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Comparison of Simple Random Sampling and Two-stage P. P. S. Sampling Methods for Timber Volume Estimation[1]

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林木材積 算定을 為한 Simple Random Sampling과 Two-stage P. P. S. Sampling 方法의 比較[1]

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ABSTRACT

The purpose of this paper was to figure out the efficiencies of two sampling techniques, a simple random sampling and a two-stage P.P.S. (probability proportional to size) sampling, in estimating the volume of the mature coniferous stands near Salzburg, Austria. With black-and-white infrared photographs at a scale 1:10,000, the following four classes were considered; non-forest, young stands less than 40 years, mature beech and mature coniferous stands. After the classification, a field survey was carried out using a relascope with a BAF (basal area factor) 4. For the simple random sampling, 99 points were sampled, while for the P.P.S. sampling, 75 points were sampled in the mature coniferous stands. The following results were obtained. 1) The mean standing coniferous volume estimate was 422.0m^3/ha for the simple random sampling and 433.5m^3/ha for the P.P.S. sampling method. However, the difference was not statistically significant. 2) The required number of sampling points for a 5% sampling error were 170 for the two stage P.P.S. sampling, but 237 for the simple random sampling. 3) The two stage P.P.S. method reduced field survey time by 17% as compared to the simple random sampling.

Key words ; simple random sampling; two-stage P.P.S. sampling; forest inventory; black-and-white infrared aerial photograph.

要 約

Simple random sampling과 P. P. S. sampling의 효율을 비교하기 위하여 오스트리아 Salzburg부근의 침엽수 장령림 임분에서 임목조사를 실시하였다. 축척 1 : 10,000의 흑백 적외선 사진을 판독하여, 조사 임지를 제지, 유령림, 너도 밤나무 장령림, 침엽수 장령림으로 구분하고, 침엽수 장령림 내에서 random sampling에 의한 99개의 표본점과 P. P. S. sampling에 의한 75개의 표본점을 흥고 단면적 계수 4인 Relascope에 의하여 야외 조사한 자료를 비교한 결과는 다음과 같다. 1) random sampling에 의한 임분 재적의 추정치는 420.0 ㎥/ha이었고, P. P. S. sampling에 의해서는 433.5 ㎥/ha이었으나 이들간의 통계적 유

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의성은 없었다. 2) 5%의 허용 오차내에서는 P. P. S. sampling에 의하여는 170점, random sampling에 의하여는 237점이 필요하였다. 3) P. P. S. sampling은 random sampling에 비하여 야외 조사 시간을 17% 감소시킬 수 있었다.

INTRODUCTION

Forest inventory is an essential part of forest management and planning because it provides various basic forestry data about the area surveyed; forest boundary, timber volume, species composition, growth and accessibility, etc.

Aerial photographs have been used in volume estimation since the late 1920's with some of the earliest work being done by Canadians (A.S.P. 1983). With appropriate aerial photogaphs, timber stands can be classified by forest type, species, size and stand height. However, the use of aerial photographs reqires additional field checks to be made (Banyard 1977, Stellingwerf 1982).

The popularity of the use of aerial photographs in forestry in Korea is caused by rising costs of traditional forest inventory techniques, which is especially true when the inventories are carried out more frequently (Kim 1966, 1973, 1976). This paper describes the determination of the stand volume of the mature conifers (≧40 years) while using two sampling techniques. From the results of these two methods the sampling intensity is determined in order to obtain an allowable sampling error of 5% and the efficiency of each sampling is compared.

The study was done under the field-work scheme of the Forestry department of the I.T.C. (International Institute for Aerial Survey and Earth Sciences) at Enschede, the Netherlands.

MATERIALS AND METHODS

1. Environment of study area

The study area in which the sampling methods were applied is the Schneegattern Forest covering 3450 ha, and there is located 40km northeast of Salzburg in the federal state of Ober-Osterreich. The terrain is hilly with elevations ranging from 540 to 760 meters above sea level. Slopes are generally not steeper than 25%. The climate is typical of temperate regions with average highest and lowest temperatures of 17.3 and −2.2°C. Night frost occurs from September to mid-June and temperature inversions occur from December to March. Humidity remains relatively high throughout the year. Most of the timber damage is caused by snow, frost, wildlife, air pollution, insects and fungus. Species composition in order of importance concerning timber volume is: norway spruce, beech, white fir, white pine.

2. Materials used

1) Management map: a management map at a scale 1:10,000 showing the distribution of the forest stands in 20 year classes, updated in 1979, was used.

2) Orthophotos: four sheets at 1:10,000 scale, produced by the ITC from 1:30,000 scale infrared black-and-white photos were supplied. The assemblage of these four sheets covered the entire area.

3) Photo index map: a copy of the assemblage of the orthophotomap reduced to 1:30,000 scale was used as a photo index map.

4) Aerial photographs: a block (98 sheets) of infrared black-and-white photographs at 1:10,000 scale, taken in September, 1979 with a forward overlap of 80 per cent and sidelap of 40 per cent were supplied.

5) Instrument: mirror stereoscope, pocket stereoscope, caliper, relascope, planimeter, dot-grid, clinometer.

3. Inventory design

The inventory at hand has been conveniently divided into three phases.

1) Pre-field work phase; the pre-field work phase or preparation phase involved the collection of the

necessary information and the materials needed to carry out the photo-interpretation and compilation of the preliminary interpretation map. Other activities in this phase included the collection of tools for field work, area measurements and the location of sampling points on photo and map according to the two sampling methods.

2) Field work phase; the field work phase involved checking and correcting the preliminary interpretation map and the measurements of trees using the relascope.

3) Post-field work phase; the post-field work phase or data processing phase involved the drawing of the final interpretation map, the processing of data collected in the field and the comparison of the time and cost involved in the simple random sampling and two-stage P.P.S. sampling methods.

4. Description of the two sampling methods

1) Simple random sampling

Random sampling is a method in which the sample plots or points are randomly and independently selected. Each sampling unit should furthermore have an equal chance of being selected and the method makes it possible to calculate the precision of the estimate.

Plot centers were chosen on the orthophotomap using randomly generated X, Y coordinate data. A minimum distance (3mm on the orthophoto) between the enumeration point and the boundary of the mature conifer stands was taken to accept the point or not.

The formulas for calculating the estimates of the population parameters of the simple random sampling method are;

· mean volume

· variance

· standard error of mean volume

where yi is the calculated volume (m^3) on the i-th sample point, n is the number of points and (1 - f) is the correction factor for finite populations.

2) Two-stage P.P.S. sampling

The study area was subdivided into a 49 primary sampling units (PUs) which varied in size within the given one kilometer grid squares. Some of these units were then selected in the sample of the first stage with probability proportional to the areas of the mature conifer stands. In the selected PUs a number of secondary units (SUs) were randomly selected as the sample units of the second stage. The larger the PU area, the more chance the PU had to be selected in the primary stage sample, and the areas were highly related to the timber volume. The following procedure was used to select the sampling points;

(1) A grid of kilometer squares was constructed on the orthophotomap based on the Austrian grid network.

(2) List of mature coniferous stand areas and accumulated areas within each kilometer square was constructed.

(3) 17 primary units were chosen with replacement from the list of accumulated areas using random numbers and in accord with the rule of probability proportional to size.

(4) 5 SUs within each of the 17 selected PUs were chosen randomly without replacement. When the same PU was selected more than once, previously selected SU's data of this PU were used again. Officially, however, new sets of SUs should be selected in this PU, because of the without replacement condition.

The formulas used to calculate the estimates of the mean and its variance of the volume of the spruce trees for this two-stage P.P.S. sampling are;

· mean volume

· variance

· standard error of mean volume

where Yj is the calculated volume of the j-th pu

yij is the calculated volume of the i-th SU in the j-th PU

Xj is the area of the j-th PU

xij is the area of the i-th SU in the j-th PU

n is the number of sample SU per PU

m is the number of PUs selected in the sample

5. Time and cost analysis

In order to be able to compare the efficiencies of the two sampling methods the following assumptions were made:

1) the working time per day was fixed at a miximum of 7 hours,

2) the crew consisted of four persons,

3) the field work was performed by walking only.

4) each day field work started and finished at a fixed base camp which was located at the periferi of the study area,

5) the positions of sampling points were spread over the forest with equal intervals and the distances between the points were straight. This assumption was only used for the calculation of the survey time involved in the two methods.

6) the walking speed was 50 m/min.

7) the relascope method was used to enumerate sample points.

8) the area covered by spruce which was determined with dot grid had a standard error smaller than 2%. Because of this low error and because the error was same for both methods, the random error in area was not considered in this paper.

9) The cost was $400.00 per crew day.

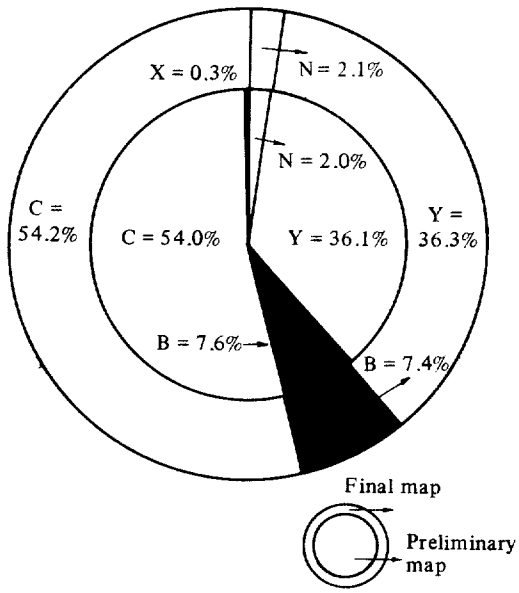
RESULTS AND DISCUSSION

1. Final area measurement

Area determination of the various forest types within the study area were carried out by means of dot counts. The grand total of 13,737 dots falling within the study area boundary corresponded with an area of 3,450 ha according to the management map. Areas per forest types were obtained by calculating the proportion of the total dots in relation with the fixed 3,450 ha.

Results are shown for both the preliminary and final measurement in Figure 1 and Table 1.

In total 11 ha was interpreted differently from the management map. Therefore it had to be checked in the field prior to the final classification. The difference proved to be caused by cuttings just before taking the photographs.



N = non forest
Y = young forest stand
B = mature broadleaved forest stand
C = mature coniferous forest stand
X = area interpreted different from management map and to be checked in the field prior to classification.

Fig. 1. Pictogram showing the area distribution of the various forest types according to the preliminary map (inner circle) and final map (outer circle).

Table 1. Final area of the various forest types

Type	None forest	Young stand	Broadleaved mature stand	Coniferous mature stand	Total
Area (ha)	72	1253	254	1871	3450

2. Timber volume assessment of conifers

A relascope was used with basal area factor BAF 4 for enumerating the sample points. Using this method, it was not necessary to set up sample plot boundaries, and only for trees of which their location was doubtfull, distances to the point were measured. Individual coniferous timber volume was calculated using the relevant I.T.C. local volume table.

Table 2. I.T.C. local volume formula for the conifers in the study area

Species	Individual timber volume (m^3)
Spruce	$V = -.0063909 - .0099198 \times D + .00131876 \times D^2$
Silver fir	$V = -.0169500 - .0012632 \times D + .00113358 \times D^2$
Other conifers	$V = -.0283850 - .0058650 \times D + .00115188 \times D^2$

After calculating the tree factor which was calculated as BAF over basal area, the tree volume factor was calculated by multiplying single tree volume with the tree factor. The sum of all individual tree volume factors per point gave the volume estimate per ha for that sample point (Banyard, 1977). A computer program was used for the calculation of the timber volume per ha and its basic parameters. The result is shown in table 3.

Table 3. Comparison between basic parameters of simple random sampling and two-stage P.P.S. sampling

		Random sampling	Two-stage P.P.S. sampling
Mean timber volume	m^2/ha	422.0	433.5
Standard error of mean volume	m^3/ha	32.6	34.9
Confidence interval for t = 2	m^3/ha	422.0±65.2	433.5±69.8
Number of points (PU's)		99	(17)

A t-test was used for the comparison of the mean timber volume.

$$t_{calculated} = 0.06 \quad > t_{tabulated} = 2.05$$

Because the calculated to value was less than the tabulated t value, the two mean timber volumes were considered to be same.

3. Time and cost analysis

The difference between the efficiencies depends only on the sampling intensities required to carry out the inventories to a same specified sampling error of the estimate.

The sampling intensities for a specified sampling error of the mean timber volume of 5 per cent were calculated for both methods using the means and standard deviations of the coniferous timber volume, which were calculated from the preliminary forest inventories.

For the simple random sampling 237 sample points were required. With two-stage P.P.S. the number of required primary units was 44, because the PUs were chosen at random with replacement, the actual number of PUs to be visited in the field was only 34 and because the number of SU per PU was fixed at five, the total number of SUs to be enumerated was 170.

With the sampling intensity acquired above, the distance between sample units was calculated using the formula $D = \sqrt{\frac{A}{n}}$, where area A is 3450 ha, n is the number of sample points, and D is a straight line distance between sample units in meters.

Table 4. Distances between sampling points for simple random sampling and two-stage P.P.S. sampling

Sampling methods	Distances between points (m)	Distance from base camp to the center of forest (m)
Simple random	382	4153
Two-stage P.P.S.	1007 between PUs 447 between SUs	4153

Considering the walking speed, enumeration time, required sampling intensity and the distribution of sample points, the maximum number of sample points that were enumerated per day was 8 points for simple random sampling and 7 SU's for two-stage P.P.S. sampling. However, five crew days or $2,000 were saved when compared to simple random sampling. This is a 17 percent reduction in field costs. These results are summarized in Table 5. However, when dealing with larger areas with a higher number of PU, the number of reselected

Table 5. Times and costs for simple random sampling and two-stage P.P.S. sampling

Sampling method	Sample random	Two-stage P.P.S.
Number of points (or SU's) to be enumerated	237 points	170 points (=SU's)
Number of enumerating points (or SU's) per day	8 points	7 points (=SU's)
Number of days required for Complete survey	30 days	25 days
Costs per crew day	$400	$400
Total cost for survey	$12000	$10000

PUs in the sample will be reduced and therefore this advantage in the reduced time is then not applicable.

CONCLUSION

1) Timber volume estimates were 422.0 m^3/ha for simple random sampling and 433.5 m^3/ha for two-stage P.P.S. sampling. It is assumed that these values remain the same with the number of sampling points and SU's. However, difference between these values is not statistically significant.
2) Sampling intensity for a five percents error was 237 points for simple random sampling and 170 points for two-stage P.P.S. sampling.
3) Two-stage P.P.S. sampling saved five crew days over simple random sampling. This led to a 17 percent reduction in field costs in the study area condition.

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