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A Study on Forest Inventory Method Using Aerial Photographs[1]

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航空寫眞을 利用한 山林調査 方法에 관한 硏究[1]

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ABSTRACT

This survey was carried out in Schneegattern Forest District which is located 40 km northeast of Salzburg, Austria. The purpose of interpretation with two sampling methods, stratified sampling and unstratified sampling, on B & W infrared photos, with a scale of 1:10,000 was to know coniferous stand volumn and to reduce the cost. Forest stands were classified into 4 groups; those were non-forest, young stands, beech, coniferous stands. Coniferous and beech stands were devided into age classes I (41-80 years), II (above 81 years). After this delineation sample points were designated on the orthophoto map whose data were transferred from the aerial photos. The volumn data were calculated from DBH using relascope in the field and the results were as follows. 1) Coniferous stand volumn per hactare was 470 ± 31.9 m^3 2) The diameter distribution of C_1 was binomial, but C_2 showed normal distribution. 3) The stratified sampling method was better than unstratified sampling method.

Key words: aerial photography; forest inventory.

要 約

오스트리아 salzburg에서 약 40km 떨어진 schneegattern 林에서 實施한 이 調査는 赤外線 黑白 航空寫眞을 判讀, 解析하여 林地를 除地, 幼齡林, 너도밤나무林, 針葉樹林으로 나누고 針葉樹林은 林齡別로 41～80年生과 81年生 以上으로 區分한 후 다시 이것을 樹冠密度 60%를 基準으로 疎密을 區分하였다. 여기서 無作爲로 抽出한 標本點을 現地에서 確認하고 relascope로 直徑을 調査하여 얻은 結果는 다음과 같다. 1) 針葉樹林의 ha當 平均蓄積은 470.1± 31.9m^3이었다. 2) 針葉樹林 40～80年生의 直徑分布가 二項分布인 반면 81年生 以上 林分은 正規分布이었다. 3) 5%의 標準誤差內에서 C_2는 尺化하는 것이 27 plot의 現地 調査數가 減少되었다. 4) 年平均 生長量은 C_1, C_2에 關係없이 ha當 5.7m^3으로 生長이 아주 느렸다.

INTRODUCTION

In the execution of the tasks involved in forest inventory and management nowadays the areial photography is a time and money saving tool, since it gives an overall view of the area with its topography, access and forest stands.

At a larger scale they allow the examination of individual trees including the identification of the

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species, the tree height and stand volum.[10]

In 1887 a German forester using a kite balloon took the first aerial photographs for forestry purposes in an attempt to find a faster way of mapping his forest stands.[7] Nowadays aerial photographs are used by foresters for several purposes:

1. mapping of vegetation types and forest stands
2. forest inventory and management planning
3. road construction and logging planning
4. flood control, and soil and water conservation
5. control of damage caused by forest fires, wind throw, insect and pest infestations, timber logging
6. wild life control and recreation development

Most of the information obtained from the photographs may be gathered through terrestrial surveys, but only at considerably higher cost consuming more time and man power. It should be realized however that an aerial survey can never replace a terrestrial survey completely. It remains desirable to carry out a field reconnaissance prior to the photo interpretation. Moreover it is indispensable to organize a field check afterwards in order to test the reliability of interpretation results.

This survey was undertaken in order to inventory the coniferous forest areas using unstratified sampling and stratified sampling method in Schneegattern Forest District which is located 40 km northeast of Salzburg in Austria.

Forest stands were interpreted by black and white infrared-photographs, after that the field survey was accomplished in 1982.

Generally IR-film is preferred for recording mixed forest stands since conifers are easily distinguished from broadleaved species.

MATERIALS AND METHODS

1. Climate and geography

The area was in the cool temperate zone. The mean daily temperature ranged from -2.2°C (January) to 17.3°C (July) and the average annual temperature was 7.5°C.

The annual rainfall ranged from 1,000 to 1,400 mm and the majority of the precipitation distributed from April to September.

The substratum belonged to the mid-tertiary period. The sediment was of glacial moraine origin and consisted mostly of grey marl and agrillaceous soils. The uppers were yellow sand with deposits of quartz gravel in some locations. The soils were progressing podzolization because of high precipitation.

Therefore Mg, Ca were washed and scarced. These are classified by the following layers;

A_0 layers are composed of litter and fermented litter from 1 cm to 5 cm. The thickness of A layer was 7 cm from the A_0 and the rest of the layers consisted mainly of grey mass with light color. Generally the soils were highly acidic and poor on nutrients especially K and P.

2. Vegetation

Norway spruce was mixed with fir and beech. Natural regeneration was best at lower elevations. Only where there is dense grass, or where few seeded trees are present, the artificial regeneration was used.

At higher elevations the spruce regeneration cannot survive under the shadow of beech stands. But thinning of the stands supplied enough light so that they will regenerate naturally.

3. Material

a. Specification of aerial photographs
   - . Film type: black & white infrared
   - . Scale : 1:10,000
   - . Size : 23 x 23 cm
   - . No. of photographs : 20
   - . Year of taking photos ; 1979

b. Management map, orthophoto map, photo index map

c. Measuring instrument: clinometer, relascope, ruler, planimeter.

4. Survey method

After compiled the photo index map, the effective area and property boundary were delineated

on the photographs from the management map of 1:10,000 scale.[7)]

a. Photo interpretation

Forest type were classified into beech or conifers and these coniferous stands were again stratified as table 1.

Table 1. Stand and age class

Mark	Contents
Y	Clear cut areas, or stands less than 40 years
B_1	Beech from 41 to 80 years
B_2	Beech above 81 years
C_1O	Coniferous spp. 41-80 years, crown closure less than 60%
C_1C	Coniferous spp 41-80 years, crown closure more than 60%
C_2O	Coniferous spp. above 81 years, crown closure less than 60%
C_2C	Coniferous spp. above 81 years, crown closure more than 60%.

One of the purposes of the photo interpretation was to compile a preliminary map, showing species composition, stand boundaries, road and location of sample plots.

In order to make an accurate map, data were transferred from the aerial photos to the orthophoto map stereoscopically. Then all the interpreted details were copied from it to form a preliminary map.

On the preliminary map the areas of each stratum non-forest, young forest, were measured by polar planimeter (Table 2).

b. Plotting the sample points

A dot grid (4 dots/cm^2) was randomly put down on the orthophoto and by using random numbers, sampling points were located.

The plots too close to the boundary were rejected because the volumn in those plots was not

Table 2. Statement area

Unit : ha

Strata	N	Y	B_1	B_2	C_1		C_2		Total
					C_1O	C_1C	C_2O	C_2C	
Area	8.1	223.6	69.4	14.8	69.0	204.8	102.8	162.5	855.0

Table 3. No. of the sample points in coniferous species

Strata	C_1O	C_1C	C_2C	C_2C	Total
No. of sample points	15	45	23	37	120

representative of the stand.

c. Field survey activities

Sample plots had been located on the aerial photos. These points had to be located in the field. This required skill in orientation, and photointerpretation. By working carefully, it was possible to locate the plot center within a couple of meters of the point on the photos. Sometimes it was possible to find the exact point but in areas of dense forest lacking in sufficient cues it was very difficult to find the point by interpretation and I had to use a compass bearing obtained from the photo and a distance on the photo. This method resulted in a plot location which was random but perhaps not exactly the point on the photo.

The PPS (probability proportional to size) theory[1)] was used for the tree enumeration. Using the Relascope for the angle measurement and the BAF (Basal Area Factor) 4. Trees were found to be in or out. The trees "in" were tallied and the DBH was measured. Each plot was handled as a seperate sampling unit.

d. Field enumeration cost study

Stratified sampling vs. unstratified sampling using crown closure as the stratification parameter (open vs. closed canopy) was used. The number of plots required to survey the area with a 5% sampling error were calculated by the following fomula.[6,9)]

Unstratified sampling

$$K = \frac{t^2 \times s^2}{Ea^2}$$

t – 0.05
s – variance
Ea – 5%

Stratified sampling

$$K = \frac{t^2 \quad (Pi * Si^2)}{Ea^2}$$

Pi = area ratio

e. Data processing

The field data were reduced to statistics by use of two types of machine, hand calculator which was Hewlett – Packard 35 E and a desktop computer with plotter.

Stem diameter analysis was done using a Hewlett-Packard 9835 desktop computer. One program was written to seperate the data into size classes and calculate the number of trees per hectare. Another program was used to calculate theoretical distributions for those data. The program also utilized the Hewlett-Packard plotter to draw the distributions and the frequency histograms. A Chi-square goodness-of-fit was also calculated by the program. Utilization of the computer facilities proved to be quite advantageous because of the time savings realized.

Mis-interpretated boundary was adjusted correctly. Therefore the number of sample points in strata were also changed.

RESULTS AND DISCUSSION

1. Final measured areas and sample points

Final area measurements were completed after the compilation of the find map and the results are given in table 4.[7)]

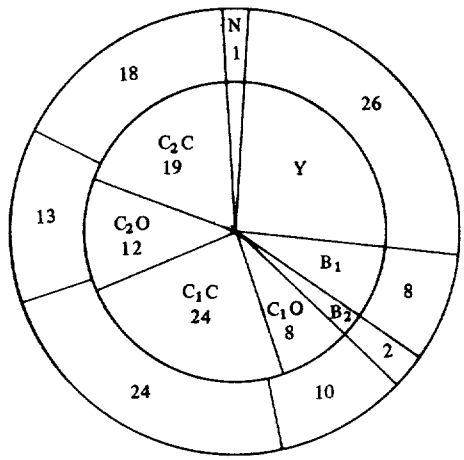

Fig. 1. Percent change-preliminary (inside) vs. final cover type from interpretation map. (%)

Table 4. Statement area unit : ha

Type	N	Y	B_1	B_2	C_1		C_2		Total
					C_1O	C_1C	C_2O	C_2C	
Area	8	224	69	15	87	203	108	154	868

This fig 1. shows that the differences of the area was caused by thinning or cut after taking the photos.

The increased total area was 13 ha which was adjusted by the boundaries of forests and non-forests which were not clear on the photos.

The sample points are also changed as table 5.

Table 5. Final sample points

Strata	C_1O	C_1C	C_2O	C_2C	Total
Sample points	19	42	27	34	122

2. Determination of coniferous timber volumn in different age classes

C_2 needed to be stratified for saving sample plots. Because the results of volumn determination between two sampling methods were same finally.[9)]

Therefore as much as possible, if it is highly significant, statification will be better.

The stratification can be evaluated by campari-son of the means of the strata. The more significant the difference between them is, the more efficient the stratification. This significance can be

Table 6. Comparison of mean volumn between two sampling methods

Type	Unstratification		Stratification			
			C_1		C_2	
	C_1	C_2	C_1O	C_1C	C_2O	C_2C
			425.2	451.8	420.6	557.1
Mean volumn(m^3/ha)	443.0	496.7	443.5		496.7	
Standard error (%)	5.0	4.1	5.0		3.7	
Confidence interval (m^3/ha)	±44.0	±40.3	±44.3		±18.3	

Table 7. Tree growth in strata

Class Year	C_1			C_2		
	1973 (A)	1982 (B)	B-A	1973 (A)	1982 (B)	B-A
Mean volumn(m^3/ha)	392.0	443.5	51.5	445.0	496.7	51.7
No. of trees (ha)		1048		534		
Annual growth(m/ha)			5.7			5.7
Volumn per tree (m^3)		0.4			0.9	

tested by t-test.[5)]

Actually t(=0.54) value of strata C_1 was less than t 0.05 (60, 1) = 2.001 but in C_2 strata t(=3.74) value was high significant.

As this volumn campared with 1973[12)] the differences of growth volume during 9 years between C_1 and C_2 were exactly same and the average annual growth volumn was 5.7m^3 per ha. (Table 7)

The number of trees in C_1 is almost twice as C_2. Therefore the more the age the less the number of trees.

3. Stem diameter class analysis

Distribution of the number of stems per hectare was calculated on the basis of five centimeter classes starting with a minimum diameter value of ten centimeters. These calculations were carried out for each of the age classes and strata. According to frequency histograms and fitted theoretical distribution curves, about 87% of trees of C_1 existed in less than 40cm DBH and 81% trees of C_2 ranged from DBH 25cm to 55cm. (Fig. 2,3)

The distribution of stem diameters per hectare showed a rough binomial tendency. This was not unexpected since a young stand had many stems of small diameter with a few stems which grew

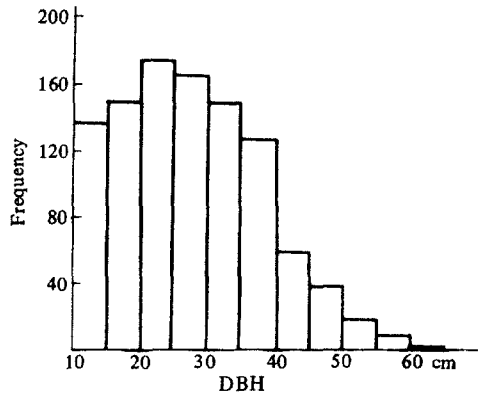

Fig. 2. Frequency histogram for conifers 41-80 years.

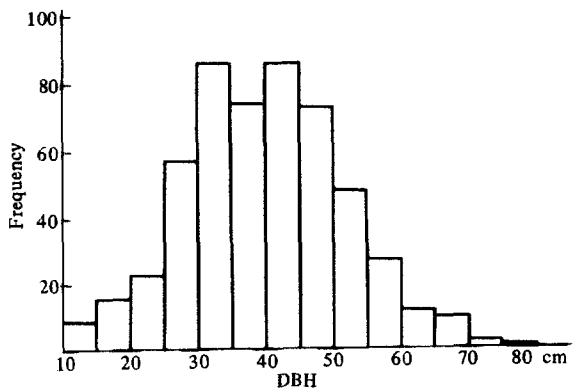

Fig. 3. Frequency histogram for conifers over 81 years.

Table 8. Summary of stem diameter class analysis

Age class	Total no. of trees per ha	Mean DBH (cm)	Standard dev. of DBH (cm)	Chi-sq. Result	Theoretical model	Skewness	Kurtosis
C_1O	415	30.4	12.4	Significant	Binomial		
C_1C	633	26.1	9.3	Significant	Binomial		
C_2O	218	40.7	13.2	Not significant	Normal	0.265	2.529
C_2C	316	39.7	11.3	Not significant	Normal	0.089	3.366

faster. With time, the stand is thinned of the weaker, smaller trees and the distribution of stem diameters becomes more and more "normal".

Number of trees per ha in stratification (open) was 66% - 69% of dense forests in no relation with C_1 and C_2. But DBH between C_1O and C_1C had big difference campared with C_2O and C_2C.

It can be estimated that the open forest received more light for the tree growth.

4. Field enumeration cost analysis

The most cost effective method is to take the minimum number of plots possible. Therefore C_1 should not be stratified and C_2 should be stratified. These yields a total of 375 samples required for the survey to give a 5% sampling error.

Table 9. Number of plots required for 5% sampling error.

Age class	Stratified	Unstratified
C_1	243	241
C_2	134	161
Sum	377	402

Assuming that a two-man crew is paid \$15/hr, and eight working hours per day can sample 10 locations/day, an estimate can be made for the cost of field enumeration.

This cost estimate is only valid for the actual field enumeration and not for office work.

COST = (8hrs/day x \$ 15/hr) x 375 samples/10 samples/day

= \$ 4,500 C_1 unstratified and C_2 stratified.

If the entire project is sampled by unstratified methods:

COST = (8hrs/day x \$ 15 /hr) x 402 samples/ 10 samples/day

= \$ 4,824

A saving of \$ 4,824 - 4,500 = \$ 324 is possible by stratification of C_2. Or a saving of 402 - 375 = 27 sample which translates into 3 field days.

CONCLUSION

1. Total coniferous stand volume for the project area was 260,000m^3 ± 17,600m^3 in 552 hactare with an average of 429 trees per hectare.

2. Analysis showed that the C_2 stratification was effective in reducting the time needed to survey the area to achieve the selected sampling error. A saving of 27 samples is possible by stratification of open versus closed crown canopies in order to achieve a 5% error.

Stand volume was 496.7m^3 /ha ± 18.3m^3. The diameter distribution was normal with a mean of 40cm. The normal distribution was expected in these strata due to the high degree of management.

3. Stratification of the younger C_1 stands proved to be ineffective as the analysis resulted in an insignificant difference between stratified and unstratified variances.

Volume of C_1 was 443.5m^3 /ha ± 44.3m^3. The diameter distribution was binomial with a mean of 28 cm.

4. Annual volume increment was only 5.7m^3 per hactare in no relation with C_1 or C_2.

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