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Planning of Forest Road Network in Palm Form Working System (II) -Selection of Representative Unit Block and Estimation of Its Stand Volume by Aerial Photographs —

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This paper deals with the selection of representative unit block and the estimation of its stand volume (m^3/ha) for the purpose of the planning of forest road network in the palm form woking system of Kyushu University Forest in Hokkaido. Based on form patterns and terrain classes, all of the 50 unit blocks were classified into six types, and a representative unit block was selected from each type. Furthermore, the stand volume in m^3 per hectare of each unit block was estimated by a linear regression equation which was constructed using the field and photo data from the sample plots. The stand volume (m^3/ha) estimated in applying the regression equation was distributed from 50 to 250 with a large variation in the same unit block. The results obtained showed the effective measure for planning of the forest road network.

INTRODUCTION

In previous paper (Cha et *al.,* 1987), the results of the establishment of unit blocks, which are necessary for the sustained yield management and are the most fundamental cell of the palm form working system applied to the Kyushu University Forest in Hokkaido, were reported as the first paper of the planning of forest road network.

To begin with, the alignment of the forest road in the unit block must be examined with a view to the planning of forest road network by which the whole area of this working system is the object. The 50 unit blocks were established, but all of these unit blocks can be classified into some types by form patterns or by the terrain conditions. Therefore it is sufficient to investigate the planning of forest road network within the representative unit blocks which are selected from each type.

Besides, a so-called theoretical model was applied as for the planning model of forest road in former periods and then the application problem often happens when an actual route is established (Matthews, 1942 ; Minamikata, 1968). Particularly, in the planning of forest road network by means of an electronic computer technique, it is to be desired that the representative unit block which can be grasped the shape of geographical feature is more preferable than the theoretical model adopted conventionally to its examination (Weintraub and Navon, 1976).

Furthermore, in investigating the planning of forest road in the representative unit blocks, it is necessary to clarify the detail composition of stands, particularly the distribution of stand volume (m^3/ha) relating directly to the maximum skidding distance which can be skidded from the route.

Accordingly, in the present paper, the authors wish to report on the results of the selection of representative unit blocks and the estimation of stand volume (m^3/ha) of these unit blocks by aerial photographs, as the second paper of the planning of forest road network in the palm form working system.

MATERIALS AND METHODS

Selection of representative unit block

Based on the form of 50 unit blocks established the applied forest of palm form working system, we discussed enough its form patterns. Then, as a result, 2 form patterns are classified as follows :

1) Triangle pattern (Isosceles triangle pattern)

2) Rectangle pattern (Rhombus pattern, Trapezoid pattern, Isosceles trapezoid pattern)

Furthermore, each unit block selected by form pattern is classified into the 3 types of even, hilly, steep terrain by Terrain Index derived by Hori (1965). Then Terrain Index is calculated by the formula :

$$I = (3\,I_i + I_r)/4 \ (\%)$$

Where I = Terrain index (%)

I_i = Index of gradient (%)

I_r = Index for unevenness of ground and density of valleys and streams (%)

Estimation of stand volume by aerial photographs

The used aerial photographs which the average flying height above scale of sea level is approximately 1,800 m and the average scale of aerial photographs is about 1 : 5,000 were taken in 1977.

In photo-plots sampling, the photo-plots are systematically distributed and are established two plots per hectare with circular 0.10 hectares plot at a scale of 1 : 7,000 on the unit block.

In the **1 :** 5,000 scale aerial photographs the crowns of the individual trees of the photo-plots were measured using a dot or circle gauge. with circles at a scale of 1: 10, 000 and two or three times from different angles.

Then the crown diameter (m) and the number of trees (trees/ha) are calculated as the arithmetic mean of these measurements.

In the case of natural broadleaved stands, the field data of average tree diameter at breast height (cm), number of trees (trees/ha), stand volume (m^3/ha) and average basal area diameter (cm) measured from the ground survey were obtained in 1978 (Chainarong, 1979). The independent variables were measured in ground sample plots located in exactly corresponding to photo-plots with the line sampling method and were obtained by measuring all dominant and co-dominant trees of each plot on the ground.

Moreover, in the case of coniferous stands, the field data was obtained from the permanent sample plots (K. U. F., 1982).

Based on the data interpreted by aerial photographs and measured from ground sample plots, the stand volume (m^3/ha) of each representative unit block was estimated by a linear regression equation.

RESULTS AND DISCUSSION

Selection of representative unit block

The **50** unit blocks are classified into six types, as shown in Table 1. As can be seen from the table, the even and hilly types make up **70%** of all unit blocks. Also Table 1 shows the representative unit block selected from each type. Furthermore, even though the unit blocks belong to the same type, the selected representative unit blocks are characterized by the property of uniform arranging of the intervals of contour lines, and Fig. 1 indicates the shape of geographical feature of the representative unit blocks selected. This indicates that the applied forest of palm from working system has a relatively moderate topography.

For that reason, it is possible that the forest area has a relatively dense road network. Particular-y the skidding methods on this working system is truck-crane, and then it requires an average skidding distance of not more than 100 m for a high utilization of forest. In this case the density of the road network should be 50-70 m per hectare including forest working road.

In addition, it is necessary to classify the forest type of each representative unit block to obtain rough information on the stand composition.

Table 1. The representative unit blocks classified by form patterns and terrain classes.

Factor		No. of Unit Block	Representative Unit Block
Form Pattern	Terrain Class		
Rectangle	Even	14, 15, 19, 20, 25, 32, 33, 34, 45	33
	Hilly	2, 3, 5, 16, 18, 23, 26, 28, 29, 31, 35, 38, 40, 41, 43, 49, 50	35
	Steep	1, 6, 7, 11, 12, 13, 21, 22, 24, 39, 48	12
Triangle	Even	36, 42, 44, 46, 47	47
	Hilly	17, 27, 30, 37	37
	Steep	4, 8, 9, 10	8

Estimation of stand volume by aerial photographs

Characteristics used in classifying forests on the aerial photographs are tree species and stand volume taking a topography map into consideration. The classification of forest type has largely effects' upon the alignment of road in planning the forest road network in connection with the upper skidding road which will be

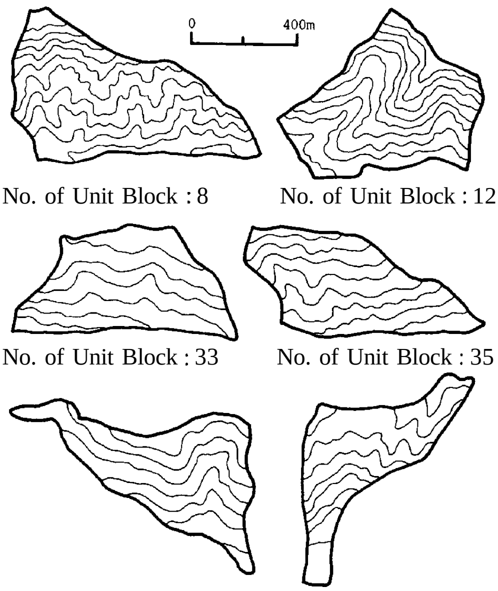

Fig. 1. The shapes of geographical features of six representative unit blocks.

constructed in the natural broadleaved stands and the lower skidding road which will be constructed in the coniferous stands. The results of forest type classification of each representative unit block by only species are shown by Fig. 2. The size of mesh is 50 m × 50 m.

Based on the these results, the stand volume (m^3/ha) of each unit block is estimated as follows :

1) Relationship between the average crown diameter by photo interpretation and the average basal area diameter by ground measurement.

Fig. 3 represents the relationship between the average crown diameter (m) obtained from photo interpretation and the average basal area diameter (cm) measured from ground sample plot, and then the regression equations are as follows :

Broadleaved stands $D_b = -5.978 + 5.253 \cdot CDp$ (r = 0.863) (1.1)

Coniferous stands $D_b = 6.111 + 4.161 \cdot CDp$ (r = 0.787) (1.2)

Where D_b = average basal area diameter by ground measurement (cm)

CDp = average crown diameter by photo measurement (m)

In the natural broadleaved stands, it is impossible to recognize the distinguishing features clearly of crown diameter on the aerial photographs, because the parts of a crown, particularly the lower and more spreading branches, are hidden by neighboring trees or sparse branching of same species at the edge of the crown. Conversely, conifers can almost always be distinguished from the same species.

Accordingly, the measurements of crown diameters of coniferous stands can be more easily and accurately determined than those of natural broadleaved stands on the

```
B B B B * * * * * * * * * * * * * *
B B B B B B * * * * * * * * * * * *
B B B B B B B B * * * * * * * * * *
B B B B B B B B B C C C * * * * * *
B B B B B B B B B C C C C C * * * *
* B C C C C B C C C C C C C C * * *
* C C C C C C C C C C C C C C C * *
●  C C C C C C C C C C C C C C C C *
* C C C C C C C C C C C C C C C C C
●  * C C C C C C C C C C C C C C C C
●  * C C C C C C C C C C C C C C C C
```

No. of Unit Block : 8

```
* * B B B B B B B B B B * *
* * B B B B B B B B B B * *
* * B B B B B B B B B B B *
* B B B B B B B B B C C C *
* B B B B B B B B B C C C *
●  B B B B B B B B B C C C C
●   % B % % % % % % % C C C C
●  B B B B B B C C C C C C *
* B B B B B C C C C C * * *
B B B B B B C C C C C * * *
B B B B B B C C C C * * * *
B B B B B C C C * * * * * *
B B B B B C C C * * * * * *
* * C C C C C * * * * * * *
```

No. of Unit Block : 12

```
C C C C C C C C C C C C C C C C C
C C C C C C C C C C C C C C C C C
C C C C C C C C C C C C C C C C C
C C C C C C C C C C C C C C C C C
* M C C C C C C C C C C C M M * *
●  M M C C C C M M C C C M M * * *
●      * M M C C C M M C C C M M * * *
* * * M M M M M M M M M M M M * * *
●     * * * M M M M M M M M * * * * *
```

No. of Unit Block : 33

```
M M M M M M M M M M M * * * * * * * *
M M M M M M M M M M M M * * * * * * *
M M C C C M M C C C C M M M M * * * *
C C C C C M M C C C C C C C C C C * *
●  C C C C C C C C C C C C C C C C C *
* * C C C C C C C C C C C C C C C C C
●  * * C C C C C C C C C C C C C C C C
* * * C C C C C C C C C C C * * * * *
* * * * * C C * * * * * * * * * * * *
```

No. of Unit Block : 35

```
M M * * * * * * * * M M M M M *
M M M M * * * * M M M M M M M *
C C C M M M M M M M M M M M M *
C C C C C C C C M M M C C C M *
* C C C C C C C C M C C C C M M
* * C C C C C C C C C C C C C C
* * * C C C C C C C C C C C C C
* * * * * C C C C C C C C C C C
●  * * * * * * C C C C C C C C C
* * * * * * * * * * * C C C C C
* * * * * * * * * * * * C C C C
* * * * * * * * * * * * * C C C
* * * * * * * * * * * * * * C C
```

No. of Unit Block : 37

```
* * * * * * * * * * C C C B
●  * * * * * * * * C C C C B
●  C C C * * C C B C C C C B
●  C C C C C C C B C C C B *
C C C C B B C C B C C B * *
C C C C B B C C B C B B * *
C C C C B B C C B B B * * *
C C C B B B B B B * * * * *
C B B B B B B * * * * * * *
B B B B B B * * * * * * * *
B B B B * * * * * * * * * *
B B B B * * * * * * * * * *
B B B * * * * * * * * * * *
B B B * * * * * * * * * * *
B B B * * * * * * * * * * *
B B B * * * * * * * * * * *
B B B * * * * * * * * * * *
```

No. of Unit Block : 47

Fig. 2. The classification of forest type for six representative unit blocks by photo interpretation.
(B : Broadleaved stands, C : Coniferous stands, M : Mixed stands)

aerial photographs.

2) Relationship between the number of trees per hectare by photo interpretation and the number of trees by ground measurement.

Fig. 4 shows the relationship between the number of trees per hectare by photo interpretation and the number of trees by ground measurement, and then the regression equations are as follows :

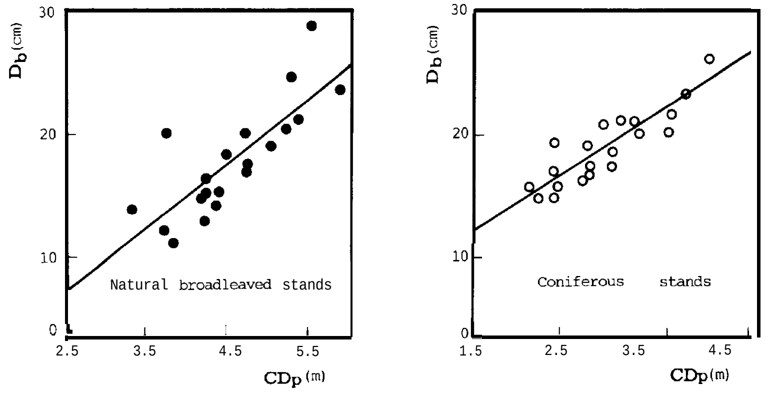

Fig. 3. Relationship between average crown diameter (CDp) by photo interpretation and average basal area diameter (D_b) by ground measurement.

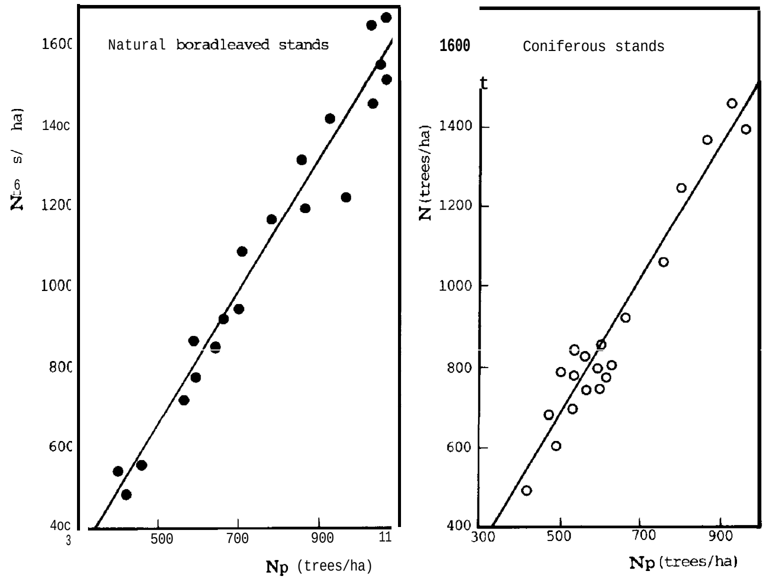

Fig. 4. Relationship between number of trees (N) by ground measurement and number of trees (Np) by photo interpretation.

Broadleaved stands : $N = -183.787 + 1.670 \cdot Np$ (r = 0.813) (2.1)

Coniferous stands : $N = -124.950 + 1.649 \cdot Np$ (r = 0.913) (2.2)

Where N = number of trees by ground measurement (trees/ha)
Np = number of trees by photo measurement (trees/ha)

As can be seen from Fig. 4, the values of the natural broadleaved stands and the coniferous stands interpreted by aerial photographs are fewer than the those measured by ground survey. This suggests a slight tendency for photo measurement to underestimate number of trees (trees/ha) on dominant and co-dominant trees.

In coniferous stands, the dominant and co-dominant trees, which form the main canopy, can easily be recognized on the aerial photographs. In natural broadleaved stands it is much more difficult to decide which trees should be included.

3) Relationship between the estimated average basal area per hectare and stand volume per hectare measured by ground survey.

The average basal area (m^2/ha) can be calculated from the relationship between the estimated values of average basal area diameter derived from the regression equation (1.1) or (1.2) and the number of trees (trees/ha) derived from the regression equation (2.1) or (2.2).

This relation is as follows :

$$B = (D_B^2 \times N \times \pi)/(4 \times 10^4) \quad (3.1)$$

Fig. 5 gives the relationship between the average basal area obtained from equation (3.1) and the stand volume per hectare measured by ground survey, and then the regression equations are as follows :

Broadleaved stands : $V = 12.964 + 6.142 \cdot B$ ($r = 0.793$) (3.2)

Coniferous stands : $V = -19.727 + 8.276 \cdot B$ ($r = 0.832$) (3.3)

Where V = stand volume per hectare (m^3/ha)

B = basal area per hectare (m^2/ha)

Theoretically, this stand volume in m^3 per hectare obtained from the above equation will be estimated by the average basal area multiplied by the average height and the stand form factor. However, it is very difficult to interpret actually the average height of trees on aerial photographs, and the stand form factor itself is different from the each stand. Accordingly, in this paper, stand volume is directly estimated from average basal area per hectare (Kogi, 1982).

Stand volume of the each representative unit block is calculated from the regression equation (3.2) and (3.3), and then the results are shown by Fig. 6. The stand volume per hectare is divided into five classes

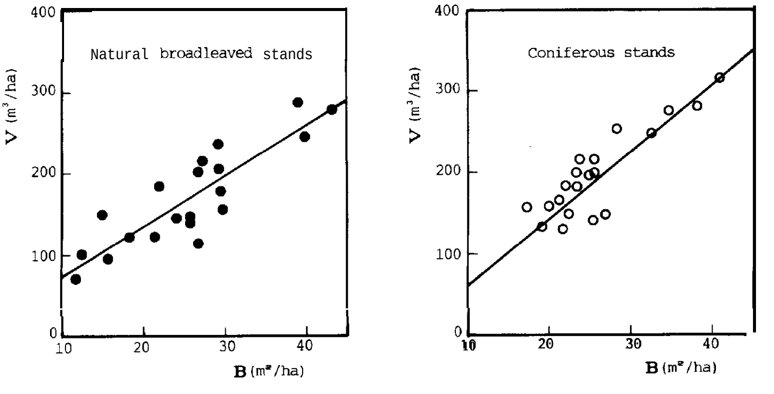

Fig. 5. Relationship between estimated average basal area (B) and stand volume (V) by ground measurement.

Class 1 : below 50 (m³/ha)
Class 2 : 51-100 (m³/ha)
Class 3 : 101-150 (m³/ha)
Class 4 : 151-200 (m³/ha)
Class 5 : above 201 (m³/ha)
and the size of mesh is 50 m x 50 m.

As the results show, the natural broadleaved stands is generally distributed on the upper parts of hillside in No. 8, 12 and 47 representative unit blocks. In addition, in No. 33, 35 and 37 unit blocks, the upper parts of hillside are distributed by mixed stands.

```
1 1 1 1 * * * * * * * * * * * * * *
1 1 1 1 1 1 * * * * * * * * * * * *
3 3 3 3 3 3 3 3 * * * * * * * * * *
3 3 3 3 3 3 3 3 3 4 4 4 * * * * * *
3 3 3 3 3 3 3 3 3 4 4 4 4 4 * * * *
●   3 5 5 5 5 3 4 4 4 4 4 4 4 4 * * *
* 5 5 5 5 5 3 4 4 4 4 4 4 4 4 4 * *
* 5 5 5 5 5 3 4 4 4 4 4 4 4 4 4 4 *
●   5 5 5 5 3 3 3 4 4 4 4 4 4 4 4 4 4
* * 5 5 5 3 3 3 3 4 4 4 4 4 4 4 4 4
●   * 5 5 5 5 3 3 3 4 4 4 4 4 4 4 4 4
```

No. of Unit Block : 8

```
* * 3 3 3 3 3 3 3 3 3 3 * *
* * 3 3 3 3 3 3 3 3 3 3 * *
* * 3 3 4 4 4 3 3 3 3 3 3 *
* 3 3 3 4 4 4 3 3 3 3 4 4 *
* 3 3 3 4 4 4 3 3 3 3 4 4 *
* 3 3 3 4 4 4 3 3 3 3 4 4 4
* 3 3 4 3 3 3 3 3 3 4 4 4 4
●   3 3 4 4 3 3 4 4 4 4 4 4 *
●   4 4 4 4 3 4 3 3 3 3 * * *
4 4 4 4 3 3 4 3 3 3 3 * * *
4 4 4 4 3 3 4 4 4 4 * * * *
4 4 4 3 3 4 4 4 * * * * * *
3 3 3 4 4 4 4 4 * * * * * *
●   * 3 4 4 4 4 * * * * * * *
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No. of Unit Block : 12

```
5 5 5 5 5 5 4 4 4 4 5 5 5 5 5 5 5
5 5 5 5 5 5 4 4 4 4 5 5 5 5 5 5 5
5 5 5 5 5 5 4 4 4 4 5 5 4 4 4 4 4
5 5 5 5 5 4 4 4 4 4 5 4 4 4 4 4 4
* 3 5 5 5 4 4 4 4 4 4 4 4 3 3 * *
●   3 3 4 4 4 4 3 3 4 4 4 3 3 * * *
●   * 3 3 4 4 4 3 3 4 4 4 3 2 * * *
* * * 3 3 3 3 3 3 3 3 3 3 2 * * *
●   * * * 2 2 2 2 2 2 2 2 * * * * *
```

No. of Unit Block : 33

```
2 2 2 2 2 2 2 2 2 2 2 * * * * * * * *
2 2 2 2 2 2 2 2 2 2 2 2 * * * * * * *
3 3 4 4 4 3 3 4 4 4 4 3 3 3 3 * * * *
4 4 4 4 4 3 3 4 4 4 4 4 4 4 4 4 4 f f
●   4 4 4 4 4 4 4 4 4 4 4 4 4 4 5 5 5 *
* * 4 4 4 4 4 4 4 5 5 5 5 5 5 5 5 5 5
* * * 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5
●   * * 4 4 4 5 5 5 5 5 5 5 5 * * * * *
* * * * * 5 5 * * * * * * * * * * * *
```

No. of Unit Block : 35

```
2 2 * * * * * * * * 2 2 2 2 2 *
3 3 3 3 * * * * 2 2 3 3 3 3 2 *
5 5 5 3 3 3 3 3 3 3 3 3 3 3 2 *
5 5 5 5 5 5 5 5 3 3 3 5 5 3 2 *
●   5 5 5 5 5 5 5 5 3 5 5 5 3 2 2
●   * 5 5 5 5 5 4 4 4 5 4 3 3 3 3
* * * 5 5 5 5 4 4 4 5 4 3 3 3 3
* * * * * 5 5 4 4 4 5 4 3 3 3 3
●   * * * * * * 4 4 5 5 4 4 4 4 4
●   * * * * * * * * * * 4 4 4 4 4
●   * * * * * * * * * * * 4 4 4 4
• * * * * * * * * * * * * 4 4 4
* * * * * * * * * * * * * * 4 4
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No. of Unit Block : 37

```
* * * * * * * * * * 1 1 1 3
* * * * * * * * * 1 1 1 1 3
* 1 1 1 * * 1 1 3 1 1 1 1 3
* 1 1 1 1 1 1 1 3 1 1 1 3 *
1 1 1 1 4 2 1 1 3 1 1 3 * *
1 1 1 1 4 2 1 1 3 1 3 3 * *
1 1 1 1 4 2 1 1 3 3 3 * * *
1 1 1 4 4 4 4 4 4 * * * * *
1 4 4 4 4 4 4 * * * * * * *
4 4 4 4 4 4 * * * * * * * *
4 4 4 4 * * * * * * * * * *
4 4 4 4 * * * * * * * * * *
4 4 4 * * * * * * * * * * *
5 5 5 * * * * * * * * * * *
5 5 5 * * * * * * * * * * *
5 5 5 * * * * * * * * * * *
5 5 5 * * * * * * * * * * *
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No. of Unit Block : 47

Fig. 6. The distribution of stand volume (m³/ha) for six representative unit blocks by photo interpretation.

Accordingly, the upper parts of these unit blocks were primarily planted by the conifers which was mainly composed of KARAMATSU ***(Lank leptolepis G.),*** but the coniferous stands was penetrated by the natural broadleaved stands in which MIZUNARA (*Quercus mongolica var. grosseserrata*) is a representative useful species. This means that the growth of conifers on the upper parts of hillside is poor. Further, it is expected that this tendency will become more pronounced in the future.

Moreover, in natural broadleaved stands the No. 8 unit block is relatively distributed by the many large trees and few middle-sized trees, and the large trees are uniformly distributed in the unit block. No. 47 unit block shows the distribution of the moderate number of large and middle-sized trees. No. 12 unit block indicates the distribution of very few large trees and is distributed as contagious distribution. In the case of coniferous stands, all of these unit blocks are distributed by middle-age class in general (Cha ***et al., 1988).***

In the estimation of stand volume by aerial photographs, the forest component factors which can be interpreted on aerial photographs are species, crown density, crown diameter, number of trees and so on (Itakaki, 1974 ; Nakajima, 1970 ; Ishikawa, 1982). However in the photo plot sampling the precision of estimation decreases as the number of interpretation variables that goes with the errors of photo interpretation is larger or the width of each interpretation variables class smaller. Accordingly, from what is mentioned above, the choice of interpretation variables is the most important objective in estimating the stand volume by using aerial photographs (Nishizawa, 1981 ; Onuki, 1986 ; Stellingwerf and chau, 1981).

As considering all possible conditions relating to the above mentioned point of views, the crown diameter (m) and the number of trees (trees/ha) are interpreted by aerial photographs. Consequently, we obtained the adequate regression equations between crown diameter and number of trees obtained from photo measurement and the corresponding values obtained by ground measurement. Particularly, the interpreted values by photo measurement for coniferous stands can be obtained more accurately than those by photo measurement for natural broadleaved stands.

For that reason, in order to promote the precision of photo interpretation for natural broadleaved stands, the large scale aerial photographs will improve the efficient utilization of aerial photographs for forest inventory.

In consequence, it is considered that stand volume (m^3/ha) of all unit blocks of the applied forests of palm form working system can be accurately estimated by these regression equations. Accordingly, the results obtained showed the effective measure for planning of forest road network.

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*The title in parentheses is tentative translation from the original Japanese title by the authors of this paper.