survey in the vast area in Brazil. The last training educated many interpreting technicians, making a base to raise the level of remote sensing technique itself. Hence, the training who attended at the last training course are expected to endeavour to spread the technique. We would like to propose to set a continuous training course and to formulate a system of qualification of the training course graduates.

IV-3-2 Construction of Aerial Volume Table

(1) Purpose

The growth of artificial plantation (mainly pine trees and eucalyptuses) in St. Paulo state is generally very well; for example, the cutting period for pine trees is said to be 20-25 years, though there are uncertain factor due to insufficient experience, and eucalyptuses can be cut in seven years. Such being the case, the area of artificial plantation itself varies extremely. Therefore, it is rather difficult to grasp the distribution of volumes at a destined point of time.

Even under such situation, if there is a rather simple way of volume estimation, that is, in a short time and with a low cost, the attempt of an experiment with such method as a temporary measure would contribute very much to the regional or short time forest policy.

So, the utilization of aerial volume table is taken up, which can estimate volume only with the interpreting work of air-photograph, though the trustability of accuracy is a little low and the range of application tends to be narrowed, and is more advantageous than practice of sampling survey, because when a proper air-photograph is taken, volume can be estimated almost simultaneously.

Further, if the survey by sampling method is practised afterwards, the air-photograph method will display its usefulness sufficiently with the monitoring effect to detect the trend thereafter in the artificial forest.

In addition, in those districts where the volume information is almost nothing at a present time, or as the rough estimate of the current growing stock where only state information is available, the use of aerial volume table, which enables to estimate growing stock in a short time and with a low cost, is advantageous.

(2) Process and accomplishment

① Determination of working process

On making an aerial volume table, it must be fundamentally examined at first whether any factors to estimate the volume directly or indirectly are included or not, and if included, how to take out those factors and make data out of them.

(a) Selection of tree species

It is probably a reasonable way of approach to make aerial volume table from such a tree species as its crown andheight, which can be the factors for photo-interpretation, have relatively simple relation to the growth of volume, and the number of trees is easy to be measured.

Thus, the species selected for the first step of making an aerial volume table is araucaria (Araucaria angustifolis).

(b) Selection of air photograph

On determining the scale of photo, it is normal to select a proper compromising scale according to the purpose. However, for the purpose to make an aerial volume table, the least limit of the scale is generally 1/10,000. Further, considering that the more recent air photograph may have less problems in comparison with ground data, it was decided to use the photo of 1/8,000 scale taken in June 1982, which was used in the photo-interpretation study in the previous section. The elements of the photo were shown in Table IV-23 in the previous section.

(c) The place of survey

Since the aerial volume table is to estimate the volume of a forest stand, and factors for interpretation are also expressed as one of average data on a forest stand, it is advantageous that a unit forest stand should have uniformity as much as possible.

In such view-point, araucaria artificial forest of Mejoramento company (privately owned) was selected as the subject. This locates 25 km north of St. Paulo city (West 46°44', South 23° 24'), with its history of forestry since about 100 years ago, where below named other kinds of trees have been well controlled.

Cupressus lusitanica
Cuningamia lanceolata
Cryptomeria japonica
Taxodium distiuim
Melia azidarachi
Pinus spp.
Eucaliptus spp.

The average above the sea level of the selected araucaria artificial forest is 780 m. As the examples of thinning is shown in Fig. IV-17 (from the data published in the 1982 first meeting of forestry society on Brazilian native tree species) to find the controlling situation, it is learned that fairly careful training has been repeated.

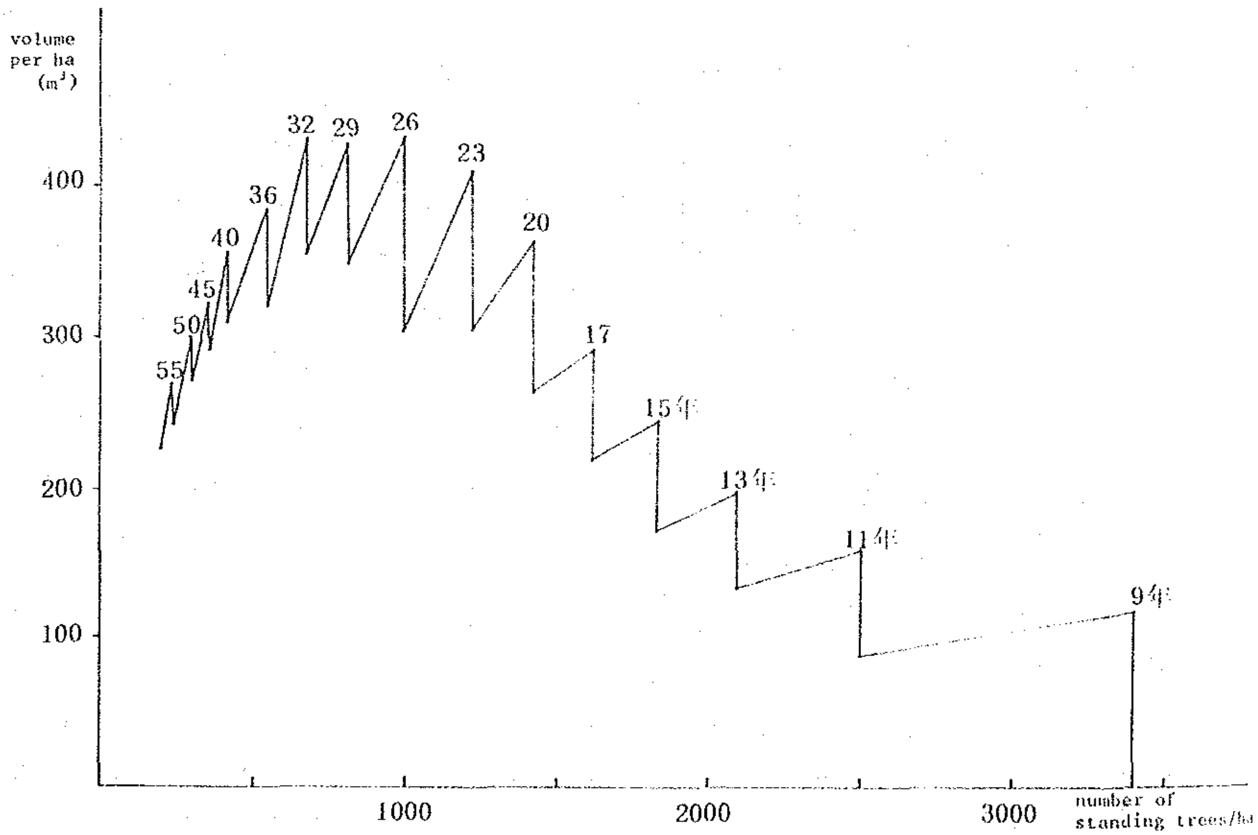


Fig . IV-17 Thinning status of araucaria artificial forest

(d) Determination of method

As for general methods, two methods are to be considered; the first is a method by a multiple regression formula where a volume unit per ha of a forest stand of a certain division is made a dependent variable, and measurement data of interpretation factors are treated as independent variables, and the second is a method by multi-valiate analysis where the above factors are extended to include the quantified data of topographical and geological features, soil and ground grade coefficient.

Here, attaching importance to the simplicity due to the previously described background and considering the meaning as the application of interpretation training in the previous section, it was decided to lead an estimation formula of a volume per ha (a multiple regression formula) from the crown diameter and the number of trees per ha in a forest stand, and make a volume table.

The reason why the factor of tree height was discarded as seen in the reading results in the previous section (Fig. IV-12) was directly due to the unskilled interpretation technique that did not express allowable accuracy. Besides, there are few cases where the measurement value of tree height could be directly used as a general factor for the use in making the aerial volume table. In other words, the factor of tree height availed in general is a way substituting for a grading factor in height comparing each other, regarding a forest stand as a unit. However, this was not also adopted because the interpreters' experience in interpretation technique on the forest aspects was insufficient.

After all, the multiple regression formula as an estimation formula is presumed as below.

Estimated volume = a + b·(crown diameter) + c·(number of trees) + d·(combination of crown diameter and number of trees)

where, a, b, c and d are coefficients.

② Practice of work

On practising, the process flow is as in Fig. IV-18.

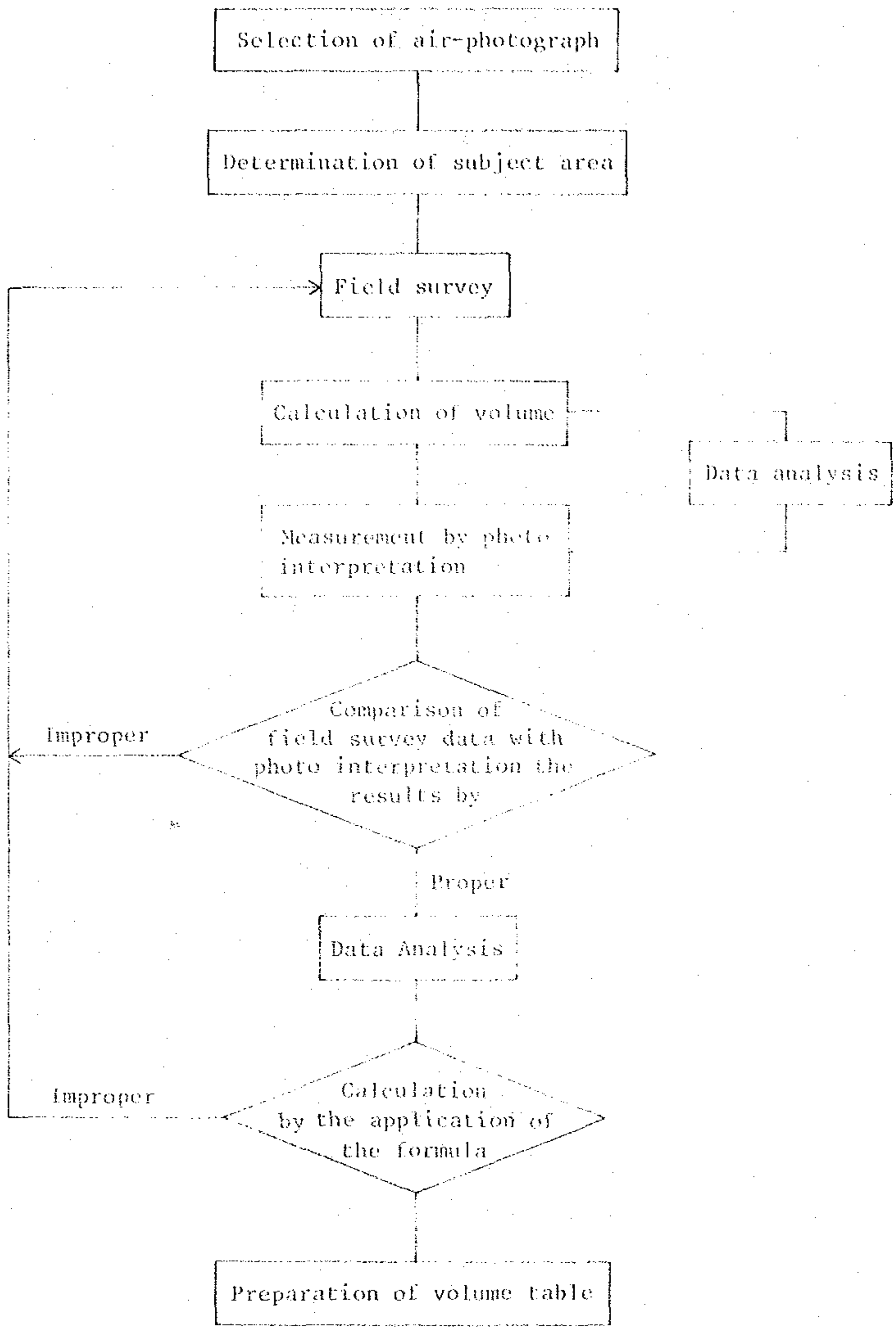


Fig. IV-18 Flow Chart of work procedure

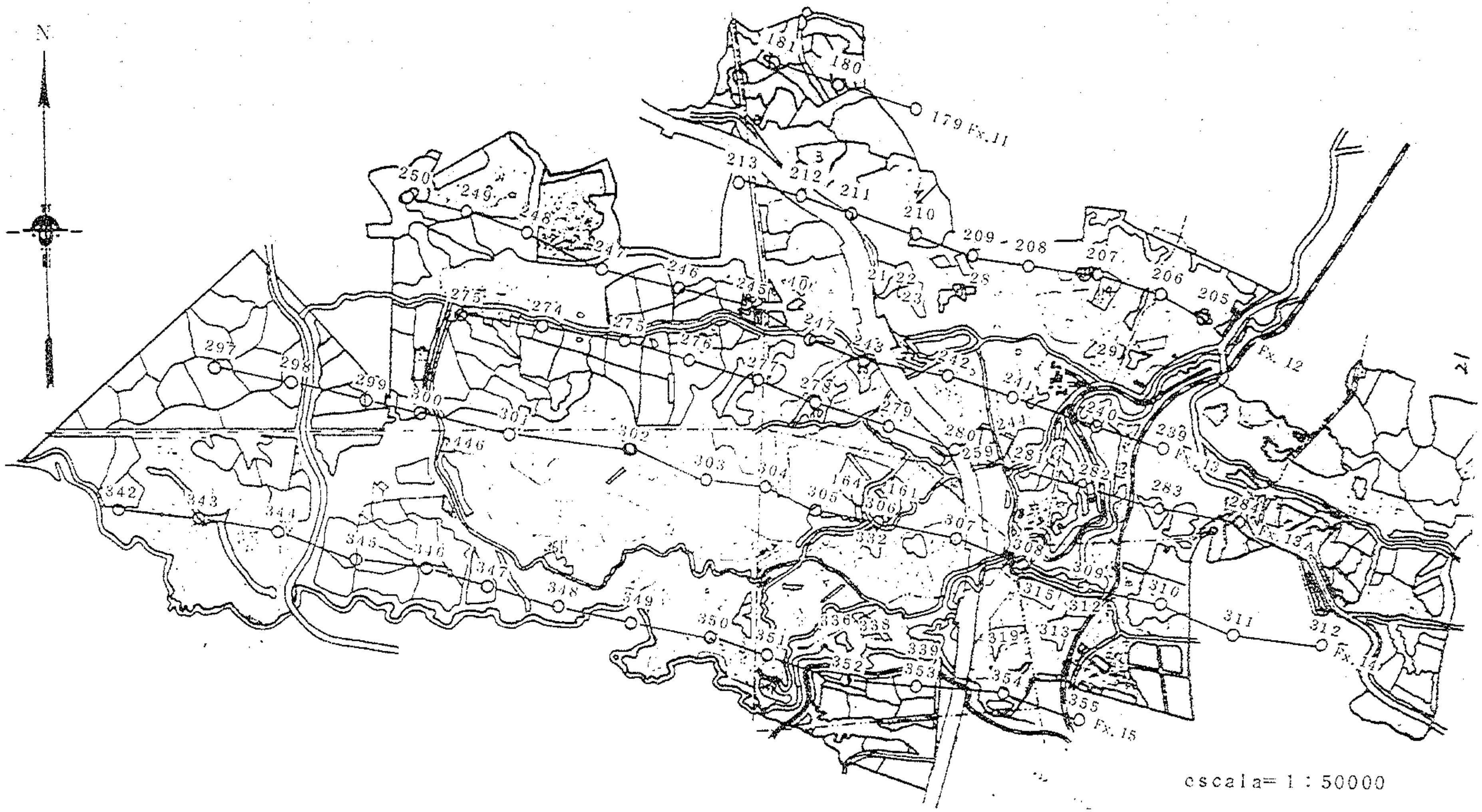


Fig. IV-19 Map showing the location of field survey plot

(a) Field survey

Every tree survey was conducted by 5 trainees at a ratio of 1-3 plots every division by forest stand as in Fig. IV-19, and the data for 34 divisions in total were collected. Here, the size of a plot was 0.1 ha (40 m x 25 m).

As a result, the frequency by forest age of the surveyed 34 divisions was as in Fig. IV-20. The items of measurement were breast height diameter, tree height, and number of trees, where were as shown in Table IV-26 respectively.

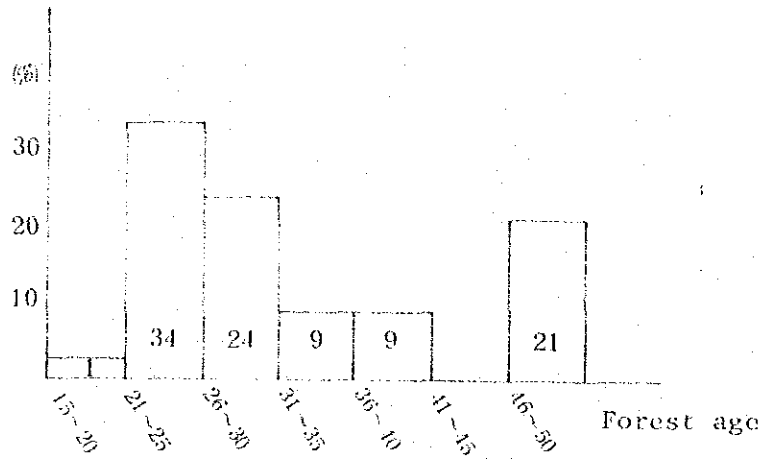


Fig. IV-20 Distribution of the collected data frequency in the forest age

(b) Average crown diameter in forest stand

Each trainee who conducted the interpretation of air-photograph, took 3 intermediate crowns in a division, measured diameters respectively by means of a crown diameter measurement plate (Fig. IV-9 in previous section), and calculated the mean value, which was considered as the value of measurement of crown diameter. Individual's measurement values thus calculated were an in Table IV-27, showing a dispersion. However, since the dispersion was around the expert's measurement value, and there was noticeable difference among individuals, as in the result of training in the previous section (Fig. IV-14), the mean of the individual's values of measurement by every division was adopted as the data for the factor of crown diameter. In addition, the standard deviation of the difference between individual's value

Table IV-26 Results of field survey

Serial number	Section number	Section area	Forest age	Diameter at breast height (cm)	Tree height (m)	Number of standing trees (trees/ha)	Volume (m^3/ha)
1	3	10.0	27	21.0	18.3	520	119.1
2	21	3.2	27	20.2	18.5	740	266.5
3	22	5.4	22	19.7	17.9	710	237.9
4	23A	6.4	22	19.8	18.1	620	209.9
5	23B	0.8	24	20.6	18.7	780	295.4
6	27	2.4	34	31.4	22.2	280	281.6
7	28	1.1	31	26.1	23.2	280	211.1
8	33	11.2	22	20.6	19.1	635	246.1
9	39	1.9	22	22.7	20.3	420	209.6
10	40	3.2	23	22.5	19.1	950	438.2
11	80	5.4	23	20.3	19.0	790	295.0
12	81	5.4	24	20.5	19.4	500	194.5
13	83A	5.4	26	21.4	19.5	715	304.6
14	83B	3.8	25	22.8	19.4	607	285.7
15	111	1.4	16	17.9	16.0	1320	302.0
16	114	8.0	26	21.4	19.6	510	218.4
17	129	3.4	29	25.0	19.6	350	197.0
18	144	2.2	49	31.5	21.5	346	339.0
19	157A	1.9	49	31.6	22.8	275	287.6
20	157B	0.6	49	30.3	22.5	325	313.1
21	160	1.1	49	31.7	20.8	308	300.9
22	161	3.8	49	33.7	23.5	267	330.9
23	167	7.7	49	34.0	24.5	240	312.3
24	312	3.7	50	33.3	24.1	308	382.4
25	313	5.8	28	18.8	17.6	580	178.5
26	315	4.0	50	30.9	21.2	282	264.9
27	319	7.2	28	21.2	19.6	520	218.5
28	332	2.6	39	27.6	23.6	280	240.1
29	336	1.0	39	21.6	16.6	510	188.4
30	338	4.3	35	27.7	21.2	385	298.4
31	339	2.2	28	27.0	21.9	340	258.9
32	349	4.2	21	22.4	19.2	630	289.5
33	361	2.7	21	18.7	17.1	1015	292.7
34	446	1.6	25	18.5	16.2	840	231.1

Table IV-27 Measurement values of crown diameters and the average

Section No. \ Measurer	1	2	3	4	5	Average
3	2.7	3.2	2.9	3.2	2.9	3.0
21	3.2	3.0	4.0	2.9	3.3	3.3
22	2.9	3.7	2.9	2.8	3.4	3.1
23A	4.0	3.3	4.1	3.3	3.7	3.7
23B	4.0	3.1	3.9	3.5		3.6
27B	5.3	4.7	5.6	6.2	4.8	5.3
28	4.8	4.2	4.9	4.1	3.8	4.4
33	3.8	3.4	3.3	3.3	3.3	3.4
39	3.5	3.4	3.4	3.4	4.2	3.6
40		3.2	3.6	3.0	3.8	3.4
80	3.6	3.1	2.7	2.7	3.9	3.2
81	3.6	2.9	3.2	3.2	3.7	3.3
83A	4.0	3.5	3.5	3.5	3.7	3.6
83B	4.0	3.9	4.8	4.7	3.7	4.2
111	1.9	1.9	1.8	1.9		1.9
114	3.5	4.3	2.9	4.0	3.7	3.7
129	4.1	4.5	4.6	4.0	4.3	4.3
144	5.3	5.3	5.0	5.4	5.7	5.3
157A	5.7	5.4	5.0	5.1	6.0	5.4
157B	4.9	5.2	5.3	5.4	5.7	5.3
160	4.9	5.6	5.0	6.2	4.9	5.3
161	5.6	5.4	4.9	5.2	5.7	5.4
167	5.2	5.4	4.1	5.2	6.4	5.3
312	5.6	5.8	5.0	6.3		5.7
313	3.9	3.6	3.6	3.6		3.7
315	6.0	5.7	4.7	5.9	4.5	5.5
319	4.3	4.0	3.4	3.0	4.0	3.9
332	4.5	5.2	5.4	4.9	5.4	5.1
336	3.0	3.5	3.5	3.5	4.1	3.5
338	3.4	3.9	3.6	4.2	4.8	4.0
339	3.9	4.2	4.0	3.6	4.6	4.1
349	3.0	3.3	2.8	2.4	3.5	3.0
361	2.8	2.8	2.6	2.7	3.6	2.9
446	3.2	3.1	3.1	3.0	3.8	3.2

Table IV-28 Measurement values of photo-numbers of trees and the average

Section No. \ Measurer	1	2	3	4	5	6	Average
3	350	484	438	438	350	397	408
21	617	350	550	325	420	360	437
22	585	475	595	458	540	400	508
23A	473	458	372	400	425	380	418
23B	625	492	360	433	500		482
27B	287	283	278	190	220	197	243
28	287	220	285	217	320	250	263
33	430	358	322	313	400	308	355
39	415	353	243	300	440	400	359
40	540		547	780			622
80	627	600	156	387	500	413	497
81	510	593	517	387	475	223	451
83A	515		140	280	375	500	422
83B	335		105	347	340	425	370
111	975		775	525	650	742	733
114	270		575	380	240	275	348
129	330		330	287	260	293	301
144	270		328	220	240		265
157A	260	200	251	233	220	187	225
157B	285	200	260	207	220	210	230
160	190	187	290	197	150	173	198
161	205	197	320	173	190	180	211
167	250	200	318	230	210	232	240
312	200	110	263	280	190	227	212
313	300	417	425	340	400	400	380
315	170	110	283	177	220	253	202
319	335	270	430	466	360		372
332	190	233	215	203	280	207	221
336	430	382	445	493	300	413	410
338	365	375	425	360	260	360	358
339	349	300	350	333	260	287	313
349	552	533	568	492	450	550	524
361	825	408	625	575	500	433	561
446	460		650	467	450	575	520

of measurement and the mean was 9.8%.

(c) Number of standing trees

In photo, select 3 forest sections which are interpreted to represent the intermediate number of trees out of forest stands in one division, overlap on a properplot size on a plot set plate (Fig. IV-10 in previous section) and count the number of trees in each photo. The mean value is to become individual's value of measurement. Thereafter, similar to the case of crown diameter in (b), the mean value of individual's value of measurement by division is considered as the interpreted number of standing trees of a division, which will be used in the estimation formula (Table IV-28). In addition, the standard deviation of the difference between individual's value of measurement and the mean was 17.7%.

③ Data analysis

(a) Ground data

ⓐ Calculation of volume

i) Former method

The volume per ha of a forest stand is obtained by the following formula.

$$V = BA \times H \times K \times F \qquad (1)$$

where, V: volume per ha
BA: average basal area at breast height per ha
H: average tree height
K: bark percentage
F: form coefficient

In addition, taking the volume of round timber with bark of 1 m x 1 m x 2.4 m as 1, a bark percentage is expressed in ratio of the volume after the bark is peeled off against the original volume, which is given by a forest age.

The form coefficient is a taper ratio from base to end, which is also given by forest age.

Thus calculated results are as in above Table IV-9.

ii) Apply to linear regression formula

Formerly, the volume was obtained by the above formula 1, using given values, by forest age, of bark percentage (K) and form coefficient (F). Taking the volume calculated with the above method as a dependent variable, and considering the value of (diameter at breast height) x (tree height) multiplied with number trees as an independent variable, when they are applied to a linear regression formula, the result in Figure IV-21 are obtained, thereby the below linear regression formula(2) is acquired.

$$\bar{V} = 12.2 + 0.578 \times \pi \times \left(\frac{DBH}{100}\right)^2 \times H \times N \qquad (2)$$

$R = 0.999$

where, V: estimated volume (m^3/ha)

π: 3.14

DBH: diameter at breast height (cm)

H: tree height (m)

N: number of standing trees (trees/ha)

R: coefficient of correlation

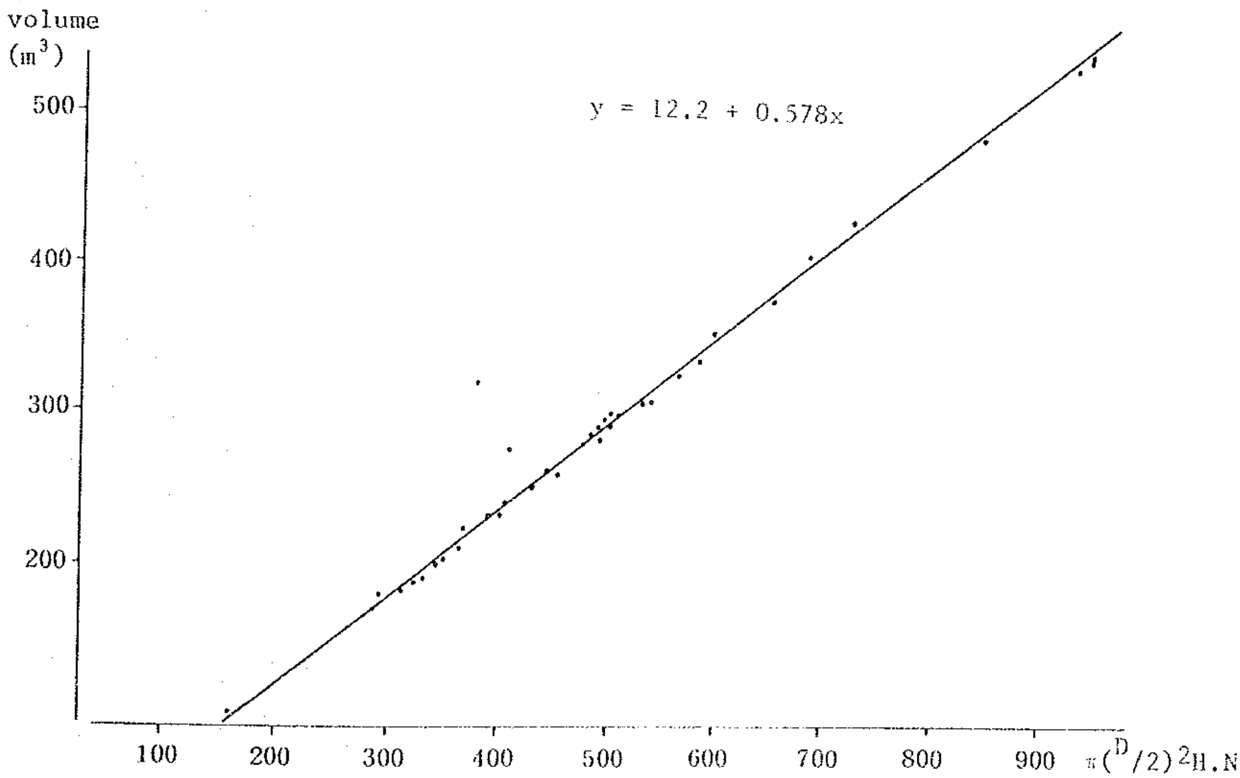


Fig. IV-21 Estimation of volume by diameter at breast height, tree height and number of standing trees

Therefore, it is possible to estimate volume by the formula (2), regardless of forest age, if only diameter at breast height, tree height, and number of standing trees are known.

ⓑ Growth curve

When the average diameter at breast height and the average tree height in a forest stand by forest ages are expressed in linear formula as well as in a logarithmic curve formula, following formulae are obtained.

Average diameter at breast height (Fig. IV-22)

$\overline{DBH}$ = 9.69 x 0.461 x I (3) R = 0.904

$\overline{DBH}$ = -23.7 + 14.1 log I (4) R = 0.907

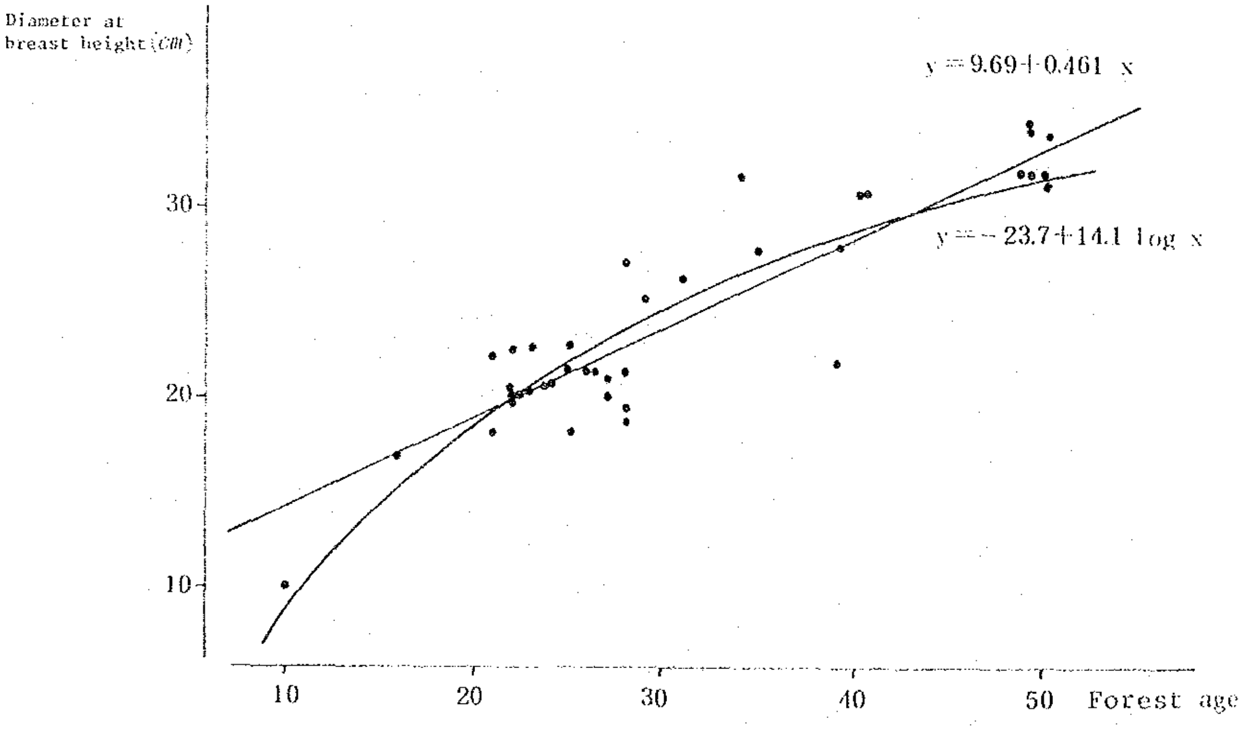


Fig. IV-22 Forest age and diameter at breast height

Average tree height (Fig. IV-23)

$\overline{H}$ = 13.7 + 0.193 x I (5) R = 0.739

$\overline{H}$ = =1.83 + 6.37 log I (6) R = 0.809

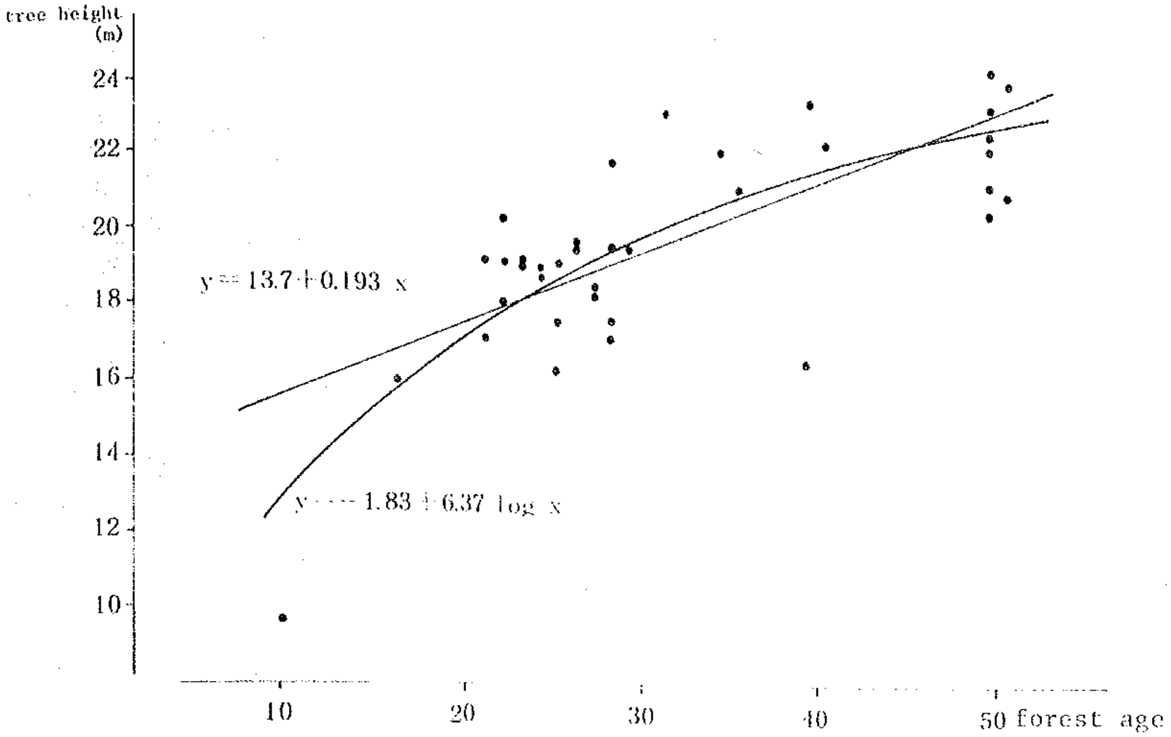


Fig. IV-23 Forest age and tree height

where, $\overline{DBH}$: estimated diameter at breast height (cm)

$\overline{H}$: estimated tree height (m)

I: forest age

R: coefficient of correlation

From those coefficience of correlation in above linear formulae and logarithmic curve formula, it can be seen that diameter at breast height indicates a linear growth, while tree height is better expressed in a logarithmic curve.

ⓒ Thinning

Same as above, the change in the number of standing trees becomes as in Fig. IV-24, where the formula is expressed as below.

$$\overline{N} = -180 + 19764 \cdot \frac{1}{I} \qquad (7) \quad R = 0.831$$

where, $\overline{N}$: estimated number of standing trees (trees/ha)

I: forest age

R: correlation coefficient

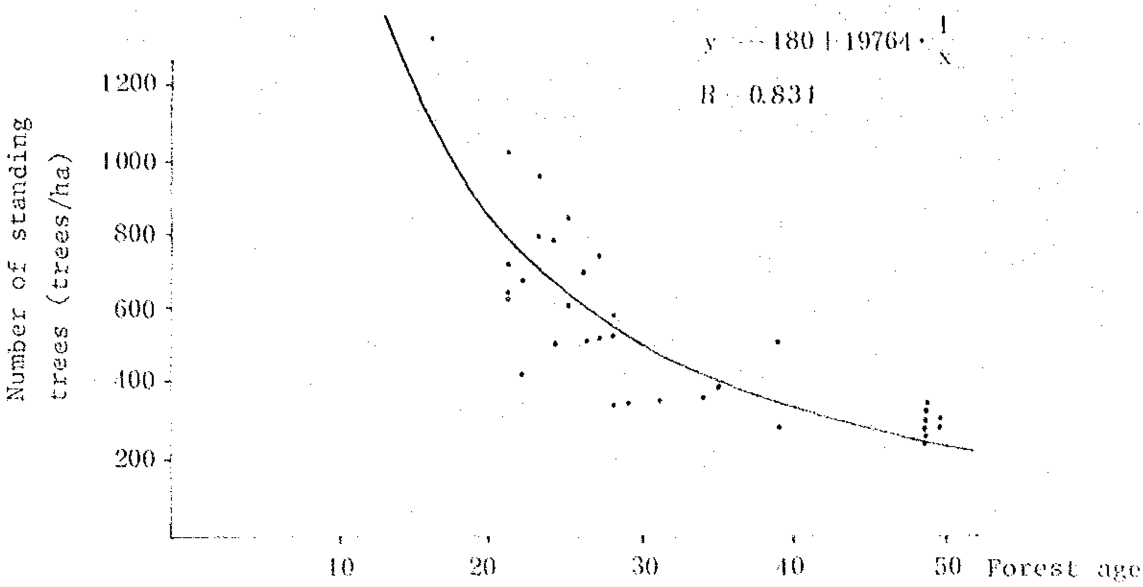


Fig. IV-24 Forest age and number of standing trees

As seen from Figure IV-24, the number of trees within 30 years forest age indicates that thinning was practised only on small number of trees, and this coincides with the decreasing tendency in volume per ha of less than 30 years forest age, which is shown in the thinning state as in Fig. IV-17 on the basis of other literature, whereby the characteristic of thinning practice in this artificial forest is realized.

Since the decisive factor in practice of thinning is supposed to be the diameter at breast height, the relation is shown in Fig. IV-25, and formula(8)is adopted.

$\bar{N} = -549 + 25489/DBH$ (8) $R = 0.846$

where, $\bar{N}$: estimated number of trees (trees/ha)

DBH: Average diameter at breast height (cm)

R: coefficient of correlation

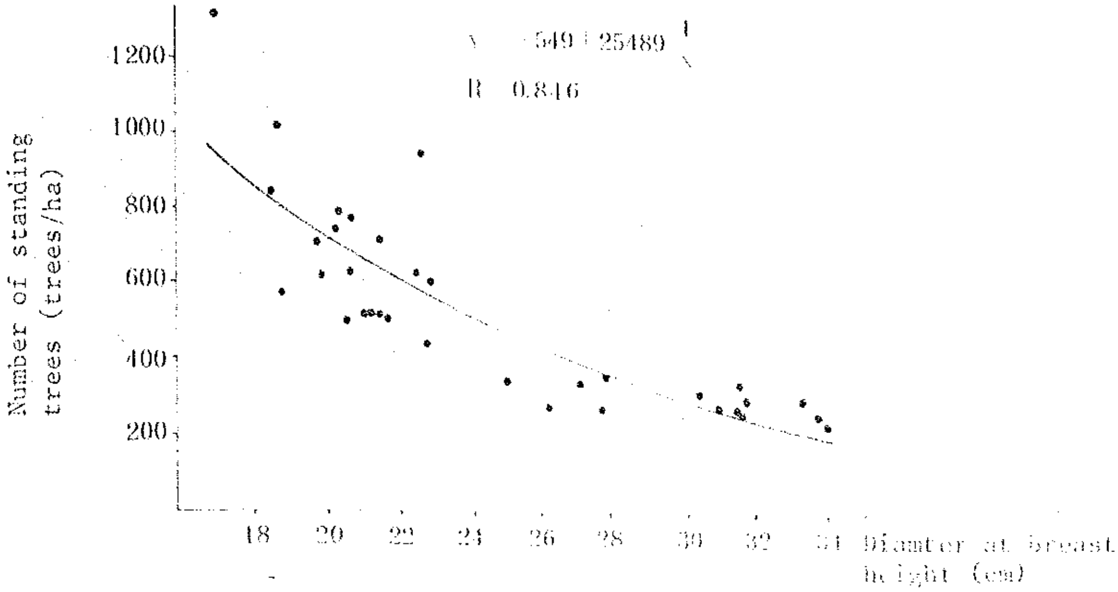


Fig. IV-25 Diameter at breast height and number of standing trees

(b) Application of crown diameter

ⓐ Diameter at breast height

Using the mean of the measurement values by trainees made on air-photograph, the relation between crown diameter and diameter at breast height is as in Fig. IV-26. When diameter at breast height is substituted with y, and average crown diameter with x, the above is expressed in the first, second, and third degree formula as follows, among which the second degree formula of (10) is judged proper.

$$\overline{DBH} = 4.14 + 5.04C \qquad (9) \quad R = 0.938$$

$$\overline{DBH} = 17.8 - 1.93C + 0.84C^2 \qquad (10) \quad R = 0.951$$

$$\overline{DBH} = 22.9 - 6.51C + 2.12C^2 - 0.10C^3 \qquad (11) \quad R = 0.951$$

where, $\overline{DBH}$: estimated diameter at breast height (cm)

C: average crown diameter (m)

R: coefficient of correlation

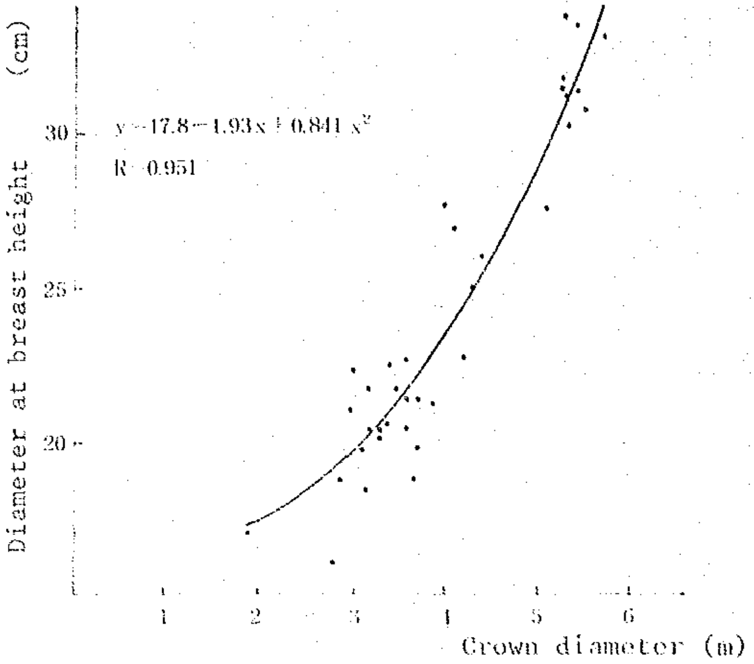


Fig. IV-26 Crown and diameter at breast height

ⓑ Tree height

Same as above, the relation with tree height is as in Fig. IV-27, and expressed in a linear formula of (12) as below.

$$\bar{H} = 11.8 + 2.03C \qquad (12) \qquad R = 0.857$$

where, $\bar{H}$: estimated tree height (m)

C: average crown diameter (m)

R: coefficient of correlation

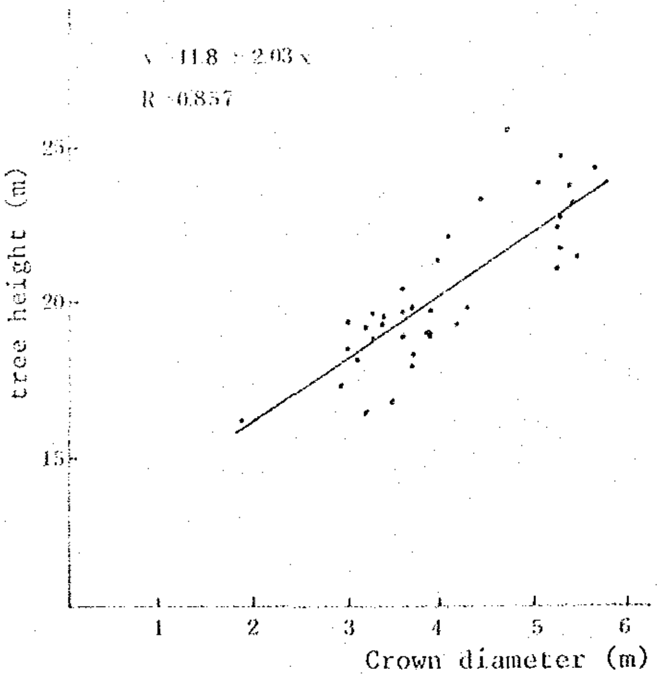


Fig. IV-27 Crown diameter and tree height

ⓒ Volume of averaging single tree

The average crown diameter by individuals (hereafter called "crown diameter") which is used in above ⓐ and ⓑ displays relatively high correlation with a diameter at breast height as well as with tree height. Then, it is naturally presumed to be of high correlation with the volume of a single tree, which is expressed in (diameter at breast height) x (tree height).

Hence, as a way to express the volume of a single tree from the ground data, when the actual volume of a forest stand obtained in formula (1) is devided with the actual number of standing trees, then the averaging volume of a single tree in the forest stand will be obtained.

Then the relation between these values and a crown diameter is as in Fig. IV-28. As the result of application of the relation to the following first, second and third degree formulae of(14), the second degree formula of(14)indicated such coefficient of correlation as high as 0.947.

$$\overline{IV} = -0.617 + 0.305C \qquad (13)\ R = 0.925$$

$$\overline{IV} = 0.474 - 0.252C + 0.0672C^2 \qquad (14)\ R = 0.947$$

$$\overline{IV} = 0.195 - 0.00787C + 0.00587C^2 \qquad (15)\ R = 0.946$$

$$\overline{IV} = 0.178 - 0.000683C^2 + 0.00583C^3 \qquad (16)\ R = 0.946$$

$$\overline{IV} = 0.667 - 0.423C + 0.115C^2 - 0.00425C^3 \qquad (17)\ R = 0.946$$

where, $\overline{IV}$: estimated volume of single tree

C: crown diameter

R: coefficient of correlation

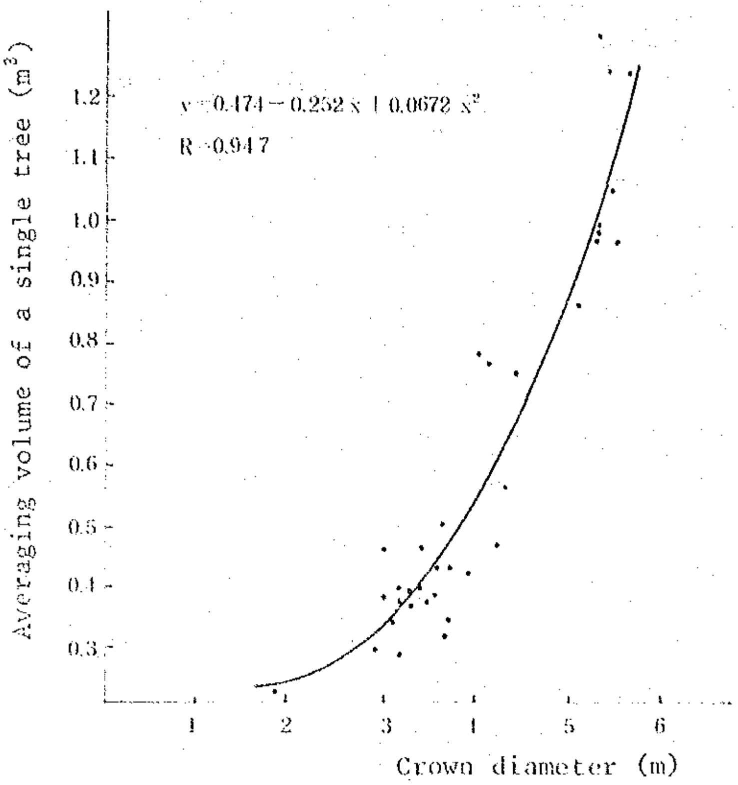


Fig. IV-28 Crown diameter and averaging volume of a single tree

(c) Application of number of standing trees

The relation between the mean of the number of standing trees measured by individuals on air-photograph (hereafter referred "photo-number of trees") and actual number of standing trees is as in Fig. IV-29, which can be expressed in formula (19) as below.

$\bar{N} = -144 + 1.82FN$ (18) R = 0.946

$\bar{N} = 56.6 + 0.730FN + 0.00132FN^2$ (19) R = 0.953

where, $\bar{N}$: estimated number of standing trees

FN: photo-number of trees

R: coefficient of correlation

When we examined the average ratio of photo-number of trees by the above formula(19) against the real number of standing trees, as shown in Table IV-29, the ratio is 70% or more for the real number of 500 trees/ha or less, and 60% or more for the real number of 1000 trees/ha or less, thus showing such number of trees can be counted by air-photograph.

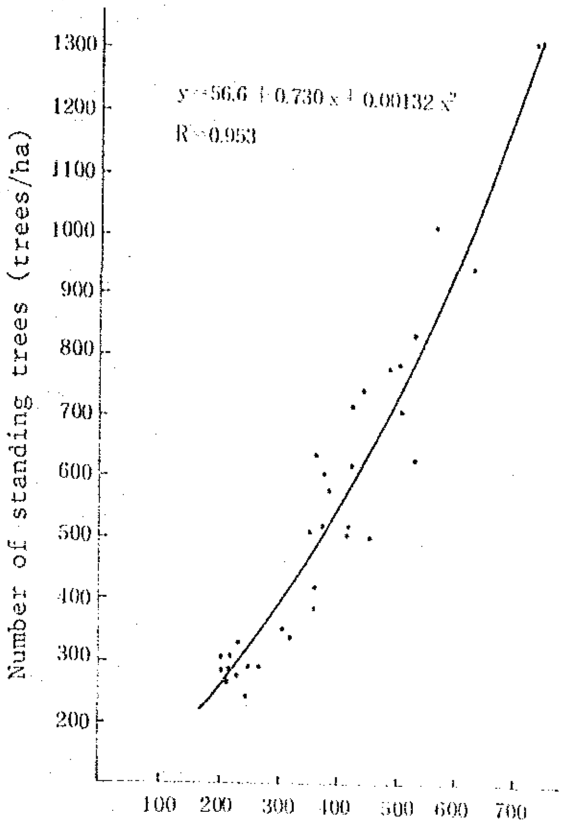


Fig. IV-29 Photo-number of standing trees and standing number of standing trees

Table IV-29 Averaging ratio of the number of standing trees to the photo-number of trees

Number of standing trees (trees/ha)	Averaging photo-number of trees (trees/ha)	Photo-number of trees / Number of standing trees x100 (%)
142	100	70
255	200	78
394	300	76
564	400	71
752	500	67
970	600	62
1214	700	58

(d) Combination of adaptable formulae

The formula of volume of a forest stand expressed in the average diameter at breast height, the average tree height and the number of trees in a forest stand is hereby again shown as below.

$$\overline{V} = a + b \times DBH \times H \times N$$

where, $\overline{V}$: estimated volume

DBH: average diameter at breast height

H: average tree height

N: number of standing trees

a,b: coefficients

Here, if the relation between volume of a single tree obtained by (diameter at breast height) x (tree height) and the crown diameter by air-photograph is expressed in the formula(14) with height coefficient of correlation, and the relation between the number of standing trees and photo-number of trees is expressed in formula(19) with high correlation, then the estimation of volume in a forest stand could be obtained, by the calculation of the estimated value of volume of a single tree by formula (14) and (19) multiplied by estimated number of standing trees. The calculation was tried, since a certain extent of accuracy is expected. If expressed in formula, it will be as follows.

$$\overline{V} = \overline{IV} \times \overline{N}$$

where, $\overline{V}$: estimated volume

$\overline{IV}$: estimated average volume of single tree by formula (14)

$\overline{N}$: estimated number of standing trees by formula (19) from the photo-number of trees

Table IV-30 compares the averaging volume of a single tree, the ground value and estimated value of number of standing trees, the ground value of volume of a forest stand, and the product of multiplication of these estimated values. The correlation with the estimated volume is relatively high as 0.786.

Table IV-30 Single tree volume and number of standing trees, and the estimate of forest stand volume

Section No.	Averaging single tree volume (m^3)		Number of standing trees (trees/ha)		Forest stand volume (m^3/ha)		Error of the estimation of volume (m^3/ha)
	Actual measurement	Estimated	Actual measurement	Estimated	Actual measurement	Estimated	
3	0.383	0.324	520	575	119.2	186.3	− 12.9
21	0.360	0.376	740	629	266.5	236.5	− 30.0
22	0.335	0.340	710	769	237.9	261.5	+ 23.6
23A	0.339	0.464	620	593	209.9	275.2	+ 65.3
23B	0.379	0.440	780	716	295.4	315.0	+ 19.6
27B	1.006	1.029	280	312	281.6	321.1	+ 39.5
28	0.754	0.669	280	340	211.1	227.5	+ 16.4
33	0.388	0.396	635	483	246.1	191.3	− 54.8
39	0.499	0.440	420	489	209.6	215.2	+ 5.6
40	0.461	0.396	950	1023	438.2	405.1	− 33.1
80	0.373	0.357	790	747	295.0	266.7	− 28.3
81	0.389	0.376	500	655	194.5	246.3	+ 51.8
83A	0.426	0.440	715	601	304.6	264.4	− 40.2
83B	0.471	0.543	607	508	285.7	275.8	− 9.9
111	0.229	0.239	1320	1303	302.0	311.4	+ 9.4
114	0.428	0.464	510	471	218.4	218.5	+ 0.
129	0.563	0.635	350	396	197.0	251.5	+ 54.5
144	0.980	1.029	346	343	339.0	353.0	+ 14.0
157A	1.046	1.076	275	288	287.6	309.9	+ 22.3
157B	0.963	1.029	325	295	313.1	303.6	− 9.5
160	0.977	1.029	308	253	300.9	260.3	− 40.6
161	1.239	1.076	267	270	300.9	290.5	− 40.4
167	1.301	1.029	240	308	312.3	316.9	+ 4.6
312	1.242	1.224	308	271	382.4	331.7	− 50.7
313	0.308	0.464	580	525	178.5	243.6	+ 65.1
315	0.939	1.124	282	258	264.9	290.0	+ 25.1
319	0.420	0.515	520	511	218.5	263.2	+ 44.7
332	0.858	0.939	280	283	240.1	265.7	+ 25.6
336	0.369	0.417	510	579	188.4	241.4	+ 53.0
338	0.775	0.543	385	488	298.4	265.0	− 33.4
339	0.761	0.573	340	415	258.9	237.8	− 21.1
349	0.460	0.324	630	803	289.5	260.2	− 29.3
361	0.288	0.310	1015	883	292.7	273.7	− 19.0
446	0.275	0.357	840	794	231.1	283.5	+ 52.4

④ Preparation of volume table by air-photograph

(a) Multiple regression analysis

Using the estimation formula of the volume of an averaging single tree and the number of standing trees, the estimated volume, which is resulted by the product of multification of the estimated values thus respectively obtained, indicated rather high correlation (0.786) as above. This volume is developed as below, making the volume estimated in the multinominal formula.

$$\overline{V} = (\text{estimated formula of volume of a single tree (14)}) \times (\text{estimated formula of number of standing trees (19)})$$
$$= 26.8 + 0.346FN + 0.000626FN^2 - 14.3C - 0.184FN \cdot C - 0.00033FN^2 \cdot C + 3.80C^2 + 0.0491FN \cdot C^2 + 0.0000890FN^2 \cdot C^2 \quad (20)$$

where, $\overline{V}$: estimated volume
FN: photo-number of trees
C: crown diameter

However, as the coefficients in the formula(20) are the combination of those coefficients, which are intended to separately estimate the volume of an averaging single tree or the number of standing trees, so if the estimation formula of volume can be made newly by the multiple regression calculation using those 8 variables, the formula of higher accuracy is expected to be obtained.

However, even if the volume can be estimated with high accuracy by a multiple regression formula of 8 variables, the range of its adoption will not be expanded. So, 3 variables at most will be adequate to be handled, also from the consideration of the practical use of the formula.

Therefore, by combining these variables by trial-and-error, the multiple regression calculation was repeated. The results are as in show Table IV-31, and the 10th trial of calculation as below (21) shown the heighest correlation (correlation coefficient 0.811).

$$\overline{V} = 27.6 + 1.37C^3 + 0.0000320FN^2 + 0.000240FN \cdot C \quad (21)$$

Table IV-31 Table of multiple regression calculation

Number of calculation \ Variables	Constant	C	C^2	C^3	FN	FN^2	FN·C	FN^2·C	FN·C^2	FN·C^3	Multiple Correlation coefficient
I	-506	118			0.814		-0.00527				0.790
II	-226		11.3		0.535		0.0719				0.796
III	-272	85.2				0.000593	0.0760				0.796
IV	-114		9.07			0.000137	0.113				0.801
V	-71.9			1.29		0.000344	0.135				0.804
VI	-458	112			0.667			0.0000500			0.792
VII	-96.3		10.1		0.229			0.000181			0.806
VIII	-226	88.1				0.000123		0.000134			0.800
IX	33.9		9.58			0.000177		0.000203			0.808
X	27.6			1.37		0.0000320		0.000240			0.811
XI	509	119			0.810				0.00105		0.790
XII	206		9.88		0.606				0.0142		0.795
XIII	188	63.2				0.000621			-0.0189		0.796
XIV	54.4		6.00			0.000531			0.0248		0.799
XV	21.5			0.807		0.000185			0.0276		0.802
XVI	467	106			0.770					0.000832	0.790
XVII	163		7.22		0.597					0.00370	0.792
XVIII	-29.9	18.9				0.000514				0.00598	0.795
XIX	16.4		1.27			0.000512				0.00657	0.795
XX	24.5			0.169		0.000503				0.00664	0.795

Table IV-32 Photo volume table of araucaria artificial forest

Crown diameter (m) \ Photo-number of trees (trees/ha)	900	850	800	750	700	650	600	550	500	450	400	350	300	250	200	150	100
1.8	411	371	333	297	263	232	203	176									
2.0	453	408	366	327	289	255	223	195	167								
2.2	496	448	401	357	317	279	244	212	182								
2.4		486	436	389	344	303	265	230	199								
2.6			472	421	373	329	288	250	216	185	157						
2.8			508	454	403	355	311	271	234	200	170						
3.0				488	433	382	335	292	253	217	185						
3.2					464	410	360	314	272	234	200	170					
3.4					497	440	387	338	293	252	217	185	158				
3.6						470	414	363	316	273	235	201	172				
3.8						502	443	388	339	294	254	218	188				
4.0							472	415	362	316	274	237	205	177	155		
4.2							504	443	389	340	296	257	223	194	171		
4.4								473	416	365	318	278	242	212	188		
4.6								505	445	391	343	300	263	232	206	187	172
4.8									475	419	369	324	286	253	226	206	191
5.0									507	448	396	350	310	276	248	227	211
5.2										479	425	377	335	300	271	249	233
5.4											456	406	363	326	296	273	257
5.6											488	437	392	354	323	299	282
5.8												469	423	384	352	327	309
6.0												504	456	416	382	357	330
6.2													491	449	415	388	369
6.4														485	449	422	402

Table IV-33 Table of results of the estimation of volumes

Section No.	Actual measurement of volume (m^3/ha)	Estimated volume (m^3/ha)	Error of estimation (m^3/ha)	Confidence range (95%)	
				Lower limit	Upper limit
3	119.2	189.9	-9.3	164.5	215.2
21	266.5	234.3	-32.2	217.5	251.1
22	237.9	268.8	30.9	250.9	286.6
23A	209.9	257.9	48.0	241.5	274.3
23B	295.4	299.8	4.4	276.1	323.5
27B	281.6	309.1	27.5	287.7	330.7
28	211.1	219.8	8.7	199.8	239.9
33	246.1	188.4	-57.7	163.6	213.3
39	209.6	207.1	-2.5	186.5	227.8
40	438.2	409.6	-28.6	355.1	464.0
80	295.0	270.2	-24.8	252.4	287.9
81	194.5	244.5	50.0	228.3	260.8
83A	304.6	251.2	-53.1	235.1	267.3
83B	285.7	251.3	-34.4	235.7	266.8
111	302.0	299.3	-2.7	230.2	368.3
114	218.4	208.6	9.8	188.1	228.9
129	197.0	233.2	36.2	216.4	249.9
144	339.0	323.6	-15.4	300.7	346.5
157A	287.6	311.1	23.5	288.0	334.2
157B	313.1	301.0	12.1	279.8	322.2
160	300.9	283.2	-17.7	260.8	305.6
161	330.9	303.0	27.9	279.8	326.2
167	312.3	307.2	5.1	285.9	328.5
312	382.4	344.9	-37.5	314.4	375.4
313	178.5	230.0	51.5	213.1	246.9
315	264.9	311.3	46.4	285.9	336.6
319	218.5	243.0	24.5	227.2	258.8
332	240.1	271.1	31.0	251.8	290.5
336	188.4	233.0	44.6	216.4	249.7
338	298.4	242.6	-55.8	226.9	258.3
339	258.9	221.8	-37.1	203.5	240.0
349	289.5	271.1	-18.3	252.5	289.8
361	292.7	290.2	-2.5	267.9	312.5
446	231.1	288.9	57.8	268.2	309.6

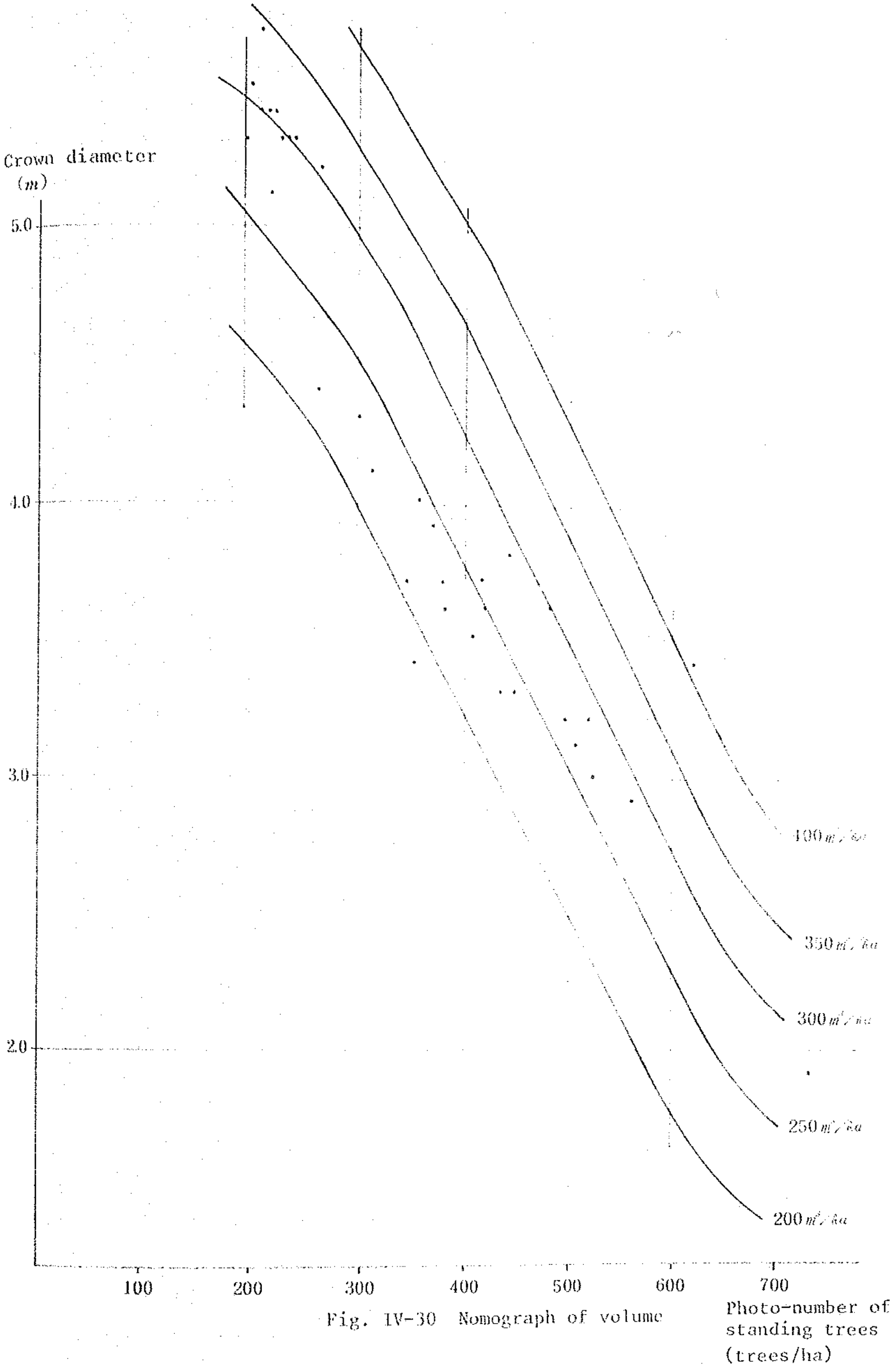


Fig. IV-30 Nomograph of volume

(b) Volume table by air-photograph

Using the formula(21), the volume table by air-photograph was made as in Table IV-32. Further, the comparison of the volume in each forest stand with the estimated values is shown in Table IV-33.

(c) Volume chart

The graphic representation of the above table is the volume chart as in Fig. IV-30, which is convenient to know the approximate volume from the photo-number of trees and the crown diameter, and also clearing the relation between these three values.

⑤ Consideration

(a) Appropriateness of ground data

The forest age, which were collected in this study, were ranged over from 16 years to 50 years age. Among them, as seen in Fig. IV-20, the frequency of both 20-30 years age and 40-50 years held 20% or more respectively, while 10% or less for 30-40 years age, whereas only one data for 16 years and none for 41-45 years, thus showing that the data were not uniformly collected for tree ages.

Those black spots in the volume chart in Fig. IV-30 were the real data used in the estimation of volume. These indicate that the data for crown diameter of 4.0-5.0m and for photo-number of trees of 300-500 trees/ha are in short. If these data are added, the chart will become most trustable.

Next, in same Fig. IV-30, when the distribution range of number of standing trees for crown diameter 5 m or more is noticed, the ground data is 240-346 trees/ha, against photo-number of trees of 190-270 trees/ha, in any case, the number of standing trees seems to be rather small. Therefore, the values of estimated volume of forest section of crown diameter of 5 m or more tend to concentrate around 300 m^3/ha, and the ground data close to this value.

Considering from these matters, those data are by the very careful practice, and this is also learned from the thinking condition by outside data as in Fig. IV-17. This shows that the thinning was always carried out prior to the contact of adjacent crowns especially on tall trees. Therefore, this is the point to be carefully considered when this study is applied to araucaria artificial forests on which careful thinning has not been carried out. The reason is, there is the possibility of deformation in crown due to the competition between crowns in such artificial forests, and so such consideration should be made using the aerial volume table which was made without such care.

(b) Use as the guide for practice

In the previous section, it is said that the data used in this study are those for the well-tended forest stand. Contrariwise, when such tending practice is aimed, the monitoring use of the study could be imagined by means of photo interpretation on araucaria artificial forest.

At first, from the relation of the diameter at breast height and the number of standing trees shown in Fig. IV-25 (3 (a) c), the relation, where the diameter at breast height is substituted with the crown diameter, is shown in Fig. IV-31; and the relation, where the diameter at breast height is substituted with the crown diameter, is shown in Fig. IV-31; and the relation, where the number of standing trees is substituted with the photo-number of trees, is shown in Fig. IV-32. Both axes in Fig. IV-32 are the interpreted values from air-photograph. Taking account of the high correlation, it is presumed that the ground practice was made by some rule, and if this adopted hypabola is the ideal thinning curve, it shows, for example, at point A the thinning is delayed, while for B and C points, a desk policy could be taken, to postpone thinning and wait the growth of trees, i.e. the growth of crown.

(c) Equalization of interpretation technique

It is proved that if the mean value of the data by measures by this method is always used, the estimation of volume of sufficiently allowable accuracy is possible. The equalization of interpretation technique hereafter is inferred as not so difficult problem.

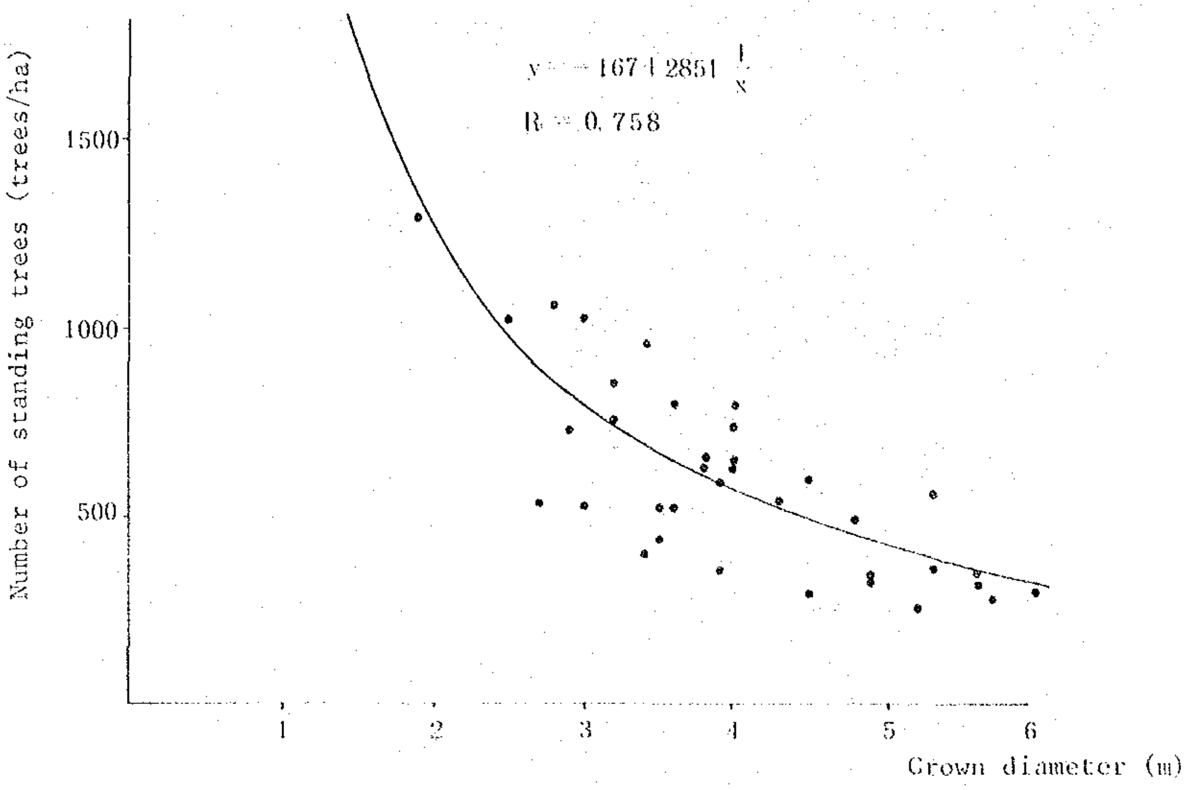


Fig. IV-31 Crown diameter and number of standing trees

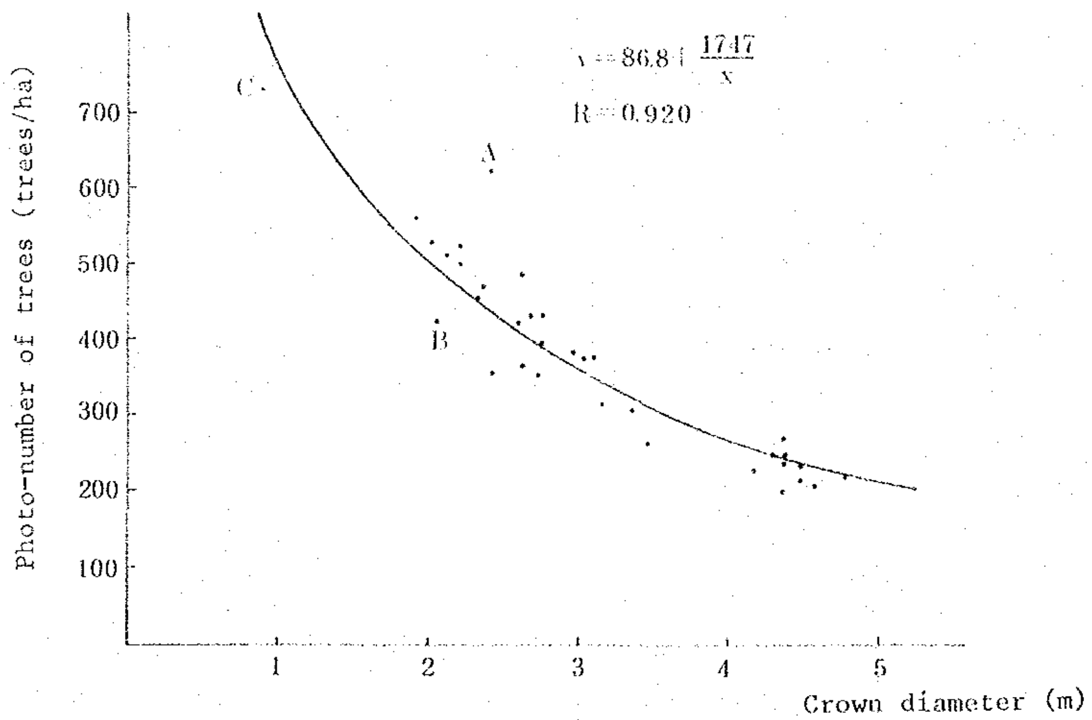


Fig. IV-32 Crown diameter and photo-number of trees

(3) Forecast and problems

It is a great accomplishment that in this study, by the completion of the photo volume table on araucaria artificial forest, the procedure of preparation, the detailed precautions, etc. were learned, so the unassisted adjustment of the same table on various tree kinds hereafter became possible. Further, the results of this study was contributed to International Conferrence of Remote Sensing held in Rio de Janeiro in June 1984.

In addition, the report of study including the mannual in Portuguese, which is the content of the guidance of interpretation technique in the previous section, has been made. As Forest Board realized it instructive to general researchers in the board, so decided to print as the official report.

① Reading of average tree height in comparison

Here, as for the problems when the photo volume table is attempted to apply to other tree kinds, the crown diameter factor which was used in this study is considered very difficult to apply to pine trees or eucalyptuses as far as experts regard. The main reason is because many of these artificial forests grow very thickly, and the whole tree crowns rarely appear on photos. Then the volume must be supplemented with factor of tree height, but this cannot be recommended, since there is a problem in the accuracy of the measurement of tree height.

Hence, it is recommendable to acquire such technique as to read out, taking a forest stand a unit, as compared with other unit forest stand, in which stand the volume is higher averagely, and how much the extent of the difficult is. Generally called "comparative reading", this needs the accumulating experience to read always a forest stand as a unit, and requirs the abundant ground data to make proper judgement. So it is not accomplished in a short period, but should be kept in mind as the guide line of improving the reading technique.

Further, this technique has a strong effect on availing of air-photograph, and directly connects with, for example, the interpretation of forest aspects as well as stratification of forest, which is needed on forest survey.

② *Application to natural forest of araucaria*

Although in recent years the artificial forest of araucaria in Brazil has rapidly increased owing to the afforesting policy of the country, its absolute quantity is less than natural araucaris. Whereas natural araucaria forests are few in unmixed state but tend to exist dispersed separately, so our knowledge does not grasp much of them.

Since one of characteristics in the application of the photo volume table is, as previously described, that it is a simple way to know a tentative volume for unknown forest, for a short time of survey and with low cost, it will be an ideal use of the table to use in the utilization for natural araucaria forest.

Speaking of some of experts' opinions, at first, the factor of a crown diameter, on which importance is set, will be effective in natural forests. However, since a tree figure (means the relative figure between a stem and a crown) may remarkably differ in ridge line or ravine where it grows, the survey of these is to be done. It may be considered to subdivide further into intermediate portions, as circumstances require.

Next, on these subjects, a field survey on a single tree shall be conducted so that the relation like a single tree volume and a crown diameter, etc. may be learned for each part (stratum) of forest. If necessary, the survey on the factor of tree height shall be added.

The survey of above matters could be an independent study subject by itself. If any relation is recognized, the forest aspects photo interpretation, in next stage, shall be conducted with the density of standing trees for the whole area of the subject of survey, and stratified.

Concerning each aspects thus stratified, reading and measurement are conducted on the representative araucaria, and the field survey on the subject is repeated. It depends on the aimed accuracy how many times such survey shall be repeated.

IV-4 Method of Predicting Area in Danger of Devastation Land

IV-4-1 Photo Interpretation on the Devastated Land and Devastation Factor

(1) Purpose

At present it is necessary in Brazil to learn what factors or the combination of factors may cause those places, where suffer various damages by flow away of soil, i.e. soil erosion due to the rapid increase in farmland and pastures, and where tend to suffer soil erosion that may affect the water polution problem. As for the analysis method, there is a method of predicting area in danger of erosion.

On the other side, since the danger of damage by the collapse of hill-side in the mountain near sea-side has been becoming more and more urgent as the polution has increased, the combined use for predicting area in danger of hill-side collapse has been attempted.

In this project, the purpose was to study the way to apply the remote-sensing technique in the process to practise these analysis methods.

i) Application of the forest interpretation learned by the use of air-photograph.

ii) Learning of interpretation technique by air-photograph on the eroded or devastated area.

iii) Way to collect data on various factors concerning method of predicting area in danger, and the development of the technique thereof.

iv) Study of the way to accumulate, manage and process the data by survey.

Here, concerning a series of study results on method of predicting area in danger of erosion and devastation in our department of watershed management will be referred. In this section, the developing process of the progress and use of remote-sensing technique is mainly discussed.

(2) Process and accomplishment

① The actual status of collapsed or eroded areas, and the study of concerned factors

When the interpretation of the devastated or eroded area was attempted by the use of remote-sensing technique, the scale, the state of distribution, the conditions of land surface, etc. were surveyed, the size of a mesh to be used in the analysis by the department of watershed management was considered, and at the same time, the field survey were proper to be adopted.

As the result of a field survey, it was judged that the size of the collapsed or eroded area could be interpreted by air-photograph, and that the mesh-size and concerned factors, which were the basis of the prediction on the devastated land, could be the same as those used in our country.

② Application of forest interpretation method

*Using the already learned interpretation technique on tree-*species, height and tree density, artificial forests can be classified into several grades, and by the aid of the interpretation technique on tree crowns and density, the reading of the aspects of natural forests becomes possible, For devastated areas, adequate interpretation should be attempted, with the understanding on the analysis theory of judgement of the devastated dangerous areas and with through knowledge on the difference in analysis results due to the different mechanism by erosion and devastation. Further, as this prediction method is based on a statistical method, the care should be taken, on practice, on the balance among categories in a factor. Concretely, it was fundamentally tried to read as minute division as possible, and such data were properly streightened up in the processing stage of quantification type II calculation. However, it was realized that in natural forest, it was hard to find objectively the border line between different forest aspects, so more experiences were required.

After all, the classification adopted in the prediction method of erosion in dangerous area was only "artificial" and "natural", partly due to the low forest area ratio against total area. In the prediction method of devastation dangerous area, surveyed forests were all natural and they were classified into the "second growth forest" existing on gentle slopes, the natural forest not including large diameter trees" growing on ridges, and others only into "natural forests".

③ Interpretation of devastated land

The interpretation of devastated land was carried out on how the trace of a small amount of soil flow away on the ground surface would appear on the air-photograph taken at the altitude of about 4000 meters against the ground, by the field survey. Further it was noticed that distinguishing, from artificial bare ground like farm land, and other various field checks were at first necessary. In addition, the scale of photograph and the printing condition were studied. Further, the grading of eroded land, the setting of border line, etc. were uncertain factors, but were properly processed, based on the nature of the method.

Slope collapsed land was almost clearly interpreted, without any special difficulty. However, since the air-photograph were taken with a wide angle lens (focal distance 153.5 mm) regardless of the steep topography of the subject area, it was rather hard to look stereographic scopically both of ridge line and valley line at the same time (the maximum height difference 300m), so it was difficult to transcribe the slope collapsed area on a topographical map. In spacious Brazil, due to the topological reason, etc., the popularized use of long focal distance lens photos is not expected, so the transcription from wide angle photos may also be regarded as a sort of technique.

④ Interpretation of topographical factors

Normally, as for the factors used in the prediction method of devastated dangerous land, slopes, directions, vertical cross section shapes, horizontal cross-section shapes, existence or not of valley streams, etc. are thought of. These were mainly interpreted from a topographical map. Also, the interpreting training of the slope and partial topography from air-photograph were carried out, since these were required in the survey of soil depths.

⑤ Other factors

Other factors are mainly obtained from the field survey and outside materials, among which the density of paturage and soil depths are exemplified. Regarding the density of pasturage, a model-like method was only once attempted on basis of the photo interpretation, so this was only a trial, not the subject of analysis study.

As for the survey of soil depths, since the local counterpart personnel was an expert in soil and topography, the existing ability was sufficient. However, in the determination of the plane distribution of soil depths, the above photo interpretation technique of topography was used.

⑥ Analysis by quantification method

As for the quantification method, the quantification type II to the devastated and category weights were examined. These results are, after the examination by also using the simple correlation analysis between devastated land and the categories of devastation factors, regarded as reasonable in Brazil.

⑦ Topographical analysis

The group of topographical factors in above are to interprete each topographical factors in every mesh.

Ordinarily, the size of the subject area to be used in the prediction method of devastated land is said to be 2000 - 3000 ha, but the interpreting work in all meshes for all topographical factors is so enormous that sometimes it may lack the objectivity.

Due to the above reasons, it is desirable to develop more objective, automatic interpretation, even though its accuracy may be a little inferior. So, in this case, the cross-point method and the middle-point method were attempted, which could derive slopes, directions, and local topography by computer processing from the data of the height above sea-level. Afterall, the cross-point method was found to be applicable to the prediction of devastated dangerous land.

⑧ Data processing system

Mesh data are adopted in the prediction of devastated dangerous land. This could be the base of a data-bank system by multiple-stage method in future, which can be used in various fields, and at the same time, could be a beneficial system for data storage in future, so this method is regarded spreadable. Hence, the unit of mesh is determined for both of 400 ha and 1 ha, that are codified. The sizing of a unit mesh observes UTM and so it is invariant. These two unit meshes were decided so that they may adapt to the existing topographical map scale of 1/50,000 and 1/10,000 both.

(3) Method of predicting area in danger of erosion

① Study method setting up

One of important subjects of this study, always intending to improve the remote-sensing technique, is to search for the way to collect quickly and exactly the required various information, and to make the most suitable method to Brazilian society. To achieve that, at first one must minutely analyse and examine various problems occuring while carrying out the procedures by the prediction method of devastated dangerous land and repeat to exert one's originality for the solution. Hence, we decided to proceed the work with the below four points as fundamental plans.

i) Digitalized information by a mesh process
ii) Extension of the interpreting technique
iii) Establishment of the computer processing
iv) Application of the topographical analysis

② Subject area of survey

Prior to determine the subject area of survey, the mesh system was set up, with the X-Y coordinates (UTM coordinates) as a standard, with the origin at the capital Brazilia, whereby intending the start of a data bank by the storing of multiple data, that will enable the various data used in the prediction method of devastated dangerous land to be repeatedly availed in many fields in future. Fortunately, the existing

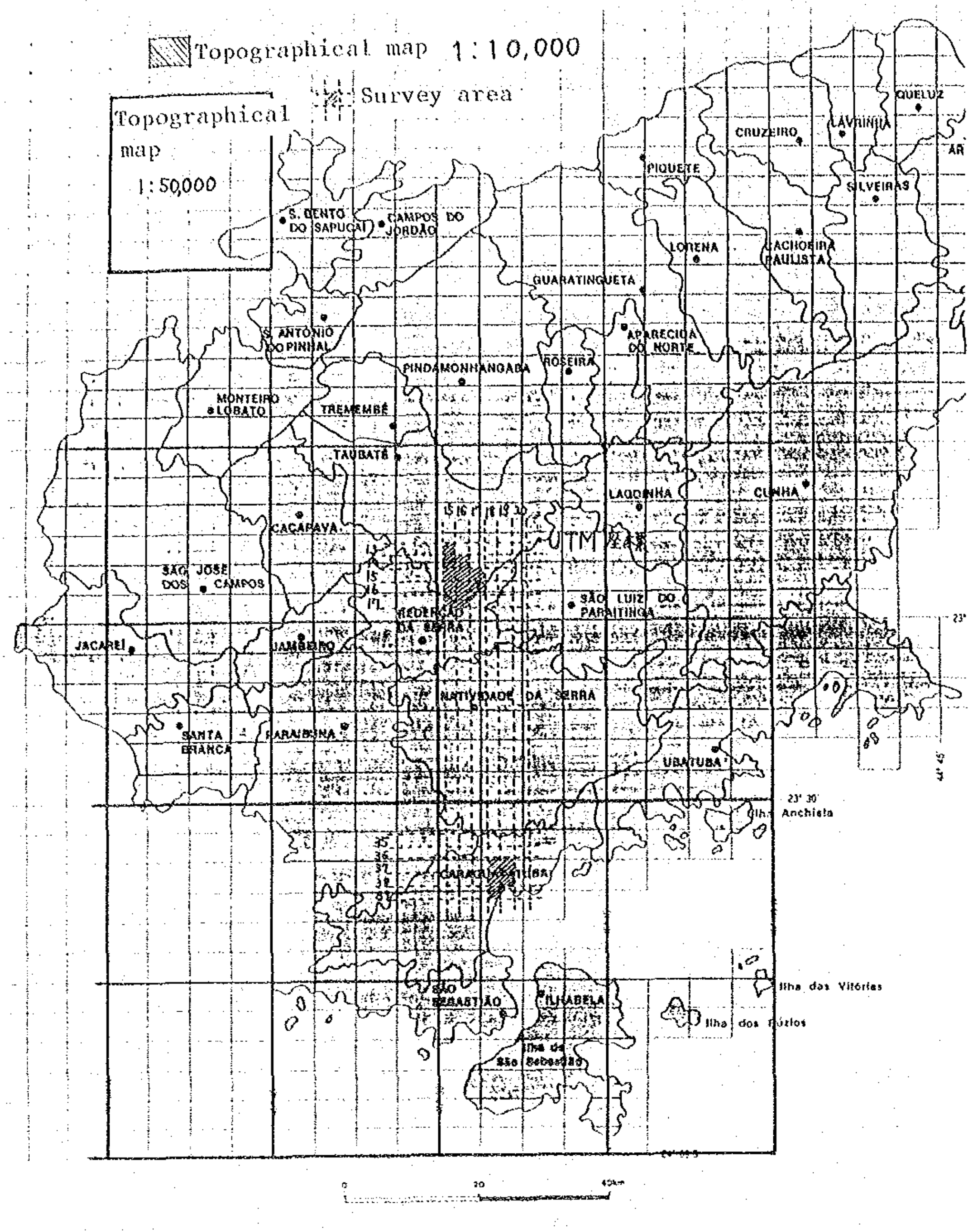


Fig. IV-33 Relation between 400 mesh and topographical map

topographical maps of 1/50,000 and 1/10,000 were provided with the X-Y coordinates, and besides, ordinates were marked every 2 km on the map of 1/50,000. Hence, this was made as a unit (400 ha) of mesh information, and code numbers of two figures were given to each direction of east, west, north and south, which were registered in computer (Fig. IV-33).

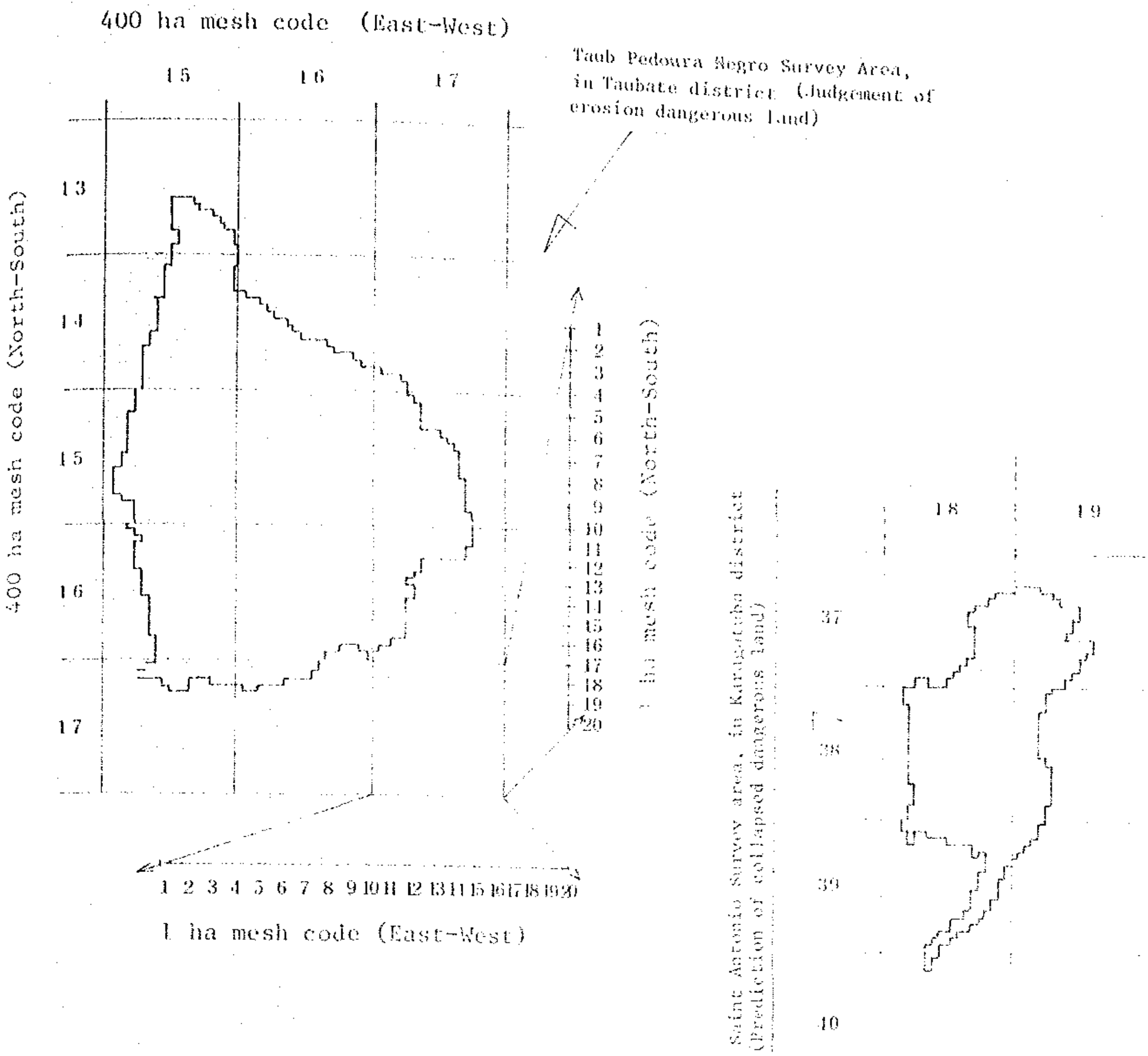


Fig. IV-34 Mesh code of survey area

Next, said 400 ha mesh is divided into 1 ha meshes (100 x 100 m), which are also code-numbered from 1 to 20 in four directions. Further, on the minimum 1 ha mesh, the code numbers of the administrative section as well as the basin section, to which the unit mesh belongs, are also input in a computer. As for the first stage to collect and store the data which were located with codes of mesh in whole constitution, and as the proper place to practise the prediction method of eroded dangerous land, 2291 ha in the basin of Pedoura Negra River, at 130 km northeast of St. Paulo city, was determined. This place has a gentle, hilly landform, and is rich in farmland and pastures. (See the section of basin management in detail.)

The shape and area of the subject area and code number are as in Fig. IV-34.

③ Air-photograph

Used air-photograph was taken in June 1973, with the scale of 1/25,000. This photo was enlarged in twice, and used with the scale of 1/12,500.

Other material use are, topographical maps (with scale of 1:10,000 and 1:50,000, a soil map and a geological map (scale 1:250,000). (Table IV-34)

Table IV-34 Photographing conditions

Photographed area	Date of photographind	Course No.	Focal distance	Photo No.	Number of photos
Taubate	June 23, 1973	Fx.273I	153.2 mm	46613-46614	2
"	June 24, 1973	Fx.277J	"	46813-46816	4
Karagatatuba	June 7, 1973	Fx.294J	"	43185-43186	2
"	June 7, 1973	Fx.293J	"	43205-43206	2

④ Survey method

(a) Interpretation of soiled land

The extent of soil erosion ranges from so slight as hardly noticeable to so deep as may lead to the corruption. In addition, erosion has continuous vastness in a plane. One must learn how extent of erosion is expressed in the photo taken at the altitude of 4,000 m. For that, a field survey must be repeated. In this report, one should judge which extent of erosion is expressed in photos.

As the result, erosion were classified into two types for interpretation as shown in Table IV-35. When classified by the normal erosion type, type 1 is the surface erosion to light rill erosion, while type 2 exceeds 1 and ranges to gully erosion.

Table IV-35 Guide to the interpretation of eroded land

Photo-image	Erosion type 1	Erosion type 2
Colour tone	Darkish white	Clear white
Fines of image	Often includes darkish spots and string-likes in white background	Almost uniformly white
Pattern	Often forms a whitish bandle-like pattern, connected with a white string-like.	Shows rather evident sections

Since the phenomenon of erosion was irregular extension as described above, even though the erosion type could be classified by photo tones, finess or shadows, etc., it has uncertain elements when it is demarcated into one eroded area as in Fig. IV-35. That is, in Fig. IV-35, A is right, while B cannot be said wrong. However, when A and B are compared in area, that will result in considerable difference. If this is considered only the problem of interpretation, A is better, and ideally, it is most accurate to demarcate small subdivisions. But it is impossible to treat them separately in fact.

In this way, it is the ultimately required data whether erosion exists or not, or if more precisely remarked, how much percentage of the area the erosion holds.

Considering above, the erosion type 1 and 2 were interpreted and divided. Then these were transcribed on a topographical map (1:10,000), by which the ratio of eroded area was read in every mesh.

(b) Interpretation of the coverage on the ground

In the subject area of the prediction method of eroded dangerous land, though mainly there was farmland and pasture in sloped land, partially there existed a reverse case like farmland in sloped land, so by the interpretation on the sections of the use of land in advance, unavailed river-side, villages and farmland were omitted. (The photo-print of farmland resembled in colour tone to eroded land, but it is judged by the fact that the border is man-made and also by the field check.) As the result, after removing the portion of above three categories out of 2291 ha, 1966 ha was obtained, on which element analysis was held.

ⓐ Interpretation of forest

The forest in this subject area is only about 30% of the whole area, among which natural forest holds 9%, while artificial 21%.

Regarding natural forest, it was decided the division would be made on the forest density, classified by every 10% from density of 30% and exceeding, resulting 8 categories made. On the other hand, the artificial forest in this area are mostly of pine trees and eucalyptuses. Pine trees forest were divided into 2 classifications, i.e. "the forest raising land" with the tree height of 2 m or less, and other "artificial forest". Further, regarding eucalyptus, there is special circumstances in its production system in Brazil, its classification standard will be later described after the explanation.

In the production of eucalyptuses, the production period in a forest stand is made for 21 years, during which the clear cutting of twice and the sprout regeneration are repeated. That is, the first clear cutting is made seven years after plantation, and the forest stand regenerated by sprout is cut after 7 more years (total 14 years). After the last cutting after 7 more years (total 21 years), the sprout ratio becomes much lower, so the trees are not regarded as economical forest thereafter.

However, the first and the second clear cutting actually often leave some grown-up trees. Since it is judged that the situation, from immediate after the cutting to the time when trees by sprout grow as high as exceeding 2 m, is comparable with the planted area, some categories as the pine tree planted area are adopted for eucalyptus.

In addition, as the growth of individual trees after plantation or whole cutting is not uniform, by the ratio of standing trees regarded as tall trees, the forest stand is classified into 8 grades, i.e. 30% and every 10% exceeding 30%. These grades are regarded as categories. Therefore, pine trees ("artificial forest"), in other than "the planted land" belong to the same category of "eucalyptuses forest with the tall tree ratio of 100%".

After all, the classification of the forests consists of "second growth forest where trees with the height of 2 m or less holds 80% or more (eucalyptuses forest)" (including the planted land of pine trees), 8 classifications of artificial forest, and 8 classifications of natural forest, that makes 17 classifications in total.

ⓑ Interpretation of grassland

In the prediction method of eroded dangerous land, grassland should be subdivided because to the mechanism of eroded land occurence. Further, since the percentage of grassland is over 70% in order to make it one category, some trouble may be anticipated in the analysis calculation due to data balance.

Whereas, this is a quite new attempt, since it has been hardly practised to interprete grassland itself and further subdivide the land, in the field of photo interpretation in the forestry in Japan. However, by the use of the technique of height discernment by the stereoscopic view that is the basis of the photo interpretation, and the technique of discriminating tones, grain shadows, etc. of photo-images, the above was interpreted and subdivided as in Table IV-36.

Table IV-36 Guide to the interpretation of grass land

Classification	Height of grass	Tone	Finess of imege	Shadow
Grassland less than 10 cm	10 cm or less	very bright	soft and very fine	none
Grassland of 11-30 cm	11-30 cm	bright	soft and fine	exists a little
Grassland of 31 - 99 cm	31-99 cm	bright	hard and course	mostly exists
Grass and tree land of 1 m or higher	1 m or higher	intermedi-ate	soft and course	regularly exists

(c) Interpretation of topography

As for the topographical factors, slopes, directions, ordinate cross section figures, abcissa cross section figures, slope lengths, etc. are thought of, and all of these can be interpreted and measured by the aspects of contour lines in the topographical map (1:10,000).

ⓐ Slope

The number of contour line in a mesh is regarded as the grades (categories) of slopes.

ⓑ Direction

The averaging directions of the slopes in a mesh are classified into eight directions. However, considering the individual differences of a counterpart personnel and workers, and aiming at more exactness, the area with 2 or less contour lines was regarded as "no direction".

ⓒ Shape of longitudinal section

As in Fig. IV-36, when the distance of contour lines above the center line of a mesh is wider than that below the center line, it is regarded as convex, while it is narrow, it is as concave. When no distance difference is observed in the contour lines above and below the center-line, it is regarded as flat.

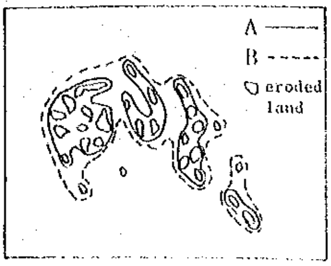


Fig. IV-35 Difference in the Judgement sections

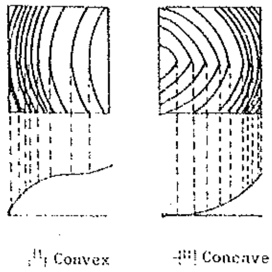


Fig. IV-36 Interpretation of cross-section shape

ⓓ Shape of cross section

The extent of a curve of the contour lines at the center of a mesh was measured as an angle in degrees, then was classified at every 10 degree. According to the ängles thus measured, the slopes were divided into three of convex, concave and flat, where the standard was to be finally determined at the computer processing on the quantification method.

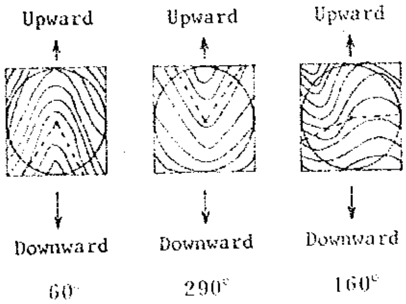


Fig. IV-37 Measurement of Cross section shape

(c) Length of slope

By tracing the line of discharge from the center point of a mesh, the horizontal distance of the steepest slope to the upper ridge line was measured and classified in every 20 m (2 mm on the topographical map).

(d) Other factors

The factors to be used in the prediction method of devastated dangerous land are composed of those obtained by the use of the above described remote-sensing technique and those from survey results obtained by various methods in the specialized fields together with availing of the remote-sensing technique. As for the latter, geological factors, soil factors, soil depth factors, pasture density factors, etc. are exemplified.

In this study, since the subject area was selected, with the premise that the whole subject area had almost similar geology and soil, these factors were not analysed. The reason was because the subject area was not sufficiently extensive to conduct the ordinary analysis in a limited period. The scale of the geological and pedelogical distribution maps was rather rough as 1/250,000, so these factors were concluded improper to attain sufficient accuracy of distribution for the application to relatively small area.

In addition, Taubate district in Pedoura Negra River basin, which was used for the prediction method of eroded dangerous land, geologically consists mainly of migmatite and partially granite, while in the soil type, the Taubate subject area is composed of podzol and latezol.

(a) Soil depth survey

The soil depth has a close correlation with the devastation phenomenon, and is deemed to have a strong influence on the occurrence of hillside collape. However, in order to obtain these data minutely, not only the survey over a long period but also the specialized knowledge of pedology is required.

Hence, in this study, the estimation on the distribution of soil depth was tried in the applicable range.

Generally, it is considered that the soil depth is distributed as peculiar to the soil-type, and there are different depths in local topography.

In this study, as the subject area in Taubate is a gentle hill land, it is deemed different to precise the distribution of locally different soil depth, so the difference in soil type itself was regarded as the distribution of soil depths.

As the procedure of survey, on basis of the existing pedological map, availing of the splay moold of roads in ten places or so, the depths of A, B and C layer were measured, and thus the depth of podzol type soil was determined to 1.4 m, while latezol to 2 m or more, and in addition, the soil-type distribution on the oridinal pedelogical map was modified by the topographical features. As the result, the distributions of the soil types and soil depths became identical.

ⓑ Pasture density survey

This factor, the pasture density was not grasped quantitatively due to the various restrictions.

At first, assuming that the extent of devastation of 8 places near cattle houses would be proportional to the number of cattles. Grading was tried by the photo interpretation. Next, because the pasturage in this district raises mainly dairy cattle, and milk collection was made twice a day, it is assumed that the farther away from cattle houses, the lower the pasture density becomes, so a model, in which the grade is, on basis of the grade of a cattle house, lowered at every 300 m away from cattle houses, it adopted (see the section of watershed management 3-3).

(e) Topography analysis

Slope factors, direction factors and local topographical factors which are obtained from the height data are substituted with those similar factors obtained from the topographical map interpretation, and it was examined whether the utilization to the prediction method is possible or not.

ⓐ Cross-point method

As in Fig. IV-38, besides the height data 1-8 of the cross-point of a mesh, the height data of center point 0 is included, so slope degrees direction angles and local topography are calculated from the above 9 points in total.

At first, the formulae for slope degrees (θ) and direction angles (α) are the following (1) and (2).

$$\sin\theta = \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+1}} \qquad (1)$$

$$\tan\alpha = \frac{b}{a} \qquad (2)$$

$$\text{where, } a = \frac{(z_1+z_2)-(z_3+z_4)}{2D}$$

$$b = \frac{(z_1+z_3)-(z_2+z_4)}{2D}$$

and $z_1 \sim z_4$: the values of height of cross point of mesh 1 - 4

D: mesh distance

Next, the programming procedure of local topography is the one which Watanabe* used in the survey of productive capacity of forest land, and categories classifying topography are as in Table IV-37. It is expressed in a figure IV-39. The procedures are as follows:

i) When, the slope inclination is below 15, using the data of 4 cross-points outside, it is distinguished whether it is a ridge slope or a piled up slope at the hill foot.

ii) When the slope inclination is at 15-45, by comparing the height of center point with the data at 4 corners, it is distinguished whether it is a convex hill-side, a concave hill-side, or an equilibrium hill-side.

iii) When the slope inclination is at 45 or more, it is regarded as an eroded slope at the hill foot.

Table IV-37 Classification items of local topograph by the topographical analysis

Category	Content
Hill top surface	The hill top and its surrounding area, with the slope clination of about 15° or less.
Table land	The top surface of table land.
Hill side equilibrated surface	The part of a hill-slope, existing between hill top table land and hill foot, where its plane shape is almost equilibrated. Here, "equilibrated" means when the curvature (the ratio of the central vertical distance to the chord length) is 1/15 or less.
Hill side convex surface	The part of hill side as above, with the curvature exceeding 1/15, with the convex shape to downward direction.
Hill side concave surface	Same as above, but with the concave shape to downward direction.
Hill foot eroded surface	This is the case when there is a slope-changing point on the hill side surface, near the hill foot. The inclination of slope is mostly 45° or more.
Hill foot eroded surface	Same as above, but the inclination is gentler than the hill side surface. The inclination is 15° or less except when a sudden inclination change exists.

ⓑ Center point method

As its characteristics, the cross-point method requires the height from sea-level besides the height of the cross point of mesh, so it needs more than twice as much as the number of meshes which are the subject of analysis calculation. Hence, it is disadvantageous for the purpose of lessening the enormous volume of work, which is the one of

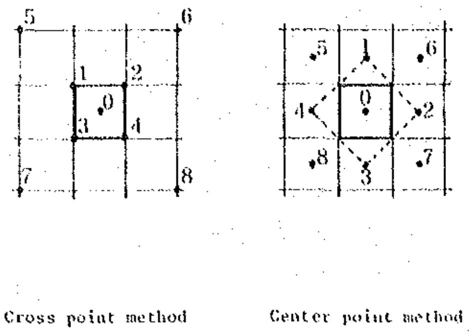


Fig. IV-38 Height above sea-level and location, required for topographical analysis

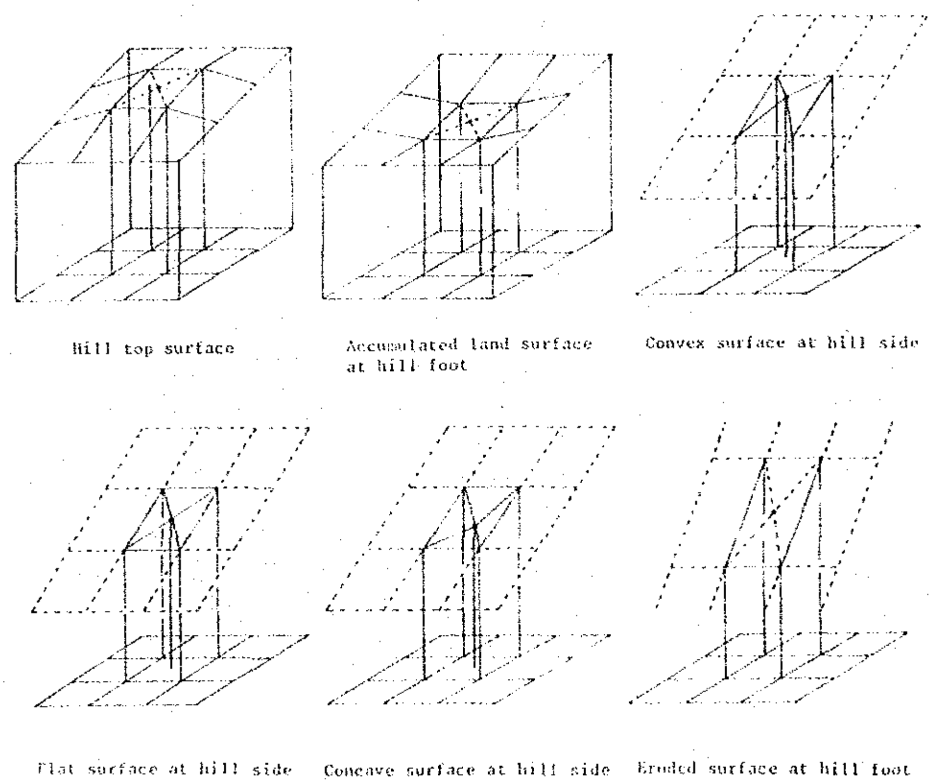


Fig. IV-39 Simulated diagram of local topography by topographical analysis the original purposes.

In this sense, since the center-point method, devised by Sawada Expert, is calculated only with the height from sea-level of the center-point of a mesh, as in Fig. IV-38, it only requires the data a little exceeding the number of subject meshes, so the collection and processing of the data becomes simpler. Whereas, thus obtained slope inclination and direction angle and for the size twice as large as the original mesh (1 ha) (the mesh of the broken line in Fig. IV-38 becomes the subject of calculation), and this is the difference from the cross point method. The formulae to be used and the procedure to judge the local topography are treated as the same as in the cross-point method.

(a) Analysis by quantification method

On the quantification calculation, the registered number of each mesh, area ratio by types of the eroded places in 1 ha meshes, and data of related factors were input as in Fig. IV-40. In addition, the eroded places are expressed in a figure of 1 digit for every type, and graded at every 10% of area ratio against the total area, so can be expressed up to 90% at maximum. Further, regarding the above "other type of erosion", the ratio of eroded area by stream erosion was input, but it was not used in the actual analysis calculation. But the procedure was set out to be used in future, when the similar analysis carried out in other district, or when other analysis calculation is attempted.

ⓐ Combination of erosion types

For the combination of type 1 and 2 of the eroded land, the quantification type II calculation was carried out 27 times, in five different ways, i.e. type 1, type 2, type 1 and type 2, type 1 + 2 x type 2, and type 1 and 3 x type 2, by the others in the column of the external standard in Table IV-29. As the result, the combination of type 1 + 2 x type 2 was best, so it is concluded that as for the number of classifications of outside standards three classifications are best suitable. The detailed analysis results are described in the section of watershed.)

ⓑ Combination of various factors and classification standard

In the previous section ⓐ, at the same time when the combination of erosion types and the classification standard are altered. The classification number (number of category) of inside standard is changed as in Table IV-39. Further, in the 15th calculation and thereafter, the factor of pasture density was omitted as improper, the reason of which was expressed in the section of watershed management. In addition, the number of various classifications in each factor and the classification standard are shown in Table IV-40, enabling the verification with the calculation results in Table IV-39.

(b) Utilization of topographical analysis

ⓐ Input and control of numerical information

On computer processing the topographical factors based on the values of heights above sea level by means of topographical analysis, when data is input, the cross point value (X) and the center point value (˙) are written in separate data sheets in Fig. IV-41.

Since the bound of the subject area is in an complex shape, the number of calculations is made to be as close as possible to the number of subject meshes, by measuring the least necessary number of data for the calculation and inputting 0 for above those outside the bound, but as there is sometimes complicated boundary in the subject area, ultimately in the quantification type II calculation, the number of factors is made to correspond to the mesh numbers which are input by Fig. IV-40. Therefore, on inputting the data of the height above sea level, it is safe to input more data than those for the subject area.

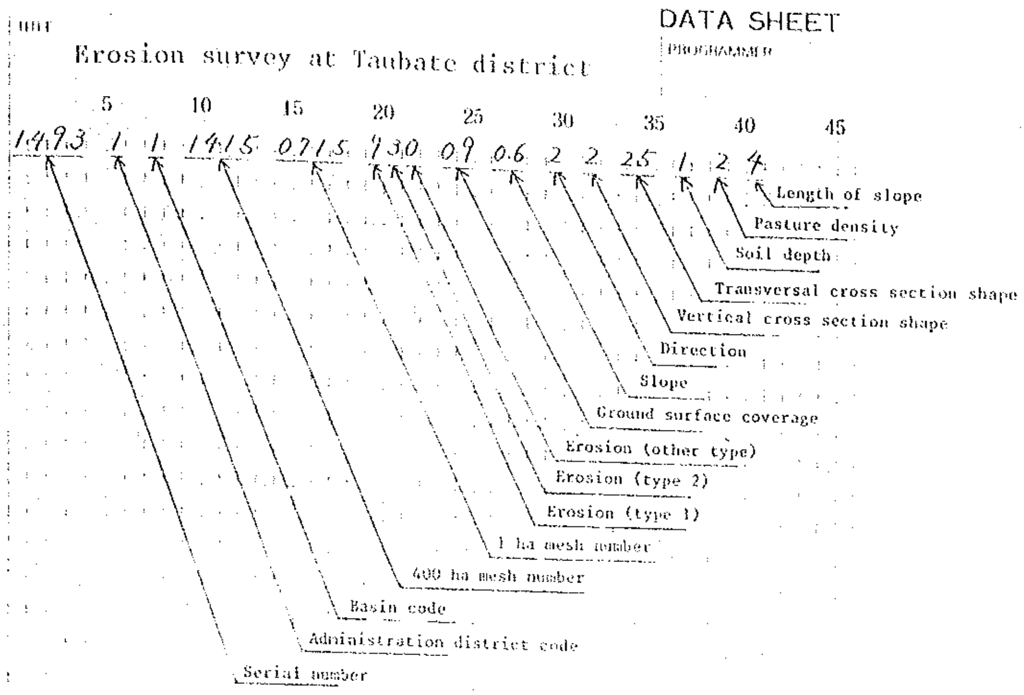


Fig. IV-40 Data input sheet of computer

ⓑ Comparison of results of quantification type calculation

As provided in the classification number of topographical factors used in the 19th calculation of analysis in Table IV-39, that was concluded most proper, and on basis of the classification standards in Table IV-40, judging that the slope inclination and the direction angle would replace the shape of cross section and longitudinal section, with 3 classifications of convex, flat and concave, the quantification type II calculation by the cross-point and center-point method was respectively carried out.

As the results, the correlation ratio thus obtained was 0.3656 by the cross point method while 0.3684 by the center point, and together with the previous value of 0.03566 by the topographical map interpretation, they do not differ so much. Whereas, when the weight of each category by factors are investigated in Fig. IV-42, the cross-section method somewhat resembles the pattern of the category

Table IV-39 Practice of quantification type II calculation
(Prediction of eroded dangerous land)

Number of calculation	Outside standard		Inside standard								Multiple correlation coefficient
	Adopted data	Number of grades	Land surface coverage	Slope	Direction	Vertical cross section shape	Traversal cross section shape	Length of slope	Soil depth	Pasture density	
1	①	4	8	6	9	3	3⑭	3	2	3①	2.1614
2	①	*1 4−10%	8	6	9	3	3⑭	3	2	3①	3.1733
3	②	4	8	6	9	3	3⑭	3	2	3①	0.5080
4	②	4−10%	8	6	9	3	3⑭	3	2	—	0.4939
5	①+②	4	8	6	9	3	3⑭	3	2	3①	2.1189
6	①	4	8	5	9	3	3⑭	3	2	3②	0.3105
7	②	4	8	5	9	3	3⑭	3	2	3②	0.3493
8	①+②	4	8	5	9	3	3⑭	3	2	3②	0.4094
9	①+2×②	4	8	5	9	3	3⑭	3	2	3②	0.4147
10	①+2×②	4	8	5	5	3	3⑭	3	2	3②	0.4074
11	①+2×②	4	6	4	9	3	3⑭	3	2	3②	0.4157
12	①+2×②	*2 3−①	6	4	9	3	3⑭	3	2	3②	0.4151*4
13	①+3×②	4	6	5	9	3	3⑬	4	2	3②	0.4177
14	①+3×②	3	6	5	9	3	3⑬	4	2	3②	0.4175*4
15	①+2×②	2	6	4	9	3	3⑭	3	2	—	6.5158
16	①+2×②	6	6	4	9	3	3⑭	3	2	—	0.3598
17	①+2×②	4	8	4	9	3	3⑭	3	2	—	0.3424
18	①+2×②	3	6	4	9	3	3⑭	3	2	—	0.3563
19	①+2×②	3	6	4	9	3	3⑬	3	2	—	0.3566
20	①+2×②	3	6	5	9	3	3⑭	3	2	—	0.3563
21	①+2×②	3	6	4	9	3	3⑭	4	2	—	0.3562
22	①+2×②	3	6	5	9	3	3⑬	4	2	—	0.3556
23	①+2×②	3	6	4	9	3	3⑯	3	2	—	0.3535
24	①+3×②	4	6	5	9	3	3⑬	4	2	—	0.3582
25	①+3×②	4−①	6	5	9	3	3⑬	4	2	—	0.3121
26	①+3×②	*3 3−②	6	5	9	3	3⑬	4	2	—	0.3125
27	①+3×②	3−②−10%	6	5	9	3	3⑬	4	2	—	0.4104

*1 Calculation was made for all that the outside standard is 1 or more, and for 10% of those random sampled out of which the outside standard is 0.

*2*3 Concerning the type of erosion, in -1 and -2, calculation was made, regarding the erosion 10% and 20% as the grade of "no erosion".

*4 This indicates that it was linearly separated with the score-values between groups.

Table IV-40 Category standard of each factor
(Prediction of eroded dangerous land)

	Land surface coverage	Occupied area (ha)	Eroded raio	Erosion ratio	Category Number	Category Occupied area raio	Category Erosion ratio	Category Number	Category Occupied area ratio	Category Erosion ratio
4	Grass land of less than 10 cm	31	4.7	15.2						
5	Grass land of 11-30 cm	999	97.4	9.7	1	52.4	9.9	1	52.4	9.9
6	Grass land of 31-99 cm	252	10.3	4.1						
7	Grass and tree land of 1m grass or higher	109	1.4	1.3	2	12.8	4.1	2	12.8	4.1
8	Secondary artificial forest	131	4.9	3.7	3	5.5	1.3	3	5.5	1.3
9	Artificial forest including high trees over 2m by 30%	71	0.2	0.3	4	6.7	3.7	4	6.7	3.7
10	〃 40 % 〃	48	0.6	1.3						
11	〃 50 % 〃	38	—	—	5	8.6	1.0			
12	〃 60 % 〃	13	0.9	6.9						
13	〃 70 % 〃	9	—	—				5	13.9	0.6
14	〃 80 % 〃	19	—	—						
15	〃 90 % 〃	12	—	—	6	5.3	—			
16	〃 100 % 〃	64	—	—						
17	Natural forest of the growing density of 30%	10	—	—						
18	40 % 〃	17	—	—						
19	50 % 〃	2	0.1	5.0	7	1.5	0.3			
20	60 % 〃		—	—						
21	70 % 〃	10	—	—				6	3.6	0.6
22	80 % 〃	2	—	—						
23	90 % 〃	4		—	8	2.1	0.7			
24	100 % 〃	125	0.1	0.8						

	Slope inclination		Occupied area (ha)	Eroded area (ha)	Erosion ratio	Category Number	Category Occupied area ratio	Category Erosion ratio	Category Number	Category Occupied area raio	Category Erosion ratio	Category Number	Category Occupied area ratio	Category Erosion ratio
1	1 コンター	(2°50′)	14	0.2	1.4									
2	2 〃	(5°40′)	65	2.4	3.7	1	4.0	3.3	1	11.1	4.3	1	11.1	4.3
3	3 〃	(8°30′)	140	6.8	4.9									
4	4 〃	(11°20′)	255	15.2	6.0	2	20.1	5.6						
5	5 〃	(14°00′)	353	18.1	5.1				2	30.9	5.5	2	30.9	5.5
6	6 〃	(16°40′)	388	29.9	7.7	3	37.7	6.5						
7	7 〃	(19°20′)	314	23.8	6.9				3	47.9	7.1	3	47.9	7.1
8	8 〃	(21°50′)	209	13.0	6.2	4	28.1	6.7						
9	9 〃	(24°10′)	101	5.9	5.8									
10	10 〃	(26°30′)	63	4.9	7.8	5	8.3	6.6	4	8.3	6.6			
11	11 〃	(28°50′)	24	1.1	4.6							4	10.1	6.1
12	12 〃	(31°00′)	8	0.2	2.5	6	1.7	3.8	5	1.7	3.8			
13	13 〃	(33°00′)	2	—	—									

	Direction	Occupied area (ha)	Eroded area (ha)	Erosion	Category Number	Category Occupied area ratio	Category Erosion ratio
1	N	234	22.9	9.8	1	11.9	9.8
2	NE	340	26.6	7.8	2	17.3	7.8
3	E	197	6.3	3.2	3	10.0	3.2
4	SE	220	8.1	3.7	4	11.2	3.7
5	S	103	0.2	0.2	5	5.2	0.2
6	SW	207	5.5	2.7	6	10.5	2.7
7	W	229	12.3	5.4	7	11.6	5.4
8	NW	352	37.0	10.5	8	17.9	10.5
9	Not determined	84	2.6	3.1	9	4.3	3.1

Table IV-40 (cont'd)

Vertical cross section shape		Occupies area (ha)	Eroded area (ha)	Erosion ratio	Category 3: Number	Category 3: Occupied area ratio	Category 3: Erosion ratio
1	Concave vertical cross cut	473	34.7	7.3	1	24.1	7.3
2	Convex vertical cross cut	1177	75.9	6.4	2	59.9	6.4
3	Flat	316	10.9	3.4	3	16.1	3.4

Traversal cross section shape		Occupies area (ha)	Eroded area (ha)	Erosion ratio	Category 3 ⑭: Number	Category 3 ⑭: Occupied area ratio	Category 3 ⑭: Erosion ratio	Category 3 ⑬: Number	Category 3 ⑬: Occupied area ratio	Category 3 ⑬: Erosion ratio	Category 3 ⑰: Number	Category 3 ⑰: Occupied area ratio	Category 3 ⑰: Erosion ratio
1	1°～ 5°	56	2.6	4.6									
2	6°～10°	191	13.9	7.3									
3	11°	34	1.0	2.9				1	19.4	7.1			
4	12°	61	4.1	6.7	1	21.8	6.6				1	29.5	6.7
5	13°	39	5.6	14.4									
6	14°	18	1.1	2.3									
7	15°	83	5.3	6.4									
8	16	68	5.1	7.5									
9	17°	95	5.4	5.7									
10	18°	411	22.3	5.7	2	55.7	5.6	2	61.6	5.5	2	32.6	5.4
11	19°	112	5.8	5.2									
12	20°	107	7.0	6.5									
13	21°	118	7.0	5.9									
14	22°	80	2.8	3.5									
15	23°	68	3.9	5.7							3	37.9	6.5
16	24°	90	6.8	7.6									
17	25°	48	4.4	9.2	3	22.4	7.1	3	19.0	7.4			
18	26°～30°	195	15.3	7.8									
19	31°～35°	40	0.5	1.3									
20	Not determined	22	0.6	2.7	2	Included above No. 2		2			2		

Slope length		Occupies area (ha)	Eroded area (ha)	Erosion ratio	Category 3: Number	Category 3: Occupies area (ha)	Category 3: Eroded raio	Category 4: Number	Category 4: Occupies area (ha)	Category 4: Eroded raio
1	0 ～ 20 m	571	37.7	6.5	1	62.8	5.9	1	62.8	5.9
2	21 ～ 40 m	663	35.0	5.3						
3	41 ～ 60 m	379	26.2	6.7	2	30.0	6.6	2	30.0	6.6
4	61 ～ 80 m	210	12.5	6.0						
5	81 ～ 100 m	74	5.1	6.9	3	7.3	7.1	3	5.5	7.6
6	101 ～ 120 m	35	3.2	9.1						
7	121 ～ 140 m	16	1.1	6.9				4	1.7	5.3
8	140 m Exceeding	18	0.7	3.9						

Soil depth		Occupied area (ha)	Eroded area (ha)	Eroded raio	Category 2: Number	Category 2: Occupied area (ha)	Category 2: Eroded raio
1	Latesol (deep)	779	47.4	6.1	1	43.4	5.8
3	Intermediate	74	2.1	2.8			
2	Podsol (shallow)	1113	72.0	6.5	2	56.6	6.5

Pasture density		Occupied area (ha)	Eroded area (ha)	Eroded raio	Category 3 ①: Number	Category 3 ①: Occupied area (ha)	Category 3 ①: Eroded raio	Category 3 ②: Number	Category 3 ②: Occupied area (ha)	Category 3 ②: Eroded raio
1	None	686	9.4	1.4	1	34.8	1.4	1	79.3	4.6
2	Thin	873	62.0	7.1	2	44.4	7.1			
3	Intermediate	308	28.5	9.2	3	20.7	12.3	2	15.7	9.2
4	Dense	99	21.6	21.8				3	5.0	21.8

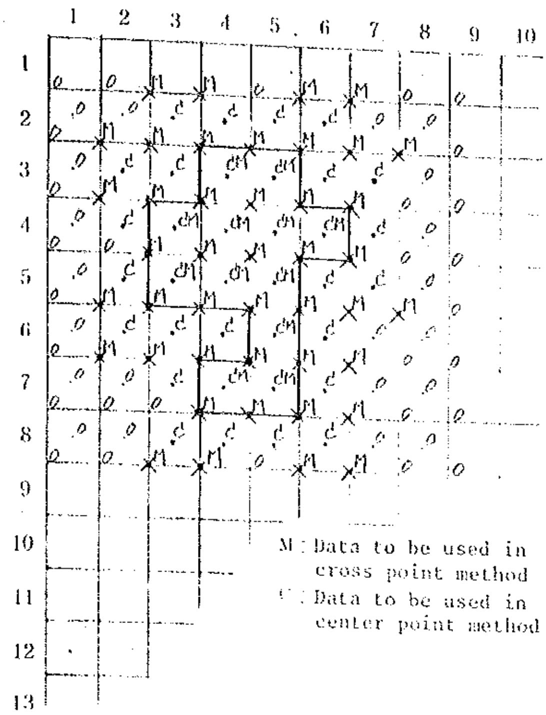


Fig. IV-41 Data to be input in topographical analysis

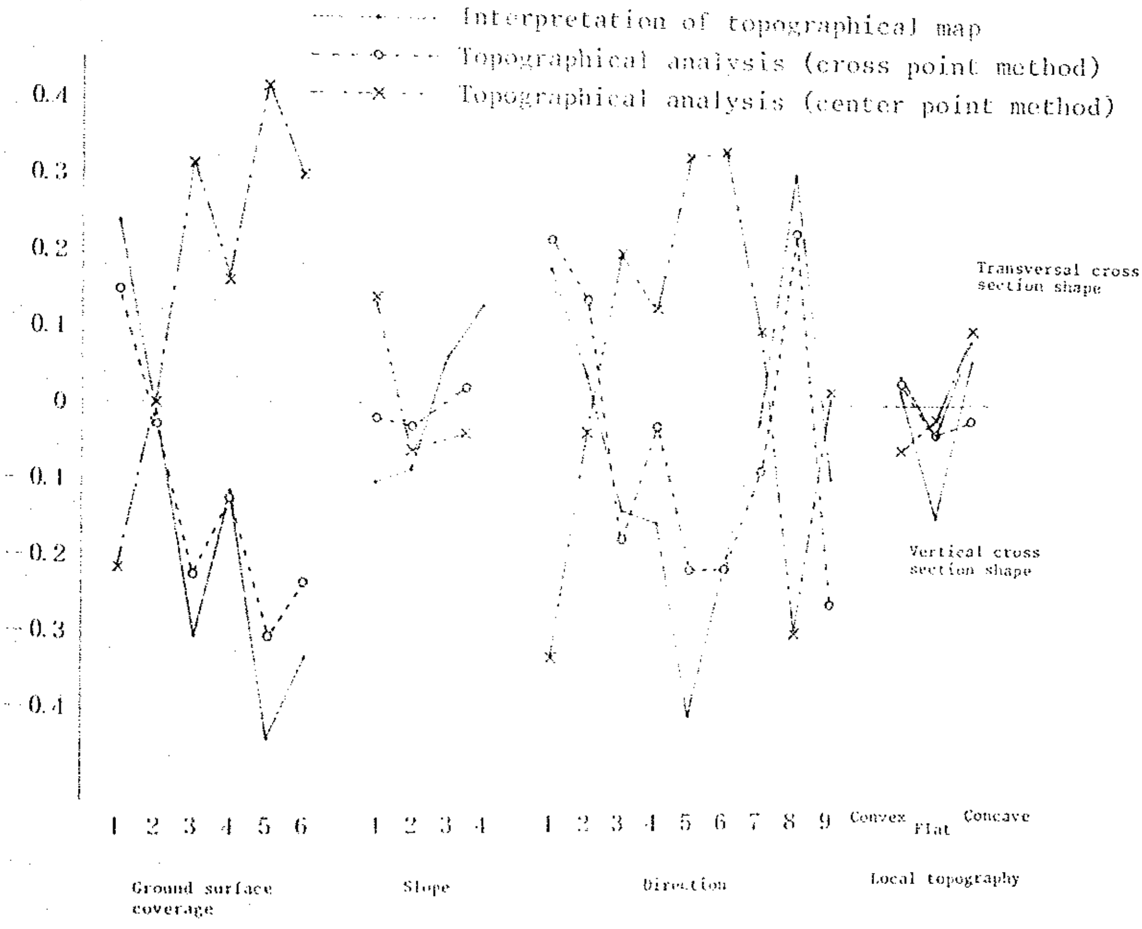


Fig. IV-42 Comparison of category weight of every factor weight of the factors by the topographical map interpretation. Therefore, it was concluded that the substitution of topographical factors by the topographical analysis in more favourable achieved by the cross point method than by the center-point.

(4) Method of predicting area in danger of slope collapse

① Determination of study method

Since it was proved that among the factors used in the above prediction method of eroded dangerous land, instead of those factors from the topographical map like slope, direction, shape of cross section and longitudinal section, when the slope, direction, and local topographical factors calculated by the computer processing programme on basis of the digitalized height data were used, the similar analysis result could be obtained, it was determined that the above 3 factors would be used as the topographical factors in the prediction method of devastated dangerous land, aiming to extend "the study of the accumulation, managing and processing of data", which is one of the subjects of this study.

Further,the slope length, used in the prediction method of eroded dangerous land, as other topographical factor, was omitted, since it was decided no concern with the mechanism of disruption occurrence. Instead, the existence or not of a stream in a mesh was added to the topographical factors, since it directly affected the slope collapse, which was interpreted from a topographical map.

After all, on the slope collapse danger analysis, taking the collapsed area ratio in a mesh as an outside standard, 6 factors of ground surface coverage, slope, direction, local topography, stream existence and soil depth were adopted as the inside standard.

In addition, the whole process of a series of the prediction method of devastated dangerous land including the prediction method of eroded dangerous land is as the flow in Fig. IV-43, among which the practice of the prediction method of eroded dangerous land is as the processes of 16-25 in the Fig.

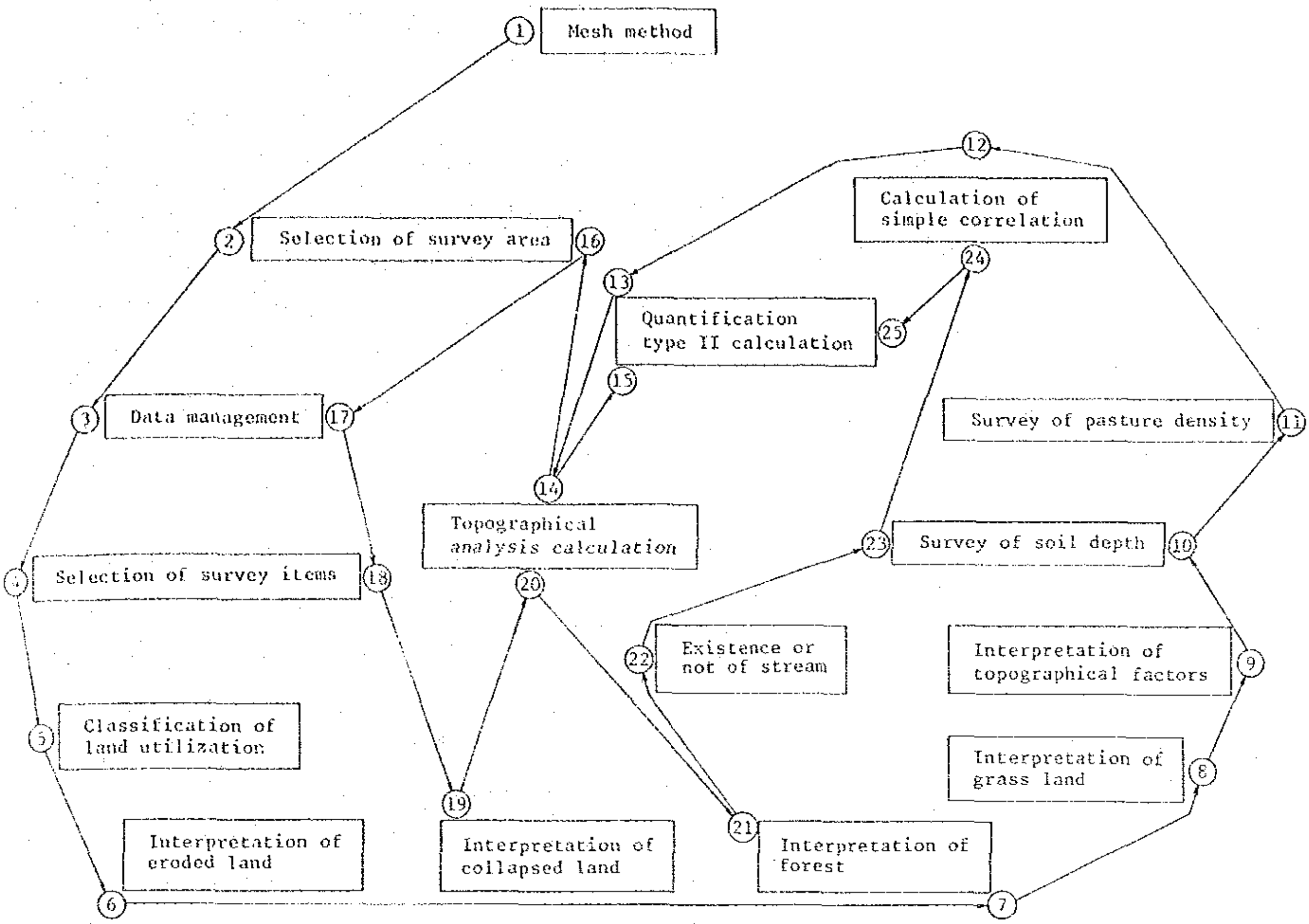


Fig. IV-43 Flow chart of work procedure

② Subject area of survey

A part of Antonio River basin, with the area of 774 ha, being the slope along the seaside in Caragatuba district, was determined as the subject area of survey, which is 125 km eastward from St. Paulo city, and almost due south through Taubata district, across the hill along the seaside (see Figure). This is a state forest, which is almost all natural, and has a steep hilly topography. (See the section of watershed management.)

③ Air-photograph

The used photo was taken in June 1973. Its original scale of 1/25,000 was enlarged by twice and used with the scale of 1/12,500 (Table IV-24).

④ Survey method

ⓐ Interpretation of collapsed land

The collapsed land has a distinct depression on its slope, which is in most cases shown as a clear white image on a photo, not requiring a high technique of interpretation. However, care should be taken not to overevaluate the depression area, since a mass of soil flows downward in a large-scale depression. Further, the depressed area was not subdivided best regarded as one type only, and the demarcated part on a photo was transcribed on a topographical map, then the ratio of the callapsed area against the total area was read in every mesh.

(b) Interpretation of ground surface coverage

This survey area mostly consists of the natural forest except about 9% of grass-land, without any artificial forest. It is rather hard to distinguish natural forests by their aspects. In the survey area, there was a distinct forest stand with a different composition of tree species on the relatively gentle slope, which was observed growing to upright and tall trees by the field survey, but the image on the photo was assumed to show a short thin second growth forest at the time of photographying. Another distinguished aspect was interpreted to exist mostly at the ridge, where tree height was rather short and dense, without large diameter trees, but as far as the field survey ascertained, no significant difference in tree species composition from other natural forest was observed. This aspect was classified as "the natural forest without any large diameter tree". Therefore, forests were divided into 3 classifications.

After all, the factors of the ground source coverage are grass land and 3 classifications of forests, which makes 4 classifications in all.

(c) Interpretation of topography

ⓐ By topographical analysis

The factors by the topographical analysis are three of slope, direction and local topography. Since the slope and direction are expressed with the continuous real numbers, these classification standards are to be optionally classified on the quantification type II calculation. The local topography is classified, as in the prediction method of eroded dangerous land, into 3 of convex, flat and concave.

ⓑ By the interpretation of topographical map

Among those topographical factors to be used in the prediction method of collapsed dangerous land, what can be obtained from the interpretation of a topographical map is only one, "the existence or not of a stream". The way of interpretation is that, the one with the ratio a/b of 1 or more in Fig. IV-44 is regarded as a stream, and any mesh involved in a stream is classified as "the existence of stream", while the other meshes are "no stream", so making 2 classifications.

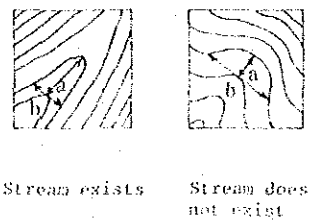


Fig. IV-44 Interpretation of stream

(d) Soil depth

Since the Caragatuba survey area geologically consists of granitic diorite and granite, and the soil is a unitary type of lithosol, the soil depth distribution was made, determining the soil depth mainly by the topographical inclination. The practice was that, judging the inclination of the slope for every local topography by means of photo interpretation, and considering the plant state (tree species, tree sizes, etc.), the classification of soil depth was graded into 4 grades, i.e. 0-50 cm, 60 cm - 1 m, 1.1 m - 2 m, and exceeding 2 m, which were stratified on a photo, then transcribed on a topographical map.

⑤ Multivariate analysis calculation

As multivariate analysis, the same quantification type II calculation as in the judgement method of eroded dangerous land was carried out. The process of the practice can be explained as the combination of the calculation order in Table IV-41 and the classification standards of factors in Table IV-42.

After all, the calculation result, concluded as best, was the 7th factor classification standard in Fig. IV-40, where the correlation ratio was 0.5059. The minute results of the analysis have been indicated in the section of watershed management.

(5) Accomplishment of study

① Data processing system and data storage

By this study, not only a series of a computer processing system have been established like the calculation of the area of the devastated land by each factor, the quantification type II calculation, the map by output data, etc., but also the 400 ha meshes and the 1 ha meshes are overlapped in good order of positions along x-y coordinates. This not only facilities the data storage hereafter but also enlarges the range of the utilization of the data.

② Establishment of prediction method of devastated dangerous land

This study has established not only the photo interpreting technique of eroded or collapsed lands, that is used in the prediction method of devastated dangerous land, but also the interpreting technique of the ground surface coverage which is based on the existing method of forest interpretation, as its application. Further, the interpreting technique from a topographical map has been remarkably improved, enabling to obtain the objective data.

In addition, it was verified, during the analysis practice of a series of the judgement method of devastated dangerous land, that by the interpretation of geological and pedological knowledge the versatile and comprehensive use of remote-sensing became possible.

③ Application of topographical analysis

By the interpretation of a topographical map, various topographical factors can be used in such form as the purpose calls,

Table IV-41 Practice of quantification type II calculation
(Prediction of disrupted dangerous land)

Number of calculation	Outside standard	Inside standard						Multiple correlation coefficient
	Number of grades	Land surface coverage	*Slope*	*Direction*	Local topography	*Soil depth*	Existence or not of stream	
1	4 *1	4	5 ㉕	9	3	4	2	0.5227
2	4	4	5 ㉕	8	3	4	2	0.5222
3	4	4	5 ㉕	5	3	4	2	0.5117
4	4	4	5 ㉕	4	3	4	2	0.5114
5	4	4	6	4	3	4	2	0.5175
6	4	4	5 ㊶	4	3	4	2	0.5118
7	4	4	4	4	3	4	2	0.5059
8	3 *2	4	5 ㉕	4	3	4	2	0.5068

*1 Grade 1 means no disruption.
2 means disruption up to 10%.
3 means disruption up to 30%.
4 means disruption 31% or more.

*2 Grade 1 means disruption up to 10%.
2 means disruption up to 30%.
3 means disruption 31% or more.

Table IV-42 Category standard of each factor (Prediction of collapsed dangerous land)

	Land surface coverage	Occupied area (ha)	Collapsed area(ha)	Collapsed area ratio (%)	Category 4: Number	Category 4: Occupied area ratio	Category 4: Collapsed area ratio
1	Grass land	68	2.9	4.2	1	8.8	4.2
2	Secondary forest	69	3.2	4.6	2	8.9	4.6
3	Natural forest (small diameter trees)	74	14.0	18.9	3	9.6	18.9
4	Natural forest (large diameter trees)	563	67.7	12.0	4	72.7	12.0

	Slope inclination	Occupied area (ha)	Collapsed area(ha)	Collapsed area ratio (%)	Category 6: Number	Category 6: Occupied area ratio	Category 6: Collapsed area ratio	Category 5(25): Number	Category 5(25): Occupied area ratio	Category 5(25): Collapsed area ratio	Category 5(41): Number	Category 5(41): Occupied area ratio	Category 5(41): Collapsed area ratio	Category 4: Number	Category 4: Occupied area ratio	Category 4: Collapsed area ratio
1	21° or less	330	20.1	6.1	1	42.6	6.1	1	60.3	7.6	1	42.6	6.1	1	60.3	7.6
2	22°～25°	137	16.1	11.8	2	17.7	11.8				2	17.7	11.8			
3	26°～29°	110	17.5	15.9	3	14.2	15.9	2	14.2	15.9	3	14.2	15.9	2	14.2	15.9
4	30°～33°	90	17.6	19.6	4	11.6	19.6	3	11.6	19.6	4	11.6	19.6	3	11.6	19.6
5	34°～40°	81	14.7	18.1	5	10.5	18.1	4	10.5	18.1	5	13.8	15.4	4	13.8	15.4
6	41° or more	26	1.8	6.9	6	3.4	6.9	5	3.4	6.9						

	Direction	Occupied area (ha)	Collapsed area (ha)	Collapsed area ratio (%)	Category 9: Number	Category 9: Occupied area ratio	Category 9: Collapsed area ratio	Category 8: Number	Category 8: Occupied area ratio	Category 8: Collapsed area ratio	Category 5: Number	Category 5: Occupied area ratio	Category 5: Collapsed area ratio	Category 4: Number	Category 4: Occupied area ratio	Category 4: Collapsed area ratio
1	339°～ 23°	16	1.4	8.8	1	2.1	8.8	1	2.1	8.8	1	7.4	18.2	1	7.4	18.2
2	24°～ 45°	3	--	--	2	0.5	--	2	2.1	1.9						
3	46°～ 68°	1	--	--												
4	69°～113°	22	1.5	6.8	3	2.8	6.8	3	2.8	6.8	2	11.6	9.8	2	11.6	9.8
5	114°～135°	67	7.3	10.9	4	17.8	11.0	4	17.8	11.0						
6	136°～158°	71	7.9	11.1												
7	159°～203°	127	11.4	9.0	5	16.4	9.0	5	16.4	9.0	3	39.7	9.7	3	41.2	9.1
8	204°～225°	109	10.5	9.6	6	20.3	9.6	6	20.3	9.6						
9	226°～248°	48	4.5	9.4												
10	249°～293°	139	13.6	9.8	7	18.0	9.8	7	18.0	9.8	4	39.8	12.5	4	39.8	12.5
11	294°～315°	121	20.4	16.9	8	20.5	18.5	8	20.5	18.5						
12	316°～338°	38	9.0	23.7							1			1		
13	No direction	12	03	2.5	9	1.6	2.5	9			5	1.6	2.5	3		

	Local topography	Occupied area (ha)	Collapsed area(ha)	Collapsed area ratio (%)	Category 3: Number	Category 3: Occupied area ratio	Category 3: Collapsed area ratio
1	Hill side convex surface	239	26.7	11.2	1	30.9	11.2
2	Hill side equilibrated surface	254	32.4	12.8	2	32.8	12.8
3	Hill side concave surface	281	28.7	10.2	3	36.3	10.2

	Soil depth	Occupied area (ha)	Collapsed area(ha)	Collapsed area ratio (%)	Category 4: Number	Category 4: Occupied area ratio	Category 4: Collapsed area ratio
1	0 ～ 0.5 m	148	40.5	27.4	1	19.1	27.4
2	0.6 ～ 1.0 m	353	32.3	9.2	2	45.6	9.2
3	1.1 ～ 2.0 m	192	13.1	6.8	3	24.8	6.8
4	2.1 m or more	81	1.9	2.3	4	10.5	2.3

	Existence or not of stream	Occupied area (ha)	Collapsed area(ha)	Collapsed area ratio (%)	Category 2: Number	Category 2: Occupied area ratio	Category 2: Collapsed area ratio
1	None	609	75.1	12.3	1	78.7	12.3
2	Exists	165	12.7	7.7	2	21.3	7.7

but thus obtained data are rather fixed, for example, every time when the classification like local topography, etc. is required to be altered, each mesh must be interpreted again, so it lacks versatility. Further, as for direction, as seen in Table IV-42, when proper classification is to be judged out of 8 directions and 4 directions, interpretations for both cases are necessary. In addition, when analysis methods differ, the repeated use would often become impossible.

In this sense, when data of height above sea-level from a topographical map are accumulated, the topographical factors as required in accordance with the purposes in the topographical analysis can be taken out, and the calculated and processed topographical information is objective, so they are very useful.

(6) Consideration

① Interpretation of devastated land

The technique to interprete the devastated land from the air-photograph information is the extension of the existing fundamental technique of interpretation of forests, so it is not called a remarkable new technique. However, since it was an unexperienced field, there could be a certain phase where it was not carried out smoothly. Particularly, the experience of the interpretation of the eroded land, even of the expert, was not sufficiently accumulated, so it was undeniably carried out by means of a trial and error. Also it made the interpretation harder that the available air-photograph were taken in 1973, as well as more than 10 years ago.

However, since it was proved that the proper data in the analysis by the judgement method of the devastated land could be obtained by the use of various remote-sensing technique besides the photo interpretation technique, this analysis method has developed a new field where it could well contribute to the programme of devastated lands prevention as well as the programme of forestry conservation in Brazil, and the analysis of the social function of forests, etc., so the spreading use as well as the storage of analysis data hereafter are expected.

Further, in the short time programme in future, it is most advisable to put an emphasis on unifying the interpreting capability of technicians. As another important matter, if the technique, to transcribe the photo interpreted sections on a topographical map, is completely acquired, the sphere of photo application will be rapidly enlarged. In fact, almost all of the existing air-photograph are by a wide-angle lens, that often makes the stereoscopic view hardly applicable, and also difficulty exists in the insufficient exactness of topographical maps where necessary small ridges and valleys are sometimes not indicated.

② Size of mesh

In this study, the analysis was conducted by making a 100 m x 100 m mesh (1 ha mesh) one data. During a series of the devastated land analysis, the information of 1 ha unit was ascertained as proper in respects of the scale and accuracy of availed air-photograph and topographical maps.

However, since it is possible that other minimal occurrence mechanism of erosion and other extremely local factor thereof might exist, other more proper mesh size might be found in the prediction method of eroded dangerous land, so the study is expected to be continued in this respect in future.

③ Topography analysis

Though the cross-point method and the center-point method have been both attempted, so far, the result shows that the cross-point method is adequate to the prediction method of devastated dangerous land. One of the reasons is probably because in the center point method the subject is practically extended to carry out the topographical analysis of a 2 ha mesh, resulting the equalization in the expression of the analysis result. In this respect, a margin is afforded for a new classification standard to be set up, fit for this analysis.

(7) Future prospect and problems

① Improvement of photographing system

In this study, we had to use such old air-photograph as taken in 1973. The reason was that the photo was selected under the restriction with the scale of 1/200,000 and more for the proper handling and accuracy to this prediction method, and as the latest thereof. Hence, some difficulties were met during the work to ascertain the scale of the eroded land or grass land in a field survey. In fact, though dried whitish grass like kapingoldoula remains in almost same pattern as in most of the slightly eroded land 1 in the photo of 1973 year, the light erosion, assumed as occured after 1973, is seen in the different places. Further, the extensively eroded area like the erosion type 2 still remains, and in some places the erosion is further progressing, while in other places a little restored. It is presumed that if the air-photograph at present were available, eroded lands and grass lands would be interpreted more minutely, and the quantification type I method could be carried out, so various analysis methods could be applied.

On the other hand, though there are 1977 year air-photograph for both survey areas, unfortunately their scale is 1/45,000. If they are with 1/30,000 or 1/35,000 scale, some other means would have been considered like enlarging by twice for the use. And it might be more interesting to observe the progress of the erosion.

From above, it is desirable to establish a photographing system based on a period photographing and a multiple plan in which the scale is decided for versatile uses, including the use of enlarged photos.

② System divided by specialized fields

The reason why the mesh data ia adopted on practising the prediction method of devastated dangerous land is, as described above, that the unit of data handling is uniform and with the advantage that uniform data can be obtained by any measurer. Besides, as the one of other back grounds, though a part of fundamental knowledge of statistics theory is required to Japanese researchers in general, there is a tendency in this country that the statistic matters are handled by specialized people as such knowledge is regarded as specialized one. So it is judged, if the weight on the data to be processed was uniform, there would be less problem.

Now, though it has been gradually recognized in this country that a researcher requires the knowledge of minimal statistical processing theory, the tendency to regard the statistical matter in a separated specialized field will last for some time in future.

Meanwhile, the improvement of the technique of interpretation of whether air-photograph or topographical maps means fundamentally the collection of data, enabling its application to the subject analysis. In other words, it is an essential element to understand the interpretation accuracy in accordance with the purposes and meet quickly, which requires to cultivate always wide knowledge.

Therefore, if the interpretation technique in such situation of the specialized system collects data at a determined accuracy, that would be a circuitous but certain way for the utilization of the obtained data in various fields. So, technical leaders should keep this in mind, instructing the versatile uses of the obtained data, and strive at educating such technicians with the reliable technique even at a rather slow interpreting technique.

③ Spreading of remote-sensing technique

During a series of interpreting work in this study, in addition to the forest interpretation that is the previous technique of photo interpretation, the interpretation of devastated land and grass land was newly attempted, acquiring considerable accomplishment.

Such accomplishment, after conducting the judgement method of devastated dangerous land by the use of various remote sensing technique, would suggest a possibility that the sphere of application of remote-sensing technique could be widely spread, by means of extending these methods to other districts or attempting the application to a new method.

Generally, the improvement of interpreting technique needs plenty of experience, and in this sense also, the extension of application of this method is aspired, by which the understanding by researchers in general on remote-sensing technique will be certainly increased. Accompanied with the increase in such understanding people, it is possible the photographing system will be improved.

④ Storage of multi-purpose useful data

The subject of this section is, besides the improvement of remote sensing technique as well as the application of the technique to analysis methods, to establish a data management system in order to enable the multi-purpose use of the data obtained by the technique.

The first is the data management by a mesh method, in which a system of data management and accumulation has been established, making the information per 1 ha a minimal unit. Further, since the 400 ha is encoded, for example, in future if 1 ha mesh data are statistically processed and expressed in some form of information for every 400 ha mesh, the data could become the statistical data for the whole state of St. Paulo or the whole country of Brazil. In addition, in case when the statistical values in a wide range are required in a short time, the sample information of every 400 ha mesh also can be used at the same time. Further, it could be possible to catch promptly any change in the statistical information in the whole country scale, by the combination of these controlled data with the Earth observation satellite information.

Second, the work of in plane extension of data accumulation to be used in the topographical analysis is considered important. The largest advantage of the topographical analysis established in this study is, the processed data are rather ever lasting, so once accumulated, can be used almost permanently. The development and extension of the use is the subject of the further problem, but at present, the preparation of various distribution map is being examined.

Hence, if on one hand, striving at the improvement of the remote-sensing technique, and extending the range of its application, and on the other hand,the accumulation of the height above sea-level data in the topographical analysis is continued, we convince that this will certainly become a precious estate of this country in future.

IV-4-2 Analysis of Factors of Devastation by Quantification Type II Calculation

(1) Purpose

In this section, the use of the programme of quantification type II made for the factor analysis of dilapidation is mainly discussed. The quantification type II is a method to classify the characteristics (outside standard), which are observed with the nominal criterions, by using other factors. Since other factors are treated as categories, this method can be used broadly in the forestry study. As for the fundamental calculation, the "Quantification" (type I)" (Kozo Kawabata), in the Report of Computer Programming at the Forestry and Forest Products Research Instituto (11) was used. Further, when the slope inclination, the slope direction and the local topography of a mesh are used as the factors, the use of topography analysis programme, to obtain these values by a calculation process from the data of heights above sea-level, is also discussed.

(2) Preceding process for quantification type II

The processing flow of quantification type II is shown in Fig. IV-45.

① Collection and ordering of a data

The data of necessary factors are collected and put in order for each mesh by means of photo-interpretation, photographical map interpretation, etc. In this study, though the mesh size was determined as 100 m, the size could be determined correspondent to the subject survey area. Though this quantification type II programme is intended for a square domain, the data to be collected and put in order are required only for the mesh to be analysed, as shown in Fig. IV-46.

② Data Input into floppy disk

Using the floppy data entry system of Forest Board, the data collected and put in order as in paragraph (1) are input. The input data format is shownin Fig. IV-47.

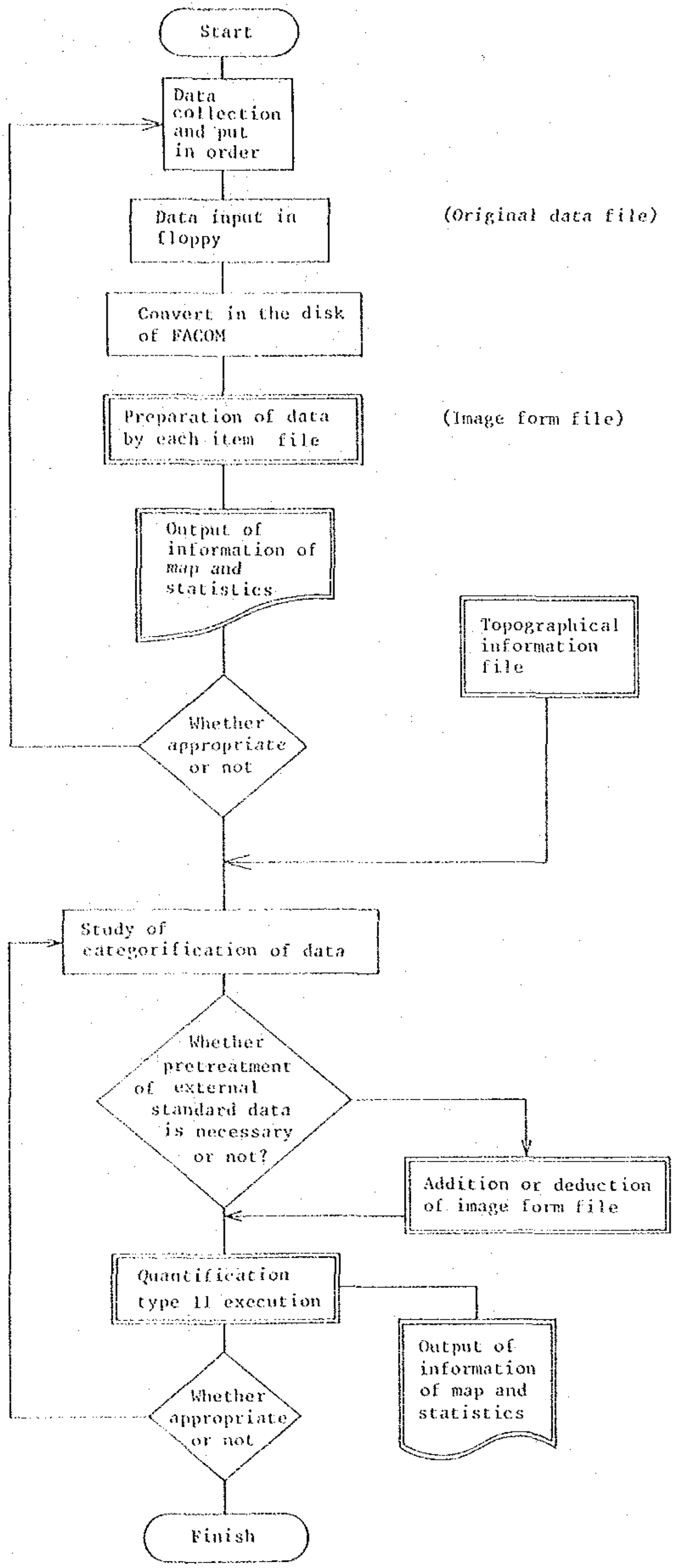


Fig. IV-45 Flow chart of quantification type II processing

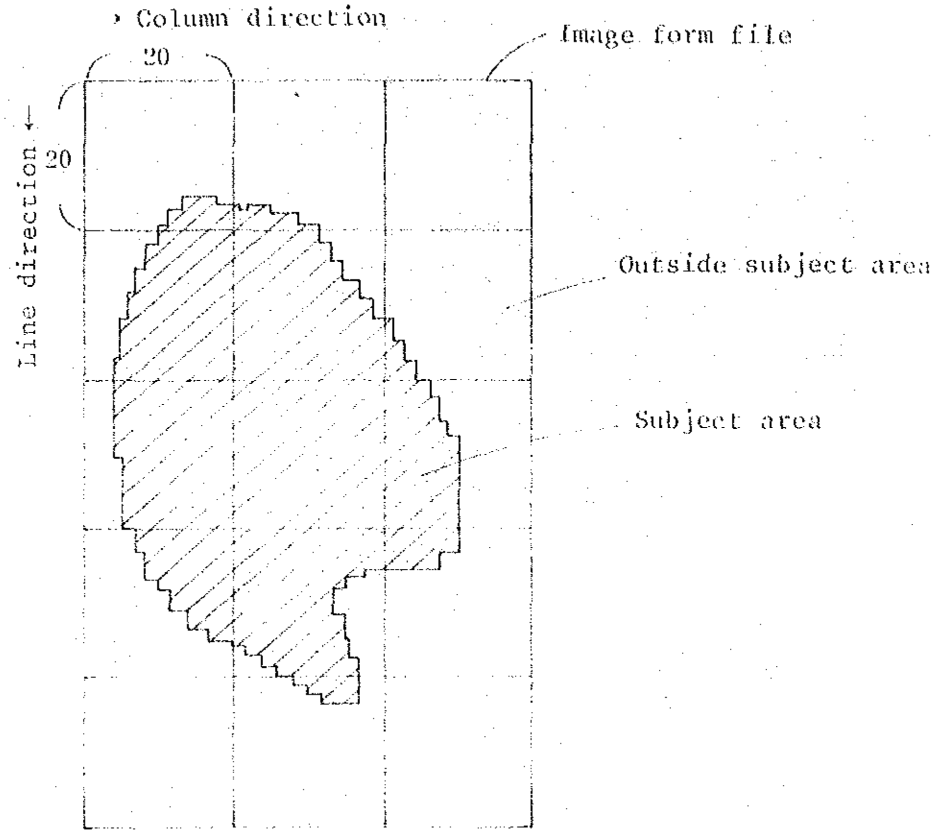


Fig. IV-46 Subject area and input data

When  is the subject area, treat only the data for that section and input in the floppy disk. However, on the disk of FACOM, the image form file with the unit of 20 lines x 20 columns is made. (Since the mesh outside the subject area is masked, its actual calculation is not practised.)

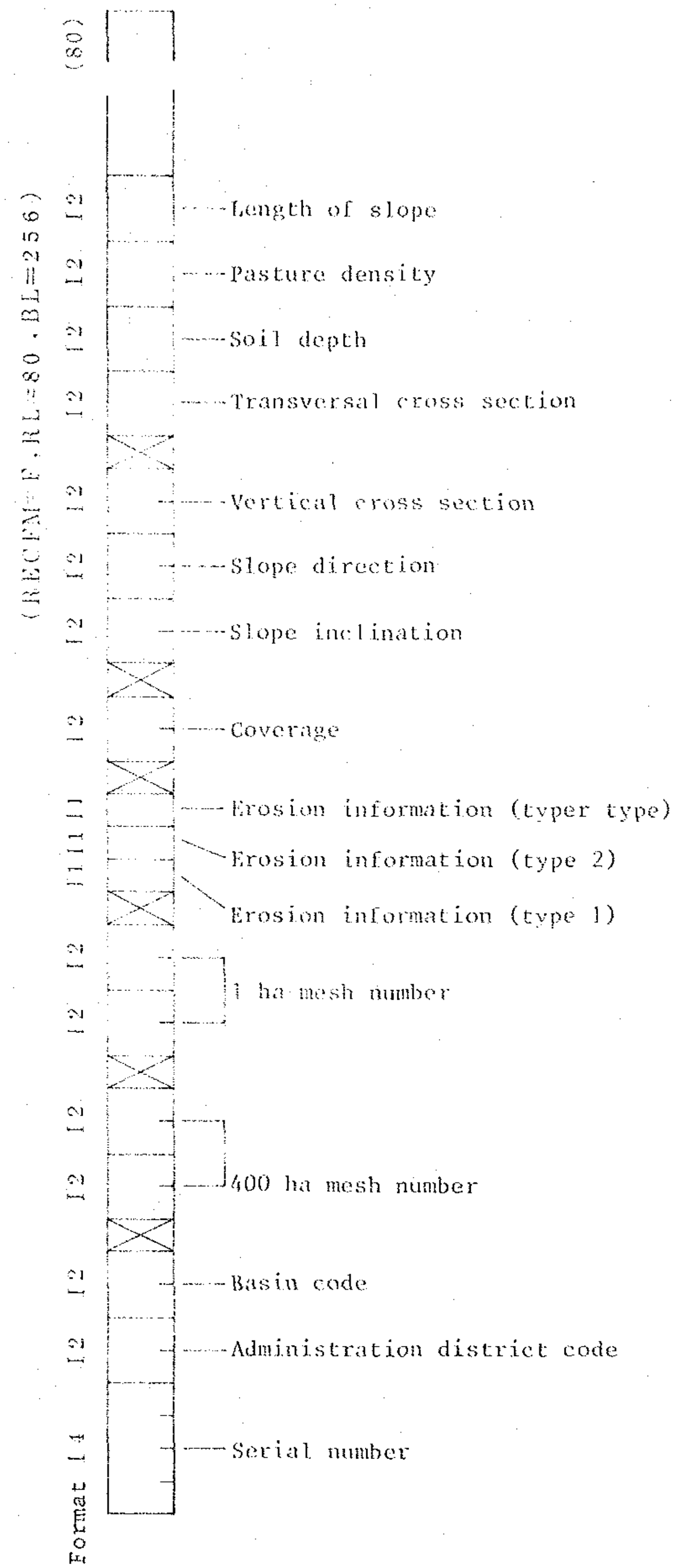


Fig. IV-47 Format of input data for quantification type II (Original data file)

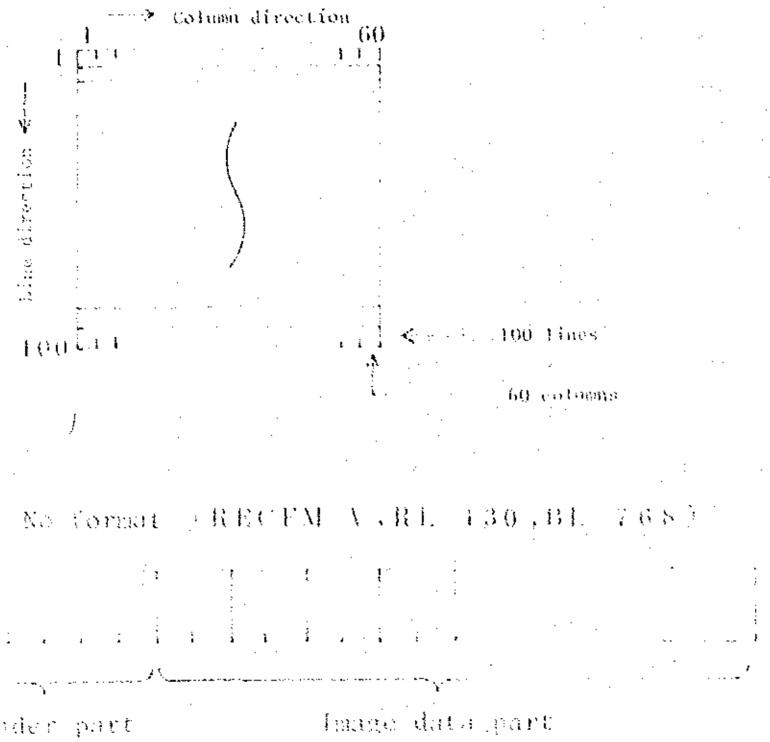


Fig. IV-48 Data format for quantification type II
(Image form file)

Note: The size of image form files to be used in the programme herewith made is (RECFM=V, RL=1300, BL=768). When the file of other size is used, the file statement of all programmes must be changed.

③ File convert

By the file convert utility of FACOM 230-28 of Forest Board, the data file in a floppy disk are saved in a disk (DP-D2) of FACOM.

④ Preparation of data file by categories

This quantification type II programme is intended to a square domain as above described, and handles only those data of each category which are stored in a file called an image type file (See Fig. IV-48). The size of file, prepared in this study, are with the line number of 100 and the column number of 60. Each data is expressed in 2-types. All programmes thereafter have used this form of file. Further, the amendment of a file size can be attained by amending the filed statement in each programme, provided the record length is 100 at maximum.

⑤ Mapping and output of statistical quantity

Outputting in image the content of the image-form file, the appearance frequency of data is obtained. Data ascertainment is also carried out by this. This process is often utilized in order to ascertain the data in a image form file.

⑥ Categorizing of data

Categorizing of each item to be used in the quantification type II is examined by using "the appearance frequency table of data" obtained in paragraph e. The number of categories that can be used in this quantification programme is 20 categories at maximum per item, so 41 categories in total. Categorizing of each item is to attempted in such range as satisfying the above restriction.

⑦ Preparation of a new outside standard file

This is used in a case where the outside standard data are obtained by the addition or the deduction between two image-form files.

(3) Quantification type II programme

In the quantification type II programme, those data of factor items and outside standards are both treated as categories, and the data for every mesh are expressed in the reaction pattern table as shown in Fig. IV-49. On basis of this reaction pattern table, the value of score (x_{jk}) to explain the outside standard is searched for the category for every factor. Here, it is presumed that the group could be estimated by the linear sum of scores. That is, on the basis of the below formula, the value αi which explains the outside standard is to be obtained.

$$\alpha i = \sum_{jk}\sum \delta i(jk)x_{jk}$$

where, $\delta i(jk)$ = 1 when data i reacts to j factor k category
= 0 when does not react

xjk : Number of scores to be furnished to j factor k category

Presuming σ_b^2 as the distribution between groups, concerning the said σi, then correlation ratio y^2 is : $y^2 = \frac{\sigma b^2}{\sigma b^2}$

where, $\sigma^2 = \frac{1}{n} \sum_{i=1} \alpha_i^2 - \overline{\alpha}^2$

$$\overline{\alpha} = \frac{1}{n} \sum_{i=1}^{n}\sum_{jk}\sum \delta\ (jk)(x_{jk})$$

When y^2 is large enough, it is deemed to be able to distinguish the group, i.e. its reaction pattern well expresses the outside standards.

So if the score x_{jk}, which is to be furnished to j-item and k-category, is decided so that $y^2 b^m$ may become maximum, the quantification, that is able to express the classification well, could be accomplished.

In addition, if the *mono-dimensional quantification* does not afford a satisfactory result, the outside standards are presumed multi-dimensional and shall be classified.

The group number, estimated by the quantification type II, is output on the image form file. Using the outside standard file and the file of thus established group, the programme of "mapping and statistical quantity output" is carried out. A figure will be furnished, that is output in 2-digit number, where the first digit expresses the original data, while the second digit shows the estimated data. The appropriateness of the estimation is examined by the output.

Further, the relation between the calculated score and the estimation of the group is shown in Fig. IV-50.

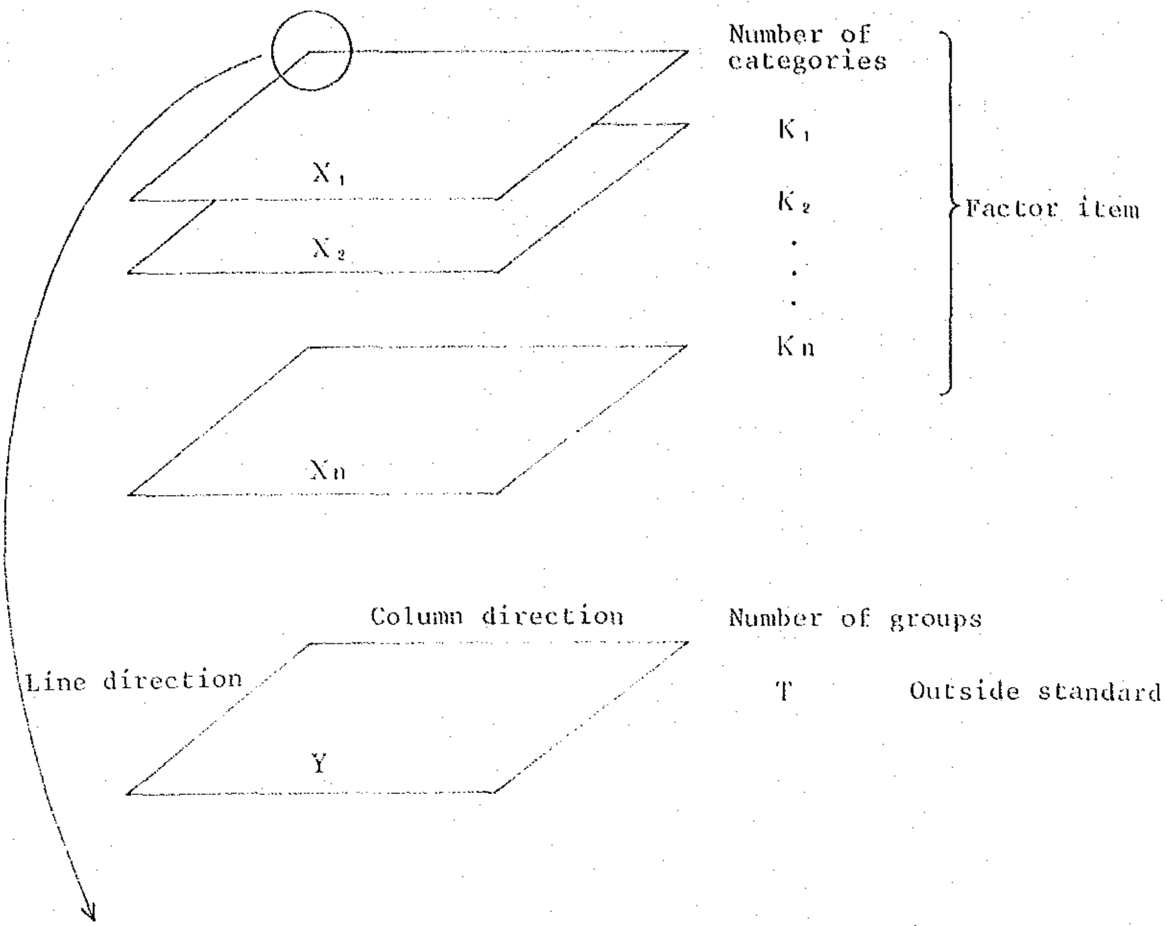
Note) Care should be taken, since this programme performs the special masking process in accordance with the original data in the 1st factor. When the original data of 1st factor is less than 3, or 99 or more, they are omitted from the subject of the whole processing. As this is stipulated in the 6th and 7th lines in the sub-routine PIXEL, it is necessary to delete these 2 lines of condition establishment, for the use of general quantification.

(4) Topography analysis programme

When slope inclination, slope direction, and local topography in each mesh are adopted as the factors in the quantification type II, the training and the lengthened period are required to interprete them from a topographical map. In order to mitigate them, a programme of the calculation of these kinds of data from the read-out data of heights above sea-level, has been prepared for FACOM230-28.

The processing flow is shown in Fig. IV-51. As indicated in Fig. IV-52, the data of heights above sea-level have to be collected from a broader range than that of the analysis subject.

A method to search slope inclination, slope direction and local topography by a topography analysis programme is shown in Fig. IV-53. Three kinds of image forming files, made by this programme, could be availed in the quantification type II without any modification.



X_1

①	1	3	3
1	2	2	2
1	1	2	2
1	2	3	3

X_2

②	2	1	1
2	3	2	3
2	2	1	3
2	2	1	1

. . .

X_n

①	2	1	1
1	1	1	1
1	2	2	2
2	2	2	2

Y

①	1	1	1
1	2	2	2
1	3	3	3
1	2	1	1

Item / Category / Column / Line	X_1			X_2				X_n			Y		
	1	2	… k_1	1	2	… k_2		1	2	… kn	1	2	… T
1 − 1	V			V				V			V		
1 − 2	V			V					V		V		
2 − 2		V			V			V				V	

Fig. IV-49 Image form file and reaction pattern table to be used in Quantification type II

Type II

Factor item	X_1				X_2					X_n				Outside standard (group)					Appropriateness
Category	1	2	……	K_1	1	2	……	K_2		1	2	……	K_n	Estimation 1	2	……	T	Original data	
score	x_{11}	x_{12}	……	x_{1k_1}	x_{21}	x_{22}	……	x_{2k_2}		x_{n1}	x_{n2}	……	x_{nk_n}	g_1	g_2	……	g_T		
Specimen number 1 − 1	✓					✓				✓				○				1	1
1 − 2	✓					✓					✓				○			1	0
1 − NC		✓			✓								✓		○			2	1
2 − 1	✓					✓				✓				○				1	1
2 − 2		✓					✓			✓				○				1	1
⋮																			
NL − NC				✓				✓		✓							✓	T	1

For example, sample 1-2 expresses that since the total value of scores, y ($y = x_{11} + x_{22} + \ldots\ldots x_{n2}$) is $g_1 < y \leqq g$, it is presumed to be group 2.

Fig. IV-50 Estimation table of outside standard by quantification

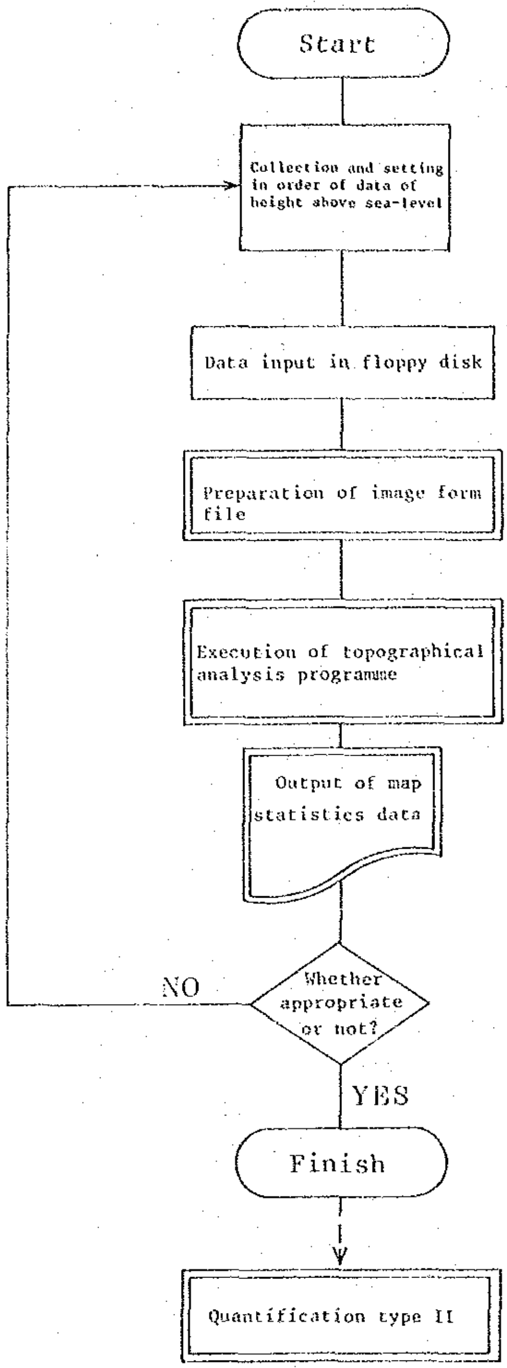
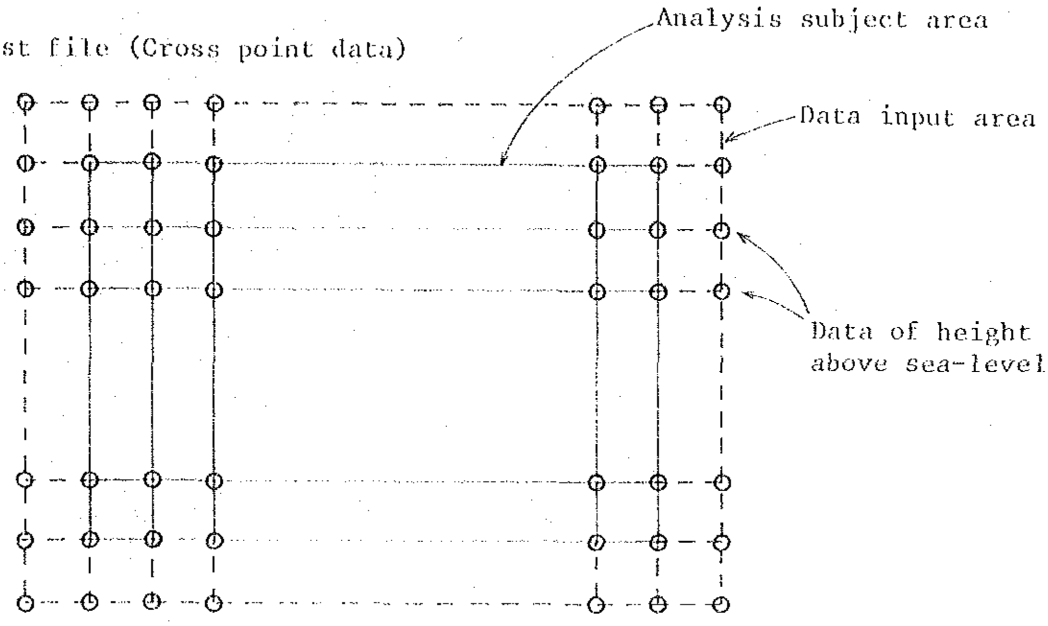


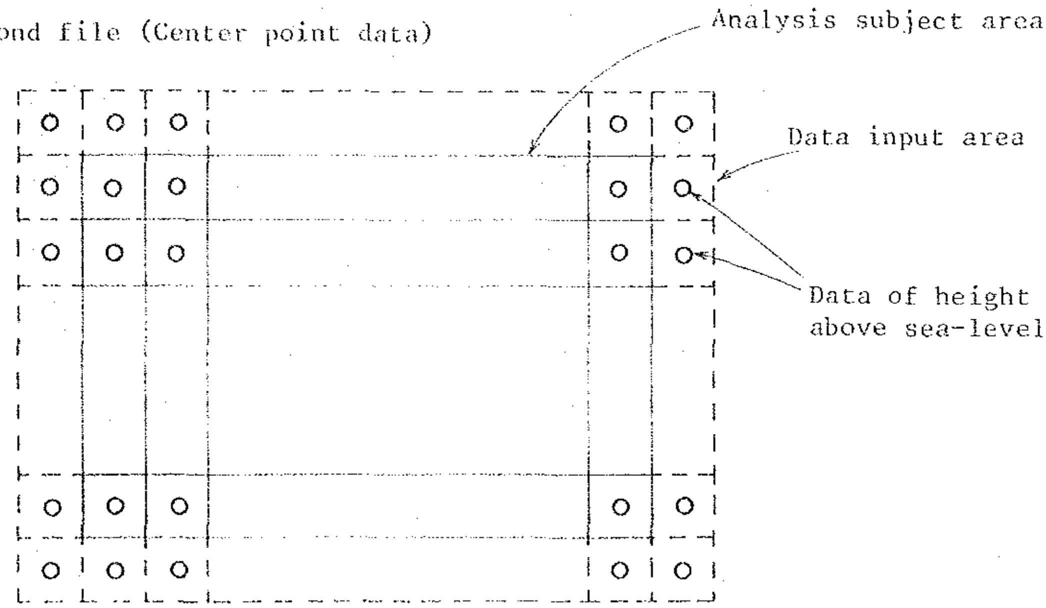
Fig. IV-51 Preparation of topographical information file by data of height above sea-level

First file (Cross point data)



Outside the analysis subject area, one more cross point data is necessary, i.e. when the analysis subject area is of line=100 and column) 60, the image form file shall be 103 lines x 63 columns.

Second file (Center point data)



Outside the analysis subject area, one more center data of height above the sea-level is necessary, i.e. when analysis subject area is of 100 lines and 60 columns, the image form file shall be 102 lines x 62 columns.

Fig. IV-52 Image form file of height above sea level for topographical analysis

The data of height above the sea-level as shown in the figure is used in topographical analysis.

1. Direction angle (α)

$$\tan \alpha = \frac{b}{a}$$

2. Slope inclination ( )

$$\sin\theta = \frac{\sqrt{a^2 + b^2}}{\sqrt{a^2 + b^2 + 1}}$$

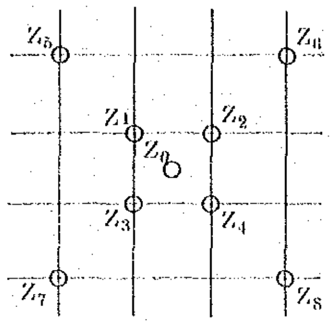


Fig. IV-53 Algorism of topographical analysis

$$\text{where, } a = \frac{(z_1 + z_2) - (z_3 + z_4)}{2D}$$

$$b = -\frac{(z_1 + z_3) - (z_2 + z_4)}{2D}$$

D : mesh distance (100 m, in this study)

whereas, α expresses angles in the folloiwng quadrants, depending on the plus or minus sign of a and b.

When $a < 0$, $b < 0$, in the first qurdrant from due north

$a > 0$, $b < 0$, in the second quardrant from due south

$a > 0$, $b > 0$, in the third quardrant from due south

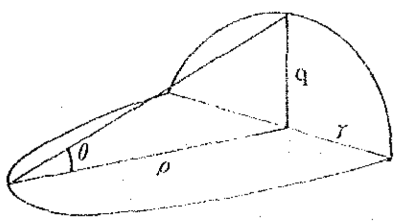
$a < 0$, $b > 0$, in the fourth quardrant from due north

Further, the limiting angle of slope inclination (θ) is determined (SLIM: 5 degrees in this study), and when the slope inclinations within the limiting angle, it is regarded as no direction.

3. Local topography

Category		z_a plane slope inclination	Other conditions
1	Hill top surface	within 15	z_a plane is extending out of z_d plane
2	Hill side convex	15 - 45	z_o plane is extending out of z_a plane more than 15:1 in horizontal plane ratio
3	Hill side equilibrium surface	15 - 45	Z_o is extending out of z_a plane within 15:1 in horizontal plane ratio
4	Hill side concave surface	15 - 45	z_o is extending out of z_a plane more than 15:1 in horizontal plane ratio
5	Hill foot eroded surface	exceeding 45	
6	Hill foot accumulated surface	within 15	z_a plane is depressed out of z_b plane

Note: A horizontal plane ratio 15:1 describes the ratio of the length of chord to the center height, which can be converted into the ratio of height by the following formula.



$$\frac{\rho}{r} = 1/15$$

$$q = \rho \tan\theta$$

$$\therefore q = (r \tan\theta)/15$$

$$= (D \tan\theta)/15$$

By comparing this q value with (z_o - (average height of z_a plane above the sea level)), category 2-4 is determined.

Appendix; Use of programmes
(Assignment of data)

DATA SHEET

PROBLEM ① Output of map and statistical quantity WRITTEN BY PAGE OF

No.	Content
1	(data)
2	1 — { 1: Map output of one image
3	Assignment parameter of image addition — 2: Output of two image-data simultaneously in two-digit number:
4	this is used to outputthe result of the quantification type II calculation and the external standard data simultaneously.
5	100 60 8 10 15 20 30 40
6	NL NP IWD ISEP(1) ISEP(2) 〃(3) 〃(4) 〃(5) 〃(6) 〃(7) 〃(8) 〃(9) ISEP(10) } set
7	1 2 3 4 1
8	NEWC(1) NEWC(2) 〃(3) 〃(4) 〃(5) 〃(6) 〃(7) 〃(8) 〃(9) NEWC(10)
9	
10	NL: Number of lines in the image form file
11	NP: Number of columns in the image form file
12	
13	IWD Map output control code — If 1 or more: Mapping is executed for the value obtained by dividing input image by IWP.
14	If 0 ;Mapping is executed for the values of NEWC (1) - NEWC (10)
15	corresponding to the upperlimit values assigned by ISEP (1) -ISEP (10).
16	
17	(Prepare the number of sets of 2 lines, 5 & 7 as required for the
18	number of images which are desired to be output. However, if IWD 1, the data of the second sheet are unnecessary as follows.)
19	
20	100 60 1
21	100 60 2
22	100 60 1
23	
24	
25	

DATA SHEET

PROBLEM ______ WRITTEN BY ______ PAGE ____ OF ____

No.	
1	(Assignment statement)
2	¥ASSIGN U01, 21, DP-D2, FILE=SAWA6
3	
4	¥ASSIGN U02, 21, DP-D2 FILE=SAWA 4
5	
6	¥ASSIGN U03, 21, DP-D2 FILE=SAWA5
7	
8	¥ASSIGN U04, 21, DP-D2, FILE=SAWA7
9	¥ASSIGN U20, 22, DP-D2, FILE=SAWA7 ...... Dummy
10	
11	When the result of the quantification type II calculation and outside standard data are simultaneously output,
12	(data)
13	
14	2
15	100 60 1
16	
17	(Assignment statement)
18	
19	¥ASSIGN U01, 21, DP-D2, FILE=SAW16 ...... Outside standard data file
20	¥ASSIGN U02, 22, DP-D2, FILE=SAW13 ...... Estimationdata file (the result of the quantification class II calculation)
21	
22	
23	
24	
25	

DATA SHEET

PROBLEM 2 Quantification type II programme WRITTEN BY PAGE OF

No.	1–80
1	
2	PROBLEM QUNT2 DATA ANALYSIS QUNT2
3	└ Comment (60 letters)
4	
5	CONTROL ITEM 8 NAME 2 COLM 6Ø LINE 1ØØ RATIO 1Ø
6	Number of items ↑ Number of ↑ Number of ↑ Number of ↑ Use ↑
7	(Max. 20 items) name cards columns of image form file lines of image file condition of outside standard data (unit 10%)
8	
9	
10	CATEGORY 6 5 9 3 3 2 4 4
11	Number of categories corresponding to each item (the maximum
12	number of categories for each item is 20 categories, and total categories shall be 41 or less)
13	
14	NAME 1 C.V. 2 I. 3 D.I. 4 F.V. 5 F.H. 6 P.S. 7 D.R.
15	Item number Item name
16	8 SUP-3
17	Prepare the item numbers and the item names sa many as assigned by the "number of name-cards"
18	One card includes seven items. in CONTROL card.
19	
20	CV 5 6 7 8 16 24 ← Upper limit of the image form data (x) of first item
21	1 2 3 4 5 6 ← New category number furnished to the image from data of first item
22	In this case when x 5, new category number is 1
23	x 6, " 2 x 7, " 3
24	x 8, " 4 9 x 16, " 5
25	17 x 24, " 6

DATA SHEET

PROBLEM ____________ WRITTEN BY ____________ PAGE ______ OF ______

No.	1–10	11–14	15–18	19–22	23–26	27–30	31–34	35–38	39–42	43–46
1										
2	I	3	5	8	10	13				
3		1	2	3	4	5				
4										
5	DI	1	2	3	4	5	6	7	8	9
6		1	2	3	4	5	6	7	8	9
7										
8	FV	1	2	3						
9		1	2	3						
10										
11	FH	8	13	23	35	38				
12		2	1	2	3	2				
13										
14										
15										
16										
17	P.S.	1	2	3						
18		1	2	1						
19										
20	D.R.	2	4	6	9					
21		1	2	3	4					
22										
23	SUP-3	1	3	6	27					
24		1	2	3	4					
25										

When one category is to correspond to 0 of the image form data, it will be treated like this. Further, the new category number can be used not always in due order. However, the assignment shall not exceed the category number assigned with the category card.

DATA SHEET

PROBLEM ____________ WRITTEN BY ____________ PAGE ______ OF ______

No.		
1		
2	¥ASSIGN U01, 21, DP-D2, FILE=SAWA4	
3	〃 U02, 22, 〃 , 〃 = 〃 5	
4	〃 U03, 23, 〃 , 〃 = 〃 6	
5	〃 U04, 24, 〃 , 〃 = 〃 7	Available items
6	〃 U05, 25, 〃 , 〃 = 〃 8	
7	〃 U06, 26, 〃 , 〃 = 〃 9	
8	〃 U07, 27, 〃 , 〃 = 〃 11	
9	〃 U08, 28, 〃 , 〃 = 〃 16	
10	〃 U09, 29, 〃 , 〃 = 〃 16	
11	〃 U10, 30, 〃 , 〃 = 〃 16	In this programme, it is necessary to allot
12	〃 U11, 31, 〃 , 〃 = 〃 16	the file up to those for the 11th item.
13	〃 U12, 11, 〃 , 〃 =QUAN1	
14	〃 U13, 12 〃 , 〃 =SAW12	Imagefile on results will be output.
15	〃 U14, 13, 〃 , 〃 =SAW13	
16	〃 U15, 14, 〃 , 〃 =QUAN4	
17		
18		
19		
20		
21		
22		
23		
24		
25		

DATA SHEET

PROBLEM ③ Addition and deduction of image form files

WRITTEN BY ______ PAGE ______ OF ______

No.	
1	(data)
2	100 60
3	NLINE NCOLM
4	Line number — Column number
5	
6	2 1 8
7	Contrast — The value of image data (x) to be newly prepared will
8	Second image coefficient (a_2) — be calculated with the following formula.
9	First image coefficient (a_1) — $X= a_1$* (first image data) + a_2* (second image data) + C
10	
11	3 1 8 ... When files with different coefficients are to be made simultaneously,
12	necessary number of data shall be prepared.
13	
14	Assignment statement
15	
16	¥ASSIGN U8 1, 29, DP-D2, FILE=SAWA1 ... First image
17	¥ASSIGN U8 2, 30, DP-D2, FILE=SAWA2 ... SEcond image
18	¥ASSIGN U8 3, 32, DP-D2, FILE=SAW16 ... New file — Data shall be prepared, equal to the
19	¥ASSIGN U8 4, 32, DP-D2, FILE=SAW15 ... " — number of files to be made simulta-
20	neously.
21	The reference number is 32.
22	
23	
24	
25	

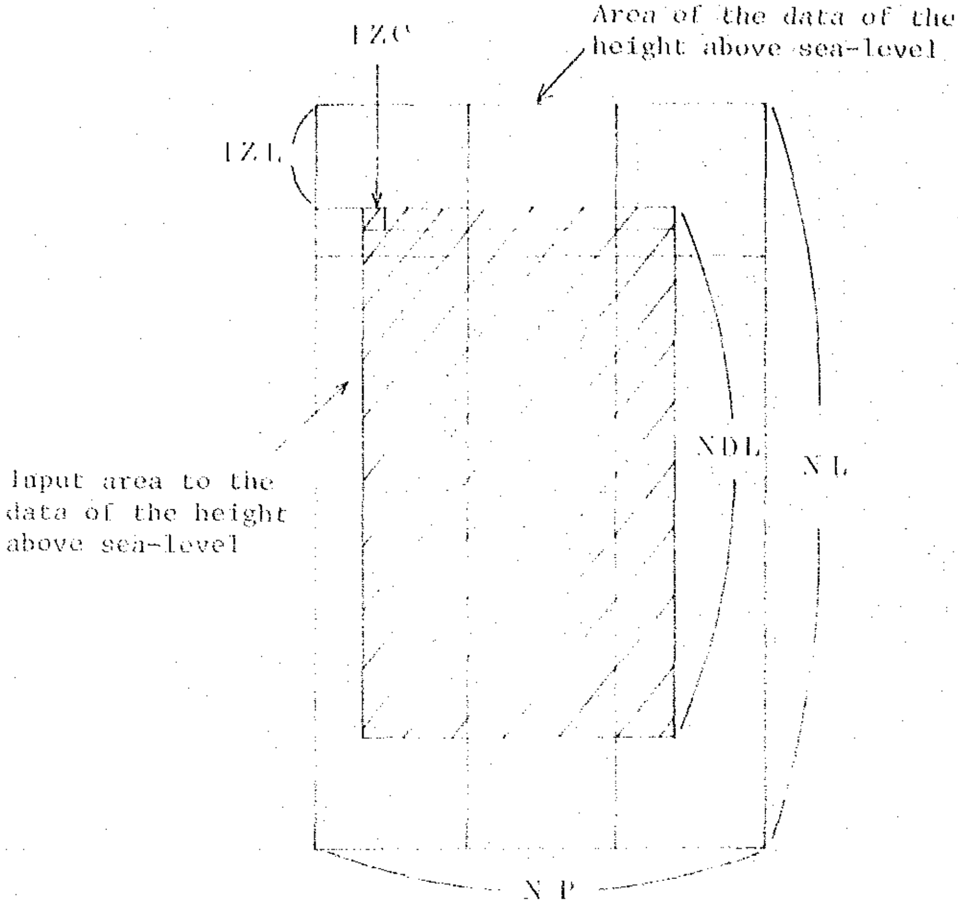
DATA SHEET

PROBLEM ④ Preparation of image form file of the height above sea-level

WRITTEN BY ______ PAGE ____ OF ____

No.	1–30	31–80
1	(data)	
2	100 60 15 2 80	NL Number of lines of the image form file to be prepared
3	NL NP IZL IZC NDL	NP Number of pixels of the image form file to be prepared
4		IZL Number of offset lines of the input data of the height above sea-level
5		IZC Position of the first pixel of the input data of the height above sea-level
6		NDL
7		Number of lines of the input data of the height above sea-level
8	528 520 522 518 510 510 ~	Data of the height above sea-level
9		This is continuously input in the column direction,
10	525 517 520 ~	and is made a new records for each line.
11		
12		
13		
14	Assignment statement	
15		
16	¥ASSIGN UR1,21,DP-D2,FILE=HATAM	
17		
18		
19		
20		
21		
22		
23		
24		
25		

Data for the preparation of image form data of the height above sea-level



DATA SHEET

PROBLEM ⑤ Topographical analysis　　WRITTEN BY ______　　PAGE ____ OF ____

No.	
1	(data)
2	100 60 100
3	NL NP INVL
4	Line number Column number Mesh size(m)
5	
6	
7	
8	
9	Assignment statement
10	
11	¥ASSIGN U01,21,DP-D2,FILE=HATA1 ..... First file of the height above sea-level, for topographical analysis (input)
12	¥ASSIGN U02,22,DP-D2,FILE=HATA2 ..... Second file of the height above sea-level, for topographical analysis (input)
13	¥ASSIGN U03,31,DP-D2,FILE=WATA1 ..... Slope inclination (output)
14	¥ASSIGN U04,32,DP-D2,FILE=WATA2 ..... Slope direction (output)
15	¥ASSIGN U05,33,DP-D2,FILE=WATA3 ..... Local topography (output)
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

IV-5 Data Analysis by Computer

IV-5-1 Computer System and Examples of its Use

(1) Summary of computer system

FACOM 230-28 system (by Fujitsu Ltd.), installed in Forest Board of St. Paulo state, is a granted instrument to proceed promptly and accurately the data analysis like statistical analysis, data analysis, simulation, etc. and thus assist the efficient advancement of the project, which is intended for the data collected in the process of various surveys and tests in the local field of Cunha, Campos de Jordan, Águas de Santa Barbara, etc. by 5 research departments of the forestry research project.

Though the hardware and software of this system are constituted only for the batch processing at present, the on-line programme package like SOM (standard on line module), CPM (conversational programme module), etc.

① Constitution of hardware

Hardware is composed of the central processing equipment which is constituted with the computing and controlling system and the main memory, and various peripheral equipment like a magnetic disk supplementing the main memory's capacity, a magnetic drum, etc., floppy disk system, data input-output floppy disk system, and line printer system.

Magnetic drum equipment, called a page-file, is used as the substituting domain of the main memory for job-processing by virtual storage method which is one of the features of this system. The virtual storage method is the one that develops and practises not in the real storage domain but in virtual storage domain, with various advantages advantages like the improvement of programme productivity.

The constitution of FACOM 230-28 system at present is illustrated in Fig. IV-54.

② Constitution of soft-ware

The operating system BOS/VS of FACOM 230-28 system is the assembly of various programme in order to shorten the processing time and

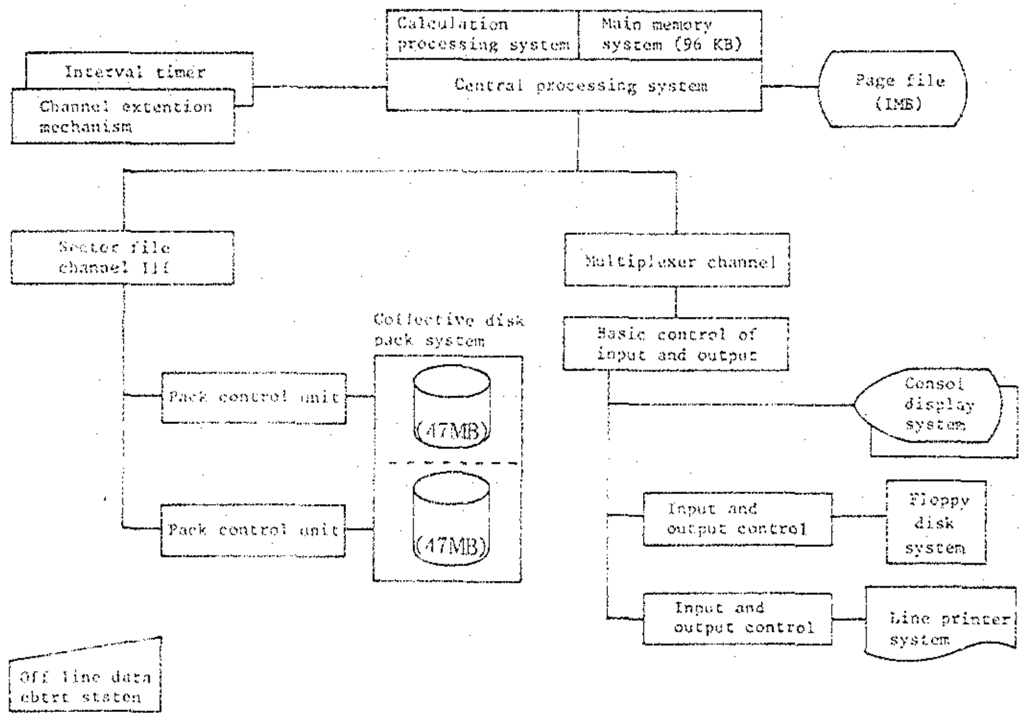


Fig. IV-54 FACOM 230-28 system composition improve the cost-performance of the computer, by the efficient use of central processing equipment, input-output equipment, etc. One job (the unit of work processed by a computer) is, from data input to result output, divided into several processings inside a computer. The operating system makes a programme start at every processing, and assists the practice of a job, securing necessary sources.

The whole constitution of the operating system is illustrated in Fig. IV-55, where the constituents of the present system have been determined after the comprehensive deliberation on the status of computer utilization, the content, quantity, etc. of data-processing.

(2) Utilization of computer system

The so-called utilization of computer system is divided into; the use in the development stage, started with the occurrence of a problem and its standardization, and the use in the practice stage.

Except those users with the programming knowledge, general users are restricted to the utilization in the stage of programme practising.

The extent of concern of users to computers also varies depending on the processing method adopted in the computer system. The processing methods are divided into the open batch processing in which user himself carries out the job processing while operating the input-output equipment, and the closed batch processing in which an appointed operator performes a job upon the user's request. Forest Board has adopted the latter method. In this section, the fundamental matters that are regarded necessary for the utilization of a computer system are discussed.

① Operation of data entry equipment

The job input to a computer is executed through such media as cards or floppy-disks, and magnetic tapes.

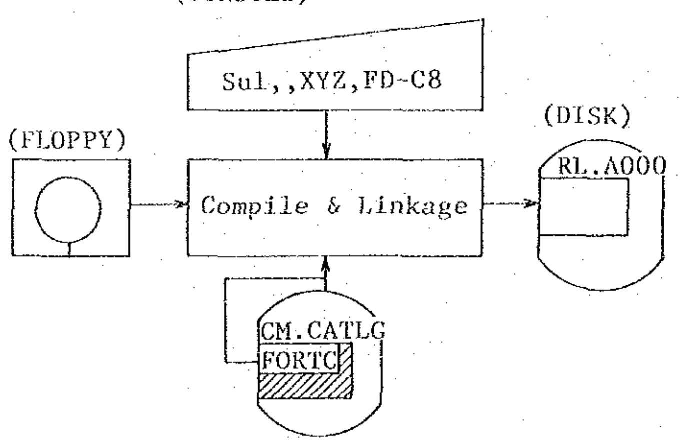
In FACOM 230-28 system is provided with floppy disk equipment instead of a card reader that has been previously often adopted. A card-punching machine, for making input medium off line, though simple at its operation, has often encountered troubles like mechanical damages due to operation mistakes, incomplete machine operation

- BOS/VS
  - Control program
    - Supervisor
    - Job management
    - VS management
    - Input output management
    - Data management
    - Online management
    - Practice utility
    - Volume management
  - Processing programme
    - Word processing programme
      - FASP
      - FORTRAN
      - COBOL
      - RPG
      - TASKFORCE
    - Service programme
      - SOFT/MERGE
      - Convert utility
      - Chinese character utility
      - TSSP
    - Application programme
      - Package programme
      - User made programme

Fig. IV-55 BOSNS operating system composition diagram

```
Y JOB User number, ACCT='FORTC'
Y CAT FORTC, LIB=DP-D1/CM.CATLG.OV
 /MERGE 13
Y DATA
Y LIED Title of programme
Y DEND
 /IEND
 /CEND
Y JEND
```

Fig.IV-56 Job control statement for load module preparation



RA.A000: Saving file of load module
CM.CATLG: Catalogue library file

Fig.IV-57 Graphic diagram of job execution

FICHA PARA O CALCULO DO VOLUME

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

N.	ALT.	DIAMETRO A ALTURA DO PEITO: COM CASCA (C/C) MAX.	C/C MIN.	C/C MED.	SEM CASCA (S/C) MAX.	S/C MIN.	S/C MED.	AREA BASAL C/C	AREA BASAL S/C	VOLUME C/C	VOLUME 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	20.30	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	AREA BASAL S/C	VOLUME C/C	VOLUME 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
PORCENTAGEN	(%)					99.67	99.67	

Fig.IV-58 Results of calculation by STEMAN/V01 programme (No. 1)

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	21.20	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	11.30	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	0.2781	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

Fig. IV-59 Results of calculation by STEMAN/VO1 programme (No. 2)

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

ESPECIE : P.ELLIOTTII , LOCAL : AGUAS DE SANTA BARBARA , EQUACAO : V=0.6746091D-02 - 0.1228141D-03*(D*D) + 0.4551750D-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	0.011	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	0.056	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	0.456
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)	23	24	25	26	27	28	29	30	31	32	33	34
	CLASSES DE DIAMETRO (CM)											
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

Fig.IV-60 Results of output of lumber volume table due to worn parts, etc. Besides above, reasons, the floppy disk entry equipment has been adopted owing to the merits as; i) record of a large quantity of data, ii) refresh and reuse of a medium are possible, iii) simplicity of storing and transporting. Further, since two seats are provided in this equipment, two operators can independently input different data simultaneously, and besides, it is provided with various intelligent functions like verify, up-date, search, etc., enabling efficient data-input.

As the operating process of the data-entry equipment is minutely described in the operation manuals in Portugues, etc., here the manuals are described as below.

1) FACOM F6852 Data Entry
2) MATERIAL SOBRE FLOPPY-DISK

Both of above 1) and 2) are Xerox copies of manuals from FACOM DO BRASIL.

② Process and job-control statement

When a job is input into a computer, inside it, the processing is carried out, being divided into such departments as compile of source programme, combination and linkage of plural programmes, allocate of files, etc. What makes these processing programmes start is the job control statement, the constitution of which is determined with the content of the job processing.

Generally, regarding fairly standardized job processing, instead of taking a trouble to provide the plural number of job control statements for each job, a method is taken, where a series of job-control statements are in advance stored with respective titles in a file called a catalogue library, and the respective file is called up and carries out the job when a job is input. By this method, any possible mistakes in the description or the order in the job control statement are eliminated, so jobs can be efficiently processed.

However, when there are mostly unstandardized jobs like scientific and technical calculation, the above catalogue function will be fairly restricted on its use.

Hence, taking account of the content of job-processing, the fundamental processing patterns were determined as follows,

1. Compile and execution
   1) with work file
   2) without work file

2. Compile only

3. Register of load module

4. Execution of load module
   1) with work file
   2) without work file

5. Execution of load module by command
   1) with work file
   2) without work file

6. Store of data by command

7. Register of catalogue procedure

8. Others

By the way, load module means execution form programme, catalogue processing and a series of job control statements stored in the same file. For the reference, in Fig. IV-56 is shown how to write the job control statement, in case when after the compile and linkage processing of source programmes, load module is registered in a file (RL.A000). In this study, load module is made, using FORTC that is registered in catalogue library, but the title is to be altered into the designated one. (This is also called over-write function)

③ Execution of job

In this system, a job is executed by the key-operation on a console. The standard job procedure is; at first set in the input equipment the floppy disk recorded with the job stream which is composed of programme, data and job control statement, then only input by key on the console the command to motive the input equipment. The typical procedure, as described in the previous (2) paragraph, to store the load module in file, is shown in Fig. IV-57.

In a floppy disk as the input medium, there must exist at least two files. That is, in one file the job-control statement in Fig. IV-56, and in the other file the source programme is stored, where the file data is optional in the former, while fixed (FRONTE) in the latter.

Job is motived by start command (abridged form: S), made by key-input together with parameter as in Fig. IV-57. Here, XYZ indicates the optional file number provided by the user, and FD-C8 shows floppy disk input equipment.

Besides above, various methods have been provided, such as key-input of job control statement at a console, as for the method of job execution, so the most adequate way can be selected, taking account of the content and quantity of processing, the simplicity of process, etc.

(3) Use of computer in the field of remote-sensing

In the field of remote-sensing, computers are mainly used for the statistical treatment of data of multi-characteristics, which are collected by sample tree survey or photo-interpretation.

In this section, the summary of the process of preparation of total tree volume table in Aguas de Santa Barbara district, which is one of the study subject of remote-sensing department, is discussed in the view point of computer processing.

The preparation of each tree volume table is performed on the collected data on 100 sample trees in the above district, in three parts of 1) rearrangement of simple tree volume analysis, 2) application of the tree volume table, and 3) printing of tree volume tables.

The main portion of the data analysis 2), one of multi-variate analysis, is applied. 1) is the pre-processing part to obtain various tree volume that is one of 3 variables to be used in 2). 3) is the after processing part, in which tree volumes, caluculated by the tree volume formula which is ultimately determined, is printed in a form of table.

At first, on basis of diameters at breast height, under branch tree heights, and diamters at determined heights, which are collected at the cutting survey of sample trees, total tree volumes, available volumes and real available volumes are calculated, then the results together with input data are printed (output) in a form resembling to the field book. (See Fig. IV-58)

After these calculations are performed for all data, then taking those calculation results as the secondary data, the volume with bark, the volume without bark, and the ratio of volume without bark against with bark are searched for each kind of volumes, which are printed in a list. (See Fig. IV-59)

A series of above calculations were treated by FORTRAN programme (STERAN/VOL) that was newly prepared for the simple stem analysis. Further, though this programme is made as the pre-treatment for the preparation of tree volume tables, if some modification, including the addition of a part of function, is made, it could be used in the research in the correlating fields as more versatile programme.

Taking diameters and tree heights for every sample trees as independent variables, and volume tables as dependent variables, the optimum regression model was selected by a multiple regression analysis.

As the volume formulae to be studied, the following five formulae, which were rather often used, were selected, among various formulae already proposed.

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

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

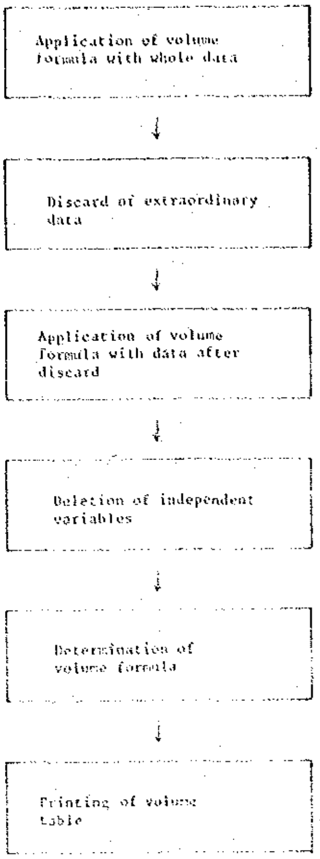
$$V = a_0 + (D^2 H)^{a_1} \qquad (3)$$

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

$$V = a_0 H a_1 D^2 + a_2 H + a_3 (D^2 H) \qquad (5)$$

Since the application of the volume formulae is executed for each of the total tree volume, the available volume and the real available volume, that makes 3x5 ways the number of treatments, so it looks fairly troublesome work but the job processing for computer can be sufficiently made only by once.

In other words, since the multiple regression programme (Forestry and Forest Products Research Institute, library programme, made by Kozo Kawabata) is provided with the conversion function, the variable selection function, etc,, if only the original data of five variables (i.e. diameter, tree height, total tree volume, available



Apply sach volume formula with whole data.

Detect and discard the extraordinary data due to mistakes on measurement or record in a field book, or improper selection of a sample tree.

Apply volume formulae again with the data after discard of extraordinary data

Delete independent variables that do not contribute to the estimation of volume, by means of the significance test of partial regression coefficients.

Estimate the adaptability of each volume formula.

Calculate the volume formula, then print the results in a form of table.

Fig. IV-61 Process of volume table preparation volume and real available volume) are input beforehand, thereafter variables for each formula are selected by the instruction, and the conversion of variables (to logarithm) is made in formula (1), (3) and (4), so the application of 15 ways of volume formula can be processed continously. The adaptability of each volume formula was evaluated from the results of above calculation. Then ultimately the following formula was adopted for all of volume formulae.

$$V = a_0 + a_1 D^2 + a_2 D^2 H$$

In addition, this volume is such as the third term is deleted in the formula (5), due to the results of significance test on the partial regression coefficients.

Once the volume formula is determined, thereafter, simply volume will be printed out in the two-dimensional table in the diameter and the tree height.

The programme is made to input three parameters of a_0, a_1 and a_2 in the volume formula, then calculated and output the volume in the range of the specified diameter and the specified tree height. (see Fig. IV-60)

As above, the summary of the preparation of the volume table, divided in three parts, is described in the view point of computer processing where a series of processes can be set in order as in Fig. IV-61. As for the detail of the study, please refer the study of volume formula of Pinus elliottee in state forest of Aguas de Santa Barbara in St. Paulo state (the 95th, Japan Forestry Society Theses, 1984), etc.

(4) Utilization of computer in future

In recent years, the research and study of forestry have become higher and diversified, meanwhile the computer using technique, to which the efficient study can be attributed, has rapidly progressed. Computers have been availed for various purposes by a research as a tool to conduct study efficiently and a mean to develop a novel research.

Though the computer in Forest Board has been availed in the research work, mainly of scientific technical calculation, its use will be enlarged to various works including clerical calculation, in future.

Under the circumstances, in order to attain the efficient employment, it is always necessary to catch users' needs and tendency and to reconsider the system, including its intensification and extension. Especially, the problem of renewal, taking account of the computer's life cycle, should be prudently disposed with the future prospect of its utilization after the many faceted deliberation.

Since the existing FACOM 230-28 system is fully provided with the functions of medium-sized versatile computer, such as imaginery memory method, multiple processing, on-line function, etc., at this moment the provision of peripheral machines like a XY-plotter, a graphic display, etc. will be the subject of deliberation.

Parallel with the provision of hardware, soft were especially the basic programme of statistical calculation and numerical value calculation should be provided by means of introduction or development, and it is necessary to establish soon such system capable of furnishing data always to users as a programme library.

In this section, though it is hard to anticipate the change in the future utilization of computer in Forest Board, several opinions are indicated to increase the future utilization of computer, taking our present use of the computer as a clue.

① Preparation of application programme

The data processing by a computer handles various problems such as data modification, calculation, illustration, searching, etc.

In recent years, as the new type of data processing, the demand for image analysis and data-base has been rapidly increasing. This owes to the improvement of the performance of image treating equipment like color-image display, drum-scanner, etc. and the advance of the availing technique, so, in fact, a versatile image analysing system, making use of remote-sensing data, has been developed. In addition, as the data base managing system for personal computers, has been prepared, its use is increasing, for example, as furnishing a small scale data base for the user's individual use.

Now, data processing in the field of research is, of non-standardized type, quite different from those clerical work that mainly handles standardized type. Therefore, even though it is a complete programme, it is necessary to conduct the addition or change of a part of function, if desired by users.

Generally, though programmes are developed, intending the specified function to meet the purpose of use by users, it is desirable, as for the concerned stuff of Forest Board, to develop and librarize such versatile programme as provided with various functions for multifaceted use.

In order to furnish efficiently the complete set of library programme, it is possible to introduce the existing basic programme of statistical calculation and numerical value calculation. Further, since programmes peculiar to forestry research are considered to be already prepared in concerned organization, university, etc., it is proper to introduce such programme through the prescribed procedure.

It will be one of problems to prepare and extend the programmes, which are necessary to the research or work in various departments of Forest Board, by the development or introduction as above, and to provide users with a system for efficient data processing without delay.

② Making common data to data base

As forestry experimental research intends for the natural phenomenon, various data required in the study in various fields are collected over many years, so requires plenty of labor and expense. Among these data, some data can be used not only in the respective field but also commonly in other wide field. The examples are the forestry hydrogical data, like meteorology, evaporation, water quantity, etc. collected by watershed management department and remote-sensing department, and the forest survey data containing minute measurement data of every sample tree.

Continuously observed and measured minute original data are preserved in a form of recording paper or a field book, or preserved in a floppy disk when data are processed.

These data can be positioned as common basic data in the forestry experimental research, usable not only individually but also as the comprehensive data combined with multi-faceted data.

In order to attempt the efficient use of the common basic data, they shall not be preserved by individuals nor laboratories, but have to be controlled in the unified form making use of computer system. For this purpose, the concrete study on the introduction of the data base management system is required. The introduction of the data base management system displays its capability of the preservation and use of mass information such as, 1) data maintenance like addition, renewal, deletion, etc. of data can be efficiently carried out, 2) necessary data can be immediately searched through simple procedure, 3) various calculation is carried out, availing of the searched results. Further, by the unified management of data, the waste of expenses, time and labor due to the collection of duplicated data will be prevented. The data base management system will remarkablly contribute to the efficient promotion of research and work, as the center of the data processing system in Forest Board.

③ Introduction of time sharing system

The present use style of FACOM 230-28 system is restricted to batch processing (jobs are processed in a lump, with higher computer availing efficiency, but shorter turn around time).

Time sharing system (TSS) is a system that furnishes a number of users with the service of conversational type, performing various processing for a divided time, and the recent tendency in the use of computers have shifted from batch processing to TSS. The way of use of this system ranges from the use depending on various functions (intelligent function) of personal computer to the use as the on line terminal, availing of communication circuit, relying on the plentiful function of the host computer.

In fact, by this system, various data processing preparation, addition, deletion, modification, etc., and like the development of gradually to the direction of TSS in near future so it will be necessary to deliberate the composition of hardware as well as software for that shift, and the technical problems