	4.8		
Trace metals						
Copper ppm	30	30	30	20		
Chromium ppm	40	40	30	30		
Manganese ppm	1310	550	530	320		
Zinc ppm	120	100	90	90		
Iron %	4.9	6.1	6.1	6.4		

PROFILE 18

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	1 km south of the junction of the new and old roads from Katire to Gilo
Elevation	1 650 m
Landform	Physiographic position: on strongly sloping planar to slightly concave long slope rising from 1 370 m to 1 680 m Landform unit: L Microtopography: nil
Slope	25°
Aspect	NW
Land use	Cultivated, under tobacco; previously cropped with millet or sorghum
Parent material	Colluvium, probably derived mainly from pegmatite
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Few scattered stones; clusters of large boulders locally
Erosion	Slight to moderate sheet

Horizon	Depth cm	
A1	0-8	Black (2.5 YR N2/-), moist; sandy loam; strong fine crumb structure; loose consistence; many fine continuous exped pores; very frequent fine roots; abrupt, smooth boundary:
A2	8-25	Very dusky red (10 R 2/2), moist; loam; moderate fine subangular blocky structure; friable consistence; common fine discontinuous exped pores; few fine roots; few small hard subangular stones (pegmatite); clear, smooth boundary:
Bt	25-48	Dusky red (10 R 3/4), moist; clay loam; moderate fine subangular blocky structure; firm consistence; pores as above; few small subangular stones (pegmatite), many small fragments of decomposing pegmatite:
C	48+	Boulder (pegmatite).

PROFILE 18 LAB. NO. 8446-48

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt			
	0-8	8-25	25-48			
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	3.8 0.85	2.6 1.00	2.2 1.07			
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	6.7 5.8 0.11	6.4 5.0 0.04	5.9 4.6 0.02			
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 0.9 10.5 34.0	0.0 0.3 5.1 12.0	0.1 0.2 2.1 4.3			
TEB meq % CEC meq %	45.5 54.5	17.4 30.6	6.7 12.5			
Base saturation %	84	57	54			
Total N % Organic C %	0.93 11.24	0.42 4.88	0.20 1.61			
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1430 2700 3000 8900	1330 2700 2450 3100	1180 2800 2050 1000			
Available P (Bray) ppm	30.4	10.5	9.3			
Mechanical analysis 2 mm - 250 µ % 250 µ% - 50 µ % 50 µ% - 2 µ % 2 µ%	 19 19 30 32	 23 19 25 33	 21 18 22 39			
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 19

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Block 7, Line 1, Plot 10
Elevation	2 225 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: G
	Microtopography: nil
Slope	17°
Aspect	W
Land use	C5, Olea-Podocarpus closed forest

Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-7	Very dark red (2.5 YR 2/2), moist; loam; moderate medium crumb structure; friable consistence; many fine continuous exped pores; frequent fine, medium and coarse roots; clear, smooth boundary:
A2	7-35	Dusky red (2.5 YR 3/2), moist; loam; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; frequent fine discontinuous exped pores; gradual, smooth boundary:
Bt1	35-95	Dark red (2.5 YR 3/6), moist; clay loam; structure, consistence and pores as above; diffuse, smooth boundary:
Bt2	95-150	Red (2.5 YR 4/8), moist; sandy clay; structure, consistence and pores as above; patchy thin cutans.

PROFILE 19 LAB. NO. 8408-11

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt1	Bt2		
	0-7	7-35	35-95	95-150		
Moisture (100-105^{o}C) %	5.6	4.8	3.1	3.8		
Bulk density g/ml	0.92	0.98	1.02	1.01		
Loss of ignition %						
pH (1:5) soil: water	5.2	4.9	4.9	4.6		
pH (1:5) soil: 1N KCl	4.2	4.1	4.0	4.0		
Conductivity mmhos	0.10	0.04	0.02	0.03		
Exch. Na meq %	0.0	0.0	0.0	0.0		
Exch. K meq %	0.4	0.2	0.2	0.2		
Exch. Mg meq %	2.3	0.8	0.3	0.4		
Exch. Ca meq %	11.0	2.6	0.2	0.4		
TEB meq %	13.7	3.6	0.7	1.0		
CEC meq %	33.9	22.3	11.3	14.6		
Base saturation %	40	16	6	7		
Total N %	0.87	0.40	0.08	0.62		
Organic C %	8.03	4.80	0.61	1.54		
Total P ppm	970	700	610	730		
Total K ppm	2350	2100	2950	3050		
Total Mg ppm	2600	2200	1850	2200		
Total Ca ppm	2700	600	< 100	<100		
Available P (Bray) ppm	13.8	8.8	9.7	9.3		
Mechanical analysis						
2 mm - 250 µ %	15	14	13	9		
250 µ% - 50 µ %	19	22	18	18		
50 µ% - 2 µ %	26	20	13	12		
2 µ%	40	44	56	61		
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 20

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Block 6, Line 2, Plot 1
Elevation	2 180 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: G
	Microtopography: nil
Slope	15°
Aspect	NW
Land use	C5, Olea-Podocarpus closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water rable	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-20	Black (2.5 YR N2/-), moist; sandy loam; strong fine crumb structure; very friable consistence; frequent fine continuous exped pores; frequent fine, medium and coarse roots; clear, smooth boundary:
A2	20-45	Dusky red (2.5 YR 3/2), moist; sandy loam; moderate fine subangular blocky structure; friable consistence; frequent fine continuous exped pores; few fine and medium roots; clear, smooth boundary:
Bt1	45-116	Dark reddish brown (2.5 YR 3/4), moist, clay loam; moderate fine subangular blocky structure; friable consistence; few fine discontinuous exped pores; few fine and medium roots; diffuse, smooth boundary:
Bt2	116-150	Weak red (10 R 4/4), moist; sandy clay; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; firm consistence; patchy thin cutans with ferro-manganese staining; few fine discontinuous pores; few medium roots.

PROFILE 20 LAB. NO. 3404-07

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt1	Bt2		
	0-20	20-45	45-116	116-150		
Moisture (100-105°C)%	5.5	4.6	4.0	3.2		
Bulk density g/ml	1.00	1.07	0.99	1.05		
Loss of ignition %						
pH (1:5) soil: water	5.8	5.2	4.9	4.9		
pH (1:5) soil: 1N KCl	4.8	4.1	3.9	3.9		
Conductivity mmhos	0.06	0.03	0.03	0.02		
Exch. Na meq %	0.0	0.0	0.0	0.0		
Exch. K meq %	0.4	0.3	0.4	0.2		
Exch. Mg meq %	4.7	0.8	0.5	0.2		
Exch. Ca meq %	15.0	2.4	1.8	0.4		
TEB meq %	20.1	3.5	2.7	0.8		
CEC meq %	33.2	18.9	15.0	12.5		
Base saturation %	61	19	18	6		
Total N %	0.63	0.20	0.09	0.09		
Organic C %	5.60	2.29	0.73	0.69		
Total P ppm	850	700	510	430		
Total K ppm	2650	2950	3400	3100		
Total Mg ppm	2650	2100	2200	1850		
Total Ca ppm	3800	600	300	<100		
Available P (Bray) ppm	9.7	18.9	14.9	10.1		
Mechanical analysis						
2 mm - 250 μ %	21	20	19	22		
250 μ% - 50 μ %	19	20	16	17		
50 μ% - 2 μ %	31	21	11	11		
2 μ%	29	39	54	50		
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 21

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Compartment 22; approximately 1.5 km east-north-east of Gilo resthouse
Elevation	1 890 m
Landform	Physiographic position: on moderately sloping convex upper slope
	Landform unit: F
	Microtopography: nil
Slope	11^{o}
Aspect	W
Land use	Plantation; <u>Pinus patula</u>
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water rable	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
O	3-0	Raw to partly decomposed pine needle litter; frequent fine roots; abrupt, smooth boundary:
A	0-32	Very dusky red (2.5 YR 2/2), moist; sandy loam; moderate fine crumb structure; friable consistence; many fine discontinuous exped pores; frequent fine, medium and coarse roots; gradual, wavy boundary:
Bts1	32-51	Red (2.5 YR 4/6), many, medium, distinct dusky red (2.5 YR 3/4) mottles, moist; loam; weak fine subangular blocky structure, breaking to moderate micro (<1 mm diameter) crumb structure; friable consistence; few fine and medium roots; clear, wavy boundary:
Bts2	51-103	Colour and mottling as above; clay loam; weak fine subangular blocky structure; firm consistence; frequent fragments of decomposing rock (gneiss); gradual, smooth boundary:
Bts3	103-145	Brown to dark brown (7.5 YR 4/4), common, fine, distinct dark reddish brown (5 YR 3/2) mottles, moist; coarse sandy clay loam; structureless, massive; very firm consistence; frequent fine fragments of decomposing feldspar; clear, smooth boundary:
C	145+	Compact weathering gneiss.

Characteristic	Horizon (depth in cm)					
	O	A	Bts1	Bts2	Bts3	
	3-0	0-32	32-51	51-103	103-145	
Moisture (100-105°C) %	1.1	1.2	0.7	1.2	1.2	
Bulk density g/ml	0.85	1.04	1.05	1.18	1.17	
Loss of ignition %						
pH (1:5) soil: water	5.9	4.7	5.0	5.2	5.6	
pH (1:5) soil: 1N KCl	4.8	4.0	4.2	4.2	4.3	
Conductivity mmhos	0.06	0.03	0.02	0.02	0.02	
Exch. Na meq %	0.1	0.0	0.0	0.0	0.0	
Exch. K meq %	0.9	0.4	0.1	0.1	0.2	
Exch. Mg meq %	2.7	0.2	0.0	0.0	0.0	
Exch. Ca meq %	8.0	0.1	0.0	0.0	0.0	
TEB meq %	11.7	0.7	0.1	0.1	0.2	
CEC meq %	18.2	11.3	6.7	5.5	4.6	
Base saturation %	64	6	2	2	4	
Total N %	0.25	0.14	0.07	0.04	0.02	
Organic C %	4.67	2.37	1.19	0.40	0.25	
Total P ppm	450	340	290	360	390	
Total K ppm	2000	1900	1800	2200	2000	
Total Mg ppm	1350	1050	1050	900	400	
Total Ca ppm	1800	<100	<100	<100	<100	
Available P (Bray) ppm	13.2	6.8	6.1	6.9	8.2	
Mechanical analysis						
2 mm - 250 µ %	28	22	22	23	30	
250 µ% - 50 µ %	28	33	33	28	28	
50 µ% - 2 µ %	24	18	17	21	26	
2 µ%	20	27	28	28	16	
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 22

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Compartment 8; north of summit of Observation Hill
Elevation	Physiographic position: on moderately sloping convex upper slope
	Landform unit: F
	Microtopography: nil
Slope	7°
Aspect	NE
Land use	Plantation; Cupressus

Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
O	4-0	Mat of decomposing Cupressus leaves; abundant very fine roots, abrupt, smooth boundary:
A	0-44	Dusky red (2.5 YR 3/2), moist; loam; weak fine subangular blocky structure, breaking to moderate micro (<1 mm diameter) crumb structure; friable consistence; common fine discontinuous exped pores; abundant fine roots decreasing to few with depth, few medium and coarse roots; gradual, smooth boundary:
Btl	44-98	Red (10 R 4/6), moist; sandy clay; moderate fine subangular blocky structure; firm consistence; few fine discontinuous exped pores; few hard subangular stones (vein quartz and gneiss), frequent angular quartz gravel; frequent fine roots; diffuse, smooth boundary:
BC	98-136	Weak red (10 R 4/4), moist; sandy clay; structure, consistence and pores as above; very frequent fragments of decomposing feldspar; gradual, smooth boundary:
R	136+	Weathering medium grained gneiss.

PROFILE 22 LAB. NO. 8484-87

Characteristic	Horizon (depth in cm)					
	O	A	Bt1	BC		
	4-0	0-44	44-98	98-136		
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	3.2 0.26 56	0.9 0.88	0.8 0.96	1.0 0.96		
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	5.8 4.9 0.12	5.0 4.1 0.03	5.0 4.3 0.02	5.2 4.2 0.01		
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 1.5 10.0 30.4	0.0 0.4 0.6 0.1	0.0 0.1 0.1 0.0	0.1 0.1 0.0 0.0		
TEB meq % CEC meq %	42.0 64.8	1.1 12.5	0.2 6.7	0.2 5.8		
Base saturation %	65	9	3	3		
Total N % Organic C %	1.05 26.18	0.19 3.20	0.08 1.12	0.04 0.44		
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	640 1000 1800 11700	380 1450 1000 100	320 1500 1000 <100	470 1350 7500 <100		
Available P (Bray) ppm	11.7	5.7	5.1	12.2		
Mechanical analysis 2 mm - 250 µ % 250 µ% - 50 µ % 50 µ% - 2 µ % 2 µ%	 20 9 38 33	 30 18 11 41	 28 15 11 46	 30 11 13 46		
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 23

Soil series	Ngairigi
Classification	FAO: Humic Nitosols
Location	Compartment 8, approximately 300 m south-west of Gilo resthouse
Elevation	1 870 m
Landform	Physiographic position; on moderately sloping concave middle slope Landform unit: F Microtopography: nil
Slope	10°
Aspect	W
Land use	Plantation; Cupressus
Parent material	Hill wash material from medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
O	3-0	Mat of decomposing Cupressus leaves; abundant fine roots; abrupt, smooth boundary:
A1	0-19	Very dusky red (10 R 2/2), moist; sandy loam; weak very fine crumb structure, breaking to strong micro (<1 mm diameter) crumb structre; very friable; many fine discontinuous exped pores; frequent fine roots, few medium roots; gradual, smooth boundary:
A2	19-43	Dusky red (10 R 3/3), moist; loam; structure, consistence, pores and roots as above; diffuse, smooth boundary:
Bt1	43-83	Dusky red (10 R 3/3), moist; clay loam; weak fine subangular blocky structure, breaking to micro crumb structure; friable consistence; many fine discontinuous exped pores; few fine roots; gradual, smooth boundary:
Bt2	83-150	Dusky red (10 R 3/3), moist; sandy clay; structure and pores as above; firm consistence; very few fine roots.

Note: vertical cracks, 20-30 cm apart, and up to 10 cm thick, occur to a depth of between 100 and 120 cm.

PROFILE 23 LAB. NO. 8490-94

Characteristic	Horizon (depth in cm)					
	O	A1	A2	Bt1	Bt2	
	3-0	0-19	19-43	43-83	83-150	
Moisture (100-105°C)%	3.5	3.0	3.1	2.6	2.1	
Bulk density g/ml	0.56	0.88	0.96	1.06	0.97	
Loss of ignition %						
pH (1:5) soil: water	5.9	4.6	4.6	4.7	5.0	
pH (1:5) soil: 1N KCl	4.9	4.0	4.1	4.2	4.1	
Conductivity mmhos	0.05	0.03	0.02	0.03	0.02	
Exch. Na meq %	0.1	0.0	0.0	0.0	0.0	
Exch. K meq %	0.8	0.2	0.1	0.1	0.1	
Exch. Mg meq %	5.9	1.0	0.2	0.1	0.1	
Exch. Ca meq %	23.0	0.0	0.0	0.0	0.0	
TEB meq %	29.8	1.2	0.3	0.2	0.2	
CEC meq %	48.6	24.4	17.0	11.7	14.8	
Base saturation %	61	5	2	2	1	
Total N %	0.59	0.32	0.22	0.14	0.08	
Organic C %	13.86	5.17	3.31	5.00	1.07	
Total P ppm	720	690	460	460	600	
Total K ppm	2250	2200	1850	2350	2650	
Total Mg ppm	2600	2100	1750	1950	2150	
Total Ca ppm	7100	200	100	100	<100	
Available P (Bray) ppm	9.8	9.2	6.9	6.2	11.4	
Mechanical analysis						
2 mm - 250 µ %	27	29	25	23	17	
250 µ% - 50 µ %	12	14	17	18	11	
50 µ% - 2 µ %	32	21	21	22	9	
2 µ%	29	36	37	37	63	
Water dispersible clay %						
total	1.4	0.8	0.8	1.2	2.8	
less OM	11.4	4.8	3.8	3.4	1.0	
Trace metals						
Copper ppm	30	30	30	30	30	
Chromium ppm	50	50	40	40	40	
Manganese ppm	330	260	170	240	180	
Zinc ppm	60	60	50	60	70	
Iron %	3.5	4.4	4.2	4.6	3.7	

PROFILE 24

Soil series	Itibol
Classification	FAO: Humic Nitosols
Location	Block 10, Line 1, Plot 15
Elevation	2 225 m
Landform	Physiographic position: on moderately sloping convex middle slope
	Landform unit: E
	Microtopography: nil
Slope	12^o
Aspect	NE
Land use	C5, <u>Olea</u>-<u>Podocarpus</u> closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
O	4-0	Decomposing mat of leaves and roots forming a mull layer; very frequent fine and medium roots; abrupt, smooth boundary:
A1	0-8	Dark reddish brown (5 YR 3/2), moist; sandy loam; moderate fine crumb structure, very friable consistence; many fine continuous exped pores; very frequent fine, medium and coarse roots; abrupt, smooth boundary:
A2	8-60	Dark reddish brown (5 YR 3/3), moist; loam; weak subangular blocky structure; breaking to strong micro (<1 mm diameter) crumb structure; many fine continuous exped pores; frequent fine, medium and coarse roots; gradual, smooth boundary:
Bt1	60-94	Dark reddish brown (2.5 YR 3/4), moist; clay loam; structure, consistence and pores as above; few medium roots; gradual, smooth boundary:
Bt2	94-150	Reddish brown (2.5 YR 4/4), moist; fine sandy clay; structure, consistence and pores as above; patchy thin cutans; very few coarse roots.

PROFILE 24 LAB. NO. 8417-21

Characteristic	Horizon (depth in cm)					
	O	A1	A2	Bt1	Bt2	
	4-0	0-8	8-60	60-94	94-150	
Moisture (100-105°C)% Bulk density g/ml Loss of ignition %	8.5 0.50	4.3 0.93	4.5 1.04	4.0 0.97	4.1 1.00	
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	6.0 5.4 0.24	4.7 3.7 0.10	4.6 4.0 0.04	4.7 3.9 0.03	4.3 3.9 0.03	
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 1.3 10.0 48.0	0.0 0.4 1.4 10.3	0.0 0.2 0.1 1.0	0.0 0.2 0.1 0.5	0.0 0.1 0.1 0.3	
TEB meq % CEC meq %	59.4 79.4	12.1 31.8	1.3 19.6	0.8 18.0	0.5 12.9	
Base saturation %	75	38	7	4	4	
Total N % Organic C %	1.81 21.85	0.93 9.25	0.27 3.16	0.13 1.50	0.08 0.75	
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	1170 2450 2850 14100	1110 2950 2350 2000	810 2950 2350 200	870 2750 2100 300	730 2500 1700 <100	
Available P (Bray) ppm	38.7	16.6	23.3	28.5	22.6	
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 10 19 39 32	 13 23 43 21	 15 25 23 37	 12 19 13 56	 11 20 15 54	
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 25

Soil series	Itibol
Classification	FAO: Humic Nitosols
Location	Block 19, Line 1, Plot -4
Elevation	2 295 m
Landform	Physiographic position: on moderately sloping planar middle slope
	Landform unit: C
	Microtopography: nil
Slope	8^o
Aspect	E
Land use	B5, Podocarpus-Dombeya open montane forest

Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-18	Dark reddish brown (5 YR 2/2), moist; loam; moderately fine crumb structure; friable consistence; many fine continuous exped pores; very frequent fine; medium and coarse roots; clear, smooth boundary:
A2	18-46	Dark reddish brown (5 YR 3/3), moist; loam; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; consistence and pores as above; few medium and coarse roots; diffuse, smooth boundary:
Bt	46-97	Dark red (2.5 YR 3/6), moist; clay loam; moderate fine subangular blocky structure, breaking to strong micro crumb structure; fine discontinuous exped pores; very few subangular stones (gneiss); few medium roots; gradual, smooth boundary:
Bts	97-150	Red (2.5 YR 4/6), common fine distinct dark red (2.5 YR 3/6) mottles, moist; coarse sandy clay; weak fine subangular blocky structure; firm consistence; pores as above; few small subangular fragments of feldspar (decomposing rock fragments).

PROFILE 25 LAB. NO. 8441-44

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt	Bts		
	0-18	18-46	46-97	97-150		
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	8.2 0.84	4.3 1.08	4.5 1.02	5.2 1.03		
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	4.9 4.2 0.08	4.6 4.1 0.03	4.7 4.1 0.02	4.9 4.0 0.02		
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 0.5 3.7 12.0	0.0 0.1 0.3 0.8	0.0 0.1 0.2 0.3	0.0 0.1 0.2 0.2		
TEB meq % CEC meq %	16.3 41.6	1.2 20.5	0.6 15.5	0.5 14.1		
Base saturation %	39	6	4	4		
Total N % Organic C %	0.94 12.60	0.23 3.44	0.14 1.78	0.09 1.16		
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	980 2050 2150 3200	560 1750 1650 300	630 2250 1650 200	650 2250 1650 100		
Available P (Bray) ppm	17.2	7.1	9.1	13.0		
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 23 10 50 17	 29 11 19 41	 26 11 12 51	 21 9 8 62		
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 26

Soil series	Konoro
Classification	FAO: Humic Nitosols
Location	Block 5, Line 1, Plot 15
Elevation	1 875 m
Landform	Physiographic position: on steeply sloping concave middle slope
	Landform unit: 
	Microtopography: nil
Slope	23°
Aspect	SE
Land use	C6, <u>Podocarpus</u>-<u>Syzygium</u> open forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	10%, locally dominant boulders
Erosion	Nil

Horizon	Depth cm	
A1	0-12	Dark reddish brown (5 YR 2/3), moist; loamy sand; moderate fine crumb structure; loose consistence; common fine exped pores; very frequent fine to coarse roots; abrupt, smooth boundary:
A2	12-42	Dark reddish brown (5 YR 3/3), moist; sandy loam; moderate very fine subangular blocky structure; firm consistence; common fine exped pores; few medium roots; few hard subangular stones (quartzite); gradual, smooth boundary:
A3	42-80	Dark reddish brown (5 YR 3/3), moist; loam; structure, consistence and pores as above; very few coarse roots; clear, smooth boundary:
Bt	80-150	Dark reddish grey (5 YR 4/2), moist; coarse sandy clay; weak very fine subangular blocky structure; firm consistence; broken moderately thick cutans; few fine exped pores; few large hard subangular stones (medium grained gneiss); few medium to coarse roots.

PROFILE 26 LAB. NO. 8400-03

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	Bt		
	0-12	12-42	42-80	80-150		
Moisture (100-105°C)%	3.6	1.3	1.1	1.4		
Bulk density g/ml	0.97	1.05	1.22	1.15		
Loss of ignition %						
pH (1:5) soil: water	7.1	6.0	5.7	5.8		
pH (1:5) soil: 1N KCl	5.9	4.8	4.7	4.4		
Conductivity mmhos	0.16	0.03	0.02	0.02		
Exch. Na meq %	0.0	0.0	0.0	0.0		
Exch. K meq %	0.8	0.3	0.3	0.3		
Exch. Mg meq %	5.7	1.8	1.4	1.8		
Exch. Ca meq %	27.2	4.4	3.3	4.5		
TEB meq %	33.7	6.5	5.0	6.6		
CEC meq %	35.4	9.6	7.7	10.1		
Base saturation %	95	68	65	65		
Total N %	0.81	0.14	0.06	0.06		
Organic C %	7.33	1.15	0.38	0.52		
Total P ppm	1240	470	300	350		
Total K ppm	2650	2350	2050	2800		
Total Mg ppm	2500	1750	1250	1850		
Total Ca ppm	6600	1000	700	800		
Available P (Bray) ppm	6.6	6.7	10.1	10.5		
Mechanical analysis						
2 mm - 250 µ %	27	28	31	30		
250 µ% - 50 µ %	22	27	28	18		
50 µ% - 2 µ %	22	21	20	16		
2 µ%	29	24	21	36		
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 27

Soil series	Konoro
Classification	FAO: Humic Nitosols
Location	Compartment 11; approximately 1.5 km east-south-east of Gilo resthouse
Elevation	Physiographic position: on moderately sloping convex upper slope immediately below a bouldery summit area
	Landform unit: F
	Microtopography: nil
Slope	11°
Aspect	W
Land use	Plantation; Cupressus
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Dry
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-4	Black (2.5 YR N2/-), moist; sandy loam; strong very fine crumb structure; friable to loose consistence; many fine discontinuous exped pores; abundant fine roots; abrupt, smooth boundary:
A2	4-21	Dark reddish brown (5 YR 3/2), moist; sandy loam; moderate fine crumb structure; friable consistence; common fine discontinuous exped pores; very frequent fine roots; abrupt, smooth boundary:
A3	21-43	Dark reddish brown (5 YR 3/2), moist: loam; structure, consistence and pores as above; few hard subangular stones (vein quartz); frequent quarts gravel; few boulders (gneiss); very few fine roots; gradual, smooth boundary:
Bt	43-77	Reddish brown (5 YR 4/6), moist; sandy clay; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; firm consistence; few discontinuous exped pores; frequent fragments of decomposing feldspar; diffuse, smooth boundary:
BC	77-150	Reddish yellow (5 YR 6/8), moist; sandy clay loam; structureless, massive; very firm consistence; very frequent fragments of decomposing feldspar (weathering rock material in situ); very few fine roots.

PROFILE 27 LAB. NO. 8479-83

Characteristic	Horizon (depth in cm)					
	A1	A2	A3	Bt	BC	
	0-4	4-21	21-43	43-77	77-150	
Moisture (100-105°C) % Bulk density g/ml Loss of ignition %	3.7 0.45	1.2 0.98	1.1 1.04	0.9 1.05	0.5 1.09	
pH (1:5) soil: water pH (1:5) soil: 1N KCl Conductivity mmhos	6.8 5.8 0.10	5.0 3.9 0.06	4.5 4.0 0.04	4.9 4.1 0.03	5.0 4.3 0.02	
Exch. Na meq % Exch. K meq % Exch. Mg meq % Exch. Ca meq %	0.1 1.3 7.8 45.0	0.0 0.4 1.3 4.3	0.0 0.2 0.3 0.1	0.0 0.3 0.3 0.0	0.0 0.1 0.1 0.0	
TEB meq % CEC meq %	54.2 64.6	6.0 22.9	0.6 13.8	0.6 6.5	0.2 2.4	
Base saturation %	84	26	4	9	8	
Total N % Organic C %	1.09 19.79	0.47 5.45	0.25 3.33	0.07 0.82	0.02 0.20	
Total P ppm Total K ppm Total Mg ppm Total Ca ppm	740 1150 2400 10100	520 1450 1150 1200	330 1200 850 <100	260 1650 1050 <100	170 2400 1050 <100	
Available P (Bray) ppm	8.1	6.9	5.4	7.8	6.9	
Mechanical analysis 2 mm - 250 μ % 250 μ% - 50 μ % 50 μ% - 2 μ % 2 μ%	 34 13 27 26	 38 22 14 26	 37 23 14 26	 31 18 15 36	 36 21 32 11	
Water dispersible clay % total less OM						
Trace metals Copper ppm Chromium ppm Manganese ppm Zinc ppm Iron %						

PROFILE 28

Soil series	Oreira
Classification	FAO: Humic Nitosols
Location	Block 9, Line 1, Plot 15
Elevation	2 325 m
Landform	Physiographic position: on moderately sloping planar middle slope
	Landform unit: G
	Microtopography: nil
Slope	20°
Aspect	W
Land use	C5, _Olea-Podocarpus_ closed forest
Parent material	Medium grained gneiss
Drainage	Well drained
Moisture condition	Moist
Water rable	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-13	Very dark brown (10 YR 2/2), moist; loam; strong medium subangular blocky; friable to loose consistence; many fine continuous exped pores; very frequent fine, medium and coarse roots; clear, smooth boundary:
A2	13-40	Dark brown (10 YR 3/2), moist; loam; weak fine subangular blocky structure, breaking to strong micro (<1 mm diameter) crumb structure; friable consistence; common fine continuous exped pores; few coarse and fine roots; grandual smooth boundary:
Bt1	40-70	Brown (7.5 YR 4/2), moist; clay loam; structure, consistence and pores as above; few subangular stones (gneiss and vein quartz); few medium roots; diffuse, smooth boundary:
Bt2	70-118	Brown (7.5 YR 4/4), moist; clay; structure, consistence and pores as above; few subangular stones (gneiss and vein quartz); few medium roots; diffuse, smooth boundary;
Bts	118-150	Dark reddish brown (2.5 YR 2/4), many fine prominent yellowish red (5 YR 4/8) mottles, moist; sandy clay; weak fine subangular blocky structure; firm consistence; patchy thin cutans; few fine discontinuous exped pores; very few subangular stones (gneiss).

PROFILE 28 LAB. NO. 8412-16

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt	Bt2	Bts	
	0-13	13-40	40-76	76-118	118-150	
Moisture (100-105°C) %	4.5	2.8	2.5	2.7	2.7	
Bulk density g/ml	0.87	1.01	1.09	1.06	0.98	
Loss of ignition %						
pH (1:5) soil: water	5.0	4.8	4.8	4.7	4.5	
pH (1:5) soil: 1N KCl	4.3	4.0	4.0	3.8	3.8	
Conductivity mmhos	0.12	0.04	0.03	0.03	0.03	
Exch. Na meq %	0.0	0.0	0.0	0.0	0.0	
Exch. K meq %	0.4	0.2	0.1	0.1	0.2	
Exch. Mg meq %	4.1	1.2	0.4	0.2	0.1	
Exch. Ca meq %	21.0	2.3	0.8	0.4	0.4	
TEB meq %	25.5	3.7	1.3	0.7	0.7	
CEC meq %	46.1	22.3	17.4	13.6	12.4	
Base saturation %	55	17	8	5	6	
Total N %	0.82	0.39	0.13	0.10	0.09	
Organic C %	9.77	4.45	1.50	0.92	0.88	
Total P ppm	1090	840	660	840	750	
Total K ppm	2500	2350	2200	2850	2700	
Total Mg ppm	2600	1750	1600	1850	1500	
Total Ca ppm	5300	700	200	100	<100	
Available P (Bray) ppm	6.4	11.0	37.1	42.6	18.6	
Mechanical analysis						
2 mm - 250 μ %	20	26	31	23	17	
250 μ% - 50 μ %	15	17	14	12	10	
50 μ% - 2 μ %	25	18	14	10	13	
2 μ%	40	39	41	55	60	
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 29

Soil series	Oreira
Classification	FAO: Humic Nitosols
Location	Block 18, Line 2, Plot 5
Elevation	1 885 m
Landform	Physiographic position: on strongly sloping planar lower slopes Landform unit: G Microtopography: nil
Slope	29°
Aspect	W
Land use	C6, <u>Podocarpus-Syzygium</u> open forest
Parent material	Highly feldspathic medium grained gneiss (syenite ?)
Drainage	Well drained
Moisture condition	Moist
Water table	Absent
Surface stones	Absent
Erosion	Nil

Horizon	Depth cm	
A1	0-20	Dark brown (7.5 YR 3/2), moist; sandy loam; moderate very fine crumb structure; friable consistence; few fine discontinuous exped pores; few fine roots; gradual, smooth boundary:
A2	20-60	Dark reddish brown (5 YR 5/2), moist; loam; weak very fine subangular structure; friable consistence; pores as above; few angular stones (gneiss); very few fine roots; gradual, smooth boundary:
Bt1	60-88	Brown (7.5 YR 4/4), moist; coarse sandy clay loam; structure, pores, stones and roots as above; firm consistence; diffuse, smooth boundary:
Bt2	88-113	Strong brown (7.5 YR 5/4), moist; coarse sandy clay; structure, consistence and pores as above; gradual, smooth boundary:
Bts1	113-142	Light yellowish brown (10 YR 6/4), common fine distinct reddish brown (5 YR 5/4) mottles, moist; coarse sandy clay; weak fine subangular blocky; firm consistence; clear, smooth boundary:
Bts2	142-160	Dusky red (10 YR 3/3), many medium prominent reddish yellow (7.5 YR 6/6) mottles, moist; gravelly coarse sandy clay; structureless, massive; compact consistence; frequent fragments of feldspar.

PROFILE 29 LAB. NO. 8435-40

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt1	Bt2	Bts1	Bts2
	0-20	20-60	60-88	88-113	113-142	142-160
Moisture (100-105°C) %	2.0	3.4	1.8	3.0	1.2	3.3
Bulk density g/ml	1.01	1.13	1.12	1.00	1.03	1.02
Loss of ignition %						
pH (1:5) soil: water	5.5	5.1	4.9	5.0	4.9	5.0
pH (1:5) soil: 1N KCl	4.5	4.2	4.2	4.0	4.0	3.9
Conductivity mmhos	0.05	0.03	0.02	0.02	0.02	0.02
Exch. Na meq %	0.0	0.0	0.0	0.0	0.0	0.1
Exch. K meq %	0.2	0.1	0.1	0.1	0.1	0.2
Exch. Mg meq %	1.6	0.3	0.1	0.1	0.0	0.1
Exch. Ca meq %	5.0	1.4	0.4	0.3	0.1	0.1
TEB meq %	6.8	1.8	0.6	0.5	0.2	0.5
CEC meq %	15.5	12.9	5.3	6.4	5.0	5.8
Base saturation %	44	14	11	8	4	9
Total N %	0.28	0.16	0.04	0.04	0.03	0.03
Organic C %	2.73	1.74	0.45	0.50	0.33	0.29
Total P ppm	670	600	310	280	220	290
Total K ppm	1500	1600	1250	1250	1300	1300
Total Mg ppm	1250	1050	700	650	650	650
Total Ca ppm	1300	400	200	<100	<100	<100
Available P (Bray) ppm	11.7	36.4	37.5	14.0	13.7	10.0
Mechanical analysis						
2 mm - 250 μ %	41	40	42	35	40	36
250 μ% - 50 μ %	14	14	18	12	14	13
50 μ% - 2 μ %	23	26	26	29	27	33
2 μ%	22	20	14	24	19	18
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

PROFILE 30

Soil series	Kipia
Classification	FAO: Humic Acrisols
Location	On air photo 4/041, Kipia Valley, approximately 400 m south-east of prominent circular dark forested area
Elevation	2 449 m
Landform	Physiographic position: on moderately sloping concave footslope Landform unit: J Microtopography: nil
Slope	12°
Aspect	SE
Land use	Hagenia woodland with sparse grass ground cover recently burned
Parent material	Colluvial deposit derived from quartzite
Drainage	Moderately well drained
Moisture condition	Moist below 125 cm
Water table	Absent, slow water seepage at 160 cm
Surface stones	Absent
Erosion	Slight sheet around grass tufts

Horizon	Depth cm	
A1	0-7	Very dark brown (10 YR 2/2, moist; sandy loam; strong medium crumb structure; very friable consistence; many fine random exped pores; very frequent fine and very fine roots; abrupt, smooth boundary:
A2	7-30	Dark reddish brown (5 YR 2/2), moist; loam; weak fine subangular blocky structure; firm consistence; very few fine discontinuous random pores; few medium and fine roots; clear, smooth boundary:
E	30-60	Reddish brown (5 YR 4/4), moist; loam; weak fine subangular blocky structure; firm consistence; thin patchy cutans; pores as above; very few fine roots; gradual, smooth boundary:
Btns	60-90	Reddish brown (5 YR 4/4), many fine faint subgammate reddish yellow (5 YR 6/8) mottles, moist; coarse sandy clay loam; weak fine subangular blocky structure; firm consistence; tin patchy cutans; pores as above; few small soft spherical black ferro-manganese nodules; few very fine angular quartz gravel; clear, smooth boundary:
Bts	90-125	Reddish brown (5 YR 4/4), many dark red (2.5 YR 3/6) and few reddish yellow (5 YR 6/3) fine faint subgammate mottles, moist; sandy clay; moderate fine subangular blocky structure; very firm consistence; cutans as above; pores as above; few coarse and fine subangular quartz gravel; clear, smooth boundary:
Btns	125-160	Dusky red (2.5 YR 3/2), many fine faint subgammate reddish yellow (5 YR 6/8) mottles, moist; sandy clay; weak fine subangular blocky structure; very firm consistence; cutans as above; pores as above; few small soft spherical black ferro-manganese nodules; with some black manganese coatings on some ped faces.

PROFILE 30 LAB. NO. 8452-57

Characteristic	Horizon (depth in cm)					
	A1	A2	E	Btns	Bts	Btns
	0-7	7-30	30-60	60-90	90-125	125-160
Moisture (100-105°C)%	2.4	1.9	1.2	1.5	1.2	1.7
Bulk density g/ml	0.86	0.99	1.08	1.19	1.17	1.14
Loss of ignition %						
pH (1:5) soil: water	5.6	5.3	5.2	5.2	5.8	5.4
pH (1:5) soil: 1N KCl	4.8	4.1	4.1	4.2	4.2	4.2
Conductivity mmhos	0.08	0.03	0.02	0.02	0.02	0.01
Exch. Na meq %	0.1	0.0	0.0	0.0	0.0	0.0
Exch. K meq %	1.1	0.2	0.1	0.1	0.1	0.1
Exch. Mg meq %	3.6	1.2	0.3	0.1	0.2	0.4
Exch. Ca meq %	10.2	3.4	1.0	0.2	0.3	0.8
TEB meq %	15.0	4.8	1.4	0.4	0.6	1.3
CEC meq %	27.0	17.2	11.2	6.9	5.8	7.7
Base saturation %	56	28	13	6	10	17
Total N %	0.43	0.25	0.14	0.08	0.05	0.05
Organic C %	5.67	3.21	1.54	0.89	0.38	0.29
Total P ppm	1320	770	550	530	870	970
Total K ppm	2650	2350	2450	2500	2950	3450
Total Mg ppm	1650	1350	1350	1200	1450	1650
Total Ca ppm	2600	900	400	300	200	300
Available P (Bray) ppm	69.5	7.9	7.6	9.0	28.0	22.5
Mechanical analysis						
2 mm - 250 μ %	15	18	19	20	18	12
250 μ% - 50 μ %	22	23	23	26	22	17
50 μ% - 2 μ %	32	27	25	27	26	22
2 μ%	31	32	33	27	34	49
Water dispersible clay %						
total	1.2	1.6	2.0	4.0	4.0	2.8
less OM	13.8	8.6	12.8	9.8	6.4	5.0
Trace metals						
Copper ppm	20	20	30	30	30	30
Chromium ppm	60	50	50	50	40	40
Manganese ppm	1360	850	390	280	250	680
Zinc ppm	50	50	50	50	60	50
Iron %	3.2	3.4	4.1	4.2	4.2	5.1

PROFILE 31

Soil series	Kipia
Classification	FAO: Humic Acrisols
Location	On air photo 4/041, Kipia Valley, approximately 350 m south of prominent circular forest area
Elevation	2 520 m
Landform	Physiographic position: on moderately sloping convex slope of hill
	Landform unit: J
	Microtopography: nil
Slope	13°
Aspect	SE
Land use	Hagenia woodland with sparse grass cover recently burned
Parent material	Colluvial deposit derived from quartzite
Drainage	Well drained
Moisture condition	Dry throughout
Water table	Absent
Surface stones	Absent
Erosion	Slight sheet around grass tufts

Horizon	Depth cm	
A1	0-1	Black (5 YR 2/1), moist; sandy loam; weak fine crumb structure; very loose consistence; many fine discontinuous exped pores; many fine roots; abrupt, smooth boundary:
A2	1-22	Dark reddish brown (5 YR 2/2), moist; loam; weak very fine crumb structure; firm consistence; few fine discontinuous exped pores; many fine roots; clear, smooth boundary:
Bt	22-80	Yellowish red (5 YR 4/8), moist; coarse sandy clay loam; weak very fine subangular blocky structure; firm consistence; pores as above; few subangular quartz gravel and stones; few fine and coarse roots; abrupt, smooth boundary;
Btns	80-130	Weak red (10 YR 4/4), moist; few medium, faint, subgammate yellowish red (5 YR 4/8) mottles; coarse sandy clay loam; weak fine subangular blocky structure; extremely firm consistence; thin discontinuous exped pores; few small soft spherical black ferro-manganese nodules; few subangular quartz gravel; few subangular to rounded quartzite stones. (This horizon is weakly cemented, probably with silica and manganese).

PROFILE 31 LAB. NO. 8458-61

Characteristic	Horizon (depth in cm)					
	A1	A2	Bt	Btns		
	0-1	1-22	22-80	80-130		
Moisture (100-105°C)%	3.0	1.4	1.4	2.5		
Bulk density g/ml	0.83	1.01	1.09	1.03		
Loss of ignition %						
pH (1:5) soil: water	6.4	5.2	4.9	5.2		
pH (1:5) soil: 1N KCl	5.5	4.3	4.1	4.2		
Conductivity mmhos	0.09	0.04	0.02	0.02		
Exch. Na meq %	0.0	0.1	0.0	0.0		
Exch. K meq %	0.7	0.2	0.1	0.1		
Exch. Mg meq %	6.1	2.2	0.2	0.2		
Exch. Ca meq %	16.5	4.7	0.2	0.3		
TEB meq %	23.3	7.2	0.5	0.6		
CEC meq %	29.9	16.2	10.5	10.7		
Base saturation %	78	44	5	6		
Total N %	0.49	0.25	0.13	0.04		
Organic C %	6.53	3.21	1.26	0.15		
Total P ppm	1140	640	670	1000		
Total K ppm	1900	1600	2000	2800		
Total Mg ppm	1900	1350	1250	1300		
Total Ca ppm	4200	1100	100	<100		
Available P (Bray) ppm	57.5	6.0	9.5	16.4		
Mechanical analysis						
2 mm - 250 µ %	18	24	23	12		
250 µ% - 50 µ %	21	20	18	12		
50 µ% - 2 µ %	25	19	16	12		
2 µ%	36	37	43	64		
Water dispersible clay %						
total						
less OM						
Trace metals						
Copper ppm						
Chromium ppm						
Manganese ppm						
Zinc ppm						
Iron %						

Publications of the Land Resources Division

These publications have a restricted distribution and are not available to booksellers. The Division makes a report on each completed project. The report is published as a *Land Resource Study* or *Technical Bulletin* only with the consent of the government concerned.

*1 SPOONER R J & JENKIN R N (1966) The development of the Lower Mgeta River area of the United Republic of Tanzania.

*2 BAWDEN M G & TULEY P (1966) The land resources of Southern Sardauna and Southern Adamawa Provinces, Northern Nigeria.

*3 BAWDEN M G & CARROLL D M (1968) The land resources of Lesotho.

4 JENKIN R N & FOALE M A (1968) An investigation of the coconut growing potential of Christmas Island.

5 BLAIR RAINS A & McKAY A D (1968) The Northern Statelands, Botswana.

6 HILL I D (1969) An assessment of the possibilities of oil palm cultivation in Western Division, The Gambia.

7 MITCHELL A J B (1976) The irrigation potential of soils along the main rivers of eastern Botswana: a reconnaissance assessment.

8 VERBOOM W C & BRUNT M A (1970) An ecological survey of Western Province, Zambia, with special reference to fodder resources. Volume 1, The environment. Volume 2, The grasslands and their development.

*9 AITCHISON P J, BAWDEN M G, CARROLL D M, GLOVER P E, KLINKENBERG K, LEEUW P N de & TULEY P (1972) The land resources of North East Nigeria. Volume 1, The environment.

*9 AITCHISON P J & GLOVER P E (1970) The land resources of North East Nigeria. Volume 2, Tsetse and trypanosomiasis.

*9 BAWDEN M G, CARROLL D M & TULEY P (1972) The land resources of North East Nigeria. Volume 3, The land systems.

*9 LEEUW P N de, LESSLIE A & TULEY P (1972) The land resources of North East Nigeria. Volume 4, Present and potential land use.

9 TULEY P ed. (1972) The land resources of North East Nigeria. Volume 5, Appendices and tables.

10 JOHNSON M S (1971) New Hebrides Condominium. Erromango forest inventory.

*Out of print

*11 BLAIR RAINS A & YALALA M (1972) The Central and Southern State Lands, Botswana.

12 BERRY M J & HOWARD W J (1973) Fiji forest inventory. Volume 1, The environment and forest types. Volume 2, Catchment groups of Viti Levu and Kandavu. Volume 3, Catchment groups of Vanua Levu.

13 JOHNSON M S & CHAFFEY D R (1973) A forest inventory of part of the Mountain Pine Ridge, Belize.

14 JOHNSON M S & CHAFFEY D R (1973) An inventory of the Chiquibul Forest Reserve, Belize.

16 HENRY P W T (1974) Pine forests of the Bahamas.

17 BERRY M J, LAURENCE J F, MAKIN M J & WADDAMS A E (1974) Development potential of the Nawalparasi area of Nepal.

18 HANSELL J R F & WALL J R D (1974-6) Land resources of the British Solomon Islands Protectorate. Volume 1, Introduction and recommendations. Volume 2, Guadalcanal and the Florida Islands. Volume 3, Malaita and Ulawa. Volume 4, New Georgia group and the Russell Islands. Volume 5,† Santa Isabel. Volume 6,† Choiseul and the Shortland Islands. Volume 7, San Cristobal and adjacent islands. Volume 8, Outer Islands.

19 MANSFIELD J E, BENNETT J G, KING R B, LANG D M & LAWTON R M (1975/6) Land resources of the Northern and Luapula Provinces, Zambia – a reconnaissance assessment. Volume 1, Introduction, conclusions and recommendations. Volume 2, Current land use. Volume 3, Land capability and development potential. Volume 4, The biophysical environment. Volume 5, Social and economic factors. Volume 6, The land systems.

20 THOMAS P, ACRES B D, BOWER R P, BURROUGH P A, FOLLAND C J, KALSI M S & WRIGHT P (1975). The soils of Sabah. Volume 1, Classification and description. Volume 2, Sandakan and Kinabatangan Districts. Volume 3, Western parts of Tawau and Lahad Datu Districts. Volume 4, South-Western Districts. Volume 5, References and appendices.

21 MAKIN M J, KINGHAM T J, WADDAMS A E, BIRCHALL C J & TAMENE TEFERRA (1975) Development prospects in the southern Rift Valley, Ethiopia.

22 DUNSMORE J R, BLAIR RAINS A, LOWE G N, MOFFAT D J, ANDERSON I P & WILLIAMS J B (1976) The agricultural development of The Gambia: an agricultural, environmental and socioeconomic analysis.

23 MURDOCH G, OJO-ATERE J, COLBORNE G, OLOMU E I, & ODUGBESAN E M (1976) Soils of the Western State Savanna in Nigeria. Volume 1, The environment. Volume 2, Descriptions of Basement complex soil series. Volume 3, Atlas of sample blocks mapped during the survey.

24 JENKIN R N, ROSE INNES R, DUNSMORE J R, WALKER S H, BIRCHALL C J & BRIGGS J S (1976) The agricultural development potential of the Belize Valley, Belize.

25 THOMAS P, LO F K C & HEPBURN A J (1976) Land capability classification of Sabah. Volume 1, The Tawau Residency. Volume 2, The Sandakan Residency. Volume 3, The West Coast and Kudat Residencies. Volume 4, The Interior Residency and Labuan.

*Out of print †In press

26 MAKIN M J, KINGHAM T J, WADDAMS A E, BIRCHALL C J & EAVIS B W (1976) Prospects for irrigation development around Lake Zwai, Ethiopia.

27 LITTLE B G, BUCKLEY D K, CANT R, HENRY P W T, JEFFERISS A, MATHER J D, STARK J & YOUNG R N (1977) Land resources of the Bahamas: a summary.

TECHNICAL BULLETINS

1 CARROLL D M & BASCOMB C L (1967) Notes on the soils of Lesotho.

*2 PIGGOTT C J (1968) A soil survey of Seychelles.

LAND RESOURCE BIBLIOGRAPHIES

1 POSNETT N W & REILLY P M comp. (1971) Nigeria.

2 POSNETT N W, REILLY P M & WHITFIELD P comp. (1971) Nigeria.

3 POSNETT N W & REILLY P M comp. (1973) Belize (British Honduras).

4 POSNETT N W & REILLY P M comp. (1973) Fiji.

5 GREENWAY M E, POSNETT N W & REILLY P M comp. (1974) New Hebrides and New Caledonia.

6 REILLY P M comp. (1974) Nepal.

7 POSNETT N W & REILLY P M comp. (1975) Solomon Islands.

8 REILLY P M comp. (1976) Sabah, Malaysia.

9 POSNETT N W & REILLY P M comp. (1977) Zambia.

*Out of print.

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Garia Series Profile 2 is typically representative of the series. It consists of a thin layer of closely admixed humus and mineral material overlying abruptly, without a weathering zone, fresh compact rock. A high organic matter content is shown by the figure for carbon, the same applies for nitrogen. The pH is within the acid range. A moderate level of exchangeable bases is indicated, with a high value for exchangeable potassium and medium values for magnesium and calcium. The CEC is high, partly reflecting the high organic matter content. Available phosphorus is unusually high. The data for the trace elements show nothing unusual. These soils occur adjacent to all rock exposures, and have been described as such on Landform Units A, B, C, D, E, F and I. Their shallow nature severely restricts root development and, accordingly, they are not suited for plantation development.

Fluvisols

Even though alluvial deposits of significant extent are rare, localised tracts may be found adjacent to the larger stream courses. These are, however, never extensive enough to be mapped at the scale of 1:50 000. Fluvisols are developed from such deposits. They are characterised by a lack of diagnostic horizons apart from some accumulation of humus in the surface horizon. One series is recognised: Sasai Series.

Sasai Series This occurs on low terraces which are subject to periodic flash-flooding and, therefore, receives fresh material at regular intervals. The soil consists of a relatively thin, dark surface horizon over a sandy, bouldery deposit, with evidence of a seasonal water table at depth. Even though these soils afford an adequate substratum for root development, their water retention capacity is low which might result in some drought stress for exotic tree species. The description of a representative soil is given under Profile 3. This is an acid to strongly acid soil, with a slight depression of pH in the second horizon, followed by a small increase below. The CEC is low; largely reflecting the low organic matter and clay contents. There is a slight accumulation of organic matter at the surface, which is marked by medium levels of nitrogen and exchangeable potassium, magnesium and calcium; otherwise low to very low levels occur. Available phosphorus follows an unusual distribution pattern; occurring at a medium level at the surface and increasing to very high levels below. The trace elements occur at normal levels, except for low manganese in the subsurface horizons.

Humic Cambisols

These are relatively young soils which lack evidence of soil development except for some structural aggregation. Evidence of clay movement is lacking and the sandy loamy textures which predominate, together with the presence of weatherable rock material, testify to their juvenile nature. These then are essentially shallow to moderately shallow soils with bedrock or boulders occurring within 150 cm of the surface. Humic Cambisols differ from other Cambisols by the presence of the well developed, dark, humus-rich horizons, which in the soils described during the survey, usually extend throughout the solum. Five series have been defined: Kinyeti, Otolo, Lohocho, Dumusum and Sahue Series.

Kinyeti Series These are essentially shallow soils overlying quartz-rich leucocratic gneiss within 50 cm of the surface. They have medium to coarse textures and occur in localised pockets, amongst bare rock exposures, on Landform Unit I. Soils of this series have also been located on Landform Unit B marking the localised occurrence of quartz-rich leucocratic gneiss. Profile 4 is a description of a typical profile. A high organic matter content is shown by the data for organic carbon and the very high levels of nitrogen. The CEC is very high due to the organic matter content. Available phosphorus in the surface horizon is very high, below which horizon it decreases to medium concentrations. The pH also decreases with depth, from acid to strongly acid down the profile; and a similar trend can be discerned for exchangeable potassium, magnesium and calcium which decrease from high to medium values. The shallow nature of these soils precludes their use for forest plantations.

Otolo Series The quartz-conglomerate beds of Landform Unit J described in the Kipia Uplands give rise to these distinctive soils. Profile 5 is a typical representative, the soil consisting of a dark, loamy, weakly structured horizon overlying at a shallow depth a layered colluvial deposit. By far the greatest proportion of the plant nutrients are retained in the thick surface horizon which has medium levels of organic carbon, exchangeable potassium, magnesium and calcium, and total nitrogen. Although available phosphorus decreases slowly with depth, medium concentrations are maintained throughout the profile. Soil reaction is strongly acid, except in the lowest horizon where it increases to pH 6.0. The CEC is low except in the surface horizon, where it is high. Although being derived from highly siliceous material the nutrient status of these soils appear adequate for forest plantation development, especially with pines.

Lohocho Series Profile 6 is a typical representative of this series. These are distinctively red (hues in the 10 R to 2.5 YR range), loamy soils, with dominant boulders of gneiss occurring at moderately shallow depths, i.e. between 50 and 150 cm. The surface horizon has an acid reaction but below this the pH decreases to very acid levels. The base saturation is high near the surface, with potassium, magnesium and calcium at high levels, and decreases to very low in sub-surface horizons; there is a corresponding increase in magnesium and calcium, but potassium remains at medium levels. The topsoil is well supplied with nitrogen. The CEC varies from high near the surface to medium in the subsoil. The data for the trace elements show nothing unusual. Their distribution is widespread, occurring on bouldery slopes described on Landform Units B, D, E, F, G and L. Although generally suited for forest plantation development, their bouldery nature may limit the growth of some species.

Dumusum Series Soils of this series have similar characteristics to those of the Lohocho Series described above. They differ, however, in having coarse textures, ranging from sand to sandy loam. A description of a typical representative is given under Profile 8. The organic matter content, although high to medium, does not reach the high levels suggested by the blackness of the soil. Both carbon and nitrogen are high in the surface horizon and decrease to medium in the lower horizon. The CEC varies, largely dependent on the organic matter content, decreasing with depth but remaining with medium levels. The exchangeable cations also decrease with depth, with high levels of potassium, magnesium and calcium in the top horizon, but with magnesium and calcium decreasing to very low and potassium to medium levels. Soil reaction in the surface horizon is acid and strongly acid below. Their occurrence is restricted to the bouldery sites described on Landform Units B, D, F, G and K. As for the Lohocho Series, their suitability for exotic softwoods would be moderate; but their low water retention capacity due to coarse texture might give rise to drought stress particularly in predominantly water-shedding sites on summits and upper slope areas.

Sahue Series This is the third soil series of the Humic Cambisols derived from leucocratic and augen gneiss. It differs mainly from the other two, Lohocho and Dumusum Series, however, in colour, which is predominantly reddish brown with a hue of 5 YR. Rock is usually encountered at shallow depths, i.e. around or above 50 cm (Plate 10). Descriptions of those typical profiles are given in Appendix 7. Profiles 9 and 11 occur under *Olea-Podocarpus* forest and Profile 10 in a *Pinus patula* stand. Both forest soils have a medium content of organic matter with nitrogen being high in the surface horizon. The reaction is strongly acid to acid and the levels of exchangeable cations appear to be adequate for most plant growth. This is also indicated by the data for available phosphorus. The CEC varies from very high to high with depth. A distinctive feature of Profile 10, which occurs in a plantation, is that many of the lowest values are recorded in the second horizon. This may be due to the increase in nutrient mobility induced by the pine vegetation. Most of the nutrients, however, appear to be stored in the surface horizon which has medium levels of exchangeable potassium, magnesium and calcium, nitrogen and organic carbon, and a very high level of available phosphorus. Below the surface horizon these decrease to low to very low levels, except for calcium and available phosphorus which, after the initial decrease in the second horizon, increase to medium to high levels respectively in the third horizon. Soils of this series have been mapped as occurring amongst the rock outcrops described on Landform Units B, D, E, F and G. Their shallow nature would limit prospects for development except for, perhaps, pines.

Humic Nitosols

These constitute the deep, friable, strongly coloured soils which are so conspicuous in the area. Most are coloured red (hues 10 R to 2.5 YR), others reddish brown (hue 5 YR). Brown coloured soils (hues 7.5 YR to 10 YR) are relatively rare. Textures vary from clay to loam, never coarser. Below the dark, humus-rich horizons, there is usually a slight increase in clay content, but this is rarely significant. There is some evidence of clay translocation, particularly at depth, but the continuous turnover of the soils material as the result of the termite activity tends to minimise its effect. Many of these soils appear to be associated with older and more stable geomorphic features and also an advanced stage of weathering in that some subsurface horizons contain only small amounts of water-dispersible clay, have low base saturation figures and some very low values when the CEC is calculated on the basis of clay rather than fine earth content.

These then are deep, friable, strongly coloured soils, with thick, dark, surface horizons having medium to fine textures and showing very little, usually less than 20%, increase in clay content with depth. Seven series, all derived from leucocratic or augen gneiss are recognised: Nabakin, Gilo, Lokotulu, Ngairigi, Itibol, Konoro and the Oreira Series. Some, however, are also formed on deep, colluvial infillings derived from this rock. These deposits differ little in physical properties from those overlying gneiss *in situ.* Hence some representatives, particularly of the Nabakin and Ngairigi Series, may occur in both locations.

Nabakin Series Soils of this series are distinguished from other Humic Nitosols by their fine textures, which may vary from clay loam to clay. These are essentially red soils, with a hue of either 10 R or 2.5 YR. Profile 12 describes a typical representative. The dark surface horizons extend to a depth of 70 cm. Textures are fine and there is little increase in clay content below the humus-rich zone, although the presence of cutans indicate some movement of clay in the profile. The high porosity and strong but very fine structural aggregation which extends to a depth of 102 cm marks the zone of termite activity. The soil is developed on a fine grained deposit, while Profile 13 overlies weathering rock material. This soil also has the characteristics described above, but the presence of feldspar at depth marks the uppermost zone of the weathering rock mantle. Profile 12 also illustrates the degree to which organic matter can be dispersed to depth; organic carbon remaining above 1 per cent throughout, and total nitrogen varying from high to medium levels down to a depth as great as 70 cm. The base saturation figures show that the soil is very strongly leached, and this is verified by the low figures given for the exchangeable bases and the medium figures for the CEC below the surface horizon. The surface horizon contains most of the nutrients, with high levels of exchangeable potassium, magnesium and calcium, and available phosphorus. The available phosphorus increases with depth. Soil reaction varies from acid in the surface horizon to strongly acid below. The figures for chromium, copper, manganese and zinc all fall within the normal range. The soils of this series have a widespread distribution and have been mapped on moderately sloping sites on Landform Units F, G, H, K, L and M. They are considered to be very suited for plantation development.

Gilo Series Soils of this series are distinguished morphologically from those of the Nabakin Series by their medium textures, which may vary from loam to sandy clay loam. A typical representative is described under Profile 15. The base saturation figures show that the soil is very strongly leached; very low figures being recorded for the subsoil. The medium to high figures for the topsoil reflect its importance for nutrient retention. This is associated with the high organic matter content and high levels of exchangeable bases in which the exchange complex is dominated by calcium, although high levels are recorded for potassium and magnesium. The topsoil also contains high to very high levels of nitrogen and medium to high levels of organic carbon. The CEC is very high due to the high organic matter content. Available phosphorus occurs at medium levels throughout. Soil reaction varies from acid in the topsoil to strongly acid below. They have been mapped on Landform Unit G with the Nabakin Series. They also occur on Landform Unit L. The prospects for forestry development on these soils are also good.

Lokotulu Series Colour is used to differentiate these from the Gilo Series. These are essentially reddish brown soils with a hue of 5 YR. A description is given under Profile 16. The laboratory data show that the soil has a high nutrient status, but with the main nutrients tied-up with organic matter in the surface epipedons. An exception is shown by the figures for available phosphorus which increases from medium amounts in the top 60 cm to a very high level below. This can probably be explained by phosphates being released by the weathering of alumino-silicate minerals. Soil reaction decreases slowly with depth, from acid in the surface horizon to strongly acid below 60 cm. They are of very limited extent and have been found on Landform Unit E but they cover too small an area to be mapped. These soils are also considered to be very suitable for plantation development.

Ngairigi Series (Plate 12) This is probably the most common soil in the area and seven profiles (Nos. 17 to 23) are described in Appendix 7. It frequently occurs in association with the Nabakin Series, which it closely resembles. It differs from that series by the presence of a medium textured topsoil, finer than a sandy loam and coarser than a clay loam. Clay content variation can be higher than that normally accepted for Nitosols (within 20% of maximum value), and this is illustrated by Profiles 19, 21, 22 and 23. Unusually low figures for CEC/100 gm clay are recorded in Profile 22. Profile 17 describes a typical representative which illustrates particularly well the influence that the surface organic matter has on nutrient retention; all the major nutrients in the top horizon are at medium to high levels but below decrease to low and to very low except for nitrogen and available phosphorus, the former occurring at a medium concentration in the second horizon and the latter increasing from high to very high at depth. The soil is very strongly leached and the reaction varies from acid at the surface to strongly acid below. The CEC appears to be largely dependent on the organic matter content, decreasing from high to very low with depth. Chromium, copper, manganese and zinc occur at normal levels. These soils have been mapped extensively on the moderate slopes described on Landform Units B, E, F, G, H, K, L and M. These rank amongst the best soils for forest plantations.

Itibol Series The presence of a reddish brown topsoil (hue 5 YR) as compared to a red (hues 10 R to 2.5 YR) to a depth of around 50 cm, distinguishes this series from the Ngairigi Series. A typical representative is Profile 24. The surface horizons have higher CEC, exchangeable cations, base saturation, available phosphorus, total nitrogen and organic carbon values than the subsurface horizons. The values vary from medium to high in the topsoil to low to very low in the subsoil with the exception of available phosphorus which remains unusually high. The nutrient status is clearly linked with the organic matter content. An acid reaction is recorded for the surface horizon and strongly acid below. The range of clay distribution is somewhat higher than normal for Nitosols. On comparing this profile with Profile 17 (Ngairigi Series) it can be seen that, apart from this difference in colour, the soils are very similar. They are also closely related in the field, occurring in association on the moderate slopes of Landform Unit G. The Itibol Series is mapped only on this landform unit but it also occurs locally on Landform Unit E. It also has a high potential for plantation development.

Konoro Series Again colour is used to distinguish this soil; it is similar to the Itibol Series except for the reddish brown colour which in this case extends throughout the profile. A typical profile is described under that of Profile 26. This shows atypically, for Nitosols, high range of clay distribution and low activity of the clay fraction (CEC/100 gm clay). Compared to other soils analysed during the survey pH values are unusually high, being near neutral in the surface horizon, but decreasing to acid in the subsoil. The values given for the exchangeable cations are unusual in that they are maintained at medium levels at depth from high to very high in the surface horizon. The total nitrogen content is high in the topsoil, but follows the usual trend to very low at depth. The available phosphorus content is medium throughout. The CEC is largely dependent on the organic matter content, being very high at the surface to very low below. A low degree of leaching is exemplified by the high base saturation figures. In all the data shows that this soil has an unusually high plant nutrient status. It has been mapped with the Lohocho Series on Landform Unit E but also occurs on Landform Unit D and sometimes on F. These soils are also highly recommended for development.

Oreira Series These are essentially brown soils with a hue of 7.5 YR or 10 YR. Variegated mottling in the subsoil, showing evidence of sesquioxide accumulation, also distinguishes these soils from the other Humic Nitosols. Otherwise, in profile morphology they are similar to the Ngairigi, Itibol and Konoro Series, with loamy topsoils and clayey subsoils. Differences in clay content can be somewhat higher than normal for Nitosols. Profile 28 is representative. The base saturation figures show that the soil is very strongly leached with very low figures being recorded in the subsoil. The high figure recorded for the surface horizon is an indication of the importance of the topsoil for nutrient retention. This is in itself associated with the medium to high organic matter content and the high levels of exchangeable bases in which the exchange complex is dominated by calcium, although high levels are recorded for magnesium and medium for potassium. The topsoil also contains medium to high levels of nitrogen and organic carbon. The CEC is very high and largely dependent on the organic matter content. Available phosphorus increases from medium values in the topsoil to high and to very high values below. Soil reaction is strongly acid throughout. Soils of the Oreira Series are of very restricted extent and have been mapped on some moderate slopes of Landform Unit G only in association with the Ngairigi Series. Again, these are highly recommended for development.

Humic Acrisols

These are soils which show a marked increase in texture with depth which can be directly attributed to the translocation of clay. Though present, the dark, humus-rich surface horizons rarely extend below 30 cm. They are developed on colluvial material derived from quartz-rich leucocratic gneiss and base saturation values can be expected to be well below 50%. One series, Kipia Series, has been recognised.

Kipia Series Soils of this series are of very limited extent, having been recognised only on the moderate slopes of Landform Unit J of the Kipia Uplands. A typical representative is described in Profile 30. Dark surface horizons extend to 30 cm overlying the mineral subsoil. This consists of loam but rapidly becomes heavier in texture with depth to a sandy clay. The presence of cutans testify to the movement of clay through the solum. The mobilisation and concentration of sesquioxides and manganese is shown by the variegated mottling and discrete nodules which occur in the subsoil. The data show that most of the plant nutrients are retained in the thin surface horizon in which available phosphorus is very high, exchangeable potassium, magnesium and calcium is high, and nitrogen and organic carbon are at medium levels. The CEC is also high. Below the surface horizon the levels of the nutrients decrease from low to very low with the exception of available phosphorus which increases to very high at depth. The reaction profile is irregular, varying from acid in the topsoil to strongly acid below, with a slight increase in pH at depth to bring the levels up to within the acid range. The data for trace elements show nothing unusual. Although the nutrient status of these soils is relatively low they can be recommended for plantation, although successful development might depend on a judicious choice of species adapted for such soil conditions.

LAND SUITABILITY AND THE IDENTIFICATION OF LAND FOR PLANTATION DEVELOPMENT

The boundary of the area which has been soil surveyed is shown on Maps 3a and 3b. The mapping units are based on various combinations of landform, slope class and soil series. The soil series are distinguished by lower case letters, the first of which designates the dominant soil, the subordinate soils, if they occur, occupying more than 20% of the area, are indicated by a second letter. The letter for associated soils, i.e. those covering less than 20% of the area, is enclosed by brackets. For example, L3dg(a) indicates Landform Unit L with moderate slopes; Nabakin Series dominant, Ngairigi Series subordinate and Lohocho Series associated.

TABLE 30 The soil mapping units, their limitations, suitability for plantation development and areas

Soil mapping unit	Limitations		Suitability class	Area ha
	Slope	Soil		
B1ra	Very serious	Very serious	3	166
B1rb	Very serious	Very serious	3	366
B3ag	Minor	Serious	2	405
B3rc	Minor	Very serious	3	16
D1rb	Very serious	Very serious	3	99
D2a	Serious	Serious	2	190
D2ra	Serious	Very serious	3	83
D3rb	Minor	Very serious	3	34
D3r(c)	Minor	Very serious	3	32
E1ra	Very serious	Very serious	3	186
E2a	Serious	Serious	2	12
E2ae	Serious	Serious	2	136
E2ai	Serious	Serious	2	45
E2r	Serious	Very serious	3	12
E2r(c)	Serious	Very serious	3	67
E3a	Minor	Serious	2	22
E3ag	Minor	Serious	2	97
E3ai	Minor	Serious	2	308
E3g	Minor	None	1	20
E3ga	Minor	Minor	1	115
E3rc	Minor	Very serious	3	28
F2rag	Serious	Very serious	3	46
F2ar	Serious	Serious	2	41
F3ad	Minor	Serious	2	281
F3gd	Minor	None	1	136
F3r	Minor	Very serious	3	28
F3rb	Minor	Very serious	3	12
G1a	Very serious	Serious	3	8
G1ra	Very serious	Very serious	3	73
G1rc	Very serious	Very serious	3	73
G2a	Serious	Serious	2	848
G2ae	Serious	Serious	2	6
G2ag	Serious	Serious	2	14
G2ah	Serious	Serious	2	320
G2ar	Serious	Serious	2	18
G2b	Serious	Serious	2	30
G2rb	Serious	Very serious	3	30
G2rc	Serious	Very serious	3	36
G2rd	Serious	Very serious	3	30
G3a	Minor	Serious	2	289
G3ad	Minor	Serious	2	61
G3ag	Minor	Serious	2	324
G3dg	Minor	None	1	2 469
G3gd	Minor	None	1	73
G3gh(a)	Minor	None	1	449
G3g(j)	Minor	None	1	160
G3r	Minor	Very serious	3	14
G3r(a)	Minor	Very serious	3	18
G3ra	Minor	Very serious	3	10
G3ra(d)	Minor	Very serious	3	265
G3rc	Minor	Very serious	3	16
H3dg	Minor	None	1	478
K1bg	Very serious	Serious	3	113
K1rd	Very serious	Very serious	3	24
K3gb	Minor	None	1	20
L2a(r)	Serious	Serious	2	287
L2ar	Serious	Serious	2	38
L2gd	Serious	None	2	43
L2gd(a)	Serious	None	2	26
L3dg(a)	Minor	None	1	1 004
L3gd	Minor	None	1	109
M3gd	Minor	None	1	884
M3r	Minor	Very serious	3	8
M4d	None	None	1	55