Land Resource Study

28 Forestry development prospects in the Imatong Central Forest Reserve, Southern Sudan Volume 1 Summary

Land Resources Division, Ministry of Overseas Development

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Land Resources Division, Ministry of Overseas Development
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The Land Resources Division of the Ministry of Overseas Development assists developing countries in mapping, investigating and assessing land resources, and makes recommendations on the use of these resources for the development of agriculture, livestock husbandry and forestry; it also gives advice on related subjects to overseas governments and organisations, makes scientific personnel available for appointment abroad and provides lectures and training courses in the basic techniques of resource appraisal.

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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. Readers will be especially interested in Part 7 where development possibilities are described.

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.

Contents

TEXT MAPS

SEPARATE MAPS (in separate map folder)

Part 1

Introduction

PREFACE

This report is issued with the permission of the Sudanese Government and covers the selection of accessible areas within the Imatong Central 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 an interim report was issued in May 1976 (Jenkin *et al.*, 1976).

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; 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 that prepared the detailed terms of reference (Dorward *et al.*, 1976) for the present study.

TERMS OF REFERENCE

Briefly the terms of reference cover:

1. An inventory of the existing softwood plantations
   - i. To produce a 1:10 000 scale map of the stands
   - ii. To assess the stocking and exploitable volume
   - iii. To assess the condition of stands and to recommend silvicultural treatments.
2. A soil assessment for plantation development
   - i. To produce a geomorphological map of the reserve
   - ii. To produce a slope analysis map of the area being mapped topographically at 1:50 000 scale
   - iii. To relate tree growth in the existing softwood plantations to soil conditions
   - iv. To identify by soil survey 10 000 ha suitable for plantation development.

3. An inventory of the indigenous forest

   i. To map the forest types in the Upper Kinyeti and Ngairigi Basins and in adjacent parts of the Ateppi Basin and Imatong Mountains

   ii. To enumerate the unexploited forest in the Upper Kinyeti and Ngairigi Basins and in adjacent parts of the Ateppi Basin and Imatong Mountains

   iii. To determine by airphoto interpretation (API) the forest types in the Talanga area and on the adjacent Acholi Mountains

   iv. To enumerate the unexploited forest in the Talanga area and on the adjacent Acholi Mountains

   v. To assess by API the remaining forest in the Ateppi Basin and Lomwaga uplands.

4. A stream flow assessment on both the Ngairigi and Kinyeti Rivers.

PROCEDURE

Airphoto interpretation (API) and fieldwork enabled the existing plantations to be mapped at 1:10 000 scale, initially using a x2 enlargement of the 1:20 000 scale 1975 air photography as a base, subsequently using the base prepared by the Directorate of Overseas Surveys (DOS). Pilot sampling using circular or square plots of sufficient size to contain 15-20 trees per plot was supplemented by random basal area relascope sweeps. Volumes were obtained for *Cupressus* using a general volume table constructed during the fieldwork from data taken from felled trees. For *Pinus patula, P. kesiya* and *P. caribaea* the Tanzanian Standard Volume Table for *P. patula* (Ackhurst and Micski, 1971) was used and for the small area of *P. radiata,* the volume table for *Cupressus* was used.

API of the 1:40 000 scale 1975 photography together with data collected during the soil survey of the Upper Kinyeti and Ngairigi Basins and from reconnaissance traverses in the Ateppi Basin, the Imatong Mountains and in the Kipia Uplands were used to prepare the 1:50 000 scale geomorphological map. A soil survey was undertaken on the lower slopes of the Imatong Mountains, in the Upper Kinyeti and Ngairigi Basins and just over the watershed into the Ateppi Basin. Soil auger points and soil pits were located at densities of one per 25 ha and one per 400 ha respectively. The data collected during the soil survey were used together with the API to produce both slope and soil mapping, these two elements being plotted with the geomorphological analysis on the same map. The suitability for plantation development of the units mapped was given in the map legend. Soils were also examined and classified at 185 of the plots enumerated during the plantation inventory.

On the lower slopes of the Imatong Mountains, in the Upper Kinyeti and Ngairigi Basins and just over the watershed into the Ateppi Basin, API of the 1:20 000 scale 1975 photography was used to map the vegetation types. An inventory was made of the unexploited forest by line transects using the method outlined by Dawkins (1958). Sixteen blocks were enumerated and all trees over 20 cm diameter breast height (dbh) were measured. Volume tables were prepared for the principal species using data collected by relascope from every fifth plot on the inventory transects. Reliable minimum estimates of volume were calculated for *Podocarpus milanjianus,* hardwoods established on the timber market, potentially usable species and other species. In addition mean volumes per hectare for the main individual species were calculated.

API was completed for the Talanga area and for the adjacent Acholi Mountains, but it was impossible to differentiate between the exploited and unexploited forest because canopy disturbance had been minimal following exploitation. Because of the shortage of time inventory fieldwork was restricted to the Lowland High Forest in the Talanga area, which was treated as a single unit. Four transect lines were located at random and

standard analysis of variance techniques were used to obtain the sampling error. A general volume table covering all species was constructed from data collected by relascope. Reliable minimum estimates were calculated for two groups of species, the first comprising *Chlorophora excelsa, Khaya grandifoliola, Celtis* spp. and *Maesopsis eminii,* and the second all other species.

Vegetation mapping at 1:50 000 scale was completed for all other parts of the reserve by API of the 1975 photography, but no field reconnaissance was possible in the time available.

It proved impossible to make satisfactory arrangements for the collection of further data from the station on the River Kinyeti near Katire once used by Hasek (1963). Problems with vandals and transport shortages made collection of data from two temporary stations set up on the Kinyeti and Ngairigi Rivers between Gilo and Katire impossible.

The procedures are detailed in the main report.

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).

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 (Text Map 1). The Reserve, which includes most of the Imatong and Acholi Mountain Ranges, covers about 1 032 km^2 (see Text Map 2).

Climate

The climate ranges from warm sub-tropical at the lower altitudes to temperate at the higher altitudes. The patterns of rainfall, temperature and wind reflect the alignment and amplitude of the topography.

The mean annual rainfall at Katire and Gilo is 1 494 and 2 261 mm respectively, the latter figure being the highest recorded figure in the Sudan. The rainfall increases with altitude but possibly, in common with other parts of East Africa, it may decrease again above 2 000-2 500 m. Although Talanga is only a short distance from Katire, the rainfall is believed to be substantially higher. Throughout the area 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 to the interval between the 'long' and the 'short' rains further south. The start and finish of the rains vary considerably from year to year, and consequently the months of February to April and September to November show the greatest variation in monthly rainfall. The length and severity of the dry season varies likewise and in consequence the incidence of bush fires. In some years there may be only two really dry months; in others, drought conditions may continue for up to five months (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. The mean daily maximum temperature at Katire lies in the range 28-35°C, but Dorward *et al.* (1976) estimate that at altitudes above that of Gilo, the maximum probably rarely exceeds 30°C.

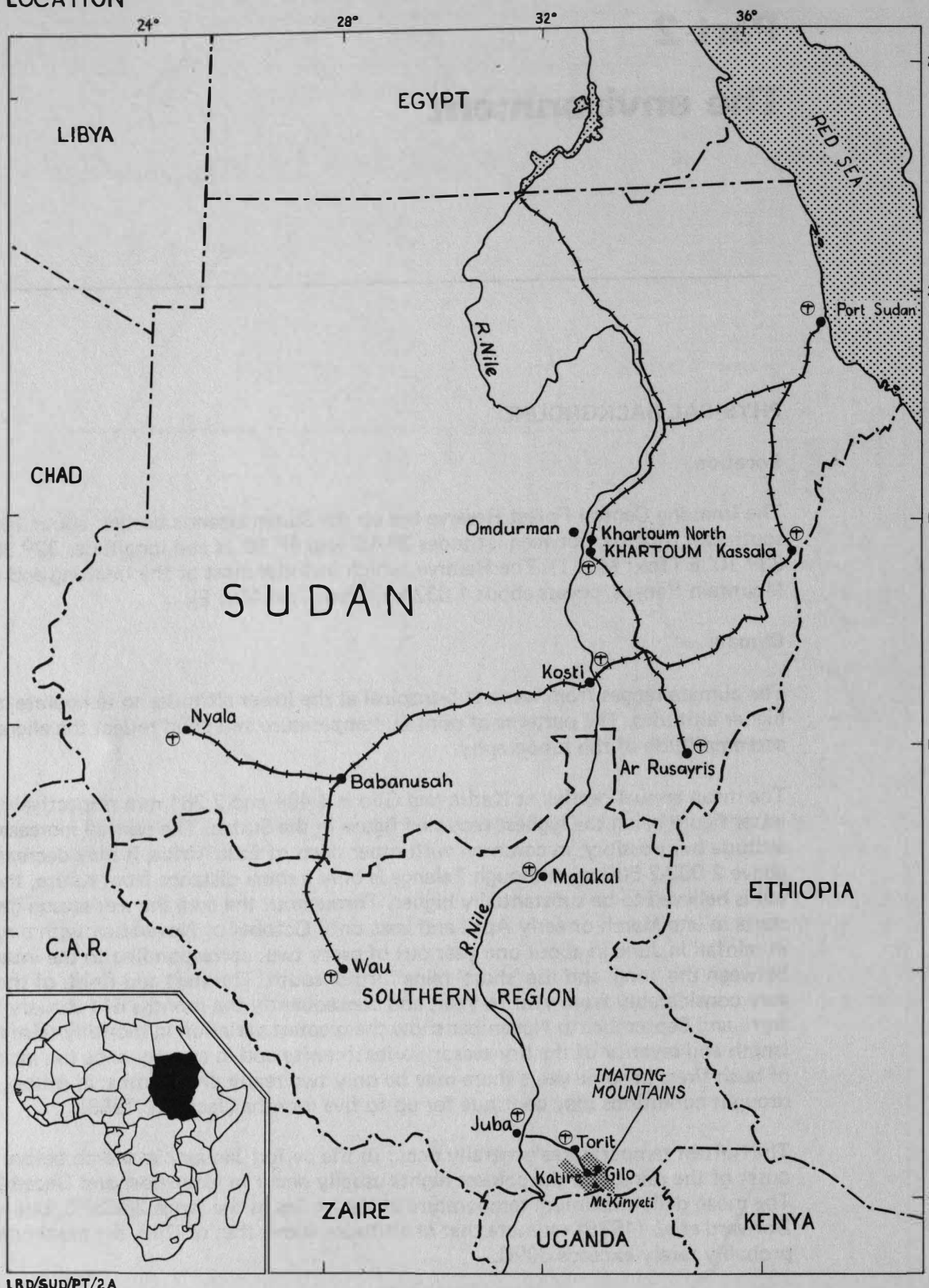
Regionally, south-easterly winds predominate, but the mountainous topography exerts considerable local influence upon both wind strength and direction. A major feature of the area during the dry season are the strong katabatic winds which blow down the valleys for about an hour after sunset. Strong and 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 of a number of conspicuous highland features formed by crystalline basement rock which rise through the Tertiary and

LOCATION

TEXT MAP 1



LRD/SUD/PT/2A

SCALE 1:12,000,000

0 100 200 400 600 800 1,000 Km

0 100 200 400 600 Mi

Town, village ●

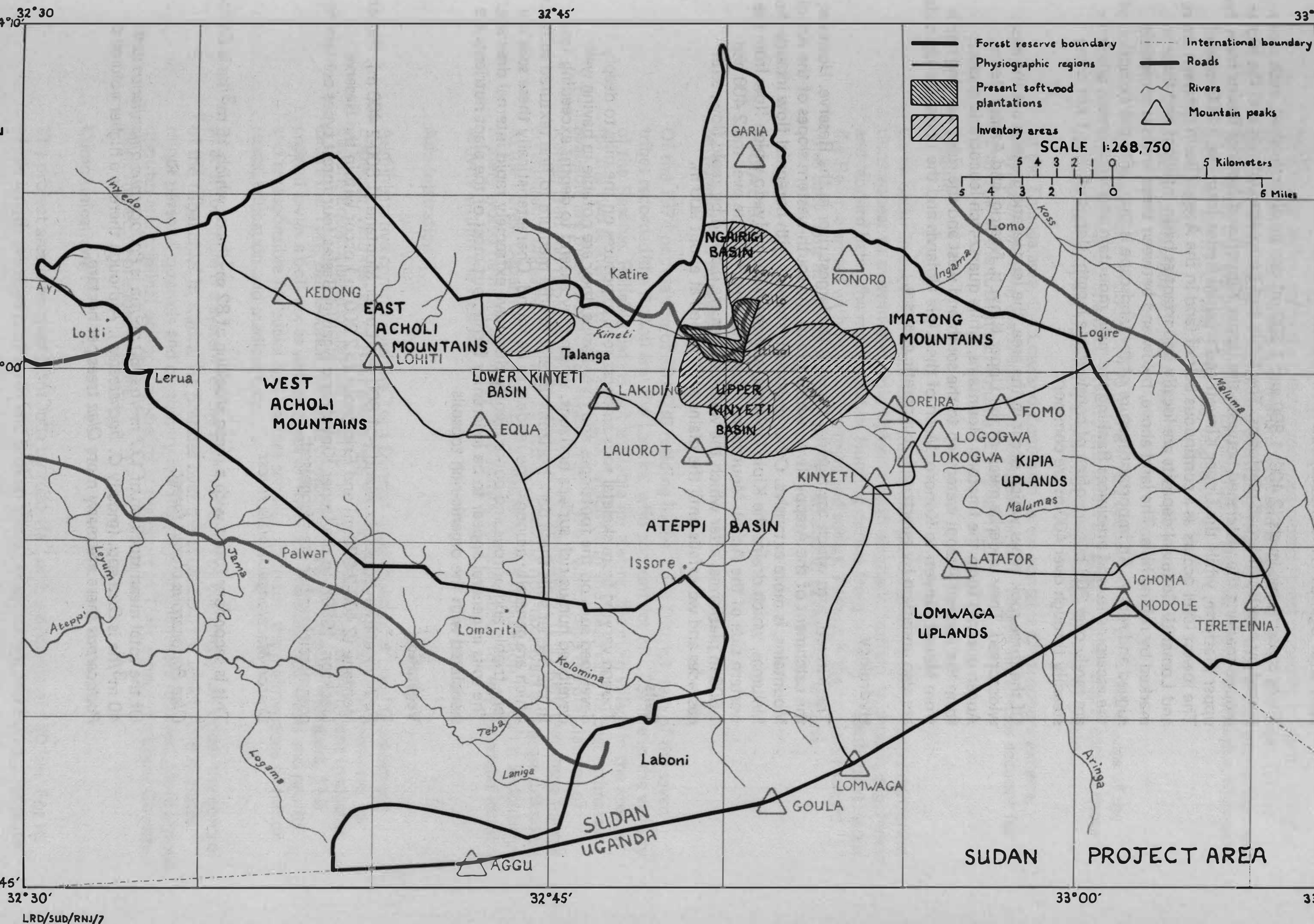
Airport Ⓣ

Railway

Road

International Boundary

Regional Boundary


Forest reserve boundary
Physiographic regions
Present softwood plantations
Inventory areas
International boundary
Roads
Rivers
Mountain peaks
SCALE 1:268,750
5 4 3 2 1 0 5 Kilometers
5 4 3 2 1 0 5 Miles
32°30
32°45'
33°05'
4°10'
4°00'
3°45'
32°30'
33°00'
GARIA
NGAIRIGI BASIN
KONORO
Lomo
Koss
Ingama
KEDONG
EAST ACHOLI MOUNTAINS
Katire
Inyedo
Ayi
Lotti
Kineti
Talanga
IMATONG MOUNTAINS
Logire
LOHITI
LOWER KINYETI BASIN
Lerua
WEST ACHOLI MOUNTAINS
LAKIDING
UPPER KINYETI BASIN
OREIRA
FOMO
Maluma
EQUA
LOGOGWA
LAUOROT
LOKOGWA
KIPIA UPLANDS
KINYETI
Malumas
ATEPPI BASIN
Palwar
Leyum
Jama
Issore
LATAFOR
ICHOMA
MODOLE
TERETEINIA
LOMWAGA UPLANDS
Ateppi
Lomariti
Kolomina
Teba
Laniga
Logama
Laboni
LOMWAGA
GOULA
Aringa
SUDAN
UGANDA
AGGU
SUDAN PROJECT AREA
LRD/SUD/RNJ/7

TEXT MAP 2

Quaternary unconsolidated deposits of the extensive plains which occur in the frontier zone with Uganda (Whitehouse, 1931; Whiteman, 1971).

Three topographic levels (2 400, 1 800 and 1 300 m) can be distinguished, each represented by a series of broad platforms. The Kipia and Lomwaga Uplands and the higher ground marking the watershed between the Upper Kinyeti and Ngairigi Basins form the upper platform, while the Upper Kinyeti and Ngairigi Basins form the 1 800 m level. The lowest level occurs as a continuous belt of land in the Ateppi Basin between Issore and Lomariti. Colluvial deposits are locally important as basin infillings and these are marked by rolling hills. The land above, below and between these levels is sometimes rugged and rocky. An important feature of the landscape is that, with the exception of the escarpments and precipices flanking the main mountain and ridge crests, gradients are rarely over 30° but are often of considerable length; slopes of over 1 km rising steadily through over 400 m are common.

Of the three rock types which occur in the area, the leucocratic gneisses are the most widespread. They underlie much of the Upper Kinyeti, Ngairigi and Ateppi Basins. Augen gneisses form the Imatong Mountains, while quartz-rich leucocratic gneisses form the Kinyeti-Ateppi watershed to the south and west and the ridge running north from Mount Kinyeti to Konoro. Much of the Kipia Uplands and the Lomwaga Uplands are 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. 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. Flow is normally gentle over the 2 400 and 1 800 m platforms, after which the watercourses are marked by rapid flow, with cascades and waterfalls until the plains are reached at about 900 m.

Soils

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 humus-rich surface horizons, which may extend to depths exceeding 1m. In the deeper soils these dark horizons usually overlie medium to fine textured subsoils, which are generally amongst the reddest to be found. Characteristically these soils are very friable and porous and consequently they have extremely rapid internal drainage. The soils in general appear to be inherently fertile, but most of the plant nutrients are associated with the organic-rich topsoils.

Vegetation

Four vegetation zones, Lowland (<1 800 m), Lower Montane (1 800-2 400 m), Higher Montane (2 400-2 900 m) and Ericaceous (>2 900 m) occur within the Reserve (Jackson, 1956). In the Upper Kinyeti and Ngairigi Basins four forest types containing commercial timber are recognised:

Croton-Macaranga-Albizia forest

This is secondary forest with a mean stocking of 82 m^3/ha of which 15 m^3/ha is *Croton.*

Olea-Podocarpus closed forest

Of the total mean stocking of 177 m^3/ha, 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 differs from the *Olea-Podocarpus* closed forest primarily in having a higher proportion of mature and overmature trees and a dearth of small-size trees. Of the apparently high total mean volume of 132 m^3/ha it is likely that a high proportion will be of trees that are 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 occur. Where this forest is found on steep slopes such as those rising up to the Kipia Uplands it should not be exploited for fear of erosion.

In the Talanga area, the Lowland Zone high forest contains *Chlorophora excelsa, Khaya grandifoliola, Celtis* spp. and *Maesopsis eminii.* These four species account for 26 m^3/ha of the total mean volume of 142 m^3/ha.

Wildlife

Game occur in substantial numbers throughout the Reserve, but the greatest concentrations appear to exist in the Kipia Uplands, with elephant, buffalo, bushbuck, pig, hyena and leopard being the most notable. Hunting parties from the nearby settlements scour the Reserve armed with bows and arrows and spears. Although the hunters have no rifles they hunt in such numbers that they are bound to deplete the game.

SOCIAL BACKGROUND

Settlement and population

Of the 1974 population of 107 636 residing in the Torit District, two of the seven tribes recorded (the Acholi and the Latuka, who account for 56 123) live in the vicinity of the Reserve. Reliable data is not available for Katire, the main village in the area, or for the two settlements, Gilo and Itibol, which lie in the Reserve. The best estimates available are those made by Dorward *et al.* (1976), which gave the populations of Katire, Gilo and Itibol as 3 612, 200 and 333 respectively. It is likely that these figures considerably underestimate the population, because non-taxpayers and those unknown to the Forest Department are excluded. Although the population is small it is doubtful if there would be much difficulty in recruiting general labour for any increased forestry activity within the Reserve.

Administration

Administrative control over the Torit District is exercised by a Local Government Inspector, who resides in Torit and is responsible to the Assistant Commissioner for Eastern Equatoria, who also has his office in Torit. The Local Government Inspector chairs the Torit Bur Council, which is composed mostly of elected members. This 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.

In addition there is a system for the administration of customary law under the control of the tribal chief in Katire. He 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 presides 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. Along this road there is a daily bus (lorry) service connecting Torit with Juba, but the service does not extend to Katire. This service also carries mail.

Road transport between Juba and the north is restricted to the dry season, and most freight is carried therefore either on the daily air service connecting Khartoum and Juba or by steamer and barge along the Nile. Two freight companies operate services to and from Kenya through Uganda.

Although Juba airport receives only a few flights each day, it has international status. There is a small all-weather airstrip at Torit, but any incoming or outgoing international flights are obliged to clear customs and immigration at Juba.

Full postal and telegraphic services are available in Torit, but although a post office is planned for Katire, no facilities yet exist within the project area.

Public services

The main regional hospital is situated in Juba; in addition, a small hospital operates in Torit and there is a dispensary at Katire. The 'Save The Children Fund' and the Norwegian Church Relief Missions in Torit both supplement local medical services. The arrangements for transporting more serious cases from Katire to Torit, dependent as they are upon the availability of a vehicle and fuel from the Forest Department, are inadequate, especially where sawmilling and the attendant logging operations are carried out.

Primary education is available at Katire; pupils from Gilo and Itibol daily make the 3-4 hour return trip on foot to Katire. Those admitted for junior secondary education have to board out in Torit; senior secondary education is not available outside Juba.

FORESTRY BACKGROUND

Timber market

In 1973/4 imports of timber to the Sudan amounted to about 55 000 m^3 of which the greater part were softwoods. By 2000 it is estimated that the demand for softwoods could reach 100 000 m^3/a, of which 80% would be used in the north and 20% in Southern Sudan. At present the principal sources of softwoods within the Sudan are the existing softwood plantations and the *Podocarpus* in the natural forest in the Imatong Central Forest Reserve.

Reservation

Since the early 1930s the Sudan Forest Department has been interested in developing the Imatong Mountains. In 1940 a road was constructed from Katire to Gilo and *Podocarpus* timber was exploited; a year later the first plantations were started. The reserve was legally gazetted in 1952.

Plantation history

The history of the plantation establishment falls into three periods:

1. 1941-54 In the first few years of planting (1941-3) a range of species including *Cupressus lusitanica, Juniperus procera, Eucalyptus grandis, Podocarpus gracilor, Callitris calcarata* and *Olea* spp. were tried. Thereafter planting was mainly of *Cupressus lusitanica* and this continued throughout the Gilo Range

2. 1955-64 In this period a range of pines, principally *Pinus patula, P. radiata* and *P. kesiya* were planted in the Dumusum and Itibol Ranges, because it was feared, following the discovery of drought crack, that insect and fungal attack might spoil the cypress timber

3. 1965-76 From 1965 to 1972 no new planting or silvicultural treatment of the established plantations was carried out, due to the disturbances. Since 1972 a small amount of land has been cleared and planted to the north and west of Gilo.

Part 3

The existing plantations and their management

AREA AND AGE CLASSES OF THE PLANTATIONS

The total area of the plantations is 490.8 ha of which 3.4 ha have been clear felled and a further 60.2 ha comprise the partially stocked stands occurring mostly 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 lusitanica.* 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. Table 1 summarises the distribution of the species by age class (see also Map 1 in the separate map folder).

TABLE 1 Summary of species, age class, area and reliable minimum estimate (RME) of total volume in the plantations

Species	Age class years	Area ha	Total vol. 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	14.8	2 975
	5-14	6.0	–
Total		479.1*	127 104*

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

PLANTATION VOLUME AND GROWTH MEASUREMENTS

The standing volumes of the different species are given in Table 1. Of the total standing volume of 127 104 m^3 *Cupressus* accounts for 108 091 m^3 and *Pinus* spp. *(P. radiata, P. patula* and *P. kesiya)* make up 15 000 m^3.

The mean annual increment based on the twelve oldest compartments is about 19 m^3/ha/a for *Cupressus,* and lies about the middle of the Quality Class II site index

curve for *Cupressus* grown in Kenya (Dyson, 1962). Less reliable data is available for the *Pinus* spp., but for *P. patula* the mean annual increment seems to lie between 13 and 19 m^3/ha/a.

PRESCRIPTIONS FOR THE SILVICULTURAL MANAGEMENT OF THE PLANTATIONS

Many of the compartments have not been managed during the disturbances and are now underthinned and liable to windblow. 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 2, in the form of silvicultural prescriptions. The prescriptions are given as first and second priorities for felling and thinning. It is recommended that the first priority fellings are completed within three years. They involve the felling of 97.5 ha, which will realise a volume of 27 980 m^3, of which 26 440 m^3 is *Cupressus.* The first priority thinning will cover 135.3 ha and will realise 8 716 m^3. Pruning covering 99.4 ha and weeding, cleaning and beating up of young stands covering an area of 60.0 ha are also recommended. The prescriptions are shown on Map 2.

TABLE 2 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	–

CHOICE OF SPECIES

Cupressus lusitanica is obviously 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.

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 Compartment 3 and 6. Improved seed for *P. patula* could be obtained from Malawi or Kenya, but seed trees should be selected within Compartments 51 and 67, in case outside supplies of seed prove to be insufficient.

Part 4

Site selection

LANDFORM UNITS

A total of 14 landform units have been recognised. Their more important characteristics are given in Table 3 and their distribution is given in Maps 3a-b. Their suitability for plantation development is indicated in the legend for Maps 3a-b. Nine landform units contain a significant proportion of land which is likely to be suitable for plantation development; they are Landform Units B, C, E, F, G, H, L, M and N.

SLOPE ANALYSIS

Each landform unit represents a recurring pattern of topography in which there is significant variation from site to site in the factors such as slope which affect plantation development. Five slope classes have been recognised and their distribution is shown in Maps 3a-b. Three of the classes (moderately sloping (6-20^{o}), gently sloping (1-6^{o}), and flat (<1^{o})) represent no limitation for the development of softwood plantations. Slopes above 20^{o} represent a greater limitation to plantation development and above 30^{o} the limitation becomes severe.

SOILS

Sixteen soil series were recognised during the soil survey of the Upper Kinyeti and Ngairigi Basins and during the reconnaissance traverses made in other parts of the Reserve. Ten of the series occur in the Upper Kinyeti and Ngairigi Basins and their distribution is shown on Maps 3a-b. They are:

a. Lohocho Series – these distinctly red, loamy soils with gneiss boulders occurring below are Humic Cambisols and are suitable for plantation development; but their bouldery nature may limit the growth of some species

b. Dumusum Series – these soils are similar to those of the Lohocho Series but have a coarser texture, ranging from sand to sandy loam, and although suitable for plantation development their coarse texture might give rise to drought stress on summits and upper slope areas

c. Sahue Series – these soils are also Humic Cambisols but are, unlike Lohocho and Dumusum Series, reddish brown in colour, and their shallowness limit the possibilities for plantation development, except perhaps for *Pinus* spp.

d. Nabakin Series – these soils are Humic Nitosols, red in colour, fine textured and with deep (70 cm) dark surface horizons and are very suitable for plantation development

e. Gilo Series – these soils differ from those of the Nabakin Series by having medium textures, loam to sandy clay loam, and are also very suitable for plantation development

f. Lokotolu Series – these soils are similar to those of the Gilo Series but are reddish brown in colour; they are equally suited for plantation development

g. Ngairigi Series – these soils are similar to those of the Nabakin Series except that they have a coarser textured topsoil; they are probably the commonest soils of the area and rank among the best soils for plantation development

h. Itibol Series – these soils are similar to those of the Ngairigi Series except that the topsoil is reddish brown in colour; they likewise have a high potential for plantation development

i. Konoro Series – these soils are similar to those of the Itibol Series but the reddish brown colour extends throughout the profile; they are also highly recommended for plantation development

j. Oreira Series – these soils are brown in colour, but resemble some of the other Humic Nitosols, particularly the Ngairigi, Itibol and Konoro Series, with loamy topsoils and clayey subsoils; although occurring only infrequently they are highly recommended for plantation development.

TABLE 3 **The main characteristics of the landform units**

Symbol	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

LAND SUITABILITY AND IDENTIFICATION OF LAND FOR PLANTATION DEVELOPMENT

Three suitability classes have been used:

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 4 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 4 Areas of land suitable for softwood plantation development

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

Part 5

Vegetation

The vegetation zones and types recognised and the areas which each cover are shown in Table 5; their distribution is shown on Maps 4a-b.

TABLE 5 Area of vegetation types in the Imatong Central Forest Reserve

Vegetation zone	Vegetation type	Map symbol	Area ha
Lowland and Transition Zones	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-Dombeya open forest	3e	8 399
Ericaceous Zone	*Erica* thicket	4a	154

The vegetation of the area has affinities with that of neighbouring countries. In the plains, below 1 800 m, the forest vegetation consists almost entirely of species belonging to the phytogeographical Guineao-Congolian 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).

Part 6
Forest inventory of the indigenous forest

INVENTORY OF THE NGAIRIGI AND UPPER KINYETI BASINS

Areas and volumes

The forest inventory covered forested land with slopes of less than 30° in the Ngairigi and Upper Kinyeti Basins. Table 6 gives the reliable minimum estimates of total volume for the four vegetation types containing merchantable timber (hereafter termed the forest types).

TABLE 6 Reliable minimum estimate† of total volume of timber (m^3) and area (ha) of the forest types in the enumerated area

Timber species/group	Min dbh cm	Forest type			
		2d (area 910.2 ha)	2e (area 1 736.0 ha)	2f (area 2 366.6 ha)	3e (area 474.5 ha)
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 including *Syzygium*	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 of the larger diameter classes

Forest Type 2d, *Croton-Macaranga-Albizia* forest, contains a high proportion of secondary species like *Croton* and only small quantities of *Podocarpus* and *Olea.* The RME of mean volume is 74 m^3/ha of which the established hardwoods account for 21 m^3/ha. Type 2e, *Olea-Podocarpus* closed forest, 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. Type 2f, *Podocarpus-Syzygium* open forest, is overmature forest in which the measured merchantable standing volume may not be realised because the trees have begun to rot. In this type the RMEs of the mean volume for *Podocarpus,* established hardwoods and all species groups are 31, 35 and 117 m^3/ha respectively. Type 3e, *Podocarpus-Dombeya* open montane forest, is a transitional type to montane forest of high elevation. The RMEs of mean volume for *Podocarpus,* established hardwoods and all species groups is 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 7 shows the mean volumes per hectare and total volumes by forest type for the main species in the enumerated area.

TABLE 7 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

Stand tables

In the *Olea-Podocarpus* closed forest (Type 2e) the mean stem frequency for *Olea* and *Podocarpus* is 10/ha 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 (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 the open forest is not regenerating. The total number of stems per hectare is 145 for Forest Type 2e and 84 for Type 2f.

INVENTORY OF THE TALANGA AREA

Areas and volumes

The total area of the lowland high forest which occurs in the Talanga area is 2 135.7 ha, of which 1 098.7 ha were enumerated.

The reliable minimum estimates of total volume are given in Table 8. Mean and total volumes by species are given in Table 9.

TABLE 8 Reliable minimum estimates (RME) of total volume in the enumerated area of the Talanga forest, m^3

Timber species group	Min.dbh, cm	Volume, 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 has been used and the volume is given in brackets

TABLE 9 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 or 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 per hectare of each species.

Stand tables

The distribution of the 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 per ha over 30 cm dbh compared with 66 for 2f and 107 for 2e. There are, on average, six stems per ha of the four named species.

Part 7

Development possibilities

NGAIRIGI AND UPPER KINYETI BASINS

An area of 9 813 ha has been identified as suitable for softwood plantation development. Within this area existing softwood plantations cover 490.8 ha. They have a standing volume of 84 863 m^3 ready for clear felling (priorities 1 and 2) and 9 833 m^3 of thinnings. A small area, 166.9 ha, of the *Cedrela toona* plantation adjacent to Katire, also falls within the area suitable for plantation development. Most of the rest of this development area, however, is covered with natural forest; only 1 749.0 ha is covered by vegetation types with little or no merchantable timber. Table 10 shows the extent of each forest type and the total standing volumes (see Map 5).

TABLE 10 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

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 Block 7.

TALANGA AREA

The standing volume in the Talanga forest, which covers 2 135.7 ha, is probably about 54 600 m^3 of merchantable hardwoods and 203 900 m^3 of unidentified species. In the enumerated area (1 098.7 ha) the standing volumes are 28 000 m^3 and 105 900 m^3, respectively. At the extraction rate of 160 logs per month, the standing volume would supply the Katire sawmill for between 5 and 11 years depending upon the area of the

Talanga forest that could be economically logged. Any exploitation should be followed by regeneration either by natural regeneration using the shelterwood system or by line planting or by clear felling and replanting.

Access to the Talanga area is via a road from the teak plantation along the Katire-Torit road. It 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. 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.

ACHOLI MOUNTAINS, ATEPPI BASIN, LOMWAGA AND KIPIA UPLANDS

It is recommended that these areas be set aside for long-term conservation of the flora and fauna.

Part 8
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