on successive days in the rate of drop (daily drop rate).

Table III-31 Variation of pre-work values on successive days

	9/17	9/18	9/19	9/20	9/25	9/26
Choker setter	0.0	0.9	0.6	-7.1	0.0	13.3
Tractor operator	0.0	0.9	1.1	-1.4	0.0	-8.6

The weekly drop rate limit of pre-work value is -3 % (cf. Table III-30). However, it is premature to judge the labor intensity with this data only, and more data shall be collected.

ii. Time course change of flicker value.

Daily drop rate for the value after work is shown in Table III-32.

Table III-32 Variation of after-work flicker value

	9/17	9/18	9/19	9/20	9/25	9/26
Choker setter	-1.5	-9.9	-12.3	-	-15.5	-5.8
Tractor operator	0.4	-1.1	- 5.2	-	- 0.0	4.1

Desirable limit in time course change of flicker value is believed to be - 10 % a day, and further investigation in detail is necessary.

III-2-4 Study on work safety

Study on work safety is a general term for studies related to prevention of labor accidents. Safety of machines, equipments, and facilities used in every forestry work is examined dynamically and in terms of human engineering and communication engineering. In the present project, cable logging equipment, that is one of the items of techniques transferred, was taken up; and holding power test for stumps was carried out for examination of safety in holding cable by stumps and standing trees , those are important structural elements of the cable logging system.

(1) Aim in testing holding power of stump and tree

Stumps are utilized for anchoring skyline and holding blocks and guy lines, and standing trees for head tree, tail tree, guide trees, or support trees of cable system. Also in tractor skidding and remote controlled winch yarding, standing trees and stumps are utilized as strong supports. Therefore, it is necessary for operation safely to understand the holding power of standing trees and sumps in advance and select those of a sufficient strength. In this regard the holding power test of stumps and standing trees was carried out in the Campos do Jordão forest with Taeda pine and Elliottii pine as the subject.

(2) Method of stump holding power test

① Selection of test area

A forest is desirable as test area where the topography and soil conditions are nearly average and stumps of large and small sizes are widely distributed. A place is selected where subject stumps are found not far from one another so that measuring instruments, traction machines, and winch were moved in a short time.

Subject trees of Taeda pine were selected in Ribeirão area, compartments 68 and 73 of Campos do Jordão forest, while those of Elliottii pine in compartment 106 near the office.

② Measuring instruments

Load cells, dynamic strain meters, recorder, and portable generator are used with addition of load indicator whenever necessary.

Load cell is used for transformation of tensile load into electric signal, and the following kinds of sets are used.

1. Load cell KYOWA LU2TE 2-t capacity, maximum strain $3,997 \times 10^{-6}$

2. Load cell KYOWA LU5TE 5-t capacity, maximum strain $3,999 \times 10^{-6}$

3. Load cell KYOWA LU20TE 20-t capacity, maximum strain $4,002 \times 10^{-6}$

One of the three kinds of load cells is used depending on the magnitude of load. Each of the load cells are connected with a standard cord of 5 m length and extension cord of 50 m length to enable measurement in the ranges, but measurement in the range of the standard cord is desirable. Dynamic strain amplifier adjusts electric balance inside load cell and amplifies the electric signal sent from the load cell to be transmitted to the recorder. Dynamic strain amplifier of 6 channels, KYOWA DPM-6E, was provided with in 1979. It can be used in DC or AC power source, but a voltage stabilizer KYOWA DPE-10H is used for keeping the source voltage constant in the case of alternate current. The six channels can measure 6 kinds of loads simultaneously.

The recorder records the measured value on a chart continuously, and the following three kinds are provided with.

1. Halogen lamp type oscillograph KYOWA RMS-11-RPT (1979)
2. Cassette data-recorder KYOWA RTP-520B (1981)
3. Pen-writing oscillograph San-ei 8K-22H (1982)

Of the three recorders the pen-writing type oscillograph, that can write manually on the chart direct, is the best suited for the stump holding power test or cable tension test. It is in six channels and thermal-pen recording system by means of a servo-galvanometer. The halogen lamp type oscillograph is an electromagnetic oscillograph characterized by a small size and light weight equipped with a highly sensitive galvanometer. The cassette recorder is for recording data on a cassette tape, and it is convenient in reproducing the data or processing on an electronic computor.

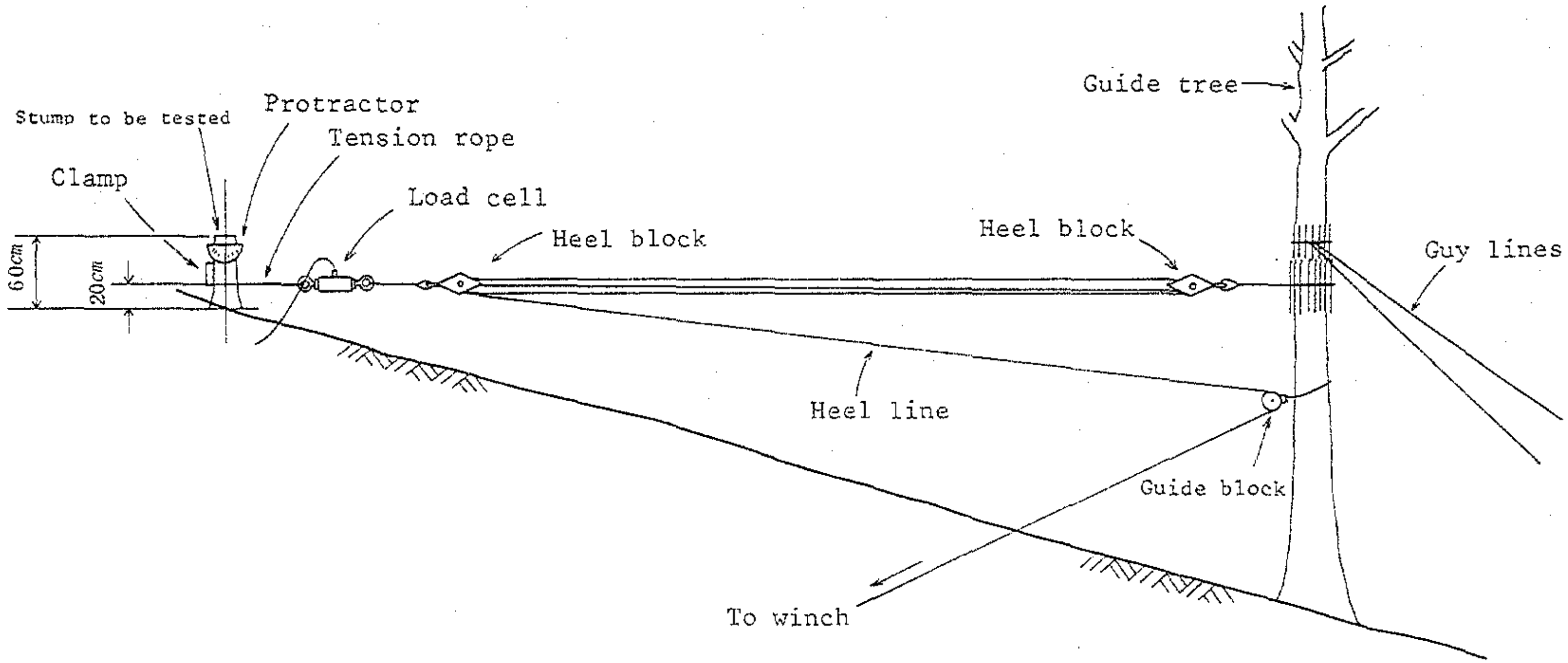


Fig. III-28 Layout of the stump holding power test

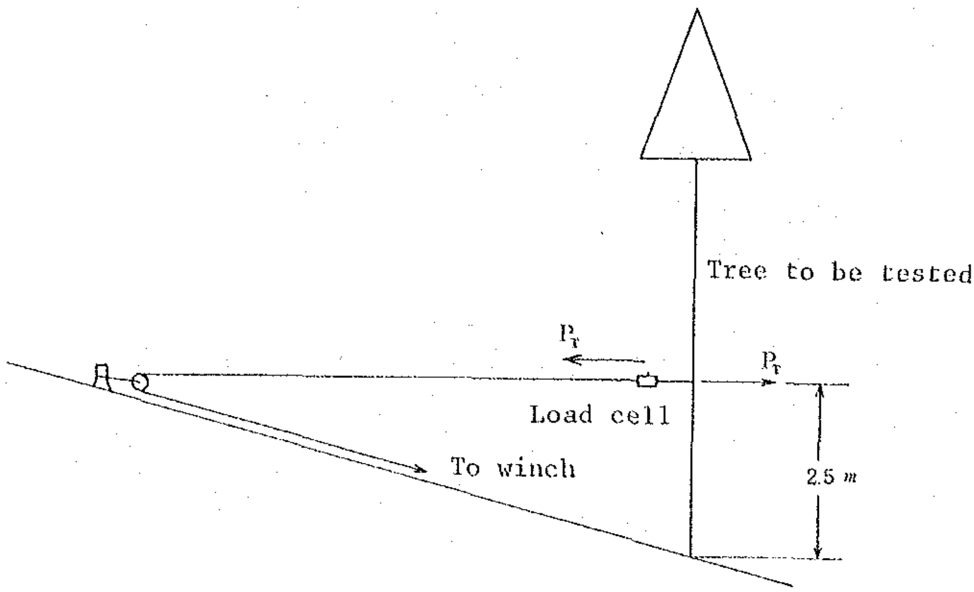


Fig. III-29 Position of load cell in the holding power test of a standing tree (1)

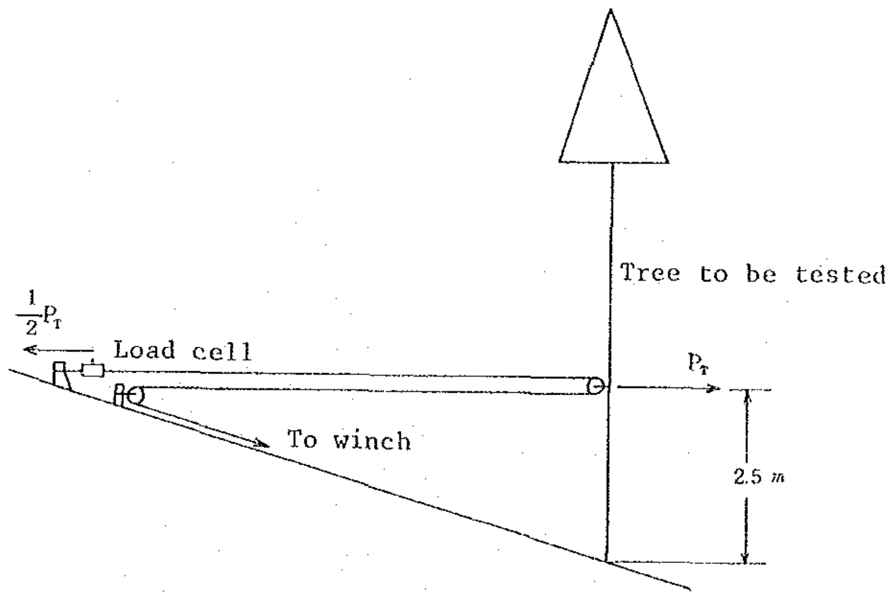


Fig. III-30 Position of load cell in the holding power test of standing tree (2)

Load indicator is a direct-reading meter KYOWA SLW-220PC that enables to read the magnitude of load on the scale board. It cannot record data, of course.

③ Preparation for test

Subject trees and stumps are selected in the test area. Fig. III-28 shows the arrangement in the stump test. Stumps of 60 cm height or higher are desirable, but existing stumps as low as 40 cm can also be tested. The tension rope is fastened 20 cm above ground, and this height must be kept constant without fail. The tension rope can slip off the stump along the inclination of stump, and this must be prevented. A grove may be cut around the stump, but two clamps were driven into the stump as shown in the figure in the test in São Paulo. Nothing is stipulated in the case of the holding power test of standing trees, but the rope is fixed at 2.5 m above ground referring to the average height of rigging mono-cable block. (cf. Fig. III-29 and Fig. III-30.)

Load cell is fixed at the end of tension rope and a heel tackle is added. A strong enough guide tree is selected and reinforced by guy lines if necessary. The distance between stump and guide tree is set at 7 - 8 m or larger. Heel blocks of three wheels are used on both sides, and the heel line is led and wound into a tractor winch or yarder. The tension rope is pulled in a horizontal direction as far as possible, and the angle between the rope and the direction of contour at the position of stump is recorded in the case of slope.

④ Preparation for measurement

Preparation for measurement is carried out along with preparation for the stump side by side. Voltage stabilizer, dynamic strain meter, pen-writing oscillograph are arranged on a table and they are connected with the load cell and power source (portable generator, etc.). The power is turned on and the unit is left standing for about 30 minutes for warming up, and the dynamic strain meter and oscillograph are adjusted under absence of load on the load cell in the following procedure.

(a) Adjusting dynamic strain meter

The dynamic strain meter is adjusted for every channel used in the following order. For the detail, refer to page 19 of the Dynamic strain meter operation manual:

ⓐ Adjust the zero point of the meter.
ⓑ Adjust the balance of guage bridge.
ⓒ Set the attenuator (ATT) at 1/10 or 1/30.

(b) Adjusting pen-writing oscillograph

The pen-writing oscillograph is adjusted for each of the channels used in the following order keeping concert with the dynamic strain meter. For the detail, refer to pages 9 - 18 of the operating manual of the pen-writing oscillograph:

ⓐ Start feeding paper at low speed (5 mm/min).
ⓑ Turn on the switch of signal conditioner, adjust sensitivity selection knob at 100 - 200 v/cm, and adjust the position of zero point of pen on the chart by means of pen position adjusting knob.
ⓒ Operate calibration knob and gain knob of dynamic strain meter to adjust the amount of strain of load cell and the amplitude of pen on the chart.
The amount of strain is calculated based on the estimated load on the load cell. The maximum strain on each of the load cells are as shown in 2) above.
ⓓ Adjust the zero point again and record the calibration value (1,000 or 3,000) on the recording paper after it is stabilized.

(c) Measuring

Attention shall be paid to the following points in measuring:

ⓐ The knobs and switches of the measuring instruments shall be left untouched after adjustment as a rule.
ⓑ Value of calibration shall be recorded during test at every opportunity.

ⓒ The zero point position on the chart shall be checked without fail before and after each test by setting the load cell free from load.

ⓓ The adjustments (1) and (2) above mentioned shall be repeated over again in cases the cord of load cell is changed, the power source is turned off by some reason, or the measurement is interrupted for a long time.

⑤ Execution of test

The diameter of stump is measured at 20 cm above ground and recorded along with inclination of the ground, angle of tension direction right and left and up and down on the chart. A protractor is attached on the stump and a weight is suspended from its center to measure the inclination of the stump.
The chart is set at 25 mm/min feeding speed, and traction is started. Safety in the neighborhood shall be confirmed, and the heel line is wound into the winch. The winding speed is kept constant at 3 - 4 m/min.

The inclination of the stump is observed by an observer stationed at the stump who sent a signal every 5° of the inclination being changed, and it is recorded on the recording paper. The conditions of the stump is recorded on a camera during the test, and other matters concerning the test are kept on the record without omission. The winch is stopped at about 45 - 50° inclination of the stump, the load of load cell is removed, and the zero point on the chart is confirmed. The stump is pulled back to the original conditions by means of a manual winch to finish the test.

The holding power of the stump P is calculated from the recorded data by the following equation.

$$P = C_L \times \frac{Sc}{Smax} \times \frac{a}{a_c} \times \cos\theta$$

where:

C_L : Capacity of load cell (t)

Sc : Calibration strain

Smax: Maximum strain of load cell

a : Amplitude of recorded value from zero point (mm)

a_c : Amplitude of calibration value (mm)

θ : Angle between direction of tension and a horizontal line (°)

The following is an example of calculation. Fig. III-31 shows a part of data from an actual test. The load cell of 20 ton capacity was used, and $\theta = 0°$. The maximum holding power P can be calculated by the following equation:

$$P = 20\ t \times (3000 \times 10^{-6})/(4002 \times 10^{-6}) \times (22\ mm/25\ mm) \times \cos 0° = 13.2\ t$$

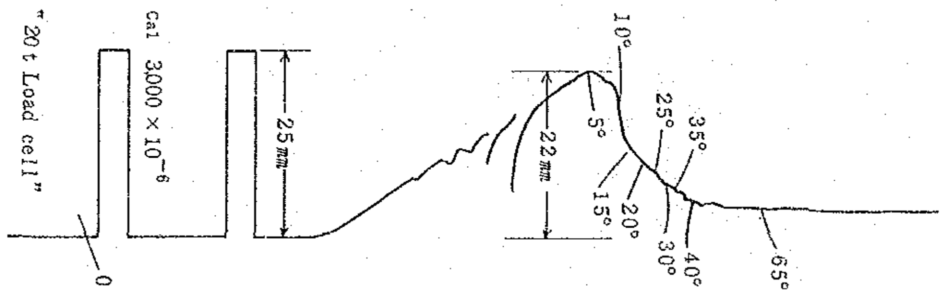


Fig. III-31 Example of stump holding power recorded no chart

(3) Discussion of the result of test

The result of tests carried out in the Campos do Jordão forest for Taeda pine and Elliottii pine on the holding power of stumps and standing trees is as follows:

① Case of Taeda pine

Testing area: Campos do Jordão state forest, compartments 68 and 73

Stand age : 21 - 22 years

Inclination of forest ground: 11°-31°, 19° on average

Soil : Red yellow latosol

Date of test: December 4 - December 20, 1984

(a) Holding power of stumps

Holding power of stumps was investigated in two directions: by traction along the tangent of the contour, that is cross-wise to the slope, and perpendicular to the tangent, that is along the slope in the direction of the valley. The holding power of a stump P was assumed to be proportional to the square of diameter of the stump D at 20 cm above ground, and the following equation was applied,

$$P = aD^2$$

where a is a constant decided by the tree species.

No significant difference in holding power was recognized

Table III-33 Holding power data of stumps of Taeda pine

Stump No.	Stump diameter	Holding power	Direction of traction	Stump No.	Stump Diameter	Holding power	Direction of traction
1	30 cm	10.25 t	Downhill	16	20 cm	3.70 t	Transverse
2	25	5.40	Transverse	17	26	8.32	Downhill
3	35	13.19	〃	18	19	3.12	〃
4	30	7.26	〃	19	24	4.27	〃
5	27	8.38	〃	20	31	7.67	〃
6	16	3.14	〃	21	31	8.20	〃
7	22	6.78	〃	22	32	9.66	〃
8	22	6.01	〃	23	16	2.09	〃
9	21	5.50	〃	24	22	5.25	〃
10	18	3.26	〃	25	26	7.00	〃
11	24	4.25	〃	26	23	6.23	〃
12	26	5.64	〃	27	18	2.24	〃
13	30	7.21	〃	28	26	6.77	〃
14	22	4.95	〃	29	35	11.15	〃
15	14	1.49	〃				

between the directions of traction according to the data obtained. Fig. III-32 shows the relationship between stump diameter and holding power for all of the data shown in Table III-33. The regression equation for Taeda pine was $P = 9.638 \times 10^{-3} D^2$ and the deviation from the regression was $s = 1.10$ and the coefficient of correlation was $r = 0.922$.

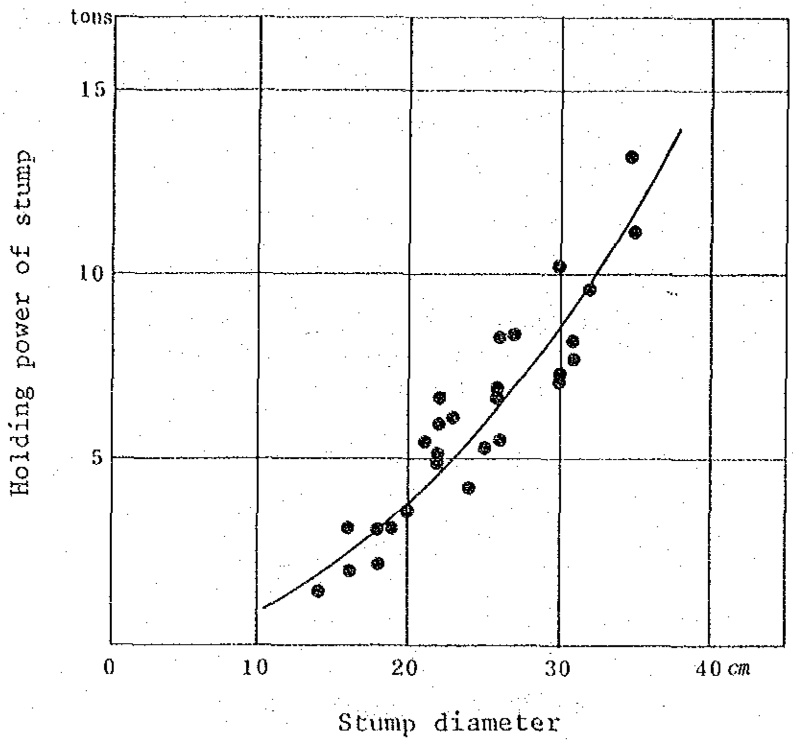


Fig. III-32 *Stump diameter versus holding power in Taeda pine*

Relation between leaning angle of stump and holding power is shown in Fig. III-33. Here the percentage of holding power at respective leaning angle against maximum holding power is taken on the ordinate. It is understood from the figure that the holding power of stump assume the maximum at leaning angle 0° - 10° and that it drops rapidly beyond the limit. The rate of drop of holding power is somewhat smaller, however, in the case of a stamp with developed taproot.

(b) Holding power of standing trees

Holding power of standing trees was investigated only in one direction uphill. The data are shown in Table III-34. The relationship between diameter breast height of Taeda pine D_B and holding power of standing tree at 2.5 m above ground P_T is shown in Fig. III-34. P_T was assumed to be proportional to the square of D_B as was in the case of stumps, and the following regression equation was obtained,

$$P_T = 3.388 \times 10^{-3} D_B{}^2$$

where s = 0.336, and r = 0.934.

Table III-34 Holding power data of standing trees of Taeda pine

Tree No.	Diameter breast height	Holding power	Direction of traction
1	12 cm	0.38 t	uphill
2	15	0.56	〃
3	18	1.10	〃
4	20	1.16	〃
5	17	0.55	〃
6	20	1.25	〃
7	11	0.29	〃
8	22	1.18	〃
9	23	2.55	〃
10	28	2.86	〃
11	21	1.45	〃

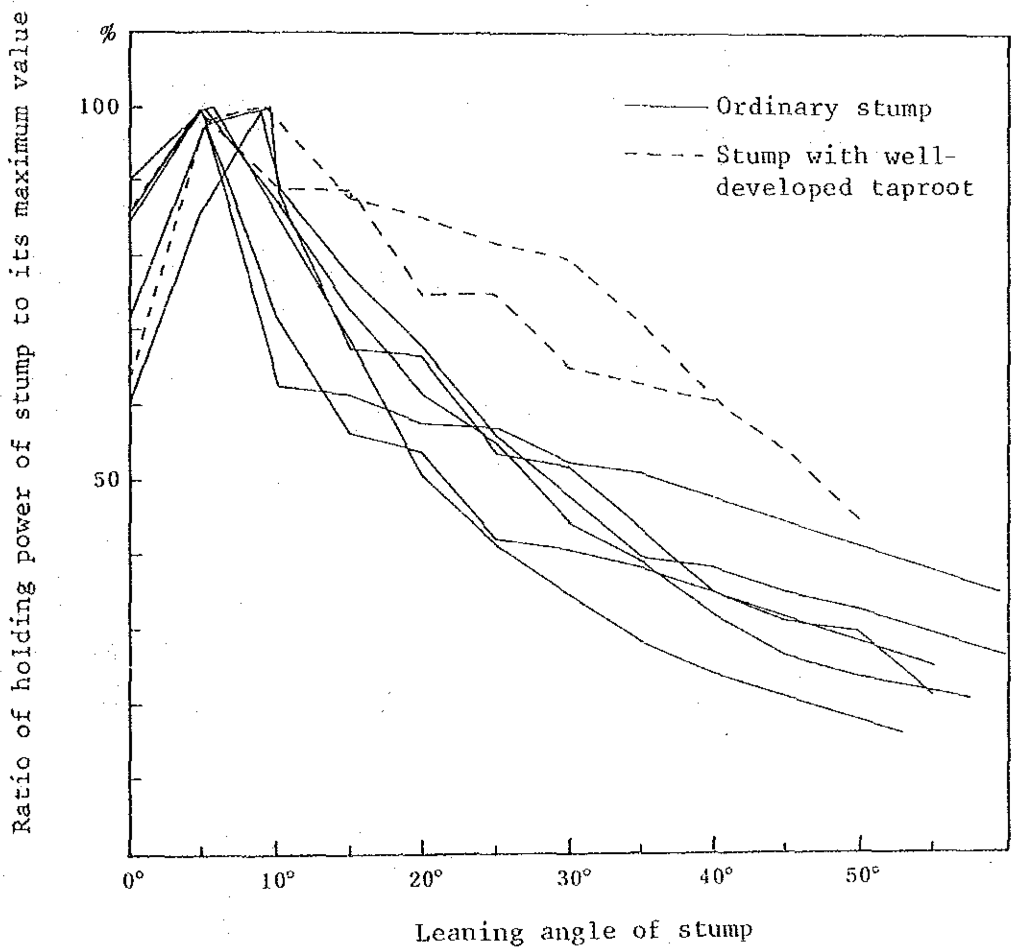


Fig. III-33 Relation between leaning angle of stump and holding power (Taeda pine)

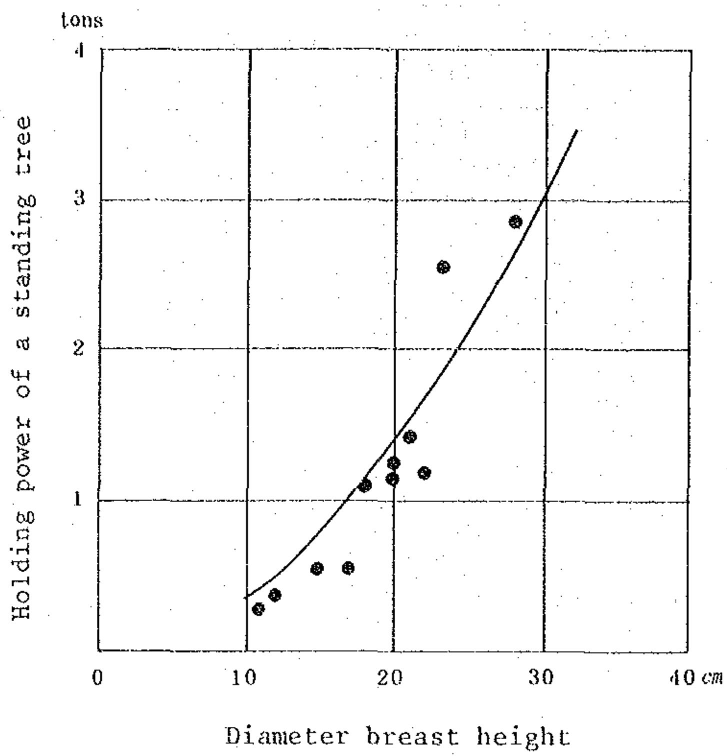


Fig. III-34 Diameter breat height versus holding power (at 2.5 m above the ground) of standing tree in Taeda pine

② Case of Elliottii pine

Test area: Campos do Jordão state forest, compartment 106

Stand age: 26 - 27 years

Inclination of forest ground: 5°- 20°, 15° on average

Soil : Red yellow latosol

Date of test: October 22 - 24, 1985

(a) Holding power of stumps

Holding power mostly in the lateral direction was tested in Table III-35 and Fig. III-35. The regression equation between D and P is as follows:

$$P = 1.404 \times 10^{-2} D^2$$

where s = 2.55, and r = 0.803.

Table III-35 Holding power data of stumps of Elliotti pine

Stump No.	Stump diameter	Holding power	Direction of traction	Stump No.	Stump diameter	Holding power	Direction of traction
1	16 cm	3.05 t	Transverse	12	21 cm	6.58 t	Transverse
2	23	13.07	"	13	25	7.23	"
3	21.5	7.11	"	14	26.5	14.51	"
4	32	15.33	"	15	27.5	13.20	"
5	27.5	9.02	"	16	30	8.50	"
6	29	12.60	"	17	18	4.05	"
7	21	5.46	"	18	21.5	5.74	"
8	30	12.56	"	19	28	9.37	Uphill
9	30	17.81	"	20	35	12.86	Transverse
10	19	4.77	"	21	25	9.56	"
11	23.5	7.16	"	22	34	15.40	"

(b) Holding power of standing trees

Holding power of standing trees was investigated mostly in lateral direction as was in the case of stumps. The result of tests is shown in Table III-36 and Fig. III-36, and the regression equation between D_B and P_T is as follows:

$$P_T = 4.724 \times 10^{-3} D_B^{\,2}$$

where S = 0.831, and R = 0.870.

Table III-36 Holding power data of standing trees of Elliottii pine

Tree No.	Diameter breast height	Holding power	Direction of traction
1	21.5	3.35	Uphill
2	17	0.72	"
3	24	1.95	"
4	15	0.48	"
5	26	3.72	"

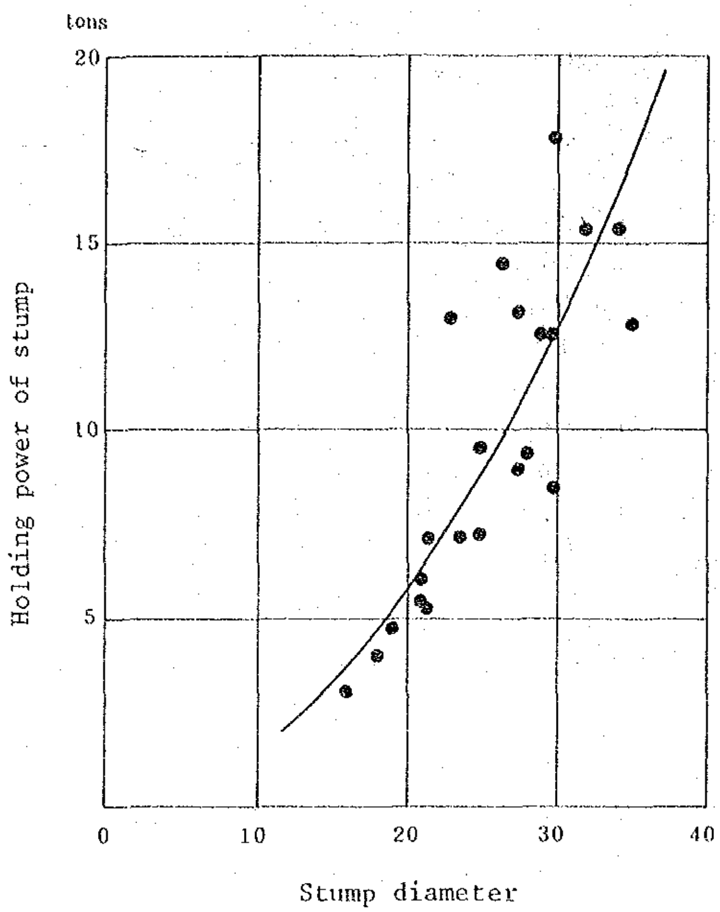


Fig. III-35 Stump diameter versus holding power of stump in Elliottii pine

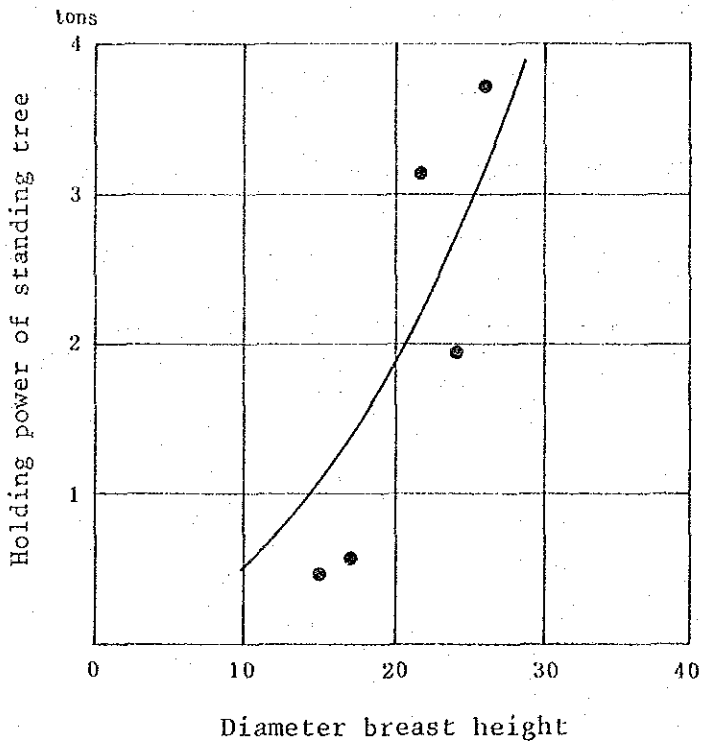


Fig. III-36 Diameter breast height versus holding power (at 2.5 m above the ground) of stand tree in Elliottii pine

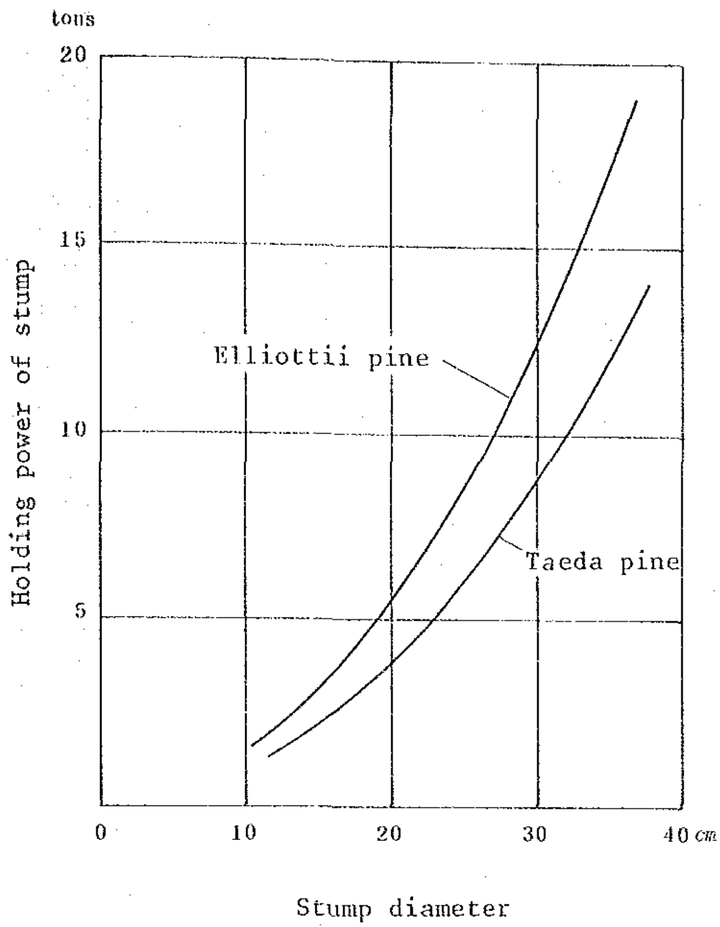


Fig. III-37 Comparison of holding power of stump between Taeda pine and Elliottii pine

③ Comparison between Taeda pine and Elliottii pine

The holding powers of stumps and standing trees were compared between Taeda pine and Elliottii pine as shown in Fig. III-37 and Fig. III-38 respectively. Elliottii pine shows a larger holding power in any cases with a marked difference. But this would be a little hasty conclusion, because holding power depends largely on soil condition, condition of root system, direction of traction, and so on. Statistical processing of data should be advanced for clarifying the difference between the two species of trees.

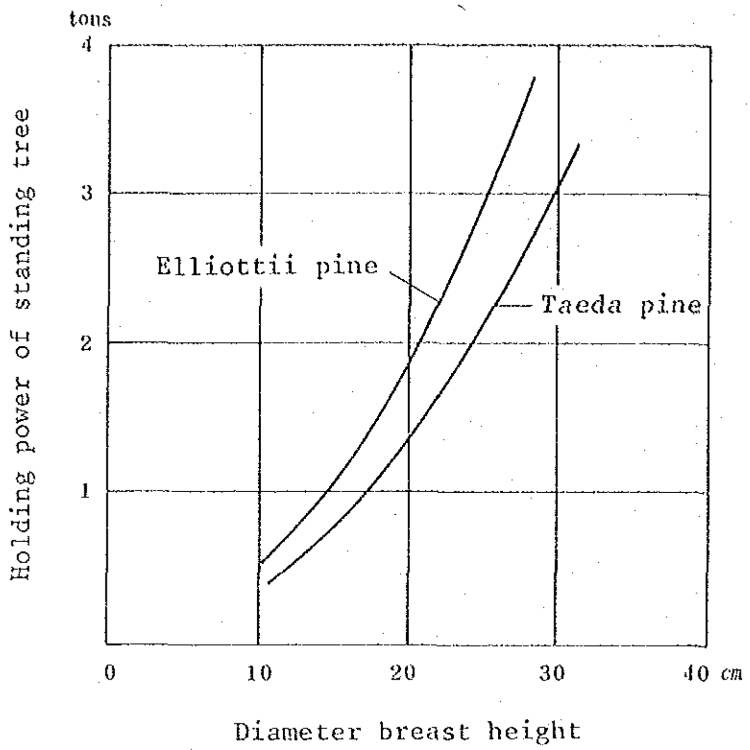


Fig. III-38 Comparison of holding power (at 2.5 m above the ground) of standing tree between Teda pine and Elliottii pine

(4) Lines of future study

Holding power data of stumps and standing trees were obtained in the Campos do Jordão forest, but more accurate information will be obtained by further investigation in forests of different conditions such as soil conditions, topography, forest age, and so on. Besides, collection of data for different species in eucalyptus forest, where clear cutting is actively operated, would be effective for the case of applying cable logging system.

III-2-5 Method for logging cost analysis

(1) Need of cost analysis

Estimation of cost for logging is important not only for securing economical advantage but also for comparison of economy between different means of production or for finding out the points of improvement in logging operation. Various elements must be considered for estimation of the cost where many of the results in the past are included, but the rapid advance in machines and instruments makes us difficult to remain only in this stage.

(2) Approach to logging cost

① Machine rate

Machine rate is used for cost estimation. It is a rate of the total machine cost spent for acquisition and operation in unit time. The content of machine rate is shown in Fig. III-39.

For estimation of depreciation cost of a machine, a linear depreciation is usually resorted to where the value of machine is decreased by a constant amount every year. The residual value of a machine is the estimated value of the machine at the end of depreciation period at 10 - 20 % of the initial price.

Interest is often calculated by multiplication of average annual investment by interest rate as a constant expenditure for the whole period of depreciation.

Tax, qualification fee, insurance, and storage are estimated at a certain rate of annual investment as a lump sum which is 2 ~ 20 % usually depending on the mechanical equipment.

Cost for repair and maintenance is conveniently estimated at a certain rate of depreciation.

Fuel consumption is estimated by the result in the past, but it can also be estimated by the fuel consumption curve and average load factor. Average load factor for the yarder of cable logging system is 50 % or lower.

The estimated cost of oils and lubricants is about 1 % of fuel for engine oil and about 5 % of fuel for other oils.

The cost of the wire rope and rigging is estimated as that of expendable articles per unit time of operation, and therefore, it is necessary to decide their lives. Their lives are often expressed not by hours but by total volume of logs produced. If the life is two years or shorter, the article can be regarded as consumables.

Costs of tires and caterpillar tracks can be treated as operating expense if their life is short, and also as the cost per unit time calculated by an estimated life.

Direct labor cost includes base wage and fringe benefit for insurance, guarantee, paid holiday, and so on. The fringe benefit are 30 - 40 % of the base wage rate.

Management expenses and current expenses are indirect costs related to operation, and they are expressed usually in a rate to the direct labor cost.

② Work time of yarding operation

Amount of production is expressed in volume carried into landing per unit time. The work time is divided into time elements as shown in Fig. III-40.

Time for hooking and unhooking among productive time (cycle time) depend on the piece size, number of logs and forest conditions, but they can be regarded constant on average for a setting. The time for outhauling and inhauling are functions of yarding distance and are affected by the speed of carriage, inclination, turn volume, and so on.

Short delay time caused by hang-ups and re-setting of chokers can be considered as one of the elements of cycle time.

Nonproductive time includes delay time by moving to a new setting or trouble of machinery. It is difficult to estimate delay time, and conditions of machinery, operational conditions, and past records of trouble time must be taken into account. Delay time can be expressed in a rate to the production time.

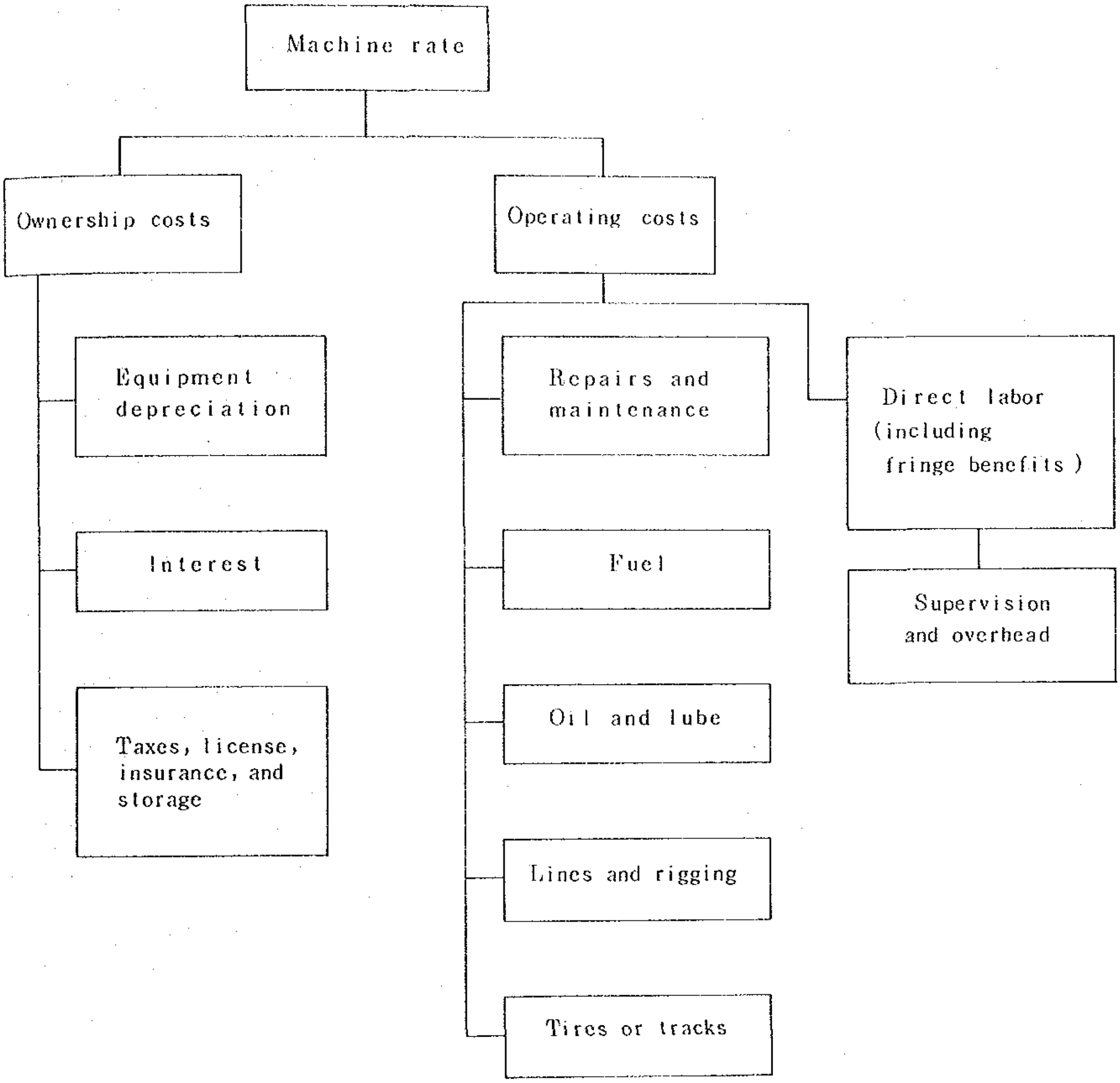


Fig. III-39 Machine rate cost ejements.(R.W. Mifflin, 1978)

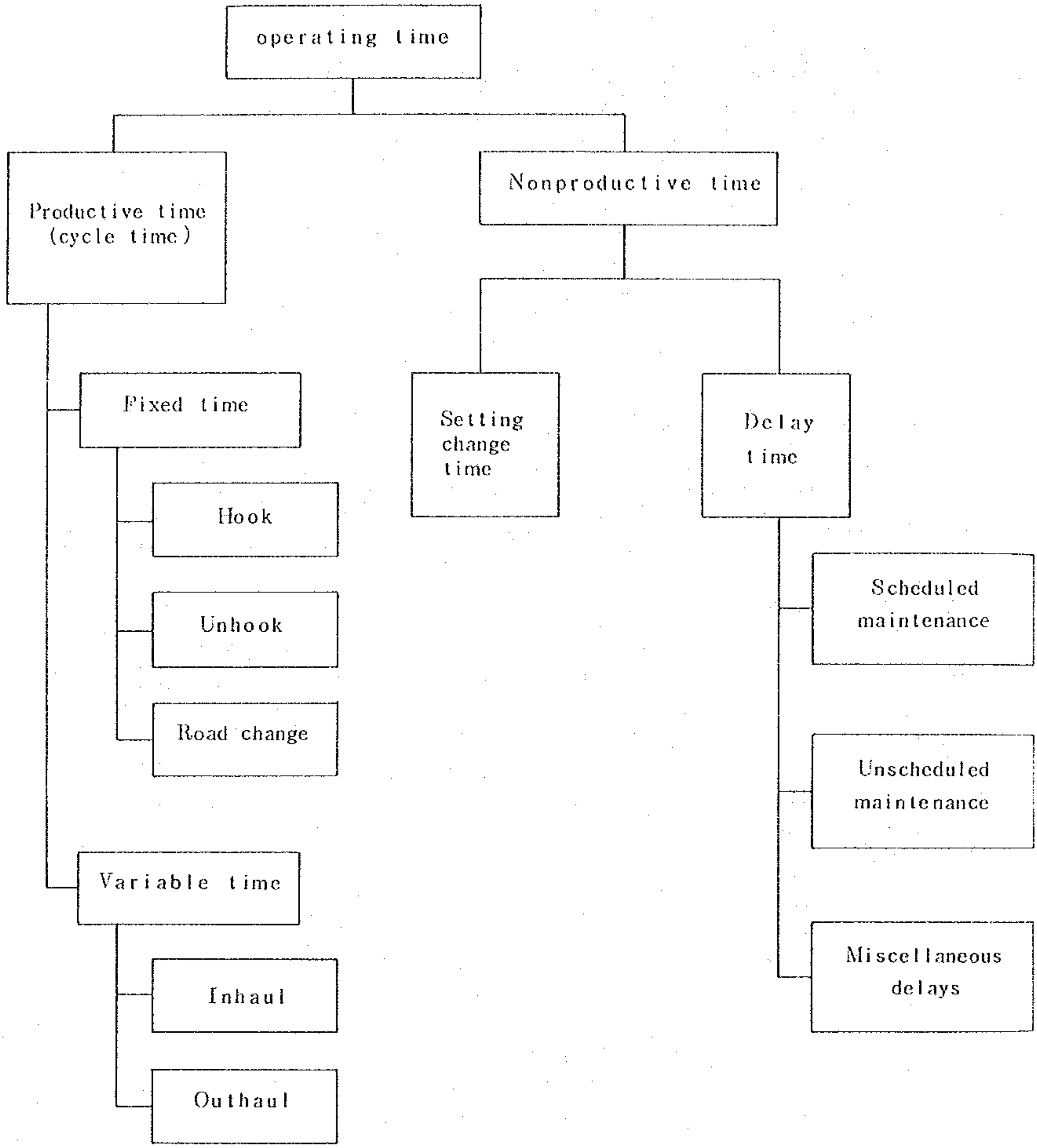


Fig. III-40 Operating time elements (R.W. Mifflin, 1978)

Unscheduled maintenance is caused by a trouble of the equipment. Nonproductive time also includes anticipated delay, delay by bad weather, and other various delays in work.

③ Estimation of logging cost per unit volume

Number of logs and volume to be collected from a given unit are obtained by investigation in advance. For estimation of pieces per turn, piece size, turn volume, conditions of landing and distribution of logs must be considered. Based on these data the logging cost can be integrated for each of the items explained above.

(3) Actual conditions of logging operation and cost estimation

Several difficulties are found in applying the said system of estimating logging cost and cost analysis to the yarding operation of thinned logs in the man-made pine forest in Campos do Jordão. The operation is not sufficiently rooted, and nothing had been recorded for number of working days, workers, harvest unit area, production, and so on. All of the workers are officers of the state park, they are paid with monthly salary, and their sense of productivity has not been developed.

Accordingly, the logging costs were estimated in a very simple method using the results of operational efficiency investigation and compared between tractor and cable systems. The calculation was made only for the main items of the above, and many of the comparisons of economy of logging operations in Japan are based on the method.

The logging cost per unit production was estimated by the following equation:

$$K = \frac{C + F + H + I}{G} + J$$

where K: Unit cost ($\$/m^3$)

C: Labor cost (Number of workers × Unit wage)

F: Fuel cost (Amount used × Unit price)

G: Efficiency (m^3/day)

H: Machine depreciation (= Purchased price × 0.9 $\times \frac{\text{Operating hours per day}}{\text{Life in hours}}$)

I: Repairing cost (= Purchased price × 0.75

$$\times \frac{\text{Operating hours per day}}{\text{Life in hours}})$$

J: Machine part cost

$$(= \frac{\text{Purchased price}}{\text{Total amount of production for life}})$$

Refer to Table III-37 for examples of life in hours, operating hours per day, and duration amount.

Table III-37 Useful life and durability of yarder and tractor

Yarding machine	Useful life	Daily working Running-time
Yarder (20 - 75 ps)	4,500	6.0
" (20 - more ps)	3,500	6.0
Tractor	5,000	6.0

Rigging	Durability
Wire rope (Operating line 10 - 13mm)	4,500 m^3
" (Operating line less 10mm)	3,800 m^3
Guyline, strap, etc.	4,500 m^3
Sling rope	1,200 m^3
Carriage, blocks	12,000 m^3
Clip, shackle	6,000 m^3

An example of estimation of logging costs of running skyline system is shown in Table III-38.

Table III-38 Example of cable yarding cost
(Running skyline system)

Item	Content	Cost
Yarder	Medium size yarder KK-2B (20 ps)	Purchase price: $7,500 Depreciation : $7500 \times 0.9 \times \frac{6}{3500} = \$11.57/day$ Repairs cost : $7500 \times 0.75 \times \frac{6}{3500} = \$9.64/day$
Line and rigging cost	Wire ropes	
	12mm, 400 m	$\$500 \times \frac{1}{4500} = \$0.11/m^3$
	10mm, 300 m	$\$300 \times \frac{1}{4500} = \$0.07/m^3$
	Slings, straps	$\$100 \times \frac{1}{1200} = \$0.08/m^3$
	Blocks, shackles	$\$250 \times \frac{1}{6000} = \$0.04/m^3$
	(Total)	($\$0.3/m^3$)
Fuel	Light oil 5 liter/day	$0.3 \times 6 = \$1.8/day$
Wage	4 workers (operator choker setter and two chasers)	$5 \times 4 = \$20/day$

Results of daily output in the said investigation of operational efficiency was applied, and it was assumed to be 11.73 m^3/day at average yarding distance of 80 m. The logging cost per cubic meter can be estimated as:

$$Ky = \frac{(20 + 1.8 + 11.57 + 9.64)}{11.73} + 0.3 = 3.97 \ (\$/m^3)$$

Table III-39 shows an example of estimating logging costs of tractor system. Assuming the operational efficiency of 25.08 m^3/day by the average of five and half days, logging costs Kt per cubic meter is caliculated as

$$kt = \frac{(15 + 3.21 + 29.16 + 24.30)}{25.08} + 0.10 = 2.96(\$/m^3)$$

Table III-39 Example of tractor yarding cost

Item	Content	Cost
Tractor	Skidder, T-20	Purchase price: $27,000.- Depreciation: $27,000 \times 0.9 \times \frac{6}{5000} = \$29.16/day$ Repairs cost: $27,000 \times 0.75 \times \frac{6}{5000} = \$24.30/day$
Line and rigging cost	Winch rope 14 mm, 50 m	$\$75 \times \frac{1}{1200} = \$0.06/m$
	Chokers	$\$50 \times \frac{1}{1200} = \$0.04/m$
Fuel	Light oil 10.7 liter/day	$\$0.3 \times 1.07 = \$3.21/m$
Wage	3 workers (operator, choker setter and chaser)	$\$5 \times 3 = \$15/day$

The above examples of cost estimation are for logs of a large size by tractor system and for logs of small size by cable system. The most effective factor on the production and logging cost is the size of logs, and the tendency shown in Fig. III-41 can be found in any logging operation. Further data shall be collected in the future for yarding of thinned logs from man-made pine forest so that they can be used in planning the logging operation.

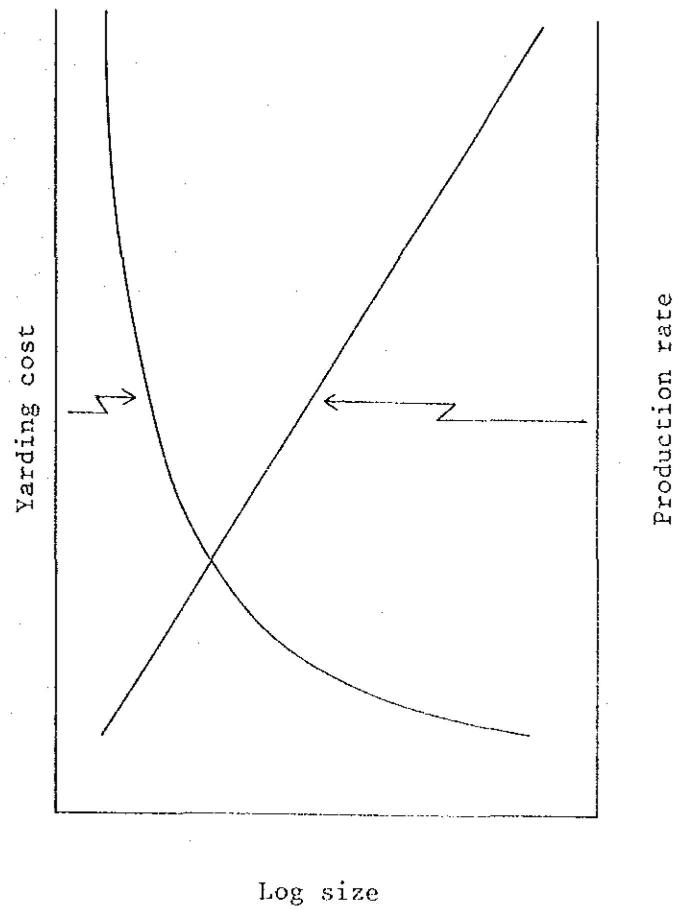


Fig. III-41 Yarding cost and production rate versus log size.

(4) Future problems

As is clear from the results of cost estimation, the rate of depreciation and repairing costs for machines to the total logging cost is as high as 46 - 70 %. This would mean that the wage is relatively low. It could be said that the totally manual operation is suitable for lowering yarding cost.

However, the present research cooperation has been advanced with an object of rooting the techniques of mechanized yarding of thinned logs from pine forest for a higher efficiency or production of lumber of higher value, in view of many forests being left untreated for thinning. Therefore, the logging cost is not the only item of consideration. Matters must be considered more in the original sense.

It is expected that the logging machines are manufactured in

Brazil at a lower cost in the future and the labor cost will rise, and the mechanized logging will be welcome also economically.

Therefore, it is necessary for the time being to collect correctly and extensively the actual data of efficiency and costs of mechanical logging operation by the existing tractors and yarders with relation to the operation plan and operational conditions. By so doing, the operation plan suitable for arrangement of suitable machines for a thinning area can be formulated in view of efficiency and cost.

III-3 Gists for rooting mechanized logging techniques

The following points will be enumerated as the gists for rooting the techniques for mechanized logging transferred during the period of research cooperation so that they will contribute to effective development of the techniques and safety of operation in the forest of São Paulo State.

(1) Common matters

① Ground conditions and forest conditions shall be closely examined so that the most suitable machines and logging system can be applied and the characteristics of the machines be displayed. Besides, the operation methods of felling and processing suitable for the logging system shall be contrived.

② Machines, instruments, tools, and parts shall be inspected and maintained properly so that troubles and accidents are prevented and that prompt actions can be taken in the case of trouble.

③ Operators of machines shall be educated for safety so that they will not operate their machines beyond the capacity.

④ Operators shall wear helmet during work.

⑤ Workers shall be instructed so that they will look around and confirm the safety of the whole workers before taking action in working as a team.

⑥ Records of every day work, such as amount of felling, amount of yarding, oil consumption, and number of workers shall be recorded for improving operational productivity.

⑦ Forest roads shall be maintained thoroughly to prevent lowering of efficiency and sales in the rainy season.

(2) Felling operation

① Saw sharpening for chain saw shall be conducted correctly by using round file for cutting edge and flat file for depth guage.

② Center of gravity of tree shall be observed in felling, under-cut and backcut shall be cut correctly, a wedge shall be used, and the tree shall be fell in the proper direction.

③ The most advantageous direction shall be selected in felling for the yarding operation that follows.

④ Method and procedure shall be selected in felling for avoiding hanging, but if it happens, use a manual winch to pull the log sidewise or backward in a safe manner.

⑤ Make logs in a dimension for sale for advantage.

(3) Cable logging

① The cable logging system for yarding of thinned logs shall roughly be selected according to the following standards.

Mono-cable system: Mono-cable system can be installed in a forest in any plane form with extension of cable as long as 500 - 600 m. Therefore, it is effective in yarding of thinned logs from a comparatively wide area. No trouble is expected by topography upto about 35° inclination. A cable of 10 - 12 mm diameter is used as the endless cable.

Running skuline system: Running skyline system is applied to a logging site of 80-200 m length and -15° to +30° inclination. In other words, upward and downward yarding is possible. Lateral yarding of about 25 m on both sides is possible by the skidding line. Wire ropes of 10 - 12 mm diameter are used as main, skidding, and haulback lines.

Slackline system: Slackline system is applied to a logging site of 50 - 150 m length, +15° - +35° inclination, and concave topography. It is used only for downward yarding, but not for lateral yarding. Lateral prehauling by a small winch is necessary. Wire ropes of 12 - 14 mm diameter is used for the skyline, while those of 8 - 10 mm diameter as haulback line.

Endless Tyler system: Endless Tyler system is used on a logging site of 150 - 800 m length with inclination of about -30° to +40°. Clear cutting is necessary under the skyline. Lateral yarding is possible in clear cutting, but it is difficult in thinning. Wire rope of 16 - 24 mm diameter is used as the skyline, that of 10 - 12 mm as lifting line, those of 8 - 10 mm diameter for main and haulback line.

High lead system: High lead system is used on a ground of -35° to +20° inclination for lateral yarding or short distance yarding for a distance of 10 - 100 m. Upward and downward yarding is possible, but more suitably in upward yarding. It is not suitable in yarding of thinned logs in the direction of contour as the logs run along the slope. At 50 m or larger distance, the main line can be pulled back by haulback line. Wire ropes of 6 - 10 mm diameter are used.

② Cable arrangement shall be so planned that logs can be collected most efficiently with one setting.

③ In the case of skyline of 150 m or larger span, longitudinal survey of the ground shall be carried out, and the data shall be put into personal computer FM-8, where the skyline design program is arranged, so that the maximum allowable load, sag, safety factor and others be estimated and that safety in installation and operation be maintained.

④ Standing trees and stumps of large enough diameter having a sufficient holding power shall be selected as head tree, tail tree, other supports, and anchors.

⑤ Felling of obstructing trees shall be limited to the minimum in setting-up of cables. Splints shall be attached to trees for fixing blocks or guy lines without fail so that the trees are protected from damage.

⑥ Fix clips and shackles in proper manner in setting-up of the cable system.

⑦ Select proper machines depending on the yarding distance and piece size. It is a yardstick that a cable system of large type is selected for 300 m or larger span, while of a small type otherwise.

⑧ Make trial operation when setting-up of cable system is finished for full inspection for safety before full scale yarding is started.

⑨ No work ever shall be operated under the line or in the bight of a line.

⑩ For actual operation, choker setters, operator, and unhookers shall keep in good contact by telephone for confirmation of their safety.

⑪ Refer for other details to texts "Standards and Explanation on Yarding Machine Operation" and "A Guide to Mono-cable System Yarding".

(4) Tractor yarding

① Always arrange 20 to 30 chokers with eye splicing on both ends.

② Proper selection of logs for skidding in advance and proper choker setting operation by choker setter is a key for efficient operation. Choker setter must be trained for an efficient operation.

③ Chokers shall be set properly and carefully so that no log can slip off.

④ For an efficient operation, logs shall be skidded in order from the nearest side of skid road. No preferential yarding shall be made.

⑤ Tree length yarding shall be conducted as a rule. However, in case that a large damage on the residual tree, or a large disadvantage in yarding efficiency is occurred, the log shall be cross-cut into 8 m or shorter.

⑥ For yarding of small size logs from thinning of an early stage, use skidder T-20. For yarding of larger logs from the second thinning and from a forest of sparse standing trees, use skidder T-50.

⑦ Stop tractor skidding after rain for protection of the forest ground.

(5) Mono-rail transportation system

① Mono-rail transportation system is used for a distance of about 100 - 300 m on a ground of 0° - 30° inclination in upward and downward yarding.

② It is used in combination with a remote-controlled winch for yarding in deep watershed or beyond a ridge.

③ A sharp curve or a sudden change of slope shall be avoided in its installation with insertion of straight portion between curves in S or upward and downward.

④ Installation work can be advanced by utilization of installed rail track for transportation of construction materials.

⑤ Supporting posts shall be erected vertically for an efficient operation in dismantling.

⑥ Select a flat and wide ground for the landing so that the logs can be unloaded and arranged easily.

⑦ Take care not to load beyond the limit of 1.0 m^3.

⑧ Operator must not get on the mono-rail wagon during operation.

(6) Forwarder Delpis

① Forwarder Delpis is used for yarding of medium distance of about 100 - 500 m on forest road.

② It is used for yarding in forest by construction of strip road of about 1.6 m width and 17° or lower inclination.

③ A remote-controlled winch are used for lateral yarding.

④ The load shall be within the range of 1.5 m^3 maximum load.

⑤ The running speed must not be over 14 km/hr under loaded conditions.

⑥ Yarding shall be stopped after rain to prevent strip road and skid trail from becoming muddy.

(7) Chute

① Chute shall be arranged on a slope of selected topography so that the average inclination is about 25° and final inclination about 10° and in a straight line as far as possible.

② Construction shall be started from the terminal, by arranging chute unit on the ground directly. The inclination must be kept uniform by laying crosspieces, utilizing posts or standing trees, on irregular parts of the slope.

③ Chute shall be fixed by ropes on standing trees and posts. Especially on curved section, it must be strong enough to stand the lateral force.

④ Use stopper attached and half launder ending unit at the terminal.

⑤ Make contact between the mountain side workers and terminal side workers for certain for the sake of safety of operation. Logs must be fed by the mountain side after confirmation of safety in the terminal side.

⑥ Arrange a sufficient protection at the terminal against jumping out of logs sliding down into nearby road road.

Conclusion

The mechanized thinning techniques transferred by the Japanese party during five years from 1951 are the logging techniques that can be applied not only to thinning operation of man-made forest but also widely to selective cutting, shelterwood cutting, seed cutting, and environment conserving operation such as overstory removal of multistory forest, and so on. We expect that the Brazilian party concerned will pursue their studies in the future, based on these techniques for their improvement, and diffuse the techniques not only in the State of São Paulo but also in the whole Brazil as the innovated techniques, so that this will be a large help for further development of Brazilian forest industry.

Reference

(1) Associação de Mecanização Florestal do Japão: *Trator florestal e sua operação*, Operação, pp155, São Paulo, 1983

(2) ——— : Manual de operação da força motriz *para* coleta de madeira, pp.61, São Paulo, 1983

(3) BUCCI, L.A., T. SUZUKI, M. KOBAYASHI e J.M. MOTTA: Colheita mecanizada em povoamentos de pináceas visando a regeneraçao de essenciais nativas, Congresso Nacional Sobre Essenciais Nativas, 1360 - 1366, Campos do Jordão, São Paulo, 1982

(4) ——— : Explorção Florestal em Topografia Acidentada, 9ª Ciclo de Atualizacão em Ciências Agrárias, Curitiba, 1982

(5) KATO, S.: Projeto e inspeção de cabos utilizados para transporte de madeira, pp. 46, São Paulo, 1983

(6) KOBAYASHI, M.: Manual de operazão da extração de madeiras com monocabo, 1983

(7) KONUMA, J., T. SUZUKI & M. KOBAYASHI: Technical cooperation on logging, São Paulo Project, Brasil, XVII IUFRO World Congress, Proceedings - Division 3, 495, 1981

(8) MOTTA, J.M. & M. KOBAYASHI: Transfer of mechanized logging techniques in São Paulo Technical Cooperation Project, J. For.Mec.Soc. (351), 52 - 59, (352), 53 - 60 (353), 56 - 62, (354), 57 - 60, 1983 (in Japanese)

(9) SUZUKI, T., L.A. BUCCI, J. KONUMA, M.KOBAYASHI e J.M. MOTTA: Mecanização florestal em Campos do Jordão, 4ª Congresso Florestal Brasileiro, 604 - 607, Belo Horizonte, 1982

(10) TANAKA, T., M. KOBAYASHI, J.M. MOTTA & L.A. BUCCI: Operational efficiency of cable logging systems in thinning operation, a case *of the Japanese technical cooperation project for the* forest research in São Paulo, Brasil, Trans. 36th Ann. Meeting. Jap.For.Soc., Kanto Bra. 219 - 222, 1985 (in Japanese)

IV. Study of Remote Sensing Technique

IV Study of Remote Sensing Technique

IV-1 Outline of Remote Sensing Technique

IV-1-1 Background and Purpose

In the State of St. Paulo, due to the enlarging development over past 100 years in various regions including coffee plantations, cotton-fields, pastures, etc., the forest, which had held 80% of total land area in the past, rapidly decreased to about 20% of land area. As the result, soil erosion proceeded, and devastated regions as well as disrupted have increased, hence human circumstances have become extremely degraded. Therefore, the forest board of the State of St. Paulo needed to promote their undertaking of forest growing, and at the same time, they are urgently obliged to establish the adequate technique for controlling the forest in the regions of water sources.

Under the circumstances, the growing of artificial plantation on private land has been encouraged by the plantation subsidy policy (the exemption of income tax by corresponding amount to the plantation area realized) through the Brazilian federal government.

As the artificial plantation has been gradually enlarged, the significance has been recognized on such subjects as the adjustment of land utilization, the survey on the current states of artificial plantation, the proper disposition of plantation as for the water source forest, and the establishment of the technique of controlling and managing plantation.

The activity of the forest board in the field of remote-sensing was conducted with the status survey on the land utilization (farm land and forest land) in the State of St. Paulo, and a survey on the areas of artificial plantations by the owners, by the kinds of trees planted, and by the age of forest in the selected two districts in the state. Besides, the map of the aspects of forests in the natural state park was completed. The utilized air photograph were those in which every area in the whole state was shot in 1971 and 1972, with a scale of 1/25000. Air photograph were retaken since 1977 till today, for the scale range between 1/20000 and 1/45000. Further, the installation of the data receiving facility from the Earth observation satellite was a little earlier than in our country, as the space institute (Institute de Pesquisas Espaciais - INPE) was established in 1971, which has conducted the digital analysis as well as analogue on the Earth observation data.

Under the circumstances as above, the technical cooperation concerning the study of remote sensing was narrowed to two subjects of the evaluation of the forest growing stock and the interpretation of the watershed conditions.

IV-1-2 Themes of Study and Process of Execution

The definite activity in the fields of the cooperation of study on remote-sensing technique was started when the receiving training was conducted, for the purpose of acquiring the technique of the evaluation of the forest resources and the judgement on the geological features in a basin as well as on the aspects of its degradation.

In this training, due to our judgement that the forest board already attained the appreciable level of qualitative technique of photo-interpretation such as the determination on the kind of trees, we put emphasis on the quantitative technique of photo-interpretation such as the determination of tree heights, the technique to estimate forest growing stock, availing of air photograph, and further improving the technique to interprete the existing status in geological features as well as in the features of the degraded area.

Afterwards, not only the method of forest survey availing of air photograph, but also the various survey methods on samples on ground, the preparation of yield estimation table, etc. were decided to be carried out.

The targets for the year were as follows.
The targets in 1980 (Remote-sensing):

1) Fundamental technique on simplified measurement by air photograph.
   Technique to make a simplified plan view.
   Measurement on tree-heights and the height above the sea level.
   Measurement on the diameter of tree-crown, the density of tree-crown, the number of standing trees.
   Measurement on the local configuration of land as well as slopes.
   Interpreting technique on tree species and the type of groups by a tree species.
   Other miscelleneous matters.

2) Survey technique on whole forest conservation by air photograph.

3) Preparation of a location drawing of afforested land in the State of St. Paulo.
Copying technique and automotive technique of measurement of area.

4) Survey method on the ground on forest.

Targets in 1981:

1) Application test of survey technique on whole forest conservation by air photograph.

2) Study of interpretation technique on the aspects of disrupted, or degraded land.

3) Study of interpretation technique of dangerous zone such as disrupted land.

4) Estimation technique on the resources of artificial plantation of eucalyptuses, pine trees, etc., by air photograph.

5) Preparation technique of merchantable volume table of artificial forests by tree species, availing of air photograph.

Targets in 1982:

1) Preparation technique of volume table of artificial forests by tree species, availing of air photograph.

2) Interpretation of group types of tree species in natural forest, the system of classification of forest types, and the estimation on the growing stock.

3) Preparation of cards for standards of air photograph by forest types as well as by tree species.

4) Survey method of various forests, using remote-sensing, and analysis thereof.

Targets in 1983:

1) Preparation technique of volume table of artificial forests by tree species, availing of air photograph.

2) Preparation of cards for standards of air photograph by forest types as well as by tree species.

3) Study of statistical analysis for forest survey.

4) Survey method on growth of volume of artificial forest, and preparation of estimated volume table.

5) Development of simplified air photograph and the study of usage.

6) Provision of mannuals for the survey method of forest, availing of air photograph.

7) Others.

IV-2 Survey Method of Forest

IV-2-1 Estimation Method of Crowing Stock and Growth of Forest Stand

(1) Preface (Purpose)

As for the methods for the survey of growing stock in forest stand as well as the growth of forest stand, there are several methods like the survey of every tree, the survey of the standard area, the sampling survey, etc. Generally, the purposes of the forest survey are divided into: ① survey for the aquisition, sale, etc. of forest land, ② survey for cutting or sale, etc., ③ survey for the management plan, ④ large scale survey to grasp natural resources, etc., and ⑤ special survey for the change in tree species, the determination of forest area, and to grasp the damaged area due to plant diseases, insects, calamity by wind or fire, etc.

As for the survey method of case ②, St. Paulo forest board provided a sample section of 1 ha (100 m x 100 m) in a part of 1 Talhão (500 m x 500 m = 25 ha) in Águas de Santa Bárbara state forest. Then the whole trees in a sample section were cut and measured, whereby the estimation for the whole area was made from the result. Since this method required much labour and expense, the field test of systematic line-plot sampling was conducted, which was one of sampling method, and effective for both purposes of ② and ③ above. Besides, the estimation on the growth of forest stand was also executed by increment core measurement. Thus it was examined whether the above survey could be supplied to the forest content in the field, and at the same time the training of the survey method was carried out.

(2) Survey Programme

① Subject area of survey

Talhão No. 8 in Águas de Santa Bárbara state forest in St. Paulo state was selected as the subject area. This locates in the almost center of the state forest, with its area of 25 ha (500 m x 500 m). The tree species is Pinus elliottii, planted 1961 - 62, 20 years age at the time of survey (1982). The number of trees planted is 4400/ha (1.5 m x 1.5 m), and thinning was carried out by 50 % (2200 trees, 21 m^3) at first in 1970, and by 50% (1100 tons, 56 m^3) at the second time in 1978. Since a part of the forest suffered the calamity of fire in 1979, and there are paticularly some damp area in the forest, so the state growth is not so good. The lay of the land is almost flat.

② Survey programme

(a) Programme for systematic line-plot sampling

In the programme for the estimation of growing stock by the systematic line-plot sampling,

① Area of forest stand to be surveyed: A = 500 m x 500 m
= 25 ha

② Coefficient of variation of forest stand: C = 30 %

③ Aimed accuracy (allowable error ratio) : e = 10 %

④ Plot area : a = 0.04 ha

On the basis of the above, the following were set

ⓐ Number of sampling in the survey plot: n

$$n = \frac{4C^2A}{e^2A + 4aC} = \frac{4 \times (30)^2 \times 25}{(10)^2 \times 25 + 4 \times 0.04 \times (30)^2}$$

$$= 34.039 \doteqdot 34$$

ⓑ Sampling error of plot sampling: e

$$e = 2C\sqrt{\frac{A-na}{nA}} = 2 \times 30\sqrt{\frac{25-34\times0.04}{34\times35}} = 10.006 \doteqdot 10.01\ (\%)$$

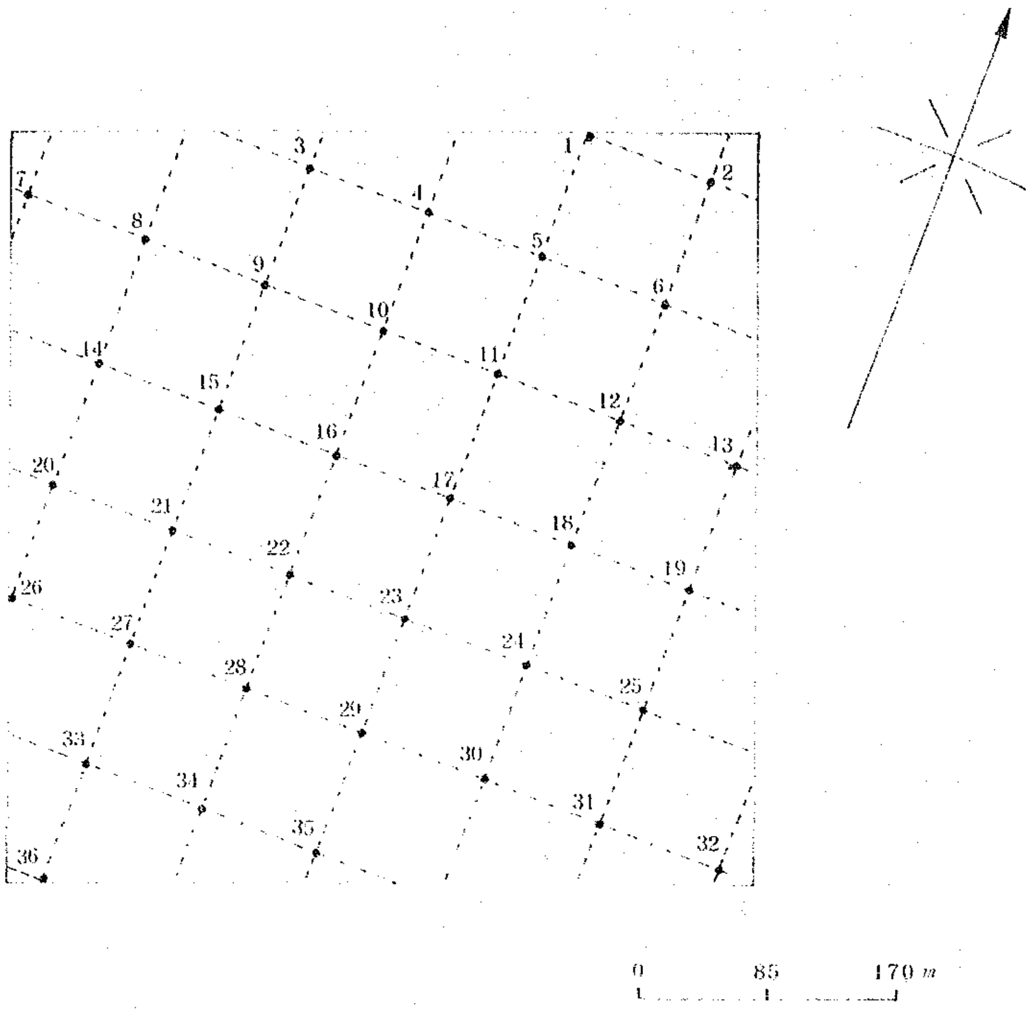
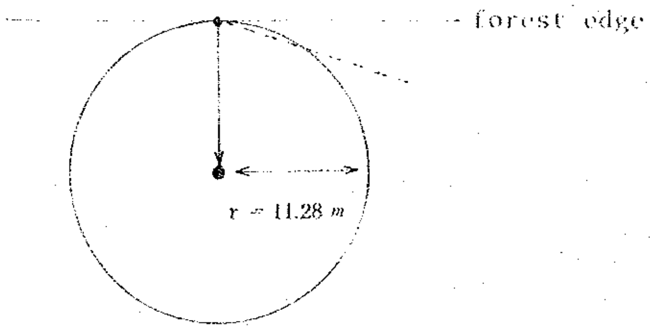
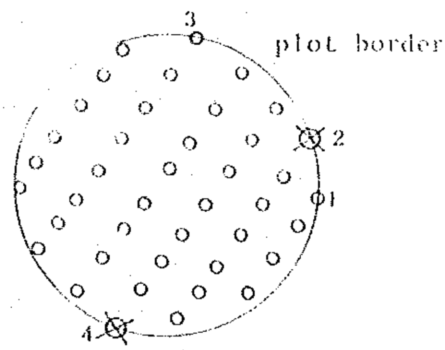


Fig. IV-1 Plot setting position (Talhão No. 8)



a. When plot center falls on forest edge, the center is removed for the survey.



b. Treatment when a tree is located on plot border.

Fig. IV-2 Treatment of plot center on forest edge and a tree on plot border

ⓒ Sampling ratio of plot: P

$$P = \frac{n}{N} \times 100 = \frac{na}{A} \times 100 = \frac{34 \times 0.04}{25} \times 100 = 5.44\ (\%)$$

ⓓ Distance of plot sampling: d

$$d ≑ \sqrt{\frac{A}{n}} \times 100 = \sqrt{\frac{25}{n}} \times 100 = 85.749 ≑ 85\ (m)$$

ⓔ Radius in case of circle plot: r

$$r = \sqrt{\frac{a(m^2)}{\pi}} = \sqrt{\frac{400}{3.14159}} = 11.2838 ≑ 11.28\ (m)$$

When the number of sampling in a plot is less than the calculated number (34), it may cause to lessen the accuracy. Therefore, to prevent low accuracy, it is desirable to take less distance than the calculated sampling distance (d), resulting the increase in the number (n). This is because only 85 m of distance was taken instead of the calculated distance d=85.749m in this example. Thus, the actual number of sampling became to be 31 as shown in Fig. IV-1. Further, the plot area a=0.04 ha means 20 m x 20 m when it is a square plot area. However, in an actual case, as a circle plot is simpler in sectioning and setting than a square plot, and saves time, we adopted a circle plot, with its calculated radius of 11.28 m.

Fig. IV-1 illustrates on a plan, that 36 survey plots were set on the surveyed forest stand Jalhão No. 8. The direction of sampling is, on basis of northern magnetic pole N, in direction of east-west and north-south. Plot No. 2 is the starting point. From the north-eastern end of forest section, the starting point extends 50 m southward (measured on the plan view) along the edge of the forest. From that point, it enters 30 m westward (also measured on the plan view) into the forest section in right angle, then the point is made to become the center of plot. Fig. IV-2 shows a case (a) when the plot center falls in the edge of forest, and treatment of trees (b) in the border of plot.

(b) Programme for increment core survey

The increment core survey for the estimation of the growth of forest stand was carried out by: select 3 sample trees of Tree No. 1, 11, and 21 every plot, take out the core (growth core) for last 10 years at the breast height (1.3 m) by increment borer, and measure the growth in millimeter. In addition, the thickness of bark at the same position was measured by a bark guage in millimeter at the same time. In order to prevent the variation in the taken out direction, the direction toward the center of plot was always maintained for measurement.

(c) Equipment and field book

The following equipment and a field book were used in the survey on the forest stand based on the above programme.

1. Equipment
A pocket compass, a tripod, a measuring rope (100 m), a Calliper (65 cm), a hypsometer (spiegel relascope), tape (20 m), chalk, an increment borer, a barkguage, a scale (30 cm).

2. Field book
A field book, which was made as with the form shown in Table IV-1, was used for the every tree survey within the plot and the increment core survey. (The filling example sows a part of Plot No. 1) Every remarks on each plot were written in different pages in the field book. Core, Casca and CD were to be written only on the sample trees. By the way, volume (V) was to be written at the indoor work after the survey.

(3) Field Survey

① Measurement with a measuring line and setting of plot section

Measuring line for plot setting was conducted with a pocket compass. In this case, when the center of plot falls outside the forest edge even a little, the plot will be discarded. On the contrary, when it falls inside, the plot will be surveyed. If it falls just on the edge, that makes 0.5 plot, therefore,

Table IV-1 Plot survey field book and its filling up example
(A part of plot No. 1)

No. 1 — 1

Plot No. : 1 , Talhão No. : 8 , Data : 08-11-1982

No.	DAP (cm)	H (m)	v (m^3)	Core (mm)	Casca (mm)	CD (m)	Nota
1	20.7	16.2		28.0	15.0	2.90	
2	14.6	13.5					Ponta bifurcado
3	21.3	15.5					
4	16.4	15.8					
5	17.7	15.3					
6	21.5	15.5					Ponta bifurcado
7	18.8	16.3					Ponta sêca
8	18.5	16.5					
9	23.7	18.0					
10	16.0	15.7					
11	18.1	16.7		28.0	12.0	3.40	
12	17.6	15.7					
13	20.8	17.0					
14	15.1	17.5					
15	17.0	16.7					
16	16.3	14.5					
17	21.1	17.0					
18	20.8	17.0					
19	15.9	16.2					
20	20.7	16.5					
21	19.1	17.5		23.0	18.0	2.70	
22	19.8	16.7					Ponta bifurcado
23	17.6	15.8					

in this case the first plot will be measured, while the second plot will be discarded, and thus this will be regarded as 0.5 plot. In this example, since Plot No. 1 and Plot No. 26 were applicable, while plot No. 26 was discarded.

When the center of Plot is determined, a circular plot with its radius r = 11.28 m was marked out and set. In this case, by using a tape of a length of 20 meters, trees within the plot will be marked a circle, while trees outside the plot will be marked X, indicating the border of a plot. In this way, taking the center as its center of the circular plot, when the marking as above completes to go around the center, the marking out of a plot is completed. Hence, the trees on the border of a plot will be counted at 0.5, i.e. the first tree will be measured, while the second will be discarded.

② Every tree measurement within a plot and increment core survey

In the every tree survey within a plot, a diameter at breast height (DAP) was measured at 1.3 m height with bark (Com casca) with a Calliper in centimeter to one-tenth of the unit, and the height (H) was measured with a spiegel-relascope to 0.1 m in precision. Further, any forked or dead-top trees were indicated in the column of Note. Dead trees were omitted. In this way, 35 plots were measured.

In a increment core survey, out of sample trees (3 trees were taken from every plot), the core taken for last 10 years, i.e. for 10 years growth from outside, was measured in millimeters, and the bark was also measured with a bark-guage in millimeters. The reason why Tree No. 1, 11, and 21 were systematically selected as sample trees was intended to prevent any possible concentration on small diameter trees or large. The number of data thus collected (sample trees) was 35 plot x 3 = 105. On these sample trees, the crown diameter (CD) also was measured in 0.1 m as reference.

③ Schedule of survey

The field survey is divided broadly into 4 categories of a measure line measurement, plot-section setting, every-tree survey,

Table IV-2 Table of results of survey procedures

Date	Plot No.	Measurement with a measuring line (85 m)	Setting of plot section	Every tree survey	Increment core survey	Total	Remarks
11.19	6	min. 10	min. 5	min. 12	min. 8	min. 35	4 persons
〃	12	7	4	11	11	33	〃
〃	13	6	5	11	11	33	〃
11.10	11	5	5	9	8	27	〃
〃	10	4	4	8	10	26	〃
〃	9	5	4	13	8	30	〃
〃	8	7	5	10	8	30	〃
〃	7	7	4	11	6	28	〃
〃	4	6	6	11	7	30	〃
〃	3	6	4	8	9	27	〃
11.23	14	7	4	14	9	34	〃
〃	15	7	4	7	8	26	〃
〃	16	4	4	9	6	23	〃
〃	17	5	4	8	6	23	〃
〃	18	7	5	12	7	31	5 persons
〃	19	7	5	7	6	25	〃
〃	25	5	5	9	6	25	〃
〃	31	5	5	7	7	24	〃

Date	Plot No.	Measurement with a measuring line (85 m)	Setting of plot section	Every tree survey	Increment core survey	Total	Remarks
11.24	32	min. 5	min. 4	min. 10	min. 6	min. 25	4 persons
〃	24	5	4	9	6	24	〃
〃	23	5	4	7	8	24	〃
〃	22	5	4	8	6	23	〃
〃	21	5	5	9	6	25	〃
〃	20	7	5	9	6	27	〃
〃	30	5	4	9	5	23	〃
〃	29	5	4	9	7	25	〃
〃	28	5	3	9	6	23	〃
11.25	27	5	3	7	6	21	〃
〃	26	5		—	—	—	(discarded)
〃	33	4	4	8	6	22	4 persons
〃	36	6	4	9	6	25	〃
〃	34	6	6	9	8	29	〃
〃	35	6	5	6	8	25	〃
n		33	32	32	32	32	
Σx		189	141	295	231	851	
$\bar{x}$		5.727	4.406	9.129	7.219	26.594	
SD		1.2317	0.7121	1.8792	1.5395	3.7058	

and increment core survey. The length of the period required for the survey for each item may differ depending on the state of forest section, land configulation, the survey team members and their skill, etc. However, if the schedule of survey, i.e. the length of the survey period, is fixed, that will be a good reference in future, in case similar survey is planned and conducted. Therefore, in parallel with the survey on forest sections, schedule examination was practised, the result of which was shown in Table IV-2.

From the results in Table IV-2, for 32 plots as the subjects of summing for 4 survey items (33 plots only for the measure-line measurement) the total hours required for survey (Σx), the average time per plot ($\bar{x}$), and standard deviation (SD) (all in minutes) were as indicated the last column in the table. From these data, the ratio of each item period against the total required time were 21.62 % for the measure-line measurement, 16.57% for the plot section setting, 34.67 % for the every-tree survey and 27.14 % for the increment core survey, respectively. Further, it seemed that in the project survey schedule per day, in case of a team consisting of 4 members, the schedule from 7-8 plots to about 10 plots would be carried out as the stuff personnel become well acquainted in the task.

(4) Estimation on forest growing stock and forest stand growth

① Summarization of number of trees and volume by plot

As the result of the field survey conducted in the above methods, the number of plots actually measured was 35. On these 35 plots, the volume was calculated for each plot, by the following formula of total tree volume with bark that was made on basis of 100 sample trees of Pinus elliottii in the same Águas de Santa Bárbara state:

$$V = 0.00675609 - 0.00012281\ D^2 + 0.00004552\ D^2H$$

The volumes were summed up for each plot, and shown in Table IV -3. Besides volume (V), regarding diameter at breast height (DAP) and height (H), the total values and the mean values per tree ($\bar{D}$, $\bar{H}$ and $\bar{V}$) were calculated and shown in Table IV-3.

Table IV-3 Over-all table of trees and volume of each plot

No.	Plot No.	Number of trees (x)	D A P		H		volume (y)	
			Total	$\bar{D}$	Total	$\bar{H}$	Total	$\bar{v}$
				cm		m		m^3
1	1	38	724.8	19.1	616.3	16.2	9.0055	0.2370
2	2	32	504.3	15.8	417.7	13.1	4.3121	0.1348
3	3	42	567.7	13.5	482.8	11.5	3.9612	0.0943
4	4	33	444.5	13.5	382.2	11.6	2.7746	0.0841
5	5	40	619.9	15.5	491.1	12.3	4.7256	0.1181
6	6	43	553.1	12.9	431.3	10.0	2.8823	0.0670
7	7	42	769.7	18.3	707.0	16.8	9.7568	0.2323
8	8	37	693.3	18.7	599.0	16.2	8.6412	0.2335
9	9	37	355.2	9.6	253.9	6.9	1.1387	0.0308
10	10	28	357.5	12.8	289.2	10.3	1.9646	0.0702
11	11	38	489.7	12.9	361.3	9.5	2.4080	0.0634
12	12	34	551.6	16.2	469.1	13.8	5.2163	0.1534
13	13	40	485.7	12.1	359.6	9.0	2.1026	0.0526
14	14	36	682.5	19.0	586.7	16.3	8.5499	0.2375
15	15	33	496.6	15.0	394.3	11.9	3.7037	0.1122
16	16	41	660.5	16.1	589.3	14.4	6.1271	0.1494
17	17	38	511.1	13.5	414.0	10.9	2.9889	0.0787
18	18	36	565.0	15.7	469.6	13.0	4.7552	0.1321
19	19	38	527.5	13.9	457.0	12.0	3.7418	0.0985
20	20	41	720.1	17.6	651.5	15.9	8.1471	0.1987
21	21	34	620.4	18.2	530.2	15.6	7.1329	0.2098
22	22	38	638.1	16.8	544.6	14.3	6.2640	0.1648
23	23	28	506.1	18.1	440.0	15.7	5.7903	0.2068
24	24	38	625.0	16.4	561.4	14.8	6.2245	0.1638
25	25	38	640.6	16.9	557.5	14.7	6.4746	0.1704
26	27	34	588.7	17.3	529.3	15.6	6.5124	0.1915
27	28	43	759.0	17.7	666.3	15.5	8.4760	0.1971
28	29	43	779.9	18.1	682.2	15.9	9.0016	0.2093
29	30	43	790.3	18.4	729.6	17.0	10.0839	0.2345
30	31	36	644.6	17.9	604.1	16.8	8.2750	0.2299
31	32	37	656.9	17.8	614.3	16.6	7.9184	0.2140
32	33	43	772.6	18.0	692.1	16.1	8.3135	0.1933
33	34	44	816.9	18.6	728.9	16.6	10.3237	0.2346
34	35	28	586.7	21.0	484.5	17.3	8.6458	0.3087
35	36	40	749.6	18.7	650.2	16.3	9.1647	0.2291
Σ	35	1314	—	—	—	—	215.5045	—

② Estimation on numbers of trees and volume

The results of the estimation on numbers of tree and volume were, from Table IV-3, as follows. In this case, the forest stand as the subject of the survey was Pinus elliottii only. Therefore, the estimation was also limited to one species of Pinus elliottii.

(a) Estimation on the number of trees

① Average number per plot:

$$\bar{X} = \frac{\Sigma(x)}{n} = 37.5 \text{ (trees)}$$

② Variance:

$$V(\bar{x}) = S_{\bar{x}}^2 = \frac{\Sigma(x-\bar{x})^2}{n(n-1)} \cdot \frac{N-n}{N} = 0.5273$$

③ Standard error:

$$SE(\bar{x}) = \sqrt{S_{\bar{x}}^2} = 0.7261$$

④ Standard error ratio:

$$e(\bar{x}) = \frac{SE(\bar{x})}{x} \times 100 = 1.93 \ (\%)$$

⑤ Estimation on the number of trees per ha:

$$X_{(ha)} = \frac{1}{a}\left[\bar{x} \pm t \cdot SE(\bar{x})\right]$$

if $n-1=34$, then $t_{0.5}=2.042$, $t_{0.1}=2.750$

hence,

for $t_{0.5}$, $X_{(ha)} = 937.5 \pm 37.1$ (trees)

(range of estimation: 900.4 ∿ 974.6 (trees))

for $t_{0.1}$, $X_{(ha)}=937.5 \pm 49.9$ (trees)

(range of estimation: 887.6 ∿ 987.4 (trees))

⑥ Estimation on the number of trees per the subject area of survey (25 ha):

$$X_{(25ha)} = \frac{A}{a}\left[\bar{x} \pm t \cdot SE(\bar{x})\right]$$

for $t_{0.5}$, $X_{(25ha)} = 23438 \pm 927$ (trees)

(range of estimation: 22511∿24365 (trees))

for $t_{0.1}$, $X_{(25ha)}$ = 23438±1248 (trees)
(range of estimation: 22190∿24686 (trees)

⑦ Error ratio of plot sampling:

$$E(\bar{x}) = \frac{t\sqrt{V(\bar{x})}}{\bar{x}} \times 100 = 3.95\ (\%)$$

⑧ Coefficient of variation

$$CV(x) = \sqrt{\frac{Sx^2}{\bar{x}}} \times 100 = 11.86\ (\%)$$

(b) Estimation on volume

① Average volume per plot:

$$\bar{y} = \frac{\Sigma(\bar{y})}{n} = 6.1573\ (m^3)$$

② Variance

$$V(\bar{y}) - S_{\bar{y}}^2 = \frac{\Sigma(y-\bar{y})}{n(n-1)} \cdot \frac{N-n}{N} = 0.19231$$

③ Standard error:

$$SE(\bar{y}) = \sqrt{S_{\bar{y}}^2} = 0.4385$$

④ Standard error ratio

$$e(\bar{y}) = \frac{SE\cdot(\bar{y})}{\bar{y}} \times 100 = 7.12\ (\%)$$

⑤ Estimation on volume per ha:

$$Y_{(ha)} = \left[\frac{1}{a}\ \bar{y} \pm t\cdot SE(\bar{y})\right]$$

for $t_{0.5}$, $Y_{(ha)}$ = 153.93 ± 22.39 (m^3)
(range of estimation: 131.55 ∿ 136.32 (m^3))
for $t_{0.1}$, $Y_{(ha)}$ = 153.93 ± 30.15 (m^3)
(range of estimation: 123.79 ∿ 184.08 (m^3))

⑥ Estimation on volume per the subject area of survey (25ha):

$$Y_{(25ha)} = \frac{A}{a}\left[\bar{y} \pm t\cdot SE(\bar{y})\right]$$

for $t_{0.5}$, $Y_{(25ha)}$ = 3848.3 ± 559.6 (m^3)
(range of estimation: 3288.7 ∿ 4407.9 (m^3))

for $t_{0.1}$, $Y_{(25ha)} = 3848.3 \pm 753.7$ (m^3)

(range of estimation: 3094 ∼ 4602.0 (m^3))

⑦ Sampling error of plot sampling:

$$E_{(\bar{y})} = \frac{t \cdot \sqrt{V(\bar{y})}}{\bar{y}} \times 100 = 14.54\ (\%)$$

⑧ Coefficient of variation

$$CV(y) = \frac{\sqrt{Sy^2}}{\bar{y}} \times 100 = 43.37\ (\%)$$

③ Frequency distribution of the number of trees by grade of diameter

To make the frequency distribution of the number of trees by the grade of diameter is not only a good reference to know how many trees of a certain diameter are growing, but also furnishes basic data for calculation of commercial volume relating to the tree height, and data for the labor plan of cutting and lumbering, for a plant site, and for a carry-out plan. This time, mainly intending to use as materials for the next estimation on the growth of forest stand, as shown in Table IV-4, we calculated diameters by grade per plot, from the data of every tree survey in 35 plots in the field survey. We grouped trees with diameter every two centimeters, like 2, 4, 6, ... 24, 26, 28. Since the diameter was measured in millimeter, for example, the group of 10 cm diameter would include 9.0 - 10.9 cm, and 12 cm diameter would include 11.0 - 12.9 cm, like that.

④ Estimation on forest stand growth

The estimation on the forest stand growth was made by the increment core survey which was conducted in parallel with the plot survey. Using 105 samples of cores, this was carried out in the following way.

(a) Calculation of diameter growth

The diameter growth for each of 105 samples is calculated at first, then the diameter growth as a whole will be calculated by the diameter growth regression formula.

① Under bark diameter: $d = D - 2b$

where, D: diameter with bark, b: thickness of bark

② Underbark diameter of the middle part for a determined period:

$x = d - 1L$

where, L: length of core for 10 years

③ Under bark average diameter growth: $y = 2L/10$

④ Diameter with bark at the determined period middle part:

$X = K \cdot x$

⑤ Diameter with bark growth: $Y = K \cdot y$

where, $K = \frac{\Sigma(D)}{\Sigma(d)} = \frac{1785.6}{1463.0} = 1.220506$

⑥ Diameter growth regression formula:

$Y = 0.3052 + 0.0169X$

(b) Calculation of volume regression formula

Using the diameter growth regression formula as calculated above, the diameter growth for each tree of every diamter grade is acquired. Then the value will be combined with the volume, where the volume for each diameter grade will be necessary as premises. The volume by each diameter grade was obtained, on basis of 105 sample trees, by the one-variable equation with a diameter as the independent variable, as follows.

$$V = 0.011804 - 0.008779D + 0.001049D^2$$

(c) Calculation of volume growth

After the calculation by the regression formula of diameter growth and volume is made, the volume growth by diameter grade is then calculated, and the result will be used to estimate the forest stand growth. The calculation method procedure is as follows.

① Grouping by diameter was made by every 2 cm in the range of diameters of sample trees (the 105 trees from which cores were taken).

② The volume per tree corresponding to each diameter (D), grouped by every 2 cm, was calculated by the volume formula

Table IV-4 Table of distribution of frequency of number of trees by diameter grade of each plot

Plot	Grade of diameter (cm)														Total
№	2	4	6	8	10	12	14	16	18	20	22	24	26	28	
1	–	–	–	–	–	–	1	6	13	11	4	2	1	–	38
2	–	–	–	–	–	5	9	6	8	1	3	–	–	–	32
3	–	1	1	5	2	10	6	8	8	–	–	1	–	–	42
4	–	–	–	–	3	10	13	5	2	–	–	–	–	–	33
5	–	–	–	–	1	6	10	10	8	5	–	–	–	–	40
6	–	–	–	–	9	15	13	4	1	–	1	–	–	–	43
7	–	–	–	–	–	–	5	9	11	8	8	–	1	–	42
8	–	–	–	–	–	–	2	8	14	5	5	1	1	1	37
9	1	1	4	10	10	7	2		1	1	–	–	–	–	37
10	–	–	–	1	6	10	5	4	2	–	–	–	–	–	28
11	–	–	–	3	7	10	11	3	4	–	–	–	–	–	38
12	–	–	–	–	1	5	4	15	2	3	3	–	–	–	34
13	–	–	–	1	8	13	12	2	1	–	–	–	–	–	40
14	–					–	2	6	12	7	7	1	1	–	36
15	–	–		1	2	1	10	7	5	4	–	–	–	–	33
16	–	–	–	–	1	2	8	15	10	5	–	–	–	–	41
17	–	–	–	–	4	14	13	3	3	1	–	–	–	–	38
18	–	–	–	–	1	7	9	5	6	7	1	–	–	–	36
19	–	–	1	1	5	7	12	5	4	2	1	–	–	–	38
20	–	–	–	–	–	1	5	11	11	8	4	1	–	–	41
21	–	–	–	–		–	3	6	11	9	4	1	–	–	34
22	–	–	–	–	1	2	4	16	6	6	2	1	–	–	38
23	–	–		–	–	–	3	6	8	7	4	–	–	–	28
24	–	–		–	1	1	9	10	13	2	1	–	1	–	38
25	–		–	–	–	2	9	7	11	5	3	1	–	–	38
27	–	–	–	–	1	1	2	11	12	4	2	–	1	–	34
28	–				–	1	6	14	11	4	4	3	–	–	43
29	–			–	–	1	2	12	14	7	6	1	–	–	43
30	–	–	–	–	–	–	4	10	11	9	9	–	–	–	43
31	–	–	–	–	–	–	3	6	14	6	5	2	–	–	36
32	–	–	–	–	–	–	4	14	5	8	6	–	–	–	37
33	–		–	–	–	–	7	12	16	5	2	1	–	–	43
34	–	–	–	–	–	–	4	12	8	14	3	1	1	1	44
35	–	–	–	–	–	–	–	4	4	5	9	3	3	–	28
36	–	–	–	–	–	–	2	8	10	12	5	2	1	–	40
Total	1	2	6	25	63	134	214	280	280	171	102	22	12	2	1314
Ratio	0.08	0.15	0.46	1.90	4.80	10.20	16.29	21.31	21.31	13.01	7.76	1.67	0.91	0.15	100.00

as in the paragraph (2) in the previous section.

③ The difference in volume of different diameter grade, i.e. volume difference Δv is calculated. For example, Δv between 2 cm diameter and 4 cm is;

$$\Delta v = 0.0045 - 0.0015 = 0.0030$$

and Δv between 4 cm diameter and 6 cm is:

$$\Delta v = 0.0100 - 0.0045 = 0.0055$$

④ Volume modified difference δv was calculated, based on the volume difference Δv. For example δv for 4 cm diameter is: (0.0030 + 0.0055)/2 = 0.0043, and for 6 cm diameter: (0.0055 + 0.0085)/2 = 0.0070.

⑤ Diameter growth Δd was calculated for each diameter grade by the diameter growth regression formula in (1) 6 above.

⑥ Using thus obtained volume modified difference δv and the diameter growth Δd, the volume growth was calculated by $V_{(g)} = (\delta V \cdot \Delta d)/2$. The figure 2 in this formula is because 2 cm is used for diameter grading. If the grading is made by 1 cm, the above figure is 1. In addition, so far the above means the volume growth per a single tree.

⑦ The number of trees at each diameter grade, N is acquired by the frequency distribution table of number of trees by diameter grade per plot in Table IV-4, based on the materials of plot survey. Here, 2 cm diameter grade is omitted from the calculation of volume growth, since the number of trees is only one. However, in the ultimate calculation (Table IV-5, a, b, and c) the number of trees was also treated among the subject of calculation.

⑧ When the volume growth $V_{(g)}$ of 6) above is multiplied with the number of trees by diameter grade, N of 7), the total volume growth $V_{(g)}$ is obtained. This is the volume growth by diameter grade, which is estimated from the 105 sample trees, and the total value of 20.125 m^3 is the total tree volume per 1.4 ha of plot area (0.04 ha x 35 plots = 1.4 ha).

⑨ When the volume per tree by diameter grade, V times the number of trees by diameter grade, N makes the volume by dismeter grade, and the total value of 216.9554 m^3 is the total volume per 1.4 ha.

From Table IV-5, the volume growth per 1.4 ha of survey plot area is obtained as 20.1205 m^3. From this figure, the estimated volume of 14.3718 m^3 per unit area (1 ha) and 359.2946 m^3 per area subject to estimate on (25 ha) were obtained.

In addition, thus calculated volume showed the results of 216.9554 m^3 per 1.4 ha, 154.9681 m^3 per unit area (1 ha), and 3874.2035 m^3 per total area (25 ha). From these, the volume growth percentage (P) of this forest stand was figured as below.

$$P = \frac{20.1205}{216.9554} \times 100 = 9.27\ (\%)$$

(5) Conclusion

① Consideration on the estimation result

(a) Coefficient of variance of forest stand

Prior to the field survey, the coefficient of variance(cv) was assumed at 30 %. This is because the state of the forest stand is regarded lacking in uniformity, since there are certain difference in the growth of tree heights, diameters and so on, and further there are burned area by forest-fire and damp ground in a part of the forest. As the result, the number of plot survey, n was 34 (actually 35 plots were surveyed). However, the calculation after the survey, the coefficient(cv) was proved to be 43.37%. So it can be said that this forest stand had average variance as artificial forest. Therefore, the required plot number for the survey in case of CV = 43.37 ≒ 44 % would be 68.9 ≒ 69 which is the sufficient number for aimed accuracy of 10 %. This value will be one of the reference materials in future survey programme.

(b) Result of estimates on growing stock

The result of estimates no number of trees as well as volume were as in Table IV-6. Comparing these with the values on the number of trees and volume based on the estimate on the volume growth of forest stand, the results were both within the range of estimation based on the plot survey, showing

Table IV-5 Table of calculation of growth of volume

Diamter at breast height ① D	Volume per tree ② v	Difference of volume ③ Δv	Difference of modified volume ④ δv	Growth of diameter ⑤ Δd	Growth of volume ⑥ $v_{(g)}$ (δv · Δd/2)	Number of trees ⑦ N	Growth of total volume ⑧ $V_{(g)}$ ($v_{(g)}$ · N)	Total volume ⑨ V (v · N)
cm	m^3	m^3	m^3	cm	m^3		m^3	m^3
2	0.0015	0.0030	—	—	—	(1)	—	—
4	0.0045	0.0055	0.0043	0.3728	0.00080	2	0.0016	0.0090
6	0.0100	0.0085	0.0070	0.4066	0.00142	6	0.0085	0.0600
8	0.0185	0.0140	0.0113	0.4404	0.00249	25	0.0623	0.4625
10	0.0325	0.0250	0.0195	0.4742	0.00462	63	0.2911	2.0475
12	0.0575	0.0370	0.0310	0.5080	0.00787	134	1.0646	7.7050
14	0.0945	0.0454	0.0412	0.5418	0.01116	214	2.3882	20.2230
16	0.1399	0.0538	0.0496	0.5756	0.01427	280	3.9956	39.1720
18	0.1937	0.0621	0.0580	0.6094	0.01767	280	4.9476	54.2360
20	0.2558	0.0706	0.0664	0.6432	0.02135	171	3.6509	43.7418
22	0.3264	0.0789	0.0748	0.6770	0.02532	102	2.5826	33.2928
24	0.4053	0.0874	0.0832	0.7108	0.02957	22	0.6506	8.9166
26	0.4927	0.0957	0.0916	0.7446	0.03410	12	0.4092	5.9124
28	0.5884	0.1041	0.0999	0.7784	0.03888	2	0.0778	1.1768
30	0.6925		—	—	—	—	—	—
ⓐ Total (per surveyed area, 1.4 ha)						1314	20.1205	216.9554
ⓑ Per unit area (1 ha)						939	14.3718	154.9681
ⓒ Per estimated survey subject area (A=25 ha)						23464	359.2946	3874.2035

a good coincidence. The sampling error ratio of plot sampling was 14.54 %.

Table IV-6 List of estimation results of the number of trees and volume

		Results of systematic line-plot sampling		Results based on the estimated volume production of a forest stand
		For $t_{0.05}$	For $t_{0.01}$	
Number of trees	Per 1 ha	937.5 ± 37.1 (900.4 ~ 974.6)	937.5 ± 49.9 (887.6 ~ 987.4)	939
	Per 25 ha	23438 ± 927 (22511 ~ 24365)	23438 ± 1248 (22190 ~ 24686)	23464
Volume (m^3)	Per 1 ha	153.93 ± 22.39 (131.55 ~ 176.32)	153.93 ± 30.15 (123.79 ~ 184.08)	154.97
	Per 25 ha	3848.3 ± 559.6 (3288.7 ~ 4407.9)	3848.3 ± 753.7 (3094.6 ~ 4602.0)	3874.20

It must be checked in future how the above estimates meet the actual forest stand. However, for the estimation on the growing stock in a forest of spacious area, since this survey method is simple in practice and easy in afterward calculation, it can be concluded as one of very efficient methods.

(c) Result of estimates on plot stand growth

The result showed that the forest stand volume growth was 14.3718 m^3 per ha, and 359,2964 m^3 per 25 ha of the subject area of estimation, and the growth percentage P was 9.27%. This percentage is not excellent. It is necessary to consider tree-species, by comparison with other species of pine trees.

2 Reference literature and correlating materials

(1) Reference literature

① H.A. Meyer: Forest measuration 1953

② G.W. Snedecor: Statistical Methods 1956

③ Kenkichi Kinashi, Masamichi Chyo: Volume survey of Mikatagake natural forest (Miyazaki Experiment forest of Kyushu University) by a random sampling methods. Report of Practice in Kyushu University 10, 1958.

④ Masamichi Chyo and others: Estimation on the volume and growth of Pinus elliottii in St. Paulo State, Theses of Kyushu Branch, Japan Forestry Society, 37, 1984.

(2) Correlating materials

Calculation process is described in the material ① below. The volume formula, which is the original of this material, is based on ②. There is also a study report ③ as a method of tree height measurement carried in the field survey.

① Masamichi Chyo, N.Haga, and H. Aoki:: The estimation of forest stand volume by systematic line-plot sampling, and the estimation of forest stand growth by increment core. International Cooperation Agency JR 84-40 (Experts' Report of International Cooperation on Study of Forestry in St. Paulo, Brazil) p347-394, 1984

② Masamichi Chyo, Toshiaki Shiibayashi, N. Haga, and H. Aoki: Study of preparationof the tree volume table of Pinus elliottii in state forest of Águas de Santa Bárbara, ditto, 0336-346, 1984.

③ M. Chyo, H. Aoki, and N. Haga:ɐRegua Auziliar para Determincao de Altura-Prototipo e Teste de Precisao. Botetim Tecnico do Instituto Florestal, Sao Paulo, V.37, p1-18, 1983

Table IV-7 Table of distribution of sample trees by the grades of diameter at breast height with bark (DAP, Com casca) and tree height

H (m)	DAP (Com casca / cm)																							Total
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
7	1		1																					2
8	1			1						1														3
9	1	1	1		1		1		1															6
10	1		1		1		1		1															5
11	1		2				1				2				1									7
12			1		2				1		1		1											6
13			1		1		3	1	1		1													8
14							2		1	1	2		2		2		1							11
15			1		1		1		1		1		1			1	1		1					9
16					2				1	1			1		2									7
17							1			1	1				1						1		1	6
18									2		1		2	1			2		1					9
19							1			1	1		2	1										6
20										1					2			1			1		1	6
21													1				1		1					3
22											1								1					2
23															1		1				1		1	4
Total	5	1	8	1	8	—	11	1	9	6	11	—	10	2	9	1	6	1	4	—	3	—	3	100

IV-2-2 Preparation of Tree Volume Table

(1) Preface (Purpose)

In St. Paulo state, from 1958 to 1965, tropical or subtropical pine trees of North or Middle America were introduced to encourage artificial plantation. Since the history is so short as about 20 years or so, tree volume tables have not been made for each district.

Hence, the study of the preparation of tree volume table, taking up Pinus elliottii in state forest of Àguas de Santa Bárbara which is one of state forests, as the subject. At the same time some examination was attempted on this topic.

(2) Collection of Materials and Calculation of Tree Volume

① Collection of materials

The whole area of the state forest of Àguas de Santa Bárbara were regarded as the subject for the area of sample trees, which would be basic material for tree volume table. Their diameter (DAP) and height (H) were intentionally selected so that they could be almost equally taken out from maximum to minimum. As the result, 100 sample trees of Pinus elliottii in total were collected as in Table IV-7.

② Calculation of volume of sample trees

Six cases of the volumes are used in St. Paulo State, i.e. A:the whole tree volume, B:the commercial volume of and diameter without bark of up to 5 cm, C: the real commercial volume of end diameter without bark of up to 5 cm which was lumbered into the length of 2.4 m, equal to the truck bed length (there are also some cases marking use of as short as the half length, 1.2 m), and with bark and without bark for each of above 3 cases, all of which make 6 cases. These 6 volumes as below are being used for each purpose.

1. Total tree volume with bark (Volume Total Com casca)
2. Total tree volume without bark (Volume Total Sem casca)
3. Commercial volume with bark (Volume Commercial Com casca)
4. Commercial volume without bark (Volume Commercial Sem casca)
5. Real commercial volume with bark (Volume Commercial Real Com

casca)

6. Real commercial volume without bark (Volume Commercial Real Sem)

Therefore, cutting of sample trees, measurement in case of clean cutting, and volume calculation thereafter, were planned to furnish materials for each case. The measurement at cutting down and clean cut, volume calculation, etc. was carried out by simplified analysis method as shown in Table IV-8, based on the method of stem analysis (Método de análise de tronco). Table IV-9 is a list of values on sample trees, as above obtained. Various calculations were carried out by computer, as in the flow in Figure IV-3. Table IV-10 indicated one example of sample tree No. 12, and Table IV-11 show a list of the results of various volume calculations of all sample trees (100 trees).

③ Examination on the volume equation

In the past, various volume equations have been proposed. Properly speaking, it is appropriate to examine each formula separately and select the most adaptable formula. However, in this study, the examination was made on the following five formulae which had been relatively often used.

$$V = a_0 D^{a_1} \quad (1)$$

$$V = a_0 + a_1(D^2H) \quad (2)$$

$$V = a_0 + (D^2H)^{a_1} \quad (3)$$

$$V = a_0 + D^{a_1}H^{a_2} \quad (4)$$

$$V = a_0 + a_1D^2 + a_2H + a_3(D^2H) \quad (5)$$

In order to solve these 5 equations by linear least square method, we apply logarithmic conversion to equation (1), (3) and (4), and the following are obtained.

$$\log V = \log a_0 + a_1 \log D \quad (1')$$

$$\log V = \log a_0 + a_1 \log (D^2H) \quad (3')$$

$$\log V = \log a_0 + a_1 \log D + a_2 \log H \quad (4')$$

When y is substituted for dependent variant, X_i for an independent variable, a_0 for a regression constant, a_i for a regression coefficient, these formulae can be expressed in a general formula as below.

Table IV-8 Field book for simplified stem analysis for the purpose of measurement of sample trees

-FICHA PARA O CÁLCULO DO VOLUME-

Nº ÁRVORES	12	ESPÉCIE	P. elliottii	IDADE	18
DATA DA MEDIÇÃO	3 de Junho De 1982	LOCAL	Águas de Santa Bárbara (31)		

Nº	ALT.	DIÂMETRO À ALTURA DO PEITO (d) COM CASCA (C/c) MÁX.	MIN.	MED.	SEM CASCA (S/c) MÁX.	MIN.	MED.	AREA BASAL (g) C/CASCA (g_b)	S/CASCA (g_i)	VOLUME (v) C/CASCA (v_b)	S/CASCA (v_i)	PORC.
	m	cm	cm	cm	cm	cm	cm	m²	m²	m³	m³	%
0	1.3			28.5			24.1					
1	1.1			29.3			24.1	0.0674	0.0456	0.1348	0.0912	67.66
2	3.1			25.7			22.5	0519	0398	1038	0796	76.69
3	5.1			25.0			22.2	0491	0387	0982	0774	78.82
4	7.1			24.5			21.7	0471	0370	0942	0740	78.56
5	9.1			24.0			21.2	0452	0353	0904	0706	78.10
6	11.1			21.7			19.8	0370	0308	0740	0616	83.24
7	13.1			21.7			19.3	0370	0293	0740	0586	79.19
8	15.1			16.4			15.0	0211	0177	0422	0354	83.89
9	17.1			13.0			12.0	0133	0113	0266	0226	84.96
10	19.1			7.2			6.8	0041	0036	0082	0072	87.80
11	21.1			4.5			3.8	0016	0011	0032	0022	68,75
12	22.1			2.1			1.9	0003	0003	0001	0001	100.00
13												
14												
15												
16												
17												
18												
(19)	19.3			7.5			6.5	0044	0033	0067	0051	76.12
(20)	20.5			5.9			5.0	0027	0020	0025	0019	76.00
D A P (D)				cm 28.5			cm 24.1					
ALTURA (H)				m 22.8			m 22.8					
COMP. DO PONTEIRO (ℓ_T)				m 0.7			m 0.7					
COMP. ACIMA DE 5.0cm (ℓ_{05})				m 2.3			m 2.3					
AREA BASAL TOTAL(Σg_i)								m² 0.3748	m² 0.2902			
① VOL. DAS SECÇÕES (Σv_i)										m³ 0.7496	m³ 0.5804	
② VOL. DO CONE (v_T)										0001	0001	
①+② VOL. TOTAL (v_A)										7497	5805	% 77.43
③ VOL. ACIMA DE 5cm ($v_{.05}$)										0025	0019	
V_A-③ VOL. COMERCIAL (v_B)										7472	5786	77.44
PORCENTAGEM (%)										% 99.67	% 99.67	

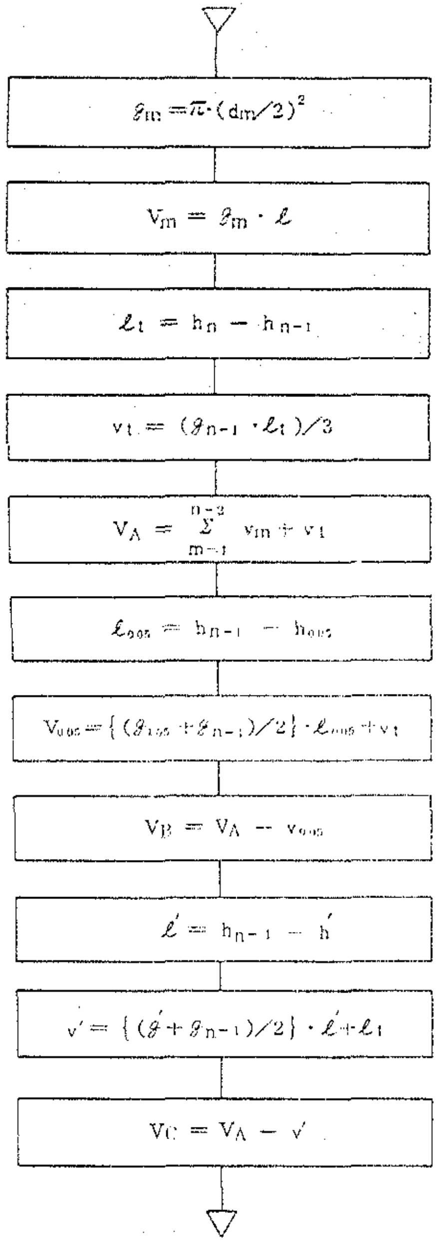
RESPONSÁVEL : Chyo, Haga, Aoki, Adauto, Ataide

Table IV-9 List of sample trees

(Coleta de dados dendrométricos)

No.	Talhão No.	Idade	DAP C. casca	DAP S. casca	H	Altura da COPA	Comp. do Ponteiro (ℓ_T)	Comp. Acima de 50 cm (ℓ_{05})	Pont. Final (ℓ_F)	No.	Talhão No.	Idade	DAP C. casca	DAP S. casca	H	Altura da COPA	Comp. do Ponteiro (ℓ_T)	Comp. Acima de 5.0cm (ℓ_{05})	Pont. Final (ℓ_F)
			cm	cm	m	m	m	m	m				cm	cm	m	m	m	m	m
1	4	20	21.0	17.8	19.1	11.5	1.00	2.12	2.20	51	118	13	12.0	10.0	8.6	3.7	0.50	3.20	3.80
2	16	〃	13.8	12.0	17.1	10.9	1.04	2.69	2.64	52	〃	〃	10.5	8.8	12.1	9.0	2.00	3.60	3.70
3	〃	〃	25.0	21.0	19.8	10.8	1.74	2.56	2.94	53	〃	〃	11.8	9.0	12.7	8.8	0.60	4.30	4.30
4	10	〃	12.5	10.2	15.1	8.5	0.95	2.95	2.95	54	〃	〃	20.0	18.0	14.8	9.0	0.70	2.50	2.80
5	〃	〃	8.2	6.7	10.5	5.6	0.40	6.64	5.60	55	12	20	26.0	22.5	22.4	11.7	0.30	2.40	3.20
6	〃	〃	7.7	6.2	8.5	1.8	0.35	4.75	3.55	56	〃	〃	20.0	17.0	21.0	14.6	0.90	2.90	3.00
7	15	〃	13.6	12.0	13.3	1.9	1.20	3.07	3.60	57	〃	〃	22.0	19.0	22.7	13.7	0.60	3.30	3.50
8	〃	〃	15.7	14.3	15.7	7.8	1.60	3.04	3.60	58	〃	〃	30.0	26.8	22.7	14.0	0.60	2.00	2.30
9	〃	〃	17.5	15.3	16.2	7.8	0.10	1.70	1.70	59	〃	〃	24.0	20.2	23.0	13.1	0.90	3.30	3.80
10	35	18	21.2	19.0	17.6	8.7	1.50	2.60	3.10	60	〃	〃	18.0	16.5	22.0	15.4	1.90	2.70	2.80
11	〃	〃	16.8	14.8	20.0	10.0	1.90	2.90	3.10	61	〃	〃	14.2	12.0	18.6	11.6	0.50	2.20	3.00
12	31	〃	28.5	24.1	22.8	14.5	0.70	2.30	3.50	62	103	17	18.0	15.5	17.6	9.5	1.50	2.80	3.20
13	12	20	21.8	18.8	19.7	12.2	1.60	2.60	2.80	63	〃	〃	18.0	15.2	17.2	12.6	1.10	2.70	2.80
14	〃	〃	17.3	15.2	19.5	11.9	1.40	2.65	3.80	64	〃	〃	20.0	17.5	18.0	11.8	1.90	2.70	3.60
15	〃	〃	15.8	12.8	18.0	11.7	1.90	2.74	3.50	65	〃	〃	10.0	8.2	15.0	11.2	0.90	5.30	6.40
16	〃	〃	12.0	10.1	16.4	11.3	0.30	3.95	4.30	66	〃	〃	10.4	8.3	13.2	11.7	1.10	5.90	6.00
17	123	13	8.1	7.2	11.5	8.1	1.40	4.40	5.40	67	〃	〃	24.0	20.5	18.0	12.7	1.90	2.30	2.40
18	〃	〃	10.1	8.4	10.8	6.3	0.70	4.70	4.70	68	〃	〃	17.4	14.8	16.9	11.5	0.80	2.40	2.50
19	〃	〃	12.0	10.7	12.5	8.3	0.40	2.80	2.80	69	118	13	18.0	15.8	13.0	6.4	0.90	2.10	2.20
20	〃	〃	10.0	8.0	11.2	7.8	1.10	5.95	6.30	70	〃	〃	20.0	17.5	11.9	3.3	1.80	2.20	2.30
21	85	17	14.0	11.8	14.0	6.8	1.90	2.70	3.10	71	10	20	8.0	5.8	7.2	3.1	1.10	4.00	4.80
22	〃	〃	14.0	11.2	12.6	7.4	0.50	3.23	4.10	72	〃	〃	9.0	7.0	8.7	3.8	0.60	3.80	3.90
23	〃	〃	16.0	13.4	14.0	8.2	1.90	2.65	3.10	73	〃	〃	7.7	5.7	9.3	3.2	1.20	5.60	5.70
24	〃	〃	18.0	15.2	14.5	7.8	0.40	2.40	2.40	74	〃	〃	11.4	8.3	8.0	4.2	1.90	2.90	3.20
25	〃	〃	20.0	17.0	15.6	7.8	1.50	2.30	2.30	75	118	13	18.0	16.0	12.2	4.6	1.10	3.00	3.80
26	〃	〃	14.3	12.0	14.8	8.1	0.70	2.90	3.90	76	〃	〃	21.0	20.5	14.0	5.1	1.90	2.40	3.20
27	118	14	23.4	20.0	15.4	8.0	1.30	2.00	2.10	77	〃	〃	22.0	19.0	16.5	7.3	0.40	3.30	3.30
28	〃	〃	21.8	18.5	14.4	6.0	0.30	2.30	2.30	78	〃	〃	14.0	11.5	10.8	8.0	0.70	2.70	3.60
29	〃	〃	17.5	14.8	14.1	7.2	2.00	2.50	3.30	79	〃	〃	20.0	17.5	13.9	7.3	1.80	2.60	3.10
30	〃	〃	15.2	13.1	13.2	7.0	1.10	3.50	3.50	80	〃	〃	12.0	10.3	11.7	6.5	1.60	3.10	3.30
31	126	13	18.3	15.8	13.8	6.9	1.70	2.70	2.90	81	〃	〃	16.0	12.5	11.6	6.8	1.50	3.00	3.20
32	〃	〃	20.0	17.0	13.9	7.1	1.80	2.50	3.00	82	〃	〃	16.0	13.8	12.7	7.4	0.60	3.10	3.10
33	〃	〃	10.1	8.8	10.5	5.6	0.40	4.40	4.50	83	〃	〃	18.0	15.0	10.7	3.8	0.60	2.80	3.50
34	〃	〃	10.0	8.2	9.5	5.1	1.40	4.00	4.70	84	〃	〃	14.0	11.6	12.9	7.1	0.80	2.90	3.30
35	〃	〃	12.2	10.4	10.2	5.6	0.10	2.90	3.00	85	〃	〃	18.0	15.0	11.1	4.4	1.00	2.10	2.70
36	124	〃	24.2	21.5	14.8	7.2	0.70	1.70	2.80	86	15	20	30.0	27.0	17.0	7.5	0.90	2.90	3.80
37	〃	〃	28.0	25.8	16.8	9.0	0.70	1.70	2.40	87	12	〃	24.0	21.0	18.1	9.2	2.00	3.30	3.70
38	〃	〃	26.0	22.5	18.0	11.8	1.90	2.10	2.30	88	〃	〃	16.0	13.8	15.3	7.8	1.20	3.10	3.30
39	〃	〃	26.0	22.0	15.3	8.4	1.20	2.00	2.10	89	〃	〃	20.0	17.2	17.6	11.3	1.50	2.70	3.20
40	25	20	24.0	21.0	21.2	14.2	1.10	2.60	3.10	90	〃	〃	12.0	10.5	16.5	11.4	0.40	3.20	3.30
41	〃	〃	22.0	19.0	16.8	9.8	0.70	2.30	2.40	91	〃	〃	16.0	13.2	17.8	9.2	1.70	2.80	3.40
42	〃	〃	20.0	18.0	19.5	13.4	1.40	2.40	2.70	92	〃	〃	18.0	14.8	19.2	13.5	1.10	3.60	3.60
43	〃	〃	20.0	19.0	19.5	9.3	1.40	2.60	2.70	93	〃	〃	22.0	18.0	19.7	12.0	1.60	3.20	4.10
44	〃	〃	14.2	12.3	13.6	8.0	1.50	2.20	2.80	94	〃	〃	28.0	24.7	20.5	10.2	0.40	1.90	2.50
45	118	13	18.0	16.0	13.9	7.0	1.80	1.80	1.90	96	〃	〃	30.0	25.0	20.1	9.7	2.00	2.10	2.10
46	〃	〃	22.0	18.8	11.0	4.3	0.90	2.70	2.80	96	〃	〃	26.0	23.5	21.5	12.8	1.40	2.00	2.30
47	〃	〃	17.0	13.7	8.5	4.0	0.40	1.40	2.50	97	117	13	16.0	14.0	9.1	4.0	1.00	1.90	1.90
48	〃	〃	10.0	7.5	7.0	4.6	0.90	3.30	3.40	98	〃	〃	22.0	19.0	15.7	7.8	1.60	2.50	2.50
49	〃	〃	14.0	11.0	10.3	4.4	0.20	2.60	3.10	99	〃	〃	14.0	11.0	9.1	5.3	1.00	3.90	4.30
50	〃	〃	15.8	13.0	9.6	4.6	1.50	1.80	2.40	100	〃	〃	22.0	18.5	14.1	7.1	1.90	2.80	3.20

(Local : Águas de Santa Bárbara)



g_m : cross section area (m^2)

π : the ratio of the circumference of a circle to its diameter (3.1415926)

d_m : diameter (cm)

v_m : separated trunk volume (m^3)

ℓ : separated length (m) (2.0m)

ℓ_t : length to tree neck (m)

h_n : total tree height (m)

h_{n-1} : tree height for the part for measurement after cutting (m) (corresponding to the tree height of the subject of separated trunk volume)

v_t : volume to tree neck (m^3)

g_{n-1} : cross section area at tree neck (m^2)

V_A : total trunk volume (m^3)

ℓ_{005} : length from the part of 5 cm without bark diameter to tree neck (m)

h_{005} : tree height to the part of 5 cm without bark diameter (m)

v_{005} : volume of less than 5 cm without bark diameter (m^3)

V_B : Commercial volume (m^3)

ℓ' : length from the last lumbered part to tree neck (m)

h' : total lumber length separated by every 2.4m (or 1.2m) (m)

v' : volume not to be lumbered (m^3)

g' : cross section area of last lumbered part (m^2)

V_C : real commercial volume (m^3)

Fig. IV-3 Flow of Volume Calculation by Computer

Table IV-10 Example of result of volume calculation by computer (Sample tree No. 12)

FICHA PARA O CALCULO DO VOLUME

N.ARVORES : 12-(1)
ESPECIE : P.ELLIOTTII
IDADE : 18
DATA : 03/06/1982
LOCAL : AGUAS DE SANTA BARBARA (31)

N.	ALT.	DIAMETRO A ALTURA DO PEITO: CON CASCA (C/C) MAX.	MIN.	MED.	SEM CASCA (S/C) MAX.	MIN.	MED.	AREA BASAL C/C	S/C	VOLUME C/C	S/C	PORC.
0	1.30	0.0	0.0	28.5	0.0	0.0	24.1					
1	1.10	0.0	0.0	29.3	0.0	0.0	24.1	0.0674	0.0456	0.1348	0.0912	67.66
2	3.10	0.0	0.0	25.7	0.0	0.0	22.5	0.0519	0.0398	0.1038	0.0796	76.69
3	5.10	0.0	0.0	25.0	0.0	0.0	22.2	0.0491	0.0387	0.0982	0.0774	78.82
4	7.10	0.0	0.0	24.5	0.0	0.0	21.7	0.0471	0.0370	0.0942	0.0740	78.56
5	9.10	0.0	0.0	24.0	0.0	0.0	21.2	0.0452	0.0353	0.0904	0.0706	78.10
6	11.10	0.0	0.0	21.7	0.0	0.0	19.8	0.0370	0.0308	0.0740	0.0616	83.24
7	13.10	0.0	0.0	21.7	0.0	0.0	19.3	0.0370	0.0293	0.0740	0.0586	79.19
8	15.10	0.0	0.0	16.4	0.0	0.0	15.0	0.0211	0.0177	0.0422	0.0354	83.89
9	17.10	0.0	0.0	13.0	0.0	0.0	12.0	0.0133	0.0113	0.0266	0.0226	84.96
10	19.10	0.0	0.0	7.2	0.0	0.0	6.8	0.0041	0.0036	0.0082	0.0072	87.80
11	21.10	0.0	0.0	4.5	0.0	0.0	3.8	0.0016	0.0011	0.0032	0.0022	68.75
12	22.10	0.0	0.0	2.1	0.0	0.0	1.9	0.0003	0.0003	0.0001	0.0001	100.00
13	19.30	0.0	0.0	7.5	0.0	0.0	6.5	0.0044	0.0033	0.0067	0.0051	76.12
14	20.50	0.0	0.0	5.9	0.0	0.0	5.0	0.0027	0.0020	0.0025	0.0019	76.00

		C/C	S/C	AREA BASAL C/C	S/C	VOLUME C/C	S/C	PORC.
D. A. P.	(CM)	28.50	24.10					
ALTURA	(M)	22.80	22.80					
COMP. DO PONTEIRO	(M)	0.70	0.70					
COMP. ACIMA DE 5CM	(M)	2.30	2.30					
AREA BASAL TOTAL	(M**2)			0.3748	0.2902			
VOL. DAS SECCOES	(M**3)					0.7496	0.5804	
VOL. DO CONE	(M**3)					0.0001	0.0001	
VOL. TOTAL	(M**3)					0.7497	0.5805	77.43
VOL. ACIMA DE 5CM	(M**3)					0.0025	0.0019	
VOL. COMERCIAL	(M**3)					0.7472	0.5786	77.44
PORCENTAGEM	(%)					99.67	99.67	

Table IV-11 List of the calculation results of various volume and ratios on sample trees (100 trees)

A TABELA SUMARIADA

N.	D.A.P. C/C	D.A.P. S/C	ALT.	VOL. TOTAL (VA) C/C	VOL. TOTAL (VA) S/C	VOL. TOTAL (VA) %	VOL. COMERCIAL (VB) C/C	VOL. COMERCIAL (VB) S/C	VOL. COMERCIAL (VB) %	VB/VA C/C	VB/VA S/C	VOL. COMERCIAL REAL (VC) C/C	VOL. COMERCIAL REAL (VC) S/C	VOL. COMERCIAL REAL (VC) %	VC/VA C/C	VC/VA S/C
1	21.00	17.60	19.10	0.3542	0.2817	79.53	0.3523	0.2803	79.56	99.46	99.50	0.3517	0.2801	79.64	99.29	99.43
2	13.80	12.00	17.14	0.1411	0.1096	77.68	0.1380	0.1073	77.75	97.80	97.90	0.1382	0.1076	77.86	97.94	98.18
3	25.00	21.00	19.84	0.4758	0.3776	79.36	0.4734	0.3757	79.36	99.50	99.50	0.4719	0.3745	79.36	99.18	99.18
4	12.50	10.20	15.05	0.0928	0.0729	78.56	0.0896	0.0705	78.68	96.55	96.71	0.0896	0.0705	78.68	96.55	96.71
5	8.20	6.70	10.50	0.0248	0.0178	71.77	0.0158	0.0116	73.42	63.71	65.17	0.0191	0.0134	70.16	77.02	75.28
6	7.70	6.20	8.45	0.0200	0.0140	70.00	0.0136	0.0096	70.59	68.00	68.57	0.0171	0.0119	69.59	85.50	85.00
7	13.60	12.00	13.30	0.1090	0.0897	82.29	0.1060	0.0874	82.45	97.25	97.44	0.1039	0.0856	82.39	95.32	95.43
8	15.70	14.30	15.70	0.1602	0.1357	84.71	0.1569	0.1330	84.77	97.94	98.01	0.1546	0.1311	84.80	96.50	96.61
9	17.50	15.30	16.20	0.2450	0.1998	81.55	0.2429	0.1981	81.56	99.14	99.15	0.2429	0.1981	81.56	99.14	99.15
10	21.20	19.00	17.60	0.2985	0.2439	81.71	0.2955	0.2418	81.83	98.99	99.14	0.2941	0.2406	81.81	98.53	98.65
11	16.80	14.80	20.00	0.2307	0.1886	81.75	0.2274	0.1858	81.71	98.57	98.52	0.2268	0.1854	81.75	98.31	98.30
12	28.50	24.10	22.80	0.7497	0.5805	77.43	0.7472	0.5786	77.44	99.67	99.67	0.7430	0.5754	77.44	99.11	99.12
13	21.80	18.80	19.70	0.4025	0.3291	81.76	0.3999	0.3271	81.80	99.35	99.39	0.3990	0.3264	81.80	99.13	99.18
14	17.30	15.20	19.50	0.2548	0.2035	79.87	0.2523	0.2016	79.90	99.02	99.07	0.2500	0.2000	80.00	98.12	98.28
15	15.80	12.80	18.00	0.1859	0.1425	76.65	0.1829	0.1405	76.82	98.39	98.60	0.1804	0.1387	76.88	97.04	97.33
16	12.00	10.10	16.40	0.0982	0.0740	75.36	0.0935	0.0703	75.19	95.21	95.00	0.0906	0.0684	75.50	92.26	92.43
17	8.10	7.20	11.50	0.0340	0.0283	83.24	0.0294	0.0247	84.01	86.47	87.28	0.0276	0.0234	84.78	81.18	82.69
18	10.10	8.40	10.80	0.0389	0.0268	68.89	0.0324	0.0222	68.52	83.29	82.84	0.0324	0.0222	68.52	83.29	82.84
19	12.00	10.70	12.50	0.0732	0.0560	76.50	0.0694	0.0531	76.51	94.81	94.82	0.0694	0.0531	76.51	94.81	94.82
20	10.00	8.00	11.20	0.0389	0.0255	65.55	0.0320	0.0198	61.87	82.26	77.65	0.0310	0.0189	60.97	79.69	74.12
21	14.00	11.80	14.00	0.1050	0.0782	74.48	0.1028	0.0764	74.32	97.90	97.70	0.1014	0.0756	74.56	96.57	96.68
22	14.00	11.20	12.60	0.0911	0.0664	72.89	0.0872	0.0634	72.71	95.72	95.48	0.0847	0.0617	72.85	92.97	92.92
23	16.00	13.00	14.00	0.1514	0.1077	71.14	0.1489	0.1058	71.05	98.35	98.24	0.1475	0.1049	71.12	97.42	97.40
24	18.00	15.20	14.50	0.2014	0.1536	76.27	0.1987	0.1516	76.30	98.66	98.70	0.1987	0.1516	76.30	98.66	98.70
25	20.00	17.00	15.60	0.2476	0.1973	79.68	0.2448	0.1949	79.62	98.87	98.78	0.2448	0.1949	79.62	98.87	98.78
26	14.30	12.00	14.80	0.1195	0.0924	77.32	0.1161	0.0900	77.52	97.15	97.40	0.1127	0.0876	77.73	94.31	94.81
27	23.40	20.00	15.40	0.3485	0.2797	80.26	0.3466	0.2784	80.32	99.45	99.54	0.3462	0.2761	80.33	99.34	99.43
28	21.80	18.50	14.40	0.2674	0.2048	76.59	0.2646	0.2027	76.61	98.95	98.97	0.2646	0.2027	76.61	98.95	98.97
29	17.50	14.80	14.10	0.1656	0.1315	79.41	0.1632	0.1297	79.47	98.55	98.63	0.1608	0.1279	79.54	97.10	97.26
30	15.20	13.10	13.20	0.1090	0.0837	76.79	0.1047	0.0804	76.79	96.06	96.06	0.1047	0.0804	76.79	96.06	96.06
31	26.00	22.50	22.40	0.6696	0.5372	80.23	0.6666	0.5350	80.26	99.55	99.59	0.6641	0.5330	80.26	99.18	99.22
32	20.00	17.00	21.00	0.3188	0.2627	82.40	0.3155	0.2603	82.50	98.96	99.09	0.3155	0.2602	82.52	98.90	99.05
33	22.00	19.00	22.70	0.4219	0.3484	82.58	0.4182	0.3454	82.59	99.12	99.14	0.4166	0.3449	82.79	98.74	99.00
34	30.00	26.80	22.70	0.8803	0.7575	86.05	0.8780	0.7557	86.07	99.74	99.76	0.8773	0.7550	86.06	99.66	99.67
35	24.00	20.20	23.00	0.5134	0.4324	84.22	0.5096	0.4292	84.22	99.26	99.26	0.5075	0.4274	84.22	98.85	98.84

N.	D.A.P. C/C	D.A.P. S/C	ALT.	VOL. TOTAL (VA) C/C	VOL. TOTAL (VA) S/C	VOL. TOTAL (VA) %	VOL. COMERCIAL (VB) C/C	VOL. COMERCIAL (VB) S/C	VOL. COMERCIAL (VB) %	VB/VA C/C	VB/VA S/C	VOL. COMERCIAL REAL (VC) C/C	VOL. COMERCIAL REAL (VC) S/C	VOL. COMERCIAL REAL (VC) %	VC/VA C/C	VC/VA S/C
36	18.00	16.50	22.00	0.3095	0.2620	84.65	0.3064	0.2596	84.73	99.00	99.08	0.3062	0.2594	84.72	98.93	99.01
37	14.20	12.00	18.60	0.1613	0.1384	85.80	0.1359	0.1185	87.20	84.25	85.62	0.1331	0.1158	87.00	82.52	83.67
38	18.00	15.50	17.60	0.2281	0.1906	83.56	0.2254	0.1884	83.58	98.82	98.85	0.2239	0.1873	83.65	98.16	98.27
39	18.00	15.20	17.20	0.2200	0.1755	79.77	0.2172	0.1735	79.88	98.73	98.86	0.2171	0.1734	79.87	98.68	98.80
40	20.00	17.50	18.00	0.2811	0.2418	86.02	0.2786	0.2400	86.15	99.11	99.26	0.2754	0.2374	86.20	97.97	98.18
41	10.00	8.20	15.00	0.0557	0.0409	73.43	0.0497	0.0357	71.83	89.23	87.29	0.0482	0.0345	71.58	86.54	84.35
42	10.40	8.30	13.20	0.0482	0.0333	69.09	0.0410	0.0277	67.56	85.06	83.18	0.0409	0.0276	67.48	84.85	82.88
43	24.00	20.50	18.00	0.3743	0.3014	80.52	0.3721	0.2997	80.54	99.41	99.44	0.3718	0.2995	80.55	99.33	99.37
44	17.40	14.80	16.90	0.1992	0.1577	79.17	0.1964	0.1556	79.23	98.59	98.67	0.1962	0.1555	79.26	98.49	98.60
45	18.00	15.80	13.00	0.1748	0.1470	84.10	0.1725	0.1453	84.23	98.68	98.84	0.1723	0.1452	84.27	98.57	98.78
46	20.00	17.50	11.90	0.1660	0.1340	80.72	0.1639	0.1323	80.72	98.73	98.73	0.1637	0.1321	80.70	98.61	98.58
47	8.00	5.80	7.20	0.0183	0.0113	61.75	0.0137	0.0080	58.39	74.86	70.80	0.0115	0.0064	55.65	62.84	56.64
48	9.00	7.00	8.70	0.0261	0.0178	68.20	0.0218	0.0144	66.06	83.52	80.90	0.0217	0.0143	65.90	83.14	80.34
49	7.70	5.70	9.30	0.0201	0.0131	65.17	0.0136	0.0082	60.29	67.66	62.60	0.0135	0.0080	59.26	67.16	61.07
50	11.40	8.30	8.00	0.0376	0.0246	65.43	0.0346	0.0222	64.16	92.02	90.24	0.0336	0.0216	64.29	89.36	87.80
51	18.30	15.80	13.80	0.1760	0.1416	80.45	0.1733	0.1395	80.50	98.47	98.52	0.1728	0.1392	80.56	98.18	98.31
52	20.00	17.00	13.90	0.2126	0.1622	76.29	0.2098	0.1599	76.22	98.68	98.58	0.2079	0.1584	76.19	97.79	97.66
53	10.10	8.80	10.50	0.0382	0.0308	80.63	0.0328	0.0268	81.71	85.86	87.01	0.0327	0.0267	81.65	85.60	86.69
54	10.00	6.20	9.50	0.0388	0.0287	73.97	0.0340	0.0250	73.53	87.63	87.11	0.0316	0.0228	72.15	81.44	79.44
55	12.20	10.40	10.20	0.0550	0.0426	77.45	0.0512	0.0397	77.54	93.09	93.19	0.0511	0.0396	77.50	92.91	92.96
56	24.20	21.50	14.80	0.3354	0.2805	83.63	0.3336	0.2791	83.66	99.46	99.50	0.3288	0.2748	83.58	98.03	97.97
57	28.00	25.80	16.80	0.5163	0.4495	87.06	0.5147	0.4482	87.08	99.69	99.71	0.5136	0.4474	87.11	99.48	99.53
58	26.00	22.50	18.00	0.4899	0.3850	78.59	0.4884	0.3839	78.60	99.69	99.71	0.4877	0.3834	78.61	99.55	99.58
59	26.00	22.00	15.30	0.3845	0.2918	75.89	0.3824	0.2902	75.89	99.45	99.45	0.3819	0.2897	75.86	99.32	99.28
60	24.00	21.00	21.20	0.4503	0.3736	82.97	0.4476	0.3715	83.00	99.40	99.44	0.4459	0.3703	83.05	99.02	99.12
61	22.00	19.00	16.80	0.3195	0.2657	83.16	0.3171	0.2638	83.19	99.25	99.28	0.3169	0.2636	83.18	99.19	99.21
62	20.00	18.00	19.50	0.3006	0.2467	82.07	0.2985	0.2451	82.11	99.30	99.35	0.2980	0.2447	82.11	99.14	99.19
63	20.00	19.00	19.50	0.2951	0.2498	84.65	0.2929	0.2481	84.70	99.25	99.32	0.2928	0.2480	84.70	99.22	99.28
64	14.20	12.30	13.60	0.1258	0.1002	79.65	0.1240	0.0988	79.68	98.57	98.60	0.1218	0.0975	80.05	96.82	97.31
65	18.00	16.00	13.90	0.1958	0.1608	82.12	0.1944	0.1596	82.10	99.28	99.25	0.1942	0.1594	82.08	99.18	99.13
66	22.00	18.80	11.00	0.1930	0.1479	76.63	0.1902	0.1457	76.60	98.55	98.51	0.1806	0.1391	77.02	93.58	94.05
67	17.00	13.70	8.50	0.0927	0.0656	70.77	0.0911	0.0644	70.69	98.27	98.17	0.0881	0.0623	70.72	95.04	94.97
68	10.00	7.50	7.00	0.0246	0.0161	65.45	0.0207	0.0132	63.77	84.15	81.99	0.0205	0.0131	63.90	83.33	81.37
69	14.00	11.00	10.30	0.0692	0.0516	74.57	0.0660	0.0492	74.55	95.38	95.35	0.0643	0.0481	74.81	92.92	93.22
70	15.80	13.00	9.60	0.0901	0.0715	79.36	0.0886	0.0703	79.35	98.34	98.32	0.0872	0.0692	79.36	96.78	96.78

Nº	D.A.P. C/C	D.A.P. S/C	ALT.	VOL. TOTAL (VA) C/C	VOL. TOTAL (VA) S/C	VOL. TOTAL (VA) %	VOL. COMERCIAL (VB) C/C	VOL. COMERCIAL (VB) S/C	VOL. COMERCIAL (VB) %	VB/VA C/C	VB/VA S/C	VOL. COMERCIAL REAL (VC) C/C	VOL. COMERCIAL REAL (VC) S/C	VOL. COMERCIAL REAL (VC) %	VC/VA C/C	VC/VA S/C
71	12.00	10.00	8.60	0.0425	0.0282	66.35	0.0388	0.0252	64.95	91.29	89.36	0.0365	0.0239	65.48	85.88	84.75
72	10.50	8.80	12.10	0.0490	0.0368	75.10	0.0458	0,0343	74.89	93.47	93.21	0.0456	0.0342	75.00	93.06	92.93
73	11.80	9.00	12.70	0.0643	0.0424	65.94	0.0590	0.0383	64.92	91.76	90.33	0.0590	0.0383	64.92	91.76	90.33
74	20.00	18.00	14,80	0.2357	0.1929	81.84	0.2328	0.1907	81.92	98.77	98.86	0.2321	0.1901	81.90	98.47	98.55
75	18.00	16.00	12.20	0.1452	0.1216	83.75	0.1407	0.1186	84.29	96.90	97.53	0.1391	0.1166	83.82	95.80	95.89
76	24.00	20.50	14.00	0.2662	0.2156	80.99	0.2642	0.2140	81.00	99.25	99.26	0.2606	0.2111	81.01	97.90	97.91
77	22.00	19.00	16.50	0.3304	0.2706	81.90	0.3263	0.2674	81.95	98.76	98.82	0.3263	0.2674	81.95	98.76	98.82
78	14.00	11.50	10.80	0.0650	0.0500	76.92	0.0623	0.0478	76.73	95.85	95.60	0.0606	0.0459	75.74	93.23	91.80
79	20.00	17.50	13.90	0.2079	0.1671	80.38	0.2058	0.1654	80.37	98.99	98.98	0.2038	0.1639	80.42	98.03	98.08
80	12.00	10.30	11.70	0.0678	0.0551	81.27	0.0646	0.0524	81.11	95.28	95.10	0.0638	0.0518	81.19	94.10	94.01
81	16.00	12.50	11.60	0.0971	0.0680	70.03	0.0935	0.0651	69.63	96.29	95.74	0.0928	0.0645	69.50	95.57	94.85
82	16.00	13.80	12.70	0.1105	0.0872	78.91	0.1070	0.0844	78.88	96.83	96.79	0.1070	0.0844	78.88	96.83	96.79
83	18.00	15.00	10.70	0.1299	0.1003	77.21	0.1266	0.0977	77.17	97.46	97.41	0.1237	0.0954	77.12	95.23	95.11
84	14.00	11.60	12.90	0.1016	0.0827	81.40	0.0982	0.0801	81.57	96.65	96.86	0.0974	0.0795	81.62	95.87	96.13
85	18.00	15.00	11.10	0.1481	0.1120	75.62	0.1460	0.1103	75.55	98.58	98.48	0.1441	0.1088	75.50	97.30	97.14
86	30.00	27.00	17.00	0.6011	0.4937	82.13	0.5981	0.4913	82.14	99.50	99.51	0.5901	0.4849	82.17	98.17	98.22
87	24.00	21.00	18.10	0.3926	0.3173	80.82	0.3906	0.3158	80.85	99.49	99.53	0.3898	0.3151	80.84	99.29	99.31
88	16.00	13.80	15.30	0.1629	0.1220	74.89	0.1595	0.1194	74.86	97.91	97.87	0.1583	0.1183	74.73	97.18	96.97
89	20.00	17.20	17.60	0.2684	0.2192	81.67	0.2656	0.2171	81.74	98.96	99.04	0.2643	0.2161	81.76	98.47	98.59
90	12.00	10.50	16.50	0.1052	0.0800	76.05	0.1016	0.0771	75.89	96.58	96.37	0.1010	0.0765	75.74	96.01	95.63
91	16.00	13.20	17.80	0.1723	0.1350	78.35	0.1695	0.1327	78.29	98.37	98.30	0.1681	0.1316	78.29	97.56	97.48
92	18.00	14.80	19.20	0.2325	0.1812	77.94	0.2283	0.1779	77.92	98.19	98.18	0.2283	0.1779	77.92	98.19	98.18
93	22.00	18.00	19.70	0.3546	0.2809	79.22	0.3512	0.2781	79.19	99.04	99.00	0.3479	0.2755	79.19	98.11	98.08
94	28.00	24.70	20.50	0.6355	0.5308	83.52	0.6333	0.5291	83.55	99.65	99.68	0.6310	0.5272	83.55	99.29	99.32
95	30.00	25.60	20.10	0.6868	0.5590	81.39	0.6849	0.5576	81.41	99.72	99.75	0.6849	0.5576	81.41	99.72	99.75
96	26.00	23.50	21.50	0.6971	0.5919	84.91	0.6956	0.5908	84.93	99.78	99.81	0.6948	0.5902	84.95	99.67	99.71
97	16.00	14.00	9.10	0.0898	0.0708	78.84	0.0878	0.0694	79.04	97.77	98.02	0.0878	0.0694	79.04	97.77	98.02
98	22.00	19.00	15.70	0.2708	0.2189	80.83	0.2686	0.2171	80.83	99.19	99.18	0.2686	0.2171	80.83	99.19	99.18
99	14.00	11.00	9.10	0.0593	0.0407	68.63	0.0550	0.0374	68.00	92.75	91.89	0.0529	0.0360	68.05	89.21	88.45
100	22.00	18.50	14.00	0.2468	0.1906	77.23	0.2440	0.1884	77.21	98.87	98.85	0.2414	0.1862	77.13	97.81	97.69

$$y = a_0 + \sum_{i=1}^{p} a_i x_i \qquad (6)$$

where, P = 1, 2, 3

Here formula (6) is called a linear multiple regression formula. Therefore, in order to determine a volume formula to be adopted, apply each material obtained to five formulae, evaluate their adaptability, and determine the formula furnishing the least value of standard errors for each of residual. Table IV-12 indicates only the standard errors of residual, out of series of calculation results due to the multiple regression formula programme. In addition, standard error (SE) are acquired by formula (7). (In this formula, n: number of samples, k: number of independent variables, V: real volume, $\hat{V}$: estimated volume).

$$SE = \{\frac{1}{n - (k + 1)} \sum_{i=1}^{n} (V - \hat{V})^2\}^{\frac{1}{2}} \qquad (7)$$

However, standard error determined by the logarithmic formula cannot be simply compared with that by the non-logarithmic formula. For such purpose, when standard errors in (1'), (3') and (4') formula in Table IV-6 are demanded, calculate by substituting $\hat{V}$ multiplied by correction factor (c.f.), which is given in formula (8), for $\hat{V}$ in formula (7). (Where, $S_{yx_1x_2}^2$: standard error of residual)

$$c.f. = 10^{\frac{n-1}{n} Sy_1x_2^{2 \cdot 1 \cdot 151293}} \qquad (8)$$

Table IV-12 Standard erros of residual

Kind		(1')	(2)	(3')	(4')	(5)
Total volume formula	1. with bark	0.05828	0.02134	0.02107	0.01990	0.01989
	2. without bark	0.05105	0.02129	0.02109	0.02000	0.01986
Commercial volume formula	1. with bark	0.05998	0.02135	0.02345	0.02264	0.02020
	2. without bark	0.05388	0.02120	0.02566	0.02485	0.01999
Real Commercial volume formula	1. with bark	0.06011	0.02162	0.02322	0.02219	0.02028
	2. without bark	0.05417	0.02143	0.02580	0.02488	0.02008

As the result of the above calculation, the standard error of residual became minimum in formula (5) for any of volume formula. (See Table IV-12) Hence, we decided to adopt formula (5), which is called Australian formula, for our volume calculation.

Further, in order to examine the effect of independent variable in formula (5) to dependent variable, a significance test in partial regression coefficient in each volume formula was conducted by the formula as below, under a nul hypothesis (H: $a_i = 0$), where partial regression coefficient, a_i is assumed 0,

$$t = \frac{a_i}{\sqrt{S_{ii} V_e}} \geq t(n-P-1;\ \alpha)$$

(where, Sii: reverse matrix in matrix of deviation square sum and product sum, V_e: error variance)

The result was obtained as in Table IV-13, showing the second variable ($X_2 = H$) was eliminated in all formulae of volume. Therefore, the formula of volume was determined as formula (9).

$$V = a_0 + a_1 D^2 + a_2 (D^2 H) \qquad (9)$$

Next, in order to prevent the effect of abnormal material to the estimated volume, a rejecting zone, when formula (9) was applied, was calculated by formula (10). (where, t: value of t at 99% level when freedom is n-3, $S_{yx_1x_2}$: error variance, $V_{(\hat{V})}$: variance of estimated value $\hat{V}$)

$$E_{yx_1x_2} = t\{S_{yx_1x_2} - V(\hat{V})\}^{\frac{1}{2}} \qquad (10)$$

Compare $E_{yx_1x_2}$ obtained by formula (10) with variance $V-\hat{V}$ from regression, and reject i-th sample when $E_{yx_1x_2} < |V_i - \hat{V}_i|$ exists. As the result, material No. 94 was rejected in total volume formulae, and material No. 98 was rejected in formulae with bark.

In linear regression model, there is a provision that the relation among variable is linear over the whole range of materials. But in this case, since the number of samples are only 100, and the range is narrow, as 8 cm - 30 cm in diameter, and 7 m - 23 m in height, one volume formula is taken for the whole diameter grade, as follows. (Application of volume formula is omitted.)

① Total tree volume with bark formula

$\hat{V} = 0.00674609 - 0.00012281D^2 + 0.00004552D^2H$ (E=14.96)

② Total tree volume without bark formula

$\hat{V} = 0.00226291 - 0.00009136D^2 + 0.00003656D^2H$ (E=16.65)

③ Commercial volume with bark formula

$\hat{V} = 0.00113217 - 0.00010899D^2 + 0.00004506D^2H$ (E=15.46)

④ Commercial volume without bark formula

$\hat{V} = -0.00204230 - 0.00008071D^2 + 0.00003621D^2H$ (E=17.05)

⑤ Real commercial volume with bark formula

$\hat{V} = 0.00116770 - 0.00011814D^2 + 0.00004539D^2H$ (E=15.61)

⑥ Real commercial volume without bark formula

$\hat{V} = -0.00200872 - 0.00008761D^2 + 0.00003644D^2H$ (E=17.20)

(4) Tree volume table of Pinus elliottii

The tree volume table of Pinus elliottii are as shown in from Table IV-14 to Table IV-19, which are calculated by 6 kinds of volume formulae, by the purpose of use, determined by the results of analysis and examination carried out by the above. Volume tables were made, corresponding to the forest stands, for the range of diameter of 6 cm - 34 cm graded by 1 cm, and for the tree height of 5 - 25 m graded by 1 m. The volume tables were indicated in any case in values of diameter with bark, because it was impossible to measure diameter without bark. Therefore, by measuring a diameter with bark, volumes without bark are estimated.

By the way, the relation between diameter with bark (x) and diameter without bark (y) is as shown in Fig. IV-4, and the regression formula and the coefficient of correlation are as follows.

$y = -0.962 + 0.909x$ (r=0.989)

(5) Conclusion

① Consideration to the result of adjusted volume tables

The six kinds of tree volume tables were made for study of adjustment methods, but hereby some consideration was attempted on the adjusted volume tables.

First, on 98 samples left after 2 extraordinary ones were discarded out of 100 sample trees which were selected and cut in a forest stand, the relation between diameter at breast height (DAP with bark + D) and tree height (H) were as follows.

Table IV-13 Test of partial regression coefficients

Kind	Variable		Partial regression coefficient	95% confidence limit of a_i		Standard error	Standard partial regression coefficients	t-test
				Upper limit	Lower limit			
A. Total volume formula	① with bark	x_1	−0.00015592	−0.000242	−0.000069	0.0000	−0.1768836	−3.581**
		x_2	−0.00044804	−0.002418	0.001522	0.0010	−0.0099104	−0.451
		x_3	0.00004781	0.000042	0.000052	0.0000	1.1713886	19.412**
	② without bark	x_1	−0.00015530	−0.000241	−0.000069	0.0000	−0.2113804	−3.573**
		x_2	−0.00046669	−0.002433	0.001500	0.0010	−0.0123852	−0.471
		x_3	0.00004095	0.000036	0.000045	0.0000	1.2036333	16.654**
B. Commercial volume formula	③ with bark	x_1	−0.00014332	−0.000231	−0.000055	0.0000	−0.1619246	−3.241**
		x_2	−0.00048609	−0.002486	0.001514	0.0010	−0.0107079	−0.482
		x_3	0.00004744	0.000042	0.000052	0.0000	1.1576738	18.971**
	④ without bark	x_1	−0.00014617	−0.000233	−0.000059	0.0000	−0.1982326	−3.340**
		x_2	−0.00051635	−0.002496	0.001463	0.0010	−0.0136536	−0.518
		x_3	0.00004070	0.000035	0.000045	0.0000	1.1921310	16.442**
C. Real commercial volume formula	⑤ with bark	x_1	−0.00015342	−0.000241	−0.000065	0.0000	−0.1736585	−3.455**
		x_2	−0.00051834	−0.002527	0.001490	0.0010	−0.0114392	−0.512
		x_3	0.00004784	0.000042	0.000052	0.0000	1.1693535	19.047**
	⑥ without bark	x_1	−0.00015377	−0.000241	−0.000066	0.0000	−0.2088885	−3.498**
		x_2	−0.00053076	−0.002519	0.001458	0.0010	−0.0140581	−0.530
		x_3	0.00004099	0.000036	0.000045	0.0000	1.2024670	16.484**

Table IV-14 Table of total volume with bark.

*** TABELA PARA VOLUME TOTAL COM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=0.6746091D-02 - 0.7228141D-03*(D*D) + 0.4551750D-04*(D*D*H)

ALTURA (M)	CLASSES DE DIAMETRO (CM) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
5	0.011	0.012	0.013	0.015	0.017	0.019	0.022	0.024	0.027	0.030	0.034	0.037	0.041	0.045	0.049	0.053	0.057
6	0.012	0.014	0.016	0.019	0.022	0.025	0.028	0.032	0.036	0.041	0.045	0.050	0.055	0.061	0.067	0.073	0.079
7	0.014	0.016	0.019	0.023	0.026	0.030	0.035	0.040	0.045	0.051	0.057	0.063	0.070	0.077	0.085	0.093	0.102
8	0.015	0.019	0.022	0.026	0.031	0.036	0.041	0.048	0.054	0.061	0.069	0.076	0.085	0.094	0.103	0.113	0.124
9	0.017	0.021	0.025	0.030	0.035	0.041	0.048	0.055	0.063	0.071	0.080	0.090	0.100	0.110	0.121	0.133	0.146
10	0.019	0.023	0.028	0.034	0.040	0.047	0.055	0.063	0.072	0.082	0.092	0.103	0.114	0.127	0.140	0.153	0.168
11	0.020	0.025	0.031	0.037	0.045	0.052	0.061	0.071	0.081	0.092	0.103	0.116	0.129	0.143	0.158	0.173	0.190
12	0.022	0.027	0.034	0.041	0.049	0.058	0.068	0.078	0.090	0.102	0.115	0.129	0.144	0.160	0.176	0.193	0.212
13	0.024	0.030	0.037	0.045	0.054	0.063	0.074	0.086	0.099	0.112	0.127	0.142	0.159	0.176	0.194	0.214	0.234
14	0.025	0.032	0.040	0.048	0.058	0.069	0.081	0.094	0.108	0.122	0.138	0.155	0.173	0.192	0.213	0.234	0.256
15	0.027	0.034	0.043	0.052	0.063	0.074	0.087	0.101	0.116	0.133	0.150	0.169	0.188	0.209	0.231	0.254	0.278
16	0.029	0.036	0.045	0.056	0.067	0.080	0.094	0.109	0.125	0.143	0.162	0.182	0.203	0.225	0.249	0.274	0.300
17	0.030	0.039	0.048	0.059	0.072	0.086	0.100	0.117	0.134	0.153	0.173	0.195	0.218	0.242	0.267	0.294	0.322
18	0.032	0.041	0.051	0.063	0.076	0.091	0.107	0.124	0.143	0.163	0.185	0.208	0.232	0.258	0.285	0.314	0.344
19	0.033	0.043	0.054	0.067	0.081	0.097	0.114	0.132	0.152	0.174	0.197	0.221	0.247	0.275	0.304	0.334	0.366
20	0.035	0.045	0.057	0.071	0.085	0.102	0.120	0.140	0.161	0.184	0.208	0.234	0.262	0.291	0.322	0.354	0.388
21	0.037	0.048	0.060	0.074	0.090	0.108	0.127	0.148	0.170	0.194	0.220	0.247	0.277	0.307	0.340	0.374	0.410
22	0.038	0.050	0.063	0.078	0.095	0.113	0.133	0.155	0.179	0.204	0.232	0.261	0.291	0.324	0.358	0.394	0.432
23	0.040	0.052	0.066	0.082	0.099	0.119	0.140	0.163	0.188	0.215	0.243	0.274	0.306	0.340	0.376	0.414	0.454
24	0.042	0.054	0.069	0.085	0.104	0.124	0.146	0.171	0.197	0.225	0.255	0.287	0.321	0.357	0.395	0.434	0.476
25	0.043	0.056	0.072	0.089	0.108	0.130	0.153	0.178	0.206	0.235	0.267	0.300	0.336	0.373	0.413	0.454	0.498

ALTURA (M)	CLASSES DE DIAMETRO (CM) 23	24	25	26	27	28	29	30	31	32	33	34
5	0.062	0.067	0.072	0.078	0.083	0.089	0.095	0.101	0.107	0.114	0.121	0.128
6	0.086	0.093	0.101	0.108	0.116	0.125	0.133	0.142	0.151	0.161	0.170	0.180
7	0.110	0.120	0.129	0.139	0.149	0.160	0.171	0.183	0.195	0.207	0.220	0.233
8	0.134	0.146	0.158	0.170	0.183	0.196	0.210	0.224	0.239	0.254	0.270	0.286
9	0.158	0.172	0.186	0.201	0.216	0.232	0.248	0.265	0.282	0.300	0.319	0.338
10	0.183	0.198	0.214	0.231	0.249	0.267	0.286	0.306	0.326	0.347	0.369	0.391
11	0.207	0.224	0.243	0.262	0.282	0.303	0.325	0.347	0.370	0.394	0.418	0.444
12	0.231	0.251	0.271	0.293	0.315	0.339	0.363	0.388	0.414	0.440	0.468	0.496
13	0.255	0.277	0.300	0.324	0.349	0.374	0.401	0.429	0.457	0.487	0.517	0.549
14	0.279	0.303	0.328	0.355	0.382	0.410	0.439	0.470	0.501	0.534	0.567	0.601
15	0.303	0.329	0.357	0.385	0.415	0.446	0.478	0.511	0.545	0.580	0.617	0.654
16	0.327	0.355	0.385	0.416	0.448	0.481	0.516	0.552	0.589	0.627	0.666	0.707
17	0.351	0.382	0.414	0.447	0.481	0.517	0.554	0.593	0.632	0.673	0.716	0.759
18	0.375	0.408	0.442	0.478	0.514	0.553	0.593	0.634	0.676	0.720	0.765	0.812
19	0.399	0.434	0.471	0.508	0.548	0.588	0.631	0.675	0.720	0.767	0.815	0.865
20	0.423	0.460	0.499	0.539	0.581	0.624	0.669	0.716	0.764	0.813	0.864	0.917
21	0.447	0.487	0.527	0.570	0.614	0.660	0.707	0.756	0.807	0.860	0.914	0.970
22	0.472	0.513	0.556	0.601	0.647	0.696	0.746	0.797	0.851	0.906	0.964	1.022
23	0.496	0.539	0.584	0.631	0.680	0.731	0.784	0.838	0.895	0.953	1.013	1.075
24	0.520	0.565	0.613	0.662	0.714	0.767	0.822	0.879	0.939	1.000	1.063	1.128
25	0.544	0.591	0.641	0.693	0.747	0.803	0.860	0.920	0.982	1.046	1.112	1.180

Table IV-15 Table of total volume without bark

*** TABELA PARA VOLUME TOTAL SEM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=0.2262907D-02 - 0.9136363D-04*(D*D) + 0.3655926D-04*(D*D*H)

ALTURA (M)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	CLASSES DE DIAMETRO (CM)																
5	0.006	0.007	0.008	0.010	0.011	0.013	0.015	0.018	0.020	0.023	0.026	0.029	0.032	0.035	0.039	0.043	0.047
6	0.007	0.009	0.010	0.013	0.015	0.018	0.021	0.024	0.027	0.031	0.035	0.039	0.044	0.048	0.053	0.059	0.064
7	0.008	0.010	0.013	0.016	0.019	0.022	0.026	0.030	0.035	0.039	0.044	0.050	0.056	0.062	0.068	0.075	0.082
8	0.010	0.012	0.015	0.019	0.022	0.027	0.031	0.036	0.042	0.048	0.054	0.060	0.067	0.075	0.083	0.091	0.100
9	0.011	0.014	0.017	0.022	0.026	0.031	0.036	0.042	0.049	0.056	0.063	0.071	0.079	0.088	0.097	0.107	0.117
10	0.012	0.016	0.020	0.024	0.030	0.035	0.042	0.049	0.056	0.064	0.072	0.082	0.091	0.101	0.112	0.123	0.135
11	0.013	0.017	0.022	0.027	0.033	0.040	0.047	0.055	0.063	0.072	0.082	0.092	0.103	0.114	0.127	0.139	0.153
12	0.015	0.019	0.024	0.030	0.037	0.044	0.052	0.061	0.070	0.080	0.091	0.103	0.115	0.128	0.141	0.155	0.170
13	0.016	0.021	0.027	0.033	0.041	0.049	0.058	0.067	0.078	0.089	0.101	0.113	0.127	0.141	0.156	0.172	0.188
14	0.017	0.023	0.029	0.036	0.044	0.053	0.063	0.073	0.085	0.097	0.110	0.124	0.138	0.154	0.170	0.188	0.206
15	0.019	0.025	0.032	0.039	0.048	0.058	0.068	0.080	0.092	0.105	0.119	0.134	0.150	0.167	0.185	0.204	0.223
16	0.020	0.026	0.034	0.042	0.052	0.062	0.073	0.086	0.099	0.113	0.129	0.145	0.162	0.180	0.200	0.220	0.241
17	0.021	0.028	0.036	0.045	0.055	0.066	0.079	0.092	0.106	0.122	0.138	0.155	0.174	0.194	0.214	0.236	0.259
18	0.023	0.030	0.039	0.048	0.059	0.071	0.084	0.098	0.113	0.130	0.147	0.166	0.186	0.207	0.229	0.252	0.277
19	0.024	0.032	0.041	0.051	0.063	0.075	0.089	0.104	0.121	0.138	0.157	0.177	0.198	0.220	0.244	0.268	0.294
20	0.025	0.034	0.043	0.054	0.066	0.080	0.094	0.110	0.126	0.146	0.166	0.187	0.210	0.233	0.258	0.284	0.312
21	0.027	0.035	0.046	0.057	0.070	0.084	0.100	0.117	0.135	0.154	0.175	0.198	0.221	0.246	0.273	0.301	0.330
22	0.028	0.037	0.048	0.060	0.074	0.089	0.105	0.123	0.142	0.163	0.185	0.208	0.233	0.260	0.287	0.317	0.347
23	0.029	0.039	0.050	0.063	0.077	0.093	0.110	0.129	0.149	0.171	0.194	0.219	0.245	0.273	0.302	0.333	0.365
24	0.031	0.041	0.053	0.066	0.081	0.097	0.115	0.135	0.156	0.179	0.203	0.229	0.257	0.286	0.317	0.349	0.363
25	0.032	0.043	0.055	0.069	0.085	0.102	0.121	0.141	0.163	0.187	0.213	0.240	0.269	0.299	0.331	0.365	0.400

ALTURA (M)	23	24	25	26	27	28	29	30	31	32	33	34
	CLASSES DE DIAMETRO (CM)											
5	0.051	0.055	0.059	0.064	0.069	0.074	0.079	0.085	0.090	0.096	0.102	0.108
6	0.070	0.076	0.082	0.089	0.096	0.103	0.110	0.117	0.125	0.133	0.142	0.150
7	0.089	0.097	0.105	0.113	0.122	0.131	0.141	0.150	0.160	0.171	0.181	0.192
8	0.109	0.118	0.126	0.138	0.149	0.160	0.171	0.183	0.196	0.208	0.221	0.235
9	0.128	0.139	0.151	0.163	0.176	0.189	0.202	0.216	0.231	0.246	0.261	0.277
10	0.147	0.160	0.174	0.188	0.202	0.217	0.233	0.249	0.266	0.283	0.301	0.319
11	0.167	0.181	0.197	0.212	0.229	0.246	0.264	0.282	0.301	0.321	0.341	0.362
12	0.186	0.202	0.219	0.237	0.255	0.275	0.294	0.315	0.336	0.358	0.381	0.404
13	0.205	0.223	0.242	0.262	0.282	0.303	0.325	0.348	0.371	0.395	0.420	0.446
14	0.225	0.244	0.265	0.286	0.309	0.332	0.356	0.381	0.406	0.433	0.460	0.488
15	0.244	0.266	0.288	0.311	0.335	0.361	0.387	0.414	0.441	0.470	0.500	0.531
16	0.263	0.287	0.311	0.336	0.362	0.389	0.417	0.446	0.477	0.508	0.540	0.573
17	0.283	0.308	0.334	0.361	0.389	0.418	0.448	0.479	0.512	0.545	0.580	0.615
18	0.302	0.329	0.356	0.385	0.415	0.447	0.479	0.512	0.547	0.583	0.619	0.657
19	0.321	0.350	0.379	0.410	0.442	0.475	0.510	0.545	0.582	0.620	0.659	0.700
20	0.341	0.371	0.402	0.435	0.469	0.504	0.540	0.578	0.617	0.657	0.699	0.742
21	0.360	0.392	0.425	0.459	0.495	0.533	0.571	0.611	0.652	0.695	0.739	0.784
22	0.379	0.413	0.448	0.484	0.522	0.561	0.602	0.644	0.687	0.732	0.779	0.826
23	0.399	0.434	0.471	0.509	0.549	0.590	0.633	0.677	0.723	0.770	0.818	0.869
24	0.418	0.455	0.494	0.534	0.575	0.619	0.663	0.710	0.756	0.807	0.858	0.911
25	0.437	0.476	0.516	0.558	0.602	0.647	0.694	0.743	0.793	0.845	0.898	0.953

Table IV-16 Table of commercial volume with bark

*** TABELA PARA VOLUME COMERCIAL COM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=0.1132166D-02 - 0.1089870D-04*(D*D) + 0.4506449D-04*(D*D*H)

ALTURA (M)	CLASSES DE DIAMETRO (CM) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
5	0.005	0.007	0.009	0.011	0.013	0.015	0.018	0.021	0.024	0.027	0.031	0.035	0.039	0.043	0.048	0.052	0.057
6	0.007	0.009	0.011	0.014	0.017	0.021	0.024	0.028	0.033	0.037	0.042	0.048	0.053	0.059	0.066	0.072	0.079
7	0.009	0.011	0.014	0.018	0.022	0.026	0.031	0.036	0.042	0.048	0.054	0.061	0.068	0.076	0.084	0.092	0.101
8	0.010	0.013	0.017	0.022	0.026	0.032	0.037	0.044	0.050	0.058	0.066	0.074	0.083	0.092	0.102	0.112	0.123
9	0.012	0.016	0.020	0.025	0.031	0.037	0.044	0.051	0.059	0.068	0.077	0.087	0.097	0.108	0.120	0.132	0.145
10	0.013	0.018	0.023	0.029	0.035	0.042	0.050	0.059	0.068	0.078	0.089	0.100	0.112	0.124	0.138	0.152	0.166
11	0.015	0.020	0.026	0.032	0.040	0.048	0.057	0.066	0.077	0.088	0.100	0.113	0.126	0.141	0.156	0.172	0.188
12	0.017	0.022	0.029	0.036	0.044	0.053	0.063	0.074	0.086	0.098	0.112	0.126	0.141	0.157	0.174	0.192	0.210
13	0.018	0.024	0.032	0.040	0.049	0.059	0.070	0.082	0.095	0.108	0.123	0.139	0.156	0.173	0.192	0.211	0.232
14	0.020	0.027	0.035	0.043	0.053	0.064	0.076	0.089	0.103	0.119	0.135	0.152	0.170	0.190	0.210	0.231	0.254
15	0.022	0.029	0.037	0.047	0.058	0.070	0.083	0.097	0.112	0.129	0.146	0.165	0.185	0.206	0.228	0.251	0.276
16	0.023	0.031	0.040	0.051	0.062	0.075	0.089	0.105	0.121	0.139	0.158	0.178	0.199	0.222	0.246	0.271	0.297
17	0.025	0.033	0.043	0.054	0.067	0.081	0.096	0.112	0.130	0.149	0.169	0.191	0.214	0.238	0.264	0.291	0.319
18	0.026	0.036	0.046	0.058	0.071	0.086	0.102	0.120	0.139	0.159	0.181	0.204	0.229	0.255	0.282	0.311	0.341
19	0.028	0.038	0.049	0.062	0.076	0.092	0.109	0.127	0.146	0.169	0.192	0.217	0.243	0.271	0.300	0.331	0.363
20	0.030	0.040	0.052	0.065	0.080	0.097	0.115	0.135	0.156	0.179	0.204	0.230	0.258	0.287	0.318	0.351	0.385
21	0.031	0.042	0.055	0.069	0.085	0.102	0.122	0.143	0.165	0.190	0.215	0.243	0.272	0.303	0.336	0.370	0.406
22	0.033	0.044	0.056	0.073	0.089	0.108	0.128	0.150	0.174	0.200	0.227	0.256	0.287	0.320	0.354	0.390	0.428
23	0.035	0.047	0.060	0.076	0.094	0.113	0.135	0.158	0.183	0.210	0.239	0.269	0.302	0.336	0.372	0.410	0.450
24	0.036	0.049	0.063	0.080	0.098	0.119	0.141	0.165	0.192	0.220	0.250	0.282	0.316	0.352	0.390	0.430	0.472
25	0.038	0.051	0.066	0.084	0.103	0.124	0.148	0.173	0.201	0.230	0.262	0.295	0.331	0.368	0.408	0.450	0.494

ALTURA (M)	CLASSES DE DIAMETRO (CM) 23	24	25	26	27	28	29	30	31	32	33	34
5	0.063	0.068	0.074	0.080	0.086	0.092	0.099	0.106	0.113	0.120	0.128	0.136
6	0.087	0.094	0.102	0.110	0.119	0.128	0.137	0.146	0.156	0.166	0.177	0.188
7	0.110	0.120	0.130	0.141	0.152	0.163	0.175	0.187	0.200	0.213	0.226	0.240
8	0.134	0.146	0.158	0.171	0.184	0.198	0.213	0.228	0.243	0.259	0.275	0.292
9	0.158	0.172	0.187	0.202	0.217	0.234	0.251	0.268	0.286	0.305	0.324	0.344
10	0.182	0.198	0.215	0.232	0.250	0.269	0.288	0.309	0.329	0.351	0.373	0.396
11	0.206	0.224	0.243	0.263	0.283	0.304	0.326	0.349	0.373	0.397	0.422	0.448
12	0.230	0.250	0.271	0.293	0.316	0.340	0.364	0.390	0.416	0.443	0.471	0.500
13	0.253	0.276	0.299	0.323	0.349	0.375	0.402	0.430	0.459	0.489	0.520	0.552
14	0.277	0.302	0.327	0.354	0.382	0.410	0.440	0.471	0.503	0.536	0.569	0.604
15	0.301	0.328	0.355	0.384	0.414	0.446	0.478	0.511	0.546	0.582	0.619	0.657
16	0.325	0.354	0.384	0.415	0.447	0.481	0.516	0.552	0.589	0.628	0.666	0.709
17	0.349	0.380	0.412	0.445	0.480	0.516	0.554	0.593	0.633	0.674	0.717	0.761
18	0.373	0.406	0.440	0.476	0.513	0.552	0.592	0.633	0.676	0.720	0.766	0.813
19	0.396	0.432	0.468	0.506	0.546	0.587	0.630	0.674	0.719	0.766	0.815	0.865
20	0.420	0.457	0.496	0.537	0.579	0.622	0.667	0.714	0.763	0.812	0.864	0.917
21	0.444	0.483	0.524	0.567	0.612	0.658	0.705	0.755	0.806	0.859	0.913	0.969
22	0.468	0.509	0.553	0.598	0.644	0.693	0.743	0.795	0.849	0.905	0.962	1.021
23	0.492	0.535	0.581	0.628	0.677	0.728	0.781	0.836	0.892	0.951	1.011	1.073
24	0.516	0.561	0.609	0.659	0.710	0.764	0.819	0.876	0.936	0.997	1.060	1.125
25	0.539	0.587	0.637	0.689	0.743	0.799	0.857	0.917	0.979	1.043	1.109	1.178

Table IV-17 Table commercial volume without bark

*** TABELA PARA VOLUME COMERCIAL SEM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=-0.2042303D-02 - 0.8070821D-04*(D*D) + 0.3620599D-04*(D*D*H)

ALTURA (M)	CLASSES DE DIAMETRO (CM) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
5	0.002	0.003	0.004	0.006	0.008	0.010	0.012	0.015	0.018	0.021	0.024	0.027	0.030	0.034	0.038	0.042	0.047
6	0.003	0.005	0.007	0.009	0.012	0.014	0.018	0.021	0.025	0.029	0.033	0.037	0.042	0.047	0.053	0.058	0.064
7	0.004	0.006	0.009	0.012	0.015	0.019	0.023	0.027	0.032	0.037	0.042	0.048	0.054	0.060	0.067	0.074	0.082
8	0.005	0.008	0.011	0.015	0.019	0.023	0.028	0.033	0.039	0.045	0.051	0.058	0.066	0.073	0.082	0.090	0.099
9	0.007	0.010	0.014	0.018	0.022	0.028	0.033	0.039	0.046	0.053	0.061	0.069	0.077	0.086	0.096	0.106	0.117
10	0.008	0.012	0.016	0.021	0.026	0.032	0.038	0.046	0.053	0.061	0.070	0.079	0.089	0.100	0.110	0.122	0.134
11	0.009	0.014	0.018	0.024	0.030	0.036	0.044	0.052	0.060	0.069	0.079	0.090	0.101	0.113	0.125	0.138	0.152
12	0.011	0.015	0.021	0.027	0.033	0.041	0.049	0.058	0.067	0.078	0.089	0.100	0.113	0.126	0.139	0.154	0.169
13	0.012	0.017	0.023	0.030	0.037	0.045	0.054	0.064	0.074	0.086	0.098	0.111	0.124	0.139	0.154	0.170	0.187
14	0.013	0.019	0.025	0.032	0.041	0.050	0.059	0.070	0.081	0.094	0.107	0.121	0.136	0.152	0.168	0.186	0.204
15	0.015	0.021	0.028	0.035	0.044	0.054	0.065	0.076	0.089	0.102	0.116	0.132	0.148	0.165	0.183	0.202	0.222
16	0.016	0.022	0.030	0.038	0.048	0.058	0.070	0.082	0.096	0.110	0.126	0.142	0.160	0.178	0.197	0.218	0.239
17	0.017	0.024	0.032	0.041	0.051	0.063	0.075	0.088	0.103	0.118	0.135	0.153	0.171	0.191	0.212	0.234	0.257
18	0.019	0.026	0.035	0.044	0.055	0.067	0.080	0.094	0.110	0.126	0.144	0.163	0.183	0.204	0.226	0.250	0.274
19	0.020	0.028	0.037	0.047	0.059	0.071	0.085	0.101	0.117	0.135	0.153	0.173	0.195	0.217	0.241	0.266	0.292
20	0.021	0.029	0.039	0.050	0.062	0.076	0.091	0.107	0.124	0.143	0.163	0.184	0.206	0.230	0.255	0.282	0.309
21	0.022	0.031	0.041	0.053	0.066	0.080	0.096	0.113	0.131	0.151	0.172	0.194	0.218	0.243	0.270	0.298	0.327
22	0.024	0.033	0.044	0.056	0.070	0.085	0.101	0.119	0.138	0.159	0.181	0.205	0.230	0.256	0.284	0.314	0.344
23	0.025	0.035	0.046	0.059	0.073	0.089	0.106	0.125	0.145	0.167	0.190	0.215	0.242	0.269	0.299	0.330	0.362
24	0.026	0.037	0.048	0.062	0.077	0.093	0.111	0.131	0.152	0.175	0.200	0.226	0.253	0.283	0.313	0.346	0.379
25	0.028	0.038	0.051	0.065	0.080	0.098	0.117	0.137	0.160	0.183	0.209	0.236	0.265	0.296	0.328	0.362	0.397

ALTURA (M)	CLASSES DE DIAMETRO (CM) 23	24	25	26	27	28	29	30	31	32	33	34
5	0.051	0.056	0.061	0.066	0.071	0.077	0.082	0.088	0.094	0.101	0.107	0.114
6	0.070	0.077	0.083	0.090	0.097	0.105	0.113	0.121	0.129	0.138	0.147	0.156
7	0.089	0.097	0.106	0.115	0.124	0.133	0.143	0.153	0.164	0.175	0.186	0.198
8	0.108	0.118	0.129	0.139	0.150	0.162	0.174	0.186	0.199	0.212	0.225	0.239
9	0.128	0.139	0.151	0.164	0.177	0.190	0.204	0.219	0.234	0.249	0.265	0.281
10	0.147	0.160	0.174	0.188	0.203	0.219	0.235	0.251	0.268	0.286	0.304	0.323
11	0.166	0.181	0.196	0.213	0.229	0.247	0.265	0.284	0.303	0.323	0.344	0.365
12	0.185	0.202	0.219	0.237	0.256	0.275	0.295	0.316	0.336	0.360	0.383	0.407
13	0.204	0.223	0.242	0.262	0.282	0.304	0.326	0.349	0.373	0.397	0.423	0.449
14	0.223	0.243	0.264	0.286	0.309	0.332	0.356	0.382	0.408	0.434	0.462	0.491
15	0.243	0.264	0.287	0.311	0.335	0.360	0.387	0.414	0.442	0.471	0.501	0.532
16	0.262	0.285	0.310	0.335	0.361	0.389	0.417	0.447	0.477	0.509	0.541	0.574
17	0.281	0.306	0.332	0.359	0.388	0.417	0.448	0.479	0.512	0.546	0.580	0.616
18	0.300	0.327	0.355	0.384	0.414	0.446	0.478	0.512	0.547	0.583	0.620	0.658
19	0.319	0.348	0.377	0.408	0.441	0.474	0.509	0.544	0.581	0.620	0.659	0.700
20	0.338	0.369	0.400	0.433	0.467	0.502	0.539	0.577	0.616	0.657	0.699	0.742
21	0.357	0.389	0.423	0.457	0.493	0.531	0.570	0.610	0.651	0.694	0.738	0.784
22	0.377	0.410	0.445	0.482	0.520	0.559	0.600	0.642	0.686	0.731	0.777	0.825
23	0.396	0.431	0.468	0.506	0.546	0.588	0.630	0.675	0.721	0.768	0.817	0.867
24	0.415	0.452	0.491	0.531	0.573	0.616	0.661	0.707	0.755	0.805	0.856	0.909
25	0.434	0.473	0.513	0.555	0.599	0.644	0.691	0.740	0.790	0.842	0.896	0.951

Table IV-18 Table of real commercial volume with bark

*** TABELA PARA VOLUME COMERCIAL REAL COM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=U.1167702D-02 - 0.1187430D-03*(D*D) + 0.4538718D-04*(D*D*H)

ALTURA (M)	CLASSES DE DIAMETRO (CM) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
5	0.005	0.006	0.008	0.010	0.012	0.014	0.017	0.020	0.022	0.026	0.029	0.033	0.036	0.040	0.045	0.049	0.054
6	0.007	0.009	0.011	0.014	0.017	0.020	0.023	0.027	0.031	0.036	0.041	0.046	0.051	0.057	0.063	0.069	0.076
7	0.008	0.011	0.014	0.017	0.021	0.025	0.030	0.035	0.040	0.046	0.052	0.059	0.066	0.073	0.081	0.089	0.098
8	0.010	0.013	0.017	0.021	0.026	0.031	0.036	0.043	0.049	0.056	0.064	0.072	0.081	0.090	0.099	0.109	0.120
9	0.012	0.015	0.020	0.025	0.030	0.036	0.043	0.050	0.058	0.066	0.075	0.085	0.095	0.106	0.117	0.129	0.142
10	0.013	0.018	0.023	0.028	0.035	0.042	0.050	0.058	0.067	0.077	0.087	0.098	0.110	0.122	0.135	0.149	0.164
11	0.015	0.020	0.026	0.032	0.039	0.047	0.056	0.066	0.076	0.087	0.099	0.111	0.125	0.139	0.154	0.169	0.186
12	0.017	0.022	0.028	0.036	0.044	0.053	0.063	0.073	0.085	0.097	0.110	0.124	0.139	0.155	0.172	0.189	0.208
13	0.018	0.024	0.031	0.039	0.048	0.058	0.069	0.081	0.094	0.107	0.122	0.138	0.154	0.172	0.190	0.209	0.230
14	0.020	0.027	0.034	0.043	0.053	0.064	0.076	0.069	0.103	0.118	0.134	0.131	0.169	0.188	0.208	0.229	0.252
15	0.021	0.029	0.037	0.047	0.057	0.069	0.082	0.096	0.111	0.128	0.145	0.164	0.183	0.204	0.226	0.249	0.273
16	0.023	0.031	0.040	0.050	0.062	0.075	0.089	0.104	0.120	0.138	0.157	0.177	0.198	0.221	0.244	0.269	0.295
17	0.025	0.033	0.043	0.054	0.067	0.080	0.095	0.112	0.129	0.148	0.168	0.190	0.213	0.237	0.263	0.289	0.317
18	0.026	0.035	0.046	0.058	0.071	0.086	0.102	0.119	0.138	0.158	0.180	0.203	0.228	0.253	0.281	0.309	0.339
19	0.028	0.038	0.049	0.061	0.076	0.091	0.108	0.127	0.147	0.169	0.192	0.216	0.242	0.270	0.299	0.329	0.361
20	0.030	0.040	0.052	0.065	0.080	0.097	0.115	0.135	0.156	0.179	0.203	0.229	0.257	0.286	0.317	0.349	0.383
21	0.031	0.042	0.055	0.069	0.085	0.102	0.121	0.142	0.165	0.189	0.215	0.242	0.272	0.303	0.335	0.369	0.405
22	0.033	0.044	0.058	0.072	0.089	0.108	0.128	0.150	0.174	0.199	0.227	0.256	0.286	0.319	0.353	0.389	0.427
23	0.034	0.047	0.060	0.076	0.094	0.113	0.134	0.158	0.183	0.209	0.238	0.269	0.301	0.335	0.371	0.409	0.449
24	0.036	0.049	0.063	0.080	0.098	0.119	0.141	0.165	0.192	0.220	0.250	0.282	0.316	0.352	0.390	0.429	0.471
25	0.038	0.051	0.066	0.084	0.103	0.124	0.148	0.173	0.200	0.230	0.261	0.295	0.331	0.368	0.408	0.449	0.493

ALTURA (M)	CLASSES DE DIAMETRO (CM) 23	24	25	26	27	28	29	30	31	32	33	34
5	0.059	0.064	0.069	0.075	0.080	0.086	0.093	0.099	0.106	0.113	0.120	0.127
6	0.083	0.090	0.098	0.105	0.114	0.122	0.131	0.140	0.149	0.159	0.169	0.179
7	0.107	0.116	0.126	0.136	0.147	0.158	0.169	0.181	0.193	0.206	0.218	0.232
8	0.131	0.142	0.154	0.167	0.180	0.193	0.207	0.222	0.237	0.252	0.268	0.284
9	0.155	0.168	0.183	0.197	0.213	0.229	0.245	0.262	0.280	0.298	0.317	0.337
10	0.179	0.195	0.211	0.228	0.246	0.264	0.284	0.303	0.324	0.345	0.367	0.389
11	0.203	0.221	0.239	0.259	0.279	0.300	0.322	0.344	0.367	0.391	0.416	0.442
12	0.227	0.247	0.268	0.289	0.312	0.336	0.360	0.385	0.411	0.438	0.466	0.494
13	0.251	0.273	0.296	0.320	0.345	0.371	0.398	0.426	0.455	0.484	0.515	0.547
14	0.275	0.299	0.324	0.351	0.378	0.407	0.436	0.467	0.498	0.531	0.564	0.599
15	0.299	0.325	0.353	0.382	0.411	0.442	0.474	0.508	0.542	0.577	0.614	0.652
16	0.323	0.351	0.381	0.412	0.444	0.478	0.513	0.548	0.586	0.624	0.663	0.704
17	0.347	0.378	0.410	0.443	0.478	0.513	0.551	0.589	0.629	0.670	0.713	0.757
18	0.371	0.404	0.438	0.474	0.511	0.549	0.589	0.630	0.673	0.717	0.762	0.809
19	0.395	0.430	0.466	0.504	0.544	0.585	0.627	0.671	0.716	0.763	0.812	0.861
20	0.419	0.456	0.495	0.535	0.577	0.620	0.665	0.712	0.760	0.810	0.861	0.914
21	0.443	0.482	0.523	0.566	0.610	0.656	0.703	0.753	0.804	0.856	0.910	0.966
22	0.467	0.508	0.551	0.596	0.643	0.691	0.742	0.794	0.847	0.903	0.960	1.019
23	0.491	0.534	0.580	0.627	0.676	0.727	0.780	0.834	0.891	0.949	1.009	1.071
24	0.515	0.561	0.608	0.658	0.709	0.763	0.818	0.875	0.934	0.996	1.059	1.124
25	0.539	0.567	0.617	0.668	0.742	0.798	0.856	0.916	0.977	1.042	1.108	1.176

Table IV-19 Table of real commercial volume without bark

*** TABELA PARA VOLUME COMERCIAL REAL SEM CASCA ***

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=-0.2008719D-02 - 0.8760883D-04*(D*D) + 0.3644112D-04*(D*D*H)

ALTURA (M)	CLASSES DE DIAMETRO (CM) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
5	0.001	0.003	0.004	0.006	0.007	0.009	0.012	0.014	0.017	0.019	0.022	0.025	0.029	0.032	0.036	0.040	0.044
6	0.003	0.004	0.006	0.009	0.011	0.014	0.017	0.020	0.024	0.027	0.032	0.036	0.040	0.045	0.050	0.056	0.061
7	0.004	0.006	0.009	0.012	0.015	0.018	0.022	0.026	0.031	0.036	0.041	0.046	0.052	0.058	0.065	0.072	0.079
8	0.005	0.008	0.011	0.015	0.018	0.023	0.027	0.032	0.036	0.044	0.050	0.057	0.064	0.072	0.080	0.088	0.097
9	0.007	0.010	0.013	0.017	0.022	0.027	0.033	0.039	0.045	0.052	0.060	0.067	0.076	0.085	0.094	0.104	0.114
10	0.008	0.012	0.016	0.020	0.026	0.031	0.038	0.045	0.052	0.060	0.069	0.078	0.088	0.098	0.109	0.120	0.132
11	0.009	0.013	0.018	0.023	0.029	0.036	0.043	0.051	0.059	0.068	0.078	0.089	0.099	0.111	0.123	0.136	0.150
12	0.011	0.015	0.020	0.026	0.033	0.040	0.048	0.057	0.067	0.077	0.088	0.099	0.111	0.124	0.138	0.152	0.167
13	0.012	0.017	0.023	0.029	0.037	0.045	0.054	0.063	0.074	0.085	0.097	0.110	0.123	0.137	0.152	0.168	0.185
14	0.013	0.019	0.025	0.032	0.040	0.049	0.059	0.069	0.081	0.093	0.106	0.120	0.135	0.151	0.167	0.184	0.203
15	0.015	0.020	0.027	0.035	0.044	0.054	0.064	0.076	0.088	0.101	0.115	0.131	0.147	0.164	0.182	0.200	0.220
16	0.016	0.022	0.030	0.038	0.048	0.058	0.069	0.082	0.095	0.109	0.125	0.141	0.159	0.177	0.196	0.216	0.238
17	0.017	0.024	0.032	0.041	0.051	0.062	0.075	0.088	0.102	0.118	0.134	0.152	0.170	0.190	0.211	0.233	0.255
18	0.018	0.026	0.034	0.044	0.055	0.067	0.080	0.094	0.109	0.126	0.143	0.162	0.182	0.203	0.225	0.249	0.273
19	0.020	0.028	0.037	0.047	0.058	0.071	0.085	0.100	0.117	0.134	0.153	0.173	0.194	0.216	0.240	0.265	0.291
20	0.021	0.029	0.039	0.050	0.062	0.076	0.090	0.106	0.124	0.142	0.162	0.183	0.206	0.229	0.254	0.281	0.308
21	0.022	0.031	0.041	0.053	0.066	0.080	0.096	0.113	0.131	0.150	0.171	0.194	0.218	0.243	0.269	0.297	0.326
22	0.024	0.033	0.044	0.056	0.069	0.084	0.101	0.119	0.138	0.159	0.181	0.204	0.229	0.256	0.284	0.313	0.344
23	0.025	0.035	0.046	0.059	0.073	0.089	0.106	0.125	0.145	0.167	0.190	0.215	0.241	0.269	0.298	0.329	0.361
24	0.026	0.037	0.048	0.062	0.077	0.093	0.111	0.131	0.152	0.175	0.199	0.225	0.253	0.282	0.313	0.345	0.379
25	0.028	0.038	0.051	0.065	0.080	0.098	0.117	0.137	0.159	0.183	0.209	0.236	0.265	0.295	0.327	0.361	0.397

ALTURA (M)	CLASSES DE DIAMETRO (CM) 23	24	25	26	27	28	29	30	31	32	33	34
5	0.048	0.052	0.057	0.062	0.067	0.072	0.078	0.083	0.089	0.095	0.101	0.107
6	0.067	0.073	0.080	0.087	0.094	0.101	0.108	0.116	0.124	0.132	0.141	0.149
7	0.087	0.094	0.103	0.111	0.120	0.129	0.139	0.149	0.159	0.169	0.180	0.192
8	0.106	0.115	0.125	0.136	0.147	0.158	0.169	0.182	0.194	0.207	0.220	0.234
9	0.125	0.136	0.148	0.160	0.173	0.186	0.200	0.214	0.229	0.244	0.260	0.276
10	0.144	0.157	0.171	0.185	0.200	0.215	0.231	0.247	0.264	0.281	0.299	0.318
11	0.164	0.178	0.194	0.210	0.226	0.244	0.261	0.280	0.299	0.319	0.339	0.360
12	0.183	0.199	0.217	0.234	0.253	0.272	0.292	0.313	0.334	0.356	0.379	0.402
13	0.202	0.220	0.239	0.259	0.279	0.301	0.323	0.346	0.369	0.393	0.418	0.444
14	0.222	0.241	0.262	0.284	0.306	0.329	0.353	0.378	0.404	0.431	0.458	0.486
15	0.241	0.262	0.285	0.308	0.333	0.358	0.384	0.411	0.439	0.468	0.498	0.529
16	0.260	0.283	0.308	0.333	0.359	0.386	0.415	0.444	0.474	0.505	0.538	0.571
17	0.279	0.304	0.330	0.358	0.386	0.415	0.445	0.477	0.509	0.543	0.577	0.613
18	0.299	0.325	0.353	0.382	0.412	0.444	0.476	0.509	0.544	0.580	0.617	0.655
19	0.318	0.346	0.376	0.407	0.439	0.472	0.507	0.542	0.579	0.617	0.657	0.697
20	0.337	0.367	0.399	0.431	0.465	0.501	0.537	0.575	0.614	0.655	0.696	0.739
21	0.356	0.388	0.422	0.456	0.492	0.529	0.568	0.608	0.649	0.692	0.736	0.781
22	0.376	0.409	0.444	0.481	0.519	0.558	0.599	0.641	0.684	0.729	0.776	0.823
23	0.395	0.430	0.467	0.505	0.545	0.586	0.629	0.673	0.719	0.767	0.815	0.866
24	0.414	0.451	0.490	0.530	0.572	0.615	0.660	0.706	0.754	0.804	0.855	0.908
25	0.434	0.472	0.513	0.555	0.598	0.644	0.690	0.739	0.789	0.841	0.895	0.950

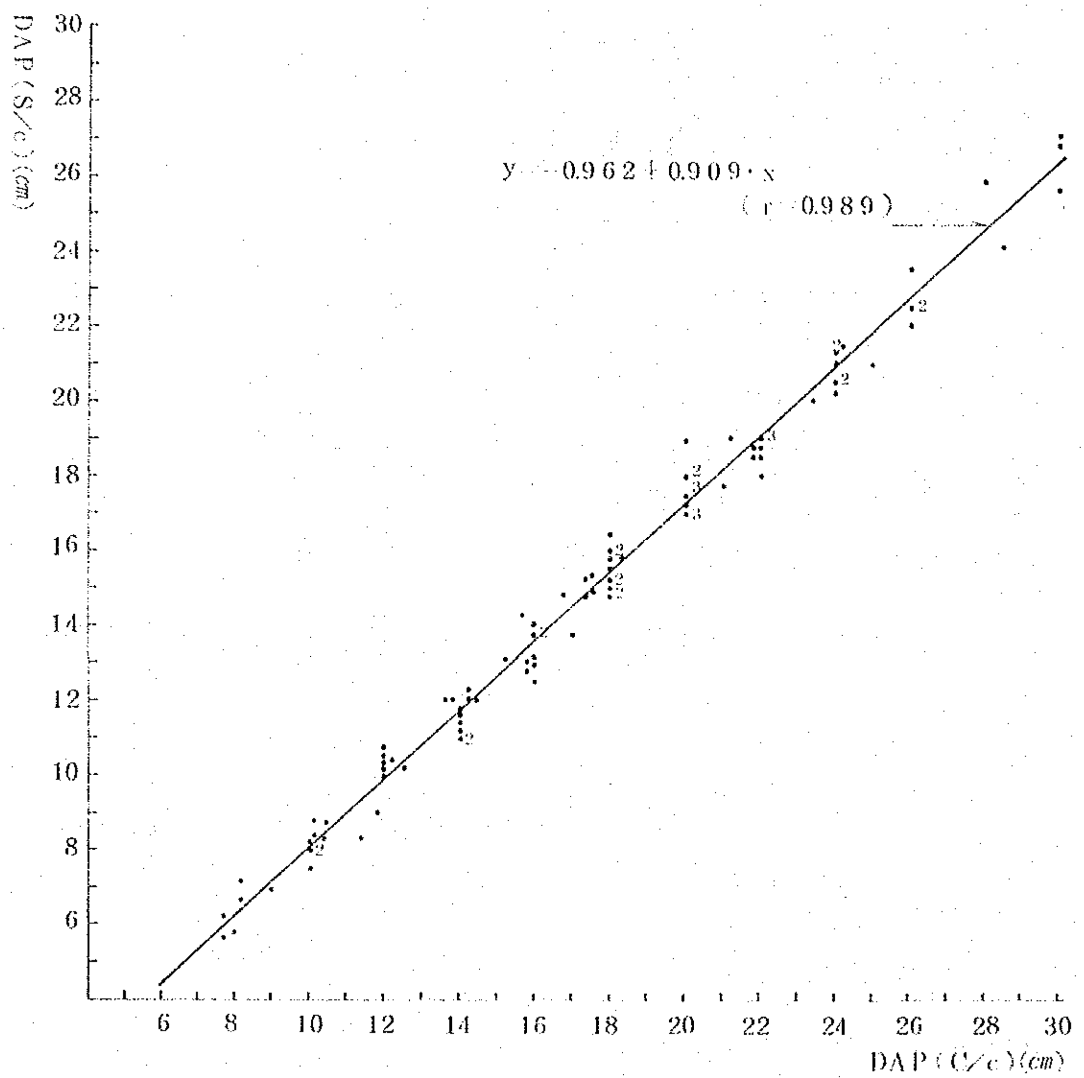


Fig. IV-4 Relation between with bark diameter at breat height (DAP,C/c) and without bark diameter at breat height (DAP, S/c)

$$H = 3.759 + 0.790D - 0.008D^2 \qquad (r = 0.694)$$

When these data are shown on a graph, the distribution indicates scattering to some extent, so the coefficient of correlation cannot be regarded high. But this is the result of that sample trees were intentionally collected so that tree height might distribute in a certain range by each diameter grade. The scattering of this extent is often seen in any forest stand. Viewed from another angle, it means that such scattering as this extent always exists due to the different places or different land positions even in the same state forest of Águas de Santa Bãrbara.

Next, the relation between bark and volume without bark are as in Table IV-20.

Table IV-20 List of parameters and correlation coefficients in the regression formula of diameter to volume

Kind of volume		Parameter a_0	a_1	a_2	Correlation coefficient
With bark	a. Total volume	0.08603	-0.01649	0.00127	0.895
	b. Commercial volume	0.07084	-0.01591	0.00126	0.897
	c. Real commercial volume	0.06875	-0.01567	0.00125	0.895
Without bark	d. Total volume	0.03923	-0.01118	0.00122	0.890
	e. Commercial volume	0.03400	-0.01106	0.00123	0.892
	f. Real commercial volume	0.03480	-0.01117	0.00123	0.890

From Table IV-20, in case of with bark, the regression formula is formed with nearly similar tendency in a, b, and c. The volume was as a b c , so the values of parameter became a little smaller in order of a, b, and c. In three of d, e, and f, the values of parameter became smaller than those with bark. But the order is not definite as the former three. The coefficients of correlation are generally in a range between 0.890 and 0.897.

The relation between total volume with bark and other volumes, between commercial volume with bark and those without bark, and between real volume with bark and that without bark are shown in Table IV-21.

Table IV-21 List of parameters and correlation coefficients in regression formulae based on the corresponding volume

Concerned formula	Parameter		Correlation coefficient
	a_0	a_1	
i Total volume with bark to total volume without bark	-0.006	0.832	0.998
ii Total volume with bark to commercial volume with bark	-0.004	1.004	0.999
iii Total volume with bark to commercial volume without bark	-0.006	0.829	0.999
iv Total volume with bark to real commercial volume with bark	-0.005	1.002	0.999
v Total volume with bark to real commercial volume without bark	-0.010	0.834	0.997
vi Commercial volume with bark to commercial volume without bark	0.006	0.832	0.998
vii Real commercial volume with bark to real commercial volume without bark	0.004	0.829	0.998

From Table IV-21, in all formulae the coefficients of correlation are as high as in a range of 0.997 - 0.999, showing good correspondence. Regarding individual formula, ii and iv show hardly any difference on a graph. On the contrary, in i, iii, and v, volume values are much smaller than the total volume with bark. The cases of vi and vii show the same tendency. So it is inferable that the main cause for the difference exists in bark. It is guessed that this is probably the reason why St. Paulo state measures the volume with bark always together with the the volume without bark. By the way, the result of stem analysis carried on Pinus elliottii of 21 years age (DAP = 22.0 cm, H = 22.1 m, Tathão No. 15) in the same state forest of Águas de Santa Bãrbara, indicated total volume without bark 0.3331 m^3 against total volume with bark 0.4109 m^3 , showing bark ratio of 18.93%.

Here, consideration is mainly limited to the relating formulae corresponding to breast height diameter and various volumes, on basis of 6 different volume formulase. However, the problem is whether the prepared volume value would be adaptable to the actual measurement or not. In this respect, we must wait for the field study result.

② Reference literature and correlating materials

(a) Reference literature

① Forestry Experiment Station, Management division: Explanatory book for the preparation of tree volume table 1956.

② Masamichi Chyo, Toshiaki Shiibavashi, N. Naga, and H. Aoki: Examination on volume formula of Pinus elliottii in Águas de Santa Bărbara state forest in St. Paulo state. Trans. 95th Mtg. Jap. For. Soc., 1984

(b) Correlating materials

Various materials, calculating method based to thereof, application of volume formulae, graphs for various considerations, etc. are minutely described in ①. Among these, measurement of sample trees, calculating method of volume, etc. are based on material ② Also materials regarding volume are ③ and ④. These show the examination on the adaptability of the volume tables with actual example, taking state forest of Águas de Santa Bărbara and Compos de Jordao as subjects.

① Masamichi Chyo, Toshiaki Shiibavashi, N. Haga, and H. Aoki: Study on the adjustment of tree volume table of Pinus elliottii in state forest of Águas de Santa Bărbara. This has been reported as the study results and the manual of preparing a volume table. to International Cooperation Agency as well as the forest board of state of St. Paulo. The printing has not been decided. 1985.

② Masamichi Chyo, N. Haga, and H. Aoki: Stem analysis - Mannual by stem analysis of Pinus Elliottii. International Cooperation Agency JR 84-40 (Experts' Report of International Cooperation on Study of Forestry in St. Paulo, Brazil) p395-444, 1984.

③ Masamichi Chyo, Toshiaki Shiibayashi, N. Haga, and H. Aoki: Examination of the conformity between actual measurement of Volume table, for Pinus elliottii in state forest of Águas de Santa Bãrbara, ditto, p291-310, 1984

④ Masamichi Chyo, Masaru Kobayashi, Hiroshi Suzuki, L.Z. Bucci, and J.M. Motta: Examination of the conformity between actual measurement of volume and volume table used, for Pinus elliottii and Pinus patula in state forest of Campos do Jordão, ditto, p311-335, 1984.

IV-3 Forest Analysis by Air Photograph

IV-3-1 Interpretation of Forest by Air-Photograph

(1) Purpose

As a part of proper managing technique of water-reservoir forest, this is intending to practise the interpretation technique of air photograph on forests, in order to establish the way of availing forest in the economics, and also aims to place foundation to educate technical personnel to attain systematization and organization in order to use such technique in various fields in future.

(2) Process and accomplishment

① Institution of a study and training course

In order to achieve the above purposes, a study and training course was instituted, thereby attempting to instruct from the basic principle of air-photograph to the using technique for forest-survey, and at the same time train the technique by the practice of interpretation.

Table IV-22 List of trainees

Name	Qualification	Occupation	Training in Japan
Hideyo Aoki	Master	Researcher	Aug. 20,'81-Oct. 19,'81
Leãndro José Bellix Faurin	Bachelor of agriculture	Agricultural engineer	
Ivan Suarez da Mota	Bachelor of forestry	Forestal engineer	
Iliana Rajo Saraiva	Bachelor of agriculture	Agricultural engineer	
Sandra Regina Gomes	Student	Estagiario*	

* temporary personnel

② Content of study and training

(a) Preparation of mannual

Since distinct difference was perceived in individual's ability, because there were unexperienced people in air-photograph, or some people who handled photographs without any precise theory, it was necessary to unify the knowledge level of trainees. So, in order to ascertain the basic principles of air-photograph, the existing textbooks of photogrammetry in Portuguese were used, whereby each trainee was to take share of reading aloud.

By doing this, a mannual for the practice in Portuguese was prepared.

(b) Making of index map

The ability to use the interpretation technique of air-photograph is significantly affected by the accuracy corresponding to a topographical map. Therefore, to know trainees' interpreting ability on topographical map, the practice training was carried out to make index maps on the topographical maps scaled 1/50,000, corresponding to 69 pieces of air-photograph of a scale of 1/8,000 with photo-elements in Table IV-23.

Table IV-23 Photographing conditions

Date of photographing	Course No.	Focal distance	Photo No.	Number of photos
June 2, 1977	Fx. 11	151.44 (mm)	179 - 181	3
June 28, 1977	Fx. 12	"	204 - 217	13
July 9, 1977	Fx. 13	152.67	239 - 248	10
July 7, 1977	Fx. 13A	151.44	273 - 284	12
June 10, 1977	Fx. 14	"	296 - 312	17
June 19, 1977	Fx. 15	"	342 - 355	14
			Total	69

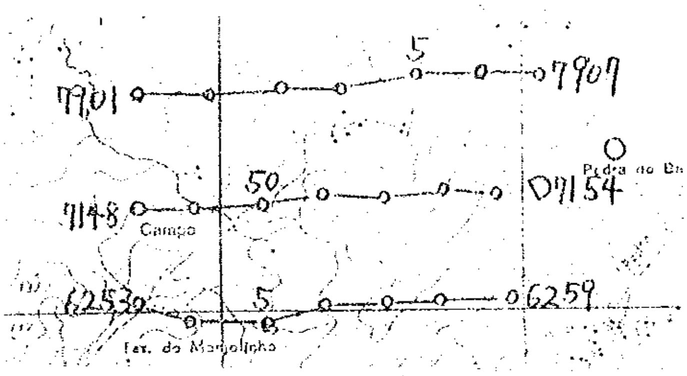


Fig. IV-5 Index drawing

In this country, index maps have not been used, but photo-index (Fig. IV-6) has been used. The reason is probably because the kind of topographical maps is few still now in this country, and besides, the interpretation of geographical features is difficult since there are many flat districts where no significant building structure exists, so photo-index may be used instead, which anybody can easily understand.

The features for both of index maps and index-photos are expressed in Table IV-24. The prominent feature of using index map is that it is less in the cost and easy to

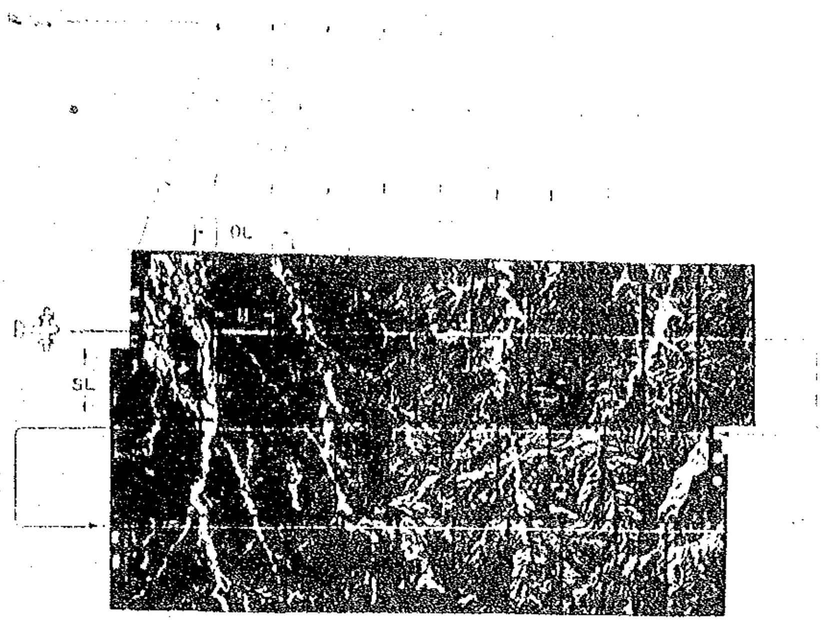
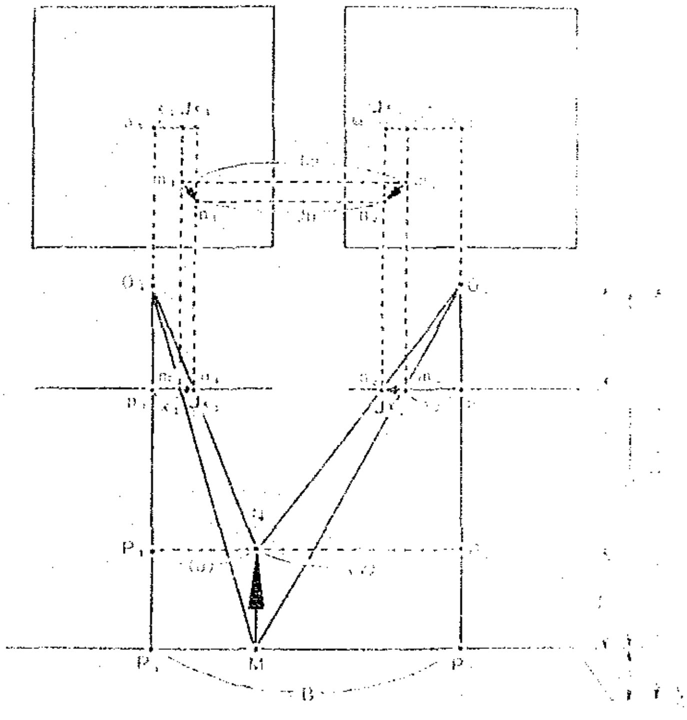


Fig. IV-6 Index photographs



$$h = \frac{H \cdot dp}{P + dp}$$

h : tree height

H : altitute above ground

P : Length of standard line of a place on photo

dp : parallax difference

Fig. IV-7 Theory of tree height measurement be kept handled, and this is regarded superior to the feature of photo-index that does not need the simplest technique of topographical map reading.

Table IV-24 Characteristics of index map and index photos

Item	Index map	Index photo
Topographical map	Necessary	Unnecessary
Interpretation of Topographical map	"	"
Correspondence to Topographical map	Complete	Incomplete
Production cost	Very inexpensive	Very expensive
Handling	Simple	Too large
For a flat topography	Difficult	Manageable
Range of area	Clear	Vague

Further, during the index map making practice, 1 a photo-system, 2 deformation characteristics of photo, 3 conditions of a flight course, etc. were clearly understood by trainees, and promptness in reading topographical maps was cultivated. These are considered to be helpful in improving the reading technique.

(c) Measurement of tree height

Starting with the principle of air-photograph, and attempting to let understand the theory of measuring the difference in the height, substantial training of three dimensional view was carried out.

ⓐ Stereoscopic view of a floating mark

Availing a figure model for the practice of parallax measurement, make practice repeatedly until one can accurately catch the height difference of stereoscopic images

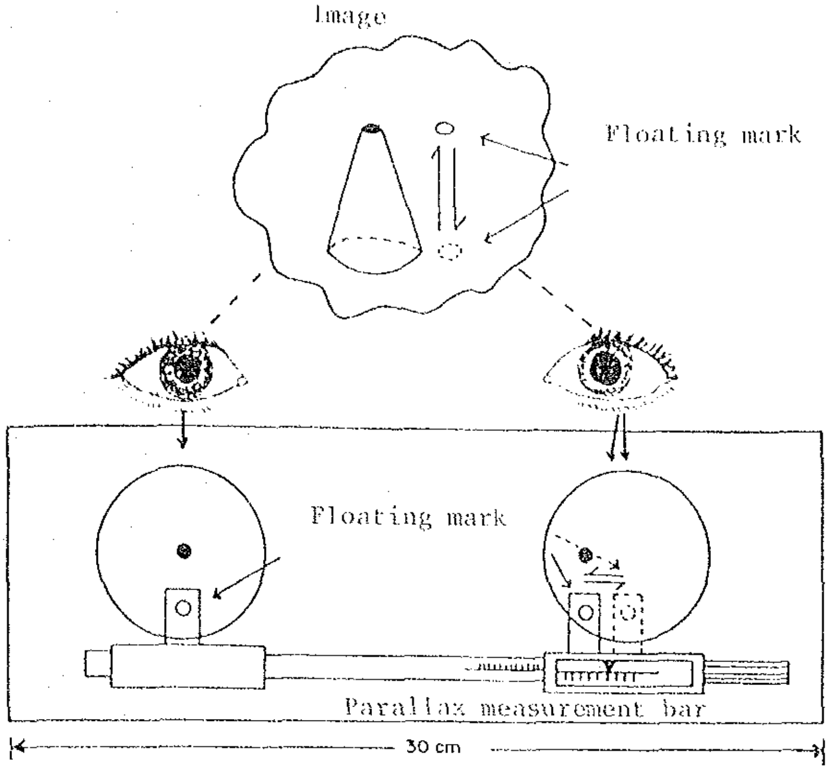


Fig. IV-8 Model for the practice of tree height measurement and the image of a floating mark

Table IV-25 Example of measurement test table of parallax differences

	VALOR MÉDIO		P	MÉDIA - P	z
	J	J_n	J - J_n		
1	14,66	13,74	0,92	0,01	0,0001
2	14,66	13,74	0,92	0,01	0,0001
3	14,67	13,73	0,89	0,02	0,004
4	14,66	13,74	0,92	0,00	0,0000
5	14,62	13,74	0,91	0,00	0,0000
6	14,61	13,68	0,93	0,02	0,004
7	14,61	13,69	0,91	0,00	0,0000
8	14,60	13,69	0,91	0,00	0 0000
9	14,63	13,69	0,94	0,03	0,0009
10	14,62	13,73	0,89	0,02	0,0004
Total			9,14		0,0023
MEDIA			0,91		
TESTE	$\frac{}{n-1}$	$= \frac{}{9}$	0,02		

EXEMPLO: $\frac{0,0023}{9} = 0,01598$

é boa

through a stereoscope with the point (a floating mark) as in Fig. IV-8 marked on the parallax measuring bar. Table IV-25 illustrates an example of point-table of a trainee, who attempted 10 times of measurement using this figure model, and acquired an allowable accuracy.

ⓑ Measurement of single tree

After having finished the practice of a, repeat to compare the measurement read on an actual tree with the real tree length, so that may remember a stereoscopic feeling when a floating mark locates very close to the ground surface and locates at the top of tree crown, thus obtain the technique concerning image in photograph.

ⓒ Measurement of tree crown

For this measurement, a crown diamter measuring plate, a transparent plate on which a number of black circles of different sizes are drawn as in Figure IV-9 is used.

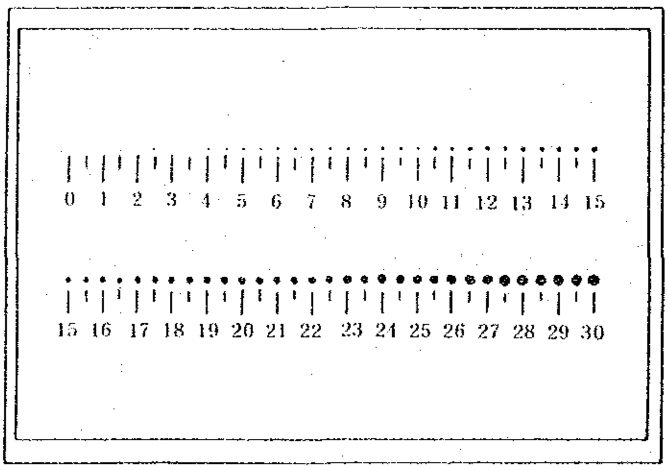


Fig. IV-9 Plate for crown diameter measurement

This is rather simple measuring technique, but guidance was conducted with emphasis on the following mark.

The black circles on the measuring plate are arranged by the size with the difference in diameter of every 0.05 mm. On measuring, by using a stereoscope of 3 magnifications, the unit becomes 0.15 mm Care was taken to assure the feeling by eye on the delicate difference.

(d) Measurement of number of standing trees

Measurement of number of standing trees is to count the number of standing trees on the photo and convert into the number per 1 ha usually.

In the practice, place a transparent plot set plate as in Figure IV-10 on the forest stand in photo, and count the number of standing trees in a plot, through a stereography.

As a point of guidance, though there are many points like the prevention of mis-counting, the definition of a standing tree on a plot border line, the selection of a plot size, etc., the most important point is how to read an inferior tree under a dominant tree in a forest stand. Excluding such case as an inferior tree is completely hided under a dominant one, the percentage to find an inferior tree by the ability of stereographical view can be improved to some extent by training. Of course, improving the ability to read an inferior tree is important, but it is also important that an expert discerns the count level, which readers unanimously understand, and provides a proper direction.

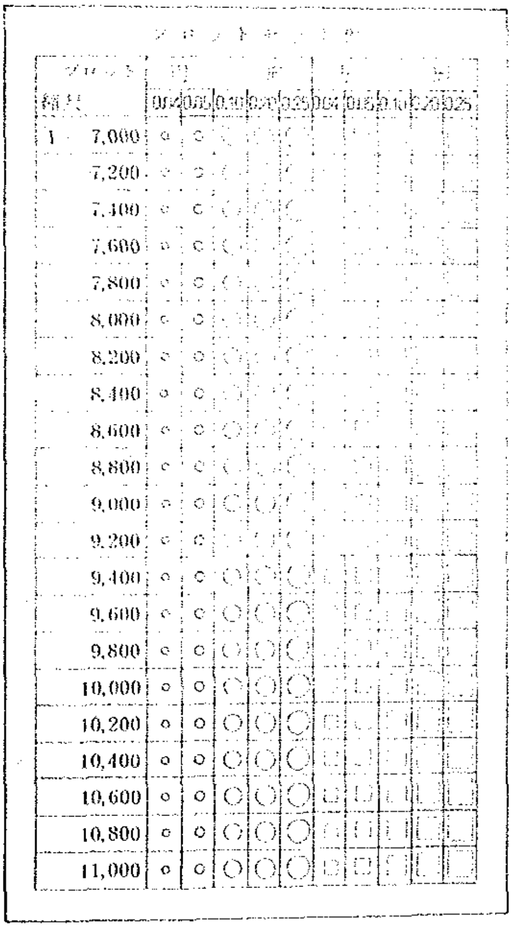


Fig. IV-10 Plot set plate

(e) Utilization to forest survey method

Forest Board, from 1976 to 1978, carried out the area survey, with the name of "forest survey in St. Paulo State", of artificial forests (pine trees and eucalyptuses) in 32 towns or villages (1,443,000 ha) in the watershed of Palaiba River. (Figure IV-11)

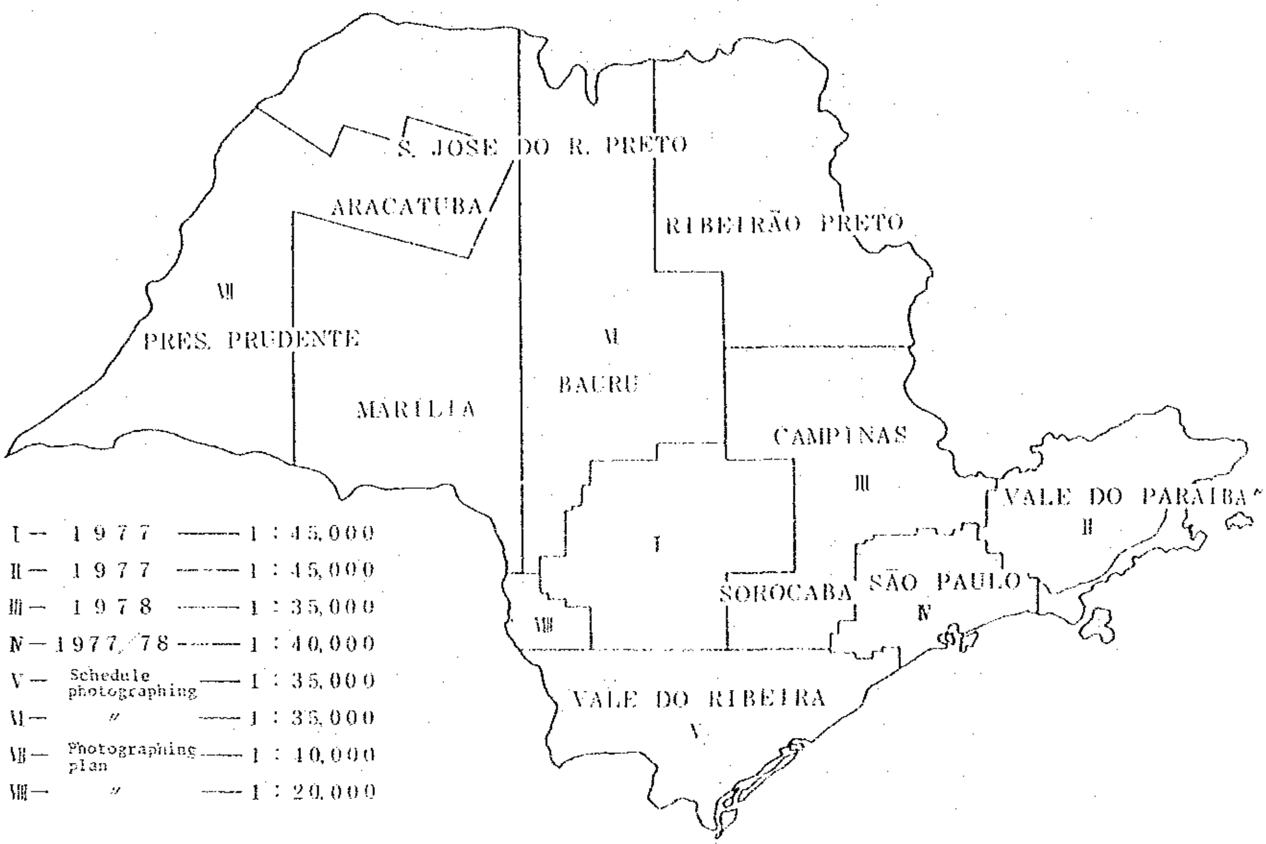


Fig. IV-11 Photographing plan of State of St. Paulo

In this survey, pine trees were classified into tropical and temperate pine trees, while eucalyptuses were classified into for pulp and for lumber. Further, pine trees were divided by forest age into 1-4, 5-6, 7-9, 10-12, 13-16, 17-20 years and exceeding 20 years, while eucalyptuses were into 1-3, 4-5, 6-11, 12-17 and exceeding 17 years. The respective areas for each division were summed up by city, town or village. Data collection was made by the information obtained by inquiry and the ascertaining survey of areas by air-photograph.

Further, since the personnel who took part in the above survey were the principal coastituents of the trainees of this course, they were so much interested in how to utilize the accomplishment of this training course in the volume survey of artificial forest of the state that the practice of the interpretation technique was carried out concerning the statistical analysis by sampling method as well as the reading of forest aspects of artificial forest.

On basis of the state survey materials, the technique to estimate a volume value per ha by forest age from outside information was instructed, thereby the way to figure the tentative total volume in Palaiba River basin was shown.

③ Results of training

After practising this training course, we were impressed with the following:

First, the technique to interprete topographical map, i.e. the technique to know the topographical state of the land and relative locations thereof from the aspects of contour lines of topographical map, was learned well sufficient to make an index map but is insufficient to identify the exact location, due to the lack in experience. Particularly the speed of performance was unsatisfactory.

Second, as for the interpretation technique on tree heights and crowns, by means of carrying out exactly the detailed working procedure, following furnished precautions, it was concluded that the measurement results were of allowable accuracy.

Third, in order to interprete average tree height, crowns and number of trees in a forest stand, it is necessary to obtain such ability as to grasp in which state the above items are distributed in the subject forest stand, when the forest stand is looked as a whole.

In the below, showing the values of measurement by experts on artificial forest stand of Araucaria (Araucaria angusti folia) as the basis and the distribution of measurements by trainees, the accomplishment and the level of the interpreting techniques are considered.

(a) Average tree height

From Fig. IV-12, it seems that the interpreter 4's value is nearest to the expert's measurement. Though the interpreter 4 has the first experience in measuring tree heights this time, he has so far directly handled a number of airphotograph for our survey, and so it seems that his abundant experience in photos has affected favourable results on the measurement.

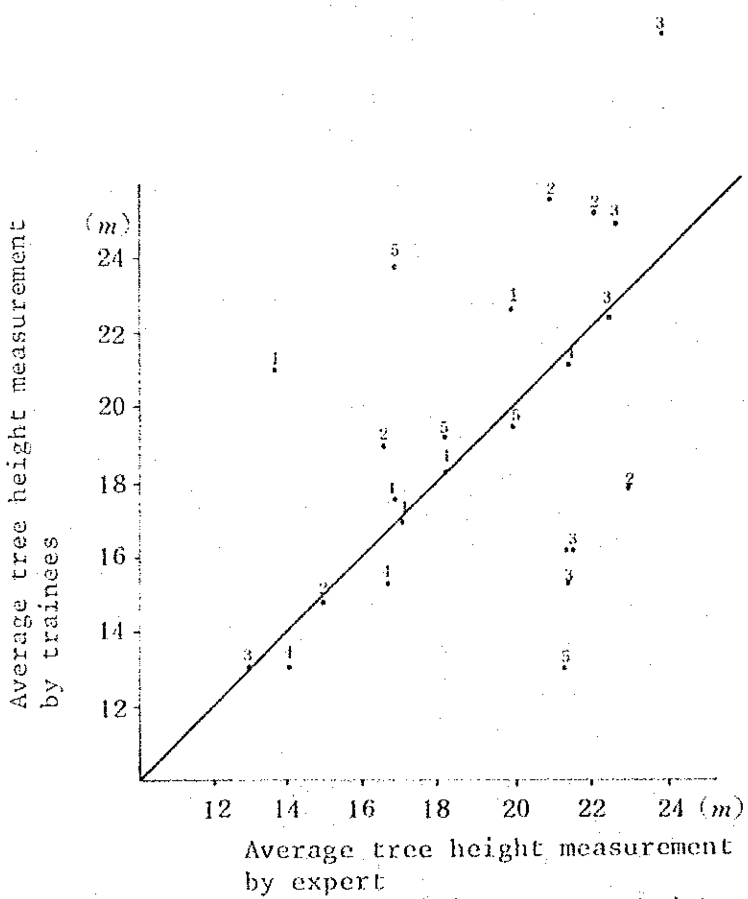


Fig. IV-12 Results of training of tree height measurement

Though individual's skill difference was not particularly recognized, sometimes quite different values by other trainees from those by experts were noticed. To prevent such dispersed measurement, it is advisable to make the upward and downward movement of a floating mark as slowly

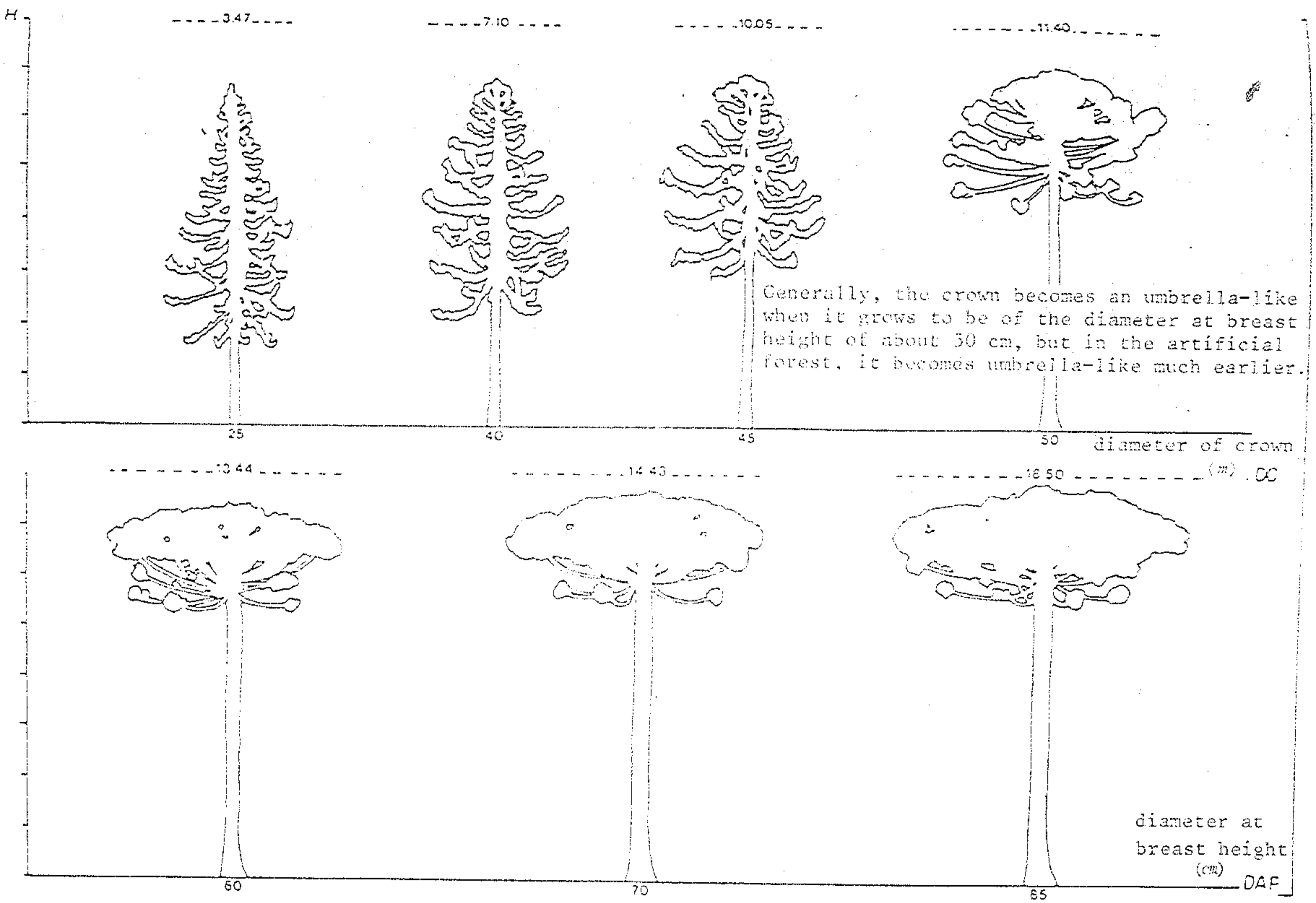


Fig. IV-13 Transition of araucaria crown as possible, sometimes neglecting the view of a floating mark, thus concentrate on the stereoscopic view of the subjects then try to look the stereoscopic view of a floating mark, and repeat the above.

(b) Average diameter of crowns

The crown of Araucaria displays, when it grows up to a certain age, a figure like a spread umbrella, as in Fig. IV-13.

Individual's skill difference was not perceived from the trainees' measurement results, providing almost uniform dispersion around the expert's values, though the extent of dispersion seemed a little too much as shown in Fig. IV-14. It was judged the mean values of their measurement could be used as fairly trustable values.

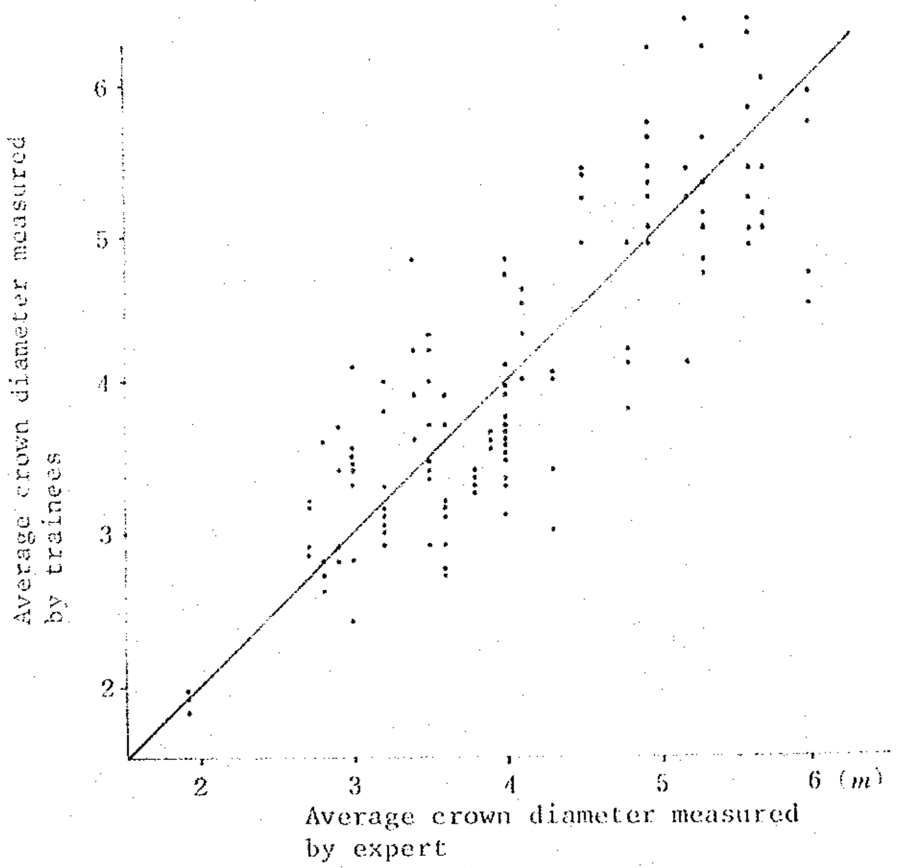


Fig. IV-14 Results of training of crown diameter measurement

(c) Number of trees

Fig. IV-15 indicates, when the number of trees per ha exceeds 500-600, the reading of the number of inferior trees becomes unsuccessful.

On the other hand, the measurement on about 200 trees/ha are also extremely dispersed, tending to overcount the expert's value. Probably this is due to the fact that a crown of araucaria has such characteristic figure as each part of adjacent crown circles is looked together like forming another circle, and this causes misinterpretation. (Fig. IV-16).

When the measurement results of trainees are looked through, excluding those values regarded as miscount, the results indicated nearly certain dispersion. It is concluded that when the mean value of the measurement is used, that will lead to some relation formula concerning the actual number of trees.

④ Accomplishment

As the detailed work procedure to separate items is described in Portugues, we believe the foundation has been set so that the trainees can independently guide the practice to other researchers or workers interested in photo interpretation in the future.

Therefore, it is expected that from now on they will apply the available data for interpretation in the various fields of research and study, thus become able to judge by themselves the extent of trustable accuracy, and accumulate their experience. As an expert, it will be rather efficient if they try to indicate, as much as possible, how to use the interpretation data.

(3) Future forecast and problems

① Stereoscopic view by naked eyes

The stereoscopic view by naked eyes means, when one looks at similar images on a pair of photos, one looks directly at a left image with a left eye and, a right image with a right eye,

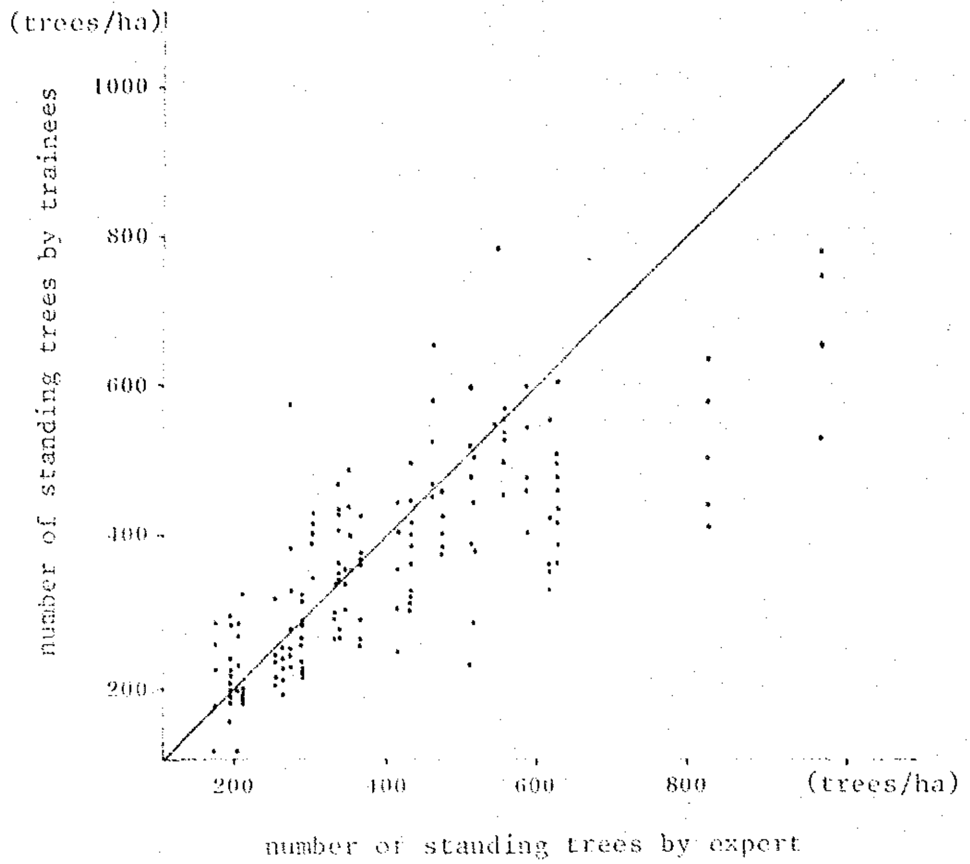


Fig. IV-15 Results of training of number of standing tree measurement

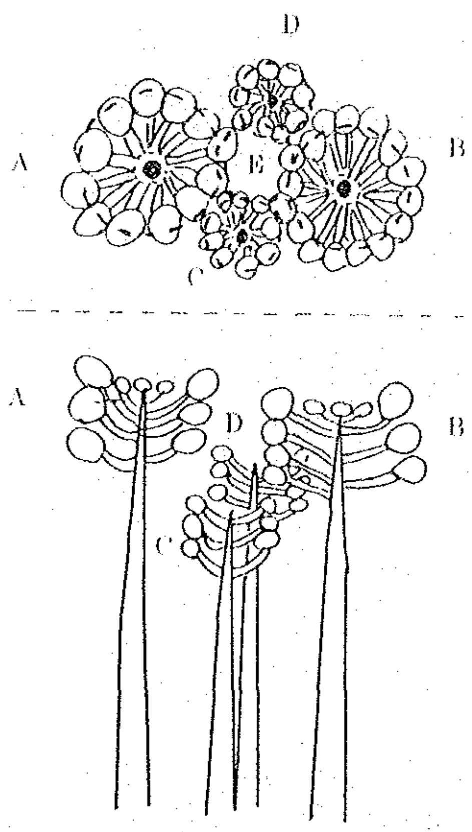


Fig. IV-16 Judgement and mis-judgement on resembling crowns without availing a stereoscope, thus obtains a stereoscopic feeling with the image built in one's brain. However, the action of looking at something is normally by human habit to look at the object with both eyes, whereas the naked eye stereoscopic view forces physiological reflect nerves of both eyes to forcus separately by one's intention, so considerable training is required.

In Japan, this naked eye stereoscopic view is deemed an essential technique for interpreting technicians and researchers who frequently use photo interpretation. Since no equipment like a stereoscope is required, the benefit of this technique is, needless to say, that whenever a pair of photos are available, regardless of the place or time, the stereoscopic view of the image could be obtainable, so it is not only convenient in checking the detailed stereoscopic feeling at site but also helps to accumulate various useful interpretation experience, whereby contributing to improve the technique.

However, in Northern and Southern American continent, including U.S.A., there are very few interpretation technicians capable of the naked eye stereoscopic view. In other words, they seem to study only in the sphere of interpretation technique that need not the naked eye stereoscopic view technique.

② Large-scale air-photograph

For the guidance of fundamental technique of photo interpretation, a large-scale photo of at least 1/10,000 is desirable. However, the recent situation of air-photograph in this country indicates the photos with the scale of 1/45,000 - 1/35,000 are many in number. This fact is also considered as one of obstacles in educating interpreting technicians.

But, on the contrary, as the availability of the interpreting technique increases, the demand for a large-scale photo will increase, hence the spreading effect of this training is expected in future.

③ Training system of photo interpretation technique

Remote sensing technique, that is able to a great mass of information into data quickly, displays much benefit in various