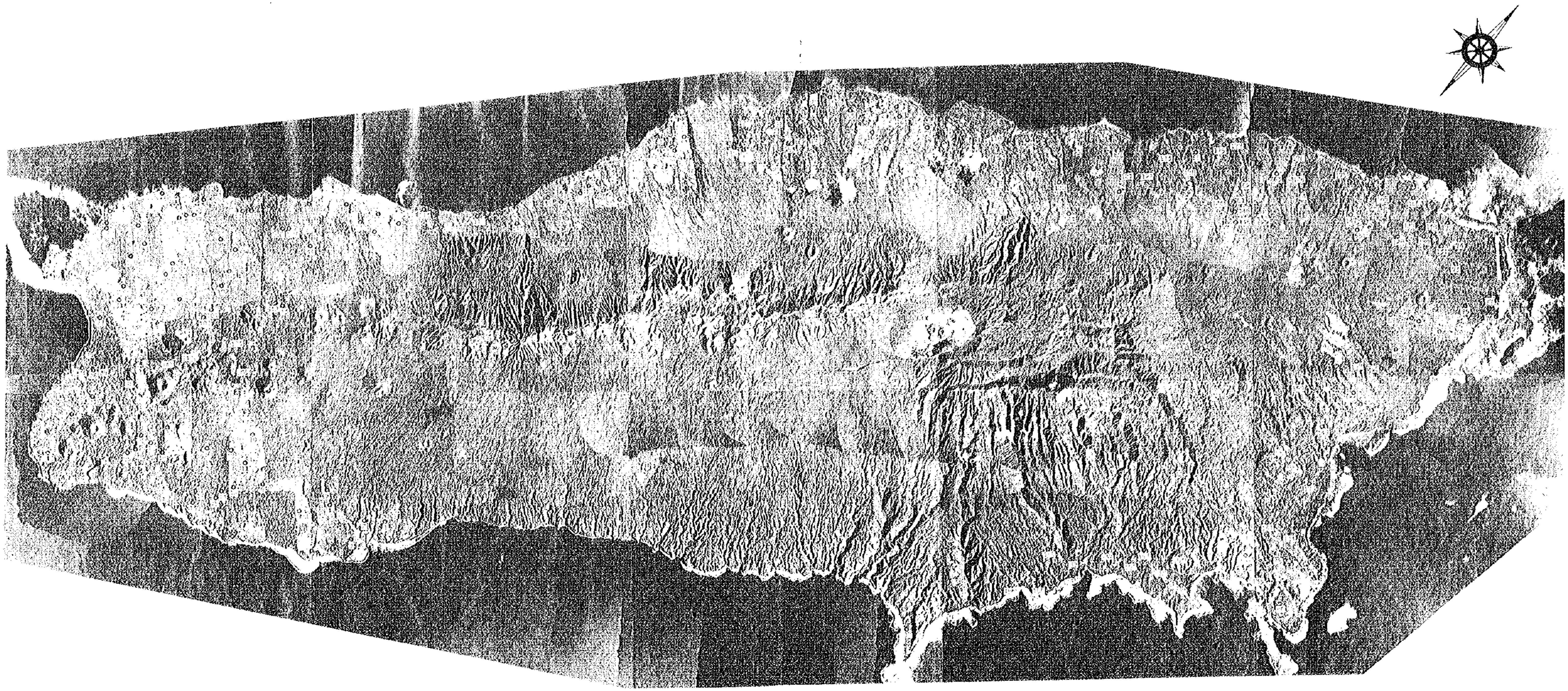
REPORT OF AN ANALYTICAL SURVEY OF COCONUT FORESTS IN TAVEUNI ISLAND OF FIJI

June, 1978

Japan International Cooperation Agency

Taveuni Island, Fiji



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PURPOSE OF SURVEY

1. Objectives of the survey

The survey was conducted for the purpose of providing data such as a coconut distribution map, results of coconut forest inventroy and other information necessary for utilization of coconut timber, by means of aerial photography.

It was also intended for establishing a procedure of the research on coconut forests in tropical areas by means of aerial photography.

2. Implications of the survey of coconut forest

Copra, which provides one of the important resources for export in developing countries of the tropics, is made from coconuts. Since it is fairly easy to grow coconut even on barren land, it is widely cultivated in plantations of the Southeast Asia and the Oceania, and provides a major industry for these regions.

In Fiji, too, copra is an important export item with the total value of $5,669,000 (1973) which comes after sugar ($34,280,000) and gold ($6,125,000). Copra production in Fiji amounts to 25,000 metric tons, making the country the second largest producer of copra in Melanesia and Polinesia, only next to Papua New Guinea (Pacific Island Year Book 1977). It is hoped, therefore, that management of plantations will be continued, producing stable yield of copra.

However, an important problem has arisen in recent years in connection with coconut plantation. That is, those coconut trees cultivated in plantations are expected to over-mature in 40 to 50 years with continuous cropping of coconuts. This will result in lower yield of copra per unit area and threaten the management of plantations as an industry. (See Table 3 in IV-1.)

Most of those coconut plantations in Fiji, which were actively cultivated throughout the long colonical period, now seem to be in such a situation, and there is a pressing need for some measures to maintain the country's major industry.

For that purpose it is necessary to carry out regeneration of over-matured coconut forests at an early date to change them into young forests. Further, not only the problem of regeneration but also the problem of how the yield of plantations as a whole can be raised by utilizing as timber the stems of those coconut trees which are to be felled in large numbers has come to the fore.

It is also important from the view point of national policy for forestry and of sustained yield of timber in the world to extend the choice of species to provide timber resources from those which have hitherto been developed to new species with possibilities of utilization such as coconut so that limited timber resources may be conserved and utilized effectively.

In order to deal with these problems, technical development for the utilization of coconut trees as timber has to be carried out first. At the same time, collection of data on the amount of the resources and the annual standard felling volume which can be supplied as timber is necessary for determining the feasibility of the industry. In short, accurate assessment of the resources is essential.

However, studies and statistics estimating the volume of coconut as timber are practically nil and even the area of plantations is approximately documented. Even a stand volume table is not available at present, nor has the procedure of research been developed.

The present survey was conducted, in view of the situation, to develop a method of estimating the total growing stock of coconut timber mainly by means of aerial photography, and, at the same time, to carry out coconut forest inventory in Taveuni Island as a training area.

These problems mentioned above are not peculiar only to Fuji; they are equally important to other countries of Southeast Asia and the Oceania. Therefore, the results of the present research will no doubt contribute to international cooperation with expanding into other nations.

II. SURVEY BACKGROUND

1. Background of the realization of the survey.

In September, 1975, the Government of Fuji made a request through the Japanese Ambassador in Australia for Japan's technical cooperation in hardwood re-afforestation and so on (Dispatch No. 0966 Australia). In response to the request, the Government of Japan and the Japan International Cooperation Agency sent in November, 1976, a preliminary survey team headed by Mr. Tomohisa Fukumori, President of Japan Forest Technical Association, to discuss the contents of the technical cooperation requested by the Fiji Government.

As a result, it became clear that Japan's technical cooperation was requested for the following purposes in connection with forest utilization in Fiji.

① Hardwood re-afforestation of areas already logged.

② Production of wood chips form natural forests.

③ Coconut utilization plan and pulping trials.

The Japanese Government and the Japan International Cooperation Agency reported back the results of the Feasibility Survey for Forestry Development in Fiji (March, 1977) to the Fiji Government on the possibility of cooperation regarding the above items, and, at the same time, asked the Fiji Government as to which of the items for technical cooperation should be given priority. In reply the Fiji Government transmitted its intention to the Japanese Government of giving priority to the item ③ in the Survey report, Planning for utilization of coconut stands in Taveuni and its adjacent areas, and aerial photographing, mapping and collection of data necessary for the purpose (Dispatch No. 0392 Australia).

After examination, the Japanese Government decided to cooperate in the survey for planning utilization of coconut forest in Taveuni Island.

2. Organization for the realization of the survey.

The survey was carried out by a joint venture as below.
Fiji Forest Aerial Survey Joint Venture.

Representative: Japan Forest Technical Association;
President, Tomohisa Fukumori;
No. 7, Rokuban-cho, Chiyoda-ku, Tokyo.
Member: as above.
Member: Kokusai Aerial Survey Co., Ltd.;
President, Kenji Masuyama;
No. 2, Rokuban-cho, Chiyoda-ku, Tokyo.
Member: Asia Air Survey Co., Ltd.,
President, Hiroshi Motojima;
2-16, 5-chome, Tsurumaki, Setagaya-ku, Tokyo.

3. Survey Team

For the purposes described, the following survey teams were organized and sent to Fiji.

1) Preliminary survey team for forest exploitation.

Scope: S/W discussed and an agreement signed. (See appendix 3.)
Collecting material and making arrangements for full-scale surveys 2) and 3).

Period: May 30-June 14, 1977.

Members of the team:

Leader	Sadamoto Watanabe	Vice Director of Forestry Road Division, Forestry Agency.
Aerial survey	Fumio Ishii	Fiji Forest Aerial Survey Joint Venture (Kokusai Aerial Survey Co., Ltd.)
Forest inventory	Hiroshi Watanabe	As above (Japan Forest Technical Association).
Coordinator	Nobumitsu Miyazaki	Vice Director of Forestry Development Division, JICA.

2) Survey team for aerial photographing.

Scope: Aerial photographing.

Period: July 6-August 24, 1977.

Numbers of the team:

Coordinator	Fumio Ishii	Fiji Forest Aerail Survey Joint Venture (Kokusai Aerial Survey Co., Ltd.).
Aerial photographing	Masaru Shiromaru	Same as above.
	Masatsugu Miyama	Same as above.

3) Survey team for mapping and coconut forest inventory.

Scope: Survey for preparation of topographical maps.
Coconut forest inventory.

Period: September 30-November 8, 1977.

Members of the team:

Supervisor	Masao Hanega	Vice Director of Forestry Planning Division, Forestry Agency.
Coordinator	Hiroshi Watanabe	Fiji Forest Aerial Survey Joint Venture (Japan Forest Technical Association).
Mapping	Takashi Yokokawa	Same as above. (Kokusai Aerial Survey Co., Ltd.).
	Yoshiaki Ohtoku	Same as above. (Asia Air Survey Co., Ltd.).
Coconut Forest Inventory	Tadami Imai	Same as above. (Japan Forest Technical Association.)
	Masaaki Mizukami	Same as above.
	Yoshimasa Koike	Same as above.

4. Fujian agencies and personnel connected with the survey.

Department of Foreign Affairs: Under-Secretary
P.E. Sotutu.

Forestry Agency: Conservator of Forests
G.H.D. Williams.

Deputy Conservator of Forests
K.T. Yabaki.

Senior Assistant Conservator of Forests
A. Oram.

Ministry of Agriculture: Under-Secretary
W. Tompson.

Assistant Director of Agriculture
J.M. McPaul.

Agricultural Statistician
R. Rothfierd.

Assistant Agricultural Statistician
J. Kumar.

Ministry of Land and Minerals:

Director of Land and Survey General
B. Dutt.

Assistant Director of Land and Survey
G.P. Gautam.

Principal Surveyer
A. Spower.

Institute of the Timber Utilization Research:

Principal Utilization Officer
A.S. Alston.

Senior Utilization Officer
J. Richolson.

Taveuni Regional Office:

Principal Officer
P. Thompson.

III. SURVEY AREA

1. Location

The survey area covers about 10,000 ha(hectars) of coconut forests and the surrounding areas in Taveuni Island. (See Fig. 1 and 2, and also the inside of the front cover.)

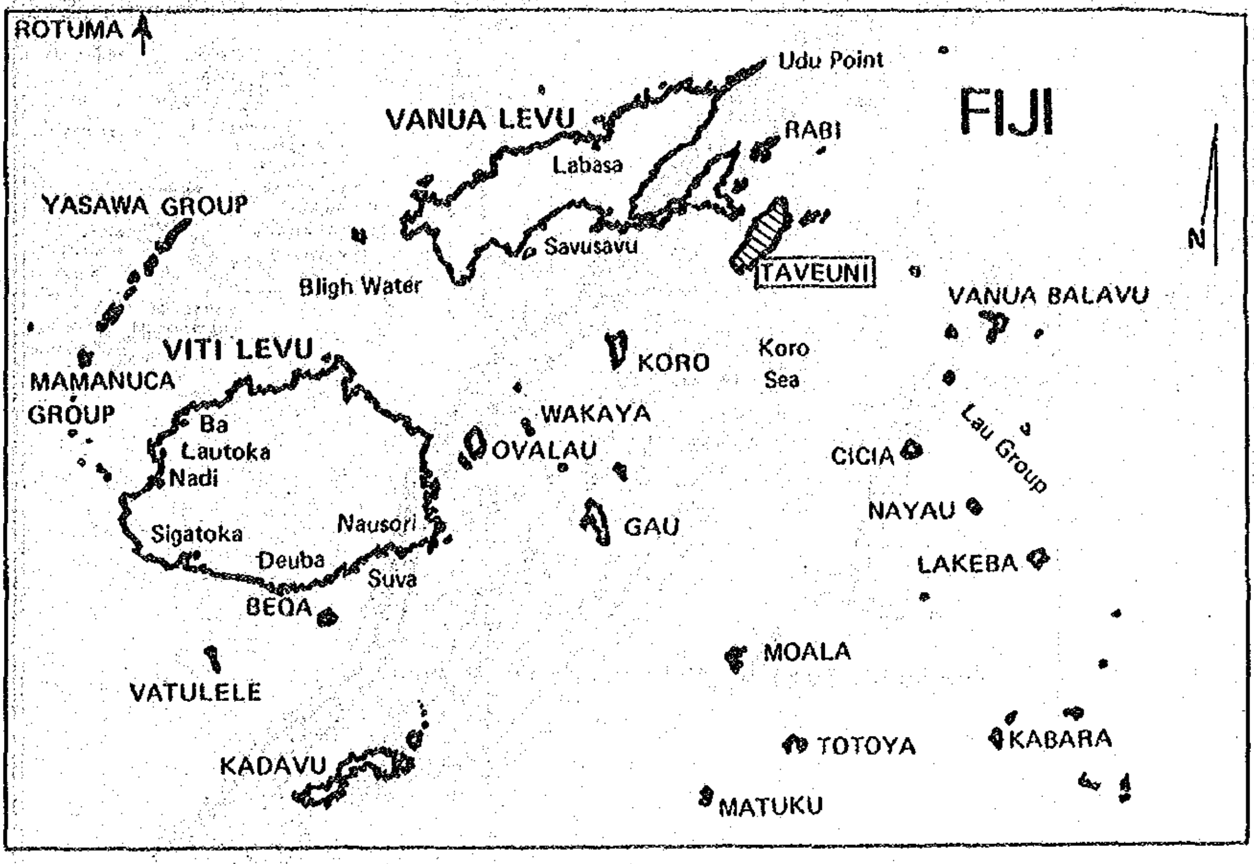


Fig. 1. Location map of Fuji

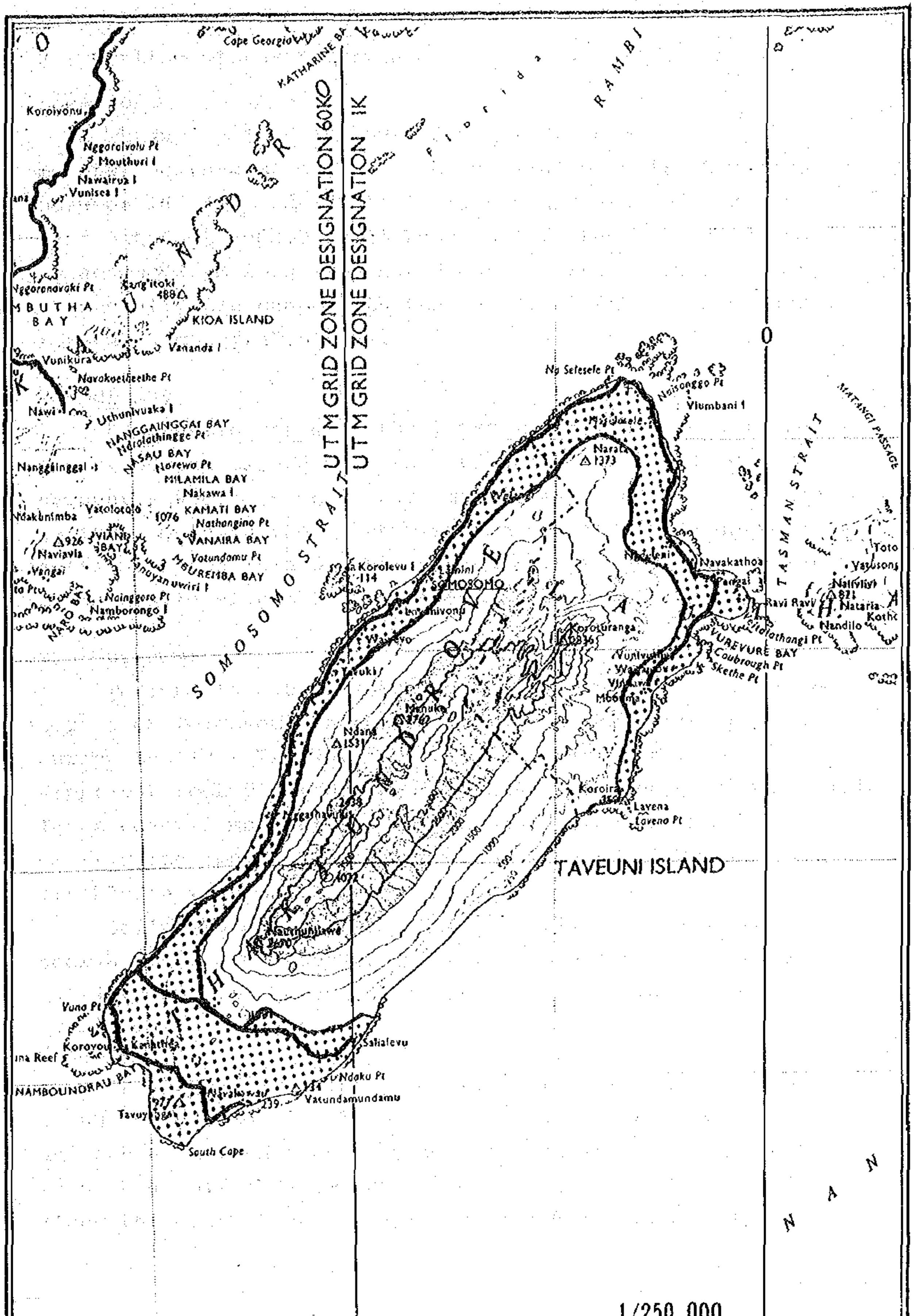


Fig. 2. Location map of Taveuni Island and the extent of coconut forests

2. Outline of the survey area

Location

Taveuni Island is located about 200 km (kilometers) north-east of Suva, the capital of Fiji, and lies between 16° 41' and 17° 1' in latitude South and between 179° 54' East and 179° 14' West in longitude. The island is about 42 km long from north-east to south-west, forming a long elliptic shape with the average width of 12 km and a total area of 43,500 ha.

Topography

A mountain range of the 1,000 meter class runs in the center of the island with the average width of 12 km. Consequently the terrain is extremely steep and the level area is found only in the south-west and a part of the north-east section of the island. Most areas rise from the coast through short gentle slopes to the steep mountain area.

Geology and soil

Taveuni is a high volcanic ridge belonging to a linear series of volcanoes in the Pacific. It was formed mainly during the late Tertiary period, but some of the larger eruptions took place during the late Pleistocene when basaltic lavas covered most of the island and prevented the formation of fringing reefs. Even at present remains of craters are visible in many parts of the island.

Soils are mostly reddish loam derived from decomposed scoria, tuff and vegetable matter. They are very rich in nutrient and may be over 1 meter deep in lowland areas.

Climate

The prevailing winds are from the south-east. They bring heavy rainfall of up to 5,000 mm per annum to the peaks and south-eastern slopes while the northwestern areas receive less than half this amount. There is a great deal of cloud along the main ridge and upper slopes throughout the year.

Temperatures range from 16° to 32°C and occasionally exceed this with annual means of 31° maximum and 18° minimum and monthly means ranging from 23° to 27°C.
Humidity is high throughout the year; morning humidities average 80% while afternoon humidities average 70%. (relative humidity)

Land utilization

Land is divided up roughly as follows:-

Native reserve	4,000 ha	
Forest reserve	11,300	
Coconut plantations	7,900	(Estates- 6,100 ha)
Villages, bush and cultivation	20,300	
Total	43,500 ha	

Forest area

The forest covers the central and southeastern parts of the island. Since it has not been throughly mapped and typed, its details are not available. It seems, however, that the forest contains a large number of tropical rain forest species. The forest is divided into Native reserve and Forest reserve, and is distinguished from the estates and the unreserved land.

There is no timber production apart from small quantities for local use by landowners and villagers.

Industry

The island once produced cotton and, later, sugar; but the major crop now is copra produced from coconut plantations. The island is also a large producer of vegetables, especially Dalo which is shipped to other islands. Cattle and pigs are also bred in the forest.

Population

As of September, 1976, population is 7,700. While the number of Fijians of Indian stock is increasing in Fiji, native Fijians occupy a comparatively large proportion of the population of Taveuni.

The native Fujians, who practiced cannibalism until about 100 years ago, are naive and friendly people; and they are fairly diligent.

Taveuni seems to have a higher level of standard of living than other islands probably because of the production of copra.

Transportation, etc.

There are public roads along the coast in the northeast, northwest and southwestern parts of the island and bus services three times a day to connect the scattered villages in these areas. There are also work roads passable for motor vehicles transporting copra from coconut plantations in the southwest and northeastern parts.

Inter-island transportation is provided by boats. However, because of the coral reefs, there is only one harbor at Somosomo at the center of the island. There is an airstrip at Matei in the northeastern part, operating air service once a day for Suva.

Though there is no remarkable tourist attraction in Taveuni, but some visitors come in search of nature and primitivity. There is a resort hotel in Waiyevo, and a villa development has begun recently in Sogulu district.

IV. PRESENT SITUATION OF COCONUT FORESTS

1. Present situation of coconut forests and copra production in Fiji.

1-1. Area of coconut forests.

Present situation regarding coconut forests and copra production in Fiji according to the data collected can be summarized as follows:-

Table 1. Present situation of coconut forests

Tree age	Area		Number of trees	%
	Hectare	Acre		
Under 10	21,040	52,000	2,600,000	23.7
10 - 22	2,020	5,000	250,000	2.3
22 - 30	5,460	13,480	674,000	6.1
30 - 42	8,590	21,220	1,061,000	9.7
42 - 57	14,110	34,860	1,743,000	15.9
57 - 72	16,810	41,540	2,077,000	18.9
Over 72	20,860	41,540	2,577,000	23.5
Total	88,890	219,640	10,982,000	-

Source: Feasibility survey for forestry development in Fiji.

According to the table, those trees over 42 years occupy 51,780 ha (58.3% the total), and even those over 57 years occupy 37,670 ha (42.4%). The existence of these old forests reveals the situation referred to in I-2. The distribution by age class shows clearly that middle and young forests are very few and that the distribution is considerably unbalanced. Thus, it is clear that cutting should not be carried out by simply starting with the old age class and that cutting and regeneration should be planned on the basis of sustained yield management.

Table 2 gives the distribution of coconut forests by area.

Table 2. Distribution of coconut forests by area

	Area	Hectare	Acre
NORTHERN DIVISION	Taveuni	7,861	19,410
	Qamea	1,418	3,500
	Rabi	1,081	2,670
	Natewa Bay	4,054	10,011
	Wainunu	3,547	8,758
	Bua	2,275	5,618
	Macuata	4,167	10,288
	Rest of Cakaudrove	9,492	23,437
	Total	33,895	83,692
LOMAIVITI GROUP	Batiki	166	410
	Gau	705	1,740
	Nairai	257	635
	Koro	2,643	6,525
	Ovalau, Moturiki, Makogai, Wakaya	960	2,370
	Total	4,731	11,680
LAU GROUP	Cicia Tuvuca	912	2,252
	Kabara Komo	269	665
	Lakeba	1,324	3,270
	Vanua Balavu, Yanuca Cikobia	1,827	4,510
	Matuku	478	1,180
	Madla	1,632	4,030
	Oneata, Namuka, Moce	834	2,060
	Nayau	267	660
	Vanuavatu, Totoya	239	590
	Vatoa, Ono	634	1,565
	Ogea, Fulaga	454	1,120
	Munia, Katafaga, Mago, Naitauba, Kanacea	2,215	5,470
	Total	11,085	27,372
OTHER AREAS	Kabavu	3,252	8,030
	Rotuma	1,320	3,260
	Yasawas	2,722	6,720
	Vatulele	435	1,074
	Tailevu	?	?
	Rewa	?	?
	Beqa	719	1,775
	Total	8,448	20,859
FIJI TOTAL–by Divisions	Grand total	58,159	143,603

Source: Data for Tables 2, 3 and 4 supplied by the Fiji Timber Utilization Reserch Institute

Note: The total area of 58,189 ha given by Table 2 differs from 88,890 ha given by Table 1. This is because the figures given by Table 2 are only those of bearing forests. According to the Department of Agriculture, preregeneration forests account for 21% of the total and over-matured forests 45% and the rest are production forests of those younger than 60 years.

According to the table 2, coconut plantations are concentrated in the Northern Division, particularly in Cakaudnove (the southeastern part of Vanna Levu Island along Natewa Bay) and Taveuni. In terms of the proportion of the area of coconut forests in the total land area, Taveuni has the largest proportion, hence the reason for being the target area of the present survey.

1-2. Production of copra.

Tables 3 and 4 give the production of copra during the period from 1963 to 1976 and the distribution by area.

Table 3. Annual production of copra (unit: ton)

Year	-	Production
1963	-	41244
1964	-	41209
1965	-	29883
1966	-	25356
1967	-	24864
1968	-	27734
1969	-	33449
1970	-	28260
1971	-	28550
1972	-	29160
1973	-	27060
1974	-	27278
1975	-	23496
1976	-	26510

Table 4. Production of copra by area (unit: ton)

	1975	1976
Viti Levu and adjacent islands	964	1,594
Lomaiviti	2,550	2,676
Vanua Levu	8,916	8,867
Taveuni	5,833	6,852
Lau	4,385	4,831
Kadavu	291	379
Rotuma	466	1,256
Miscellaneous	91	55
	23,496	26,510

Production in recent years ranged from 25,000 to 27,000 tons. Though there are fluctuations in production, the figures show a slight decreasing trend, an indication of the decreasing production capacity of over-matured forests.

Areal distribution of production of copra corresponds roughly to the areal distribution of coconut forests.

1-3. Species of coconut

According to the Plants of the Fiji Island by J.W. Parpham (Government Printer, 1972), those species of coconut found in Fiji are as follows:-

Cocos nucifera Linn. Coconut; Niu; Niu Dina.

The coconut is the best known of all the palms. The products of the coconut have a wide variety of uses; one of Fiji's major exports is coconut oil which is produced by crushing the copra. It is estimated that coconuts for copra production occupy 170,000 acres.

The following names are applied to different types of coconut palms in Fiji:

TALL PALMS:

NIU VULA: Tall palms with green nuts.

NIU DAMU: Tall palms with orange nuts.

NIU DRAU: Tall palms bearing a large number of small nuts.

NIU NI TOGA: Tall palms with large nuts.

NIU NI MAGIMAGI: Tall palms with elongated nuts which have a large area of husk *(mesocarp)* which is used for making sennet *(magimagi)*.

ROTUMAN: Tall palms with the reputation of bearing very large nuts. Usually not heavy bearers.

NIU YABIA: The "weeping" coconut. Tall palms with drooping pinnae; not common, usually bears few, small nuts.

DWARF PALMS:

NIU LEKA: The Fijian dwarf which usually bears green nuts; it grows to a height intermediate between the Malayan dwarf and the typical tall palm.

MALAYAN DWARF: Introduced. The nuts are either orange or yellow.

NIU LEKA X MALAYAN DWARF (FIJI HYBRID): The hybrid is a result of Marechal's work in the late 1920's and is considered to be a good type of palm, usually bearing an above average number of orange or green coloured nuts.

The former group is normally called Fiji Tall and the latter Malayan Dwarf.

Fiji Tall are common species in Fiji. With regard to Malayan Dwarf species, the number has been increasing recently because they bear a large number of nuts, resulting in a large yield of copra per unit area, though they are not very tall. Their defects are that they decay after 40 to 50 years and that they are not strong against hurricanes.

2. Present situation of coconut forests in Taveuni

Present situation of coconut forests in Taveuni based on the results of the survey can be summarized as follows:-

The total area of coconut forests is 10,876 ha, having the total volume of 754,047 m^3. (cubic meters) Thus the volume per hectare is 69 m^3/ha.

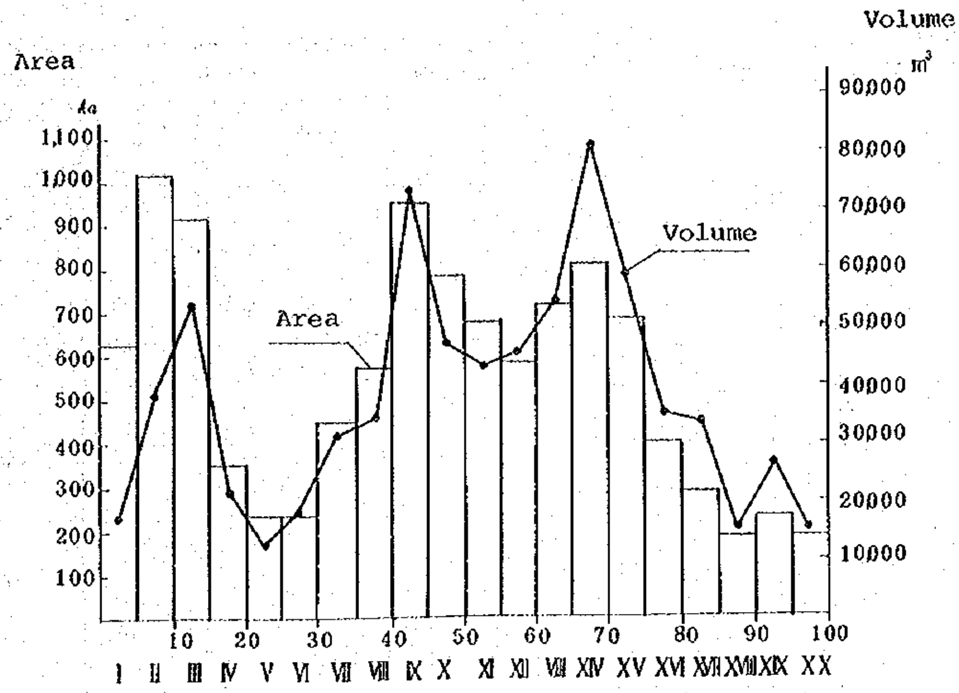
The forests are located mainly along the coast except the southeastern part of the island, particularly in the flat area of the southwest and also in the northeast.

Fig. 3 and Table 5 give the distribution area and the volume by age class.

These data show that those trees over 50 years account for 43.7% of the total and that regeneration is a pressing need. The distribution of area by age class is almost identical to that for Fiji as a whole (Table 1): very unbalanced distribution with very few production forests in the age class V.

Production of copra in Taveuni was 5,833 tons in 1975 and 6,852 tons in 1976, accounting roughly a quarter of the total production in Fiji.

Most of the existing species are Fiji Tall, and Malayan Dwarf, planted mainly as the lower story of the two-storied forest.



Area
ha
1,100
1,000
900
800
700
600
500
400
300
200
100
Volume
m³
90,000
80,000
70,000
60,000
50,000
40000
30,000
20,000
10,000
Area
Volume
10
20
30
40
50
60
70
80
90
100
I II III IV V VI VII VIII IX X XI XII XIII XIV XV XVI XVII XVIII XIX XX

Fig. 3.

Table 5. Coconut forests in Taveuni

Age class	Area	Percentage	Area	Percentage
I	621.00 ha	5.7 %	16,311 m³	2.2 %
II	1,027.27	9.5	38,403	5.1
10				
III	893.78	8.2	51,932	6.9
IV	348.23	3.2	20,729	2.7
20				
V	232.15	2.1	12,247	1.6
VI	232.15	2.1	17,865	2.4
30				
VII	446.89	4.1	30,112	4.0
VIII	580.38	5.3	34,858	4.6
40				
IX	951.82	8.9	74,488	9.9
X	777.71	7.2	46,886	6.2
50				
XI	679.04	6.2	42,740	5.7
XII	580.38	5.3	44,677	5.9
60				
XIII	737.08	6.8	53,514	7.1
XIV	812.53	7.5	80,787	10.7
70				
XV	679.04	6.2	59,241	7.9
XVI	406.26	3.7	36,030	4.8
80				
XVII	290.19	2.7	33,603	4.5
XVIII	174.11	1.6	15,956	2.1
90				
XIX	232.15	2.1	27,521	3.6
XX and over	174.12	1.6	16,147	2.1
	10,876.28		754,047	

Note: The age classes have been estimated by the method described in VIII-1.

V. PHOTOGRAPHING OPERATION

1. Planning

The present survey begins with aerial photographing. First, the following photographing plan based on the existing topographical map on a scale 1:50,000 was worked out.

Photographing specifications

Photo scale:	1/2000.
Camera:	Wide angle camera with a 15 cm focal length lens.
Height of the datum level:	617 m.
Flight altitude:	3,670 m.
Number of courses:	5 courses parallel to the length of the island.
Overlap:	60%.
Sidelap:	30%.
Films:	B/W panchromatic.

2. Photographing operation

Photographing operation was conducted from July 6 to August 24, 1977. The airstrip at Matei was used as the base for the operation, and photographing flights were made according to the weather condition. However, there was not even one day when the weather was clear over the whole island, and, consequently, photographing was carried out piecemeal, supplemented by additional flights.

Particularly the central ridge of the island was always covered with thick clouds, and it was not possible to obtain completely clear photographs in spite of repeated attempts.

However, photographing within the range of cloudiness specified in the Scope of Work was carried out, and clear photographs of the coconut plantation areas, the objective of the survey, were obtained.

Aircraft and other items used for the operation were as follows:-

Aircraft	Beechcraft Co. (Chartered from Fiji Air.)	Beech 95-C55
Camera	Wild Co. RC-8 (F. 152.02 mm).	
Films	Fuji Film Co. Fuji Aerofilms SS.	

3. Processing and editing

Exposed films were developed and edited, and the following results were obtained.

Negative films	1 copy
Positive films	1 copy
Contact prints	2 copies
Original index map	1 copy
Copy of the above	2 copies

Table 6 gives the details of the edited aerial photographs, and Fig. 4 the index map.

Table 6.

Course No.		Photo no.	Copies	Date
C1	A	1 ∿ 5	27	7/30
	B	1 ∿ 22		7/24
C2	A	1 ∿ 22	32	7/29
	B	1 ∿ 10		7/29
C3	A	1 ∿ 9	34	7/27
	B	1 ∿ 13		7/30
	C	1 ∿ 12		7/29
C4	A	1 ∿ 12	29	7/29
	B	1 ∿ 9		7/30
	C	1 ∿ 8		7/29
C5		1 ∿ 15	15	7/29

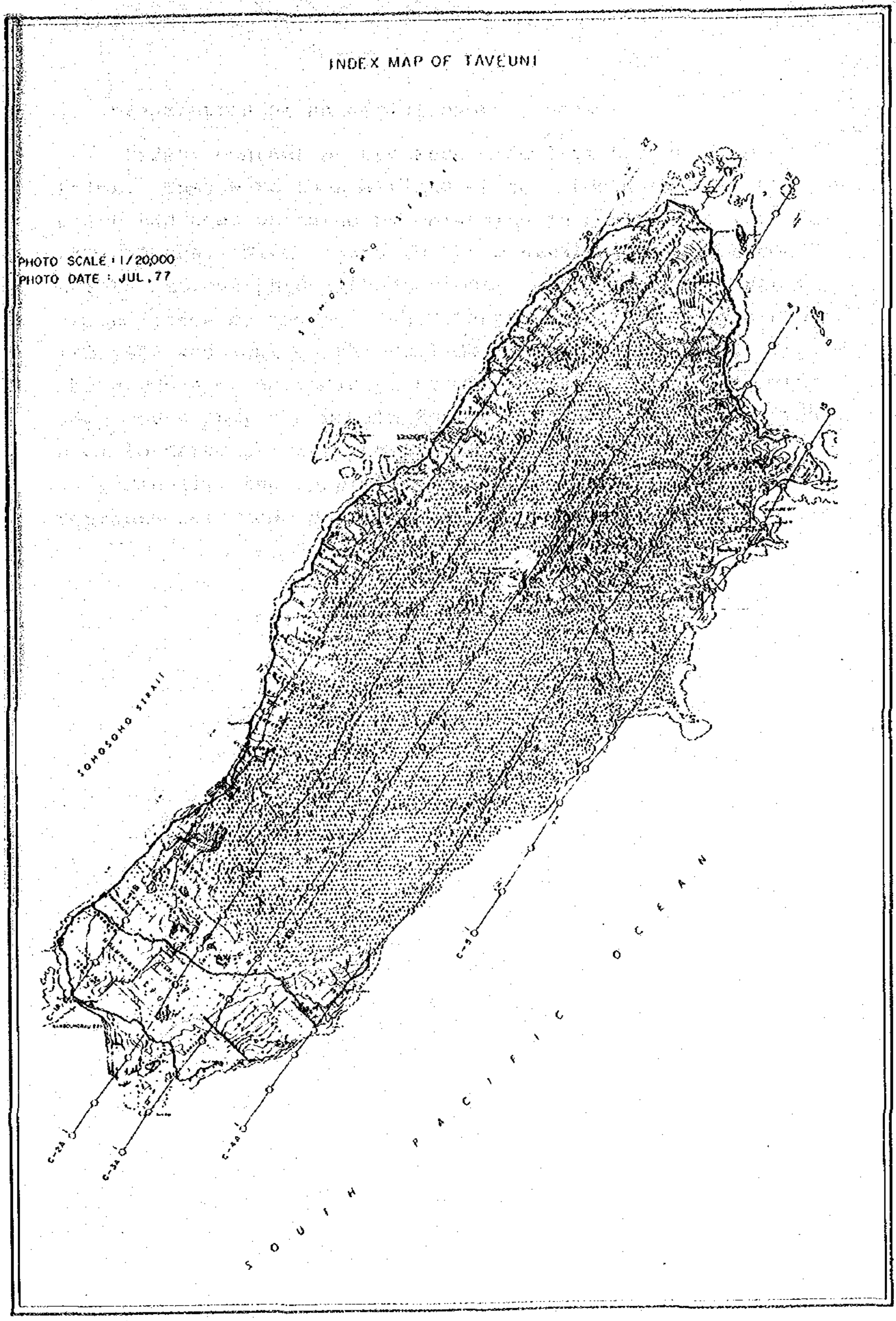


Fig. 4. Index map of Taveuni

4. Preparation of an aerial photo mosaic

First, contact prints were made from the developed films. They were then affixed on to a topographical map which had been prepared by enlarging in scale from 1/50,000 to 1/20,000. With regard to the central ridge which could not be photographed without clouds, existing aerial photographs taken by the British Government in 1965 (photo scale 1/20,000 and kept by the Fiji Government) were used. Though there was a lapse of 12 years with those photographs, since they cover only the virgin forest area near the peaks, they seem to serve the purpose of the present survey.

Finally, the completed mosaic was panelled, and its reprints were made on CH paper.

IV. PREPARATION OF A TOPOGRAPHICAL MAP

1. Field working

1-1. Pricking of control points for aerial triangulation.

Pricking of control points necessary for aerial triangulation was carried out at the existing triangulation points and subtriangulation points.

As Fig. 5 shows, datum points in Taveuni have already been surveyed and there are 15 triangulation points (including 3 subtriangulation points). Thus, aerial photographs enlarged four times were brought over to Taveuni for pricking of triangulation points. The triangulation points in this area are comparatively well kept, though many of them are under deep vegetation. Eventually the following points, excluding those at Uluiqalac and Viubani, were pricked.

Triangulation points	11
Sub-triangulation points	2

The operation included skeches of a position map of control station so that aerial triangulation could be carried out satisfactorily.

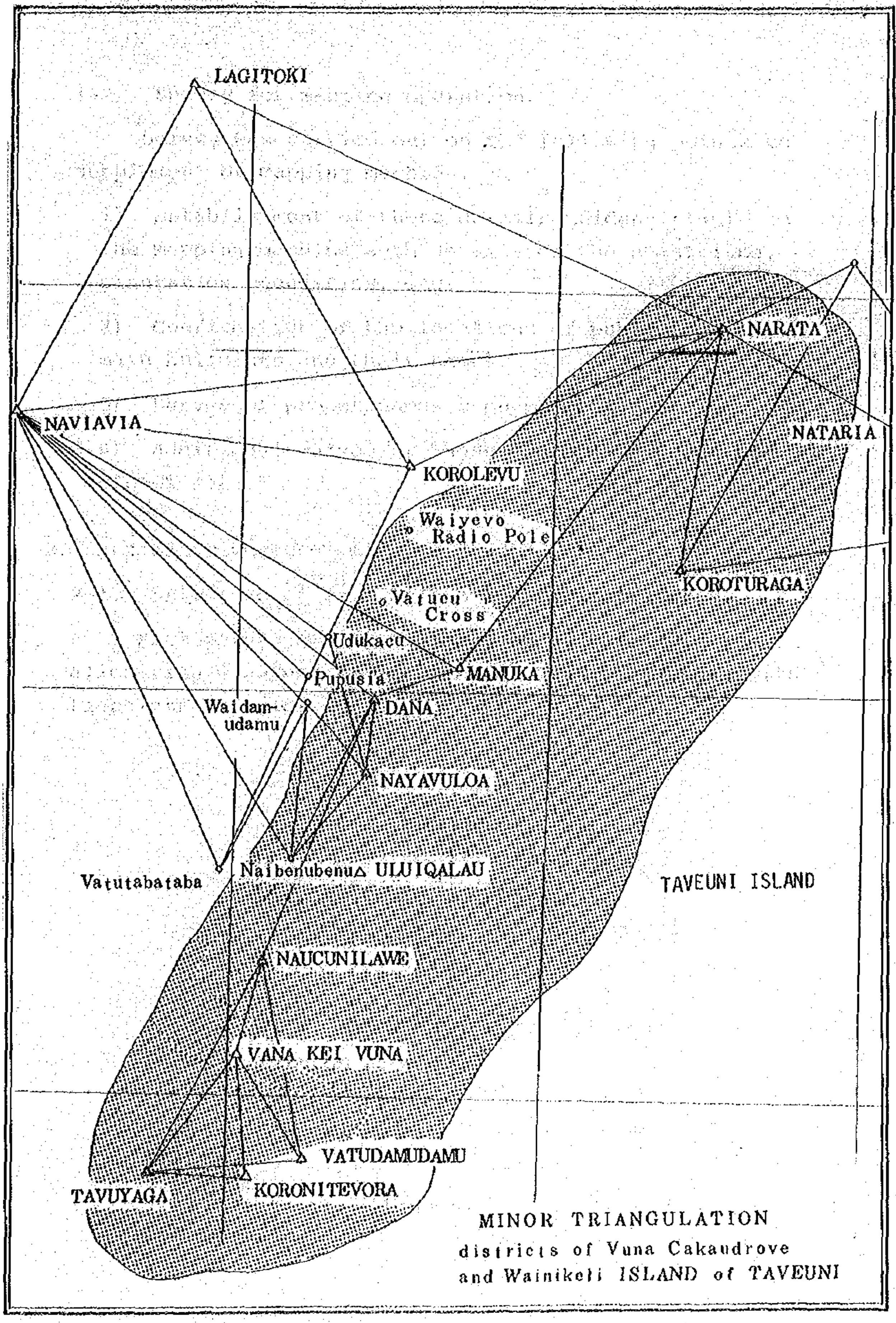


Fig. 5. Control point network for Taveuni Island

1-2. Survey for mapping operation

Survey was carried out on the following points to supplement by mapping machine.

1) Establishment of those details unidentifiable on the mapping machine such details of the coast line, plantation boundaries, etc.

2) Confirmation of the locations of public bodies and main buildings and their names.

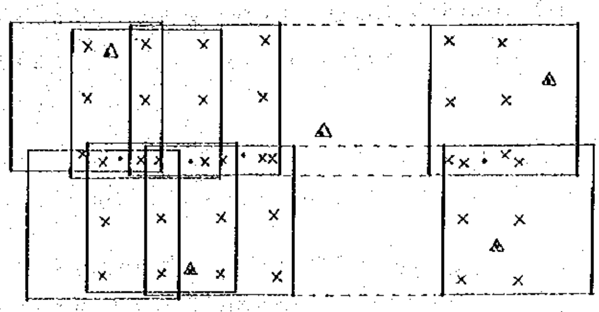
3) Survey of proper names such place names.

4) Additional survey of those incomplete areas due to cloudiness.

2. Aerial triangulation

2-1. Selection of pass points and their transfer.

Pass points necessary for mapping were selected, allocating 6 points to each aerial model, together with tiepoints as below.



Δ Control point
(Triangulation point)
× Pass point
• Tiepoint

Fig. 6.

Further, the positions of these pass points and of control points pricked in Taveuni were transfered on to positive films by using a point transfer device, P.U.G. by Wild Co.

2-2. Determination and calculation of coordinates

Coordinates on photographs were determined regarding the pass points and control points by using a stereo-comparator by Carl Zeiss.

Based on these coordinates, ground coordinates of pass points were calculated for each course by the analytical aerial triangulation method. Then, adjustment for all the courses was carried out by block adjustment method with tiepoints as connections. However, since there were not enough elevation points, clear independent elevation points were selected from a topographical map of the scale 1/50,000 to provide information on elevations. The electronic computer used for calculation was FACOM230-45OS.

The following results were obtained from the above operation (attached):-

Position map of control stations.	1 copy
Results of aerial triangulation.	1 copy
Positive films with pass points transferred (transferred on to the results obtained in V-3).	1 copy

3. Mapping of a topographical map

Mapping of a topographical map was carried out on the basis of pass points coordinates obtained by aerial triangulation described in the previous section and the results of the field survey. The mapping scale was 1/10,000 and the interval between contour lines was 10 m for main lines and 50 m for index contour lines. As for the mapping machine, the Planimat D2 by Carl Zeiss was used.

However, as for those area affected by clouds and the virgin forest areas not connected with coconut plantations, the contour lines were drawn on the basis of the topographical map of the scale 1/50,000 (prepared by the British Government and kept by the Fiji Government).

Finally, an original map was prepared by tracing the mapped original on polyester paper, which was then copied to obtain a copied original map.

VII. COCONUT FOREST INVENTORY

1. Formation of survey method.

1-1. Items needed for the survey.

In order to prepare basic material for the policy for regenerating and utilizing the aging coconut forests, those items required for the present survey can be summarized as follows:-

1) Accurate estimation of the total volume of coconut timber in Taveuni.

2) Its distribution and detail.

3) Development of procedure of research for coconut forest inventory and preparation of a work manual.

4) Preparation of aerial photo volume table and standard interpretation cards as basic material.

In other words, the survey was to obtain the total volume of coconut timber in Taveuni, to show exactly where it exists by a distribution map and a detailed table, to establish the method of coconut forest inventory through these operations and prepare a work manual which can be used by Fiji Government independently in future.

1-2. Outline of the method

The method to be used for the above purposes can be divided into two parts: survey of the total volume and more detailed survey of sections.

For the estimation of the total volume given under 1-1- 1), we decided to take a sampling method because of restrictions on the cost and the time.

The sampling method is to select at random samples from the target area for detailed examination. The results obtained are then used to induce the whole.

Since this method is based on statistical theories for induction, the estimates obtained possess statistical meanings.

However, the sampling method is basically to estimate the whole (total volume). Therefore, it does not provide the distribution and detail for the purpose given under 1-1- 2). Accordingly, another method has to be devised.

Since it is difficult in terms of costs to carry out field survey on the entire area, the method based on interpretation of aerial photographs was devised.

Aerial photographs have the function to catch directly the actual situation, and these are, therefore, most suitable for obtaining the distribution. Further, by using a photo volume table (a volume table for aerial photographs) or by comparing them with standard interpretation cards, (cards for interpretation of aerial photographs), the volume in each section can also be obtained. Since both the aerial photo volume table and standard interpretation cards are not available at present, the survey has to begin with preparation of these material first. However, in view of the possible extension of the survey to the entire country in future, it is worthwhile to prepare these material.

Thus, it was concluded that the best procedure for the present survey would be the combination of the sampling method and the detailed survey based on interpretation of aerial photographs.

Further, since the total volume will be accumulated in detailed survey, it can be evaluated to see if it is within the confidence limit of the total volume obtained by sampling method.

Fig. 7 gives the flow chart for the survey based on the combination method.

Further, for the above operation it is necessary to obtain a volume table of coconut stem as the basis. Therefore, sectional measurement will be carried out for about

100 sample trees. By analysing factors such as stem height a volume equation will be obtained to prepare a volume table.

By this method, data for each block of coconut forests (area, number of trees, tree height and volume), distribution map (1/10,000), location map (1/50,000) and a utilization plan can be obtained. For wider use, a coconut volume table, photo volume table, standard interpretation cards and a manual of coconut forest inventory were also obtained.

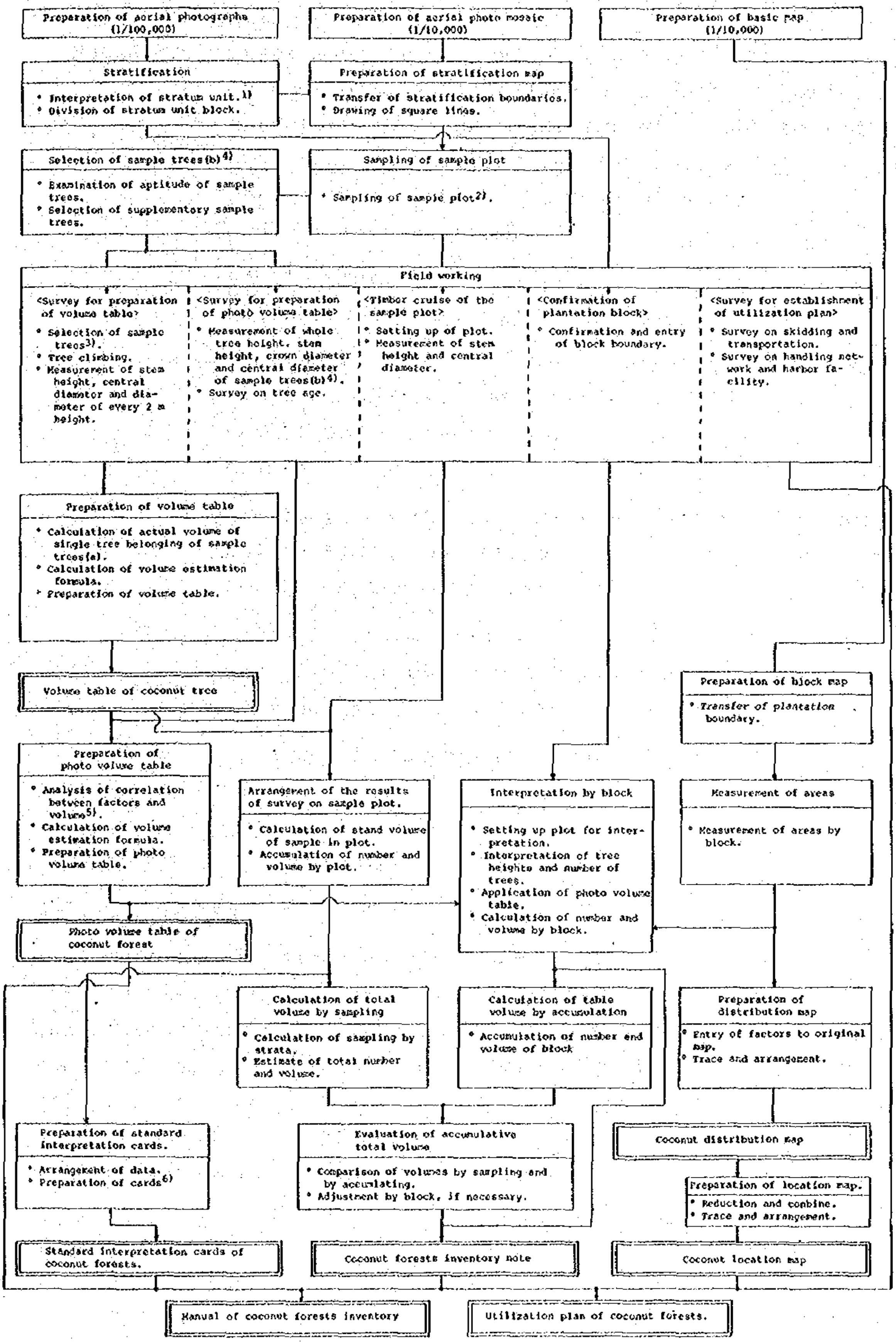


Fig. 7. Flow chart for survey of coconut forests

Notes: 1) Stratum unit.
Depends on age class (young, middle and old), structure of crown story (single, two-storied) and degree of utilization (in use, idle). 5 strata (4 strata in the case of sampling to exclude idle stratum).

2) Sample plot.
180 plots. Size: 0.2 ha (circle).

3) Sample trees (a).... For preparation of volume table, numbering 100. Measurement of stem height and diameter every 2 m height taken by climbing.

4) Sample trees (b).... For preparation of photo volume table, numbering 180. Trees closest to the center of sample plot.

5) Factors for correlation analysis. Factors examined for photo volume table: for example tree height, crown diameter and tree age.

6) Standard interpretation cards.
Cases: 20.

2. Planning and preparation

2-1. Planning

In order to carry out the survey satisfactorily, material relating to the survey was collected. The material collected included results obtained by the feasibility study team and the preliminary survey team and also various reports relating to coconut.

The survey was planned on the basis of these material and the situation in the target area.

2-2. Preparation

The following material was prepared to be used for the survey.

1) Aerial photograph (1/100,000).....The negatives obtained under V-3 were used to produce enlarged prints (2 times).

2) Aerial photo mosaic.....The negatives used for aerial photo mosaic under V-4 were used to produce 1/10,000 aerial photo mosaic.

3) Basic map (1/100,000).....The original map obtained under VI-3 was used to produce a copied original map to be used as the basic map.

4) 1/50,000 topographical map. The existing map was used.

3. Preliminary interpretation

First, the area of coconut forests was marked by interpreting aerial photographs. Further, plantation boundaries and boundaries in terms of planted year and forest type were marked.

Then, general data such as tree height and crown density were interpreted for every section. They were then arranged according to age class (young, middle and old), structure of the crown (single and two-storied) and the degree of utilization (utilized or idled) and marked temporarily with dermatograph pencil on the photograph.

4. Stratification

Stratification for sampling should be determined in such a way that variance within stratum would be small and variance between strata would be large depending on the type.

Various factors were examined to be considered for stratum unit, and age class (tree height considered), structure of crown story and the degree of utilization were found to be most suitable. Thus, stratification was carried out on the criteria given by Table 7. By using the temporary marks entered on the aerial photographs each section was examined in terms of stratification, and the boundaries based on stratification were then entered on the photographs.

Table 7.

Stratum unit	Code
Young forest in use	[YI]
Middle forest in use	[MI]
Old forest in use	[OI]
Two-storied forest in use	[DI]
Idle forest	[E]

These boundaries were then transferred on to the aerial photo mosaic. Polyester paper with square lines, each block representing an area 100 m x 100 m, was placed on the mosaic to trace the stratification boundaries. A running number was then given to each stratum to produce a stratification map.

An example of the aerial photo mosaic used for stratification and stratification map are given in Fig. 8.

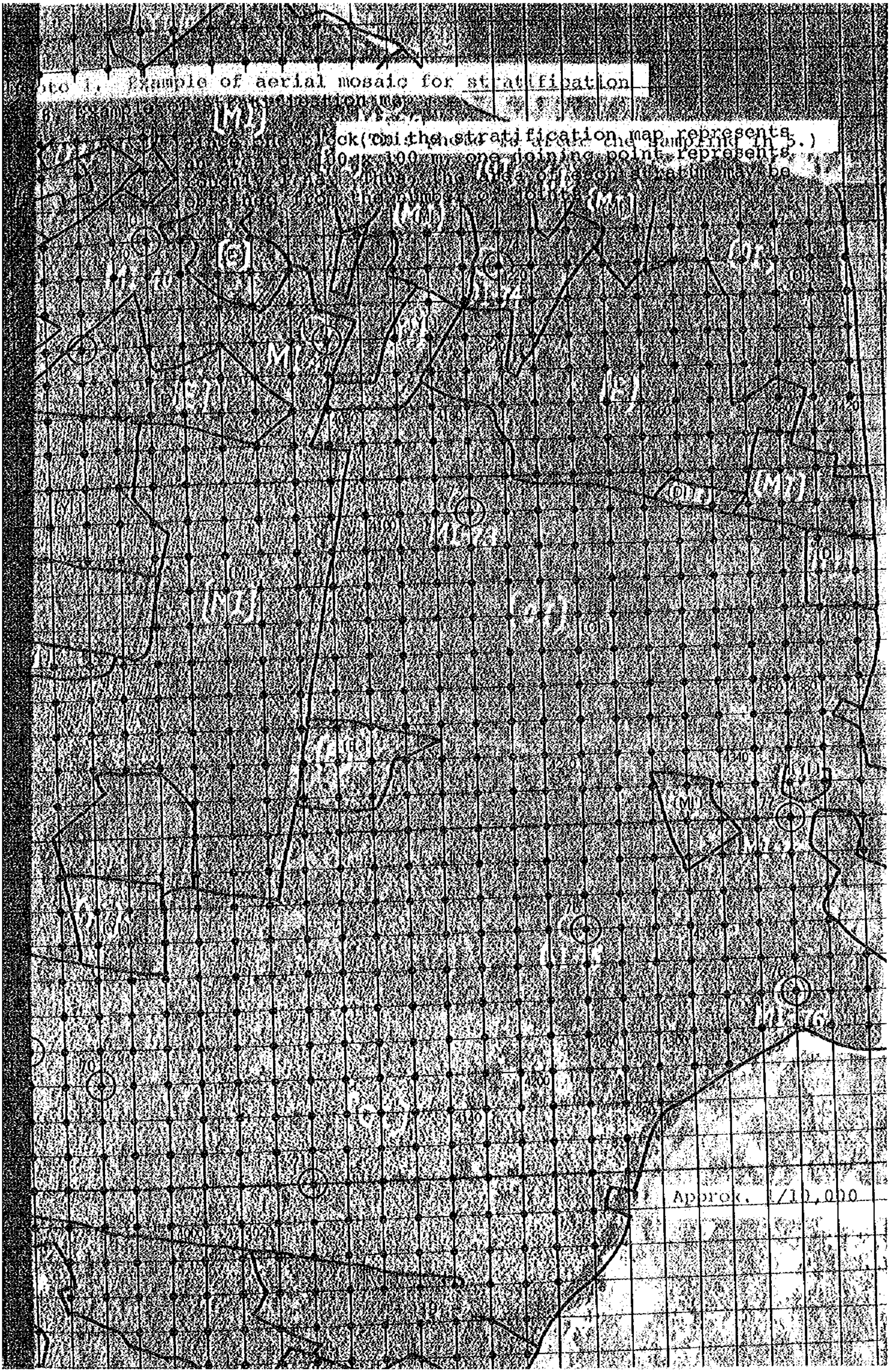


Photo 1. Example of aerial mosaic for stratification

...ck (on the stratification map represents
...00 x 100 m, one joining point represents

Photo 1. Example of aerial mosaic for stratification

(This photo is after the sampling in 5.)

Approx. 1/10,000

5. Sampling of sample plot and sample trees

5-1. Sampling of sample plot

Samples were selected by stratified random sampling. In the light of the work schedule and costs, the number of samples was to be 167, and allocation to each stratum was based on proportional allocation.

$$ni = \frac{Ai}{A} \cdot n$$

ni: number of samples in i-stratum.
n : total of samples (167)
Ai: area of i-stratum.
A: total area.

With regard to those belonging to E-stratum, since they are left idle, many of them are of extremely low density. Therefore, though they were dispersed over a wide area, they were not expected to influence the total volume, and it was decided not to include them as a target of sampling estimation. Allocation was, therefore, for the first four strata. However, since it might be necessary to have material concerning E-stratum for interpretation by block under the section 11, 13 samples were selected independently (thus the number of sample plots for timber cruise under 6-1 would be 180).

Allocation to each stratum was thus calculated as Table 8.

Table 8.

	Number of sample	Area (measured on photo mosaic)
[YI]	18	1,028 ha
[MI]	48	2,750
[OI]	90	5,181
[DI]	11	634
[E]	(13)	1,283
Total	180	10,876

These area volues were calculated from the aerial photo mosaic, and are not, therefore, real values on the field. However, they are expected to have enough accuracy to provide information for allocation to strata.

Selected samples were entered on the aerial photo mosaic with sample numbers. They were further transferred to aerial photographs for convenience in field work.

5-2. Selection of sample trees (b)

Sample trees (b) are those to be used for preparation of photo volume table. It requires more than 100 samples. Since it would not be objective enough to adopt observational sampling in this case, it was decided to use standing trees in those sample plots selected by random sampling under 5-1. In practice those which were closest to the center of the plot were used as a rule. Accordingly, the number of sample trees is the same as that of sample plots--180.

5-3. Selection of sample trees (a)

Sample trees (a) are those to be used for preparation of volume table. It also requires more than 100 samples. Basically they are of the same nature as that of sample trees (b), and it is desirable to have identical ones. However, since the field work for that purpose would be too extensive, it was decided to have the minimum number of about 100 which were selected from the sample trees (b).

6. Field working

6-1. Timber cruise of sample plot (survey for estimation of total volume).

Those photographs on which positions of samples were entered were taken to the survey area and the center of the sample plot was determined, and the circular plot of 0.2 ha (radial 25.23 m) was set up.

Then all the trees in the plot were measured for stem height (height from ground to first leaf) and central diameter (stem diameter at central height). Results of the measurement are contained in the Field survey note (Table 9 contains part of it).

Equipment used for the survey included Blume Leiss for stem height and the Relaskop for central diameter. Instructions for the use of Relaskop are given in Appendix IV.

Table 9. Field survey note

Plot No. - Plot area 0.2 ha

Tree No.	Stem height (m)	Central diameter: Measurement value with Relaskop	Central diameter: Correction value	Volume (m^3)	Tree No.	Stem height (m)	Central diameter: Measurement value with Relaskop	Central diameter: Correction value	Volume (m^3)
1					26				
2					27				
3					28				
4					29				
5					30				
6					31				
7					32				
8					33				
9					34				
10					35				
11					36				
12					37				
13					38				
14					39				
15					40				
16					41				
17					42				
18					43				
19					44				
20					45				
21					46				
22					47				
23					48				
24					49				
25					50				

	Number of tree per plot	Mean stem height	Mean central diameter: Measurement value	Mean central diameter: Correction value	Volume per plot	Number of tree per ha.	Volume per ha.
Upper tree							
Lower tree							
Total							

6-2. Survey for preparation of volume table

107 sample trees (a) were selected from sample trees (b) in the survey area to prepare volume table, taking into consideration the stratified distribution.

For preparing the volume table, stem volume, central diameter stem height, as the factor for estimation, are necessary in actual value. In order to obtain the actual volume of stem, the specimen tree should be felled, divided into roughly equal sections at the shortest possible intervals and measured at each section for diameter at bottom end and for diameter at top end. Then the volume can be obtained by Smalian's formula (see 7-1).

However, it was anticipated that cutting of some 100 sample trees would meet restrictions from the work schedule and also from compensation. Thus, it was decided to measure the standing tree by climbing at intervals of 2 m in height.

With regard to measuring by climbing, as Fig. 9 shows, the climber lowers one end of a 50 m tape to the ground and has it secured. He then takes the reading of stem height and measures the diameter at top end of stem (diameter tape to be used).

Then the end of the tape is secured at 0.3m above the ground level to exclude the stump section, and the climber measures the diameter at even numbers on the tape, (i.e., 24, 22...6, 4, 2m), while coming down from the top. Finally the diameter at 0.3m above the ground level and that at the ground level are to be measured.

With regard to the central diameter, it was obtained by taking the average of diameters at bottom and top ends of the section corresponding to the median of stem height.

For example, if the stem height is 15.0m, the median would be 15m/2=7.5m. Thus, if the diameter at 6m+0.3m is 28cm and that at 8m+0.3m is 26cm, the central diameter can be obtained as follows:-

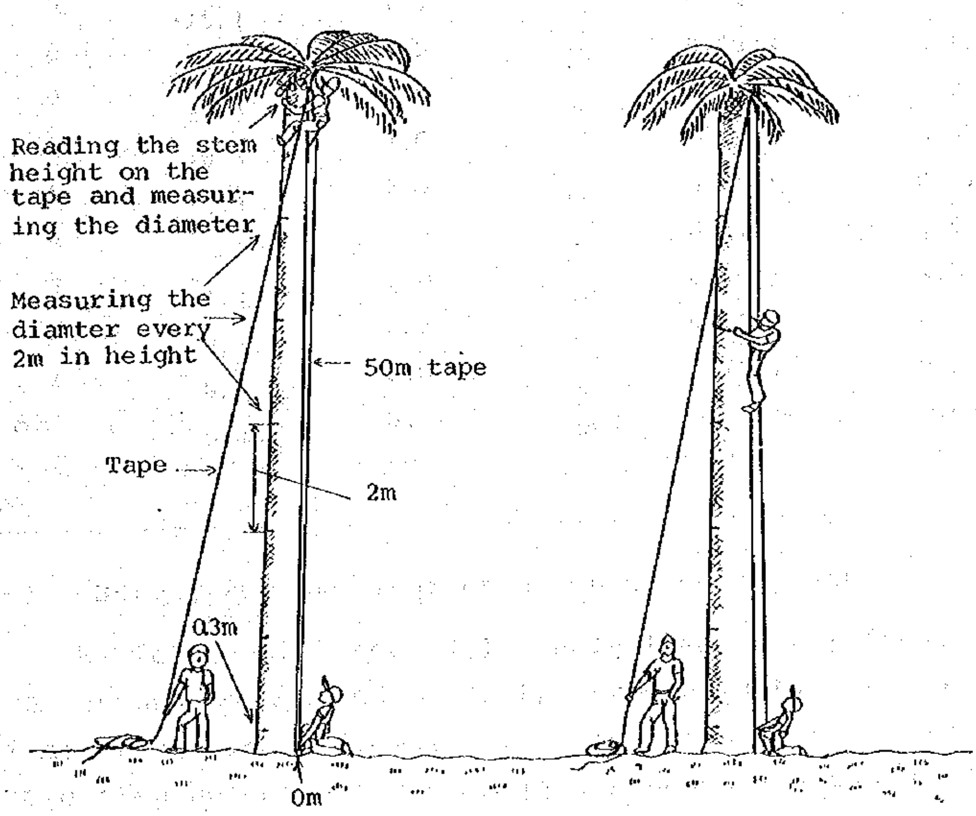
Difference in diameter between at
6+0.3m and at 8+0.3m .... 2 cm

Interval at the median ......(8m+0.3m)-(6m+0.3m)=2m
7.5m-(6m+0.3m)=1.2m

Difference in diameter for every 1 cm in height
2cm÷200cm=0.01cm

Difference in diameter from the height 6m+0.3m
0.01cm x 120cm=1.2cm
≑1cm

Therefore, the central diameter in this case would be
28cm-1cm=27cm



(1) The tape is to be secured at the ground level. Stem height and the diameter at top end of stem are to be measured.

(2) Then the tape is to be secured at 0.3m above the ground level, and the diameter is to be measured every 2m in height.

Fig. 9 Measurement of diameter, etc. by climbing

Results of the survey on sample trees are given in the appendix Coconut stem analysis report by climbing. (Table 10 gives an example.)

Table 10.

Sample tree No. 0-71 Species: Fiji Tall

Whole tree height : 235m Crown diameter: 75m Breast height diameter : 32cm Tree age : 70

Section No.	Accumulative height	Interval length	Diameter	Interval volume	Accumulative volume
Under	19.5		19		
leaf		1.19		0.0375	1.2153
section	18.3		21		
9	16.3	2.0	22	0.0727	1.1778
8	14.3	2.0	24	0.0833	1.1051
7	12.3	2.0	26	0.0983	1.0218
6	10.3	2.0	26	0.1062	0.9235
5	8.3	2.0	29	0.1191	0.8173
4	6.3	2.0	31	0.1416	0.6982
3	4.3	2.0	30	0.1462	0.5566
2	2.3	2.0	31	0.1462	0.4104
1	0.3	2.0	42	0.2140	0.2642
Stump	0.0m	0.3m	50cm	0.0502m^3	0.0502m^2

MEMO

6-3. Survey for preparation of photo volume table

As for sample trees (b), whole tree height (height from ground to top end of leaf), stem height, central diameter and crown diameter were measured. For measuring whole tree height and stem height Blume-Leiss was used and for central diameter and crown diameter Relaskop was used.

However, actually only whole tree height and crown diameter were measured as others duplicated those obtained under timber cruise in the plot.

Further, though tree age was surveyed as the plot represented the block, it was difficult to obtain accurate figures as many of the trees were 70 to 80 years old due to the old history of plantations in Taveuni. Information was obtained verbally from the native workers, which was supplemented by information obtained from the plantation owners. Results of the survey are given as Table 11.

Incidentally, the field survey revealed that the plot of 0.2ha in MI-stratum and also in E-stratum had no coconut trees. This was because the sample plot was selected at random from the stand in a stratum unit under Section 4. As a result, the number of samples to be used for analysis was 178.

Table 11. Survey results for preparation of photo volume table

Sample tree No.	No. in Stratum	Tree age	Age class Young	Middle	Old	Whole tree height (m)	Stem height (m)	Central diameter (cm)	Crown diameter (cm)
1	(OI)-1	60			○	22.5	18	22	750
2	2	65			○	21.5	18	22	750
3	3	60			○	19.5	16	24	600
4	4	50			○	21.5	18	24	750
5	5	60			○	17	13	24	780
6	6	60			○	27	23	24	600
7	7	60			○	19	16	24	560
8	8	60			○	18	15	20	740
9	9	60			○	21	18	24	700
10	10	60			○	16	12	26	560
11	11	60			○	21	17	24	740
12	12	60			○	18	15	24	720
13	13	60			○	16.5	13	20	960
14	14	60			○	19.5	16	24	800
15	15	60			○	21	17	26	700
16	16	65			○	24	20	24	720
17	17	70			○	19	15	22	620
18	18	15	○			15	10	28	900
19	19	10	○			12.5	8	28	750
20	20	15	○			15	10	24	720
21	21	60			○	23	18	24	700
22	22	70			○	25	20	22	700
23	23	30~40		○		25	21	32	800
24	24	25		○		17	13	24	820
25	25	40		○		24	20	32	700
26	26	25		○		19.5	15	32	800
27	27	50			○	18.5	14	24	720
28	28	19	○			17.5	13	28	760
29	29	10	○			11	6	30	820
30	30	13	○			16	8	28	850
31	31	50			○	22	18	24	750
32	32	70			○	28	21	22	800
33	33	70			○	27	20	28	800
34	34	80			○	23	20	24	550
35	35	80			○	19	16	20	540
36	36	80			○	24	21	26	660
37	37	70			○	23	19	22	580
38	38	50			○	18	14	20	830
39	39	50			○	21	17	24	750
40	40	60			○	19.5	16	26	820
41	41	50~60			○	22	18	26	680
42	42	50~60			○	23	20	24	660
43	43	50~60			○	21	18	24	660
44	44	40~50		○		16	13	20	540
45	45	60~70			○	21	18	20	540
46	46	70			○	22	17	20	680
47	47	70			○	23	18	22	750
48	48	60			○	18.5	14	20	700
49	49	60			○	15	11	32	820
50	50	20	○			20	14	26	640

Sample tree No.	No. in Stratum	Tree age	Age class			Whole tree height (m)	Stem height (m)	Central diameter (cm)	Crown diameter (cm)
			Young	Middle	Old				
51	[OI]-51	70			○	24	20	26	600
52	52	70			○	28	23	30	620
53	53	50			○	17.5	14	22	440
54	54	65			○	18.5	15	24	600
55	55	70			○	22	19	26	660
56	56	60~70			○	21	16	22	480
57	57	60~70			○	23	18	22	640
58	58	45		○		18.5	14	18	800
59	59	50			○	20.5	15	26	780
60	60	25		○		14	9	24	820
61	61	60			○	21	17	24	600
62	62	60			○	22	19	24	560
63	63	60			○	15	11	24	640
64	64	70			○	23	19	24	620
65	65	70			○	17	14	22	560
66	66	50			○	17	14	26	680
67	67	40			○	20	16	28	680
68	68	50			○	20	17	24	520
69	69	70			○	24.5	21	28	720
70	70	70			○	28	24	26	840
71	71	70			○	23	19	26	750
72	72	50			○	19.5	16	26	660
73	73	60			○	22.5	18	24	760
74	74	10	○			10	5	24	750
75	75	60				18	15	22	720
76	76	60			○	18	15	26	720
77	77	45		○		20.5	16	26	650
78	78	70			○	23	20	26	720
79	79	50			○	19	16	24	600
80	80	50			○	18	15	26	560
81	81	60			○	21	18	22	640
82	82	60			○	23.5	19	26	740
83	83	60			○	24	20	26	560
84	84	70			○	21.5	19	24	480
85	85	77			○	23	20	24	560
86	86	50			○	21	17	26	680
87	87	55~60			○	21	18	24	620
88	88	79			○	23	20	20	720
89	89	75			○	21	18	24	600
90	90	60			○	26	23	24	720

Sample tree No.	No. in Stratum	Tree age	Age class			Whole tree height (m)	Stem height (m)	Contral diameter (cm)	Crown diameter (cm)
			Young	Middle	Old				
91	(MI)-1	70			○	18	12	20	400
92	2	15	○			14	9	26	900
93	3	15	○			15	11	26	820
94	4	30~40		○		18.5	16	24	760
95	5	13	○			10	5	24	780
96	6	10	○			11	6	34	860
97	7	70			○	23	20	28	700
98	8	70			○	23.5	20	26	820
99	9	70			○	25	21	26	740
100	10	60			○	23	19	22	720
101	11	60			○	21.5	17	26	820
102	12	50			○	21.5	17	26	760
103	13	60			○	19	15	22	780
104	14	6~7	○			12	7	32	840
105	15	5	○			11	4	22	720
106	16	30		○		17.5	14	20	750
107	17	40		○		11	9	18	640
108	18	50~60			○	24	20	26	700
109	19	60~70			○	22	19	24	720
110	20	60			○	20	17	22	640
111	21	70			○	20	17	20	520
112	22	50			○	18	15	22	560
113	23	50			○	19	16	22	620
114	24	60			○	20	16	24	680
115	25	60			○	19	15	22	720
116	26	12	○			10	4	32	870
117	27	8~10	○			16	9	22	960
118	28	30		○		17	13	22	720
119	29	—		—		—	—	—	—
120	30	40		○		19	15	28	780
121	31	60			○	22.5	19	26	720
122	32	15	○			18	14	26	680
123	33	60			○	22	19	24	520
124	34	10	○			12	7	24	840
125	35	25		○		17	14	24	760
126	36	55			○	17	15	24	460
127	37	50			○	23	19	28	760
128	38	50			○	18.5	15	24	720
129	39	50			○	19	15	24	750
130	40	40		○		15.5	12	20	750
131	41	45		○		18.5	15	24	700
132	42	25		○		16	12	24	640
133	43	50~60			○	18	15	24	560
134	44	40		○		20	15	22	680
135	45	60			○	17	14	20	720
136	46	40		○		15	11	22	600
137	47	30		○		14.5	8	26	840
138	48	30~40		○		15	10	24	720

Sample tree No.	No. in Stratum	Tree age	Age class			Whole tree height (m)	Stem height (m)	Central diameter (cm)	Crown diameter (cm)
			Young	Middle	Old				
139	(YI) -1	6~7	○			12	5	26	980
140	2	6	○			12	5	22	880
141	3	10	○			13.5	9	30	800
142	4	15	○			12	7	24	960
143	5	60			○	27	21	24	720
144	6	7	○			6.5	2	24	800
145	7	10	○			14	11	24	800
146	8	10	○			14	11	24	680
147	9	10	○			17	8	26	880
148	10	7	○			7.5	3	24	800
149	11	4	○			12	5	32	880
150	12	7	○			5	1.5	22	560
151	13	19		○		9	4	24	800
152	14	7	○			11	5	26	880
153	15	5	○			8	2.5	28	760
154	16	15		○		9	5	28	780
155	17	10	○			11	6	28	750
156	18	5~6	○			8	5	22	640
157	(DI) -1	60			○	24	21	18	600
158	2	5	○			9.5	1.5	36	720
159	3	6	○			10	4	24	760
160	4	15		○		11	6.5	22	600
161	5	12	○			17	8	26	980
162	6	50			○	21	17	26	720
163	7	12	○			10	5	20	800
164	8	50			○	20	18	20	560
165	9	28		○		11	5	22	720
166	10	35		○		15.5	11	20	780
167	11	5	○			9.5	3	28	760
168	(E)— 9	40		○		20	17	22	680
169	12	50			○	18	15	18	560
170	13	—		—		—	—	—	—
171	20	75			○	20	17	20	540
172	21	50			○	20	16	26	780
173	22	40		○		22	19	26	640
174	31	15	○			11	6	22	800
175	38	5	○			9	4	26	640
176	40	60			○	16	13	18	640
177	44	52			○	18	14	20	540
178	45	70			○	21	17	22	560
179	48	65			○	24	19	22	800
180	50	45~50		○		21	18	26	560

6-4. Confirmation of plantation blocks

Plantations in Taveuni can be classified in three categories: 1) large-scale management (called estates locally and are often owned by foreigners); 2) Fijian management (around the villages); and 3) public plantations run by the government.

Information was collected verbally at the Agricultural Office in Taveuni regarding the plantation boundaries, which were entered on the photo mosaic. However, it was difficult to determine the plantation boundaries. Because these boundaries were not clear, and futher more, were not corresponded with owened boundaries. Since accurate plans were not available and information was based on personal recollections of the office staff, objectivity could not be established. However, as for afforestation after 1964, the area of afforestation in the plantation has been recorded on cards as it was financed by the Government.

Therefore, the plantation boundaries referred to in the present survey should be understood as those for the survey.

With regard to a disparate section due to the difference in tree height, the number of trees and density, it was treated as a forest type in preliminary interpretation of aerial photographs. It was then confirmed in the field survey and was entered on the photographs. Information on tree age obtained at the site was also considered.

6-5. Survey for establishment of utilization plan.

Survey was also conducted regarding skidding and transportation necessary for the establishment of utlization plan. Further, survey was conducted regarding the hauling network and harbor facilities for exportation, and new facilities were to be planned if necessary.

According to the results of the survey, the target area (coconut forests) are comparatively flat or gentle sloping ground. Consequently, skidding can be carried out by tractor or even by truck equipped with a winch in some parts. As for hauling, there were already walking roads in the plantations and they seemed to be suitable for the purpose, and there was no necessity of planning new roads.

Since there is only one harbor at present, it was anticipated that it would not be able to cope intensively with large quantities of export such as amounting to the total volume available in the island. However, it was found out through calculation of sustained yield that exportation amount to 16,000-17,000m^3 a year, so it would be able to cope. It was, however, found to be necessary to plan a new timber basin attached to the harbor.

7. Preparation of a volume table

7-1. Calculation of actual volume of a single tree belonging to sample trees (a).

Actual volume of a single sample tree was calculated by using the diameter values for every 2m in height obtained by climbing.

As for stereometry, Smalian's formula was used, and the results were accumulated to obtain the actual volume as below.

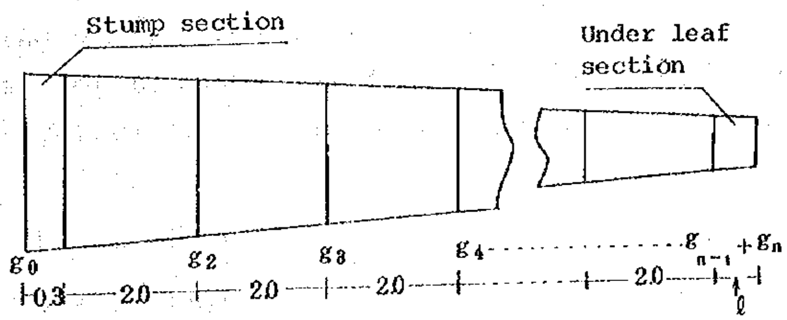


Fig. 10

Actual volume of a single tree = stump volume* + interval volume + volume of under leaf section.

$$\text{Stump volume} = \frac{g_0 + g_1}{2} \times 0.3$$

$$\text{Interval volume} = \frac{g_1+g_2}{2}\times 2.0 + \frac{g_2+g_3}{2}\times 2.0 + \ldots + \frac{g_{n-2}+g_{n-1}}{2}\times 2.0$$

$$= \left(\frac{g_1+g_{n-1}}{2} + g_2 + g_3 + \cdots + g_{n-2}\right) \times 2.0$$

$$\text{Volume of under leaf section} = \frac{g_{n-1} + g_n}{2} \times \ell$$

Results obtained are contained in the appendix Results of measurement of sample trees under Interval volume and Accumulative volume. The table gives as single tree volume the volume including stump volume, but the volume to be used as dependent variables for volume estimation formula described in the next section does not include stump volume.

7-2. Calculation of volume estimation formula and preparation of volume table.

In order to obtain volume estimation formula, regression analysis was made, using actual volumes of sample trees calculated under 7-1 as dependent variables and using stem height and central diameter which were thought to be closely related to them as variables.

However, since analytical study of this kind has never been made, it is necessary to find a suitable formula for estimating volume of coconut. For that purpose, the following three formula were examined to select the basic formula in the light of the nature of coconut stem which is close to log.

1	$V = a\ D^b \cdot H^c$	V	: Volume
2	$V = a\ (DH)^b$	D	: Central diameter
3	$V = a\ (D^2H)^b$	H	: Stem height
		a,b,c	: Parameter

Calculation was carried out by electronic computer (IBM 370/168). The results of regression analysis are given as Table 12.

Table 12.

	Stand volume formula	Multipl correlation coefficient	Number of data
1	$V = 0.0003\ D^{1.6235237} \cdot H^{0.967452}$	0.9806	107
2	$V = 0.0025\ (DH)^{0.9748259}$	0.9738	"
3	$V = 0.0001\ (D^2H)^{0.9549867}$	0.9791	"

As another indicator of precision, standard deviation of residuals and the rate of standard error were obtained from the difference between the actual measurements and estimated values for each formula as Table 13.

Table 13

	Mean residuals	Standard deviation of residuals	Rate of standard error
1	0.0074	0.0762	9.85 %
2	0.0087	0.0900	11.64 %
3	0.0076	0.0781	10.10 %

*Number of data = 107

$$\text{*Rate of standard error} = \frac{\text{Standard deviation of residual}}{\text{Mean of actual measurement}} \times 100$$

(Total of actual measurements 82.7594
Mean of actual measurements 0.77345)

As a result, the first formula with the highest multiple correlation coefficient and a low rate of standard error was found to be most suitable for volume estimation formula.

Thus, the volume estimation formula for coconut is:-

$$V = 0.0003 \cdot D^{1.6235237} \cdot H^{0.967452}$$

The volume table was prepared by the above formula, having central diameter and stem height as factors, presented as Table 14.

Though it was thought to be desirable to calculate separately for Fiji Tall and Malayan Dwarf, they were combined for calculation as there were few sample trees of Malayan Dwarf and there was not much difference in relation between stem volume and stem height.

Table 14. Volume table of coconut tree

V: Volume (m^3)
D: Central diameter (cm)
H: Stem height (m)

Volume estimation formula
$V = 0.0003 \times D^{1.6235237} \times H^{0.967452}$

H(m) \ D(cm)	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
1	0.0170	0.0218	0.0270	0.0327	0.0388	0.0453	0.0522	0.0595	0.0671	0.0750	0.0833	0.0919	0.1009	0.1101	0.1197
2	0.0311	0.0426	0.0529	0.0640	0.0760	0.0887	0.1021	0.1163	0.1312	0.1467	0.1629	0.1798	0.1973	0.2154	0.2341
3	0.0491	0.0630	0.0783	0.0948	0.1125	0.1313	0.1512	0.1722	0.1942	0.2172	0.2412	0.2661	0.2920	0.3188	0.3465
4	0.0648	0.0832	0.1034	0.1252	0.1485	0.1734	0.1997	0.2274	0.2565	0.2869	0.3186	0.3515	0.3857	0.4211	0.4577
5	0.0804	0.1033	0.1283	0.1553	0.1843	0.2152	0.2478	0.2822	0.3183	0.3560	0.3954	0.4362	0.4787	0.5226	0.5680
6	0.0959	0.1232	0.1531	0.1853	0.2199	0.2567	0.2956	0.3367	0.3797	0.4247	0.4716	0.5204	0.5710	0.6234	0.6775
7	0.1114	0.1430	0.1777	0.2151	0.2553	0.2980	0.3432	0.3908	0.4408	0.4930	0.5475	0.6041	0.6628	0.7237	0.7865
8	0.1267	0.1628	0.2022	0.2448	0.2904	0.3391	0.3905	0.4447	0.5015	0.5610	0.6230	0.6874	0.7542	0.8234	0.8950
9	0.1420	0.1824	0.2266	0.2743	0.3255	0.3800	0.4376	0.4984	0.5621	0.6287	0.6982	0.7704	0.8453	0.9228	1.0030
10	0.1573	0.2020	0.2509	0.3038	0.3604	0.4208	0.4846	0.5518	0.6224	0.6962	0.7731	0.8530	0.9360	1.0219	1.1106
11	0.1725	0.2215	0.2751	0.3331	0.3952	0.4614	0.5314	0.6051	0.6825	0.7634	0.8477	0.9354	1.0264	1.1206	1.2179
12	0.1876	0.2410	0.2993	0.3624	0.4300	0.5019	0.5718	0.6583	0.7425	0.8305	0.9222	1.0176	1.1165	1.2190	1.3248
13	0.2027	0.2604	0.3234	0.3915	0.4646	0.5423	0.6246	0.7113	0.8022	0.8973	0.9964	1.0995	1.2064	1.3171	1.4315
14	0.2178	0.2797	0.3474	0.4206	0.4991	0.5826	0.6710	0.7642	0.8619	0.9640	1.0705	1.1812	1.2961	1.4150	1.5379
15	0.2328	0.2990	0.3714	0.4497	0.5336	0.6229	0.7174	0.8169	0.9214	1.0306	1.1444	1.2628	1.3856	1.5127	1.6441
16	0.2478	0.3183	0.3953	0.4786	0.5679	0.6630	0.7636	0.8695	0.9807	1.0970	1.2181	1.3441	1.4748	1.6101	1.7500
17	0.2628	0.3375	0.4192	0.5076	0.6022	0.7030	0.8097	0.9221	1.0400	1.1632	1.2917	1.4253	1.5639	1.7074	1.8557
18	0.2777	0.3567	0.4431	0.5364	0.6365	0.7430	0.8557	0.9745	1.0911	1.2294	1.3652	1.5064	1.6528	1.8045	1.9612
19	0.2926	0.3759	0.4668	0.5652	0.6707	0.7829	0.9017	1.0268	1.1581	1.2954	1.4385	1.5873	1.7416	1.9014	2.0665
20	0.3075	0.3950	0.4906	0.5940	0.7048	0.8227	0.9476	1.0791	1.2170	1.3613	1.5117	1.6680	1.8302	1.9981	2.1716
21	0.3224	0.4141	0.5145	0.6227	0.7389	0.8625	0.9934	1.1312	1.2759	1.4271	1.5847	1.7486	1.9187	2.0947	2.2766
22	0.3372	0.4331	0.5380	0.6514	0.7729	0.9022	1.0391	1.1833	1.3346	1.4928	1.6577	1.8291	2.0070	2.1911	2.3814
23	0.3520	0.4522	0.5616	0.6800	0.8068	0.9419	1.0848	1.2353	1.3932	1.5584	1.7305	1.9095	2.0952	2.2874	2.4816
24	0.3668	0.4712	0.5852	0.7086	0.8407	0.9814	1.1304	1.2872	1.4518	1.6239	1.8033	1.9898	2.1832	2.3856	2.5905
25	0.3816	0.4901	0.6088	0.7371	0.8746	1.0210	1.1759	1.3391	1.5103	1.6893	1.8759	2.0699	2.2712	2.4796	2.6949
26	0.3964	0.5091	0.6323	0.7656	0.9084	1.0605	1.2214	1.3909	1.5687	1.7546	1.9484	2.1500	2.3590	2.5755	2.7991
27	0.4111	0.5280	0.6559	0.7941	0.9422	1.0999	1.2668	1.4426	1.6270	1.8199	2.0209	2.2299	2.4468	2.6718	2.9032
28	0.4258	0.5469	0.6794	0.8225	0.9760	1.1393	1.3121	1.4942	1.6853	1.8850	2.0933	2.3098	2.5344	2.7669	3.0072
29	0.4406	0.5658	0.7028	0.8509	1.0097	1.1786	1.3575	1.5458	1.7435	1.9501	2.1655	2.3895	2.6219	2.8624	3.1110
30	0.4552	0.5847	0.7262	0.8793	1.0433	1.2179	1.4027	1.5974	1.8016	2.0151	2.2378	2.4692	2.7093	2.9579	3.2148
31	0.4699	0.6035	0.7497	0.9076	1.0769	1.2572	1.4479	1.6489	1.8597	2.0806	2.3099	2.5488	2.7966	3.0532	3.3184
32	0.4846	0.6224	0.7730	0.9359	1.1105	1.2964	1.4931	1.7003	1.9177	2.1450	2.3819	2.6283	2.8839	3.1485	3.4219
33	0.4992	0.6412	0.7964	0.9642	1.1441	1.3356	1.5382	1.7517	1.9756	2.2098	2.4539	2.7077	2.9710	3.2436	3.5235
34	0.5138	0.6600	0.8197	0.9925	1.1776	1.3747	1.5883	1.8030	2.0335	2.2745	2.5258	2.7871	3.0581	3.3386	3.6286

8. Arrangement of the results of survey on sample plot

8-1. Examination of remote measurements of stem height, etc.

In the survey of sample plot under 6-1, stem height and central diameter of those trees in the plot were measured remotely with Blume-Leiss and Relaskop respectively. Therefore, there was some doubt as to the use of the values as they were for the volume table. Hence it was decided to examine them.

As for material, sample trees (a) for preparation of volume table were measured for stem height and central diameter, and they were also measured remotely as part of the timber cruise in the sample plot for sampling. It was decided, therefore, to use these figures.

Table 15 is a result of combining actual measurements and remote measurement values for each sample tree taken from the appendix Results of the survey on sample trees and Table 9.

Table 15-1. Actual measurements and remote measurements (with Blume-Leiss) of stem height of sample trees (a)

Sample tree		Stem height		Sample tree		Stem height		Sample tree		Stem height	
№	No. in Stratum	Actual measurement	Remote measurement	№	No. in Stratum	Actual measurement	Remote measurement	№	No. in Stratum	Actual measurement	Remote measurement
1	O-34	21.0	20.0	37	O-61	17.2	17.0	73	Y-11	4.5	5.0
2	O-38	14.2	14.0	38	E-38	3.4	4.0	74	O-89	18.9	18.0
3	O-37	20.0	19.0	39	D-3	3.0	4.0	75	M-47	6.9	8.0
4	D-4	5.8	6.5	40	Y-2	4.4	5.0	76	O-88	20.0	20.0
5	O-36	21.2	21.0	41	S-1	12.0	12.0	77	Y-16	5.4	5.0
6	O-8	15.5	15.0	42	S-2	19.9	19.0	78	O-85	18.8	20.0
7	O-12	15.3	15.0	43	D-5	7.0	8.0	79	M-48	10.0	10.0
8	O-14	15.3	16.0	44	S-3	13.5	14.0	80	O-10	12.7	12.0
9	O-15	17.7	17.0	45	O-50	12.5	14.0	81	M-15	3.9	4.0
10	O-11	16.7	17.0	46	O-51	21.6	20.0	82	Y-6	2.2	2.0
11	O-6	22.6	23.0	47	M-26	5.6	4.0	83	E-31	5.8	6.0
12	O-7	15.4	16.0	48	M-25	18.3	15.0	84	O-58	15.3	14.0
13	O-9	17.3	18.0	49	E-20	18.3	17.0	85	M-30	15.5	15.0
14	Y-4	6.3	7.0	50	O-52	21.3	23.0	86	O-59	15.0	15.0
15	M-9	20.0	21.0	51	E-21	15.3	16.0	87	M-31	20.3	19.0
16	M-8	19.3	20.0	52	D-8①	20.3	18.0	88	M-32	14.6	14.0
17	O-35	16.5	16.0	53	〃 ②	4.5	4.0	89	M-39	16.0	15.0
18	M-7	19.9	20.0	54	O-56	16.3	16.0	90	Y-10	3.0	3.0
19	D-2	1.5	1.5	55	M-27①	8.3	9.0	91	M-40①	11.4	12.0
20	M-33	2.0	2.0	56	〃 ②	18.3	17.0	92	〃 ②	4.0	4.0
21	Y-12	1.6	1.5	57	D-7①	5.8	5.0	93	M-41	14.3	15.0
22	Y-15	2.3	2.5	58	〃 ②	15.3	16.0	94	O-72	15.9	16.0
23	O-76	14.4	15.0	59	M-28	13.3	13.0	95	M-38	14.7	15.0
24	M-18	20.0	20.0	60	O-57	17.3	18.0	96	D-10	11.3	11.0
25	M-17	9.2	9.0	61	E-45	16.0	17.0	97	O-74	5.6	5.0
26	O-45	21.0	18.0	62	E-44	13.3	14.0	98	O-73	16.6	18.0
27	E-12	16.6	15.0	63	E-40	13.3	13.0	99	O-84	19.0	19.0
28	M-22	16.4	15.0	64	O-63	11.3	11.0	100	O-83	20.6	20.0
29	M-23	15.7	16.0	65	O-64	19.3	19.0	101	O-82	19.5	19.0
30	O-53	15.8	14.0	66	Y-9	7.4	8.0	102	O-86	17.1	17.0
31	D-6	18.0	17.0	67	O-65	15.3	14.0	103	O-69	21.0	21.0
32	E-22	18.0	19.0	68	D-9①	18.3	17.0	104	O-70	23.6	24.0
33	O-54	16.0	15.0	69	〃 ②	5.4	5.0	105	O-67	16.3	16.0
34	O-55	19.5	19.0	70	M-44	14.4	15.0	106	O-71	19.5	19.0
35	Y-7	11.5	11.0	71	Y-13	4.0	4.0	107	O-77	16.6	16.0
36	Y-8	10.8	11.0	72	E-48	17.6	19.0				

* Under No. within Stratum, O, M, Y, D, E are abbreviations of [OI]; [MI]; [YI]; [DI] · and [E] respectively.
* Under No. within Stratum, S 1-3 are data collected outside the sample plot.

Table 15-2. Actual measurements and remote measurements (with Relaskop) of central diameter of sample trees (a)

Sample tree		Central diameter		Sample tree		Central diameter		Sample tree		Central diameter	
№	No. in Stratum	Actual measurement	Remote measurement	№	No. in Stratum	Actual measurement	Remote measurement	№	No. in Stratum	Actual measurement	Remote measurement
1	O-34	28.0	24.0	37	O-61	24.0	24.0	73	Y-11	32.5	32.0
2	O-38	24.0	20.0	38	E-38	28.0	26.0	74	O-89	28.5	24.0
3	O-37	25.0	22.0	39	D-3	29.0	24.0	75	M-47	24.0	26.0
4	D-4	25.0	22.0	40	Y-2	23.5	22.0	76	O-88	26.5	20.0
5	O-36	28.0	26.0	41	S-1	23.5	20.0	77	Y-16	28.0	28.0
6	O-8	26.0	20.0	42	S-2	27.0	20.0	78	O-85	25.5	24.0
7	O-12	26.0	24.0	43	D-5	32.5	26.0	79	M-48	27.0	24.0
8	O-14	26.0	24.0	44	S-3	22.5	24.0	80	O-10	24.0	22.0
9	O-15	27.0	26.0	45	O-50	29.5	26.0	81	M-15	24.0	22.0
10	O-11	28.0	24.0	46	O-51	28.5	26.0	82	Y-6	24.0	24.0
11	O-6	24.0	24.0	47	M-26	32.0	32.0	83	E-31	25.0	22.0
12	O-7	25.0	24.0	48	M-25	27.5	22.0	84	O-58	22.0	18.0
13	O-9	27.0	24.0	49	E-20	24.5	20.0	85	M-30	29.0	28.0
14	Y-4	27.0	24.0	50	O-52	29.0	30.0	86	O-59	29.0	26.0
15	M-9	29.0	26.0	51	E-21	25.5	26.0	87	M-31	28.0	26.0
16	M-8	28.0	26.0	52	D-8(1)	25.0	20.0	88	M-32	26.0	26.0
17	O-35	25.0	20.0	53	〃 (2)	21.5	22.0	89	M-39	26.0	24.0
18	M-7	31.0	28.0	54	O-56	27.0	22.0	90	Y-10	24.0	24.0
19	D-2	39.0	34.0	55	M-27(1)	30.5	22.0	91	M-40(1)	21.0	20.0
20	M-33	40.0	30.0	56	〃 (2)	24.5	20.0	92	〃 (2)	22.0	22.0
21	Y-12	24.0	22.0	57	D-7(1)	24.0	20.0	93	M-41	26.0	24.0
22	Y-15	30.0	28.0	58	〃 (2)	29.0	24.0	94	O-72	28.0	26.0
23	O-76	27.0	26.0	59	M-28	26.5	22.0	95	M-38	24.0	24.0
24	M-18	30.0	26.0	60	O-57	23.0	22.0	96	D-10	21.0	20.0
25	M-17	20.0	18.0	61	E-45	21.5	22.0	97	O-74	24.0	24.0
26	M-45	26.0	20.0	62	E-44	23.0	20.0	98	O-73	29.0	24.0
27	E-12	25.0	18.0	63	E-40	24.0	18.0	99	O-84	27.0	24.0
28	M-22	26.0	22.0	64	O-63	31.0	24.0	100	O-83	25.0	26.0
29	M-23	27.0	22.0	65	O-64	27.5	24.0	101	O-82	26.0	26.0
30	O-53	22.0	22.0	66	Y-9	31.0	26.0	102	O-86	26.0	26.0
31	D-6	27.0	26.0	67	O-65	25.5	22.0	103	O-69	27.0	28.0
32	E-22	27.0	26.0	68	D-9(1)	24.0	20.0	104	O-70	28.0	26.0
33	O-54	26.0	24.0	69	〃 (2)	24.0	22.0	105	O-67	29.0	28.0
34	O-55	25.0	26.0	70	M-44	24.5	22.0	106	O-71	26.0	26.0
35	Y-7	31.0	24.0	71	Y-13	23.0	24.0	107	O-77	26.0	26.0
36	Y-8	27.0	24.0	72	E-48	28.0	22.0				

On the basis of actual values and measured values, the result of correlation analysis and regression formula can be obtained by means of regression analysis as below.

Examination of stem height:

Mean of measured value .... $\bar{x} = 1459 / 107 = 13.64$

Mean of actual values .... $\bar{y} = 1474.4 / 107 = 13.78$

Sum of the square deviation
of measured values .... $S^2x = 3595.79$

Sum of the square deviation
of actual values........................ $S^2y = 3762.59$

Sum of products deviation
of measured and actual values .... $Sxy = 3636.80$

Sum of products deviation of
measured and actual values .... $b = 1.0114$

Regression constant .... $a = -0.0155$

Regression formula .... $y = -0.0155 + 1.0114x$

Correlation coefficient .... $e = 0.98873$

Where

Sum of the measured value .... $\Sigma x = 1459$

Sum of the squared measured value .... $\Sigma x^2 = 23490$

Sum of the actual value.................. $\Sigma y = 1474.4$

Sum of the squared actual value .... $\Sigma y^2 = 24079.0$

Sum of products of measured
and actual values .... $\Sigma xy = 23741$

Number of sample : 107

Examination of central diameter

Mean of measured values .... $\bar{x} = 2554 / 107 = 23.87$

Mean of actual values .... $\bar{y} = 2830.5 / 107 = 26.45$

Sum of the square deviation
of measured values .... $S^2x = 970.17$

Sum of the square deviation
of actual values .... $S^2y = 1073.27$

Sum of products deviation
of measured and actual values .... $Sxy = 71635$

Regression coefficient .... $b = 0.7384$

Regression constant .... $a = 8.824$

Regression formula .... $y = 8.8 + 0.7384x$

Correlation coefficient .... $e = 0.7020z$

Where

Sum of the measured value .... $\Sigma x = 2554$

Sum of the squared measured value .... $\Sigma x^2 = 61932$

Sum of the actual value .... $\Sigma y = 28305$

Sum of the squared actual value .... $\Sigma y^2 = 759425$

Sum of products of measured
and actual values .... $\Sigma xy = 68278$

Number of sample : 107

According to the above results, measured values of stem height had a high correlation coefficient of 0.98873, and the regression formula was close to actual value=measured value. Thus it was found out that remote measurements could be used without any problem if they were used in meters unit.

On the other hand, as for central diameter, the measurements showed a low correlation coefficient of 0.70202 compared with that in the case of stem height. Further, the regression constant was high with 8.8. Thus it was found necessary to make adjustments.

In order to bring measured values nearer to actual values, it is necessary to adjust as below.

8.8 + 0.7384 × (measured values with Relaskop).

For that purpose, it was decided to adjust the measured values of central diameter taken with Relaskop in timber cruise based on Table 16.

Table 16.

Central diameter		Central diameter	
Measured value	Adjusted value	Measured value	Adjusted value
10 cm	16.2 cm	30 cm	31.0 cm
12	17.7	32	32.4
14	19.1	34	33.9
16	20.6	36	35.4
18	22.1	38	36.9
20	23.6	40	38.3
22	25.0	42	39.8
24	26.5	44	41.3
26	28.0	46	42.8
28	29.5	48	44.2

8-2. Accumulation of number and volume by each plot

By using the stand volume table prepared under 8-1 (Table 17), stand volume of all the trees in the plot was obtained and written under Volume of the Field survey note. And volumes of single trees were accumulated for each plot, thus the number and volume were arranged by each plot. The results are given as Appendix I: Table of field survey results.

In this case, the volume table prepared under 7-2 is not suitable for the following operations as it was prepared using the measurement of central diameter taken for every 2 cm. Therefore, another volume table using adjusted values of central diameter which respond to measured values for every 2 cm with Relaskop was prepared as Table 17.

Table 17. Volume table of coconut tree (for measured values with Relaskop)

V : Volumes (m^3)
D_1: Measured central daimeter with Relaskop
D2: Modified central diameter
H : Stem height (m)

Volumes estimation formula

$$V = 0.0003 \times D^{1.6235237} \times H^{0.967452}$$

D_1 (cm) / D_2 / H (m)	(12) 17.7	(14) 19.1	(16) 20.6	(18) 22.1	(20) 23.6	(22) 25.0	(24) 26.5	(26) 28.0	(28) 29.5	(30) 31.0	(32) 32.4	(34) 33.9	(36) 35.4	(38) 36.9	(40) 38.3
0.5	0.0163	0.0184	0.0208	0.0234	0.0260	0.0285	0.0314	0.0343	0.0373	0.0405	0.0435	0.0468	0.0502	0.0537	0.0570
1	0.0319	0.0361	0.0408	0.0457	0.0580	0.0558	0.0613	0.0671	0.0730	0.0791	0.0850	0.0915	0.0982	0.1050	0.1116
1.5	0.0472	0.0534	0.0603	0.0676	0.0752	0.0826	0.0908	0.0993	0.1081	0.1171	0.1259	0.1355	0.1453	0.1554	0.1651
2	0.0623	0.0750	0.0797	0.0893	0.0994	0.1091	0.1200	0.1312	0.1428	0.1547	0.1662	0.1789	0.1920	0.2053	0.2181
2.5	0.0773	0.0875	0.0980	0.1109	0.1233	0.1354	0.1489	0.1628	0.1772	0.1920	0.2063	0.2220	0.2382	0.2548	0.2707
3	0.0922	0.1044	0.1180	0.1322	0.1471	0.1615	0.1776	0.1942	0.2114	0.2291	0.2461	0.2649	0.2842	0.3040	0.3229
3.5	0.1071	0.1211	0.1370	0.1535	0.1708	0.1875	0.2061	0.2254	0.2453	0.2659	0.2857	0.3075	0.3299	0.3528	0.3748
4	0.1218	0.1378	0.1558	0.1747	0.1943	0.2134	0.2346	0.2565	0.2792	0.3026	0.3251	0.3499	0.3755	0.4015	0.4265
4.5	0.1365	0.1545	0.1746	0.1958	0.2178	0.2391	0.2629	0.2875	0.3129	0.3391	0.3643	0.3921	0.4206	0.4500	0.4780
5	0.1512	0.1711	0.1934	0.2168	0.2412	0.2648	0.2911	0.3183	0.3464	0.3755	0.4034	0.4342	0.4658	0.4982	0.5293
6	0.1803	0.2040	0.2307	0.2586	0.2877	0.3159	0.3472	0.3797	0.4133	0.4479	0.4812	0.5179	0.5556	0.5944	0.6314
7	0.2093	0.2369	0.2678	0.3002	0.3339	0.3667	0.4031	0.4408	0.4797	0.5220	0.5586	0.6012	0.6450	0.6899	0.7329
8	0.2382	0.2695	0.3047	0.3416	0.3800	0.4173	0.4587	0.5015	0.5459	0.5917	0.6357	0.6841	0.7339	0.7851	0.8340
9	0.2669	0.3012	0.3415	0.3828	0.4259	0.4676	0.5140	0.5621	0.6118	0.6631	0.7124	0.7667	0.8225	0.8799	0.9347
10	0.2956	0.3345	0.3782	0.4239	0.4716	0.5178	0.5692	0.6224	0.6774	0.7342	0.7888	0.8490	0.9108	0.9743	1.0350
11	0.3241	0.3668	0.4147	0.4648	0.5171	0.5678	0.6242	0.6825	0.7492	0.8052	0.8650	0.9310	0.9988	1.0684	1.1350
12	0.3526	0.3990	0.4511	0.5056	0.5625	0.6177	0.6790	0.7425	0.8081	0.8759	0.9410	1.0127	1.0865	1.1622	1.2346
13	0.3810	0.4311	0.4874	0.5463	0.6078	0.6674	0.7336	0.8022	0.8732	0.9464	1.0167	1.0943	1.1740	1.2558	1.3340
14	0.4093	0.4632	0.5236	0.5869	0.6530	0.7170	0.7882	0.6619	0.9381	1.0167	1.0923	1.1756	1.2612	1.3491	1.4332
15	0.4376	0.4951	0.5598	0.6275	0.6981	0.7665	0.8426	0.9214	1.0028	1.0869	1.1677	1.2567	1.3485	1.4422	1.5321
16	0.4658	0.5270	0.5959	0.6679	0.7430	0.8159	0.8969	0.9807	1.0674	1.1569	1.2430	1.3377	1.4351	1.5352	1.6308
17	0.4939	0.5589	0.6319	0.7082	0.7879	0.8652	0.9510	1.0400	1.1319	1.2268	1.3180	1.4185	1.5218	1.6279	1.729
18	0.5220	0.5906	0.6678	0.7485	0.8327	0.9144	1.0051	1.0991	1.1963	1.2966	1.3930	1.4992	1.6084	1.7204	1.8277
19	0.5500	0.6224	0.7036	0.7887	0.8774	0.9635	1.0591	1.1581	1.2605	1.3662	1.4678	1.5797	1.6947	1.8128	1.9258
20	0.5780	0.6540	0.7394	0.8288	0.9221	1.0125	1.1130	1.2170	1.3246	1.4357	1.5424	1.6600	1.7809	1.9051	2.0238
21	0.6059	0.6850	0.7752	0.8689	0.9666	1.0614	1.1668	1.2759	1.3887	1.5051	1.6170	1.7403	1.8676	1.9971	2.1216
22	0.6338	0.7172	0.8109	0.9089	1.0111	1.1103	1.2205	1.3346	1.4526	1.5774	1.6914	1.8204	1.9530	2.0891	2.2193
23	0.6617	0.7487	0.8465	0.9488	1.0556	1.1591	1.2741	1.3932	1.5164	1.6436	1.7658	1.9004	2.0388	2.1809	2.3168
24	0.6895	0.7802	0.8821	0.9887	1.0999	1.2078	1.3276	1.4518	1.5802	1.7127	1.8400	1.9803	2.1245	2.2726	2.4142
25	0.7173	0.8116	0.9176	1.0285	1.1442	1.2565	1.3811	1.5103	1.6438	1.7816	1.9141	2.0600	2.2101	2.3641	2.5114
26	0.7450	0.8430	0.9531	1.0683	1.1885	1.3051	1.4345	1.5687	1.7074	1.8506	1.9881	2.1397	2.2955	2.4555	2.6086
27	0.7727	0.8743	0.9885	1.1080	1.2327	1.3536	1.4879	1.6270	1.7709	1.9194	2.0621	2.2193	2.3809	2.5468	2.7056
28	0.8004	0.9057	1.0239	1.1477	1.2768	1.4021	1.5412	1.6853	1.8343	1.9881	2.1359	2.2988	2.4662	2.6380	2.8025
29	0.8280	0.9369	1.0593	1.1873	1.3209	1.4505	1.5944	1.7435	1.8976	2.0568	2.2097	2.3781	2.5513	2.7291	2.8992

Thus, there are two kinds of volume table which are to be used in the following manner.

Table 14 ..... Volume table of coconut tree (A).

This is the original stand volume table. This can be used in a timber cruise when central diameter can be measured directly.

Table 17 ..... Volume table of coconut tree (B).

The stand volume table to be used exclusively for the present survey. In general measured values of central diameter by Relaskop tend to be biased from actual values. Therefore, in future timber cruises it will be necessary to obtain regression formula for adjustment from source trees numbering several tens and volume table (B) for operation can be prepared, as it was done for the present survey.

9. Preparation of photo volume table

9-1. Analysis of correlation between factor and volume

A photo volume table is a volume table using to estimate volume of a single tree or a stand with measurable factors on aerial photographs. For preparation of a hoto volume table, various factors should be examined first to find out if they are suitable as such. Thus, whole tree height, crown diameter and tree age were selected as possible factors, correlation between stand volume and each factors was obtained for sample trees (b) as Figs. 11-13.

They show that whole tree height has the highest correlation and is most suitable as the factor. With regard to stand age, the correlation can be described as tolerable for the fact that the information was obtained verbally. However, the correlation was practically nil with crown diameter which was clearly unsuitable as the factor for photo volume table.

The number of trees can also be considered as the factor for photo volume table for stand. The planting of coconut in plantations is uniform with the planting space of about 10m. Thus, as they form thin stand, they are easy to be identified from photographs. Further, each count between on the ground and on the photograph was completely coincided except for extremely young stand of Malayan Dwarf. Therefore, correlation analysis was deemed unnecessary for the number of trees.

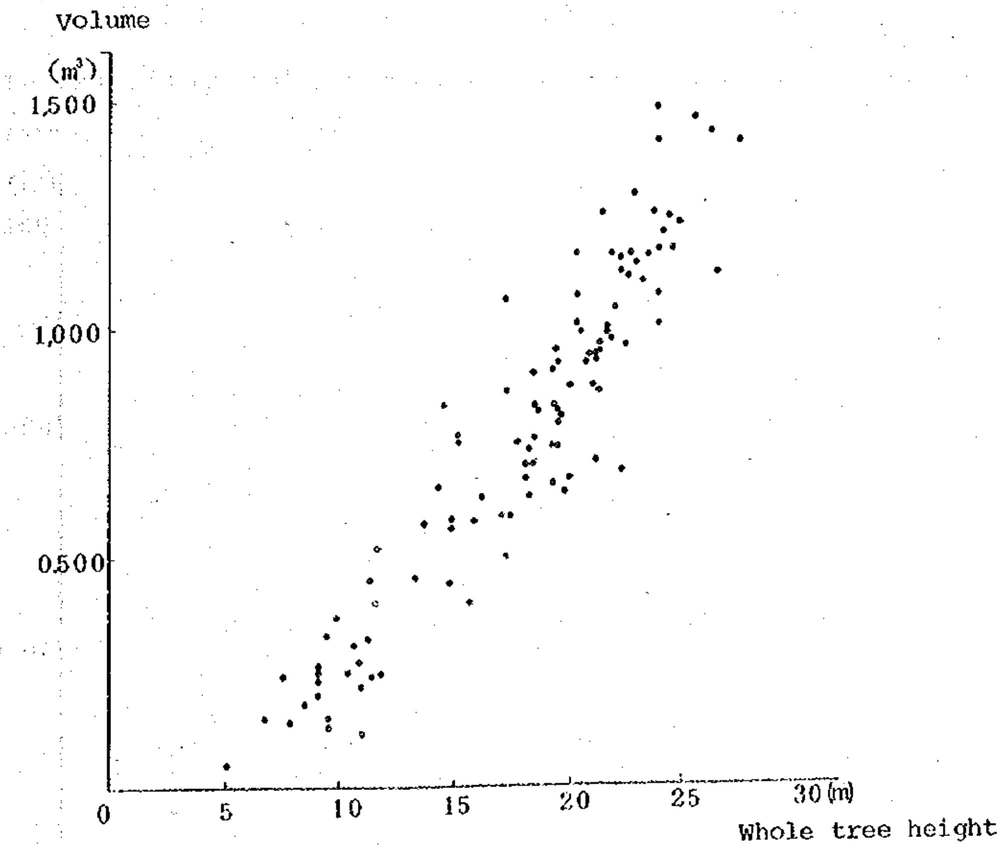


Fig. 11. Correlation between volume and whole tree height

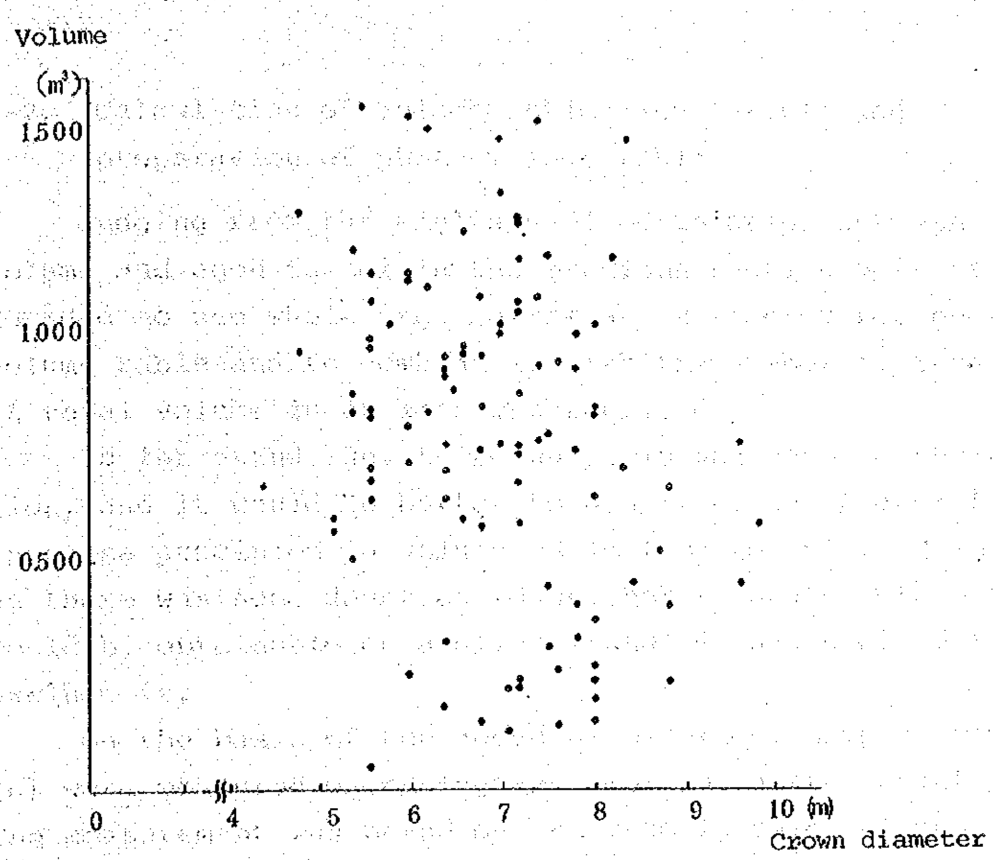


Fig. 12. Correlation between volume and crown diameter

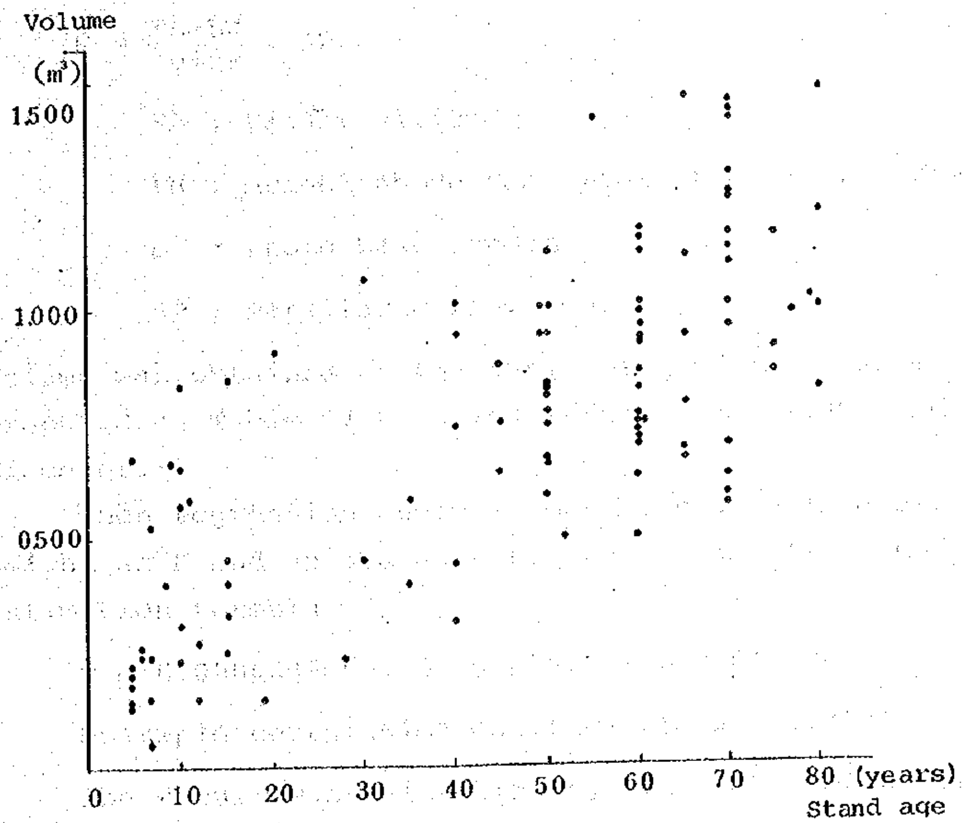


Fig. 13. Correlation between volume and stand age

9-2. Calculation of volume estimation formula and preparation of photo volume table

Judging from the analysis of correlation between volume and each factor in the previous section 9-1, it was decided to use whole tree height as the factor for photo volume table and to combine it with the number of trees if total volume in an area was required.

As for stand age, there was some degree of correlation, and it would be better to use it as the factor to increase precision in volume estimation formula. However, as there was some doubt as to whether accurate information would be obtainable on a given stand, it was decided to exclude it.

On the basis of the above examination, sample trees (b) were measured on photographs for whole tree height. The measurement was based on the formula below by measuring parallax difference with parallax bar.

$$H = \frac{FA-LH}{b+\Delta P} \times \Delta P$$

FA : Flight altitude

LH : Height above sea level at a sample tree

b : Photo base length

ΔP : Parallax difference

Volume was obtained on the basis of the stand volume table prepared as Table 17 by using actual stem height and central diameter.

Then regression analysis was made with interpreted height as H and volume as v to induce the following volume estimation formula.

$$v = 0.0000586H^2 + 0.0640992H - 0.3181620$$

Multiple correlation coefficient $\rho = 0.8601$

The result was multiplied by the number of trees to prepare volume table for stand.

Thus, volume estimation formula for stand will be:

$$V = N\ (-\ 0.0000586H^2 + 0.0640992H - 0.3181620)$$

The volume table is given as the appendix photo volume table, and is given as Table 18.

PHOTO VOLUME TABLE (1-1)

SPECISE: COCONUT
AREA: TAVEUNI, FIJI
(UNIT: m^3/ha)

MEAN WHOLE HEIGHT (MEASURED BY PHOTO-INTERPRETATION) H(m) \ N	NUMBER OF TREES/HA (MEASURED BY PHOTO-INTERPETATION) 4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128
5															0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.3	2.6	2.8	3.1	3.3	3.6	3.9	4.1	4.4	4.6	4.9	5.1	5.4	5.7	5.9	6.2	6.4	6.7	6.9	7.2	7.5	7.7	8.0	8.2
7	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.7	8.2	8.7	9.2	9.7	10.2	10.7	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.3	15.8	16.3
8	0.8	1.5	2.3	3.1	3.8	4.6	5.3	6.1	6.9	7.6	8.4	9.2	9.9	10.7	11.5	12.2	13.0	13.7	14.5	15.3	16.0	16.8	17.5	18.3	19.1	19.9	20.6	21.4	22.1	22.9	23.7	24.4
9	1.0	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.1	10.2	11.2	12.2	13.2	14.2	15.2	16.3	17.3	18.3	19.3	20.3	21.3	22.4	23.4	24.4	25.4	26.4	27.4	28.4	29.5	30.5	31.5	32.5
10	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4	12.7	13.9	15.2	16.5	17.8	19.0	20.3	21.6	22.8	24.1	25.4	26.6	27.9	29.2	30.4	31.7	33.0	34.2	35.5	36.8	38.0	39.3	40.6
11	1.5	3.0	4.6	6.1	7.6	9.1	10.6	12.2	13.7	15.2	16.7	18.2	19.8	21.3	22.8	24.3	25.8	27.3	28.9	30.4	21.9	33.4	34.9	36.5	38.0	39.5	41.0	42.5	44.1	45.6	47.1	48.5
12	1.8	3.5	5.3	7.1	8.9	10.6	12.4	14.2	15.9	17.7	19.5	21.2	23.0	24.8	26.6	28.3	30.1	31.9	33.6	35.4	37.2	38.9	40.7	42.5	44.3	46.0	47.8	49.6	51.3	53.1	54.9	56.7
13	2.0	4.0	6.1	8.1	10.1	12.1	14.1	16.2	18.2	20.2	22.2	24.3	26.3	28.3	30.3	32.3	34.4	36.4	38.4	40.4	42.4	44.5	46.5	48.5	50.5	52.5	54.6	56.6	58.6	60.6	62.6	64.7
14	2.3	4.5	6.8	9.1	11.4	13.6	15.9	18.2	20.4	22.7	25.0	27.3	29.5	31.8	34.1	36.3	38.6	40.9	43.1	45.4	47.7	50.0	52.2	54.5	56.8	59.0	61.3	63.6	65.9	68.1	70.4	72.7
15	2.5	5.0	7.6	10.1	12.6	15.1	17.6	20.2	22.7	25.2	27.7	30.2	32.8	35.3	37.8	40.3	42.8	45.4	47.9	50.4	52.9	55.5	58.0	60.5	63.0	65.5	68.1	70.6	73.1	75.6	78.1	80.7
16	2.8	5.5	8.3	11.1	13.8	16.6	19.4	22.2	24.9	27.7	30.5	33.2	36.0	38.8	41.5	44.3	47.1	49.9	52.6	55.4	58.2	60.9	63.7	66.5	69.2	72.0	74.8	77.6	80.3	83.1	85.9	88.6
17	3.0	6.0	9.1	12.1	15.1	18.1	21.1	24.1	27.2	30.2	33.2	36.2	39.2	42.3	45.3	48.3	51.3	54.3	57.3	60.4	63.4	66.4	69.4	72.4	75.5	78.5	81.5	84.5	87.5	90.6	93.6	96.6
18	3.3	6.5	9.8	13.1	16.3	19.6	22.9	26.1	29.4	32.7	35.9	39.2	42.5	45.7	49.0	52.3	55.5	58.8	62.1	65.3	68.6	71.9	75.1	78.4	81.7	84.9	88.2	91.5	94.7	98.0	101.3	104.5
19	3.5	7.0	10.5	14.1	17.6	21.1	24.6	28.1	31.6	35.1	38.7	42.2	45.7	49.2	52.7	56.2	59.7	63.3	66.8	70.3	73.8	77.3	80.8	84.3	87.9	91.4	94.9	98.4	101.9	105.4	108.9	112.5
20	3.8	7.5	11.3	15.0	18.8	22.6	26.3	30.1	33.9	37.6	41.4	45.1	48.9	52.7	56.4	60.2	63.9	67.7	71.5	75.2	79.0	82.8	86.5	90.3	94.0	97.8	101.6	105.3	109.1	112.8	116.6	120.4
21	4.0	8.0	12.0	16.0	20.0	24.0	28.1	32.1	36.1	40.1	44.1	48.1	52.1	56.1	60.1	64.1	68.1	72.1	76.2	80.2	84.2	88.2	92.2	96.2	100.2	104.2	108.2	112.2	116.2	120.2	124.3	128.3
22	4.3	8.5	12.8	17.0	21.3	25.5	29.8	34.0	38.3	42.5	46.8	51.1	55.3	59.6	63.8	68.1	72.3	76.6	80.8	85.1	89.3	93.6	97.9	102.1	106.4	110.6	114.9	119.1	123.4	127.6	131.9	136.1
23	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0	49.5	54.0	58.5	63.0	67.5	72.0	76.5	81.0	85.5	90.0	94.5	99.0	103.5	108.0	112.5	117.0	121.5	126.0	130.5	135.0	139.5	144.0
24	4.7	9.5	14.2	19.0	23.7	28.5	33.2	38.0	42.7	47.5	52.2	57.0	61.7	66.4	71.2	75.9	80.7	85.4	90.2	94.9	99.7	104.4	109.2	113.9	118.6	123.4	128.1	132.9	137.6	142.4	147.1	151.9
25	5.0	10.0	15.0	20.0	25.0	29.9	34.9	39.9	44.9	49.9	54.9	59.9	64.9	69.9	74.9	79.9	84.8	89.8	94.8	99.8	104.8	109.8	114.8	119.8	124.8	129.8	134.8	139.7	144.7	149.7	154.7	159.7
26	5.2	10.5	15.7	20.9	26.2	31.4	36.6	41.9	47.1	52.4	57.6	62.8	68.1	73.3	78.5	83.8	89.0	94.2	99.5	104.7	109.9	115.2	120.4	125.6	130.9	136.1	141.4	146.6	151.8	157.1	162.5	167.5
27	5.5	11.0	16.4	21.9	27.4	32.9	38.4	43.8	49.3	54.8	60.3	65.8	71.2	76.7	82.2	87.7	93.1	98.6	104.1	109.6	115.1	120.5	126.0	131.5	137.0	142.5	147.9	153.4	158.9	164.4	169.9	175.3
28	5.7	11.4	17.2	22.9	28.5	34.3	40.1	45.8	81.5	57.2	62.9	68.7	74.4	80.1	85.8	91.6	97.3	103.0	108.7	114.5	120.2	125.9	131.6	137.3	143.1	148.8	154.5	160.2	166.0	171.7	177.4	183.1

(1-2)

NUMBER OF TREES/HA (MEASURED BY PHOTO-INTERPETATION)

MEAN WHOLE HEIGHT (MEASURED BY PHOTO-INTERPRETATION)

H(m) \ N	132	136	140	144	148	152	156	160	164	168	172	176	180	184	188	192
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
6	8.5	8.7	9.0	9.3	9.5	9.8	10.0	10.3	10.5	10.8	11.1	11.3	11.6	11.8	12.1	12.4
7	16.9	17.4	17.9	18.4	18.9	19.4	19.9	20.4	20.9	21.4	22.0	22.5	23.0	23.5	24.0	24.5
8	25.2	26.0	26.7	27.5	28.3	29.0	29.8	30.5	31.3	32.1	32.8	33.6	34.4	35.1	35.9	36.6
9	33.5	34.5	35.6	36.6	37.6	38.6	39.6	40.6	41.7	42.7	43.7	44.7	45.7	46.7	47.7	48.8
10	41.8	43.1	44.4	45.6	46.9	48.2	49.4	50.7	52.0	53.3	54.5	55.8	57.1	58.3	59.6	60.9
11	50.1	51.7	53.2	54.7	56.2	57.7	59.3	60.8	62.3	63.8	65.3	66.9	68.4	69.9	71.4	72.9
12	58.4	60.2	62.0	63.7	65.5	67.3	69.0	70.8	72.6	74.4	76.1	77.9	79.7	81.4	83.2	85.0
13	66.7	68.7	70.7	72.8	74.8	76.8	78.8	80.8	82.9	84.9	86.9	88.9	90.9	93.0	95.0	97.0
14	74.9	77.2	79.5	81.8	84.0	86.3	88.6	90.8	93.1	95.4	97.7	99.9	102.2	104.5	106.7	109.0
15	83.2	85.7	88.2	90.7	93.3	95.8	98.3	100.8	103.3	105.9	108.4	110.9	113.4	115.9	118.5	121.0
16	91.4	94.2	96.9	99.7	102.5	105.2	108.0	110.8	113.6	116.3	119.1	121.9	124.6	127.4	130.2	132.9
17	99.6	102.6	105.6	108.7	111.7	114.7	117.7	120.7	123.8	126.8	129.8	132.8	135.8	138.8	141.9	144.9
18	107.8	111.1	114.3	117.6	120.9	124.1	127.4	130.7	133.9	137.2	140.5	143.7	147.0	150.3	153.5	156.8
19	116.0	119.5	123.0	126.5	130.0	133.5	137.1	140.6	144.1	147.6	151.1	154.6	158.1	161.7	165.2	168.7
20	124.1	127.9	131.7	135.4	139.2	142.9	146.7	150.5	154.2	158.0	161.7	165.5	169.2	173.0	176.8	180.6

H(m) \ N	196	200	204	208	212	216	220	224	228	232	236	240	244	248	252	256
5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6	12.6	12.9	13.1	13.4	13.6	13.9	14.2	14.4	14.7	14.9	15.2	15.4	15.7	16.0	16.2	16.5
7	25.0	25.5	26.0	26.6	27.1	27.6	28.1	28.6	29.1	29.6	30.1	30.6	31.1	31.7	32.2	32.7
8	37.4	38.2	38.9	39.7	40.5	41.2	42.0	42.8	43.5	44.3	45.0	45.8	46.6	47.3	48.1	48.9
9	49.8	50.8	51.8	52.8	53.8	54.9	55.9	56.9	57.9	58.9	59.9	61.0	62.0	63.0	64.0	65.0
10	62.1	63.4	64.7	65.9	67.2	68.5	69.7	71.0	72.3	73.5	74.8	76.1	77.3	78.6	79.9	81.1
11	74.4	76.0	77.5	79.0	80.5	82.0	83.6	85.1	86.6	88.1	89.6	91.2	92.7	94.2	95.7	97.2
12	86.7	88.5	90.3	92.1	93.8	95.6	97.4	99.1	100.9	102.7	104.5	106.2	108.0	109.8	111.5	113.3
13	99.0	101.0	103.1	105.1	107.1	109.1	111.1	113.2	115.2	117.2	119.2	121.3	123.3	125.3	127.3	129.3
14	111.3	113.5	115.8	118.1	120.4	122.6	124.9	127.2	129.4	131.7	134.0	136.3	138.5	140.8	143.1	145.3
15	123.5	126.0	128.5	131.1	133.6	136.1	138.6	141.2	143.7	146.2	148.7	151.2	153.8	156.3	158.8	161.3
16	135.7	138.5	141.3	144.0	146.8	149.6	152.3	155.1	157.9	160.6	163.4	166.2	169.0	171.7	174.5	177.3
17	147.9	150.9	153.9	157.0	160.0	163.0	166.0	169.0	172.0	175.1	178.1	181.1	184.1	187.1	190.2	193.2
18	160.1	163.3	166.6	169.9	173.1	176.4	179.7	182.9	186.2	189.5	192.7	196.0	199.3	202.5	205.8	209.1
19	172.2	175.7	179.2	182.7	186.3	189.8	193.3	196.8	200.3	203.8	207.3	210.9	214.4	217.9	221.4	224.9
20	184.3	188.1	191.8	195.6	199.4	203.1	206.9	210.6	214.4	218.2	221.9	225.7	229.5	233.2	237.0	240.7

10. Preparation of standard interpretation cards

10-1. Arrangement of data

Those data from sample plots obtained in the field survey were arranged, and 20 plots suitable for interpretation were selected. In the light of forest type mark and the difference in forest condition within the forests type, the selection was made as follows:-

[YI] .... 4 cases

[MI] .... 4 cases

[OI] .... 7 cases

[DI] .... 3 cases

[E] .... 2 cases

10-2. Preparation of cards

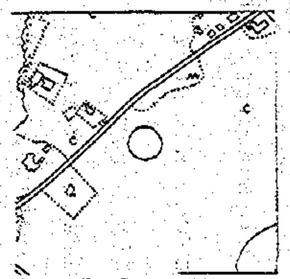
Standard interpretation cards to record necessary data obtained from sample plots were prepared. Portion of aerial photographs (1/10,000) in stereo-pair and a ground photograph were affixed on the card for visual effects, and the results of the field survey were also supplied so that the card could supply material for interpreting coconut stand. (Fig. 14.)

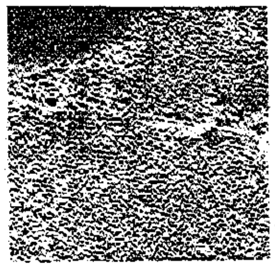
Plot No.	(OI)- 38
District Name	Taveuni
Plantation Name	VUNA
Compartment & Sub-compartment	4-34
Planned by	J.I.C.A. Fiji Goverment
Enforced by	J.F.T.A.
Surveyed on	Octorber, 1977
Plot Area	0.2ha

Site Conditions	
Gradient	flat
Direction	no-direction
Altitude	7 m
Forest Conditions	
Local Name	Fiji Tall
Tree age	70

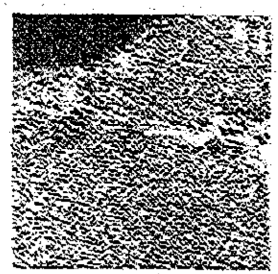
		Upper tree	Lower tree	Total
Mean Stem Height		16.8 m	m	m
Mean Central Diameter		26.2 cm	cm	cm
Number of Trees	Plot	35		35
	Per ha	175		175
Volume	Plot	32.32 m³	m³	32.32 m³
	Per ha	162 m³	m³	162 m³

Data of Aerial Photograph	
District Name	Taveuni
Photographed	J.I.C.A.
Photographed on	22 July, 1977 ~30 July, 1977
Photo Scale	1 : 20,000
Flight Altitude	3,670m
Focal Length	152.02mm
Course No. & Photo No.	C1A-3,4
Base Length	171 mm


Plot Location Map (Scale 1 : 10,000)




Ground Photograph


Stereo Photograph (Scale 1 : 10,000)

Japan Forest Technical Association

Plot No.	(OI)- 38

Fig. 14. Example of standard interpretation card

11. Preparation of a block map

11-1. Preparation of the original block map

Those plantation boundaries and forest type block boundaries set up roughly in preliminary interpretation under section 3 and adjusted or confirmed in the field working were transferred to the basic map of the scale 1/10,000 prepared under section 2 to prepare an original block map.

Then a running number was given to the plantations, starting with Saliavu in the southwest, through Somosomo, and round the island to Lavena in view of the distribution.

Forest type blocks in the plantations were also given a running number, though left-over areas (hardwood forest, housing sites and roads) were excluded.

These numbers, together with the established plantation and block boundaries, are entered on the aerial photographs. (Photograph 2.)

11-2. Measurement of areas

The areas of plantations and of forest type blocks were measured on the original block map. For measurement, Dot plate (1 dot for 0.25ha) were used to count the number of dots for each block. Measurement was repeated three times to get the average which was multiplied by 0.25ha for the area.

The area of coconut stand in each plantation is given by Table 19. However, left-over areas in plantations are excluded, and the total areas of plantations are given in the right-hand column.

Approx. 1/10,000

Table 19. Planation areas

Plantation No.	Name of plantation	Number of blocks	Stand area (ha)	Plantation area (including left-over areas: ha)
1	SALIALEVU	23	1199.95	1271.95
2	NAVAKAWAU (Fi)	11	160.17	236.17
3	VUNA(Fi)	41	659.64	709.39
4	VUNA	55	2087.97	2520.47
5	URA	18	649.87	909.12
6	LIKUVAUSOMO	4	45.09	304.34
7	NAQILAI	2	74.01	77.76
8	QATHAVULA	15	260.68	283.18
9	SOGULU	21	346.20	364.70
10	WALA	4	60.59	60.59
11	MALAWAI (№1 / №2)	7	140.67	144.67
12	TUTU	6	122.12	132.62
13	WAIRIKI	9	139.66	185.41
14	TAVUKI (Fi)	4	29.77	37.52
15	NAIYALAYALA	10	95.74	105.74
16	WAIYEVO	3	36.59	81.59
17	WAITAVALA	6	108.02	111.02
18	NALELE	4	43.44	43.44
19	LOVONIVONU (Fi)	17	179.04	328.04
20	DELAIWENI (№1 / №2)	15	194.50	337.00
21	SOMOSOMO (Fi)	8	242.03	282.78
22	NAMBAU	3	36.09	36.09

Note: (Fi) stands for Fijian village name.

Plantation No.	Name of plantation	Number of blocks	Stand area (ha) (ha)	Plantation area (including left-over areas; ha)
23	VATUULO	8	164.36	201.61
24	NIUSAWA	4	39.31	46.31
25	WELAGI (Fi)	15	264.32	295.82
26	NGILA	16	381.16	394.16
27	NAMBEKA	5	62.21	62.21
28	MUA	30	528.44	547.69
29	VACALA	3	41.75	44.00
30	MATEI	17	136.47	189.97
31	NASELESELE	16	224.49	242.99
32	NASELESELE (Fi)	8	133.42	143.67
33	NAGASAU	6	208.36	210.86
34	NAWIWI (Fi)	9	96.75	166.50
35	NACOGAI	11	269.12	275.12
36	NGGELENI (Fi)	38	257.31	320.31
37	VACOA (Fi)	18	136.21	177.46
38	VUNIVASA	21	417.35	528.35
39	WAI (Fi)	12	51.82	68.57
40	VITALA	18	107.30	149.80
41	WAITAMBU	10	29.99	43.24
42	VINDAWA (Fi)	9	53.60	59.60
43	MBOUMA (Fi)	15	128.76	177.01
44	LAVENA (Fi)	47	231.94	246.94
Total		622	10876.28	13155.78

12. Interpretation by block

12-1. Analysis of data

Before the interpretation of photographs it is necessary to examine correlation between tree height and stand age.

From the data on sample trees (b), given as Table 10, for preparation of photo volume table, correlation between whole tree height of single trees and stand age can be obtained as Fig. 15. The mean whole height curve can be shown as a logarithmic curve starting at 6m. It shows that the height is about 22m at 70 years.

Since the data include measurements of stem height, correlation between crown height (residual between whole tree height and stem height) and stand age can also be obtained (Fig. 16). The mean curve shows the height of 6 to 5m with young growth, which decreases as the age progresses, showing 4m at 30 years and maintaining 3.5m after 50 years. The fact that the crown of coconut is entirely made up of leaves explains the crown height of young trees with abundant leaves and strength. However, as the tree ages the amount of leaves decreases and they also bend down, thus affecting the crown height.

Further, from the results of the field working of a sampling plot, correlation between the average stem height and stand age can be obtained as Fig. 17. The mean stem height curve is a logarithmic curve starting at 0 meter.

Since Fig. 15 concerns single trees and Fig. 17 is based on the average of trees in sample plot, direct comparison is difficult. However, Fig. 17 was adjusted in scale to Fig. 15 to obtain Fig. 18, to which the crown height of Fig. 16 was added, as shown as the broken line. When the curve including crown height is placed on the mean whole height curve of Fig. 15, they are found to be almost identical except for the section around 40-50 years where the latter is lower than the former by around 1m.

This is perhaps to be expected since sample trees (b) have been selected at random from those closest to the center of the plot. However, it serves to examine the reliability of the data being used.

Since two kinds of mean height curve were obtained, it was decided to use Fig. 15 for estimating stand age from whole tree height and Fig. 17 from stem height.

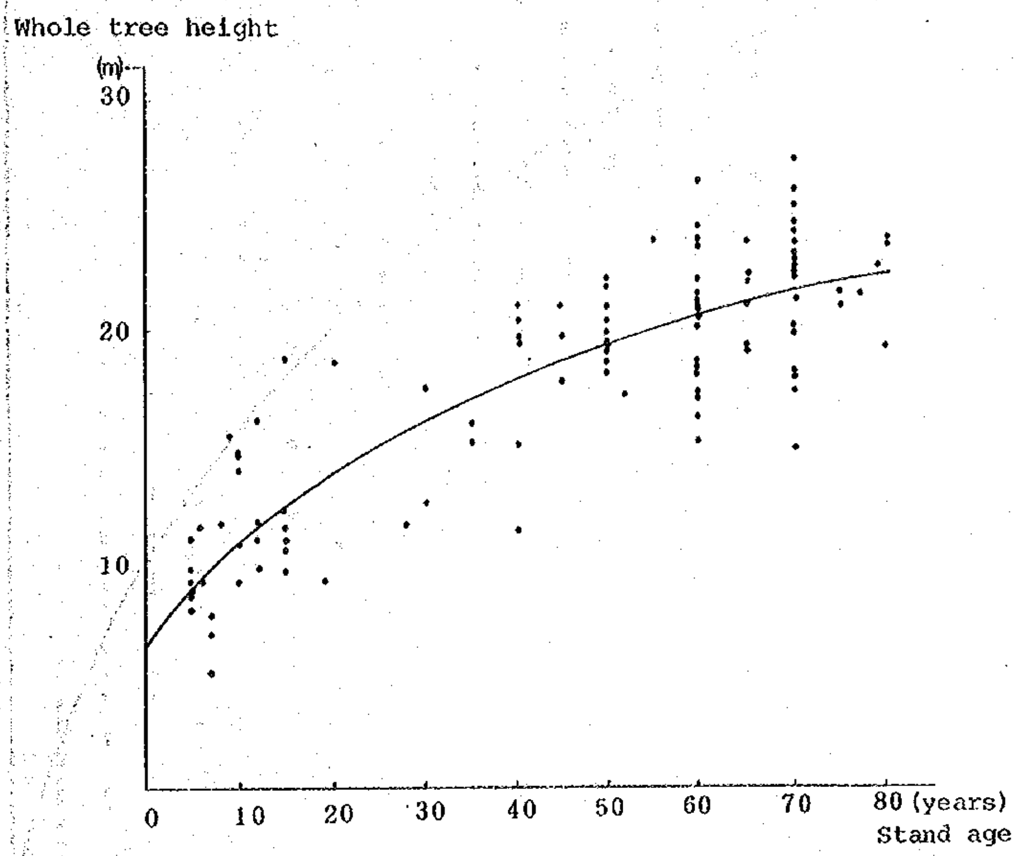


Fig. 15. Correlation between stand age and whole tree height and the mean whole height curve

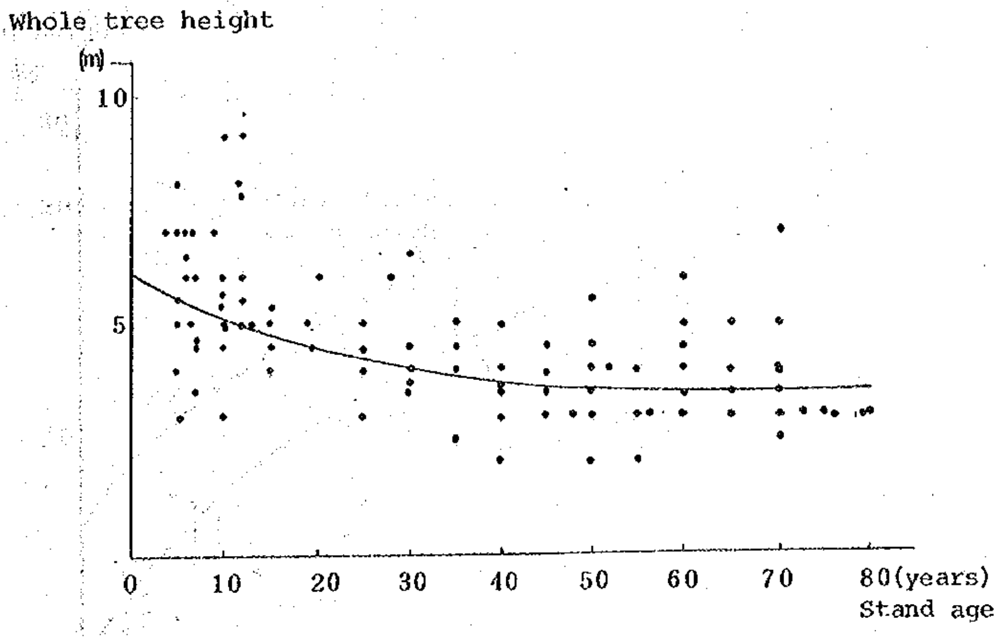


Fig. 16. Correlation between stand age and crown height and the mean crown height curve

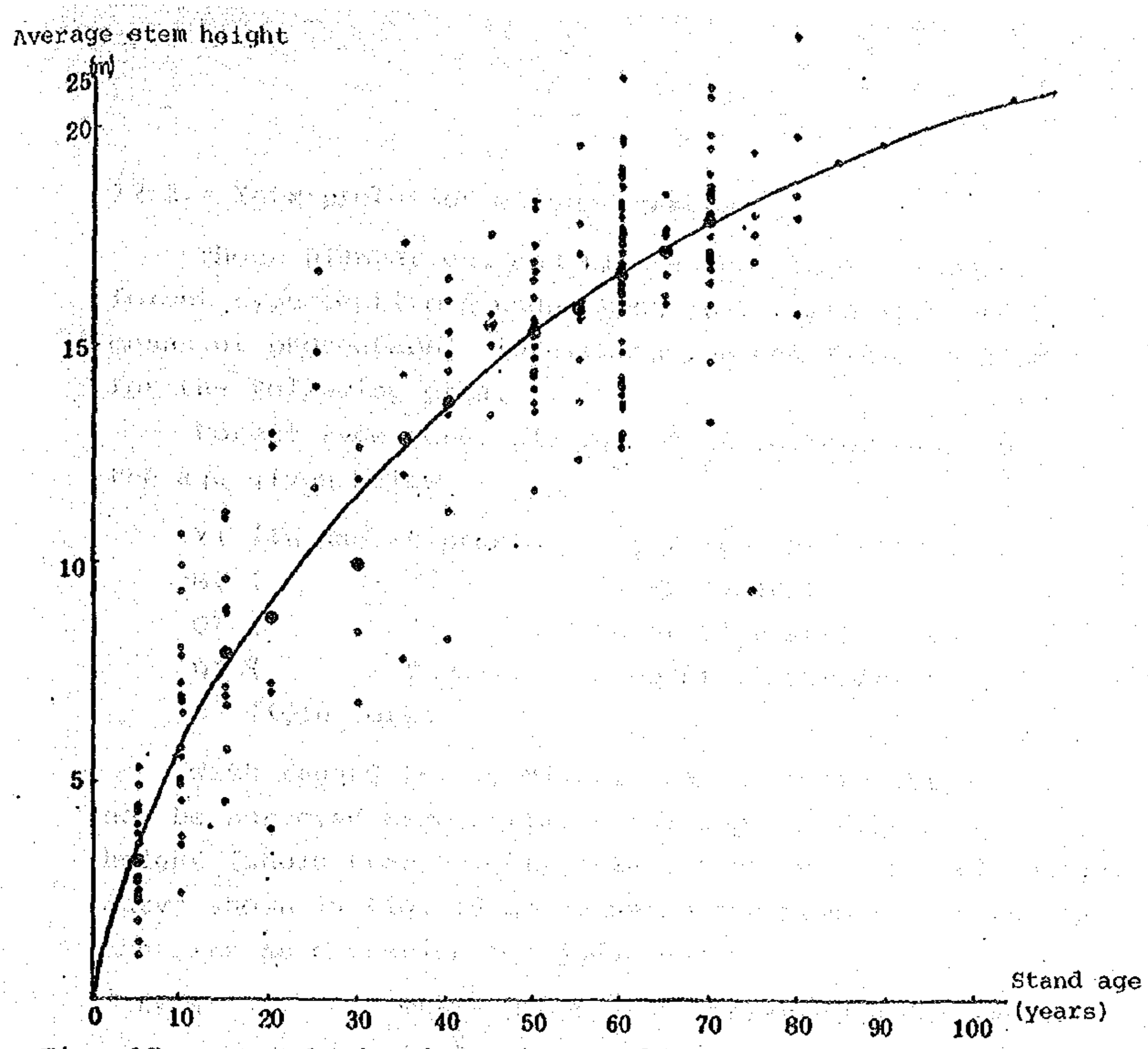


Fig. 17. Correlation between stand age and average stem height and the mean stem height curve

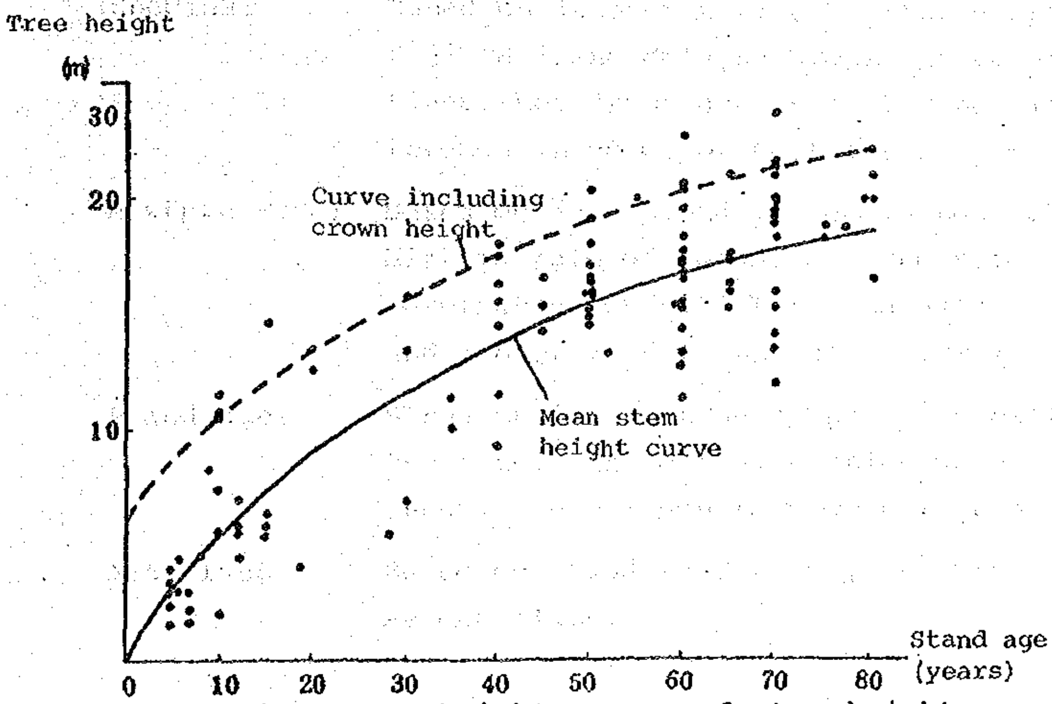


Fig. 18. Mean height curves of stem height and including crown height

12-2. Interpretation of photographs

Those plantations and plantation blocks based on forest type confirmed under section 11 were surveyed by means of photographic interpretation and field working for the following data.

Forest type code: Classified as follows based on the age given below.

YI (in use at present. 0-25 years)
MI (" 26-50 years)
OI (" Over 51 years)
DI (" Two-storied forest)
E (idle forest)

With regard to YI, MI, OI, those blocks which could not be surveyed were estimated by applying the average height (whole tree height) interpreted to mean whole height curve shown in Fig. 15 or by using the number of trees and the site as criterion for judgement.

Area: Those block areas measured under section 11-2 were transferred.

Species: Based on interpretation of photographs. Fiji Tall and Malayan Dwarf can be distinguished from each other by the difference in color on photograph.

Mixture rate: Based on interpretation of photographs. Mixture rate of volume was recorded for combination of Fiji Tall and Malayan Dwarf, and two-storied forest of Fiji Tall.

Stand age: Based on information supplied verbally at the site. Those blocks which were either unsurveyed or uncertain were left blank.

Age class: Based on stand age, five years were counted as one class.

Average height
(whole tree height): A few typical plots (for 0.25ha) for interpretation were set up within a block on the photographs with the use of the plot-setting plate. Parallax differences of several trees in the plot were measured with parallax bar, which were then converted into tree heights. The method of conversion is the same as the estimation of height for photo volume table. And measured tree heights were taken to supply the average values.

Number of trees per ha: The number of trees in the plot setted up above was counted and converted into the number per ha.

Volume per ha: Calculated by applying the measured heights and the number of trees to the photo volume table prepared under the section 9-2.

Results of the interpretation are given as Appendix Coconut forest inventory note which gives plantation areas, number of trees and volumes, and Table 20 is a part of it.

Table 20. Forest inventory note (part)

Plantation Name QATHAVULA Plantation № 8.

Plantation №	Block №	Forest-type	Area (HA)			Forest Condition								Remarks
			forest area	left-over area	total area	local name	mixture rate	tree age	tree age class	mean whole height	number of trees per HA	volume per HA	total volume	
8	1	OI	32.58			Fiji Tall	100	50	X	18 m	84	68.6 m³	2,235 m³	
	2	MI	7.93			〃	〃			16	140	96.9	768	
	3	E	27.83			〃	〃			18	64	52.3	1,456	
	4	〃	1.50			〃	〃			15	52	32.8	49	
	5	MI	13.33			〃	〃			17	72	54.3	724	
	6	DI	2.33			Fiji Tall Malayan	67 33			18 12	48 44	39.2 19.5	76	
	7	MI	27.25			Fiji Tall	100			19	100	87.9	2,395	
	8	OI	60.83			〃	〃	70	XIV	21	88	88.2	5,365	
	9	〃	39.83			〃	〃			20	68	63.9	2,545	
	10	E	12.68			〃	〃			18	60	49.0	621	
	11	OI	9.75			〃	〃			18	72	58.8	573	
	12	〃	17.08			〃	〃	60	XII	19	104	91.4	1,561	
	13	E	2.18			〃	〃			18	48	39.2	85	
	14	OI	2.25			〃	〃			19	44	38.7	87	
	15	〃	3.33			〃	〃			19	44	38.7	129	
			260.68	22.50	283.18						21,151		18,669	

12-3. Calculation of total volume by accumulation

The numbers and volumes of forest types calculated under the section 12-2 were added up for each plantation and then for the entire area to obtain the total number of trees and the total volume. The results obtained were 996.768 trees and 754,047m^3 in volume. Table 21 gives the number and volume for each plantation.

Table 21. Number and volume by plantation

Plantation No.	Name of plantation	Number	Volume (m^3)
1	SALIALEVU	62,745	59,611
2	NAVAKAWAU(Fi)	10,275	7,373
3	VUNA (Fi)	54,160	34,662
4	VUNA	195,474	163,183
5	URA	49,252	44,116
6	LIKUVAUSOMO	4,123	3,835
7	NAQILAI	8,173	7,624
8	QATHAVULA	21,151	18,669
9	SOGULU	24,094	19,612
10	WALA	5,135	5,039
11	MALAWAI (No.1, No.2)	15,935	15,813
12	TUTU	8,176	5,342
13	WAIRIKI	10,644	8,971
14	TAVUKI (Fi)	3,047	2,385
15	NAIYALAYALA	10,102	8,802
16	WAIYEVO	3,566	3,426
17	WAITAVALA	14,022	6,380
18	NALELE	3,817	2,536

Plantation No.	Name of plantation	Number	Volume (m^3)
19	LOVONIVONU (Fi)	13,741	8,693
20	DELAIWENI (No.1 No.2)	17,807	16,441
21	SOMOSOMO (Fi)	20,178	9,426
22	NAMBAU	4,858	2,413
23	VATUULO	9,853	8,771
24	NIUSAWA	3,557	2,263
25	WELAGI (Fi)	23,408	8,502
26	NGILA	36,282	23,969
27	NAMBEKA	6,984	5,569
28	MUA	56,736	39,636
29	VACALA	4,548	2,773
30	MATEI	16,320	11,899
31	NASELESELE	32,174	26,400
32	NASELESELE (Fi)	16,773	12,612
33	NAGASAU	26,050	25,328
34	NAWIWI (Fi)	12,089	8,999
35	NACOGAI	27,074	25,691
36	NGGELENI (Fi)	27,215	12,357
37	VACOA (Fi)	15,630	9,623
38	VUNIVASA	48,731	35,813
39	WAI (Fi)	6,426	2,136
40	VITALA	15,447	10,257
41	WAITAMBU	3,013	1,496
42	VINDAWA (Fi)	5,851	4,101
43	MBOUMA (Fi)	13,722	6,325
44	LAVENA (Fi)	28,410	15,175
	Total	996,768	754,047

13. Calculation of the total volume by sampling

By using number of trees and volume per ha obtained fro a plot under the section 8-2, totalling by samplin method was carried out. The method of calculation was the stratified random sampli g method given below.

[Codes]

- X : Target of the survey (volume or number of trees)
- x : X in a sample
- A : Area (number of population block N x sample area)
- ω : Proportion of stratum area (proportion stratum number of population block)
- n : Number of samples
- $\bar{X}$: Mean value of the target
- S_x^2 : Variance of samples
- $S_{\bar{x}}^2$: Variance of mean value
- $S_{\bar{x}}$: Standard deviation of mean value
- R : Confidence limit of estimate
- ε : Error rate of estimate
  - i : ith stratum
  - j : jth sample

[Formula]

Stratum area

Proportion of stratum area $\omega_i = \frac{A_i}{\Sigma A_i}$

Mean value of x in samples $\bar{X}_i = \frac{1}{n_i} \Sigma x_{ij}$

" $\bar{X} = \bar{x} = \sum_i \omega_i \cdot \bar{x}_i$

Variance in samples $S^2_{xi} = \frac{1}{n_{i-1}} \left\{ \sum_j x_{ij} - \frac{(\Sigma x_{ij})^2}{n_i} \right\}$

Variance of mean value	$S_{\bar{x}i}^2$	$= \frac{S^2 xi}{ni}$
"	$S_{\bar{x}}^2$	$= \sum_i \omega_i^2 \cdot \frac{S^2 xi}{ni}$
Standard deviation of mean value	$S_{\bar{x}_i}$	$= \sqrt{S_{\bar{x}i}^2}$
"	$S_{\bar{x}}$	$= \sqrt{S_{\bar{x}}^2}$
Confidence limit of mean value	R_i	$= t_i \cdot S_{\bar{x}_i}$
"	R	$= t \cdot S_{\bar{x}}$
Error rate of estimate	ϵ_i	$= \frac{R_i}{\bar{x}_i} \times 100$
"	ε	$= \frac{R}{\bar{x}_i} \times 100$
Estimated total	X_i	$= A_i \; (\bar{x}_i \pm t \cdot S_{\bar{x}_i})$
"	X	$= A \cdot (\bar{x} \pm t \cdot S_{\bar{x}})$

Results of calculation are given as Table 22/1-2

Table 22-1. Results of calculation (volume)

Stratum		(Y I)	(M I)	(O I)	(D I)	Total	
Stratum area	A_i (ha)	1,028	2,750	5,181	634	9,593	
Proportion of stratum area	ω_i	0.1072	0.2867	0.5400	0.0661	1.0000	
Square of the above	ω_i^2	0.0115	0.0822	0.2916	0.0044	0.3897	
Number of samples	n_i	18	48	90	11	167	
Sum of sample volume (per ha)	$\sum_j x_{ij}$	643.4	3641.8	7,845.9	1,006.5	13,137.6	
Sum of squared sample volume	$\sum_j x_{ij}^2$	34551.3	327005.7	863881.5	105643.6	1331082.1	
Mean volume (per ha)	$\bar{x}_i = \sum_j x_{ij} / n_i$	35.7	75.9	87.2	91.5	78.7	$\leftarrow \sum_j \omega_i \bar{x}_i$
Variance of samples	$S^2 x_i = 1/n_i - 1 \{ \sum_j x_{ij}^2 - (\sum_j x_{ij})^2 / n_i \}$	679.6073	1078.5773	2021.4077	1355.4393	1792.5899	
Variance of mean volume	$S_{\bar{x}_i}^2 = S^2_{x_i} / n_i$	37.7560	22.4704	22.4601	123.2218	10.7341	$\leftarrow \sum_j \omega_i^2 \cdot S_{\bar{x}_i}^2$
Standard deviation of mean volume	$S_{\bar{x}_i} = \sqrt{S_{\bar{x}_i}^2}$	6.14	4.74	4.74	11.10	3.28	
Confidence limit of mean volume	$R = t \cdot S_{\bar{x}_i}$	12.91 (t=2.10)	9.58 (t=2.01)	9.29 (t=1.96)	24.73 (t=2.23)	6.42 (t=1.96)	
Error rate of estimate	$\varepsilon_i = (R / \bar{x}_i) \times 100$	36.1	12.6	10.7	27.0	8.2	
Total volume	$X = A_i (\bar{x}_i \pm R)$	23,474 ~ 50,017	182,302 ~ 234,992	403,536 ~ 499,787	42,329 ~ 73,689	693,063 ~ 816,266	

Table 22-2. Results of calculation (number of trees)

Stratum		(YI)	(MI)	(OI)	(DI)	Total	
Stratum area	A_i (h (ha))	1,028	2,750	5,181	634	9,593	
Proportion of stratum area	ω_i	0.1072	0.2867	0.5400	0.0661	1.0000	
Square of the above	ω_i^2	0.0115	0.0822	0.2916	0.0044	0.3897	
Number of samples	n_i	18	48	90	11	167	
Sum of sample value (per ha)	$\sum_j x_{ij}$	1,785	5,230	9,160	2,120	18,295	
Sum of squared sample value	$\sum_j x_{ij}^2$	201,675	665,850	1,141,500	485,100	2,494,125	
Average number (per ha)	$\bar{x}_i = \sum_j x_{ij} / n_i$	99.2	109.0	101.8	192.7	109.6	$\leftarrow \sum_j \omega_i \cdot \bar{x}_i$
Variance of samples	$S^2 x_i = 1/n_i - 1 \{ \sum_j x_{ij}^2 - (\sum_j x_{ij})^2 / n_i \}$	1450.7353	2042.5089	2350.7366	7651.8182	2951.1525	
Variance of mean number	$S_{\bar{x}_i}^2 = S^2 x_i / n_i$	80.5964	42.5523	26.1193	695.6198	17.6715	$\leftarrow \sum_j \omega_i^2 \cdot S_{\bar{x}_i}^2$
Standard deviation of mean number	$S_{\bar{x}_i} = \sqrt{S_{\bar{x}_i}^2}$	8.98	6.52	5.11	26.37	4.20	
Confidence limit of mean number	$R = t \cdot S_{\bar{x}_i}$	18.87 (t=2.10)	13.11 (t=2.01)	10.02 (t=1.96)	58.76 (t=2.23)	8.23 (t=1.96)	
Error rate of estimate	$\varepsilon_i = (R / \bar{x}_i) \times 100$	19.0	12.0	9.8	30.5	7.5	
Total number	$X = A_i (\bar{x}_i \pm R)$	82,579 ~ 121,376	263,578 ~ 335,692	475,413 ~ 579,269	84,934 ~ 159,445	972,442 ~ 1,130,343	

According to the results above, the error rate of estimate was 8.2% with volume and 7.5% with number. They show that estimates were made with desirable precision for the small number of samples.

The number of samples corresponding to the estimated precision in future sampling survey which can be conducted by a similar method in a different area can be calculated as below. It shows that 450 samples will be required to attain precision of 5% and 120 samples for 10%.

$$CV = \frac{\varepsilon}{t} \cdot \sqrt{n} = \frac{8.2}{1.96} \times 167 = 54.06$$

$$n = \left(\frac{t \cdot CV}{\varepsilon}\right)^2 \begin{cases} \left(=\left(\frac{1.96 \times 54.06}{5}\right)^2 = 449 \div 450 \cdots \text{In the case of 5\%}\right. \\ \left(=\left(\frac{1.96 \times 54.06}{10}\right)^2 = 112 \div 120 \cdots \text{In the case of 10\%}\right. \end{cases}$$

Further, the overall average of volume per ha was 78.7m^3/ha and that of number per ha was 109.6/ha.

14. Evaluation of the accumulative total volume

According to the results of sampling, the total volume of coconut timber and the total number were, with the confidence rate of 95%, 693,063 to 816,266m^3 and 972,442 to 1,130,343 trees respectively.

It should be recalled here that the accumulative total volume and number obtained by photographic interpretation and the use of photo volume table were 754,047m^3 and 996,768 respectively. However, these values include the stand type E (idle forest) which was not included by the sampling survey. Therefore, if 10,720m^3 and 17,959 trees of the E type are deducted from the total volume and number given above, the total volume of 743,327m^3 and the total number of 978,809 are obtained. Comparison of the two sets of values show clearly that the accumulative values are within the confidence limit of the values by sampling totalling and that those values estimated for each block were accurate.

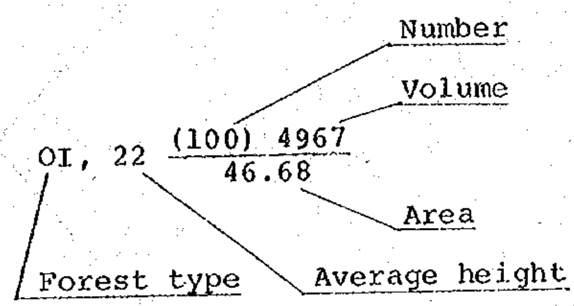
The fact that the total number is at the very limit of confidence is probably due to the fact that in photographic interpretation only the upper story can be interpreted (possible in a clear case such as two-storied forest). Therefore, if the number of trees per ha (Appendix I) which provides the data on numbers in a sampling survey can exclude the number in the lower story, the total number will then be well within the confidence limit.

15. Preparation of distribution and location maps of coconut forests

15-1. Preparation of distribution map

The average height, number of trees and volume interpreted for each block under the section 12 were entered on the original block map in the following style.

Example of entry



Then the original map was traced and arranged on the polyester paper to obtain the Coconut forest distribution map (appendix). Fig. 19 shows a part of it.

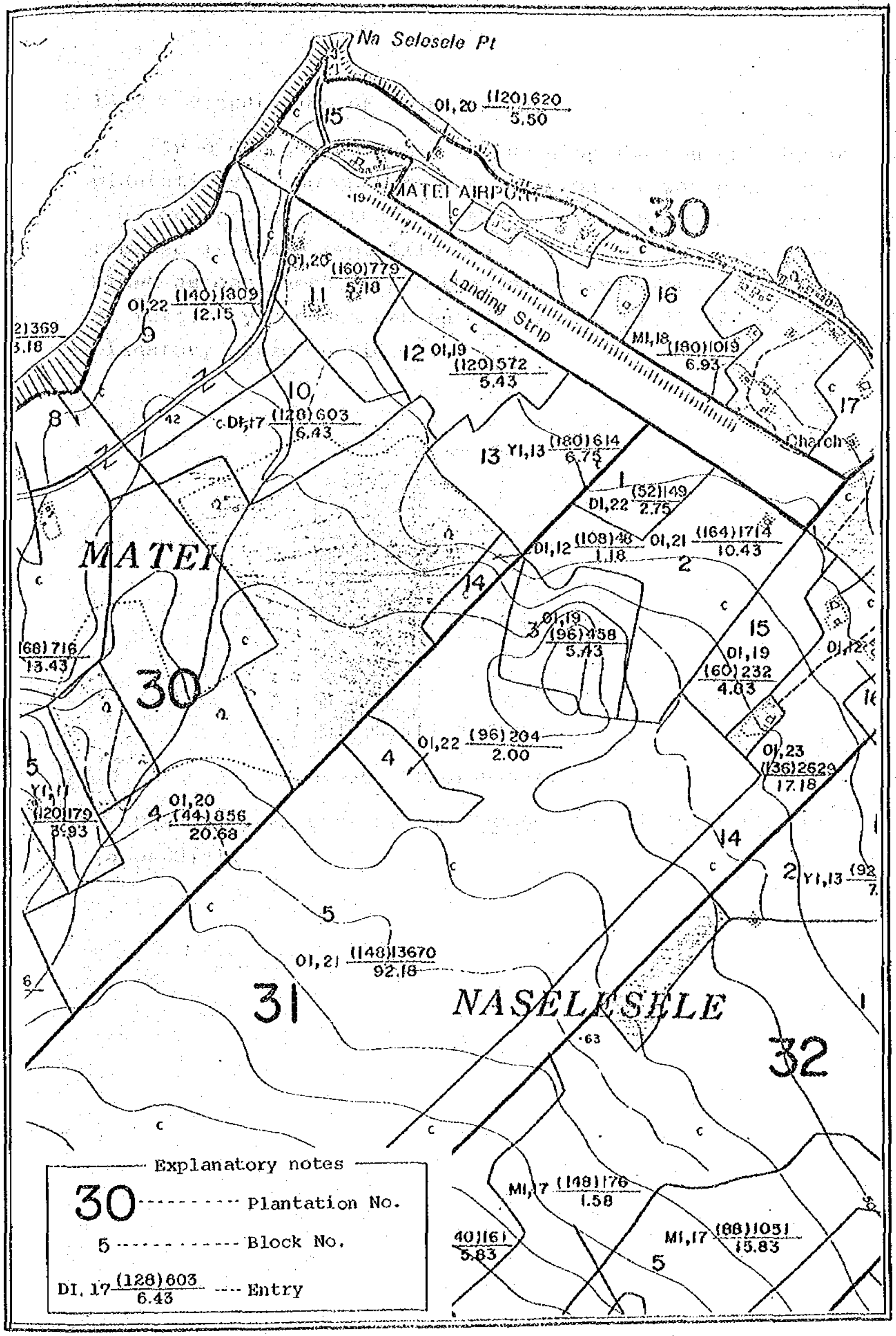


Fig. 19. Coconut forest distribution map (part)

15-2. Preparation of location map

In order to show clearly the distribution of coconut plantations, a coconut forest location map was prepared.

For preparing the map, the original block maps were reduced in scale from 1/10,000 to 1/50,000 and were combined as one sheet. Then the necessary information based on forest type codes was entered in the style of the explanatory notes on Fig. 20.

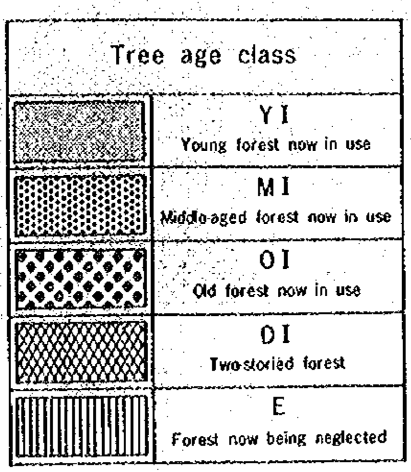


Fig. 20. Explanatory notes

Fig. 21 is a part of the Coconut forest location map (appendix).

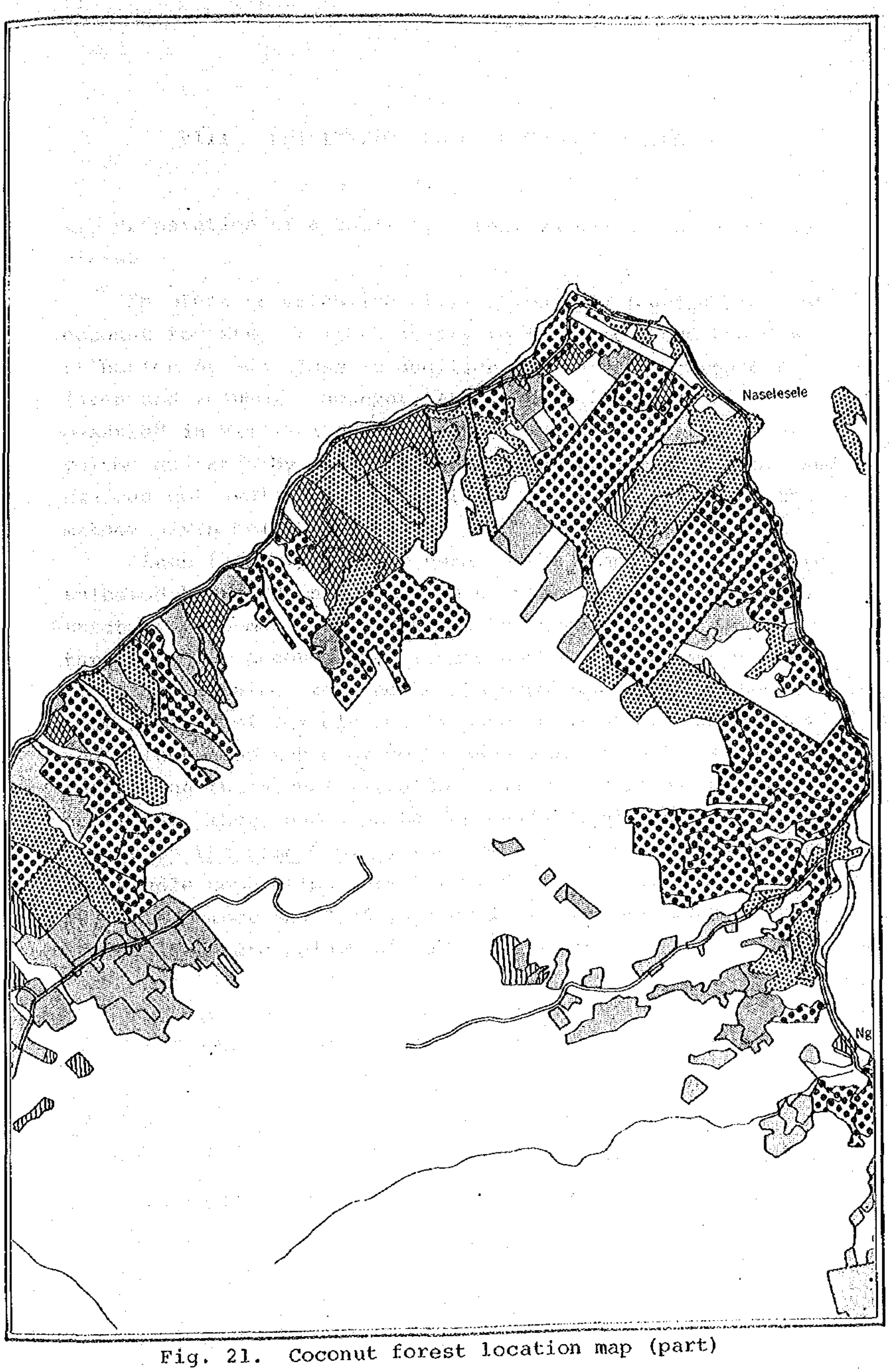


Fig. 21. Coconut forest location map (part)

VIII. UTILIZATION PLAN OF COCONUT FORESTS

1. Preparation of a table of actual volume and area by age class.

In order to establish utilization plan (cuting plan) of coconut forests, it is necessary to find out about the distribution by age class in addition to the total resources (area and volume). However, the volume of each block measured in VII-11-1 cannot be used for prepare a table of volume and area by each age class because in many cases stand age was not available. Thus, the table was prepared by the method given below.

Since the sample plots used in the sampling survey were selected by random sampling and proportionally allocated by stratum, presumably they reflect the general trend in the target area. Accordingly, if the number and volume by age class are obtained for the sample population, and if the distribution of age classes is used to allot the total area and volume, the table of volume and area of each age class reflecting the actual situation fairly accurately can be obtained. Thus, based on the appendix Results of the field survey on the sample plot, the numbers and volumes regarding the sample population were totalled, and the results were 187.4 in number and 2,764,5053m^3 in volume which are given in the left-hand column of Table 23 below.

Table 23. Number and volume of the sample plot by age class; distribution of area and volume by age class

Age class	Number of samples	Total volume of sample plot	Area alloted	Volume alloted
I	10.7	59.8111	621.00	16,311
II	17.7	140.7915	1,027.27	38,403
III	15.4	190.3922	893.78	51,932
IV	6.0	76.0218	348.23	20,729
V	4.0	44.9258	232.15	12,247
VI	4.0	65.5385	232.15	17,865
VII	7.7	110.4487	446.89	30,112
VIII	10.0	127.7968	580.38	34,858
IX	16.4	273.1036	951.82	74,488
X	13.4	171.8537	777.71	46,886
XI	11.7	156.6713	679.04	42,740
XII	10.0	163.7892	580.38	44,677
XIII	12.7	196.1559	737.08	53,514
XIV	14.0	296.2387	812.53	80,787
XV	11.7	217.1565	679.04	59,241
XVI	7.0	132.0581	406.26	36,030
XVII	5.0	123.1739	290.19	33,603
XVIII	3.0	58.5146	174.11	15,956
XIV	4.0	100.8745	232.15	27,521
XX以上	3.0	59.1888	174.12	16,147
	187.4	2,764.5053	(10,876.28)	(754,047)

Note: With regard to the samples of E-stratum, since only this stratum had a different sampling process (conversely the weight given to the sample's area), they are adjusted by that ratio (weight for E-stratum 98.72 and for other strata 57.44=1.72). This is the reason why the numbers are not integral numbers.

Accordingly, the total area of 10,876.28ha and the toal volume of 754,047m^3 can be alloted according to the ratio of each age class as shown in the right column of the table.

It should be mentioned, however, these age classes of samples were not obtained directly from the stand age given by the survey results but from the mean stem height curve (VII-12-1: Fig. 17) with the average stem height of plot as an index.

This was due to the fact that since the survey on stand age was based on verbal information, the age was roughly given in 10s or more and was seldom in 5s, causing extreme unbalance on the table which required the structural ratio at a five-year interval.

Further, though the mean whole height was obtained for the entire block and the mean whole height curve (Fig. 15) showing the relationship with stand age, samples were used on purpose, because the mean whole height was interpreted in meters, with the application of the mean whole height curve 1m corresponded to an interval of 15-20 years and the necessary information for every five years was not obtainable.
(The average stem height obtained as a result of the sample survey was the average of actual values, it was obtained in the unit of effective figure 0.1m.)

The table of actual volume and area by each age class obtained is Table 24.

Table 24. Table of volume and area by each age class

	①	②	③	
	Species: coconut			
	Area	Volume	Volume per ha	Remarks
	From forest inventory note		② / ①	
I	621	16, 311	26. 3	
II (10)	1,027	38, 403	37. 4	
III	894	51, 932	58. 1	
IV (20)	348	20, 729	59. 5	
V	232	12, 247	52. 8	
VI (30)	232	17, 865	77. 0	
VII	447	30, 112	67. 4	
VIII (40)	580	34, 858	60. 1	
IX	952	74, 488	78. 3	
X (50)	778	46, 886	60. 3	
XI	679	42, 740	62. 9	
XII (60)	581	44, 677	77. 0	
XIII	737	53, 514	72. 6	
XIV (70)	813	80, 787	99. 4	
XV	679	59, 241	87. 2	
XVI (80)	406	36, 030	88. 7	
XVII	290	33, 603	115. 8	
XVIII (90)	174	15, 956	91. 6	
XIX	232	27, 521	118. 5	
XX 以上	174	16, 147	92. 7	

2. Preparation of a growth prediction table

In order to calculate sustained yield it is necessary to use a prediction table which predicts how stand volume will increase. However, such material was not available not only in the survey area but also in Fiji as a whole. Therefore, it was decided to prepare a stand growth prediction table which can be called a yield table of actual stand based on the table of actual volume and area of each age class of Table 24.

First, from Table 24 the relationship between each age class and mean volume per ha can be obtained as Fig. 22 which shows that they follow a certain trend. When the uneven age class values were adjusted, the yield curve shown on Fig. 22 was obtained.

The value of volume at a five-year interval obtained from the curve is shown in the left-hand column of Table 25. These values can be used to calculate the growth of each age class which can supply the annual growth and the cut volume at the rotation period, thus providing the growth prediction table.

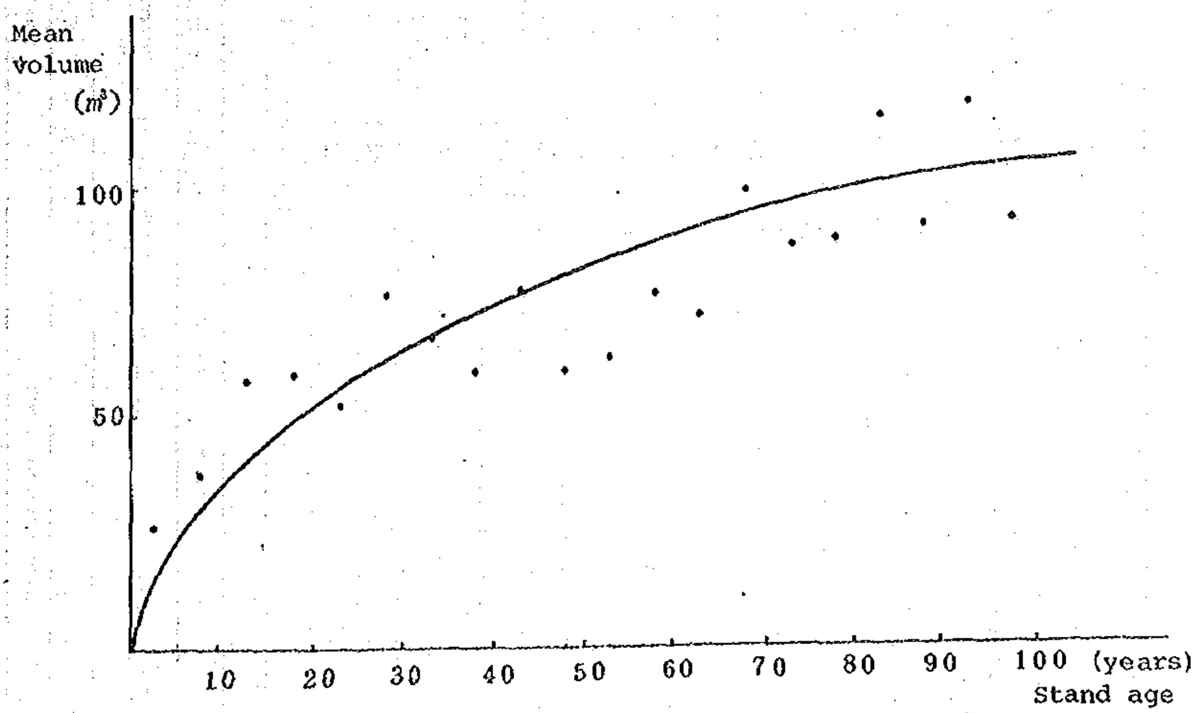


Fig. 22. Relationship between age class and mean volume and yield curve

Table 25. Yield prediction table and calculating table for correction coefficient

Yield prediction table			Converted yield prediction table						Calculating table for correction coefficient			
	①			②	③	④	⑤			⑥		
Stand age	Volume	Remarks	Age class	Volume	Annual growth	25Z	Cut volume at rotation period	Remarks	Age class	Actual volume per ha by age class (From table of actual volume and area of each age class)	Correction coefficient	Remarks
		(From yield curve)		$\frac{①_t+①_{t+1}}{2}$	$\frac{②_{t+1}-②_t}{5}$	③×25	②+④				$\frac{⑥}{②}$	
0	0											
			I	12.0	3.8	9.5	21.5		I	26.3	219	
5	24											
			II	31.0	2.3	5.8	36.8		II	37.4	121	
10	38											
			III	42.5	1.6	4.0	46.5		III	58.1	137	
15	47											
			IV	50.5	1.3	3.3	53.8		IV	59.5	118	
20	54											
			V	57.0	1.1	2.8	59.8		V	52.8	93	
25	60											
			VI	62.5	1.0	2.5	65.0		VI	77.0	123	
30	65											
			VII	67.5	1.0	2.5	70.0		VII	67.4	100	
35	70											
			VIII	72.5	0.9	2.3	74.8		VIII	60.1	83	
40	75											
			IX	77.0	0.8	2.0	79.0		IX	78.3	102	
45	79											
			X	81.0	0.8	2.0	83.0		X	60.3	74	
50	83											
			XI	85.0	0.7	1.8	86.8		XI	62.9	74	
55	87											
			XII	88.5	0.6	1.5	90.0		XII	77.0	87	
60	90											
			XIII	91.5	0.6	1.5	93.0		XIII	72.6	79	
65	93											
			XIV	94.5	0.5	1.3	95.8		XIV	99.4	105	
70	96											
			XV	97.0	0.4	1.0	98.0		XV	87.2	90	
75	98											
			XVI	99.0	0.4	1.0	100.0		XVI	88.7	90	
80	100											
			XVII	101.0	0.4	1.0	102.0		XVII	115.8	115	
85	102											
			XVIII	103.0	0.3	0.8	103.8		XVIII	91.6	89	
90	104											
			XIX	104.5	0.2	0.5	105.0		XIV	118.5	113	
95	105											
			XX	105.5	0.2	0.5	106.0		XX	92.7	88	
100	106											

3. Preparation of a succession table

In the case of the coconut stand left to grow, plant succession of growth and cut volume at the rotation period can be predicted by preparing a succession table.

With regard to the growth prediction table prepared under the section 2, actual volumes of age classes are un-even. Therefore, if they are adjusted accordingly and multiplied by final volume of growth per year, the growth and the cut volume at the rotation period can be obtained. If this calculation is repeated for each rotation period such as 5 years later or 10 years later, the succession table can be obtained.

Table 26. Succession table

Age class	Yield prediction table for age class ① Growing stock	② Annual growth	③ Cut volume at rotation period	Succession table: 1st working period ④ Correction coefficient (from calculating table for correction coefficient)	Growing stock ④×①	Growth ④×②	Cut volume at rotation period ④×③	2nd working period ④' Correction coefficient shown before (Slided by one column)	Growing stock ④'×①	Growth ④'×②	Cut volume at rotation period ④'×③	3rd working period Correction coefficient	Growing stock	Growth	Cut volume at rotation period	4th working period Correction coefficient	Growing stock	Growth	Cut volume at rotation period	5th working period Correction coefficient	Growing stock	Growth	Cut volume at rotation period
	From converted yield prediction table											(Same as left.)				(Same as left.)				(Same as left.)			
I	12.0	3.8	21.5	219	26.3	8.3	47.1	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5
II (10)	31.0	2.3	36.8	121	37.5	2.8	44.5	219	67.9	5.0	80.6	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8
III	42.5	1.6	46.5	137	58.2	2.2	63.7	121	51.4	1.9	56.3	219	93.1	3.5	101.8	100	42.5	1.6	46.5	100	42.5	1.6	46.5
IV (20)	50.5	1.3	53.8	118	59.6	1.5	63.5	137	69.2	1.8	73.7	121	61.1	1.6	65.1	219	110.6	2.8	117.8	100	50.5	1.3	53.8
V	57.0	1.1	59.8	93	53.0	1.0	55.6	118	67.3	1.3	70.6	137	78.1	1.5	81.9	121	69.0	1.3	72.4	219	124.8	2.4	131.0
VI (30)	62.5	1.0	65.0	123	76.9	1.2	80.0	93	58.1	0.9	60.5	118	73.8	1.2	76.7	137	85.6	1.4	89.1	121	75.6	1.2	78.7
VII	67.5	1.0	70.0	100	67.5	1.0	70.0	123	83.0	1.2	86.1	93	62.8	0.9	65.1	118	79.7	1.2	82.6	137	92.5	1.4	95.9
VIII (40)	72.5	0.9	74.8	83	60.2	0.7	62.1	100	72.5	0.9	74.8	123	89.2	1.1	92.0	93	67.4	0.8	69.6	118	85.6	1.1	88.3
IX	77.0	0.8	79.0	102	78.5	0.8	80.6	83	63.9	0.7	65.6	100	77.0	0.8	79.0	123	94.7	1.0	97.2	93	71.6	0.7	73.5
X (50)	81.0	0.8	83.0	74	59.9	0.6	61.4	102	82.6	0.8	84.7	83	67.2	0.7	68.9	100	81.0	0.8	83.0	123	99.6	1.0	102.1
XI	85.0	0.7	86.8	74	62.9	0.5	64.2	74	62.9	0.5	64.2	102	86.7	0.7	88.5	83	70.6	0.6	72.0	100	85.0	0.7	86.8
XII (60)	88.5	0.6	90.0	87	77.0	0.5	78.3	74	65.5	0.4	66.6	74	65.5	0.4	66.6	102	90.3	0.6	91.8	83	73.5	0.5	74.7
XIII	91.5	0.6	93.0	79	72.3	0.5	73.5	87	79.6	0.5	80.9	74	67.7	0.4	68.8	74	67.7	0.4	68.8	102	93.3	0.6	94.9
XIV (70)	94.5	0.5	95.8	105	99.2	0.5	100.6	79	74.7	0.4	75.7	87	82.2	0.4	83.3	74	69.9	0.4	70.9	74	69.9	0.4	70.9
XV	97.0	0.4	98.0	90	87.3	0.4	88.2	105	101.9	0.4	102.9	79	76.6	0.3	77.4	87	84.4	0.3	85.3	74	71.8	0.3	72.5
XVI (80)	99.0	0.4	100.0	90	89.1	0.4	90.0	90	89.1	0.4	90.0	105	104.0	0.4	105.0	79	78.2	0.3	79.0	87	86.1	0.3	87.0
XVII	101.0	0.4	102.0	115	116.2	0.5	117.3	90	90.9	0.4	91.8	90	90.9	0.4	91.8	105	106.1	0.4	107.1	79	79.8	0.3	80.6
XVIII (90)	103.0	0.3	103.8	89	91.7	0.3	92.4	115	118.5	0.3	119.4	90	92.7	0.3	93.4	90	92.7	0.3	93.4	105	108.2	0.3	109.0
XIV	104.5	0.2	105.6	113	118.1	0.2	119.3	89	93.0	0.2	94.0	115	120.2	0.2	121.4	90	94.1	0.2	95.0	90	94.1	0.2	95.0
over XX	105.5	0.2	106.0	88	92.8	0.2	93.3	113	119.2	0.2	119.8	89	93.9	0.2	94.3	115	121.3	0.2	121.9	90	95.0	0.2	95.4

Age class	Yield prediction table for age class			Succession table																			
				6th working period				7th working period				8th working period				9th working period				10th working period			
	①	②	③	④				④′															
	Growing stock	Annual growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period	Growing stock	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period
	(From converted yield prediction table)			(Same as left.)				(Same as left.)				(Same as left.)				(Same as left.)				(Same as left.)			
I	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5
II	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8
III	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5
IV	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8
V	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8
VI	62.5	1.0	65.0	219	136.9	2.2	142.4	100	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0
VII	67.5	1.0	70.0	121	81.7	1.2	84.7	219	147.8	2.2	153.3	100	67.5	1.0	70.0	100	67.5	1.0	70.0	100	67.5	1.0	70.0
VIII	72.5	0.9	74.8	137	99.3	1.2	102.5	121	87.7	1.1	90.5	219	158.8	2.0	63.8	100	72.5	0.9	74.8	100	72.5	0.9	74.8
IX	77.0	0.8	79.0	118	90.9	0.9	93.2	137	105.5	1.1	108.2	121	93.2	1.0	95.6	219	168.6	1.8	173.0	100	77.0	0.8	79.0
X	81.0	0.8	83.0	93	75.3	0.7	77.2	118	95.6	0.9	97.9	137	111.0	1.1	113.7	121	98.0	1.0	100.4	219	177.4	1.8	181.8
XI	85.0	0.7	86.8	123	104.6	0.9	106.8	93	79.1	0.7	80.7	118	100.3	0.8	102.4	137	116.5	1.0	118.9	121	102.9	0.8	105.0
XII	88.5	0.6	90.0	100	88.5	0.6	90.0	123	108.9	0.7	110.7	93	82.3	0.6	183.7	118	104.4	0.7	106.2	137	121.2	0.8	123.3
XIII	91.5	0.6	93.0	83	75.9	0.5	77.2	100	91.5	0.6	93.0	122	112.5	0.7	114.4	93	85.1	0.6	86.5	118	108.0	0.7	109.7
XIV	94.5	0.5	95.8	102	96.4	0.5	97.7	83	78.4	0.4	79.5	100	94.5	0.5	95.8	123	116.2	0.6	117.8	93	87.9	0.5	89.1
XV	97.0	0.4	98.0	74	71.8	0.3	72.5	102	98.9	0.4	100.0	83	80.5	0.3	81.3	100	97.0	0.4	98.0	123	119.3	0.5	120.5
XVI	99.0	0.4	100.0	74	73.3	0.3	74.0	74	73.3	0.3	74.0	102	101.0	0.4	102.0	83	82.2	0.3	83.0	100	99.0	0.4	100.0
XVII	101.0	0.4	102.0	87	87.9	0.3	88.7	74	74.7	0.3	75.5	74	74.7	0.3	75.5	102	103.0	0.4	104.0	83	83.8	0.3	84.7
XVIII	103.0	0.3	103.8	79	81.4	0.2	82.0	87	89.6	0.3	90.3	74	76.2	0.2	76.8	74	76.2	0.2	76.8	102	105.1	0.3	105.9
XIV	104.5	0.2	105.6	105	109.7	0.2	110.9	79	82.6	0.2	83.4	87	90.9	0.2	91.9	74	77.3	0.1	78.1	74	77.3	0.1	78.1
over XX	105.5	0.2	106.0	90	95.0	0.2	95.4	105	110.8	0.2	111.3	79	83.3	0.2	83.7	87	91.8	0.2	92.2	74	78.1	0.1	78.4

Age class	Yield prediction table for age class			Succession table																			
				11th working period				12th working period				13th working period				14th working period				15th wroking period			
	①	②	③	④				④′															
	Growing stock	Annual growth	Cut volume at rotation period	Correction coefficient (From calculating table for correction coefficient)"	Growing stock	Growth	Cut volume at rotation period	Correction coefficient shown before (Slided by one column)	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period	Correction coefficient	Growing stock	Growth	Cut volume at rotation period
	From converted yield prediction table				④×①	④×②	④×③		④′×①	④′×②	④′×③	(Same as left.)				(Same as left.)				(Same as left.)			
I	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5	100	12.0	3.8	21.5
II	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8	100	31.0	2.3	36.8
III	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5	100	42.5	1.6	46.5
IV	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8	100	50.5	1.3	53.8
V	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8	100	57.0	1.1	59.8
VI	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0	100	62.5	1.0	65.0
VII	67.5	1.0	70.0	100	67.5	1.0	70.0	100	67.5	1.0	70.0	100	67.5	1.0	70.0	100	67.5	1.0	70.0	100	67.5	1.0	70.0
VIII	72.5	0.9	74.8	100	72.5	0.9	74.8	100	72.5	0.9	74.8	100	72.5	0.9	74.8	100	72.5	0.9	74.8	100	72.5	0.9	74.8
IX	77.0	0.8	79.0	100	77.0	0.8	79.0	100	77.0	0.8	79.0	100	77.0	0.8	79.0	100	77.0	0.8	79.0	100	77.0	0.8	79.0
X	81.0	0.8	83.0	100	81.0	0.8	83.0	100	81.0	0.8	83.0	100	81.0	0.8	83.0	100	81.0	0.8	83.0	100	81.0	0.8	83.0
XI	85.0	0.7	86.8	219	186.2	1.5	190.1	100	85.0	0.7	86.8	100	85.0	0.7	86.8	100	85.0	0.7	86.8	100	85.0	0.7	86.8
XII	88.5	0.6	90.0	121	107.1	0.7	108.9	219	193.8	1.3	197.1	100	88.5	0.6	90.0	100	88.5	0.6	90.0	100	88.5	0.6	90.0
XIII	91.5	0.6	93.0	137	125.4	0.8	127.4	121	110.7	0.7	112.5	219	200.4	1.3	203.7	100	91.5	0.6	93.0	100	91.5	0.6	93.0
XIV	94.5	0.5	95.8	118	111.5	0.6	113.0	137	129.5	0.7	131.2	121	114.3	0.6	115.9	219	207.0	1.1	209.8	100	94.5	0.5	95.8
XV	97.0	0.4	98.0	93	90.2	0.4	91.1	118	114.5	0.5	115.6	137	132.9	0.5	134.3	121	117.8	0.5	118.6	219	212.4	0.9	214.6
XVI	99.0	0.4	100.0	123	121.8	0.5	123.0	93	92.1	0.4	93.0	118	116.8	0.5	118.0	137	135.6	0.5	137.0	121	119.8	0.5	121.0
XVII	101.0	0.4	102.0	100	101.0	0.4	102.0	123	124.2	0.5	125.5	93	93.9	0.4	94.9	118	119.2	0.5	120.4	137	138.4	0.5	139.7
XVIII	103.0	0.3	103.8	83	85.5	0.2	86.2	100	103.0	0.3	103.8	123	126.7	0.4	127.7	93	95.8	0.3	96.5	118	121.5	0.4	122.5
XIV	104.5	0.2	105.6	102	106.6	0.2	107.7	83	86.7	0.2	87.6	100	104.5	0.2	105.6	123	128.5	0.2	129.9	93	97.2	0.2	98.2
over XX	105.5	0.2	106.0	74	78.1	0.1	78.4	102	107.6	0.2	108.1	83	87.6	0.2	88.0	100	105.5	0.2	106.0	123	129.8	0.2	130.4

4. Establishment of standard rotation period and calculation of cutting area and cut volume

The standard rotation period is normally decided by the stand age with the largest mean growth. However, the mean growth calculated from Table 26 revealed that it attains the maximum in the fifth year. It is clear that the growth as volume is rapid; but it does not possess the utility as timber yet if cutting is done, as the formation of tissue is incomplete at the stand age. Since the problem was raised with the lower yield of nuts, it is more appropriate to use the period when the yield of nuts passes its maximum point as the standard rotation period. Thus, it was decided to use 50 years as the standard rotation period on the basis described in III-1.

Accordingly, the cutting area per one working period is:-

Total area ÷ (stand age at X or XI age class) × 5 years

Thus,

10,876 ha ÷ 47.5 (middle stand age at X working period)
5 years = 1,145 ha

10,876 ha ÷ 52.5 (middle stand age at XI working period)
× 5 years = 1,036 ha

will, therefore, be between 1,000 and 1,150ha.

Cut volume is:-

cutting area × (total of annual growth to cutting period
× 5 years)

and 1,145ha x 14.6m^3/ha (total of annual growth to X age class)
× 5 years) = 83,585

1,036 x 15.3m^3/ha (total of annual growth to XI age class)
× 5 years) = 79,254

thus, it will be between 79,000 and 84,000m^3 per working period.

5. Calculation of sustained yield

Calculation of sustained yield was made from the above data. Firstly, in terms of plant succession, cutting area can vary between 1,000 and 1,150ha per working period and volume at rotation period between 79,000 and 84,000m^3. As Table 24 shows, however, there is considerable deviation regarding the area per each age class, it is impossible for both of them to be compatible to each other.

Therefore, horisontal sustained yield of cut volume was to be the first principle, and calculation was carried out on the understanding that fluctuations to some extent in cutting area should be allowed (since it would presumably take two to three cycles to correct deviation regarding the area).

Further, planting is to be carried out on the premise that only the portion felled will be replenished in the following year, and expansion of area by expansive afforestation has not been considered.

Results of calculation based on sustained yield calculation formula are given as Table 27. Further, the total area and total volume at the head of each working period, cutting area and cut volume at each working period can be obtained from Table 27 and are given as Table 28, and Fig.23 shows succession of area and volume by each age class at working period 1st, 5th, 10th and 15th.

Table 27. Calculation table of sustained yield

Age class	Yield prediction table by age class			Calculation table of sustained yield																		Remarks
				1st working period						2nd working period						3rd working period						
	①	②	③	④	⑤			⑥		④'	⑤'			⑥'								
								Cutting						Cutting						Cutting		
	Growing stock	Annual growth	Cut volume at rotation period	Correction coefficient (From converted table for correction coefficient)	Area (From table of actual volume and area of each age class)	Growing stock	Growth	Area	Volume	Correction coefficient Shown before (Slided by one column)	Area (Slided by one column)	Growing stock	Growth	Area	Volume	Correction coefficient	Area	Growing stock	Growth	Area	Volume	
	From converted yield prediction table					④×⑤×①	④×⑤×②	Trial	⑥×④×②		③-⑥	④'×⑤'×①	④'×⑤'×②	Trial	⑥'④'③		(same as left)					
0 (Carried over from the last year of the previous period)											154						161					
I	12.0	3.8	21.5	219	621	16,320	5,168			100	614	7,368	2,333			100	800	9,600	3,040			
II	31.0	2.3	36.8	121	1,027	38,523	2,858			219	621	42,160	3,128			100	614	19,034	1,412			
III	42.5	1.6	46.5	137	894	52,053	1,960			121	1,027	52,813	1,988			219	621	57,800	2,176			
IV	50.5	1.3	53.8	118	348	20,737	534			137	894	61,851	1,592			121	1,027	62,755	1,615			
V	57.0	1.1	59.8	93	232	12,298	237			118	348	23,406	452			137	894	69,812	1,347			
VI	62.5	1.0	65.0	123	232	17,835	285			93	232	13,485	216			118	348	25,665	411			
VII	67.5	1.0	70.0	100	447	30,173	447			123	232	19,262	285			93	232	14,564	216			
VIII	72.5	0.9	74.8	83	580	34,902	433			100	447	32,408	402			123	232	20,689	257			
IX	77.0	0.8	79.0	102	962	74,770	777			83	580	37,068	385			100	447	34,419	358			
X	81.0	0.8	83.0	74	778	46,633	461			102	952	78,654	777			83	580	38,993	385			
XI	85.0	0.7	86.8	74	679	42,709	352			74	778	48,936	403			102	952	82,538	680			
XII	88.5	0.6	90.0	87	581	44,734	303			74	679	44,468	301			74	778	50,951	345			
XIII	91.5	0.6	93.0	79	737	53,274	349			87	581	46,251	303			74	679	45,975	301			
XIV	94.5	0.5	95.8	105	813	80,670	427	63	6,337	79	737	55,021	291	87	6,584	87	581	47,767	253	71	5,918	
XV	97.0	0.4	98.0	90	679	59,277	244	79	6,968	105	750	76,388	315	170	17,493	79	650	49,810	205	150	11,613	
XVI	99.0	0.4	100.0	90	406	36,175	146	56	5,040	90	600	53,460	216	100	9,000	105	580	60,291	244	230	24,150	
XVII	101.0	0.4	102.0	115	290	33,684	133	90	10,557	90	350	31,815	126	150	13,770	90	500	45,450	180	220	20,196	
XVIII	103.0	0.3	103.8	89	174	15,951	46	74	6,836	115	200	23,690	69	200	23,874	90	200	18,540	54	200	18,684	
XIV	104.5	0.2	105.6	113	232	27,396	52	232	27,684	89	100	9,301	18	100	9,398	115	—	—	—			
over XX以上	105.5	0.2	106.0	88	174	16,154	31	174	16,231	113	—	—	—	—	—	89	—	—	—			
Toal					10,876	754,268	15,243	768	79,653		10,876	757,805	13,600	807	80,119		10,876	754,653	13,479	871	80,561	
Cut area carried over from the previouse period ⓐ																						
Cutting area of the present period ⓑ				0						154						161						
Cutting area carried over to the next period ⓒ=ⓑ/5				768						807						871						
Planting area of the present period ⓓ=ⓐ+〔ⓑ−ⓒ〕				154						161						174						
				614+0=614						646+154=800						697+161=858						

Age class	Yield prediction table by age class			Calculation table of sustained yield																		Remarks
				4th working period						5th working period						6th working period						
	①	②	③	④	⑤			⑥		④'	⑤'			⑥'								
	Growing stock	Annual growth	Cut volume at rotation period	Correction coefficient (From converted table for correction coefficient)	Area (From table of actual volume and area of each age class)	Growing stock	Growth	Cutting Area	Cutting Volume	Correction coefficient (Shown before) (Slided by one column)	Area (Slided by one column)	Growing stock	Growth	Cutting Area	Cutting Volume	Correction coefficient	Area	Growing stock	Growth	Cutting Area	Cutting Volume	
	(From converted yield prediction table)					④×⑤×①	④×⑤×②	Trial	⑥×④×③		⑤−⑥	④'×⑤'×②	④'×⑤'×②	Trial	⑥'×④'×③			(Same as left.)				
0 (Carried over from the last year of the previous period)					174						185						196					
I	12.0	3.8	21.5	100	858	10,296	3,260			100	916	10,992	3,481			100	971	11,652	3,690			
II	31.0	2.3	36.8	100	800	24,800	1,840			100	858	26,598	1,973			100	916	28,396	2,107			
III	42.5	1.6	46.5	100	614	26,095	982			100	800	34,000	1,280			100	858	36,465	1,373			
IV	50.5	1.3	53.8	219	621	68,679	1,768			100	614	31,007	798			100	800	40,400	1,040			
V	57.0	1.1	59.8	121	1,027	70,832	1,367			219	621	77,519	1,496			100	614	34,998	675			
VI	62.5	1.0	65.0	137	894	76,549	1,225			121	1,027	77,667	1,243			219	621	84,999	1,360			
VII	67.5	1.0	70.0	118	348	27,718	411			137	894	82,673	1,225			121	1,027	83,880	1,243			
VIII	72.5	0.9	74.8	93	232	15,643	194			118	348	29,771	370			137	894	88,797	1,102			
IX	77.0	0.8	79.0	123	232	21,973	228			93	232	16,614	173			118	348	31,619	329			
X	81.0	0.8	83.0	100	447	36,207	358			123	232	23,114	228			93	232	17,477	173			
XI	85.0	0.7	86.8	83	580	40,919	337			100	447	37,995	313			123	232	24,256	200			
XII	88.5	0.6	90.0	102	952	85,937	583			83	580	42,604	289			100	447	39,560	268			
XIII	91.5	0.6	93.0	74	778	52,678	345	58	3,992	102	952	88,850	583	62	5,881	83	580	44,048	289	180	13,894	
XIV	94.5	0.5	95.8	74	679	47,482	251	79	5,600	74	720	50,350	266	120	8,507	102	890	85,787	454	200	19,543	
XV	97.0	0.4	98.0	87	510	43,039	177	210	17,905	74	600	43,068	178	150	10,878	74	600	43,065	178	200	14,504	
XVI	99.0	0.4	100.0	79	500	39,105	158	100	7,900	87	300	25,839	104	200	17,400	74	450	32,967	133	250	18,500	
XVII	101.0	0.4	102.0	105	350	37,118	147	200	21,420	79	400	31,916	126	300	24,174	87	100	8,787	35	100	8,874	
XVIII	103.0	0.3	103.8	90	280	25,956	76	280	26,158	105	150	16,223	47	150	16,349	79	100	8,137	34	100	8,200	
XV	104.5	0.2	105.6	90	–	–	–	–	–	90	–	–	–	–	–	105	–	–	–	–	–	
over XX	105.5	0.2	106.0	115	–	–	–	–	–	90	–	–	–	–	–	90	–	–	–	–	–	
Total					10,876	751,026	13,707	927	82,975		10,876	746,800	14,173	982	83,189		10,876	745,293	14,673	1,030	83,515	
Cut area carried over from the previouse period ⓐ				174						185						196						
Cutting area of the present period ⓑ				927						982						1,030						
Cutting area carried over to the next period ⓒ = ⓑ/5				185						196						206						
Planting area of the present period ⓓ = ⓐ+(ⓑ−ⓒ)				742+174=916						786+185=971						824+196=1,020						

Age class	Yield prediction table by age class ① Growing stock	② Annual growth	③ Cut volume at rotation period	Calculation table of sustained yield — 7th working period ④ Correction coefficient (from converted table for correction coefficient)	⑤ Area (From table of actual volume and area of each age class)	Growing stock	Growth	⑥ Cutting Area	Cutting Volume	8th working period ④' Correction coefficient Shown before (slided by one column)	⑤' Area (slided by one column)	Growing stock	Growth	⑥' Cutting Area	Cutting Volume	9th working period Correction coefficient	Area	Growing stock	Growth	Cutting Area	Cutting Volume	Remarks
	From converted yield prediction table					④⑤①	④⑤②	Trial	⑥④②		③ ⑤	④⑤①	④⑤②	Trial	⑥④③		(same as left)					
0 (Carried over from the last year of the previous period)					206						203						169					
I	12.0	3.6	21.5	100	1020	12,240	3,876			100	1,020	12,240	3,876			100	880	10,560	3,344			
II	31.0	2.3	36.8	100	971	30,101	2,233			100	1,020	31,620	2,346			100	1,020	31,620	2,346			
III	42.5	1.6	46.5	100	916	38,930	1,466			100	971	41,268	1,554			100	1,020	43,350	1,632			
IV	50.5	1.3	53.8	100	858	43,329	1,115			100	916	46,258	1,191			100	971	49,036	1,262			
V	57.0	1.1	59.8	100	800	45,600	880			100	858	48,906	944			100	916	52,212	1,008			
VI	62.5	1.0	65.0	100	614	38,375	614			100	800	50,000	800			100	858	53,625	858			
VII	67.5	1.0	70.0	219	621	91,799	1,360			100	614	41,445	614			100	800	54,000	800			
VIII	72.5	0.9	74.8	121	1027	90,094	1,118			219	621	98,599	1,224			100	614	44,515	553			
IX	77.0	0.8	79.0	137	894	94,308	980			121	1,027	95,686	994			219	621	104,719	1,088			
X	81.0	0.8	83.0	118	348	33,262	329			137	894	99,207	980	44	5,003	121	1,027	100,656	994	57	5,725	
XI	85.0	0.7	86.8	93	232	18,340	151			118	348	34,904	287	118	12,086	137	850	98,983	815	100	11,892	
XII	88.5	0.6	90.0	123	232	25,254	171			93	232	19,095	129	82	6,863	118	230	24,019	163	80	3,496	
XIII	91.5	0.6	93.0	100	447	40,901	268	87	8,091	123	232	26,110	171	82	9,380	93	150	12,764	84	50	4,325	
XIV	94.5	0.5	95.8	83	400	31,374	166	100	7,951	100	360	34,020	180	160	15,328	123	150	17,435	92	50	5,892	
XV	97.0	0.4	98.0	102	690	68,269	282	230	22,991	83	300	24,153	100	100	8,134	100	200	19,400	80	100	9,800	
XVI	99.0	0.4	100.0	74	400	29,304	118	400	29,600	102	460	46,451	188	260	26,520	83	200	16,434	66	200	16,600	
XVII	101.0	0.4	102.0	74	200	14,948	59	200	15,096	74	–	–	–	–	–	102	200	20,604	82	200	20,808	
XVIII	103.0	0.3	103.8	87	–	–	–	–	–	74	–	–	–	–	–	74	–	–	–	–	–	
XIV	104.5	0.2	105.6	79	–	–	–	–	–	87	–	–	–	–	–	74	–	–	–	–	–	
over XX	105.5	0.2	106.0	105	–	–	–	–	–	79	–	–	–	–	–	87	–	–	–	–	–	
Total					10,876	746,428	15,186	1,017	83,729		10,876	749,962	15,578	846	83,314		10,876	753,932	15,267	837	83,538	
Cut area carried over from the previous period	ⓐ			206						203						169						
Cutting area of the present period	ⓑ			1,017						846						837						
Cutting area carried over to the next period	ⓒ=ⓑ/5			203						169						167						
Planting area of the present period	ⓓ=ⓐ+[ⓑ−ⓒ]			814+206=1020						677+203=880						670+169=839						

Age class	Yield prediction table by age class ① Growing stock	② Annual growth	③ Cut volume at rotation period	Calculation table of sustained yield: 10th working period ④ Correction coefficient (from converted table for correction coefficient)	⑤ Area (From table of actual volume and area of each age class)	Growing stock ④⑤①	Growth ④⑤②	⑥ Cutting Area Trial	Cutting Volume ⑥④②	11th working period ④' Correction coefficient Shown before (Slided by one column)	⑤' Area (Slided by one column) ⑨-⑥	Growing stock ④'⑤'①	Growth ④'⑤'②	⑥' Cutting Area Trial	Cutting Volume ⑥'④'③	12th working period Correction coefficient	Area (same as left)	Growing stock	Growth	Cutting Area	Cutting Volume	Remarks
	From converted yield prediction table																					
0 (Carried over from the last year of the previous period)					167						142						139					
I	12.0	3.8	21.5	100	839	10,068	3,188			100	736	8,832	2,797			100	697	8,364	2,649			
II	31.0	2.3	36.8	100	880	27,280	2,024			100	839	26,009	1,930			100	736	22,816	1,693			
III	42.5	1.6	46.5	100	1,020	43,350	1,632			100	880	37,400	1,408			100	839	35,658	1,342			
IV	50.5	1.3	53.8	100	1,020	51,510	1,326			100	1,020	51,510	1,326			100	880	44,440	1,144			
V	57.0	1.1	59.8	100	971	55,347	1,068			100	1,020	58,140	1,122			100	1,020	58,140	1,122			
VI	62.5	1.0	65.0	100	916	57,250	916			100	971	60,688	971			100	1,020	63,750	1,020			
VII	67.5	1.0	70.0	100	858	57,915	858			100	916	61,830	916			100	971	65,543	971			
VIII	72.5	0.9	74.5	100	800	58,000	720			100	858	62,205	772			100	916	66,410	824			
IX	77.0	0.8	79.0	100	614	47,278	491			100	800	61,600	640			100	858	66,066	686			
X	81.0	0.8	83.0	219	621	110,159	1,088	41	7,453	100	614	49,734	491	14	1,162	100	800	64,800	640	45	3,735	
XI	85.0	0.7	86.8	121	970	99,765	822	70	7,352	219	580	107,967	889	55	10,455	100	600	51,000	420	10	868	
XII	88.5	0.6	90.0	137	750	90,934	617	300	36,990	121	900	96,377	653	275	29,948	219	525	101,753	690	135	26,609	
XIII	91.5	0.6	93.0	118	150	16,916	106	50	5,487	137	450	56,410	370	250	31,853	121	625	69,197	454	300	33,759	
XIV	94.5	0.5	95.8	93	100	8,789	47	50	4,455	118	100	11,151	59	50	5,652	137	200	25,893	137	100	13,125	
XV	97.0	0.4	98.0	123	100	11,931	49	100	12,054	93	50	4,511	19	50	4,557	118	50	5,723	24	50	5,782	
XVI	99.0	0.4	100.0	100	100	9,900	40	100	10,000	123	–	–	–	–	–	93	–	–	–	–	–	
XVII	101.0	0.4	102.0	83	–	–	–	–	–	100	–	–	–	–	–	123	–	–	–	–	–	
XVIII	103.0	0.3	103.8	102	–	–	–	–	–	83	–	–	–	–	–	100	–	–	–	–	–	
XIV	104.5	0.2	105.6	74	–	–	–	–	–	102	–	–	–	–	–	83	–	–	–	–	–	
over XX	105.5	0.2	106.0	74	–	–	–	–	–	74	–	–	–	–	–	102	–	–	–	–	–	
Total					10,876	755,672	14,992	711	83,791		10,876	754,364	14,363	694	83,627		10,876	749,553	13,816	640	83,878	
Cut area carried over from the previous period Ⓐ				167						142						139						
Cutting area of the present period Ⓑ				711						694						640						
Cutting area carried over to the next period Ⓒ=Ⓑ/5				142						139						128						
Planting area of the present period Ⓓ=Ⓐ+(Ⓑ-Ⓒ)				569+167=736						555+142=697						512+139=651						

Age class	Yield prediction table by age class ① Growing stock	② Annual growth	③ Cut volume at rotation period	13th working period ④ Correction coefficient (from converted table for correction coefficient)	⑤ Area (from table of actual volume and area of each age class)	Growing stock ④×⑤×①	Growth ④×⑤×②	⑥ Cutting Area Trial	Cutting Volume ⑥×④×②	14th working period ④' Correction coefficient shown before (slided by one column)	⑤' Area (slided by one column) ⑤-⑥	Growing stock ④'×⑤'×①	Growth ④'×⑤'×②	⑥' Cutting Area Trial	Cutting Volume ⑥'×④'×③	15th working period Correction coefficient	Area ((same as left))	Growing stock	Growth	Cutting Area	Cutting Volume	Remarks
	From converted yield prediction table																					
0 (Carried over from the last year of the previous period)					123						127						116					
I	12.0	3.8	21.5	100	651	7,812	2,474			100	634	7,608	2,409			100	592	7,104	2,250			
II	31.0	2.3	36.8	100	697	21,607	1,603			100	651	20,181	1,497			100	634	19,654	1,458			
III	42.5	1.6	46.5	100	736	31,280	1,178			100	697	29,623	1,115			100	651	27,668	1,042			
IV	50.5	1.3	53.8	100	839	42,370	1,091			100	736	37,168	957			100	697	35,199	906			
V	57.0	1.1	59.8	100	880	50,160	968			100	839	47,823	923			100	736	41,952	810			
VI	62.5	1.0	65.0	100	1,020	63,750	1,020			100	880	55,000	880			100	839	52,438	839			
VII	67.5	1.0	70.0	100	1,020	68,850	1,020			100	1,020	68,850	1,020			100	880	59,400	880			
VIII	72.5	0.9	74.8	100	971	70,398	874			100	1,020	73,950	918			100	1,020	73,950	918			
IX	77.0	0.8	79.0	100	916	70,532	733			100	971	74,767	777			100	1,020	78,540	816			
X	81.0	0.8	83.0	100	858	69,498	686	58	4,814	100	916	74,196	733	76	6,308	100	971	78,651	777			
XI	85.0	0.7	86.8	100	755	64,175	529	100	8,680	100	800	68,000	560	60	5,208	100	840	71,400	558			
XII	88.5	0.6	90.0	100	590	52,215	354	20	1,800	100	655	57,968	393	15	1,350	100	740	65,490	444			
XIII	91.5	0.6	93.0	219	390	78,150	512	155	31,569	100	570	52,155	342	70	6,510	100	640	56,560	384			
XIV	94.5	0.5	95.8	121	325	37,162	197	200	23,184	219	235	48,634	257	235	49,303	100	500	47,250	250			
XV	97.0	0.4	98.0	137	100	13,289	55	100	13,426	121	125	14,671	61	125	14,823	219	—	—	—			
XVI	99.0	0.4	100.0	118	—	—	—	—	—	137	—	—	—	—	—	121	—	—	—			
XVII	101.0	0.4	102.0	93	—	—	—	—	—	118	—	—	—	—	—	137	—	—	—			
XVIII	103.0	0.3	103.8	123	—	—	—	—	—	93	—	—	—	—	—	118	—	—	—			
XIV	104.5	0.2	105.6	100	—	—	—	—	—	123	—	—	—	—	—	93	—	—	—			
over XX	105.5	0.2	106.0	83	—	—	—	—	—	100	—	—	—	—	—	123	—	—	—			
Total					10,876	741,248	13,294	633	83,473		10,876	730,594	12,842	581	83,502		1,876	717,256	12,362			
Cut area carried over from the previous period	ⓐ			128						127												
Cutting area of the present period	ⓑ			633						581												
Cutting area carried over to the next period	ⓒ=ⓑ/5			127						116												
Planting area of the present period	ⓓ=ⓐ+(ⓑ−ⓒ)			506+128=634						465+127=592												

Table 28. Total area and total volume at the head of each working period cutting area and cut volume at each working period

	Total area at the head of each working period	Total volume at the head of each working period	Cutting area	Cut volume
working period	10, 876	754, 268	768	79, 653
2	10, 876	757, 805	807	80, 119
3	10, 876	754,653	871	80, 561
4	10, 876	751,026	927	82,975
5	10, 876	746,800	982	83,189
6	10, 876	745,293	1, 030	83,515
7	10, 876	746, 428	1, 017	83,729
8	10, 876	749,962	846	83, 314
9	10, 876	753,932	837	83,538
10	10, 876	755, 672	711	83, 791
11	10, 876	754,364	694	83, 627
12	10, 876	749,553	640	83, 878
13	10,876	741, 248	633	83,473
14	10,876	730,594	581	83,502
15	10,876	717, 256	—	—

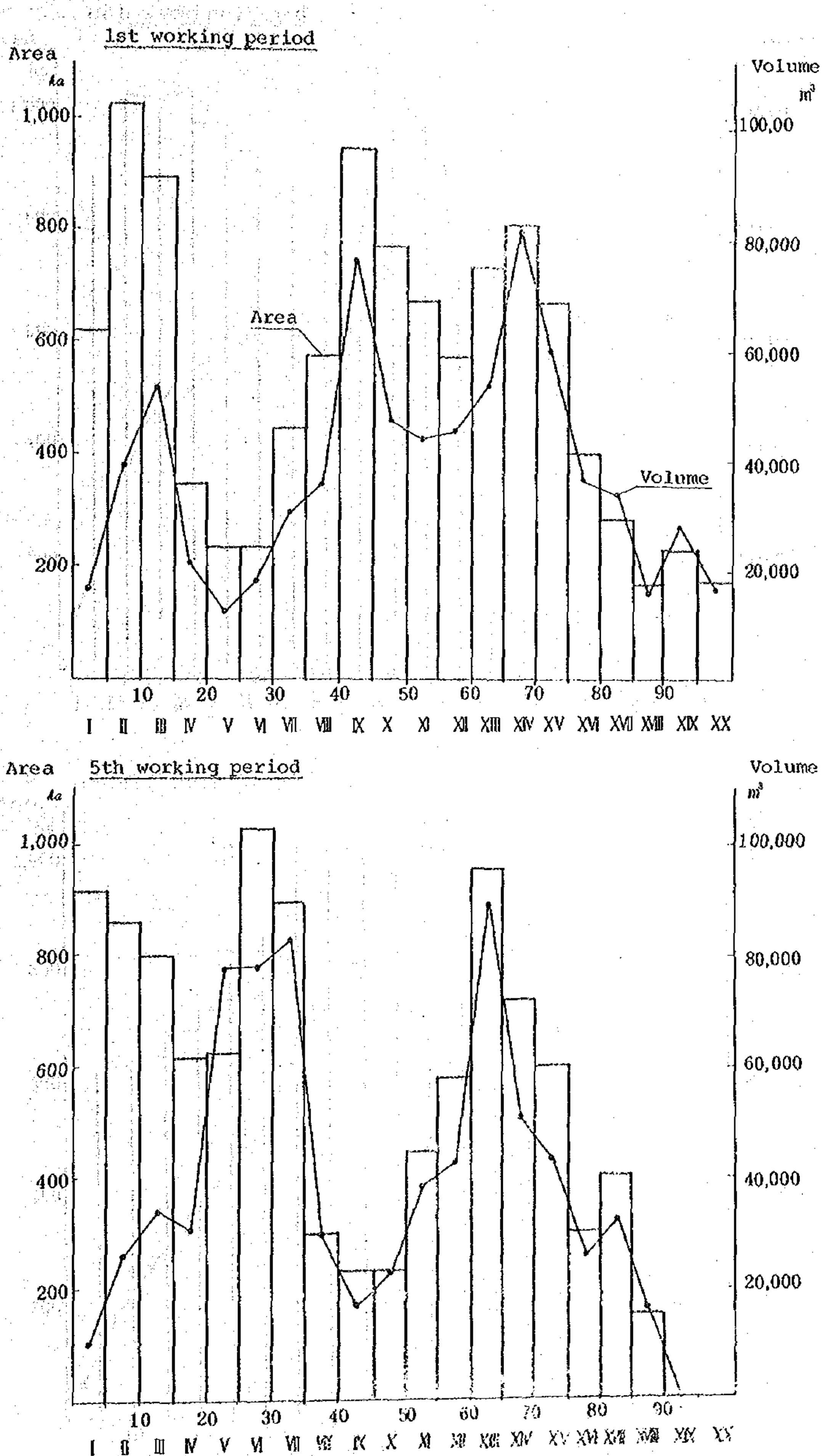
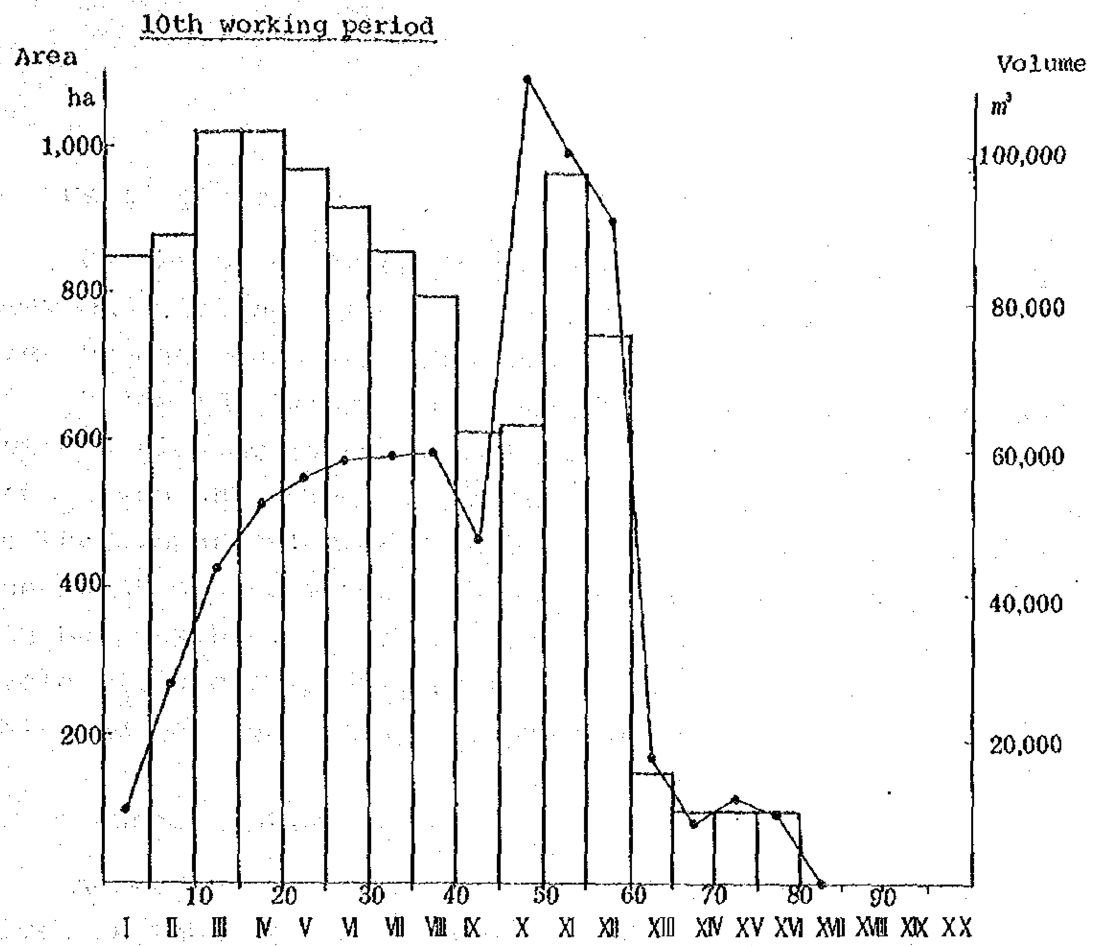
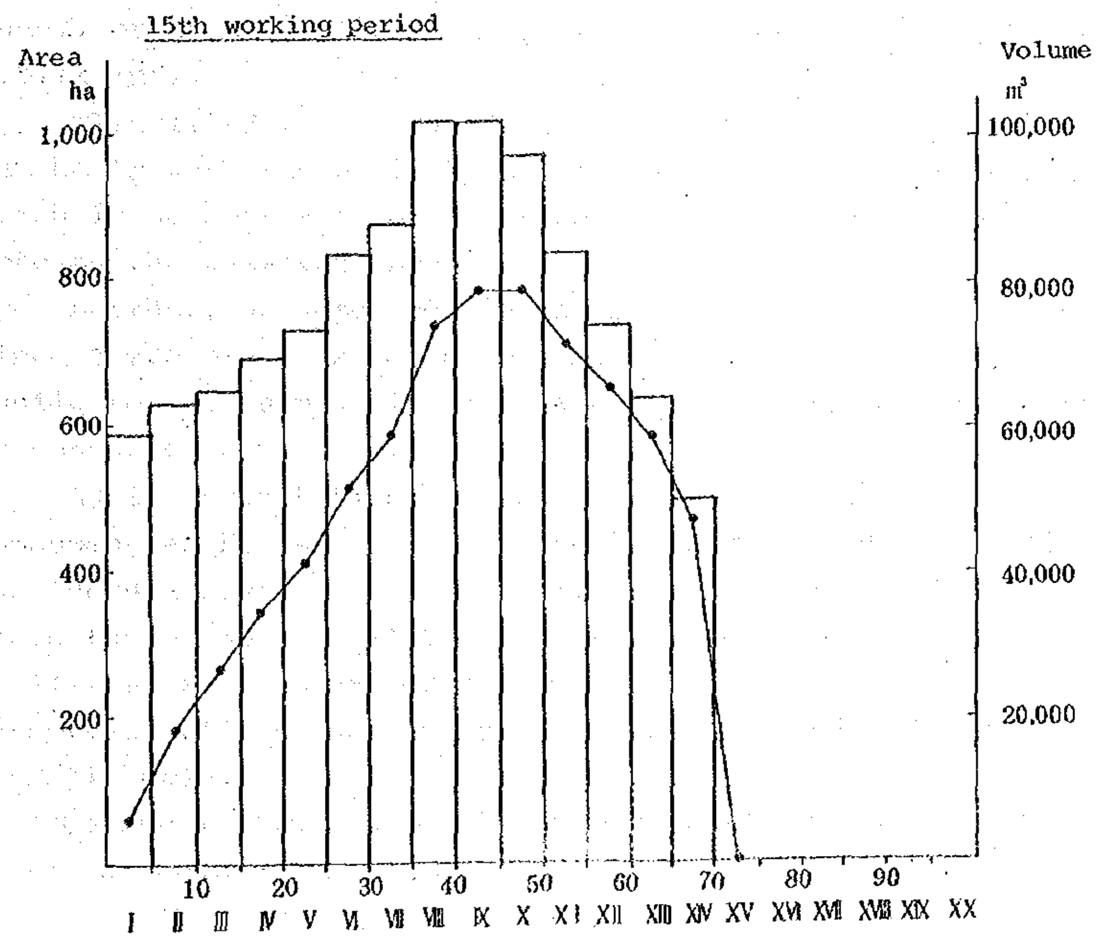


Fig. 23. Area and volume by age class at each working period


10th working period
Area
ha
1,000
800
600
400
200
Volume
m³
100,000
80,000
60,000
40,000
20,000
10 20 30 40 50 60 70 80 90
I II III IV V VI VII VIII IX X XI XII XIII XIV XV XVI XVII XVIII XIX XX


15th working period
Area
ha
1,000
800
600
400
200
Volume
m³
100,000
80,000
60,000
40,000
20,000
10 20 30 40 50 60 70 80 90
I II III IV V VI VII VIII IX X XI XII XIII XIV XV XVI XVII XVIII XIX XX

6. Cutting plan

By the calculation of sustained yield described in the previous working period, the total cut volume and cutting area by age class were obtained.

Since the target area consists of private plantations, further placing is not possible. However, if the Fiji Government gives an advice, as administrative guidance, on felling to the amount calculated above, and if it is accompanied by regeneration, permanent and stable supply of coconut timber can be possible. Further, after a lapse of two to three cycles (1 cycle is 50 years), coconut stand structure of balanced per age class area and volume can be obtained.

7. Transport plan, etc.

According to the calculation table of sustained yield given on Table 27, cut volume will be on average about 82,000m^3 per working period, amounting to about 16,400m^3 per annum, or about 17,600 tons in weight (as green density is 1,071kg/m^3).

This is 88 tons a day (200 working days a year), and can be transported by 18 trucks (capacity 5-ton). Therefore, there is no necessity of constructing solid roads or reinforcing the existing ones.

Further, as described in the results of the field survey, since there are work roads to transport coconuts, apart from public roads, running in the plantations, it is not necessary to construct new roads.

As for exportation, the existing harbor facilities at Somosomo can be used, with a vessel (capacity 500-ton) calling every 6 days. Accordingly, it is not necessary to improve the present facilities. However, as there are no facilities at present for storing timber collected at the harbor, it will be necessary to construct a timber basin of a small scale.

Collection in the stand can be carried out with tractor or truck equipped with a winch.

IX. Preparation of a Manual of Coconut Forest Inventory

1. Evaluation of inventory procedure

Through the procedure described above, coconut timber resources were confirmed and the utilization plan (cutting plan) was formed. This work process was almost as it was planned at the outset in VII-1, and there was no major alteration. This satisfactory outcome was probably because the Preliminary survey team had grasped the situation by collecting material and information thoroughly and by carrying out field survey to some extent.

With regard to the preparation of a manual of coconut forest inventory, in view of the successful outcome of the present survey, the procedure will be simply to repeat that of the present survey. In the case of carrying out inventory of coconut stand in a given target area, it can be done as the present survey following the flow chart of Fig. 7.

However, with regard to the items below, it will be desirable to prepare them anew, though those prepared under the present survey can be used as substitutes if it presents problems in view of costs and staff.

① Preparation of volume table and the necessary field survey of sample trees (a).

② Preparation of photo volume table and the necessary field survey of sample trees (b).

③ Preparation of standard interpretation cards.

If the target area is far from Taveuni Island, or if the form of coconut stand is unusual, it seems necessary to select sample trees to find out if the data obtained under the present survey are valid for the area.

2. Manual of coconut forest inventory

By sorting out the data and the various survey methods described above, a Manual of coconut forest inventroy was obtained, which is given as Appendix II. As the procedure is a repetition of the present survey itself, as mentioned above, detailed are excluded from the manual. For details and examples, the results of the present survey given in VII and VIII can be consulted. Further, sections on photographing and mapping operation are omitted from the manual as they are regarded as completed.

X. LIST OF THE PRODUCTS

Those material resulted from the present survey can be listed as below.

[Photographs]

1)	Aerial photographing films (negative films)	1 copy
2)	Positive films (with pass points transferred)	1 copy
3)	Contact prints	2 copies
4)	Original index map	1 copy
5)	Aerial photo mosaic	1 copy

[Topographical map]

1)	Position map of control stations	1 copy
2)	Results of aerial triangulation	1 copy
3)	Topographical original map	1 copy
4)	" copied original map (It was used as material for Coconut forest distribution)	1 copy

[Coconut forest inventroy]

1)	Coconut forest distribution map (1/10,000)	1 set
2)	Coconut forest location map (1/50,000)	1 set
3)	Photo volume table (with explanatory notes in English)	3 copies
4)	Standard interpretation cards	1 set
5)	Coconut forest inventory note (Table of area, number of trees and volume of each plantation)	2 copies
6)	Field survey note	1 copy
7)	Results of measurement of sample trees	1 copy
8)	Report of the survey	

Appendix

I. Table of Field Survey Result (results of the survey for estimation of the total volume).

II. Manual of Coconut Forest Inventory.

III. Scope of Work.

IV. Instructions for the use of Relaskop

Appendix I

Table of Field Survey Result
(results of the survey for estimation of the total volume)

Sample point No.	No. within Stratum	Stand age (years)	Age class: Young	Age class: Middle	Age class: Old	Forest condition: Mean stem height (m)	Forest condition: Mean central diameter (cm)	Plot volume: Number	Plot volume: Volume (m^3)	Volume per ha: Number	Volume per ha: Volume (m^3)	Topography: Azi-muth	Topography: Slope (°)	Remarks
1	[OI]- 1	60			o	16.4	25.7	14	12.2356	70	61.1780	Nil	Nil	
2	2	65			o	16.7	25.8	11	9.8892	55	49.4460	S	10	
3	3	60			o	16.3	26.5	12	11.0739	60	55.3695	Nil	Nil	
4	4	50			o	18.1	26.4	17	17.2253	85	86.1265	Nil	Nil	
5	5	60			o	13.6	26.9	14	11.0300	70	55.1500	SW	13	
6	6	60			o	21.2	25.0	6	6.4847	30	32.4235	Nil	Nil	
7	7	60			o	High 16.2 Low 12.5	High 26.5 Low 23.6	High 10 Low 2	High 9.0916 Low 1.1703	High 50 Low 10	High 45.4580 Low 5.8515	Nil	Nil	
8	8	60			o	14.1	25.1	9	6.5234	45	32.617	Nil	Nil	
9	9	60			o	17.6	25.9	14	13.3636	70	66.818	Nil	Nil	
10	10	60			o	13.0	25.4	4	2.7357	20	13.6785	Nil	Nil	
11	11	60			o	High 16.3 Low 12.0	High 25.7 Low 23.6	High 12 Low 1	High 10.5155 Low 0.5625	High 60 Low 5	High 52.5775 Low 2.8125	SW	7	
12	12	60			o	14.9	23.6	15	12.4175	60	62.0875	Nil	Nil	
13	13	60			o	15.1	25.4	14	11.1775	70	55.8875	Nil	Nil	
14	14	60			o	17.6	26.1	14	13.5108	70	67.554	Nil	Nil	
15	15	60			o	High 17.6 Low 13.0	High 27.2 Low 27.3	High 13 Low 2	High 13.4273 Low 1.5358	High 65 Low 10	67.1365 7.6790	Nil	Nil	
16	16	65			o	17.6	26.2	17	16.4777	85	82.3885	Nil	Nil	
17	17	70			o	16.0	25.9	12	10.4619	60	52.3095	Nil	Nil	
18	18	15	o			9.6	28.5	18	11.1002	90	55.5010	Nil	Nil	
19	19	10	o			7.2	28.6	25	12.0957	125	60.4785	Nil	Nil	
20	20	15	o			8.8	26.3	21	10.5387	105	52.6935	Nil	Nil	
21	21	60			o	High 17.7 Low 5.0	High 25.0 Lo2 26.5	High 7 Lo2 1	High 6.3166 Low 0.2911	High 35 Low 5	High 31.5830 Low 1.4555	SW	13	
22	22	70			o	13.3	24.8	29	19.4031	145	97.0155	Nil	Nil	
23	23	30-40		o		17.3	27.6	59	61.496	295	307.48	W	10	
24	24	25		o		High 16.6 Low 7.0	High 28.2 Low 25.0	High 22 Low 1	High 22.8918 Low 0.3667	High 110 Low 5	High 114.4590 Low 1.8335	Nil	Nil	
25	25	40		o		15.3	28.4	15	14.7145	75	73.5725	SW	8	
26	26	25		o		14.8	29.6	18	17.9078	90	89.5390	E	9	
27	27	50			o	14.0	27.5	26	21.7955	130	108.9775	W	7	
28	28	19	o			12.9	29.1	17	14.5365	85	72.6825	Nil	Nil	
29	29	(60 10)	o			High 19.1 Low 6.7	High 22.3 Low 26.5	High 16 Low 18	High 12.9293 Low 7.1607	High 80 Low 90	High 64.6465 Low 35.8035	Nil	Nil	

Sample point No.	No. within stratum	Stand age (years)	Age class			Forest condition		Plot volume		Volume per ha		Topography		Remarks
			Young	Middle	Old	Mean stem height (m)	Mean central diameter (cm)	Number	Volume (m³)	Number	Volume (m³)	Azi-muth	Slope (°)	
30	30	60 (12)			O	High 18.8 Low 7.1	High 22.0 Low 29.0	High 13 Low 17	High 11.7782 Low 8.0731	High 65 Low 85	High 58.8910 Low 40.3655	Nil	Nil	
31	31	50			O	High 15.1 Low 9.0	High 23.4 Low 22.0	High 17 Low 1	High 14.1605 Low 0.4676	High 85 Low 5	High 70.8025 Low 2.3380	Nil	Nil	
32	32	70			O	21.0	25.0	21	22.347	105	111.7350	Nil	Nil	
33	33	70			O	18.5	25.4	17	16.4560	85	82.2800	Nil	Nil	
34	(01)-34	80			O	22.2	25.5	26	30.3571	130	151.7855	Nil	Nil	
35	35	80			O	High 15.8 Low 13.0	High 24.5 Low 22.1	High 13 Low 2	High 10.1527 Low 1.0927	High 65 Low 10	Hihg 50.7635 Low 5.4630	Nil	Nil	
36	36	80			O	18.5	27.3	4	4.3562	20	21.7810	Nil	Nil	
37	37	80			O	High 19.9 Low 13.5	High 26.5 Low 25.0	High 14 Low 2	High 15.3950 Low 1.5940	High 70 Low 10	High 76.9750 Low 7.9520	Nil	Nil	
38	38	70			O	16.8	26.2	35	32.3181	175	161.5905	Nil	Nil	
39	39	50			O	18.3	26.5	13	13.302	65	66.5100	Nil	Nil	
40	40	60			O	18.2	27.9	17	19.0087	85	95.0435	Nil	Nil	
41	41	50-60			O	High 17.8 Low 12.3	High 27.3 Low 25.0	High 24 Low 6	High 25.0736 Low 3.8268	High 120 Low 30	High 125.368 Low 18.134	Nil	Nil	
42	42	50-60			O	15.6	25.8	16	13.4034	80	67.0170	SW	7	
43	43	50-60			O	17.1	26.3	13	12.2782	65	61.3910	SW	5	
44	44	40-50		O		High 13.4 Low 7.8	High 24.4 Low 22.1	High 11 Low 3	High 7.2524 Low 0.9834	High 55 Low 15	High 36.2620 Low 4.9170	W	10	
45	45	60-70			O	High 17.7 Low 11.8	High 25.0 Low 23.6	High 16 Low 4	High 14.4170 Low 2.1937	High 80 Low 20	High 72.0850 Low 10.9685	NW	7	
46	46	70			O	19.0	25.2	17	16.7152	85	83.5760	NW	13	
47	47	70			O	17.9	25.6	18	17.0140	90	85.0700	NW	13	
48	48	60			O	14.2	24.8	25	18.1534	125	90.7670	W	13	
49	49	60			O	13.6	27.4	15	12.0445	75	60.2225	W	10	
50	50	20	O			12.6	28.5	9	7.1675	45	35.8375	W	12	
51	51	70			O	17.6	29.7	16	17.2608	80	86.3040	NW	8	
52	52	70			O	18.6	28.2	19	22.0523	95	110.2615	W	7	
53	53	50			O	13.5	24.3	8	5.303	40	26.5150	N	12	
54	54	65			O	High 16.2 Low 9.5	High 26.1 Low 23.6	High 16 Low 6	High 14.3177 Low 2.7142	High 80 Low 30	High 71.5805 Low 13.5710	NW	8	
55	55	70			O	18.1	27.2	22	23.2677	110	116.3385	NW	12	

Sample point No.	No. within stratum	Stand age (years)	Age class: Young	Age class: Middle	Age class: Old	Forest condition: Mean stem height (m)	Forest condition: Mean central diameter (cm)	Plot volume: Number	Plot volume: Volume (m^3)	Volume per ha: Number	Volume per ha: Volume (m^3)	Topography: Azimuth	Topography: Slope (°)	Remarks
56	[OI]-56	60-70			o	High 16.0 Low 4.0	High 25.8 Low 28.0	High 10 Low 4	High 8.5446 Low 1.0268	High 50 Low 20	High 42.7230 Low 5.134	N	17	
57	57	(60-70, 9)	o		o	High 17.2 Low 3.5	High 25.8 Low 24.3	High 6 Low 2	High 5.4927 Low 0.3980	High 30 Low 10	High 27.4635 Low 1.9900	N	5	
58	58	45		o		15.7	24.3	25	19.1793	125	95.8965	NW	9	
59	59	50			o	15.6	26.4	13	11.3409	65	56.7045	W	10	
60	60	(50, 25)		o	o	High 15.4 Low 9.2	High 25.6 Low 25.8	High 5 Low 22	High 4.0875 Low 11.0232	High 25 Low 110	High 20.4375 Low 55.1160	N	8	
61	61	60			o	High 17.0 Low 12.7	High 27.0 Low 27.0	High 12 Low 3	High 11.1326 Low 2.2148	High 60 Low 15	High 55.6640 Low 11.0740	NW	9	
62	62	60			o	18.3	25.7	22	21.4415	110	10.72075	NW	5	
63	63	60			o	9.6	26.7	14	7.7507	70	38.7535	NW	7	
64	64	70			o	16.6	26.6	27	25.3053	135	126.5265	NW	5	
65	65	70			o	High 14.7 Low 2.0	High 24.5 Low 32.0	High 3 Low 2	High 2.1859 Low 0.3397	High 15 Low 10	High 10.9295 Low 1.6985	Nil	Nil	
66	66	50			o	14.7	26.6	22	18.3036	110	91.5180	E	7	
67	67	40		o		13.6	27.3	22	17.9769	110	89.8845	Nil	Nil	
68	68	50			o	15.0	25.9	22	17.8689	110	89.3445	Nil	Nil	
69	69	70			o	17.2	26.5	22	21.4551	110	107.2755	E	5	
70	70	70			o	19.8	26.8	27	30.4277	135	152.1385	E	6	
71	71	70			o	18.1	26.8	28	29.0047	140	145.0235	E	5	
72	72	50			o	16.1	26.9	20	18.6002	100	93.0010	NE	12	
73	73	70			o	19.8	27.5	24	27.8306	120	139.1530	NE	12	
74	74	10	o			4.5	27.7	41	11.1451	205	55.7255	Nil	Nil	
75	75	(60, 10)	o		o	High 14.3 Low 5.7	High 25.7 Low 29.4	High 30 Low 14	High 23.1792 Low 5.0552	High 150 Low 70	High 115.8960 Low 25.2760	Nil	Nil	
76	76	60			o	High 12.7 Low 7.7	High 26.9 Low 27.5	High 29 Low 3	High 21.0570 Low 1.4010	High 145 Low 15	High 105.2850 Low 7.0050	Nil	Nil	
77	77	45		o		High 17.5 Low 2.4	High 25.9 Low 31.0	High 21 Low 5	High 19.8395 Low 0.9304	High 105 Low 25	High 99.1975 Low 4.6520	Nil	Nil	
78	78	70			o	High 18.4 Low 12.0	High 26.5 Low 24.3	High 19 Low 2	High 19.6676 Low 1.1802	High 95 Low 10	High 98.3380 Low 5.9010	Nil	Nil	
79	79	50			o	13.7	26.3	14	10.5234	70	52.6170	Nil	Nil	

Sample point No.	No. within stratum	Stand age (years)	Age class: Young	Age class: Middle	Age class: Old	Forest condition: Mean stem height (m)	Forest condition: Mean central diameter (cm)	Plot volume: Number	Plot volume: Volume (m^3)	Volume per ha: Number	Volume per ha: Volume (m^3)	Topography: Azi-muth	Topography: Slope (°)	Remarks
80	80	50			o	14.3	27.0	23	19.1893	115	95.9465	SE	12	
81	81	60			o	High 16.8 Low 7.4	High 24.8 Low 24.0	High 28 Low 7	High 22.9220 Low 2.5490	High 140 Low 35	High 114.6100 Low 12.7450	Nil	Nil	
82	82	60			o	17.6	26.3	29	28.2709	145	141.3545	Nil	Nil	
83	83	60			o	High 18.0 Low 10.0	High 26.6 Low 28.0	High 22 Low 2	High 22.3814 Low 1.2446	High 110 Low 10	High 111.9070 Low 6.2230	Nil	Nil	
84	84	70			o	19.6	27.2	18	20.6149	90	103.0745	Nil	Nil	
85	85	77			o	19.5	27.0	11	12.3002	55	61.5010	Nil	Nil	
86	86	50			o	14.4	26.5	26	21.3588	130	106.7940	Nil	Nil	
87	87	55-60			o	High 18.7 Low 10.3	High 26.4 Lo 25.0	High 33 Low 3	High 34.4156 Low 1.6448	High 165 Low 15	High 172.0780 Low 8.2240	Nil	Nil	
88	88	(79/20)	o		o	High 18.0 Low 7.0	High 25.6 Low 25.8	High 28 Low 4	High 25.5941 Low 1.5178	High 140 Low 20	High 127.9705 Low 7.5890	Nil	Nil	
89	89	(75/20)	o		o	High 17.6 Low 7.2	High 25.0 Low 26.2	High 14 Low 25	High 12.6122 Low 10.1642	High 70 Low 125	High 63.0610 Low 50.8210	Nil	Nil	
90	90	(60/5)	o		o	High 18.9 Low 8.2	High 26.2 Low 28.3	High 40 Low 5	High 41.6675 Low 3.0708	High 200 Low 25	High 208.3375 Low 15.3540	Nil	Nil	
91	(MI)- 1	(70/10)	o		o	High 17.1 Low 5.0	High 25.7 Low 20.1	High 15 Low 3	High 14.1615 Low 0.5758	High 75 Low 15	High 70.8075 Low 2.8795	SE	Nil	
92	2	15	o			8.9	27.8	22	12.0615	110	60.3075	Nil	Nil	
93	3	15	o			11.1	27.4	21	14.0576	105	70.288	SE	11	
94	4	30-40		o		High 14.3 Low 5.4	High 25.4 Low 26.5	High 18 Low 5	High 13.6926 Low 1.5446	High 90 Low 25	High 58.4630 Low 7.7230	E	7	
95	5	13	o			High 11.3 Low 5.7	High 25.0 Low 27.8	High 3 Low 19	High 1.7532 Low 4.5715	High 15 Low 95	High 8.7660 Low 22.8588	Nil	Nil	
96	6	10	o			6.2	30.9	25	11.6062	125	58.0310	SW	13	
97	7	70			o	High 19.0 Low 14.8	High 28.0 Low 24.2	High 15 Low 5	High 17.8412 Low 3.6014	High 75 Low 25	High 89.2060 Low 18.0070	W	6	
98	8	70			o	High 18.7 Low 15.0	High 27.2 Low 25.0	High 15 Low 3	High 16.5659 Low 2.3072	High 75 Low 15	High 82.8295 Low 11.5360	Nil	Nil	
99	9	70			o	High 19.9 Low 14.0	High 27.2 Low 22.5	High 20 Low 4	High 23.1966 Low 2.4342	High 100 Low 20	High 115.9830 Low 12.1710	Nil	Nil	

Sample point No.	No. within Stratum	Stand age (years)	Age class			Forest condition		Plot volume		Volume per ha		Topography		Remarks
			Young	Middle	Old	Mean stem height (m)	Mean central diameter (cm)	Number	Volume (m^3)	Number	Volume (m^3)	Azi-muth	Slope (°)	
100	[MI]-10	60			o	18.3	26.8	19	19.985	95	99.9475	Nil	Nil	
101	11	60			o	16.9	27.9	14	14.6191	70	73.0995	Nil	Nil	
102	12	50			o	16.7	27.6	19	19.2493	85	96.2465	Nil	Nil	
103	13	60			o	High 16.3 Low 9	High 27.5 Low 25.0	High 20 Low 1	High 19.4456 Low 0.4676	High 100 Low 5	High 97.2280 Low 2.3880	Nil	Nil	
104	14	6-7	o			5.3	32.7	19	8.1887	95	40.9435	Nil	Nil	
105	15	5	o			High 4.9 Low 1.0	High 25.7 Low 28.8	High 7 Low 2	High 1.9015 Low 0.1401	High 35 Low 10	High 9.5075 Low 0.7005	E	9	
106	16	30		o		12.6	24.1	18	11.1115	90	55.5575	Nil	Nil	
107	17	40		o		8.3	22.4	12	4.3701	60	21.8505	W	5	
108	18	50-60			o	High 19.6 Low 13.2	High 27.1 Low 28.0	High 19 Low 5	High 21.5244 Low 4.0751	High 95 Low 25	High 107.6220 Low 20.3755	W	6	
109	19	60,70			o	18.5	26.5	13	13.4123	65	67.0615	NW	8	
110	20	60			o	17.3	25.0	16	14.0139	80	70.0695	NW	15	
111	21	70			o	16.5	25.8	17	15.0307	85	75.1535	NW	6	
112	22	50			o	High 16.9 Low 12.8	High 24.0 Low 22.9	High 21 Low 4	High 16.7528 Low 2.2675	High 105 Low 20	High 83.7640 Low 11.3375	NW	18	
113	23	50			o	15.5	24.3	17	12.8621	85	64.3105	NW	13	
114	24	(60, 10)	o		o	High 15.8 Low 6.8	High 25.0 Low 28.6	High 21 Low 15	High 16.9317 Low 6.6416	High 105 Low 75	High 84.6585 Low 33.080	NW	11	
115	25	60			o	17.4	25.9	22	20.6159	110	103.0795	W	8	
116	26	12	o			3.7	31.1	11	3.1236	55	15.6180	NW	17	
117	27	(60, 8-10)	o		o	High 17.5 Low 8.0	High 25.0 Low 27.0	High 13 Low 26	High 10.2281 Low 11.5959	High 65 Low 130	High 51.1405 Low 57.9795	NW	15	
118	28	30		o		High 11.9 Low 5.0	High 25.3 Low 28.0	High 35 Low 1	High 22.0657 Low 0.3183	High 175 Low 5	High 110.3285 Low 1.5915	Nil	Nil	
119	29			o				0	0	0	0	NW	17	Unstocked land
120	30	40		o		13.4	25.2	25	17.4841	125	87.4205	NW	6	
121	31	60			o	High 19.0 Low 4.3	High 27.7 Low 25.1	High 17 Low 3	High 19.6079 Low 0.7211	High 85 Low 15	High 98.0395 Low 3.6055	N	12	
122	32	15	o			11.0	27.5	27	17.7848	135	88.9240	NW	11	
123	33	(60, 7)	o		o	High 14.8 Low 2.4	High 25.6 Low 28.9	High 17 Low 23	High 13.5080 Low 4.1345	High 85 Low 115	High 67.5400 Low 20.6725	W	9	

Sample point No.	No. within stratum	Stand age (years)	Age class: Young	Middle	Old	Forest condition: Mean stem height (m)	Mean central diameter (cm)	Plot volume: Number	Volume (m)	Volume per ha: Number	Volume (m)	Topography: Azi-muth	Slope (°)	Remarks
124	34	10	o			6.2	26.3	9	3.2487	45	16.2435	NW	9	
125	35	25		o		High 14.0 Low 7.6	High 26.2 Low 25.6	High 25 Low 5	High 20.0110 Low 21.285	High 125 Low 25	High 100.0550 Low 10.6425	W	9	
126	36	55			o	12.5	26.3	22	15.2145	110	76.0725	Nil	Nil	
127	37	50			o	17.3	27.2	23	23.3773	115	116.8865	E	6	
128	38	50			o	13.7	24.6	10	6.8921	50	34.4605	SW	19	
129	39	50			o	14.4	25.0	26	19.3809	130	96.9045	Nil	Nil	
130	40	(40, 5)	o	o		High 14.8 Low 2.5	High 23.3 Low 27.9	High 26 Low 23	High 17.7446 Low 3.4572	High 130 Low 115	High 88.7230 Low 17.2860	N	6	
131	41	45		o		High 15.7 Low 4.5	High 25.7 Low 25.2	High 23 Low 8	High 19.3300 Low 1.9312	High 115 Low 40	High 96.6500 Low 9.6560	SE	19	
132	42	25		o		High 11.7 Low 7	High 26.7 Low 26.2	High 10 Low 4	High 6.6883 Low 1.5645	High 50 Low 20	High 33.4415 Low 7.8225	SE	14	
133	[MI]-10	50-60			o	14.7	26.2	21	17.0824	105	85.4120	SE	10	
134	44	40		o		14.4	25.6	21	16.4077	105	82.03835	Nil	Nil	
135	45	60			o	12.9	24.4	21	14.0733	105	70.3665	SW	13	
136	46	(40, 5)	o	o		High 11.2 Low 2.7	High 25.7 Low 29.0	High 30 Low 9	High 18.1080 Low 1.6137	High 150 Low 45	High 90.5400 Low 8.0685	Nil	Nil	
137	47	30		o		6.8	26.4	21	8.1487	105	40.7435	Nil	Nil	
138	48	30-40		o		7.8	26.9	17	7.8105	85	39.0525	NE	10	
139	[YI]- 1	6-7	o			High 16.0 Low 4.9	High 22.1 Low 26.2	High 1 Low 21	High 0.6679 Low 5.6557	High 5 Low 105	High 3.3395 Low 28.2785	SE	7	
140	2	6	o			High 2.8 Low -	High 28.6 Low -	High 12 Low 6	High 2.1334 Low 0	High 60 Low 30	High 10.667 Low 0	Nil	Nil	
141	3	10	o			6.5	28.1	22	9.4239	110	47.1195	Nil	Nil	
142	4	15	o			6.7	27.2	30	12.1259	150	60.6295	Nil	Nil	
143	5	60			o	18.9	25.6	20	19.9488	100	99.744	NW	12	
144	6	7	o			2.3	29.7	25	4.0637	125	20.3185	NW	7	
145	6	10	o			High 9.9 Low 6.0	High 27.6 Low 26.6	High 17 Low 2	High 10.2839 Low 0.6803	High 85 Low 10	High 51.4195 Low 3.4015	NW	15	
146	8	10	o			10.6	26.5	23	13.9744	115	69.872	W	13	
147	9	10	o			6.8	27.9	30	12.7219	150	63.6095	N	7	
148	10	7	o			40	27.7	22	5.4331	110	27.1655	Nil	Nil	

Sample point No.	No. within stratum	Stand age (year)	Age class: Young	Middle	Old	Forest condition: Mean stem height (m)	Mean central diameter (cm)	Plot volume: Number	Volume (m^3)	Volume per ha: Number	Volume (m^3)	Topography: Azi-muth	Slope (°)	Remarks
149	11	(12 4)	o			High 9.3 Low 3.8	High 27.0 Low 30.8	High 3 Low 23	High 1.6399 Low 5.9781	High 15 Low 115	High 8.1995 Low 29.8905	E	10	
150	12	7	o			High 1.1 Low -	High 28.6 Low -	High 13 Low 10	High 0.9872 Low 0	High 65 Low 50	High 4.9360 Low 0	E	7	
151	13	19	o			3.9	28.6	21	5.3426	105	26.713	Nil	Nil	
152	14	7	o			4.3	28.4	23	6.4554	115	32.2770	SE	21	
153	15	5	o			1.8	30.1	12	1.4949	60	7.4755	SE	10	
154	16	15	o			4.5	28.6	8	2.3717	40	11.8585	SE	22	
155	17	10	o			5.5	28.0	2	0.7597	10	3.7985	E	12	
156	18	5-6	o			High 4.4 Low -	High 25.9 Low -	High 27 Low 1	High 6.5325 Low 0	High 135 Low 5	High 32.6625 Low 0	SE	24	
157	[DI]-1	(60 10)	o		o	High 19.7 Low 7.8	High 22.0 Low 26.2	High 10 Low 26	High 8.1161 Low 11.3009	High 50 Low 130	High 40.5805 Low 56.5045	Nil	Nil	
158	2	5	o			High 18.1 Low 1.3	High 27.3 Low 37.2	High 11 Low 19	High 11.6944 Low 2.5783	High 55 Low 95	High 58.4720 Low 12.8915	Nil	Nil	
159	3	6	o			High 16.3 Low 2.4	High 23.8 Low 31.6	High 7 Low 29	High 5.3720 Low 5.5608	High 35 Low 145	High 26.8600 Low 27.8040	Nil	Nil	
160	4	15	o			High 17.1 Low 6.7	High 27.2 Low 24.6	High 17 Low 31	High 16.9824 Low 10.8985	High 85 Low 155	High 84.9120 Low 54.4925	Nil	Nil	
161	5	(70 12)	o		o	High 20.8 Low 6.9	High 25.0 Low 27.9	High 5 Low 18	High 5.2555 Low 7.6166	High 25 Low 90	High 26.2775 Low 38.0830	W	5	
162	6	50			o	High 16.7 Low 13.4	High 26.5 Low 27.1	High 17 Low 5	High 15.9378 Low 3.9346	High 85 Low 25	High 79.6890 Low 19.6730	N	6	
163	7	(60-70 12)	o		o	High 16.7 Low 4.9	High 25.6 Low 24.7	High 10 Low 64	High 8.8624 Low 16.2076	High 50 Low 320	High 44.3120 Low 81.0380	NW	7	
164	8	(50 12)	o			High 16.5 Low 3.7	High 23.9 Low 24.7	High 20 Low 41	High 15.6863 Low 7.9810	High 100 Low 205	High 78.4315 Low 39.9050	N	6	
165	9	(70 28)		o	o	High 16.4 Low 4.3	High 20.3 Low 21.8	High 14 Low 27	High 10.8453 Low 6.0926	High 70 Low 135	High 54.2265 Low 30.4630	N	9	
166	[DI]-10	35		o		High 16.0 Low 11.6	High 22.0 Low 19.7	High 4 Low 35	High 3.2893 Low 18.1711	High 20 Low 175	High 16.4465 Low 90.8555	N	5	

Sample point No.	No. within stratum	Stand age (year)	Age class			Forest condition		Plot volume		Volume per ha		Topography		Remarks
			Young	Middle	Old	Mean stem height (m)	Mean central diameter (cm)	Number	Volume (m)	Number	Volume (m)	Azi-muth	Slope (°)	
167	11	5	o			32	28.8	14	2. 178	70	14.0890	E	22	
168	(E)- 9	40-50		o		High 16.5 Low 7.0	High 25.0 Low 22.7	High 2 Low 5	High 1.6784 Low 1.5811	High 10 Low 25	High 8.3920 Low 7.9055	Nil	Nil	
169	12	50 (over)			o	15.0	22.6	18	11.8087	90	59.0435	NW	11	
170	13	-				-	-	0	0	0	0	NW	7	Unstocked land
171	20	75			o	17	23.6	1	0.7879	5	3.9395	N	8	
172	21	50			o	11.7	25.9	22	14.4523	110	72.2615	NW	10	
173	22	40		o		High 16.0 Low 8.3	High 25.9 Low 24.6	High 5 Low 4	High 4.3706 Low 1.6904	High 25 Low 20	High 21.8530 Low 8.4520	NW	8	
174	31	15	o			6.9	25.0	19	6.9443	95	34.7215	W	10	
175	38	5	o			High 5 Low 2.3	High 27.7 Low 30.0	High 5 Low 3	High 1.5186 Low 0.4906	High 25 Low 15	High 7.5930 Low 2.4530	NW	9	
176	40	60			o	High 13.9 Low 1.1	High 23.3 Low 30.2	High 19 Low 14	High 12.3052 Low 1.0721	High 95 Low 70	High 61.5260 Low 5.3605	SW	16	
177	44	52			o	13.7	24.5	23	15.5668	115	77.834	NE	13	
178	45	(70 5)			o	High 17 Low 1	High 25.8 Low 32.2	High 2 Low 10	High 1.3618 Low 1.8126	High 10 Low 50	High 6.8090 Low 9.0810	NW	10	
179	48	65			o	18.2	24.7	5	3.5844	25	17.922	Nil	Nil	
180	50	45~50		o		High 15 Low 5	High 28.0 Low 28.0	High 2 Low 1	High 1.8416 Low 0.3183	High 10 Low 5	High 9.2080 Low 1.5915	Nil	Nil	

Appendix II

Manual of Coconut Forest Inventory

MANUAL OF COCONUT FOREST INVENTORY

1. Planning and preparation

In order to carry out inventory satisfactorily, operational plan should be formed after collecting relevant material and grasping the general situation of the target area.

The following material necessary for the inventory should be prepared:

1) Aerial photographs (1/10,000).
2) Aerial photo mosaic (approx. 1/10,000).
3) Basic map (1/10,000).
4) 1/50,000 topographical map.

2. Preliminary interpretation

By interpreting aerial photographs, coconut stand is to be marked out first, and plantation boundaries and also those by planted year and forest type are to be marked out.

Then, general data such as tree height and crown density are to be interpreted for every section. They are to be arranged according to age class (young, middle and old), structure of the crown (single and two-storied) and the degree of utilization (utilized or idled), and marked temporarily with dermatograph pencil.

3. Stratification

Stratification is to be based on the following units.

Stratification unit	Code
Young forest in use	[YI]
Middle forest in use	[MI]
Old forest in use	[OI]
Two-storied forest in use	[DI]
Idle forest	[E]

As for operation, by using the temporary marks entered on the aerial photographs, each section is to be arranged according to stratum unit, and the boundaries based on stratification are to be entered on the photographs.

These boundaries are then transferred on to the aerial mosaic (approx. 1/10,000). Polyester paper with each block representing an area of 100m x 100m is then placed on it to trace the stratification boundaries. A running number is then given to those joining points within a stratum to obtain a stratification map.

Since one point represents an area of approximately 1 ha, the last number in each stratum can be used as the area of each stratum value.

4. Sampling of sample plot

Based on the stratification map prepared under the previous section, sampling of sample plot is to be carried out by stratified random sampling.

The number of samples is to be decided from the view points of precision estimate and costs; for estimate precision of 5% 450 samples will be necessary and 120 samples for 10%.

Allocation to each stratum is to based on proportional allocation.

$$ni = \frac{Ai}{A} \cdot N$$

ni : Number of samples in i-stratum

n : Total of samples (167)

Ai : Area of i-stratum

A : Total area

As for allocation, E-stratum is to be excluded from sampling survey, and allocation is to be for the first four strata. However, since it will be necessary to have material concerning E-stratum for interpretation by block under the section 12, a few samples are to be selected independently.

Selected samples are to be entered on the aerial photo mosaic with sample numbers. They are further to be transferred to aerial photographs for convenience in field work.

5. Field working

Those photographs on which positions of samples are entered are to be taken to the survey area to determine the center of the sample plot and to set up a circular plot of 0.2 ha (radial 25.23m).

Then all the trees within the plot are measured for stem height and central diameter. As for equipment for measurement, Blume-Leiss is suitable for stem height, and Relaskop for central diameter.

Results of the measurement are to be entered in the Field survey note.

For the purpose of preparing a photo volume table, survey is to be carried out on those sample trees closest to the center of plot. Item for measurement is whole tree height.

Further, measurement is to be made for the purpose of preparing volume table. Items for measurement are stem height, central diameter and diameter for every 2m height, and measuring is to be done by climbing. The results are to be arranged as the Results of measurement of sample trees.

Other operations to be conducted in the target area include confirmation of the plantation block and blocks by forest type, survey on the stand age and survey for the establishment of a utilization plan (method of skidding, transportaiton, houling network and harbor facilities).

6. Preparation of volume table

By using the diameter values measured for every two meters by climbing in the field working, actual volume of a single sample tree is to be calculated.

As for stereometry, Smalian's formula is to be used, and the results are to be accumulated to obtain actual volume of a single tree.

Actual volume of a single tree = stump volume + interval volume + volume of under leaf section

$$\text{Stump volume} = \frac{g_1 + g_1}{2} \times 0.3$$

$$\text{Interval volume} = \frac{g_1+g_2}{2} \times 2.0 + \frac{g_2+g_3}{2} \times 2.0 + \cdots + \frac{g_{n-2}+g_{n-1}}{2} \times 2.0$$

$$\left(\frac{g_1+g_{n-1}}{2}\right) + g_2 + g_3 + \cdots\cdots + g_{n-2}\ ) \times 2.0$$

$$\text{Volume of under leaf section} = \frac{g_{n-1}+g_n}{2} \times \ell$$

Using the stem volume of each sample tree as dependent variable and stem height and central diameter as independent variables, regression analysis is to be conducted to obtaine a volume estimation formula.

$V = a \cdot D^b \cdot H^c$

V: volume of a single tree
D: central diameter
H: stem height
a,b,c: parameter

From the results of regression analysis the Volume estimation formula is obtained, which can be used to prepare volume table having central diameter and stem height as factors.

7. Arrangement of the results of survey on sample plot

With the prepared volume table the stand volume within a sample plot is to be obtained. This is to be accumulated, and the number and volume should be arranged for each sample.

Prior to that, regression analysis is to be made, by using the surveyed actual central diameter and the remotely measured central diameter with Relaskop to calculate correction coefficient. If there is deviation between them, a volume table (for measured values with Relaskop) having corrected values as factor is to be prepared.

Results of the survey are to be arranged as the <u>Table of field survey results</u>.

8. Preparation of photo volume table

Volume of single trees is to be calculated from the results of the field survey. At the same time, whole tree height is to be measured from photographs. Measurement is to be made by measuring parallax difference with parallax bar and calculation is to be made by the formular below.

$$H = \frac{FA-LH}{b+\Delta P} \times \Delta P$$

FA: Flight altitude

LH: Height above sea level at a sample tree

b: Photo base length

ΔP: Parallax difference

Then, regression analysis is to be made with interpreted height as H and volume as v to induce the following volume estimation formula.

$$v = aH^2 + bH + c$$

The result is to be multiplied by the number of trees N to prepare a photo volume table for stand. Thus, volume estimetion formula will be:

$$V = N \cdot v = N(aH^2 + aH + c)$$

9. Preparation of standard interpretation cards

By arranging the data on sample plots obtained in the field working, 20 suitable sample plots for interpretation are to be selected, taking into consideration forest types and the difference in forest condition.

The standard interpretation card base is to be designed with a portion of aerial photographs (1/10,000) is stereo-pair and a ground photograph for visual effects. Results of the field survey are also to be supplied on the card which is to provide material for interpreting coconut stand.

10. Preparation of a block map

Those plantation boundaries and forest type block boundaries set up roughly in preliminary interpretation and adjusted or confirmed in the field working are transferred to the basic map of the scale 1/10,000 to prepare an original block map.

Then a running number is given to each plantion. Forest type blocks in the plantation are also given a running number, though left-over areas (hardwood forest, housing sites and roads) are to be excluded.

These numbers, together with the established plantation and block boundaries, are also entered on the aerial photographs.

Areas of plantations and of forest type blocks are then measured on the original block map. For measurement dot plate (1 dot for 0.25 ha) are to be used to count the number of dots for each block. Measurement is repeated three times to get the average which is multiplied by 0.25 ha to obtain the area of the block. The areas are to be recorded in the Forest inventory note.

11. Analysis of data on height

After preparing a chart of correlation between whole tree height and stand age measured in the field working of the section 5, the mean whole height curve is obtained by taking average of the whole tree height of each stand age.

Same operation is to be conducted for the relationship between the average stem height and stand age to obtain the mean stem height curve.

12. Interpretation by block

Those plantations and forest type blocks (plantation blocks) confirmed under the section 10 are to be surveyed by means of photographic interpretation and field working for the following data.

Forest type code: Classified as follows based on the stand-age given below

YI (in use at present. 0-25 years)
MI (" 26-50 years)
OI (" Over 51 years)
DI (" Two-storied forest)
E (idle forest)

With regard to YI, MI and OI, those blocks which cannot be surveyed in the field working are to be estimated by applying the mean height interpreted to the mean whole height curve obtained under the section 11 or by using the number of trees and the site as criterion for judgement.

Area: Those block areas measured under the section 10 are to be transferred.

Species: Based on interpretation of photographs.

Mixture rate: Based on interpretation of photographs. Mixture rate is to be recorded when different species or crown compositions (two-storied forest) are noted.

Stand age: Based on information supplied verbally at the site. Those blocks which are either unsurveyed or uncertain are to be left blank.

Age class: Based on stand age, five years are to be counted as one class.

Average height (whole tree height): A few typical plots (for 0.25 ha) for interpretation are to be set up with in a block on the photographs with the use of the plot-setting plate. Parallax differences of several trees in the plot are to be measured with parallax bar, which are then converted into tree heights. The method of conversion is the same as the estimation of height for photo volume table. And measured tree heights are to be taken to supply the average values.

Number of trees per ha: The number of trees in the plots setup above is counted and converted into the number per ha.

Volume per ha: Calculated by applying the measured height and the number of trees to the photo volume table prepared under the section 8.

Result of the interpretation are to be arranged as Coconut forest inventrry note which gives plantation areas, number of trees and volumes.

13. Calculation of total volume by accumulation

The numbers and volumes of forest typea calculated under the section 12 are to be added up for each plantation and then for the entire area to obtain the total number of trees and the total volume.

14. Calculation of total volume by sampling

By using number of trees and volume per ha obtained from a plot, sampling totalling is to be carried out. The method of calculation is the stratified random sampling method given below.

Stratum area	A_i
Proportion of stratum area	$\omega_i = \dfrac{A_i}{\sum_i A_i}$
Mean value of X in samples	$\bar{x}_i = \dfrac{1}{n_i} \Sigma x_{ij}$
"	$\bar{X} = \bar{x} = \sum_i \omega_i \cdot \bar{x}_i$
Varianve in samples	$S^2 x_i = \dfrac{1}{n_i - 1} \{ \Sigma x_{ij} - \dfrac{(\Sigma x_{ij})^2}{n_i} \}$
Variance of mean value	$S_{\bar{x}}{}^2 = \dfrac{S^2 x_i}{n_i}$
"	$S_{\bar{x}}^2 = \Sigma \omega_i^2 \dfrac{S^2 x_i}{n_i}$
Standard deviation of mean value	$S_{\bar{x}_i} = \sqrt{S_{\bar{x}_i}{}^2}$
"	$S_{\bar{x}} = \sqrt{S_{\bar{x}}{}^2}$
Confidence limit of mean value	$R_i = t_i \cdot S_{\bar{x}_i}$
"	$R = t \cdot S_{\bar{x}}$

Error rate of estimate	$\varepsilon_i = \frac{R_i}{\bar{x}_i} \times 100$
"	$\varepsilon = \frac{R}{\bar{x}} \times 100$
Estimated total	$X_i = A_i \cdot (\bar{x}_i \pm t \cdot S_{\bar{x}_i})$
"	$X = A \cdot (\bar{x} \pm t \cdot S_{\bar{x}})$

15. Evaluat on of the accumulative total volume

The accumulative total number and volume obtained under the section 13 and those statistically obtained by sampling totalling are to be compared to see if the former is within the confidence limit of the latter.

If the accumulative value is outside the confidence limit, the difference should be corrected by allocating it each block.

In this case it should be remembered that the value by sampling dose not cover the stand belonging to E-stratum, whereas the accumulative value contains it.

16. Preparation of location and distribution maps

The average height, number of trees and volume obtained under the section 12 are to be entered on the original block map prepared under the section 10.

Then the original map traced and arranged on the poly-ester paper to prepare the coconut forest distribution map.

Further, the original maps are to be reduced in scale from 1/10,000 to 1/50,000 and combined as one sheet. This is then traced and arranged to obtain the coconut forest location map.

17. Formation of the coconut forest utilization plan

A coconut forest cutting plan is to be formed to carry out cutting effectively while sustaining the stand.

For that purpous, calculation of sustained yield is to be made on the basis of the survey of sample plots, results of interpretation by block, the accumulative value by block and the coconut distribution map, so that appropriate afforestation, skidding and transportation can be planned.

Appendix III

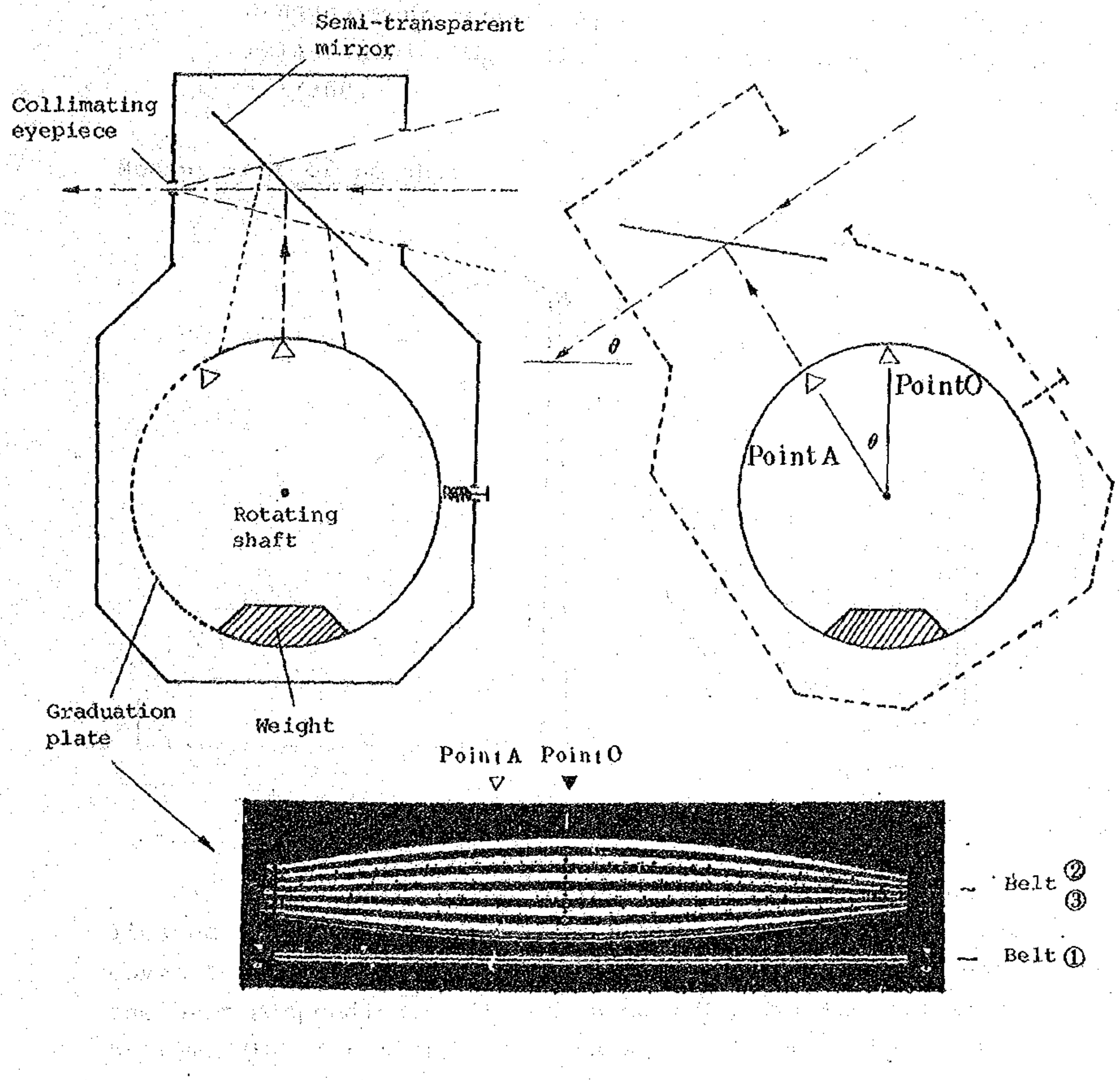
Scope of Work

Appendix IV

Instructions for the use of Relaskop

RELASKOP

1. Structure and function

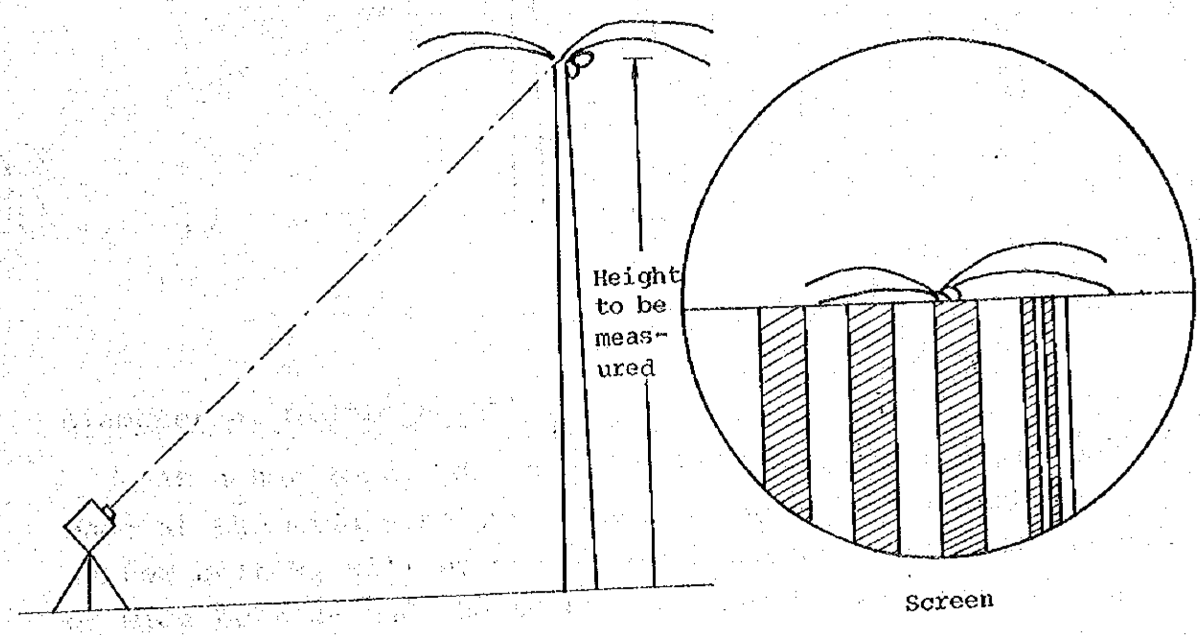


Belt 1: to measure the angle θ when tilted.

Belt 2: to measure the height corresponding to a specific horizontal distance (10m, 12m, etc.). (Value of distance × tan θ given.)

Belt 3: wide belts (W_B) and narrow belt (N_B) having the width of 1/50 and 1/200 of the distance. It has cos θ-adjustment responding to the tilt to maintain the relationships W_B = distance × 1/50 and N_B = distance × 1/200.

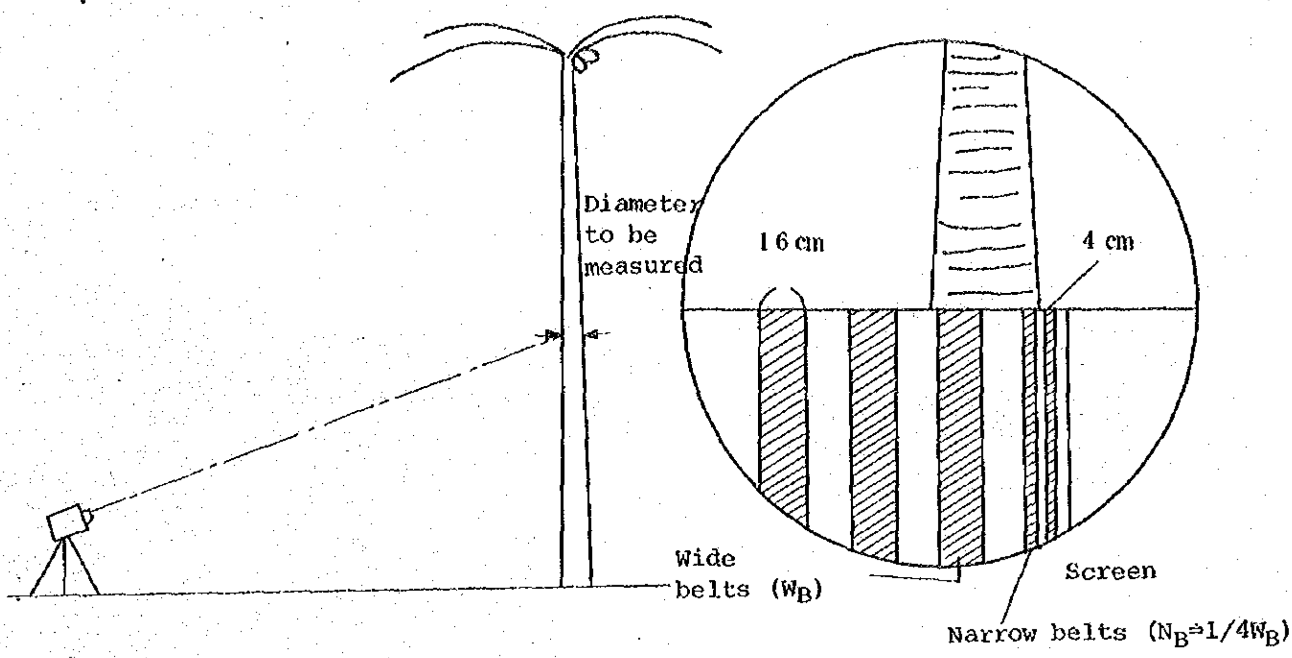
Measurement of height:



If Relaskop is tilted so that the position to be col- limated is at the center of the screen, the graduation plate moves to give the value on the belt (code over ⑩). Using the belt responding to the distance (⑩ for the distance of 10m, ⑱ for 18m), the value shown at the center of the screen will be the height.

Note: If the horizontal distance is over 20m, the belt show- ing the half of the distance is to be used and the reading is to be doubled.

Measurement of diameter:



Diameter at middle height:

At a horizontal distance of 8m, collimation is to be made at the middle height. Then the wide belt W_B and the narrow belt N_B will be shown in the screen. Count the number of wide belt n_W and the number of narrow belt n_N to use the formula: $Dcm = (4 \times n_W + n_N) \times 4$.

Example $n_N = 2$ $n_N = 1.5 \rightarrow D = (4 \times 2 + 1.5) \times 4 = 38cm$

Demonstration $1W_B = 1/50 : L$

$L = 8m = 800cm) \rightarrow$ $1W_B = 800/50 = 16cm$

$1N_B = 1/4 \cdot W = 4cm$

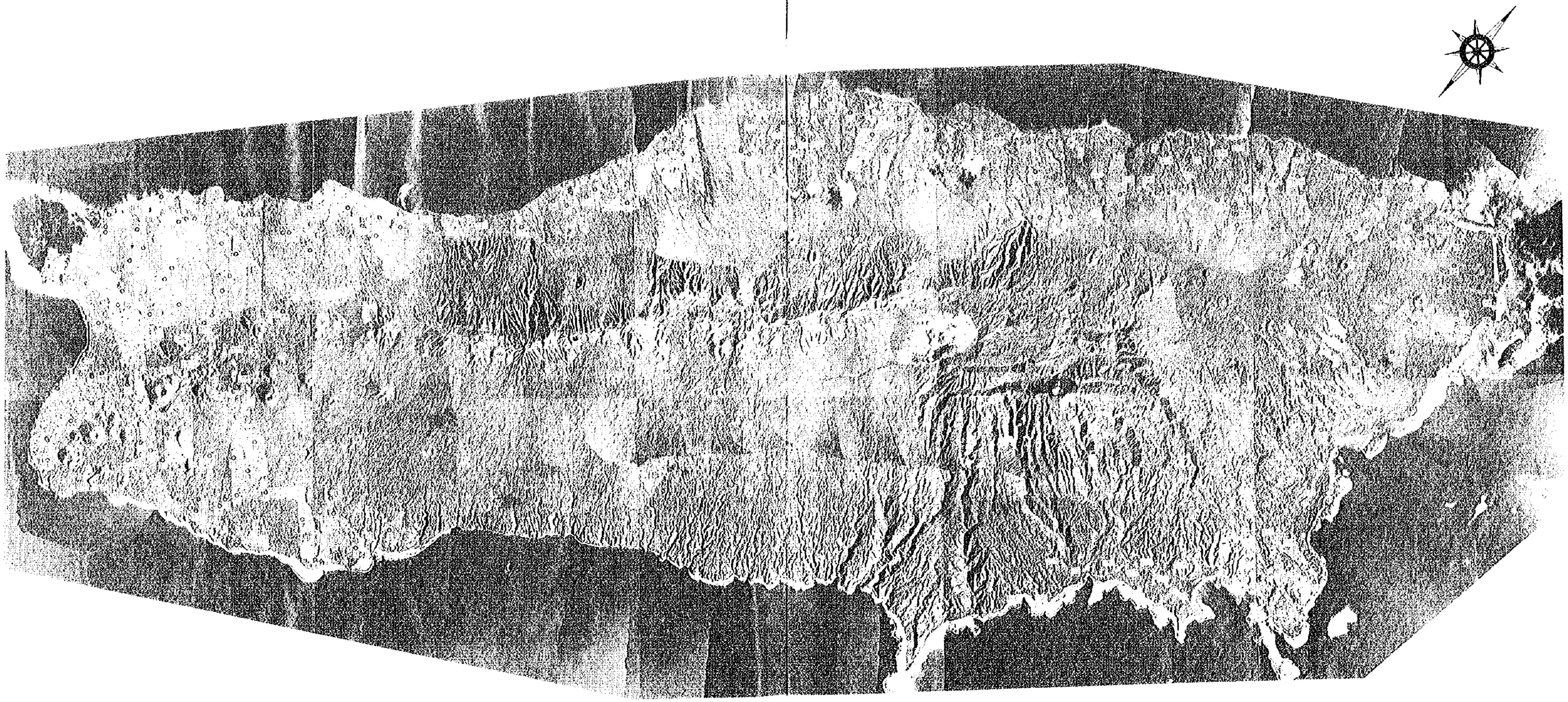
$$Dcm = 16cm \cdot n + 4cm \cdot n = (4 \cdot n_W + n_N) \times 4cm$$

Measurement of crown diameter:

At a distance of 40m, collimation is to be made at the crown. Then follow the same procedure as above to obtain the crown diameter.

$$CDm = (4 \times n_W + n_N) \times 0.2$$

Taveuni Island, Fiji



1/120,000