NO. 9

REPORT OF SITE ASSESSMENT ON PLANTATION OF HARD-WOOD IN VITI LEVU, FIJI

March 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

(J.I.C.A.)

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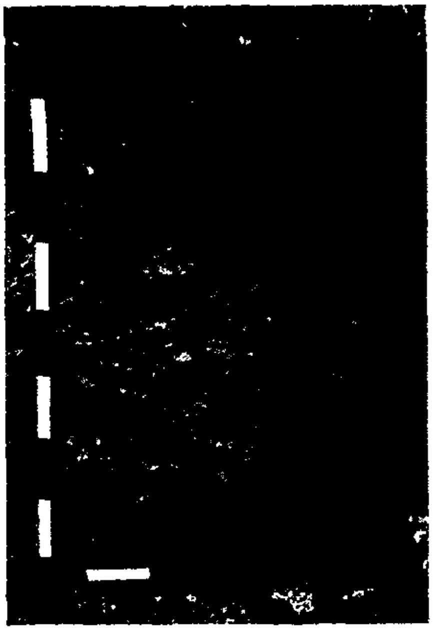
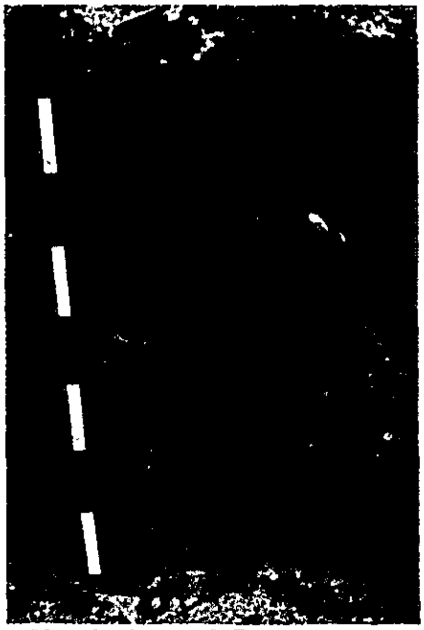
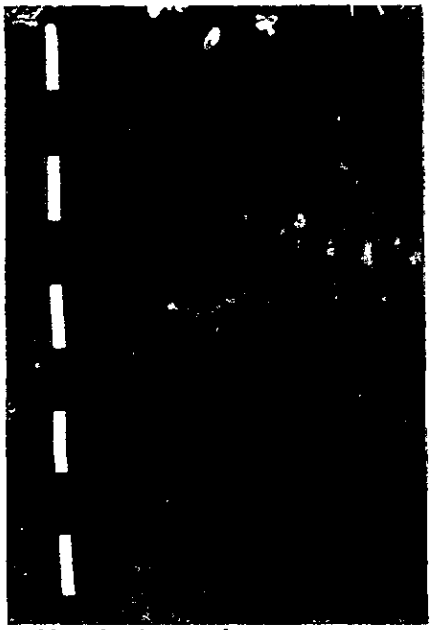
Soil Profiles



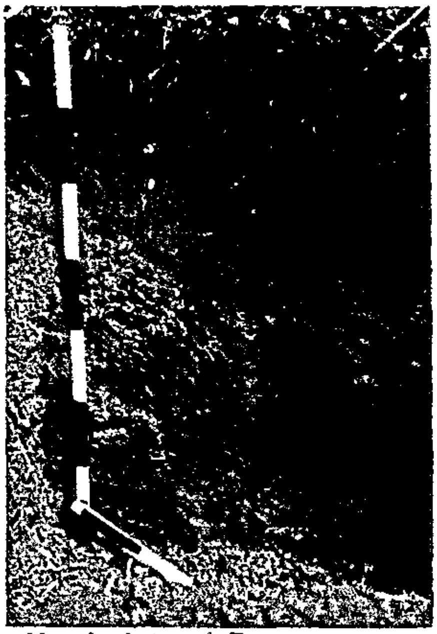
▲**Humic latosol A-type**
Residual soil on narrow ridge, characteristic reddish layer (2.5YR～10R) is recognized from the upper to lower parts of B horizon.



▲**Humic latosol B-type**
Residual soil on flat, wide ridge, characteristic reddish layer (2.5 YR～10R) is recognized in the lower of B horizon.



▲**Humic latosol c-type**
Creeping soil on slope, the arrangement of soil horizons is generally irregular, and contain various kinds of creeping materials



▲**Humic latosol D-type**
Colluvial soil on flat foot, slightly gleyed mottlings are recognized in the lower layer.

▲**Gleyed soil**
Colluvial soil on flat foot near creak, gleyed layers are developed in the lower of soil profile.

PREFACE

It is with great pleasure that I present this report on a survey on Site Assessment on Plantation of Hard-wood in Viti Levu to the Government of Fiji.

This report embodies the result of a site assessment which was carried out in Nukurua area, from 6th June to 7th August, 1981 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of Fiji to the Government of Japan.

The survey team, headed by Mr. Koichi Yamaya, had a series of discussions with the officials concerned of the Government of Fiji and conducted a wide scope of field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for forestry development in Fiji.

I wish to express my deep appreciation to the officials concerned of the Government of Fiji for their close cooperation extended to the team.

March, 1982

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

CONTENTS

1. OUTLINE OF SURVEY

1.1 Background

The Fijian afforestation consists mainly of the planting of Pinus caribaea in the dry zone and Hard-wood in the wet zone. As of the end of 1980, the plantation of pine trees and hard-woods were reported to be about 40,000 ha and 13,000 ha, respectively. Nukurua, the survey area, is in the wet zone and forms one of the nation's largest plantations of hard-woods.

The most important and the most zealously planted species in Nakurua district is mahogany (Swietenia macrophylla). The planting of this species, which involves no technical problems of afforestation and which is expected to yield superior timber at cutting, was started in 1961 and reached 4,900 ha in 1971.

But in 1970 damage to planted mahogany trees by the Ambrosia beetle, a borer, became rampant and from 1972, mahogany planting was stopped.

Experimental planting designed for selecting other species for planting was conducted in parallel with the plating of mahogany trees Particularly with the discontinuation of mahogany planting as the result of damage by the Ambrosia beetle, it suddenly became increasingly necessary to select substitute species and trees of nearly 200 species were experimentally planted. Of those, six species including mahogany were selected as hopeful for future planting. Since 1972, mainly these species have been used for afforestation.

These plantations, along with the existing natural forests, are indeed most important to the Fijian economy. Thus, it has become urgently necessary to have the complete data required for such activities as assessing the volume and distribution of resources, forming a long-range work plan and selecting trees suitable for preplantations.

As a survey on hard-wood plantations, a forest survey (on the volume and distribution of resources) was conducted in 1980 for such plantations in Nukurua district, using aerial photographs, and its results were compiled.

However, much remains to be seen as to such details as the growth of mahogany and other planting species and the places for which these species are suitable. Thus, scientific and objective data are badly needed to proceed with the planting of hard-woods in the preplantation of this and other districts.

1.2 Purpose

With this background, survey aimed at executing soil surveys for the preplantation, a productivity survey of the existing plantation and at making criteria of the forest productivity in order to establish the appropriate technology for selecting the suitable sites with the suitable species.

1.3 General description of the survey area

(1) Position and Area

The survey area is on Viti Levu Island which is located in the central of western part of the Fiji Islands and its center is at approximately lat. 18° S., long. 178° E It is the largest of the Fiji islands with an area of about 10,429 km² or 57% of the entire Fijian territory. Nukurua district, the survey area, is located in the south-eastern part of Viti Levu Island. (Fig. 1-1)

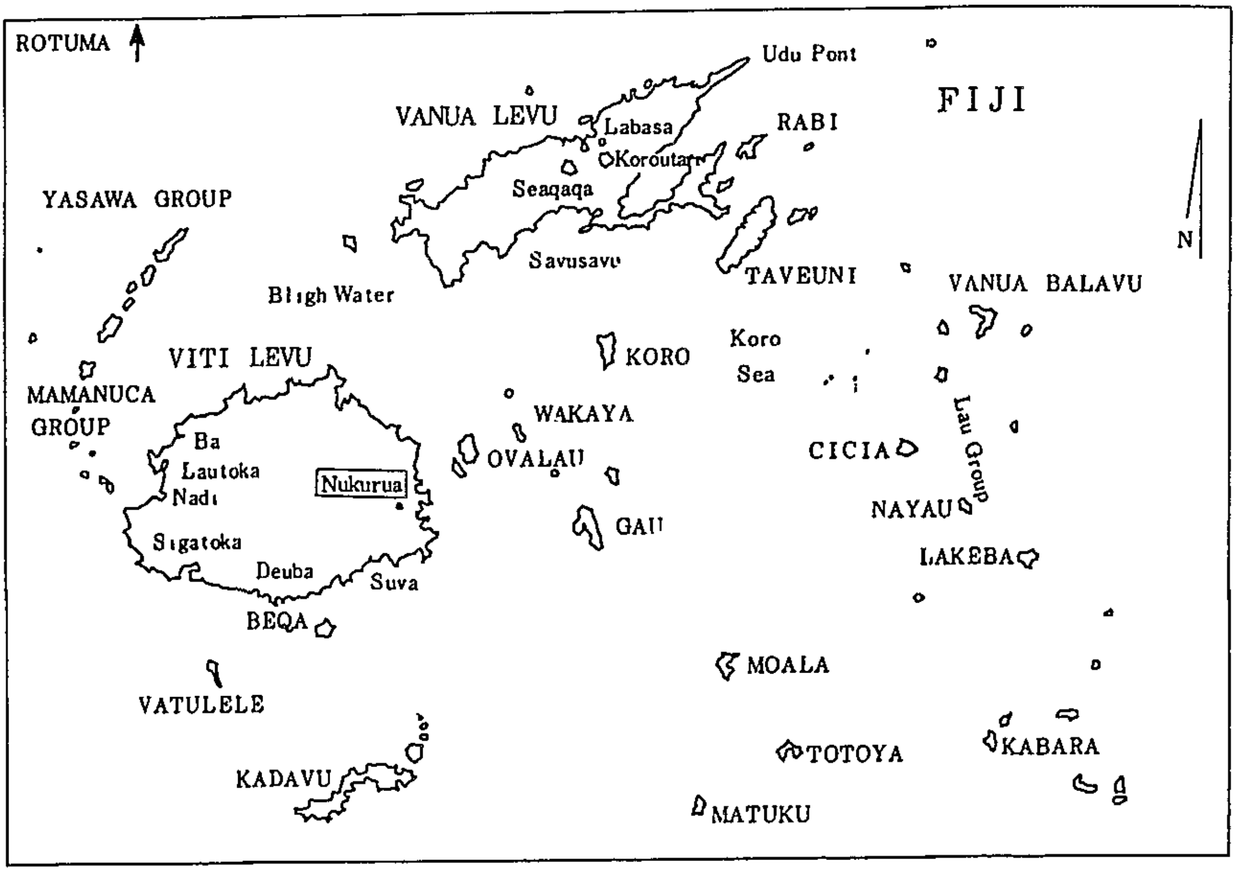


Fig 1-1 Location map of Fiji

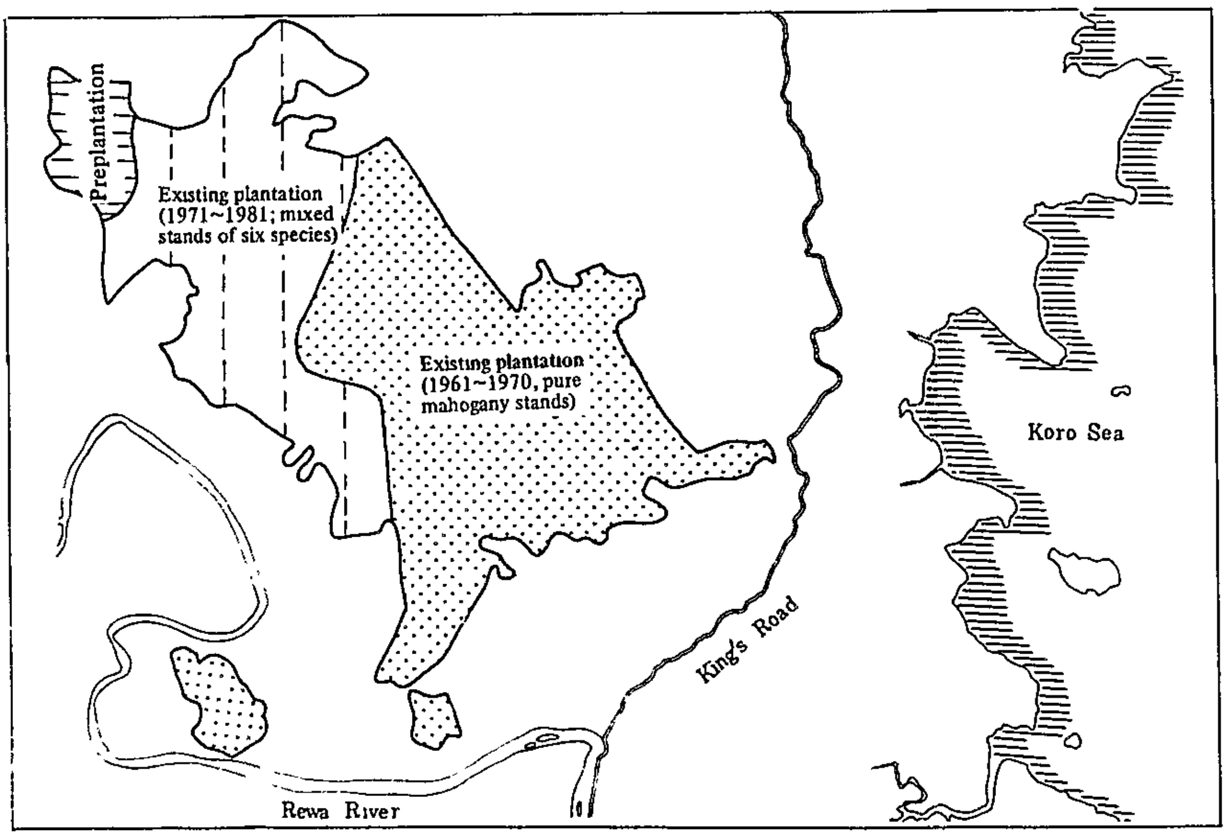


Fig. 1-2 General map of Nukurua district

This district belongs in the category of lowland tropical rain forest and was formerly covered with natural forests of Kauvula, Kaudamu and other hard-wood. In this district, from 1961, the Government of Fiji has prepared some forest land (total area: about 8,000 ha.) on a rental basis with native land owners for planting hard-woods by the line planting method, after cutting natural forests. Planting was started from the vicinity of the King's Road on the east side and gradually proceeded west. Only 425 ha. in the farthest recesses remain to be planted from 1982.

Of the existing plantations, the eastern part, which was planted by 1970, contains pure stands of mahogany while the western part, which was later planted, comprises mixed stands of six species including mahogany. (Fig. 1-2)

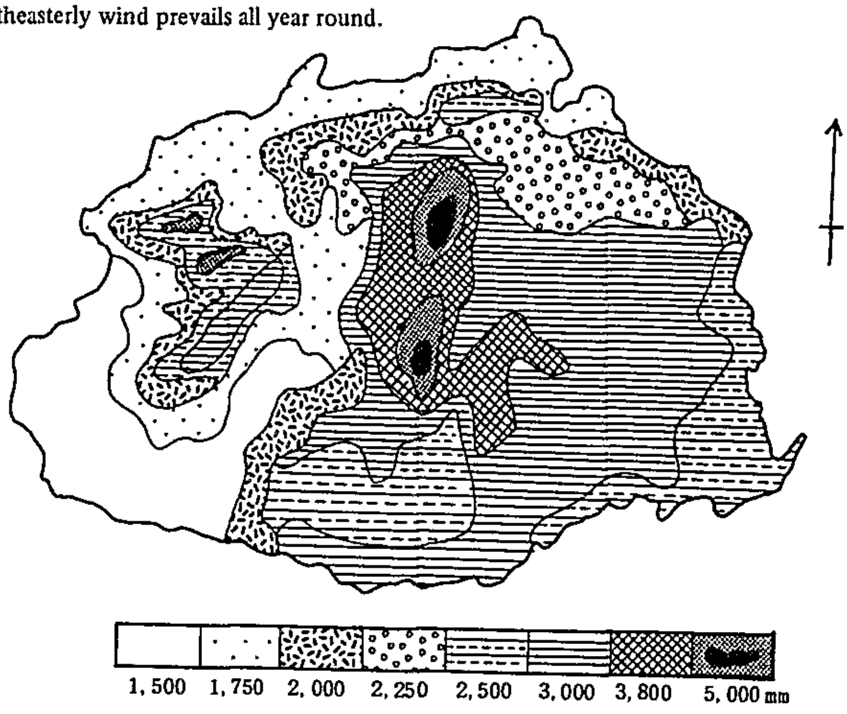
(ii) Geology and topography

Viti Levu Island is of volcanic nature. There are igneous rock, such as granite, porphyrite, andesite and agglomerate, accompanied by Tertiary Miocene, Pliocene and Pleistocene sedimentary rocks (tuff, siltstone, conglomerates, mudstone, etc.). The sedimentary rocks characteristically change from neutral to basic with transition from Pliocene to Pleistocene. In the Nukurua district, which is composed of these sedimentary rocks (Suva series), basic parent materials are predominant.

Topographically, in the middle of Viti Levu Island there is a north-to-south mountain ridge consisting of mountains higher than 1,000 m above sea level including 1,324-m Mt. Victoria, which is the highest. However, most parts of the island are less than 300 m above sea level. Nukurua district is the island's coastal flat land, called the Rewa delta and valley. Though it has some steep slopes (more than 18°), it is mostly hilly or rolling (2° ~ 18°) land.

(iii) Climate

The Fuji Islands belong in the category of tropical oceanic climate The temperature is high throughout the year but mitigated by the ocean. Viti Levu Island is distinctly divided by the mountain ridge in the middle into a wet zone on the east side and a dry zone on the west side (Fig. 1-3), because the main wind there is a trade wind and this southeasterly wind prevails all year round.



R.A.Derric, The Fuji island

Fig. 1-3 Rainfall distribution on Viti Levu Island, Fiji

In the wet zone, the annual rainfall is generally more than 2,500 mm and the annual average is more than 3,000 ~ 3,600 mm. In the dry zone, it is less than 2,500 mm and is only 1,600 ~ 1,700 mm at many places. It can be seen from the annual rainfall distribution that in both zones, there is much rainfall during December to March and little during June to October. Generally, temperatures are high during the wet months of November to March and low during the dry months of April to October.

At Colo-i-Suva in the wet zone, for example, the annual rainfall is 4,125 mm, the monthly average during June to August, the period with least rainfall, is 242 mm and the amount in the month with least rainfall is 213 mm. At Nandi in the dry zone, the annual rainfall is 1,848 mm, the monthly average during June to August, the period with least rainfall is 63 mm and the amount in the month with least rainfall is 38 mm. Thus, the difference between the two zones is, indeed, great. Further, the temperature seldom rises above 32° C in the wet zone but in the dry zone it is usually more than that.

The high-altitude mountain ridge and its vicinity, including the lee side, are rainy. At Nadarivatu (960 m above sea level) on the west side of the mountain ridge, for example, the annual rainfall is 3,587 mm, which is less than that at Colo-i-Suva, but the rainfall there during the wet period of January to March is much larger than at Colo-i-Suva while during the dry period of June to August, the tendency is similar to that at Nadi.

Generally, this area is stricken by hurricanes during the hot wet period of November to April, sometimes suffering heavy damage in many places. Also, there is localized torrential downpour during the wet period and it sometimes causes heavy local disasters. The great landslide that occurred in Galoa district in April 1980 is an extreme example due to unprecedented local downpour.

(iv) Land use

Sugar cane and coconuts are chief among the Fijian cash crops. Sugar cane is suitable for the dry zone while coconuts are suitable for the wet zone. However, apparently no coconut production is in practice on the Rewa River, which is included in the survey area. This seems to be because coconut production formerly was not feasible as an industry due to insect damage and presently for economic reasons. Rice is cultivated on the delta in the lower reaches of the Rewa River.

(v) Vegetation

Forests in the wet zone are tropical hard-woods, but in the dry zone, the land is so impoverished from recurring mountain fires that it is covered with nothing but grass except for some valleys where small forests exist. In these areas, which the Fijians call Talasiga, Caribbean pines (Pinus caribaea) are now being planted.

Vegetation on Viti Levu Island is generally divided into 1) littoral vegetation, 2) dry zone vegetation, 3) intermediate zone vegetation and 4) wet zone vegetation. Nukurua district probably is typical of the wet zone vegetation.

1.4 Survey team and concerned Fijian officials

The members of the Nukurua District Hard-Wood Plantation Site Assessment Survey Team are as follows: Survey Team

Leader:	Koichi Yamaya	Chief researcher, Japan Forest Technical Association, Inc.
	Kuniyasu Wakamori	Chief technical expert, same Association
	Akira Nomura	Technical expert, same Association
	Mitsuru Kabe	Technical expert. same Association
	Shoichiro Fukui	Technical expert, same Association
	Yoshinori Watanabe	Technical expert, same Association
	Masahiko Hara	Technical expert, same Association

The concerned Fijian officials are as follows:

K.T. Yabaki	Forestry Agency	Conservator of Forests
A. Chang	"	Deputy Conservator of Forests
A.K. Oram	"	Senior Assistant Conservator of Forests

2. SOIL SURVEY

The soil is one of the major factors deciding forest productivity and is the basis for selection of the tree species for successful afforestation.

2.1 The survey area

The soil survey was conducted in the preplantation located in the innermost section of the Nukurua area (See. Fig. 1-2).

The area, different from the existing plantation sites, is one of rolling hills with slight depressions and less steep slopes, except for some dissected slopes along the shallow creek.

2.2 Survey method

(i) Field survey

Base lines running N-S and E-W were set to equally cover the preplantation land for excuting the soil survey in profiles and soil distribution. Then, 31 representative soil profiles were based on the micro topographies along the base lines. Soil and vegetation surveys were made at the above representative sites. These were further classified by the soil classification method mentioned. Then the soil distribution was entered onto a 1/5000 scale map. The soil map developed in the field survey has been supplemented and emended by aerialphotos (See Fig.2-2).

(ii) Soil classification

Great group was greatly dependent upon the 1/126,720 scale soil map of Fiji (The Soil Resources of the Fiji Island, Vol. 1 (1965) and Vol. 2 (1961), and sub group was divided from the morphological features of the soil profiles.

2.3 Results

(i) Soil classification and soil properties

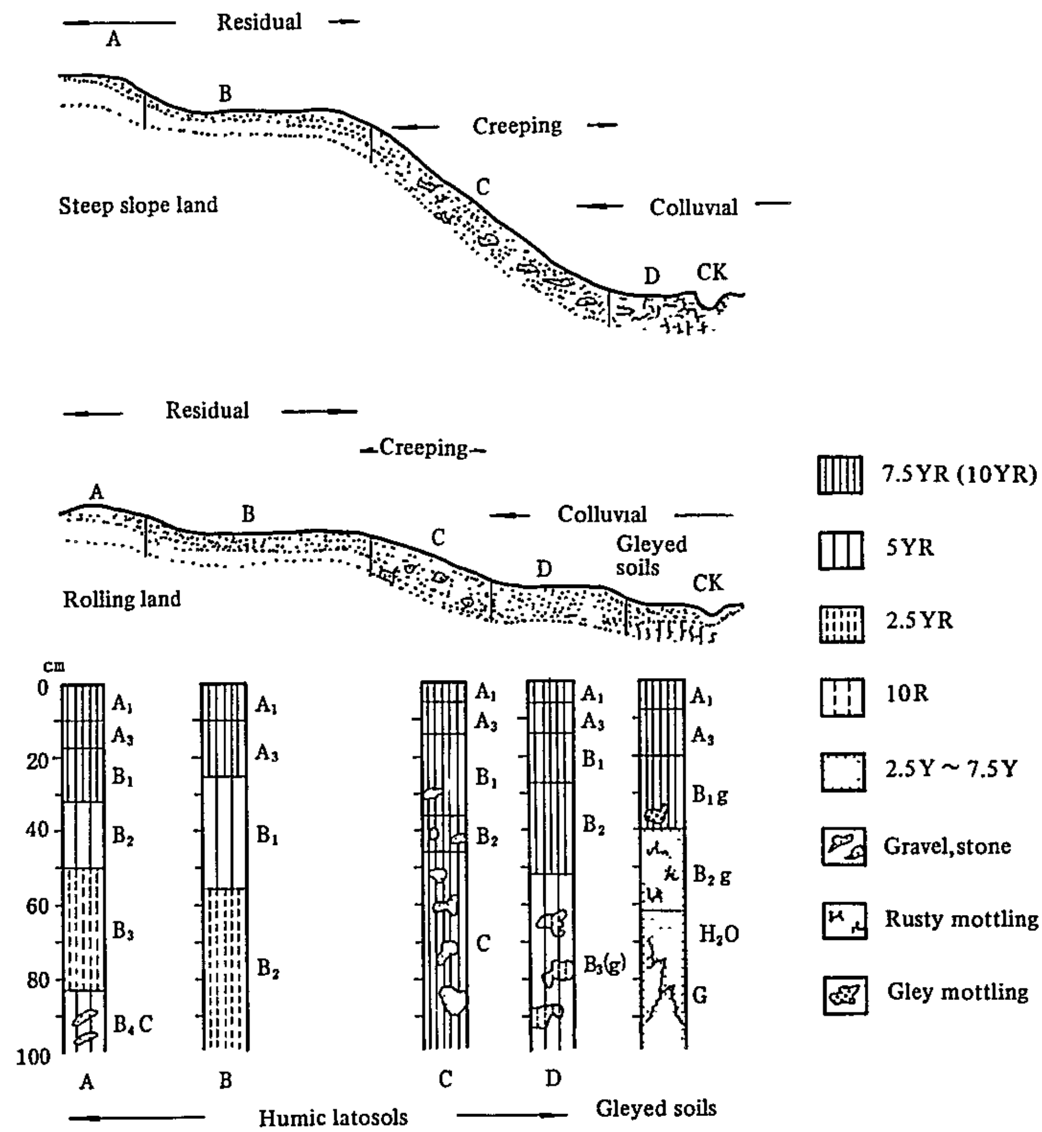
The Fijian authorities concerned have published a book giving details of the soil of Fiji as well as a soil map of the whole country of Jiji on a scale of 1/126,720. According to this, the soil of the Nukurua area is humic latosol and is further classified of texture into Sote clay and Nakavika gravelly clay.

These types of deep soil forming reddish clay derived from the basic tuff. In the current study, the humic latosols in the Nukurua area are sub-classified into four types, A, B, C, and D (shown in Table 2.1) in terms of specific soil profiles appearing in the development of the micro topograph. In some parts, gleyed soil was observed. The standard for the subclassification was the 2.5 YR–10 R, reddish layer which is regarded as a diagnostic layer, i.e., the latosol B-horizon; whether this layer exists, and its depth if it does exist, the extent of fading of the color, the influence of the forest humus, etc. (See Fig. 2-1).

Table 2-1. Soil classification of the tropical rainforest in Nukurua

Great groups	Subgroups	Topography and deposited condition	Morphological features of soil profile
Humic latosols	A-Type Humic latosol	Narrow ridge Residual	A : 7.5 YR, well developed blocky structure, loose B : upper – 7.5 YR ~ 5 YR, slightly developed blocky structure, clay lower – 2.5 YR ~ 10R, heavy clay, very hard
	B-Type Degraded humic latosol	Flat, wide ridge Residual	A : 7.5 YR, weakly developed blocky structure B : upper – 7.5 YR ~ 5 YR, comparatively thick, near massive, clay lower – 2.5 YR, heavy clay, sticky
	C-Type Soils related to latosol materials	Gentle or steep slope Creeping	A : 7.5 YR, weakly developed blocky structure B : 7.5 YR, contain weathered rocks, clayey C : 7.5 YR, contain weathered rocks, clayey, massive
	D-Type Slightly gleyed humic latosol	Flat foot Colluvial	A : 7.5 YR, slightly developed blockylike structure B : 7.5 YR, clay, massive B(g): 5 YR, contain 2.5 YR mottlings, heavy clay, massive
Gleyed soils	Gleyed soil associated to latosolic soil	Flat foot, near creek Colluvial	A : 7.5 YR, slightly developed blockylike structure B(g): 2.5 Y, heavy clay, gley and rusty mottlings, massive G : 7.5 Y, heavy clay, iron stripes, sometimes water table

Fig. 2-1. Topography-soil relationship in steep-sloped lands and rooling land in Nukurua area, Viti Levu Island (CATENA)



The morphological features of soil profiles on the tropical soils subclassified by the above-mentioned method are as follows (see the color photos of the first page):

- Humic latosols A-type (Soil profile No. N-4)

Location: Nukurua, Compartment 2

Land form: Convex ridge

Elevation: 110 m

General information of soil: Residual soil, silt stone

Vegetation: Natural hard-woods

Profile description:

LF : 1 cm, loose pile of decayed leaves.

A_1 : 0 ~ 9 cm, dark brown (7.5YR3/4), rare humus, clay, strong blocky, rich pore, soft and moist, small and middle ligneous roots, fresh soil pH 4.3, gradual boundary.

A_3 : 9 ~ 17 cm, brown (7.5YR4/4), very rare humus, clay, strong blocky, soft and moist, rare small ligneous roots, fresh soil pH 4.25, gradual boundary.

B_1 : 17 ~ 32 cm, brown to bright brown (7.5YR4.5/6), very rare humus, heavy clay, weak blocky, hard and moist, fresh soil pH 4.2, diffuse boundary.

B_2 : 32 ~ 50 cm, bright reddish brown (5YR5/6), very rare humus, heavy clay, weak massive, hard and moist, fresh soil pH 4.85, gradual boundary.

B_3 : 50 ~ 83 cm, bright brown (2.5YR5/8), very rare humus, heavy clay, massive, hard and moist, contain more reddish mottlings, fresh soil pH 4.5, diffuse boundary.

B_4C: > 83 cm, reddish brown (5YR4.5/8), very rare humus, heavy clay, decayed silt stone, massive, hard and moist, fresh soil pH 4.6.

- Humic latosol B-type (Soil profile No. N-2)

Location: Nukurua, Compartment 11

Land form: Wide flat ridge

Elevation: 100 m

General information of soil: Residual soil, silt stone

Vegetation: Natural hard-woods

Profile description:

L : Scattered.

A_1 : 0 ~ 10 cm, brown (7.5YR4/4), rare humus, clay, blocky, soft and moist, aboundant small fissures, aboundant herb roots, fresh soil pH 3.5, gradual boundary.

A_3 : 10 ~ 25 cm, bright brown (7.5YR5/7), very rare humus, heavy clay, large fissures, hard and moist, fresh soil pH 5.15, gradual boundary.

B_1 : 25 ~ 56 cm, bright reddish brown (5YR5/8), very rare humus, heavy clay, massive, hard and moist, rare small ligneous roots, fresh soil pH 5.0, diffuse boundary.

B_2 : > 56 cm, bright brown (2.5YR5/8), very rare humus, heavy clay, massive, hard and moist, fresh soil pH 4.9.

- Humic latosol C-type (Soil profile No. N-9)

Location: Nukurua, Compartment 11

Land form: Lower slope, direction S, inclination 16°

Elevation: 110 m

General information of soil: Creeping soil, silt stone

Vegetation: Natural hard-woods

F : 1 cm, loose pile of half decayed leaves.

A_1 : 0 ~ 5 cm, dark brown (7.5YR3/3), aboundant humus, clay, weak blocky, loose and moist, small and middle ligneous roots, fresh soil pH 5.05, diffuse boundary.

A_3 : 5 ~ 13 cm, brown (7.5YR4/4), rare humus, clay, weak blocky, soft and moist, rare small and middle ligneous roots, fresh soil pH 5.0, gradual boundary.

B_1 : 13 ~ 35 cm, bright brown (7.5YR5/8), very rare humus, contain weathered silt stone, heavy clay, massive, hard and moist, rare small ligneous roots, fresh soil pH 4.6, gradual boundary.

B_2 : 35 ~ 46 cm, bright brown to orange (7.5YR5.5/8), rare humus, contain creeping gravels, heavy clay, hard and moist, fresh soil pH 4.6, gradual boundary.

C : > 46 cm, orange (7.5YR6/7), rare humus, aboundant subangular silt stone, heavy clay, hard and moist, fresh soil pH 4.6.

- Humic latosol D-type (Soil profile No. N-7)

Location: Nukurua, Compartment 2

Land form: Flat foot, near creek

Elevation: 100 m

General information of soil: Colluvial soil, near residual

Vegetation: Natural hard-woods

Profile description:

L : Scattered.

A_1 : 0 ~ 6 cm, dark brown (7.5YR3/4), aboundant humus, clay, nutty, loose and moist, ligneous and herb roots, fresh soil pH 5.0, diffuse boundary.

A_3 : 6 ~ 14 cm, brown (7.5YR4/6), rare humus, heavy clay, weak blocky, soft and moist, small ligneous roots, fresh soil pH 5.15, gradual boundary.

B_1 : 14 ~ 27 cm, brown to bright brown (7.5YR4.5/6), rare humus, heavy clay, massive, hard and moist, rare small and middle ligneous roots, fresh soil pH 5.05, gradual boundary.

B_2 : 27 ~ 52 cm, bright brown (7.5YR5/8), rare humus, heavy clay, massive, hard and moist, rare small ligneous roots, fresh soil pH 5.1, clear boundary.

B_3C: > 52 cm, reddish brown to bright reddish brown (5YR4.5/8), rare humus, heavy clay, massive, hard and moist, fresh soil pH 5.0, contain reddish brown to bright reddish brown (2.5YR4.5/8) mottlings.

- Gleyed soil (Soil profile No. N-5)

Location: Nukurua, Compartment 2

Land form: Flat near creek

Elevation: 90 m

Genaral information of soil: Colluvial soil, near residual

Vegetation: Natural hard-woods

Profile description:

L : Scattered.

A_1 : 0 ~ 7 cm, dark brown (7.5YR3/3), aboundant humus, clay, blocky, loose and moist, aboundant ligneous and herb roots, fresh soil pH 4.5, gradual boundary.

A_3 : 7 ~ 20 cm, dark brown to brown (7.5YR3.5/3), rare humus, clay, blocky, soft and moist, small and middle ligneous roots, fresh soil pH 4.6, clear boundary.

B_1g : 20 ~ 40 cm, brown (7.5YR4/6), very rare humus, contain charcoals and gley mottlings, clay, soft and moist, fresh soil pH 4.7, clear boundary.

B_2g : 40 ~ 62 cm, yellowish gray (2.5Y6/1), aboundant bright brown (7.5YR5/6) rusty mottlings, very rare humus, heavy clay, hard and moist, clear boundary.

G : > 62 cm, gray (7.5Y6/1), very rare humus, aboundant reddish brown iron streaks in fissures and root tunnels, heavy clay, massive, hard and wet, typical gley horizon with water table at 65 cm depth.

These subclassifications have been illustrated in a appended table of field survey plots. The 31 representative soil profiles are classified as follows;

Humic latosol	Type A	9 plots
	B	11 "
	C	3 "
	D	7 "
Gleyed soil		1 plot

The pH values of fresh soils on five typical soils measured as one of the chemical properties are shown as Table 2-2.

Table 2-2 pH values of fresh soils under the tropical rainforest at the Nukurua district

Sub-groups	Prof. No.	Horizons	pH (H_2O)
Humic latosol A	K-I	A_1	3.8
		A_3	4.2
		B_1	4.9
		B_2	5.1
		B_3C	3.4
	N-4	A_1	4.3
		A_3	4.25
		B_1	4.2
		B_2	4.85
		B_3	4.5
		B_4C	4.6
Humic latosol B	N-2	A_1	3.5
		A_3	5.1
		B_1	5.0
		B_2	4.9
	N-3	A_1	5.0
		A_3	3.8
		B_1	3.2
		B_2	3.0
Humic latosol C	N-1	A_1	4.0
		A_3	4.4
		B_1	5.0
		B_2	4.75
		B_3C	4.8

Sub-groups	Prof. No.	Horizons	pH (H_2O)
Humic latosol C	N-9	A_1	5.05
		A_3	5.0
		B_1	4.8
		B_2	4.6
		C	4.6
Humic latosol D	N-7	A_1	5.0
		A_3	5.15
		B_1	5.05
		B_2	5.1
		$B_3C(g)$	5.0
	N-8	A_1	5.0
		A_3	5.0
		Bg	4.95
Gleyed soil	K-2	A	6.15
		B_1g	5.4
		B_2g	5.6
		Cg	5.45
	N-5	A_1	4.5
		A_3	4.6
		B_1g	4.7
		B_2g	4.8
		G	5.0

Judging from the pH values, it is presumed that soil reaction is strongly acid, and base desaturation has been severely proceeded through the weathering process of parent materials. Soil acidities generally become weak with the moving from A-type to D-type. Accordingly, soil fertility will be expected in order of A < B < C < D.

Every soils were very sticky and compact, then, straight spade and fork were needed for dig the pits. Viewing the data of soil hardness, it is recognized that the hardness of A_1 horizons are 5 ~ 15 mm, A_3 are 15 ~ 20 mm, and B are 20 ~ 25 mm by the Yamanaka's hardness tester.

(ii) Distribution of soils

The soils subclassified by the morphological features of soil profile are shown as Table 2-1. From the table, it is clear that humic latosol A-type appears on narrow ridge, B-type on flat, wide ridge, C-type on gentle and steep slope, and D-type on flat foot, and gleyed soil locally appears on flat foot near creek. And, latosol A- and B-types are residual, C-type is creeping, and D-type is colluvial, and gleyed soil is also colluvial. The state of distribution of these soils is shown as the soil map of Fig. 2-2 (reduced 1:5000 scale original map), and the areas of ditribution of every soils are shown as Table 2-3.

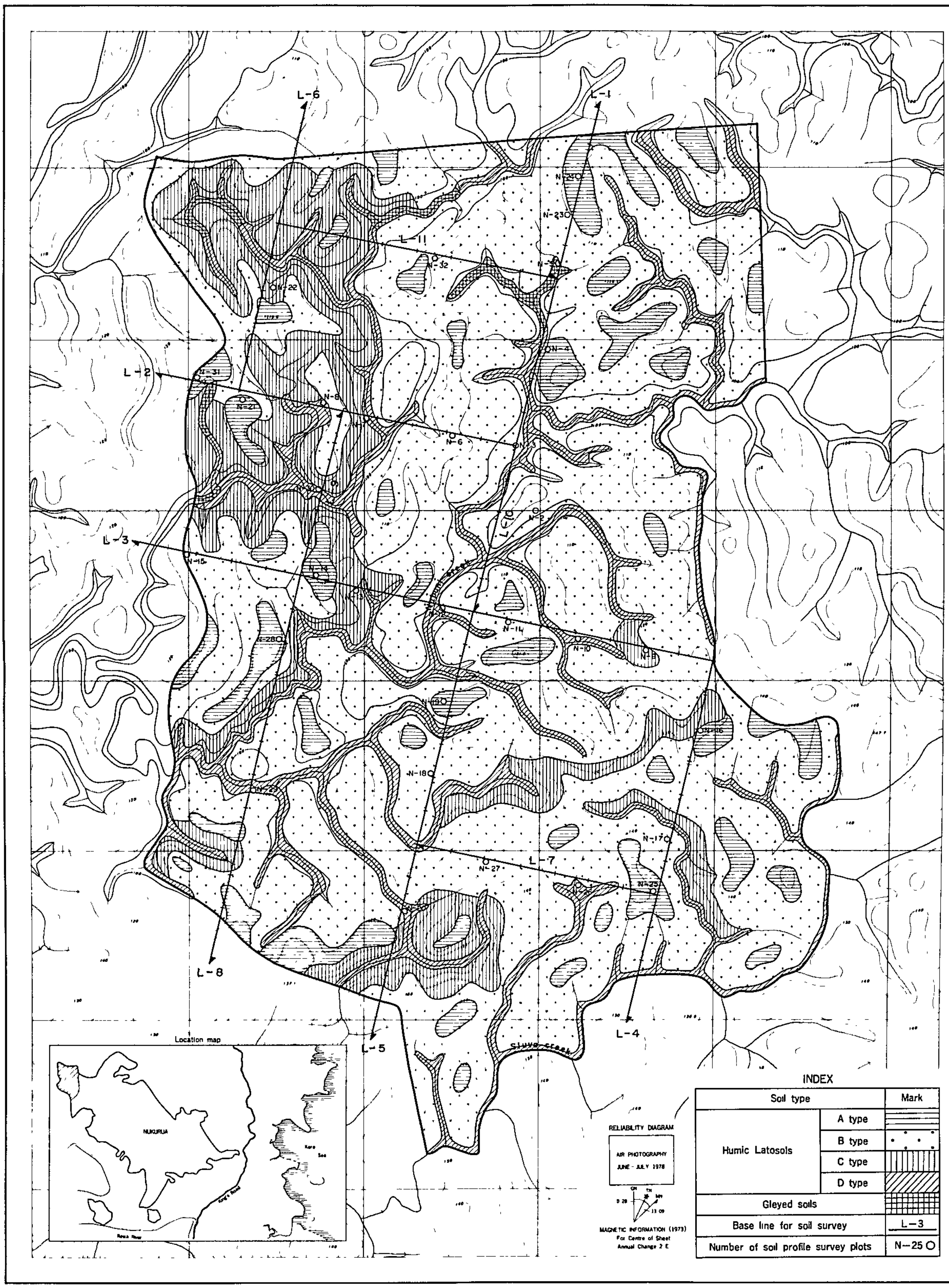
The state of soil distribution shown in the table is on hilly and rolling topography of preplantation,however, in the case of steep slope topography of existing plantation that is different from the hilly and rolling topography. That is, while humic latosol C-type is widely distributing on steep slope topography, D-type is characteristically distributing, and gleyed soil locally appears on the rolling topography (see Fig. 2-1). The relationship between micro rerief and soil distribution is known as catenea*, and the idea of catena is important problem for the land utilization.

* Catena means a chain, and shows a regular relation between micro relief and soil distribution.

Table 2-3 Soil distribution in the preplantation at the Nukurua

Soils		Distribution of soils	
		ha	%
Humic latosol	A	41.84	9.8
	B	269.00	63.8
	C	63.84	15.0
	D	46.52	11.0
Gleyed soils		3.80	0.9
Total		425.00	100.0

Fig. 2-2 SOIL MAP



iii) Vegetation research

The main plants of every survey plots have been described in a appended table of field survey plots. From the results of vegetation research, the state of vegetation in surveyed area is shown as Table 2-4. The tropical rainforests at the Nukurua area vertically consist of three layers, namely, canopy layer (dominant and subdominant class), shrub layer and grass layer. And, climbing plants and perching plants are very aboundant in the forests, and the mantles of climbing plants were observed on the conopy of forests. The tropical rainforest in Fiji have been fully presented in "Meet Fiji's rainforest (1978)".

The excellent tree species cutted and utilized in Table 3-4 at present are only Dakua and Yaka belong to coniferous tree, and Kauvula, Kaudamu and Sacau belong to hard-wood, and the others have been neglecting as unploited tree, otherwise have been poisoning as hindrance in plantation.

Table 2-4. Main plants in tropical rainforests at the Nukurua district, Viti Levu, Fiji

Fijian name	Scientific name	Fijian name	Scientific name
Dominant tree class		Kuluva	*Dillenia biflora*
Bauvudi	*Burckella brackypoda*	Lilidi	(as above−mentioned)
Dawa	*Pometia Pinnata*	Makita	〃
Dulewa	*Erythrospermum acuminatissimum*	Mavo(Davo)	*Macaranga* spp.
Duvula	*Hernandia olivacea*	Sama	*Commersonia bartramia*
Ivi	*Inocarpus fagiferus*	Sisisi	*Gironniera celtidifolia*
Kauceuti	*Kermadecia ferruginea*	Sorua	*Alstonia vitiensis*
Kaudamu	*Myristica castaneifolia*	Tirivanua	*Crossostylis seemannii*
Kaukaro	*semecarpus vitiensis*	Vau	*Hibiscus tiliaceus*
Kauvula	*Endospermum macrophyllum*	Vasavasa	*Amaroria soulameoides*
Laubu	*Garcinia myrtifolia*	Vutu	(as above−mentioned)
Lagaleka	*Neuburgia corynocarpa*	Shrub and grass class	
Lilidi	*Litsea Pickeringii*	Davo	(as above−mentioned)
Makita	*Parinari glaberrima*	Kaudamu	〃
Mako	*Cyathocalyx stenopetalus*	Kauvula	〃
Mavota	*Gonystylus punctatus*	Kaunicina	*Canarium harveyi*
Midri	*Elaeocarpus graeffei*	Kaunigai	*Haplolobus floribundus*
Moivi	*Cynometra insularis*	Koster's Curse	*Clidemia hirta*
Rogi	*Heritiera ornithocephala*	Laubu	(as above−mentioned)
Sa	*Parinari insularum*	Lilidi	〃
Sacau	*Palaquium hornei*	Losilosi	*Ficus* spp.
Sasaura	*Dysoxylum richii*	Makita	(as above−mentioned)
Tabua Rakolavo	*Pagiantha thurstonii*	Marasa	*Storckiella vitiensis*
Tivi	*Terminalia* spp.	Mavota	(as above−mentioned)
Vutu	*Barringtonia petiolata*	Rogi	〃
Yasiyasi	*Cleistocalyx* spp.	Sacau	〃
Subdominant tree class		Sisisi	〃
Bulumaga-yalewa	*Garcinia pseudoguttifera*	Sole	*Plerandra bakeriana*
Dulewa	(as above−mentioned)	Vasa Damu	*Euphorbia fijiana*
Kavika	*Syzygium malaccense*	Vuvudi	*Polyalthia laddiana*

Fijian name	Scientific name	Fijian name	Scientific name
Wavuka	*Rubus moluccanus*	Otaloa	*Athyrium melanocaulon*
Yaqoyaqona	*Piper timothianum*	Qato	*Dicranopteris lineris*
Conifers		Vativati	*Acrostichum aureum*
Dakua Makadre	*Agathis vitiensis*	Climbing plants	
Kuasi	*Podocarpus nerifolius*	Qalo	*Flagellaria indica*
Yaka	*Dacydium nidulum*	Vadra	*Pandanus* spp.
Fern plants		Wa Lai	*Entada phaseoloides*
Balabala	*Cyathea lunulata*	Wame	*Freycinetia storckii*
Basovi	*Angiopteris evecta*	Yalu	*Epipremnum pinnatum*

Scientific names were based upon "J.W.Parahm: Plants of the Fiji Islands, 1972"

3. SITE ASSESSMENT

In Nukurua district, afforestation was done from 1961 and until 1971 with pure mahogany planting being carried out by the line planting method. But in 1972, planting had to be suspended due to heavy damage caused by Ambrosia beetles. And from 1973, a switch was made to mixed planting mainly of the six species of Cadamba, Deglupta, Cordia, Maesopsis, Kauvula and Mahogany. The line planting method is used, as in the past. Thus, trees of the same species are planted for a width of several to scores of lines and a length of hundreds to thousands of meters. This terrain includes ridges and valley and flats and slopes. Further, it contains different types of soil. Such being the case, some of the places in the terrain are not necessarily suitable for the tree species used, but they may be suitable for some other species The present line planting method using the same species is convenient for planting and the cultural operations and regeneration, but it cannot make full use of the productive capacity of the land.

When afforesting a place, one does research to see what tree species is most suited to that place. This is called the species/site potential survey. As a step to determine the species/site potential, one sometimes estimates the extent to which trees of a certain species will grow if they are planted there. This is called a forest productivity survey. These surveys are necessary to make the most of the productive capacity of forests, form a forest working plan and eventually predict the long-term supply and demand of forest products.

3.1 Survey method

3.1.1 Survey procedure

In surveying forest productivity, first a table of criteria for judgement of forest productivity is made. This is done by finding the relation between the extent of growth of trees and the site conditions in existing plantations and then investigating the site conditions of preplantations. Finally productivity is estimated for each preplantation. Fig.3-1 shows a flow chart of this survey procedure.

(i) Preparation of data

Aerial photographs, base maps, tree volume tables, tree height growth curve graphs and other data necessary for survey were prepared. Data from the field survey conducted in Nukurua district in 1980 were also prepared.

(ii) Finalizing of survey area

In this survey on forest productivity, existing plantations were used for the sample survey necessary to make a table of criteria for forest productivity. Then, preplantations for 1982 on were used in making the forest productivity map, the species/site potential map, etc. (See Fig. 1-2).

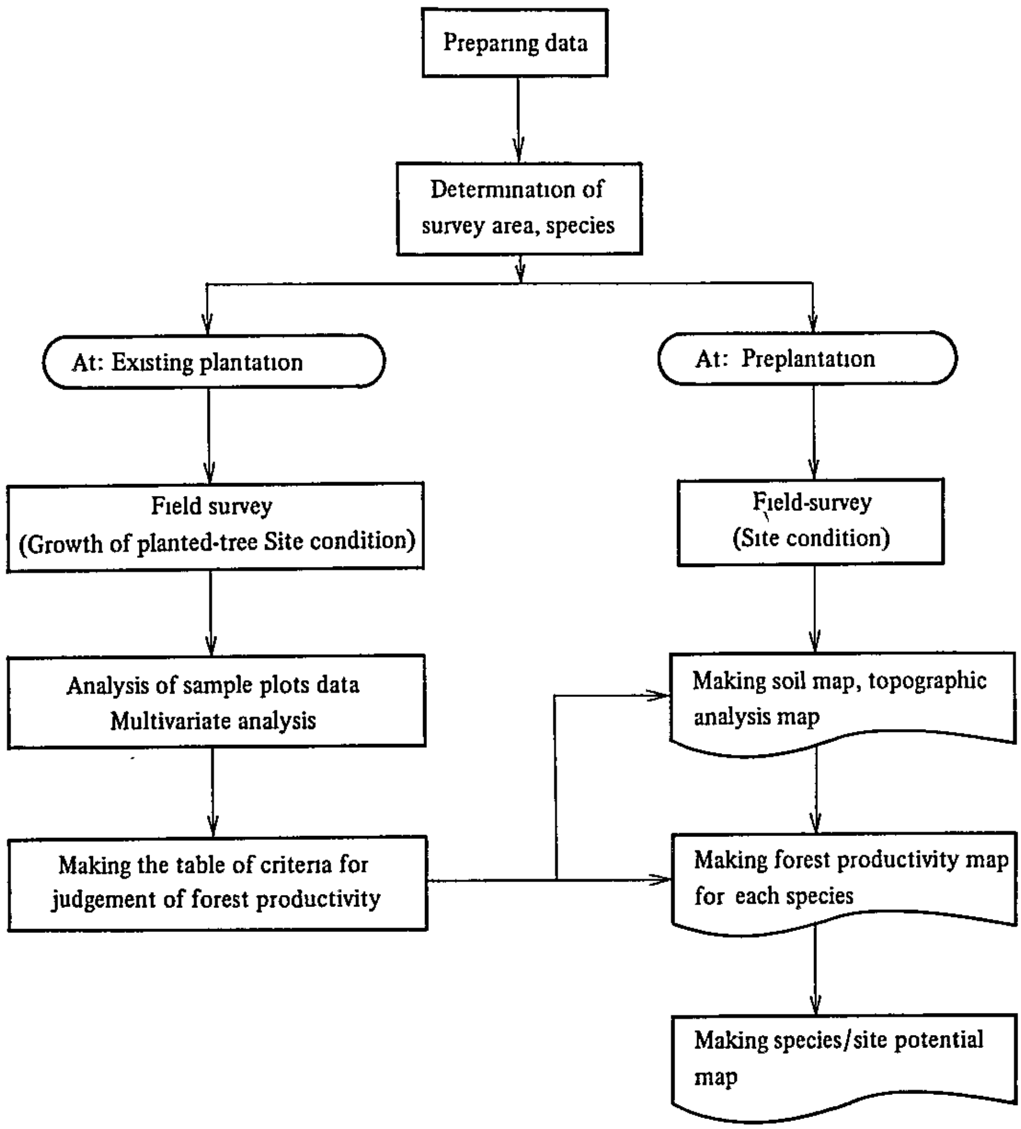
(iii) Selection of planting tree species for survey

The main species of trees planted in Nukurua district are the following six: Cadamba (Anthocephalus cadamba), Deglupta (Eucalyptus deglupta), Cordia (Cordia alliodora), Maesopsis (Maesopsis eminii), Kauvula (Endospermum macrophyllum) and Mahogany (Sweitenia macrophylla). However, only five species were used, excluding maesopsis because of its small planted area.

(iv) Field survey

The growth of trees, soil conditions and other site conditions necessary for analysis were surveyed at the existing plantations by providing more than 20 sample survey plots for each species. At the preplantations too, soil and other site conditions were surveyed by providing more than 20 soil survey plots.

Fig. 3-1. Flow chart of survey procedures for forest productivity



(v) Analysis of field survey data and making of soil map, etc.

Multivariate analysis was carried out in accordance with the data obtained from the field survey conducted at the existing plantations, and a table of criteria for judgement forest productivity was made for each species.

At the preplantation, soil and topographic analysis map was made.

(vi) Making of forest productivity maps

Forest productivity maps for each species were made for the preplantation from the results of the analysis mentioned in the preceding item.

(vii) Making of species/site potential map

A species/site potential map was made by overlaying the forest productivity maps mentioned in the preceding item.

3.1.2 Sample plot survey on the existing plantations

A forest survey and a site condition survey were carried out by providing sample plots to clarify the relationship between the growth of planted trees and their site conditions. Since survey items were practically the same as for sample plots used in the 1980 survey. What was considered helpful for effective use in the recent survey was added as data by supplementing the soil survey. The total number of sample plots was 140.

(i) Allocation of sample plots

In allocating plots, attention was given to the following matters:

(1) More than 20 sample plots were provided for each of the five tree species covered by the survey.

(2) Care was taken to place equal emphasis for each sample plot as much as possible in consideration of each site condition category; soil type, micro-topography, inclination and direction

(3) Since the average tree height at five years of age was used as the outsider (index) in the forest productivity survey, sample plots were taken in plantations with a stand age as close to five years as possible in order to minimize the correction errors of tree height by stand age.

Table 3-1 shows the number of sample plots by tree species and by stand age.

Table 3-1. Survey plot numbers by tree species and stand age

Species \ Age	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years	Total
Cadamba	7	9	4	7			2	1	30
Deglupta	6	3	5	2	3	6			25
Cordia	8	9	7	3	4		2	1	34
Kauvula	9	6	3	7					25
Mahogany	3	6	2	13	2				26
Total	33	33	21	32	9	6	4	2	140

(ii) Size of sample survey plots and measurement items

0.05 ha. or 0.1 ha. was used as the size of the sample plots. The standard shape of the plots was rectangular: 20 m (width) x 25 m (length) or 20 m (width) x 50 m (length) and adjustments were made so as to accommodate two or three lines. Surveying and measuring were done for planted trees in sample plots with respect to the following items: tree species, stand age, stem diameter, crown radius, form class and damaged trees. See Table 3-2: Inventory Data Sheet.

At the same time, the site conditions of the sample plots were surveyed, namely, soil type, micro-topography, inclination and direction.

(1) Forest survey

- Tree species inthe survey

  The five main planted tree species of Cadamba, Deglupta, Cordia, Kauvula and Mahogany were surveyed.

- Stand age

  This was determined by reading the years of planting from the stock map prepared in 1980.

- Stem diameter

  The D.B.H. (diameter breast height) was measured by 2-cm rounding, using a caliper.

- Tree height

  All tree heights were measured in meters, using a Blume-Leiss or a survey pole.

- Crown radius

  Orthogonal radii were measured using a survey pole and averaged.

Table 3-2

Inventory Data Sheet

Tree No.	Stem Diameter	Tree Height	Crown Radius	Form Class	Damaged Tree	Tree No.	Stem Diameter	Tree Height	Crown Radius	Form Class	Damaged Tree
1						31					
2						32					
3						33					
4						34					
5						35					
6						36					
7						37					
8						38					
9						39					
10						40					
11						41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					
30						60					

o Form class

This was divided into three levels: I (good), II (moderate) and III (poor) by the straightness of the stem and the spread of the lower branches.

o Damaged trees

Damaged trees were classified by the extent and type of damage as follows:

Extent of damage

Damage tree (w) { Damaged tree(n): Tree that is damaged but still alive.
Dead tree: Tree that has died of damage or is missing.

Type of damage

- Damage from fungus
- Damage from hurricanes
- Oppressed trees, trees cut by mistake in brush cutting or trees damaged by some other cause.
- Missing . . . . .Trees that are missing for some unknown reason.
- Thinning . . . .Trees that have ceased to exist due to thinning.

Single tree volumes were determined by volume formula prepared by the Government of Fiji from plantations and experimental plantations.

Table 3-3 Volume formulae by each species

Tree species	Volume formula
Cadamba	$V=00081+0.3764D^2\times H$
Deglupta	$V=0.0146+03197D^2\times H$
Cordia	$V=00012+0.3079D^2\times H$
Kauvula	$V=0.0300+03112D^2\times H$
Mahogany	$V=0.0536+0.457D^2\times H$

V is volume underbark in m^3.
D is d. b. h overbark in metres.
H is height above stump in metres.

Table 3-4 is a list of survey results for sample plots.

(2) Site condition survey

The site conditions of sample plots were surveyed and classified as follows:

o Soil

Soil types were determined from the soil profiles obtained by digging a hole in the approximate center of the sample plot. Types were divided into humic latosols, Type A, Type B, Type C and Type D and gleyed soils.

o Micro-topography

This was classified into ridge, middle-slope and valley sections.

o Inclination

This was measured, using a clinometer, and divided into the following four:

Flat	$0\sim5^\circ$
Gentle	$6\sim10^\circ$
Medium	$11\sim20^\circ$
Steep	21° or more

o Direction

This was divided into four: N, S, E and W.

Table 3-4 List of survey results for sample plots

Sample No.	Tree species	Stand age	Average d.b.h(cm)	Average tree height: Stand (m)	Average tree height: Upper trees (m)	Average tree height: Dominant trees(m)	Stand volume (m³/ha)	Basal area (m²/ha)	Form class (ratio to number of trees, %): I	Form class: II	Form class: III	Average crown radius (m)	Number of planted trees	Number of living trees	Dead trees (ratio to number of planted trees) %
			cm												
Ca − 1	Cadamba	4	21.88	16.3	18.4	20.0	90.4	9.78	31	31	38	4.3	340	260	24
2		4	17.30	11.8	11.8	16.0	46.0	7.52	50	25	25	3.9	360	320	11
3		4	14.05	11.1	11.1	14.5	24.8	4.03	39	38	23	3.1	300	260	13
4		3	8.67	7.8	8.3	11.0	10.6	1.88	44	37	19	2.1	380	320	16
5		4	7.23	7.7	9.3	12.5	10.4	1.07	54	31	15	1.6	340	260	24
6		4	12.82	9.8	12.8	20.0	25.8	3.35	31	15	54	1.6	300	260	13
7		3	4.51	5.3	5.5	8.0	5.0	0.61	63	11	26	0.6	400	380	5
8		5	26.34	15.4	16.8	18.5	138.0	17.43	25	31	44	3.8	400	320	20
9		4	22.99	17.1	19.0	21.0	123.6	13.28	69	6	25	3.4	360	320	11
10		4	19.05	12.9	13.5	18.0	59.0	8.54	33	34	33	3.0	400	300	25
11		3	6.18	5.8	6.4	9.0	5.4	0.79	69	23	8	1.9	320	260	19
12		3	3.91	3.3	4.0	7.5	4.6	0.44	17	50	33	1.2	460	360	22
13		3	12.21	8.3	8.3	13.5	23.6	4.44	16	68	16	2.4	420	380	10
14		6	25.08	15.9	15.9	20.0	147.2	16.81	0	88	12	3.4	420	340	19
15		5	22.23	16.8	17.8	19.0	107.4	12.41	23	77	0	4.1	360	320	11
16		10	29.90	22.5	24.8	32.5	367.0	26.66	21	73	6	2.5	440	380	14
17		6	17.15	13.5	14.1	19.0	79.0	6.92	33	60	7	2.9	300	300	0
18		6	16.99	16.4	16.4	20.0	179.4	20.86	20	80	0	2.3	960	920	4
19		6	16.92	15.5	15.5	19.0	151.6	18.88	2	98	0	2.7	880	840	5
20		6	17.35	10.0	11.3	13.5	42.8	7.57	0	94	6	3.4	360	320	11
21		6	23.46	14.4	14.4	17.0	116.4	15.56	0	94	6	3.7	360	360	0
22		6	27.01	21.0	21.0	24.0	198.6	18.35	0	100	0	3.4	320	320	0
23		4	16.04	10.0	11.4	15.3	30.1	5.05	72	16	12	4.0	340	250	26
24		4	11.65	8.0	8.8	10.3	14.8	2.99	61	39	0	3.2	310	280	10
25		5	15.43	10.2	10.8	12.0	27.2	4.86	77	19	4	3.8	310	260	16
26		5	14.36	11.4	12.4	15.3	42.4	6.46	89	8	3	2.9	480	400	17
27		3	13.73	9.1	9.3	11.3	31.3	6.06	47	41	12	3.6	420	410	2
28		3	16.62	10.5	10.8	12.3	38.2	6.52	67	23	10	3.7	370	300	19
29		9	31.65	22.0	23.9	28.8	265.8	22.02	58	28	14	3.0	410	280	32
30		9	32.30	23.5	24.9	29.3	351.1	27.86	47	53	0	3.2	420	340	19

Sample No.	Tree species	Stand age	Average d.b.h(cm)	Average tree height: Stand (m)	Average tree height: Upper trees (m)	Average tree height: Dominant trees(m)	Stand volume (m³/ha)	Basal area (m²/ha)	Form class (ratio to number of trees, %): I	Form class: II	Form class: III	Average crown radius (m)	Number of planted trees	Number of living trees	Dead trees (ratio to number of planted trees) %
De − 1	Deglupta	4	1.95	2.8	3.3	4.5	2.2	0.06	33	67	0	0.6	360	180	50
2		3	2.26	2.7	2.7	3.5	1.2	0.04	0	0	100	0.7	420	100	76
3		3	2.26	2.4	2.6	4.0	3.4	0.11	0	8	92	0.4	440	260	41
4		5	10.59	9.9	10.9	15.5	17.2	2.65	46	27	27	1.7	440	300	32
5		6	12.96	10.9	12.0	17.5	13.6	1.85	29	14	57	1.9	360	140	61
6		3	2.26	3.5	3.7	6.5	3.8	0.09	15	39	46	0.6	460	260	43
7		3	5.86	6.1	6.6	10.0	7.8	0.86	50	19	31	1.1	460	320	30
8		7	14.00	12.0	12.6	17.5	20.4	2.77	56	44	0	1.6	420	180	57
9		5	17.26	14.5	14.5	14.5	6.2	0.94	100	0	0	3.3	540	40	93
10		5	3.57	4.6	4.6	6.0	1.8	0.10	20	80	0	0.8	560	100	82
11		6	19.40	16.5	18.1	22.0	105.4	12.42	24	76	0	2.4	880	420	52
12		8	25.03	23.4	23.4	26.5	101.4	9.84	10	80	10	3.4	720	200	72
13		8	23.56	21.6	23.4	25.0	94.0	9.59	0	82	18	2.8	900	220	76
14		8	21.29	19.3	20.0	23.0	102.2	11.39	13	74	13	3.1	640	320	50
15		8	21.75	20.8	21.5	25.0	138.6	14.12	11	89	0	2.9	760	380	50
16		4	11.94	8.8	11.0	8.8	2.7	0.45	75	0	25	3.0	390	40	90
17		8	18.68	17.4	18.0	22.8	112.7	13.17	61	35	4	2.4	780	480	38
18		8	18.51	19.0	15.0	17.6	102.3	10.75	62	30	8	2.1	760	400	47
19		5	6.18	6.3	8.8	9.0	2.0	0.27	22	56	22	1.4	260	90	65
20		5	9.74	7.6	8.6	10.8	7.9	1.27	18	53	29	1.8	320	170	47
21		7	24.88	20.8	21.5	25.5	163.0	17.50	56	25	19	2.8	870	360	59
22		7	21.84	19.3	20.8	24.5	91.5	10.12	48	41	11	2.5	750	270	64
23		4	9.34	6.8	8.3	6.8	1.5	0.27	50	25	25	2.1	320	40	88
24		3	4.37	4.1	5.3	6.8	1.8	0.15	40	40	20	0.9	310	100	68
25		3	8.37	7.2	8.5	8.5	1.8	0.28	60	40	0	2.2	310	50	84
Co − 1	Cordia	5	12.36	10.0	11.7	14.5	15.7	3.37	7	21	72	2.0	300	280	7
2		5	15.51	12.7	13.3	16.5	26.9	4.90	15	31	54	2.3	300	260	13
3		4	4.07	4.0	5.2	7.0	2.4	0.79	0	20	80	1.0	600	600	0
4		3	3.19	3.8	4.6	6.0	1.2	0.35	36	23	41	1.0	440	440	0

Sample No.	Tree species	Stand age	Average d.b.h(cm)	Average tree height			Stand volume (m³/ha)	Basal area (m²/ha)	Form class (ratio to number of trees, %)			Average crown radius (m)	Number of planted trees	Number of living trees	Dead trees (ratio to number of planted trees) %
			cm	Stand (m)	Upper trees (m)	Dominant trees(m)			I	II	III				
Co- 5	Cordia	5	14.80	14.0	16.4	18.5	44.3	6.88	30	65	5	2.9	500	400	20
6		4	13.16	8.3	9.9	15.0	26.1	5.98	4	23	73	2.1	480	440	8
7		3	1.60	1.6	2.2	3.5	0.5	0.09	33	43	24	0.4	560	420	25
8		3	1.60	1.5	2.3	3.0	0.5	0.10	19	57	24	0.4	500	420	16
9		3	5.41	5.9	5.9	9.0	2.5	0.77	76	6	18	1.6	340	340	0
10		4	8.06	7.4	7.8	10.5	7.9	2.23	4	23	73	1.8	500	440	12
11		4	5.86	5.9	6.5	10.0	3.6	1.03	32	36	32	1.5	380	380	0
12		7	19.93	18.1	21.3	23.0	101.4	12.47	40	30	30	3.1	420	400	5
13		7	13.73	11.9	13.5	18.0	34.5	5.90	55	20	25	1.9	440	400	9
14		4	6.68	6.5	6.7	11.0	4.5	1.33	37	37	26	1.4	400	380	5
15		3	8.96	7.3	7.8	9.0	6.0	1.64	0	77	23	2.0	360	260	28
16		6	14.49	10.5	10.9	15.5	48.5	10.56	9	38	54	2.6	640	640	0
17		5	12.82	11.5	12.6	17.0	25.4	4.65	11	50	39	2.2	400	360	10
18		5	14.18	13.9	14.3	20.5	40.6	6.32	60	30	10	2.2	420	400	5
19		5	13.16	13.0	13.0	15.5	19.0	3.53	58	42	0	2.2	400	260	35
20		5	10.03	9.0	11.2	14.0	12.4	2.52	11	88	11	2.2	320	320	0
21		10	18.58	13.9	16.7	19.0	92.4	14.07	15	50	35	2.4	700	520	26
22		3	7.91	6.4	6.7	10.0	5.5	1.57	13	25	62	1.8	400	320	20
23		4	8.67	6.0	8.1	11.0	7.7	2.06	29	48	23	1.9	380	350	8
24		6	10.13	7.5	10.1	16.0	12.2	2.50	9	69	22	2.3	410	310	24
25		6	12.09	10.2	11.7	15.5	20.7	4.24	57	27	16	2.3	400	370	8
26		5	11.89	8.7	9.1	12.5	10.1	2.56	43	43	14	2.2	360	230	36
27		7	17.95	15.5	15.9	20.0	55.0	8.34	39	43	18	3.7	370	330	11
28		7	23.83	18.3	19.5	22.0	41.3	5.35	42	42	16	3.3	400	120	70
29		5	14.32	12.1	13.5	15.8	27.7	5.30	73	21	6	2.5	390	330	15
30		9	19.78	14.6	15.5	20.5	105.8	15.37	24	50	26	2.5	700	500	29
31		9	18.79	11.7	12.1	17.8	88.8	17.46	14	64	22	2.6	680	630	7
32		4	8.67	6.0	6.9	10.5	6.8	1.89	19	44	47	1.8	430	320	26
33		3	8.88	7.5	8.4	10.5	7.2	1.93	52	39	9	2.1	320	310	3
34		3	8.37	6.0	6.6	10.0	5.6	1.25	41	43	16	2.0	380	320	16

Sample No.	Tree species	Stand age	Average d.b.h(cm)	Average tree height			Stand volume (m^3/ha)	Basal area (m^2/ha)	Form class (ratio to number of trees, %)			Average crown radius (m)	Number of planted trees	Number of living trees	Dead trees (ratio to number of planted trees)%
			cm	Stand (m)	Upper trees (m)	Dominant trees(m)			I	II	III				
Ka - 1	Kauvula	3	4.92	5.2	5.8	7.5	10.4	0.58	0	27	73	1.4	380	300	21
2		3	4.22	4.0	4.3	6.0	11.1	0.47	53	41	6	0.9	440	340	23
3		4	7.05	7.2	7.2	9.0	15.2	1.41	50	17	33	1.7	420	360	14
4		4	6.08	5.0	5.5	7.8	11.8	0.94	31	31	38	1.2	460	320	30
5		3	2.76	3.0	4.0	5.0	6.7	0.14	18	27	55	0.6	360	220	39
6		3	4.65	5.4	5.7	7.0	12.2	0.62	39	17	44	1.3	420	360	14
7		3	2.99	3.8	4.2	6.0	14.3	0.33	57	35	8	0.7	500	460	8
8		3	4.22	4.6	5.0	6.0	11.1	0.48	65	35	0	1.1	460	340	26
9		3	3.74	4.7	4.8	6.5	10.9	0.36	35	41	24	1.0	420	340	19
10		3	5.64	5.7	5.7	8.0	15.2	1.04	48	29	23	1.5	460	420	9
11		4	5.53	5.8	6.2	7.5	12.3	0.83	59	29	12	1.1	360	340	6
12		6	6.58	6.3	6.3	8.0	9.5	0.81	17	66	17	1.8	420	240	43
13		6	1.95	2.3	2.3	2.5	1.8	0.02	0	100	0	0.2	420	60	86
14		6	6.18	6.8	6.8	10.0	11.0	0.85	14	50	36	1.7	400	280	30
15		5	8.88	7.1	7.8	9.0	17.6	2.22	6	88	6	1.8	480	360	25
16		6	11.23	9.4	9.4	10.5	22.9	3.37	12	82	6	2.2	360	340	6
17		6	10.80	9.0	9.3	10.0	2.1	2.93	0	100	0	2.1	400	320	20
18		6	12.31	10.6	10.8	12.0	31.0	4.53	0	79	21	2.1	420	380	10
19		6	10.14	7.9	8.2	10.0	16.2	2.26	0	64	36	2.0	400	280	30
20		5	10.16	7.3	7.4	9.0	19.0	2.84	37	49	14	2.1	440	350	20
21		5	7.31	5.7	5.7	7.3	11.0	1.13	41	50	9	1.7	370	270	27
22		4	3.74	2.7	3.6	5.8	5.6	0.22	35	40	25	0.6	360	200	44
23		4	4.31	3.9	4.6	5.8	3.6	0.16	27	46	27	1.2	410	110	73
24		3	3.19	3.2	3.2	4.3	11.4	0.30	11	50	39	0.8	410	380	7
25		3	3.74	3.9	4.4	5.8	10.9	0.37	74	17	9	0.8	390	350	10

Sample No.	Tree species	Stand age	Average d.b.h(cm)	Average tree height: Stand (m)	Average tree height: Upper trees (m)	Average tree height: Dominant trees(m)	Stand volume (m^3/ha)	Basal area (m^2/ha)	Form class (ratio to number of trees, %): I	Form class: II	Form class: III	Average crown radius (m)	Number of planted trees	Number of living trees	Dead trees (ratio to number of planted trees) %
Ma - 1	Mahogany	4	2.26	2.7	3.7	4.0	12.4	0.09	25	25	50	0.5	300	240	20
2		4	2.76	3.2	3.9	5.0	22.4	0.27	24	33	43	0.4	480	420	13
3		3	3.91	4.3	4.6	6.0	21.8	0.45	63	21	16	0.5	440	380	14
4		7	16.08	15.5	17.5	20.0	80.0	6.08	67	13	20	1.6	340	300	12
5		7	13.91	16.0	16.9	20.5	67.0	4.85	88	6	6	1.0	420	320	24
6		4	1.60	2.7	2.9	5.0	16.0	0.07	63	6	31	0.5	380	320	16
7		6	15.47	12.0	12.0	12.5	11.4	1.13	100	0	0	1.1	300	60	80
8		6	12.15	12.1	12.1	14.0	38.8	3.26	71	29	0	1.8	320	280	13
9		6	9.51	11.4	11.4	14.5	24.6	1.71	42	58	0	1.2	300	240	20
10		6	10.88	11.7	12.3	16.0	31.6	2.22	50	50	0	1.2	260	240	8
11		6	11.56	12.1	12.6	14.0	29.0	2.30	73	27	0	1.1	280	220	21
12		6	8.21	9.9	10.4	12.0	15.6	0.96	56	44	0	1.2	300	180	40
13		6	8.14	9.0	9.0	11.5	12.0	0.72	71	29	0	0.9	360	140	61
14		6	12.41	11.5	12.0	15.0	43.6	3.62	20	53	27	1.5	340	300	12
15		6	10.82	11.7	12.2	15.0	35.8	2.58	43	50	7	1.2	360	280	22
16		6	12.21	13.4	13.4	14.5	41.4	3.26	0	86	14	1.7	380	280	26
17		6	12.92	14.3	14.3	18.0	53.8	4.18	50	44	6	1.7	440	320	27
18		4	10.12	10.4	10.4	12.0	35.0	2.74	47	53	0	1.2	380	340	11
19		6	12.40	10.1	11.0	13.3	28.7	2.66	72	23	5	1.8	300	220	27
20		5	8.88	9.0	9.0	9.3	4.3	0.31	100	0	0	0.5	260	50	81
21		5	8.67	9.5	10.8	13.5	29.4	1.89	63	31	6	0.7	400	320	20
22		6	10.89	10.5	11.3	13.3	27.7	2.24	50	46	4	1.9	350	240	31
23		4	6.58	7.4	8.5	10.3	27.9	0.94	75	21	4	0.6	400	280	30
24		4	8.44	8.6	9.4	12.0	28.1	1.85	85	9	6	1.1	410	330	20
25		3	2.52	2.6	3.1	4.8	11.2	0.13	54	19	27	0.5	330	260	21
26		3	1.95	2.7	3.1	4.0	11.7	0.09	49	34	17	0.5	340	290	15

3.2 Making the table of criteria for judgement of forest productivity

3.2.1 Selection of the outsiders

As an outsider (index) for judgement of forest productivity (capacity of the land to make trees grow), one could conceivably use such factors as tree height, volume or price, at the standard stand age. But generally, the average tree height is used. In other words, forest productivity is determined by the height trees attain when they reach a certain age after planting.

Here, the stand age at which trees reach their cutting period is most desirable as the stand age to be used as the criterion of judgement In the case of a Japanese cedar plantation (Cryptomeria japonica D. DON) in Japan, for example, 40 years is the standard. But planted trees in Nukurua district are still very young and, with the exception of Mahogany, they are mostly less than seven years old. Besides, planted trees that are only one or two years old are too small and are strongly effected by the skill of planting and the oppression of undergrowth Thus they are undesirable as data. So, here the average tree height at the stand age of five years was used as the outsider and sample plots were extracted from among existing plantations of three to seven year olds (maximum. 10 years).

As the average tree height, there are the following three conceivable types.

(1) Stand (all trees) average height

(2) Upper trees average height

(3) Dominant trees average height

So, we decided to study all three types and express the forest productivity by the average tree height considered to be most suitable. "Dominant trees" mean 40 trees per ha selected in the order of tree height.

Since sample plots were distributed in the catagory of three to 10 year olds, the height/age graph and site class index prepared by the Government of Fiji were used to correct their average tree height to the average tree height at the stand age of five years. An example of this is shown in Fig. 3-2, a graph concerning cadamba. If, the stand age of a sample plot is, say, seven years and the average tree height is 18.0 m, it can be determined from this chart that the average tree height for that stand at the stand age of five years is 13.2 m.

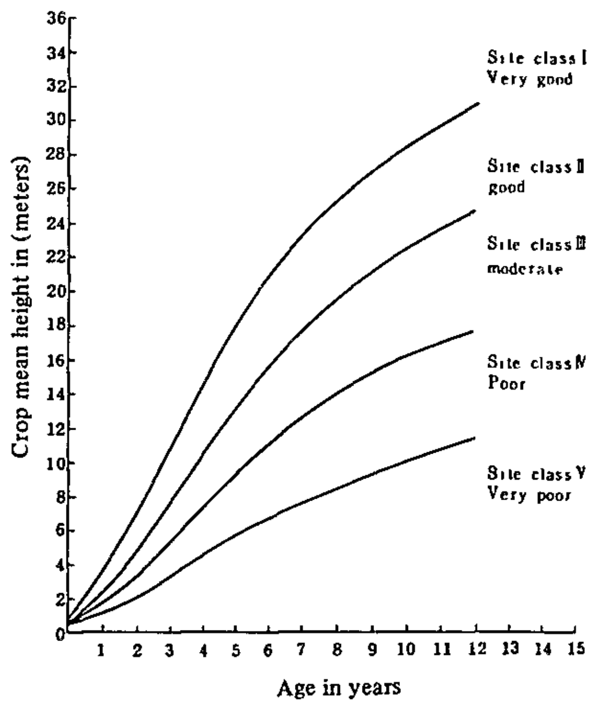


Fig. 3-2 Height/age graph and site class index (Cadamba)

3.2.2 Selection of site factors

There are indeed many factors affecting the growth of forest trees. Generally, the quality of nursery stock and correct planting and tending techniques are mentioned besides site conditions, meteorology, etc. However, from what our recent survey covered, there are no great changes due to macroscopic meteorological conditions. Also, the quality of nursery stock and correct planting and tending do affect the results at plantations but these are artificial factors, and not natural factors appropriate to forests.

Therefore, four factors likely to affect local site conditions: soil, micro-topography, inclination and direction were employed here as site factors.

The categories of each of these factors were decided as follows:

Soil	(1) Humic latosols A type	
	(2) Humic latosols B type	
	(3) Humic latosols C type	
	(4) Humic latosols D type, Gleyed soils	
Micro-topography	(1) Ridge	
	(2) Middle-slope	
	(3) Valley	
Inclination	(1) Flat	0 ~ 5°
	(2) Gentle	6° ~ 10°
	(3) Medium	11° ~ 20°
	(4) Steep	21° or more
Direction	(1) N	
	(2) S	
	(3) E	
	(4) W	

3.2.3. Multivariate analysis

(i) Preliminary calculation

In calculating for multivariate analysis, it is desirable to use factors that are not correlated. So, we first investigated internal correlations between factors and, as the result, obtained a high correlation coefficient of more than 0.8 between soil types and micro-topography. Our study of this correlation disclosed that soils in Nukurua district consist mostly of humic latosols. Since their sub classification is divided into four types by the morphological characteristics of soil profiles deriving mainly from micro-topography, soil types and micro-topography are closely related to each other. So, we decided to leave out micro-topography as a factor.

Then, we did preliminary calculations for multivariate analysis, using all the 140 sample plots and using the average tree heights (in terms of values at the standard stand age of five years) of stand trees, upper trees and dominant trees separately by tree species as outsiders. (For the details of calculation results, see the appended computer output table.)

Multiple correlation coefficients by outsiders and tree species are shown in Table 3-5 and the changes of scores between categories by outsiders, tree species and factors are shown in Figs. 3-3~5.

Table 3-5 Table of multiple correlation coefficients by outsiders and tree species (preliminary calculation)

Tree species / Outsider	Cadamba	Deglupta	Cordia	Kauvula	Mehogany
Stand average height	0.75	0.59	0.27	0.59	0.47
Upper trees average height	0.69	0.59	0.33	0.58	0.51
Dominant trees average height	0.70	0.51	0.35	0.60	0.52

It can be seen from the above table and figures that there are no great differences by tree species in the multiple correlation coefficients concerning the three average tree heights. This means that the results of survey on forest productivity are about the same regardless of which average tree height is used as the outsider. The stand covered by the recent survey consisted mainly of three to seven year old trees which take a long time to attain their cutting time. So, in the end we decided, in final calculation, to use the stand average height of stand as the outsider for the forest productivity survey.

ii) Final calculations

We studied sample plots where the difference between measured and estimated values had been great in preliminary calculations and, after discarding unsatisfactory data, correcting categories and checking with interpretations, we did the final calculations of the stand average height.

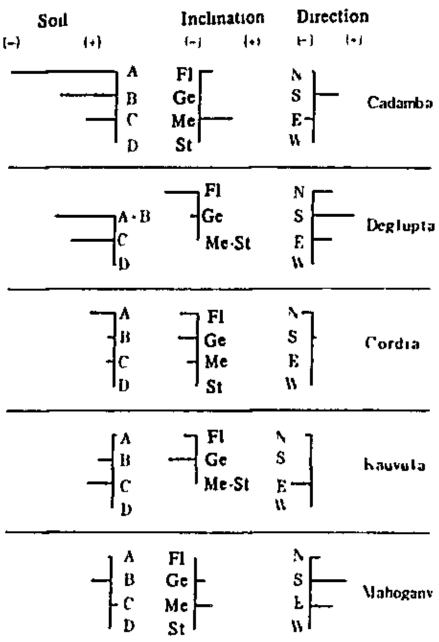


Fig. 3-3 Score changes between categories by tree species and factors (Stand average height)

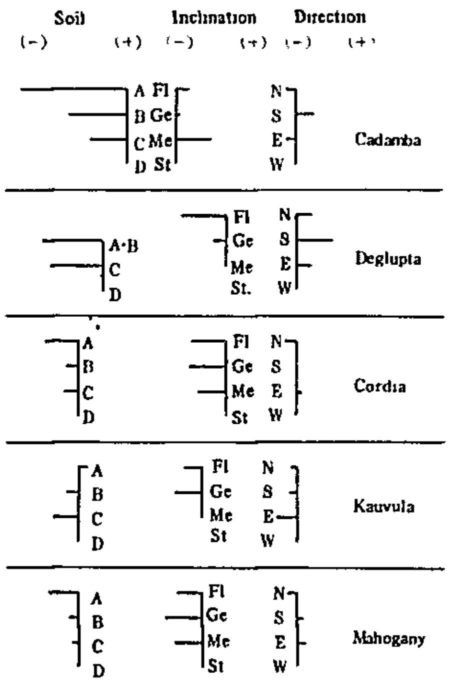


Fig. 3-4 Score changes between categories by tree species and factors (Upper trees average height)

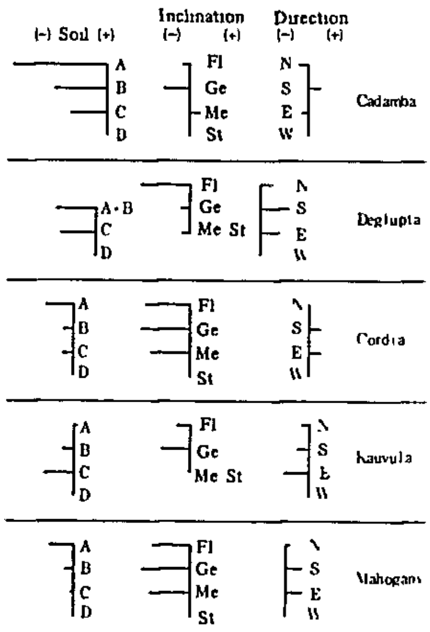


Fig. 3-5 Score changes between categories by tree species and factors
(Dominant trees average height)

Data that were discarded concerned the following four plots.

Cadamba	1 plot (Sample No. Ca-9)
Cordia	2 plots (Sample Nos. Co-7 and 8)
Kauvula	1 plot (Sample No Ka-13)

and the discarding was mainly due to oppression caused by inadequate tending.
Further, categories of inclination were corrected from the results of preliminary calculation as follows:

Slope (1) Flat (u) ~ 5° (upper part of slope)
(2) Flat (1) ~ 5° (lower part of slope)
(3) Gentle 6°~ 10°
(4) Medium and steep 11° ~

Table 3-6 Table of factors and categories (Final calculation)

Factor	Category
Soil	(1) Humic latosols A type (2) " B " (3) " C " (4) { " D " / Gleyed soils
Inclination (included micro-topography)	(1) Flat (upper) ~5° (2) " (lower) ~5° (3) Gentle slope 6° ~ 10° (4) Medium, steep slope 11° ~
Direction	(1) N (2) S (3) E (4) W

Table 3-7 Analysis table on results of final calculations

Species	Yi, Xi	Mean (m)	Sandard deviation	Multiple coefficient correlation	Number of data
Cadamba	Measured value Yi	13.1	3.10	0.80	29
	Estimated value Xi	13.1	2.49		
Deglupta	Measured value Yi	10.1	3.96	0.77	25
	Estimated value Xi	10.1	3.07		
Cordia	Measured value Yi	9.7	2.53	0.67	32
	Estimated value Xi	9.7	1.70		
Kauvula	Measured value Yi	6.7	1.46	0.87	24
	Estimated value Xi	6.7	1.27		
Mahogany	Measured value Yi	8.7	2.56	0.70	26
	Estimated value Xi	8.7	1.78		

Factors used in the final calculations and the categories of those factors are shown in Table 3-6.

The analytical table of the results of calculation is as shown in Table 3-7. By this table, the multiple correlation coefficient is 0.67 ~ 0.87, which is fairly satisfactory. Measured and estimated values for each tree species are compared in Tables 3-8 ~ 12 and Fig. 3-7 ~ 11.

Score changes between categories by tree species and factors are shown in Fig. 3-6. They are described below by factors.

Soil Types: The tendency of forest productivity being high in the order of A < B < C < D is expected from forest productivity All tree species except kauvula have this tendency. The tendency is particularly clear with Cadamba and Deglupta which grow fast.

Inclination: The tendency of flatland (upper), gentle slope < flatland (lower), medium and steep slopes is expected from forest productivity. This is because in the same flatland, residual soil abounds in the upper part of a slope and colluvial soil abounds in the lower part of a slope and this may effect on productivity. This tendency was observed with all tree species.

Direction: All tree species showed high productivity in the S direction. This tendency must be studied looking at the microclimate in the S direction and the soil characteristics.

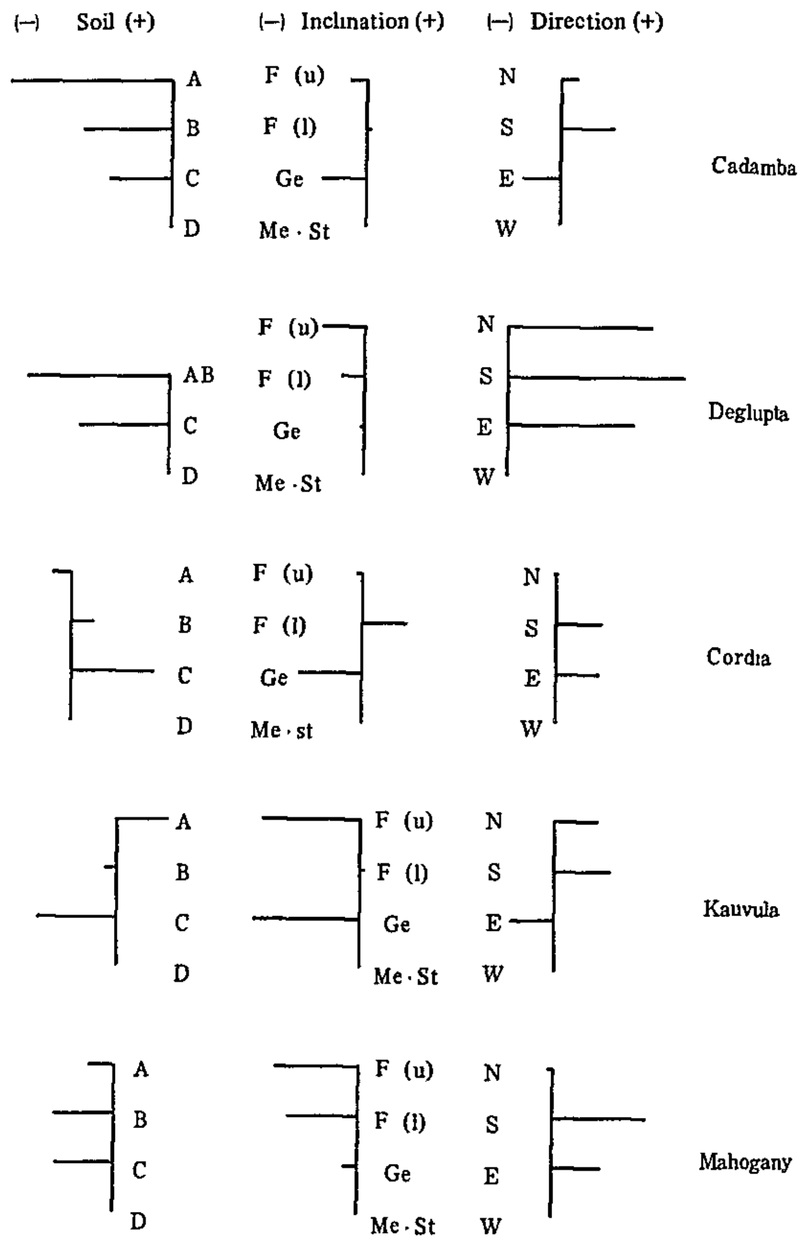
3.2.4 Preparation of table of criteria for judgement of forest productivity

Scores calculated by multivariate analysis directly serve as a table of criteria for judgement of forest productivity (Table 3-13).

This table of criteria is used to estimate the average tree height by deriving the score value of the pertinent category for each site factor according to the site conditions of the place whose productivity is to be judged and totaling these score values. If, for example, the site conditions of a preplantation are soil type A, inclination: gentle and direction: west, the estimated average tree heights five years after planting Cadamba, Deglupta, Cordia, Kauvula and Mahogany will be: for

Category	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
Soil 1	−6.95 m	−6.23 m	−0.94 m	2.09 m	−1.15 m
Inclination 3	−1.56	−0.06	−2.00	−4.35	−0.40
Direction 4	16.42	10.15	7.43	8.36	10.02
Estimated average tree height Σ	7.91	3.86	4.49	6.10	8.47

Fib. 3-2 Score change between categories by tree species and factors
(Final calculations)



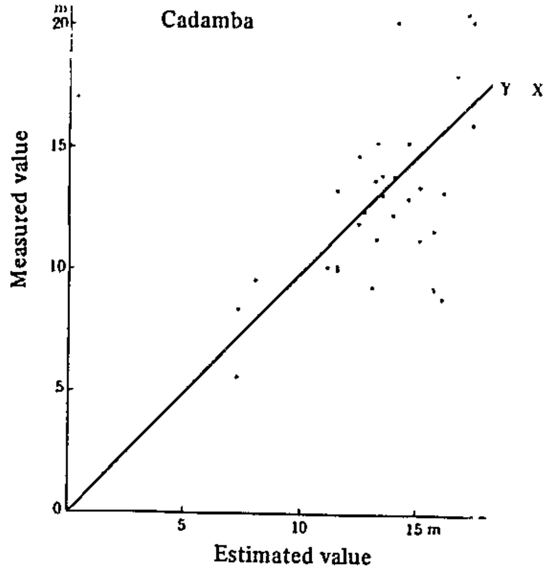


Fig. 3-7 Comparison of measured and estimated values (Average tree height)

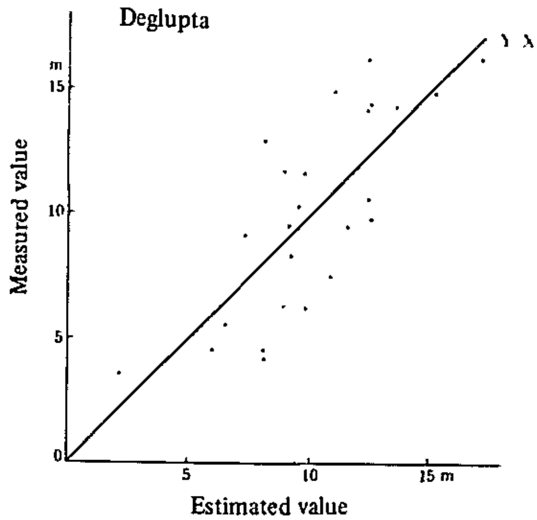


Fig. 3-8 Comparison of measured and estimated values (Average tree height)

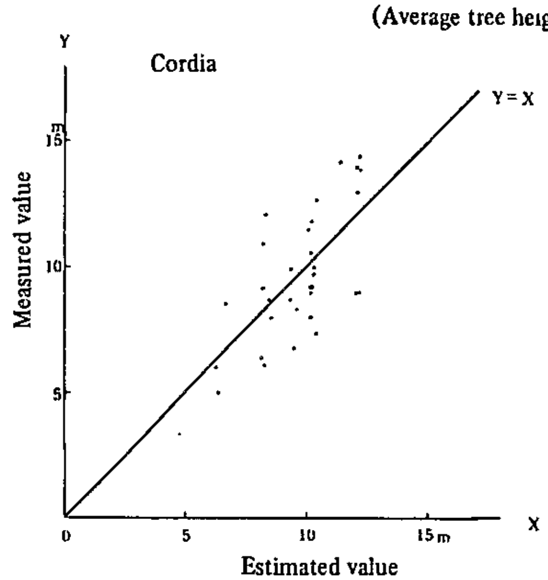


Fig. 3-9 Comparison of measured and estimated values (Average tree height)

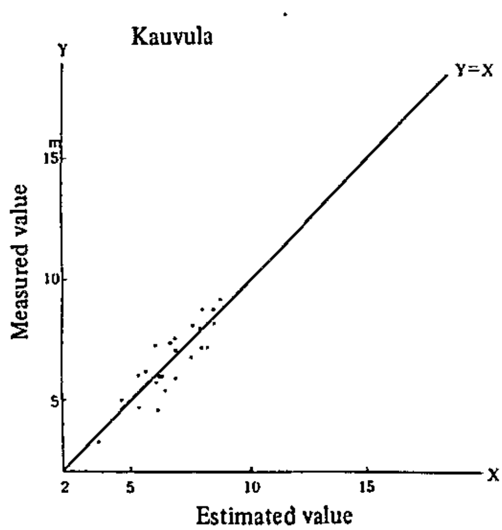


Fig. 3-10 Comparison of measured and estimated values (Average tree height)

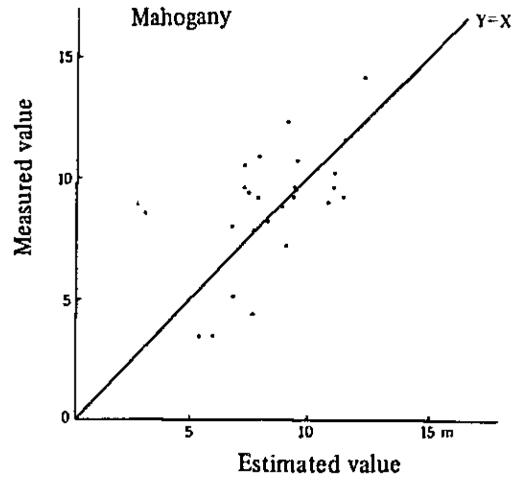


Fig. 3-11 Comparison of measured and estimated values (Average tree height)

Table 3-8 Comparison of measured and estimated values (Average tree height)

Cadamba

Sample No.	Estimated value (X)	Measured value (Y)	Difference (X−Y)
Ca−1	17.160761 m	20.4 m	−3.239239 m
2	12.418151	148	−2.381849
3	13359089	14	−0.640911
4	11.536318	13.4	−1.863682
5	8.035265	9.6	−1.564735
6	13.851595	12.4	1.451595
7	12.983953	9.4	3.583953
8	13179703	15.4	−2.220297
10	17.160761	16.2	0.960761
11	11.536318	10.1	1.436318
12	7.32789	5.6	1.72789
13	12.669412	12.5	0.169412
14	11112093	102	0.912093
15	11.536318	10.2	1.336318
16	13179703	11.4	1.779703
17	13.851595	14	−0148405
18	15969754	13.4	2.569754
19	15.552892	16.8	−1.247108
20	13429771	13.2	0.229771
21	14.987091	11.4	3.587091
22	1314422	13.8	−0.65578
23	14.541272	13.1	1.441272
24	7.32789	8.4	−1.07211
25	12.418151	12	0.418151
26	16471084	18.2	−1.728916
27	14.541272	15.4	−0.858728
28	14.361885	17.4	−3038115
29	15.03764	13.6	1.43764
30	12.418151	14.8	−2.381849

Table 3-9 Comparison of measured and estimated values (Average tree height)

Deglupta

Sample No.	Estimated value (X)	Measured value (Y)	Difference (X-Y)
De -1	2.206278 m	3.6 m	-1.393722 m
2	8.081724	4.6	3.481724
3	8.081724	4.2	3 881724
4	12.47696	9.9	2.57696
5	9.144263	9.6	-0.455737
6	6.537985	5.6	0.937985
7	11.632336	9.6	2.032336
8	7.300628	9.2	-1.899372
9	12.47696	14.5	-2.02304
10	12.413431	10 7	1.713431
11	8.945317	11.8	-2.854683
12	9.726412	11.7	-1 973588
13	9.789941	6.3	3.489941
14	10 892611	7 6	3.292611
15	5.955836	4.6	1.355836
16	12.413431	14.3	-1.886569
17	17.123696	16.4	0 723696
18	15 176402	15	0 176402
19	8.081724	13	-4.918276
20	13.57963	14.4	-0 82037
21	12.413431	16.3	-3 886569
22	10 95614	15	-4.04386
23	9.247923	8.4	0.847923
24	8.945317	6 4	2 545317
25	9.499902	10.4	-0 900098

Table 3-10 Comparison of measured and estimated values (Average tree height)

Cordia

Sample No	Estimated value (X)	Measured value (Y)	Difference (X-Y)
Co -1	9.416133 m	10 m	-0.583867 m
2	10.370769	12.7	-2.329231
3	6.409072	5	1.409072
4	6.332327	6	0.332327
5	12.131988	14	-1.868012
6	10 295884	10	0.295884
9	8 225818	9.2	-0 974182
10	12.181499	9	3.181499
11	10.213082	9.2	1.013082
12	11.376674	14.2	-2 823326
13	9.416133	8.7	0.716133
14	8.61141	8	0.61141
15	10 370769	7.4	2.970769
16	8.327467	6.1	2.227467
17	6.725795	8.5	-1.774205
18	8.453723	8.7	-0.246277
19	10.186359	11.8	-1.613641
20	12.181499	14.4	-2.218501
21	8.327467	12.1	-3.772533
22	10 220958	10.6	-0.379042
23	12.131988	9	3.131988
24	10.136847	11.5	-1.363153
25	12.181499	13.9	-1.718501
26	12.131988	13	-0.868012
27	10.220958	9	1.220958
28	10 321257	9.8	0.521257
29	10.186359	8	2.186359
30	8 168431	6.4	1.768431
31	10.186359	9.2	0.986359
32	9.491059	6.8	2.691059
33	7.4	7.4	2.129408E-13
34	8 168431	10.9	-2.731569

Table 3-11 Comparison of measured and estimated values (Average tree height)

Kauvula

Sample No	Estimated value (X)	Measured value (Y)	Difference (X-Y)
Ka -1	7.836852 m	8 m	-0.163148 m
2	5.61045	6.2	-0 58955
3	7.909528	8.8	-0.890472
4	5.295418	6	-0 704582
5	6.13028	4 6	1 53028
6	8.409306	8.2	0.209306
7	6.181389	6	0.181389
8	7.909528	7.2	0.709528
9	6 57895	7.4	-0.82105
10	8.409306	8.8	-0.390694
11	8 151883	7.2	0 951883
12	5.95377	7.3	-1.34623
14	5 95377	5.7	0.25377
15	6.402439	5 4	1.002439
16	6.836659	5.9	0.936659
17	6.836659	7 1	-0 263341
18	7.495011	8.1	-0.604989
19	6 836659	7 6	-0.763341
20	8.671714	9 2	-0 528286
21	7.495011	6 8	0 695011
22	3.56045	3.3	0.26045
23	5.295418	4.7	0 595418
24	4.637667	5	-0 362333
25	6.101883	6	0.101883

Table 3-12 Comparison of measured and estimated values (Average tree height)

Mahogany

Sample No.	Estimated value (X)	Measured value (Y)	Difference (X-Y)
Ma-1	5.959656 m	3.5 m	2.459656 m
2	7.719416	4.4	3.319416
3	8 859618	8.8	0.59618
4	7.261167	10.5	-3.238833
5	9.510285	10.7	-1.189715
6	5.351511	3 5	1.851511
7	6.848837	8	-1.151163
8	10.79438	9	1.79438
9	9.510285	9 5	0.010285
10	9.4	9.6	-0.2
11	10 986797	9.6	1.386797
12	11.445046	9 2	2.245046
13	9.4	9.2	0.2
14	7.251002	9.6	-2.348998
15	7.719416	7.8	-0.80584
16	9 052036	7.2	1.852036
17	7.894417	9.2	-1.305583
18	7.499503	9.4	-1.900497
19	7.894417	10.9	-3.005583
20	11.445046	11.5	-0.54954
21	12.197016	14.1	-1.902984
22	8.251473	8.2	0.051473
23	11.042881	10.2	0.842881
24	9.10812	12.3	-3.19188
25	6.848837	5.1	1.748837
26	6.848837	5.1	1.748837

Table 3-13 Table of Criteria for Judgement of Forest Productivity

Factor	Category	No	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
Soil Type	A type	1	-6 95^{m}	-6. 23^{m}	-0. 94^{m}	2 09^{m}	-1. 15^{m}
	B type	2	-3 75		0 82	-0 45	-2. 55
	C type	3	-2 57	-3 54	2 79	-3 26	-2 30
	D type · Gleyed soils	4	0. 00	0 00	0 00	0 00	0. 00
Inclination	0～5° F (u)	1	-0 71	-1. 71	0 16	-4. 03	-3. 30
	″ F (ℓ)	2	0 05	-0 65	1 98	0 05	-2 76
	6°～10°, Ge	3	-1 56	-0 06	-2 00	-4. 35	-0 40
	11°～Me·St	4	0 00	0 00	0 00	0 00	0 00
Direction	N	1	17. 11	16 02	7. 51	10 09	9 80
	S	2	18 49	17 19	9. 35	10 75	13. 75
	E	3	14 99	15. 24	9 40	6 58	11. 81
	W	4	16 42	10. 15	7. 43	8. 36	10 02

Table 3-14 Table of calculated values of forest productivity by tree species and by combination of categories

Soil	Inclination	Direction	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1	1	1	9 45m	8 08m	6. 73m	8 15m	5 35m
1	1	2	10 83	9. 25	8 57	8 81	9 30
1	1	3	7 33	7. 30	8 62	4. 64	7. 36
1	1	4	8 76	2 21	6. 65	6 42	5 57
1	2	1	10 21	9. 14	8 55	12. 23	5 89
1	2	2	11. 59	10 31	10. 39	12 89	9. 84
1	2	3	8 09	8 36	10 44	8 72	7. 90
1	2	4	9 52	3 27	8. 47	10. 50	6. 11
1	3	1	8 60	9. 73	4 57	7. 83	8 25
1	3	2	9. 98	10. 90	6. 41	8 49	12 20
1	3	3	6. 48	8 95	6. 46	4. 32	10. 26
1	3	4	7. 91	3 86	4 49	6 10	8 47
1	4	1	10 16	9 79	6 57	12. 18	8. 65
1	4	2	11 54	10 96	8 41	12. 84	12. 60
1	4	3	8 04	9 01	8. 46	8 67	10 66
1	4	4	9. 47	3 92	6 49	10 45	8 87
2	1	1	12. 65	8. 08	8 49	5. 61	3 95
2	1	2	14 03	9 25	10 33	6. 27	7. 90
2	1	3	10 53	7. 30	10 38	2. 10	5. 96
2	1	4	11. 96	2. 21	8 41	3. 88	4 17
2	2	1	13 41	9. 14	10 31	9. 69	4. 49
2	2	2	14. 79	10. 31	12 15	10 35	8 44
2	2	3	11. 29	8 36	12. 20	6 18	6. 50
2	2	4	12 72	3 27	10 23	7. 96	4 71
2	3	1	11. 80	9 73	6 33	5. 29	6. 85
2	3	2	13 18	10 90	8 17	5 95	10 80
2	3	3	9. 68	8 95	8 22	1. 78	8 86
2	3	4	11 11	3 86	6. 25	3. 56	7. 07
2	4	1	13. 36	9 79	8 33	9. 64	7. 25
2	4	2	14 74	10 96	10. 17	10 30	11. 20
2	4	3	11. 24	9 01	10. 22	6. 13	9. 26
2	4	4	12 67	3. 92	8. 25	7 91	7. 47
3	1	1	13 83	10 77	10. 46	2 80	4 20
3	1	2	15 21	11 94	12 30	3 46	8 15
3	1	3	11. 71	9 99	12. 35	0 71	6. 21
3	1	4	13 14	4. 90	10 38	1. 07	4. 42
3	2	1	14. 59	11 83	12. 28	6. 88	4 74
3	2	2	15 97	13 00	14 12	7. 54	8 69
3	2	3	12. 47	11 05	14 17	3 37	6. 75
3	2	4	13 90	5. 96	12. 20	5 15	4 96
3	3	1	12 98	12 42	8 30	2. 48	7. 10
3	3	2	14 36	13 59	10 14	3 14	11. 05
3	3	3	10. 86	11. 64	10 19	1 03	9 11
3	3	4	12 29	6. 55	8. 22	0 75	7. 32
3	4	1	14 54	12. 48	10 30	6 83	7. 50
3	4	2	15 92	13 65	12 14	7. 49	11 45
3	4	3	12 42	11. 70	12 19	3. 32	9. 51
3	4	4	13. 85	6 61	10 22	5. 10	7. 72
4	1	1	16 40	14 31	7. 67	6 06	6. 50
4	1	2	17. 78	15 48	9. 51	6. 72	10 45
4	1	3	14 28	13 53	9 56	2 55	8. 51
4	1	4	15 71	8 44	7 59	4. 33	6 72
4	2	1	17 16	15. 37	9 49	10. 14	7. 04
4	2	2	18 54	16 54	11. 33	10. 80	10. 99
4	2	3	15. 04	14. 59	11 38	6. 63	9 05
4	2	4	16 47	9. 50	9 41	8. 41	7 26
4	3	1	15 55	15 96	5 51	5. 74	9. 40
4	3	2	16. 93	17. 13	7. 35	6 40	13 35
4	3	3	13 43	15. 18	7. 40	2. 23	11 41
4	3	4	14 86	10. 09	5 43	4. 01	9. 62
4	4	1	17 11	16 02	7. 51	10 09	9. 80
4	4	2	18 49	17 19	9. 35	10. 75	13 75
4	4	3	14. 99	15. 24	9 40	6. 58	11. 81
4	4	4	16. 42	10. 15	7. 43	8. 36	10. 02

Thus, planting Mahogany there is best from the viewpoint of growth in terms of tree height. Cadamba ranks second in this regard.

For actual us of the table of criteria for judgement of forest productivity, a table listing the estimated average height by tree species by all combinations was prepared to save the trouble of doing the above adding for each plot. See Table 3-14: Table of Calculated Values of Forest Productivity by Tree Species and by Combination of Categories.

3.3 Making of forestry productivity map

A map showing the distribution of average tree heights five years after planting of each species to be planted in the preplantation was made, using the table of criteria for judgement of forest productivity, as calculated in the preceding section and the table of calculated values of forest productivity by combinations of categories

3.3.1 Survey on site conditions in preplantation

Making a forest productivity map, it is necessary to survey, first of all, those site conditions used in the table of criteria for judgement of forest productivity: soil, inclination and direction. So, we made a topographic analysis map based on the soil map (already described in section 2) and combining inclination and direction with it (Fig 3-12).

3.3.2 Making the forest productivity map

A forest productivity map for each tree species was made by reading the site conditions of each plot from the topographic analysis map and using the table of criteria for judgement of forest productivity. The forest productivity map for cadamba is shown in Fig. 3-13 as an example.

Table 3-15 shows by tree species the area for each estimated tree height at the age of 5 years in this preplantation in accordance with the forest distribution map that was made.

The area comprising the highest trees is larger with Cadamba than with any other species since it attains 19 m in valley. It is mostly distributed at about 13 m. It is 6 ~ 9 m tall at ridge tops with type A soil.

Deglupta widely varies in height from 2 to 17 m, depending on where it's planted. It is mostly distributed at 9 ~ 10 m. Its growth in soils type A and type B is unsatisfactory as it attains only about 4 m there.

The distribution of cordia is concentrated at 4 ~ 12 m and it is mostly distributed at about 8 m.

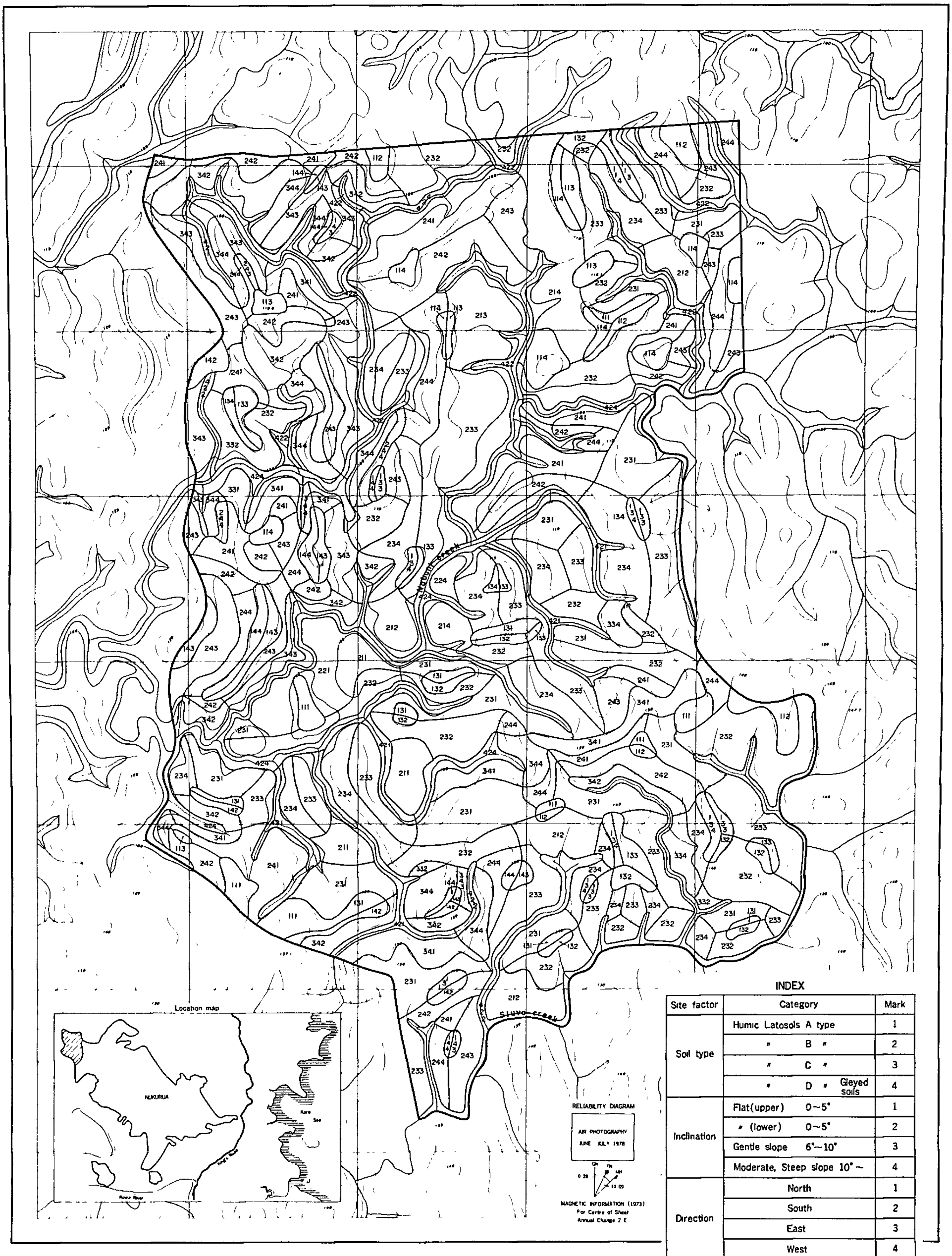
Kauvula grows most slowly and is mostly distributed at 5 ~ 6 m. In extreme instances, it attains only 1 m.

Mahogany is mostly distributed at 7 ~ 11 m and averages about 9 m in productivity.

Table 3-15 Area by tree species and estimated tree height on Nukurua district

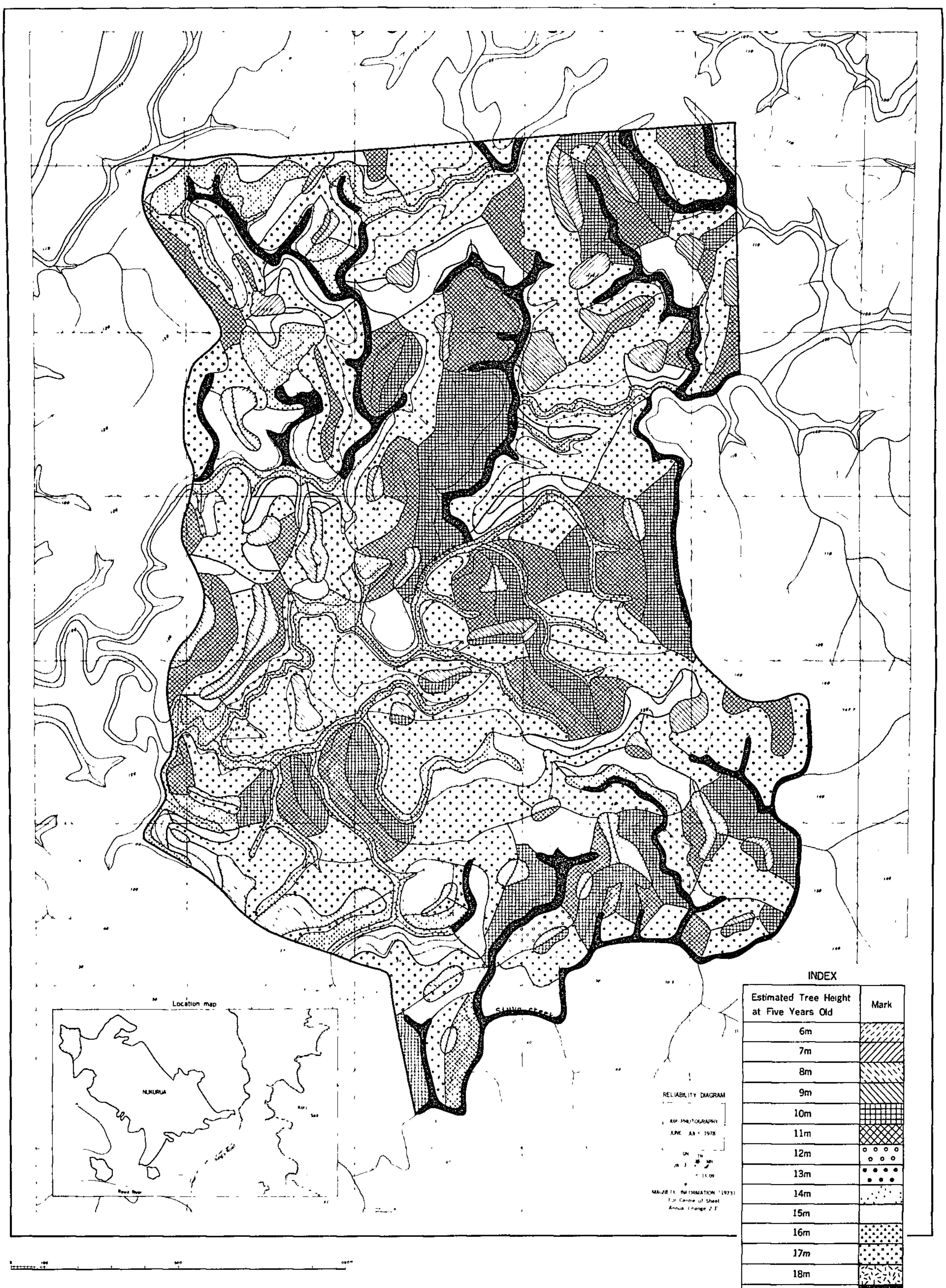
Estimated tree height at 5 years old	Area occupied (ha.)				
	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 m				2.31	
2		16.56		50.46	
3		0.94		19.26	
4		52.88	2.63	41.44	19.81
5			3.19	51.99	6.44
6	4.13		73.94	86.06	12.44
7	3.38	23.87	12.81	28.20	140.59
8	6.01	11.31	153.58	49.01	39.52
9	18.94	89.26	33.77	7.26	69.63
10	47.56	80.13	87.88	62.95	19.66
11	55.57	68.13	23.81	23.81	111.41
12	64.90	26.89	33.39		3.25
13	97.77			2.25	2.25
14	27.09	21.59			
15	31.47	9.63			
16	34.74				
17	9.63	23.81			
18					
19	23.81				
Total	425.00	425.00	425.00	425.00	425.00

Fig. 3-12 **TOPOGRAPHIC ANALYSIS MAP**



INDEX

Site factor	Category	Mark
Soil type	Humic Latosols A type	1
	〃 B 〃	2
	〃 C 〃	3
	〃 D 〃 Gleyed soils	4
Inclination	Flat(upper) 0～5°	1
	〃 (lower) 0～5°	2
	Gentle slope 6°～10°	3
	Moderate, Steep slope 10°～	4
Direction	North	1
	South	2
	East	3
	West	4
Sample 134	Soil－－A, Incl－－Gentle, Dre－－West	


INDEX
Estimated Tree Height at Five Years Old
Mark
6m
7m
8m
9m
10m
11m
12m
13m
14m
15m
16m
17m
18m
19m
Location map
NUKURUA
RELIABILITY DIAGRAM

3.4 Making the species/site potential map

A species/site potential map was prepared by overlaying the forest productivity maps made separately by tree species and as stated in the preceding section. In other words, the tree species with the fastest growth in each plot was indicated as the most suitable (indicated as No 1).

It can be seen from the forest production maps that Cadamba is best in most plots and that it is the best tree as far as the elongation of tree height is concerned.

Cadamba grows fast but it seems to have only limited applications because it is too soft. It also resembles Deglupta in some properties Kauvula, an indigenous Fijian species, is of superior quality and has many uses. It is now being selectively cut in natural forest. Cordia is also qualitatively superior.

The afforestative properties of the indigenous species, kauvula, and the exotic species, Cadamba, Deglupta and Cordia, are largely unknown and, particularly, exotic species must be given great attention. Mahogany trees planted in Nukurua district comes from tropical America. It was first planted in 1961 and, in 1970, the approximately 10th year, it was heavily damaged by the Ambrosia beetle. In these circumstances, there is no assurance that the plantations of exotic species, which are for the most part, less than 10 years old, will be healthy in the future.

Large-area afforestation by a single species is, therefore, vulnerable to various kinds of damage and it is desirable to mix different species insofar as this is possible. From the viewpoint of growth in terms of tree height, Cadamba is the suitable tree for the various soil environments but from the viewpoint of wood utilization and other aspects, it will be necessary to flexibly consider not only Cadamba but also species near Cadamba in growing capacity as suitable trees.

So, we also mentioned the species with the second fastest growth in terms of height elongation in each plot as the next best tree (No. 2), thus leaving room for its selection in practical afforestation (Fig. 3-14)

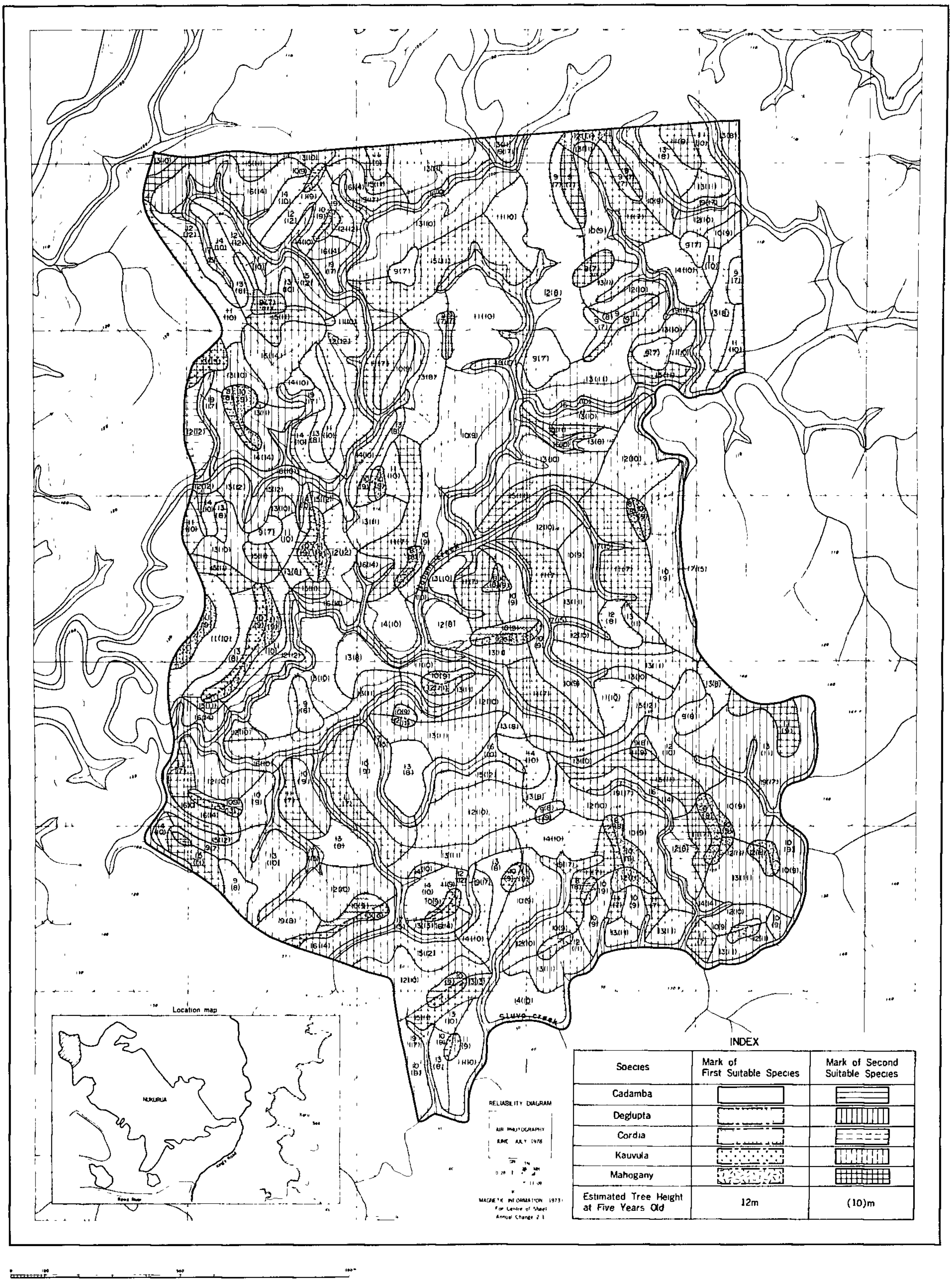
Table 3-16 shows the area separately by each species of suitable trees No. 1 and No. 2.

Table 3-16 Area by suitable tree on preplantation in Nukurua district

Tree species	Suitable tree No.1		Suitable tree No.2	
Cadamba	399.85 ha	94 1 %	8 76 ha	2. 1 %
Deglupta	3 19	0. 8	239.90	56. 4
Cordia	3. 38	0 8	112. 14	26. 4
Kauvula	5 19	1. 2	5. 50	1. 3
Mahogany	13. 39	3. 1	58. 70	13 8
計	425. 00	100 0	425 00	100 0

SPECIES / SITE POTENTIAL MAP

Fig. 3-14 SPECIES/ SITE POTENTIAL MAP



4. RELATED ANALYSES

4.1 Relation between stand age and stand factors

It is interesting in the phenomenon analysis of stands to see how a plantation of hard-woods grows by tree species and by stand factors, such as tree height, stem diameter and volume. This also provides data that are most important to forestry management. Regarding Fijian plantations of hard-woods, their tree height is already expressed as site quality curves, as exemplified by Fig. 3-2, Height/age graph and site class index, However, volume and other stand factors have not yet been consolidated as data. Fortunately, though, a total of nearly 140 data concerning more than 20 tree species were collected under this study and prepared as a computer file. So, growth by factors was estimated, using this information.

The method was to first prepare a regression formula, by tree species, of stand age and average tree height, average stem diameter, basal area, volume and crown radius and then estimate the value for each stand age from this formula. In the regression formula calculation, the following six calculating formulae which are generally used in these calculation were assumed and the regression formula likely to be most suitable was considered in view of the correlation coefficient, the difference between measured and estimated values and other factors.

Formula	1	$\log Y$	$= a + b\,(10/X)$
"	2	$10/Y$	$= a + b\,(10/X) + c\,(10/X)^2$
"	3	$1/\log Y$	$= a + b\,(10/X)$
"	4	$\log Y$	$= a + b \cdot \log X$
"	5	$1/\sqrt{Y}$	$= a + b\,(10/X)$
"	6	$\log Y$	$= a + b \log X + c\,(10/X)$

This method was employed to account for any change taking place during the two years form the time the aerial photographs used in last year's photo interpretation cards had been taken until the time of our field survey. General results were obtained last year from calculating an average number of 9 plots per tree species and 2 ~ 3 plots for the same stand age, but a further increase in the number of samples was desired. Fortunately, we conducted the field sample survey this year similarly to last year's survey. So new samples can be used in our calculation in addition to the samples used last year. The samples used were the same 136 that had been used in the final calculations of the multivariate analysis. But with respect to the stem diameter, basal area and crown radius of Mahogany, samples up to 19 year olds covered by last year's survey were added when calculating.

The regression curves adopted separately by tree species and by stand factors and the estimated values by stand age are shown in Table 4-1~7 and Fig. 4-1~7. In these charts, the estimated values for 3 ~ 7 year olds are reliable because of the large number of samples concerned but it must be remembered that the other values are estimates for cases where there were few or no samples.

(i) Average tree height

Calculations were done for three types of average tree height; stand, upper trees, dominant trees. Ther correlation coefficients are mostly at the 0.8 level, thus showing considerable fit.

Cadamba always maintains satisfactory growth as its five year olds and 10 year olds attained 13.1 m and 22.7 m, respectively, in the stand average height. In the dominant trees average height, five year olds and 10 year olds even attained 16.9 m and 30.4 m, respectively. Deglupta is fairly inferior in initial growth but later rapidly elongates and grows as well as Cadamba. Cordia shows satisfactory initial growth as it grows best after Cadamba until it is about five years old but later seems to grow poorly. Kauvual grows so slowly that its 10 year olds attain only 10.3 m, or less than a half the level of Cadamba, in the stand average height. Mahogany is most inferior in initial growth as its three year olds attain only 2.7 m in the stand average height. But it later grows well and its 10 year olds attain 20.2 m.

(ii) Average stem diameter

The tendency shown in the stem diameter is nearly the same as for the average tree height.

(iii) Basal area

Naturally, the basal area of five year olds is largest (8.23 m^2) with Cadamba. Deglupta, meanwhile, stands out for its small basal area of only 1.52 m^2. This has something to do with the high dead rate of the species. The low value for mahogany seems to be due to the small number of trees planted and the relatively high dead rate of this species.

(iv) Volume

Cadamba far exceeds other species in volume as its 10 year olds attain 388 m^3. By contrast, Deglupta 10 year olds and 16 year olds attain only 103 m^3 and 206 m^3, respectively. This is due to the high dead rate of the species

(v) Crown radius

Cadamba is also first in crown radius and its five year olds attain 3 m. However, its subsequent growth slows down. Meanwhile, Mahogany attains less than 1 m in the 5th year but continues to grow steadily and, in the 20th year, exceeds 4 m.

4.2 Form class

The rates of average number of trees for Form Classes I and III are shown in Figs. 4-8 ~ 9 by tree species and by stand age.

Table 4-1 Regression formulae and estimated values of stand age: stand average height

Estimated value by tree species Unit: (m)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 years	0.4	0.0	0.4	0.7	0.0
2	3.2	1.2	2.8	2.5	0.7
3	6.9	3.7	5.6	4.1	2.7
4	10.2	6.7	8.0	5.5	5.6
5	13.1	9.7	10.0	6.6	8.6
6	15.6	12.5	11.6	7.5	11.5
7	17.7	15.1	12.9	8.3	14.0
8	19.6	17.4	14.0	9.1	16.3
9	21.3	19.6	15.0	9.7	18.4
10	22.7	21.5	15.8	10.3	20.2
11	24.1	23.4	16.5	10.9	21.9
12	25.3	25.0	17.2	11.4	23.3
13	26.4	26.6	17.7	11.9	24.6
14	27.4	28.0	18.3	12.3	25.8
15	28.4	29.4	18.7	12.7	26.9
16	29.3	30.7	19.2	13.1	27.9
17	30.1	31.9	19.6	13.5	28.8
18	30.9	33.0	19.9	13.9	29.6
19	31.6	34.1	20.3	14.2	30.3
20	32.3	35.1	20.6	14.6	31.0

Tree species	Regression formula	r
Cadamba	$\log H = 1.3190 + 0.2131 \log A - 0.1735(10/A)$	0.81
Deglupta	$\log H = 1.3608 + 0.2469 \log A - 0.2744(10/A)$	0.88
Cordia	$\log H = 1.2717 + 0.0975 \log A - 0.1709(10/A)$	0.78
Kauvula	$\log H = 0.7616 + 0.3446 \log A - 0.0931(10/A)$	0.80
Mahogany	$\log H = 1.6768 - 0.3708(10/A)$	0.85

(Note) In heavy line : Range of measurement
Out heavy line : Indicate for reference
H = Stand average height
A = Stand age
r = Correlation coefficient

Table 4-2 Regression formulae and estimated values of stand age: upper trees average height

Estimated value by tree species

Unit (m)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 years	0.4	0 1	0 3	0.9	0.0
2	3 4	1.3	2.9	2.9	0.9
3	7.4	4.2	6.2	4.5	3.2
4	11.0	7.5	9.0	5.8	6.2
5	14.1	10.7	11.2	6.9	9.2
6	16.7	13.7	13.0	7.8	12.0
7	19.0	16.3	14 4	8 6	14.5
8	20 9	18 8	15 5	9.2	16.7
9	22 6	20 9	16 4	9.9	18.6
10	24.1	22.9	17.1	10 4	20.3
11	25.4	24.7	17.8	10.9	21.8
12	26 6	26 3	18.3	11.4	23.2
13	27.7	27.8	18.7	11.8	24.4
14	28 6	29.1	19.1	12.2	25.4
15	29.5	30.4	19.4	12.6	26 4
16	30.4	31.5	19.7	12.9	27.3
17	31.1	32.6	20 0	13.3	28.1
18	31.9	33 7	20.2	13.6	28 8
19	32.5	34 6	20 4	13.9	29.5
20	33.2	35.5	20.6	14.2	30.1

Tree species	Regression formula	r
Cadamba	$\log Hu = 1.4093 + 0.1564 \log A - 0\ 1844(10/A)$	0.84
Deglupta	$\log Hu = 1.4647 + 0\ 1728 \log A - 0.2782(10/A)$	0.87
Cordia	$\log Hu = 1.5295 + 0\ 0861 \log A - 0.2093(10/A)$	0.82
Kauvula	$\log Hu = 0.7959 + 0.3067 \log A - 0.0856(10/A)$	0.82
Mahogany	$\log Hu = 1.6500 - 0.3425(10/A)$	0.86

(Note) In heavy line: Range of measurement Hu = Upper trees average height
Out heavy line : Indicate for reference   A = Stand age
r = Correlation coefficient

Table 4-3 Regression formulae and estimated values of stand age: dominant trees average height

· Estimated value by tree species

Unit. (m)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 years	2 9	0. 2	0 5	2 4	0 0
2	6 9	2. 2	4. 3	4. 5	1. 4
3	10. 5	5. 5	8 7	6. 1	4. 4
4	13. 8	9. 1	12 2	7. 4	7. 9
5	16. 9	12. 6	14. 9	8. 6	11. 2
6	19. 8	15. 9	16. 9	9 6	14. 2
7	22 6	19. 0	18 4	10 6	16. 8
8	25. 3	21. 9	19 6	11. 5	19 1
9	27. 8	24. 6	20. 5	12. 4	21. 0
10	30 4	27. 2	21. 2	13. 2	22. 7
11	32 8	29 6	21. 8	14. 0	24 2
12	35 2	31. 9	22. 3	14. 7	25 6
13	37. 5	34. 0	22 7	15 4	26 7
14	39. 8	36. 1	23 0	16 1	27. 8
15	42. 1	38 1	23 3	16 8	28. 7
16	44. 3	40 0	23. 5	17 5	29 6
17	46. 5	41. 8	23. 7	18 1	30 4
18	48. 6	43 6	23. 8	18 7	31. 1
19	50. 7	45. 3	23 9	19. 3	31. 7
20	52. 8	46. 9	24 0	19. 9	32. 3

Tree species	Regression formula	r
Cadamba	$\log Hd = 0.7621 + 0.7495 \log A - 0.0293(10/A)$	0. 85
Deglupta	$\log Hd = 1.1609 + 0.4669 \log A - 0.1940(10/A)$	0. 88
Cordia	$\log Hd = 1.6820 - 0.1545 \log A - 0.2004(10/A)$	0. 85
Kauvula	$\log Hd = 0.5879 + 0.5539 \log A - 0.0210(10/A)$	0 86
Mahogany	$\log Hd = 1.6623 - 0.3057(10/A)$	0. 85

(Note) In heavy line: Range of measurement
Out heavy line: Indicate for reference
Hd = Dominant trees average height
A = Stand age

r = Correlation coefficient

Table 4-4 Regression formulae and estimated values of stand age: average stem diameter

Estimated value by tree species

Unit: (cm)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 years	0	0	0	1	0
2	3	1	3	2	1
3	8	3	6	4	3
4	14	7	9	6	5
5	18	10	12	8	8
6	22	13	14	9	10
7	26	17	16	11	13
8	29	20	18	13	16
9	31	24	20	15	18
10	33	27	22	17	20
11	35	30	23	19	22
12	36	33	25	21	24
13	38	36	26	22	26
14	39	39	27	24	28
15	40	42	28	26	30
16	41	45	30	28	32
17	42	48	31	30	34
18	43	50	32	32	36
19	44	53	33	33	37
20	44	55	34	35	39

Tree species	Regression formula	r
Cadamba	$\log D = 1.7722 - 0.2530(10/A)$	0.78
Deglupta	$\log D = 1.0096 + 0.6541 \log A - 0.2339(10/A)$	0 86
Cordia	$\log D = 1.0656 + 0.4085 \log A - 0.1387(10/A)$	0.80
Kauvula	$\log D = 0.2993 + 0.9799 \log A - 0.0538(10/A)$	0.91
Mahogany	$\log D = 1.0649 + 0\ 5092 \log A - 0.2719(10/A)$	0.93

(Note) In heavy line: Range of measurement
Out heavy line: Indicate for reference
D = Average stem diameter
A = Stand age
r = Correlation coefficient

Table 4-5 Regression formulae and estimated values of stand age: basal area

Estimated value by tree species Unit: (m^2)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 Years	0 00	0 00	0 05	0.03	0 00
2	0 29	0 00	0 40	0.15	0.02
3	1.81	0 09	1.11	0.39	0.16
4	4 62	0 53	2.22	0 77	0.51
5	8 23	1.52	3 71	1.28	1 07
6	12.22	3.05	5.62	1 95	1.83
7	16 33	5.02	7.92	2.78	2 75
8	20 39	7.30	10 64	3.76	3 81
9	24.35	9 76	13 76	4 92	4.99
10	28.15	12 31	17.30	6.26	6.27
11	31.29	14 88	21.26	7.77	7.64
12	35.25	17.44	25.63	9.46	9.08
13	38 55	19.94		11.35	10 59
14	41 69	22 37		13 42	12.16
15	44 68	24.71		15 69	13.78
16	47.53	26 96		18.15	15.45
17	50 25	29.11		20 82	17.16
18	52.85	31.17		23.69	18 91
19	55 34	33 14		26.76	20 70
20	57.72	35.01		30.05	22.52

Tree species	Regression formula	r
Cadamba	$\log BA = 1\ 5968 + 0\ 2974 \log A - 0.4447(10/A)$	0.77
Deglupta	$\log BA = 1.9983 - 0\ 9081(10/A)$	0.86
Cordia	$\log BA = 0.7519 + 2.0432 \log A - 0.0531(10/A)$	0 85
Kauvula	$\log BA = 1\ 4302 + 2.2405 \log A - 0\ 0140(10/A)$	0.82
Mahogany	$\log BA = 0\ 0798 + 1\ 411\ \log A - 0.4238(10/A)$	0.90

(Note) In heavy line: Range of measurement
Out heavy line: Indicate for reference
BA = Basal area
A = Stand age
r = Correlation coefficient

Table 4-6 Regression formulae and estimated values of stand age: volume

Estimated value by tree species

Unit: (m^3)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 Years	0	0	0	–	1
2	2	0	0	–	6
3	12	1	3	11	13
4	31	6	10	9	20
5	61	16	21	10	25
6	103	30	33	14	29
7	156	47	46	18	33
8	222	65	58	25	
9	299	84	71	35	
10	388	103	83	48	
11		122	94	65	
12		140	104	87	
13		158	114		
14		175	123		
15		191	131		
16		206	139		
17		221	147		
18		235	153		
19		248	160		
20		260	166		

Tree species	Regression formula	r
Cadamba	$\log V=0.8145+1.9785\log A-0.2044(10/A)$	0.84
Deglupta	$\log V=2.8172-0.8048(10/A)$	0.85
Cordia	$\log V=2.5208-0.6036(10/A)$	0.86
Kauvula	$\log V=-4.2804+5.0912\log A+0.8702(10/A)$	0.73
Mahogany	$\log V=1.8146-0.2073(10/A)$	0.44

(Note) In heavy line: Range of measurement
Out heavy line: Indicate for reference
V = volume
A = stand age
r = Correlation coefficient

Table 4-7 Regression formulae and estimated values of stand age: crown radius

Estimated value by tree species

Unit: (m)

Stand age	Cadamba	Deglupta	Cordia	Kauvula	Mahogany
1 Years	0.40	0 03	0 38	0 09	0.05
2	1 41	0.36	1.09	0 50	0 23
3	2 15	0.86	1.58	0 94	0.46
4	2.65	1.35	1.92	1.31	0.70
5	3.00	1.76	2.18	1.62	0 95
6	3 26	2.10	2.38	1 89	1.19
7	3.46	2 39	2.54	2 12	1.42
8	3.62	2.63	2.67	2.32	1.66
9	3 75	2 84	2.78	2 50	1.89
10	3.85	3.02	2 88	2 66	2.12
11	3 94	3.17	2 96	2 81	2.34
12	4 02	3.30	3.04	2 94	2 56
13	4 08	3 42	3 11	3 06	2.79
14	4 14	3.53	3 17	3 18	3 00
15	4 19	3.62	3.22	3 28	3.22
16	4 23	3 71	3 27	3 38	3 43
17	4.27	3.78	3.32	3 48	3 65
18	4.31	3.85	3 36	3 57	3.86
19	4.34	3.92	3 41	3.65	4.07
20	4.37	3 98	3 44	3.73	4 27

Tree species	Regression formula	r
Cadamba	$\log CR=0.6948-0\ 1089(10/A)$	0.42
Deglupta	$\log CR=0\ 6905+0.0181\log A-0\ 2290(10/A)$	0 74
Cordia	$\log CR=0.4264+0.1178\log A-0.0852(10/A)$	0.65
Kauvula	$\log CR=0.2974+0\ 2629\log A-0\ 1351(10/A)$	0.81
Mahogany	$\log CR=-0\ 4508+0.8657\log A-0.0894(10/A)$	0.93

(Note) In heavy line : Range of measurement
Out heavy line: Indicate for reference
CR = Crown radius
A = Stand age
r = Correlation coefficient

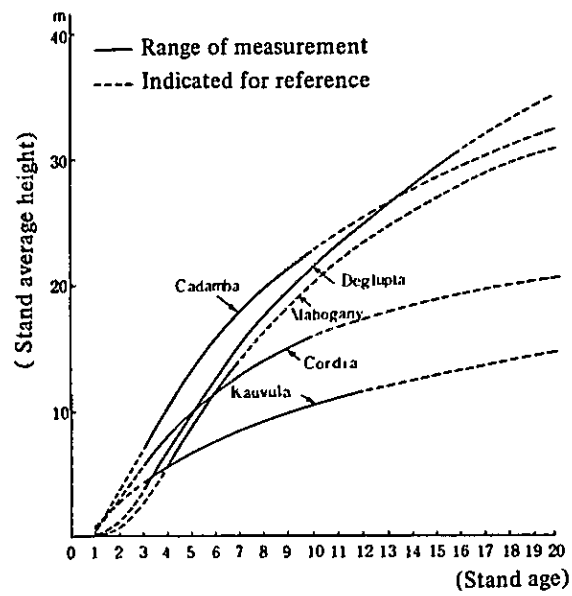


Fig. 4-1 Regression curves for stand age: stand average height

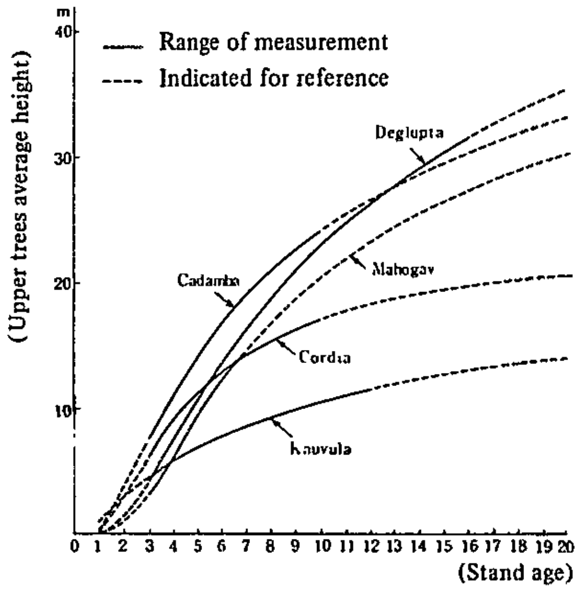


Fig. 4-2 Regression curves for stand age: upper trees average height

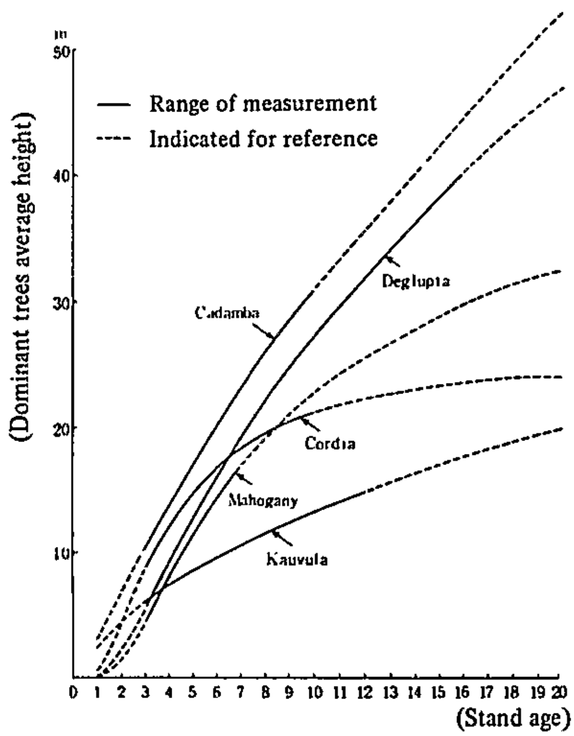


Fig. 4-3 Regression curves for stand age: dominant trees average height

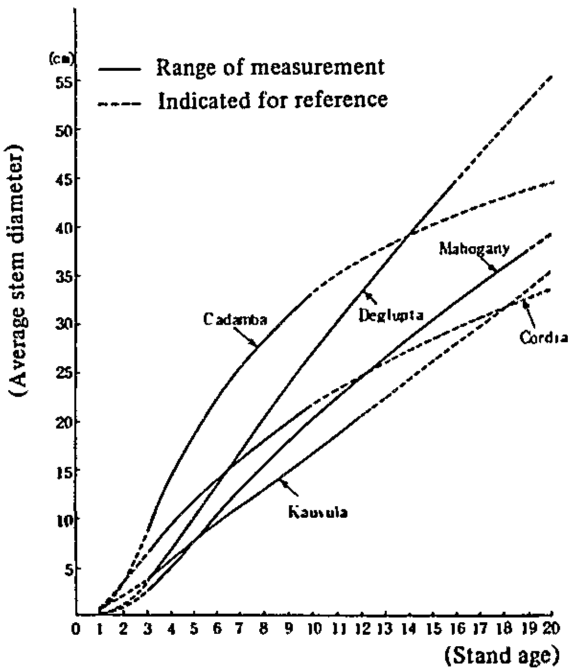


Fig. 4-4 Regression curves for stand age: average stem diameter

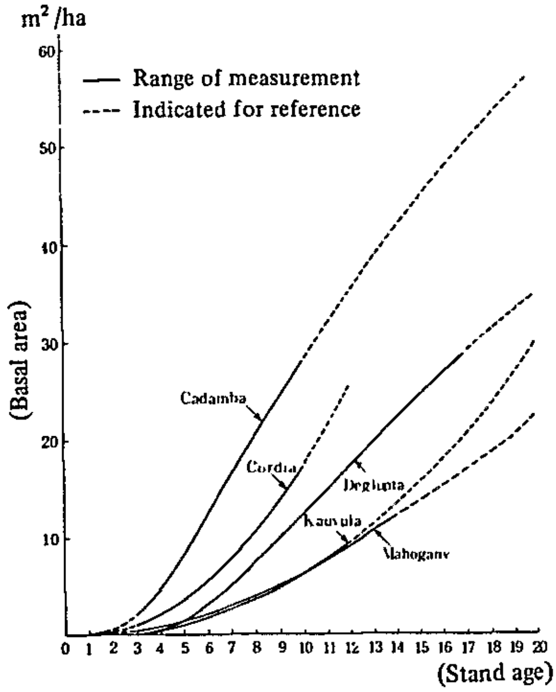


Fig. 4-5 Regression curves for stand age: basal area

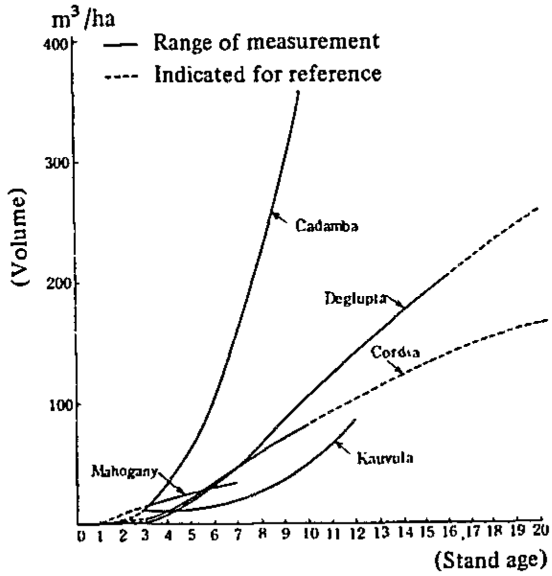


Fig. 4-6 Regression curve for stand age : volume

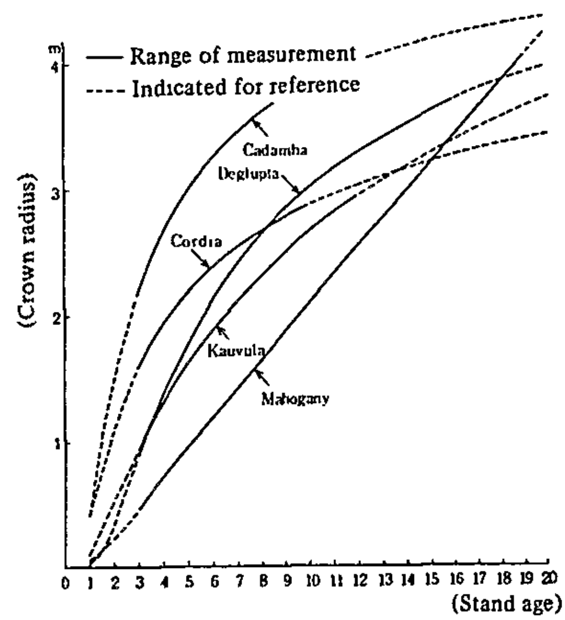


Fig. 4-7 Regression curves for stand age: crown radius

Form classes are divided as follows:

I (good): Long, straight stem with few thick lower branches.

II (moderate).

III (poor). Bent stem or with thick lower branches.

(i) Rate of the number of trees in form class I

Mahogany excells in form class and 60% of its trees in about their 5th year are in form class I and 50% of even its 20 year olds are in form class I. There is no great difference between species other than Mahogany but the number of Kauvula and Cordia trees in form class I seems to be small.

The tendency with all tree species is for the rate of number of trees in form class I, to either decrease or level off with the advance of stand age.

(ii) Rate of the number of trees in form class III

Contrary to the case of form class I, the rate of the number of trees in form class III is largest with Cordia, followed by Kauvula. The rate of the number of approximately 5-year-old Cordia trees in form class III is 30% while that for Mahogany, with the lowest rate is 10%. The tendency for all trees species is for the rate of trees in form class III to either decrease or level off with the advance of stand age.

(iii) Rate of damaged trees

The tendency of damage by tree species and by stand age is as follows: Fig. 4-10 shows the average rate of the number of damaged trees at different stand ages.

Since what is referred to here as damaged rate is the relation between the number of trees planted and the number of healthy trees that remain, it should naturally increase by gradual degrees with the advance of stand age. In fact, this is the tendency with the four species other than Deglupta. Deglupta alone showed a tendency of gradual decrease, on the contrary, but this is due to the fact that Deglupta stands with advanced stand age either are or until recently were well-tended experimental forests.

By tree species, damage is highest with Deglupta at 60% and the actual damage of Deglupta in Nukurua district is believed to be more than 90% and is in a state of total destruction. The difference is attributable to the fact that since th purpose of the recent survey was to look into forest productivity, sample plots were set deliberately at places where surviving Deglupta trees could be found.

After Deglupta, Mahogany ranks second in damaged rate. The damaged rate of five-year-old Mahogany trees is 30 ~ 40% and the rate gradually increases until it is about 60% at the age of 20 years. From the age of about 15 years, they begin to be thinned. Damge is low with Cadamba and Cordia as it is 10 ~ 20% for five year olds and about 30% for 10 year olds of these species.

Table 4-8 shows damaged rates by tree species averaged for all plots of trees 10-years-and younger to show damage by cause. In this table, damaged rates are divided into dead rates and damaged (n) rates.

By causes of death, the rate by fungus is large with Cordia but non-existent with Deglupta and Kauvula. The rate due to hurricanes tends to be large with Cordia and Mahogany. Dead by "others" is, in effect, mainly by oppression and hardly occurs to trees six years and older for any species. Thinning is only practised for 10-year-old Cadamba trees. Nearly 90% of all causes of death is "missing trees". These are planted trees that are not found where they should be in view of planting intervals; therefor, the

causes of their death are unknown. Since, however, many young trees are already missing at the age of three years, regardless of the species. The presumed cause of their death is oppression, etc. immediately after planting. The proportion of missing trees in the total of dead trees is high for Deglupta and Kauvula, at 96% and 94% respectively. This proportion is as high as 77% even with Cordia which has the smallest proportion. These figures reflect the importance of taking care of them immediately after planting.
The damage (n) rate, namely, the rate of living but damaged trees that remain at present is 2 ~ 4% of the total of living trees. Damage by fungus is heavy with Cordia and non-existent with Deglupta and Kauvula. Damage by hurricane is heaviest with all tree species. Damage by other causes including oppression is heavy with Deglupta and Cordia but hardly occurs to trees of any species that are more than five years old.

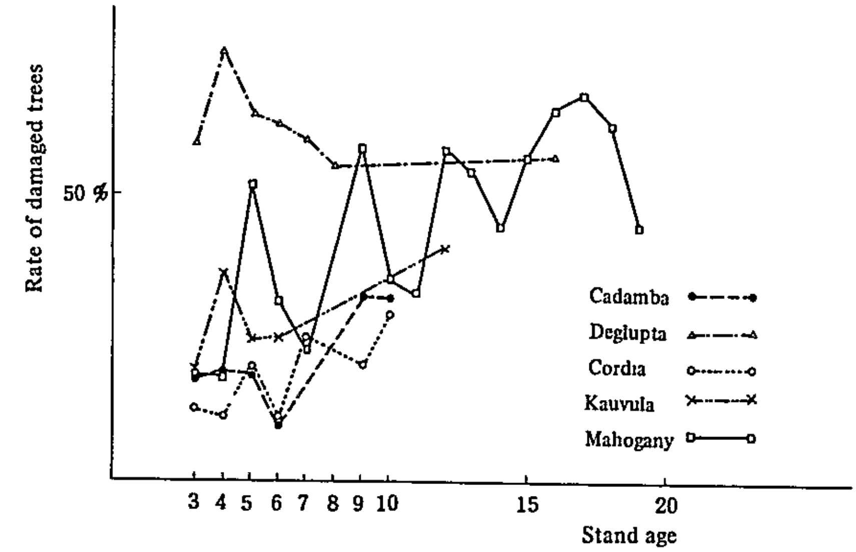


Fig. 4-10 Rate of damaged trees by tree species and by stand age

Table 4-8 Table of dead and damaged(n) rates by cause

Unit: %

Tree species	Dead rate	Dead rate by cause					Damaged (n) rate	Damaged(n) rate by cause		
		Fungus	Hurri-cane	Others	Thinning	Missing		Fungus	Hurri-cane	Others
Cadamba	14	9	2	3	1	85	4	26	64	10
Deglupta	61	0	2	2	0	96	3	0	63	37
Cordia	14	14	8	1	0	77	3	43	50	7
Kauvula	23	0	1	5	0	94	3	0	69	31
Mahogany	29	5	6	4	0	85	2	8	81	11

Dead rate: Number of dead trees/number of planted trees x 100%
Damaged(n) rate: Number of living trees having been damaged/number of planted trees x 100%
Damaged(w) rate: Number of dead and damaged(n) trees/number of planted trees x 100%

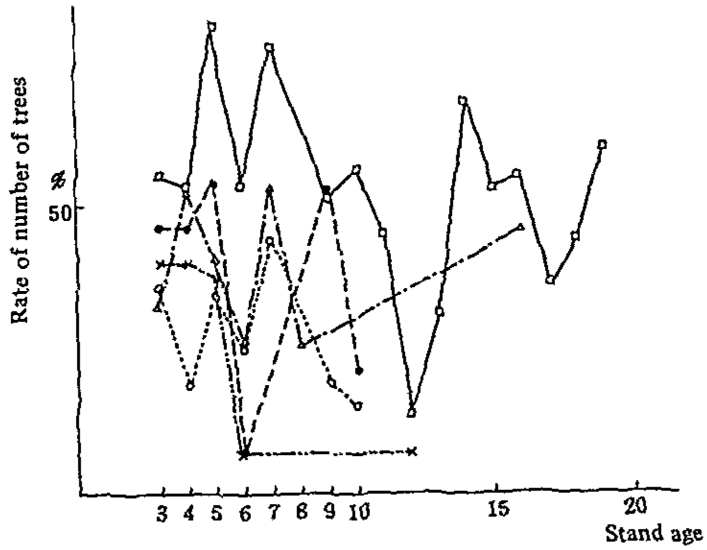


Fig. 4-8 Stand age: rate of number of trees in form class I

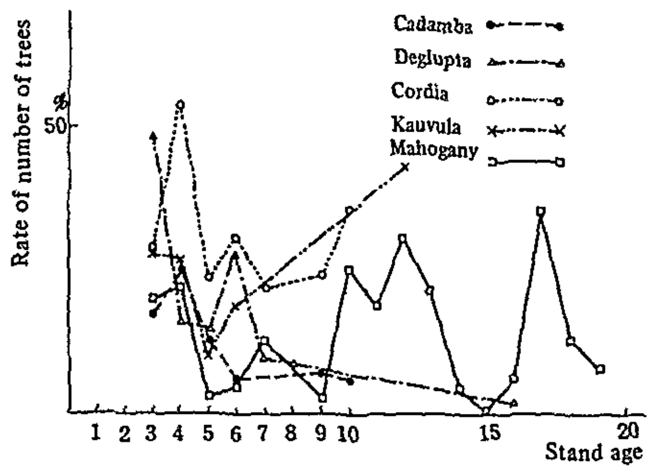


Fig. 4-9 Stand age: rate of number of trees in form class III.

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