FOREST INVENTORY BY SAMPLING METHODS. 1953

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PART 6. CONCLUSION

CHAPTER 40. SAMPLING METHODS IN THE FOREST OF JAPAN

131. General description.

In the previous chapter we discussed and illustrated the sampling methods which were first introduced in Japanese forestry. There are two important problems. One is the inventory problem connected with the management plan and the working plan. And the other is the investigation problem connected with basic forestry mensuration. On both sides we see that statistics can give satisfactory answers or have possibilities of for solving complicated problems. Based on the variation of biological frequency, the former problems are mainly discussed from the economic view, and later problems from the point of mensurational and biological view points. Practically we can solve these problems by the statistical method.

132. Characteristics of Japanese forest.

Generally speaking, Japanese forest stands have the following characteristics, i.e. comparatively small areas, complicated geographcal conditions, artificial plantation, patched distribution of many kinds of stands etc. Consequently, the inventory is commonly not so simple as in large even-aged forest areas. But there are relatively detailed maps and former investigation results which were done during the past ten years. We must use these supplementary data. After the War II, the total area of Japanese forests was reduced to twenty million chō. 38% is National Forest, 19% is Public Forest, and 43% is Private Forest. (Agricultural and Forest Ministry's statistics, 1948).

133. Defect of former forest inventories.

In Japan, the former forest inventories were carried out on the basis of standard average stands judged by the investigator or on every tree measurement. But this method should be rejected from statistical and economic view points. Because these results can not supply the base of action. We must act on the base of investigated results. There are many important phases, such as forest policy, forest economics, forest management, forest utilization, silviculture, forest protection, land conservation etc. The old method doesn't give analizable data for action. This is the greatest defect of the old forest inventory.

134. Abandonment of old methods.

From this point of view, we must abandon the old accustomed methods as rapidly as possible, even though it will be difficult to introduce the new method.

For this reason the study should be developed more and more. This basic study will supply the starting point for the future development of the new method.

135. Adaptation of Sampling Method.

As in the other fields of science, forestry in Japan should adopt the new statistical method. In this study we supplied some practical satisfactory results, and have a foundation for new development. There are the procedures of sampling and the application to small or large areas suitable to Japanese forests and the basic sampling problem of forest mensuration in the previous chapters. Without hesitation, we must push into the new field.

136. New education basis of forestry.

Basically, we can say that forestry education and forestry research should be based on the new statistical method. Our young generation should be disciplined in the field of mathematical statistics and then apply it to both economic and biological problems in forestry. Forest mensuration should give new foundational concepts to students through the reconstruction of forest mensuration itself. It should also be noted that the sampling method can not be easily executed in Japanese forestry by anyone who does not have a deep knowledge of statistics. Consequently, the most important thing is for forest education to decide to adopt this method in Japan. This method is also important in solving the more complicated statistical problems, such as understanding and applying experimental design, quality control and planning in forestry.

CHAPTER 41. SAMPLING METHODS IN THE NATIONAL FOREST

137. General description.

It is generally said that in the Japanese National Forest there are two important forestry inventories. One is the volume investigation of a stand and the other is the forest inventory for management plan. The volume investigation of a stand is commonly limited to a relatively small area for volume yielding and the forest inventory for management plan is usually covered by a relatively large area. Of course, in the case of areas less than one or two hectare every tree measurement is preferable, but even in this case height measurements should be done by some sampling. In the case of areas more than ten hectare sampling methods are preferable. And in small areas the tree sampling method is preferable. Based on every tree measurement and standard average stand, all investigations and inventories have been carried out in the National Forest. These methods should be abandoned for the random sampling method.

138. Survey procedure on a small area.

Practically, we need the investigation of small areas or subcompartments for yield measurement, sell measurement and the other studies. In Japan subcompartment areas reach from areas less than one hectare to areas of more than one hundred hectare. Of course, in the very small areas, less than one hectare, counting every tree is more rapid than the sampling process. Sampling procedure seems to be preferable in areas of more than 10 hectares. The stand of each species has individual variations. Simply we can use the following formula, (68)

$$s_m = \sqrt{\frac{s^2}{n}\left(\frac{N-n}{N}\right)},$$

where s_m is the standard error of the mean,
s is the standard deviation,
n is the number of sample plot taken.
N is the total possible number of plots in the area.

For example, since a ten hectare tract has 1000 are-plots, $N=1000$. The number of plots to be taken is according to changing the above formula as follows;

$$n = \frac{s^2}{s_m^2 + (s^2/N)}.$$

For example, assume that an estimate of average volume per ha in a ten hectares tract is $300\,\mathrm{m}^3$, the standard deviation is $100\,\mathrm{m}^3$, and a standard error of the mean of 10 percent, or $30\,\mathrm{m}^3$ is desired. Then

$$n = \frac{(100)^2}{(30)^2 + (100^2/1000)} = 10 \text{ plots},$$

That is, the needed number of $10\times10\,\mathrm{m}$ plots is 10 plots. If we use $20\times20\,\mathrm{m}$ plots, instead of $10\times10\,\mathrm{m}$ plots, the standard deviation should be reduced. The results are gained from the graph in Fig. 21. In this case the standard deviation is about $80\,\mathrm{m}^3$. Then, where

$$N = \frac{1000}{4} = 250,$$

$$n = \frac{(80)^2}{(30)^2 + (80)^2/250} = 6.9 \text{ plots}.$$

It should be noted that the variation of plot values is due to the area of one plot.

139. New volume table.

The error of single tree volume measurement, the error of volume equation and the sampling error were discussed in the previous chapters. Therefore we should show clearly the error of the volume table. It is clear that we could estimate timber volume within the necessary sampling error. The volume table equation necessarily shows itself in error. If it is necessary, the accuracy of d.b.h.-height curve should be cleared.

140. Sampling method in management plan or large area.

The plan and design of forest management is based on the older system and principle in Japan. It should be improved. First, the sampling method should be used in measurement and inventory.

The order of procedure is shown as follows; (68)

1. Preliminary reconnaissance,
2. Desicion of sampling method,
3. Stratification,
4. Allocation of samples under cost consideration,
5. Intensive sampling field work,
6. Computation,
7. Application of the results.

In Japan, if subcompartments are relatively laıge, we preferably use the representative sampling. The subcompartment should not be considered as a cluster unit. As there are actual illustrations shown in the previous chapter, we can use the representative dispropotional sampling method and the regression or ratio estimate.

141. An example of cost consideration. (69)

One example from Izumi data is shown as follows;

Stratum		Area in sampling unit N_i	Mean	Standard deviation s_i	$\sqrt{c_i}$	$N_i s_i \sqrt{c_i}$
Sugi	II	4948	2.609	1.90	9	84610.80
	III	4154	8.723	3.81	8	126613.92
	IV	5001	11.881	3.81	7	133376.67
	V	16825	13.594	5.27	7	620674.25
	VI	402	9.428	2.10	7	5909.40
Hinoki	II	1192	6.716	3.10	9	33356.80
	III	4809	8.237	3.36	8	129024.00
	IV	24556	12.126	3.78	8	742573.44
	V	7906	12.995	3.46	8	218838.08
Matsu	II	451	11.196	4.53	9	18387.27
	III	1978	6.083	0.51	8	8070.24
	IV	3813	9.558	5.83	8	177838.32
	V	14066	9.591	4.30	7	423386.60

(Cont'd on next page)

Stratum		Area in sampling unit N_i	Mean	Standard deviation s_i	$\sqrt{c_i}$	$N_i s_i \sqrt{c_i}$
B. L.	II	3313	3.068	1.76	8	46647.64
	III	7677	3.658	1,69	8	103793.04
	IV	3512	6.213	2.64	8	74173.44
	V	9336	7.026	0.76	8	56762.88
	VI	8940	5.917	4.24	8	303244.80
Mix	II	4682	2.510	1.52	9	64049.76
	III	9874	5.847	3.57	9	317251.62
	IV	3981	9.224	4.06	8	129302.88
	V	7205	8.980	4.64	8	267449.60
Total		150667				4085134.85

If we assume that the costs of different species and age classes are shown as follow;

Cost per 20 m × 20 m plot measurement (unit yen)

	II	III	IV	V	VI
Sugi	80	60	55	50	50
Hinoki	80	70	65	60	60
Matsu	80	70	60	50	40
B. L.	70	65	60	60	60
Mixed	80	75	70	65	60

Total cost $C = 50{,}000$ yen,

$$C = \sum n_i c_i ,$$

$$n_i = \frac{N_i s_i \sqrt{c_i}}{\sum (N_i s_i \sqrt{c_i})} \left(\frac{C}{c_i}\right).$$

$\sqrt{c_i}$

	II	III	IV	V	VI
Sugi	9	8	7	7	7
Hinoki	9	8	8	8	7
Matsu	9	8	8	7	6
B. L.	8	8	8	8	8
Mixed	9	9	8	8	8

$\frac{C}{c_i}$

	II	III	IV	V	VI
Sugi	622	833	908	1000	1000
Hinoki	622	714	767	833	1000
Matsu	622	714	833	1000	1248
B. L.	714	767	833	833	833
Mixed	622	666	714	767	833

Then values of n are shown as follows;

Stratum		$N_i s_i c_i$	$\frac{N_i s_i \sqrt{c_i}}{\sum(N_i s_i \sqrt{c_i})}$	$\left(\frac{C}{c_i}\right)$	n_i	Actual number of plots
Sugi	II	84610.80	0.0207	622	12.87	24
	III	126613.92	0.0310	833	25.82	15
	IV	133376.67	0.0326	908	29.60	27
	V	620674.25	0.1519	1000	151.93	84
	VI	5909.40	0.0014	1000	1.45	3
Hinoki	II	33256.80	0.0081	622	5.04	6
	III	129024.00	0.0316	714	22.56	24
	IV	742573.44	0.1818	767	139.44	126
	V	218838.08	0.0536	833	44.65	48
Matsu	II	18387.27	0.0045	622	2.79	3
	III	8070.24	0.0019	914	1.36	6
	IV	177838.32	0.0435	833	36.24	9
	V	423386.60	0.1036	1000	103.60	42
B. L.	II	46647.04	0.0114	714	8.14	19
	III	103797.04	0.0254	767	19.48	40
	IV	74173.44	0.0182	833	15.16	9
	V	56762.88	0.0139	833	11.58	51
	VI	303244.80	0.0742	833	61.81	50
Mixed	II	64049.76	0.0157	622	9.77	9
	III	317251.62	0.0777	666	51.75	24
	IV	129302.88	0.0317	714	22.63	15
	V	267449.60	0.0655	767	50.24	36
Total					827.91	670

CHAPTER 42. SAMPLING METHODS IN THE PRIVATE FOREST

142. General description.

In Japan private forest areas occupy about 62 per cent of the total forest area. (Of course, this number involves 18 percent public forest). The inventory of the private forest is the most important for forestry industry and soil conservation. At the present moment we cannot say that Japanese forest inventory is accurate or objective. The following forest inventory was prepared by modern statistical method. Private Forests have smaller individual stands than National Forest subcompartments. Also they have complex distribution, the steep topographic features, and obscurity of boundary lines. Adding to these facts, there are many political problems.

143. Adoption of sampling method.

In Japanese private inventories, we should utilize the usable supplimentary information. There are two main sources of supplimentary information. One is cadaster information and the other is corrected information. As we have discussed in the previous chapters, we should use the later rather than the former, because the correlations between them and the actual value in the later is usually higher than that of the former.

In this case the criterion of stratification is related to the difficulty of estimating by eye. The steep topographic features, the irregular boundaries increase the difficulties of investigation. Based on these stratification we can use the regression method or ratio estimate as shown in the previous chapters. The mensurations of a large area can be considered the same as in National Forests. Both survey methods of private foersts and national forests can be replaced with another, if it is necessary.

144. Cost consideration of the private forest.

Lastly we will see the allocation of costs in double sampling for private forests. The method used assumed to take the ratio estimate. An illustration of Kōyama investigation is shown as follows.

In the case of ratio estimate, (69)

$$Y = \bar{r} X,$$

$$V(\bar{r}) = s_q^2 / n \bar{x}^2 ,$$

$$V(Y) = \frac{\bar{y}^2 s_x^2}{m} + \frac{(\bar{x}^2) s_q^2}{n(\bar{x})^2} = \frac{\bar{r}^2 s_x^2}{m} + \frac{s_q^2}{n},$$

$$T = n\, c_n + m\, c_m , \quad m = (T - n\, c_n)/c_m ,$$

$$V(Y) = \frac{\bar{r}^2 s_x^2 c_m}{T - n\, c_n} + \frac{s_q^2}{n} .$$

Upon differentiating with respect to n and equating to zero, it follows that,

$$\frac{C_m C_n \bar{r}^2 s_x^2}{(T - n\, C_n)^2} - \frac{s_q^2}{n^2} = 0 .$$

Expressing

$$\frac{m}{n} = \sqrt{\frac{C_n}{C_m}} \left(\frac{T s_x}{s_q} \right) .$$

Strata	Average time per stand	Yen Cost (C_n)	Average cost is C_m (30 yen per chō)
A	3 hr	500 × 3/8 = 188	15
B	4	500 × 4/8 = 250	30
C	5	500 × 5/8 = 312	60
D	6	500 × 6/8 = 375	90
E	10	500 × 10/8 = 625	180 (mean area 6chō)

Strata	m	$\frac{C_n}{C_m}$	$\sqrt{\frac{C_n}{C_m}}$	r	s_x	$r\, s_x$	s_q
A	249	12.6	3.55	1.0357	16.6	17.19262	18
B	104	8.3	2.88	0.6979	14.4	10.04976	24
C	65	5.2	2.28	0.5973	34.4	20.54712	40
D	23	4.2	2.05	0.6062	42.4	25.70288	33
E	18	3.5	1.87	0.7923	211.6	167.65068	214
Total	459						

	$\left(\frac{r s_x}{s_q}\right)$	$\sqrt{\frac{C_n}{C_m}}\left(\frac{r s_x}{s_q}\right)$	$m\sqrt{\frac{C_n}{G_m}}\left(\frac{r s_x}{s_q}\right) = n$
A	0.9551	3.390605	73.4382
B	0.4187	1.205856	86.2457
C	0.5137	1.171236	55.4969
D	0.7789	1.596745	14.4043
E	0.7834	1.464958	12.2870
Total			240

T_1	$249 \times 15 + 188 \times 73 = 3745 + 13.724$
T_2	$104 \times 30 + 250 \times 86 = 3120 + 21.500$
T_3	$65 \times 60 + 312 \times 55 = 3900 + 17.160$
T_4	$23 \times 90 + 375 \times 14 = 2070 + 5.250$
T_5	$18 \times 180 + 625 \times 12 = 3240 + 7.500$
Total	$= 16{,}075 + 65{,}134 = 81{,}209$

When the total cost is about 80,000 yen, we should allocate small samples in each strata as shown in the above table, that is, 73, 86, 55, 14, 12.

CHAPTER 43. THE NECESSITY OF HASTENING THE USE OF AERIAL PHOTOGRAPHS

145. General description.

In Japan the first aerial photography survey of Tokyo after the Kantō earthquake, was made in 1923 to facilitate reconstruction. The first applications for forest survey were made in Korea and Kiso, in 1929 and 1930 respectively. In Korea the camera (Fairchild K. 8 type, $f = 25$ cm, $RF = 1/500$) was used. After that, aerial-photography surveys of forests were made in Saghalien (1930), (Fairchild K. 8. $f = 25$ cm, $RF = 1/15000$), Manchurian (1934), (1940) and Asakawa (1942). But they were not practical. After the War, the utilization of aerial photographs was begun from 1949. These photographs were loaned by the permission of G.H.Q. (1948) and their characteristics are shown as follows; $f = 6$ in. (15.3 cm). The size of the photos is 23 cm $\times$ 23 cm, $RF = 1/4000$, airoplane altitude 6120 m, coverage, 8464 ha, effective coverage, 2700 ha. At the present stage Japan cannot sufficently utilize them except for the observation of topographic features.

146. The first stage of utilization of aerial photographs.

It should be noted that advanced photogrammetry can make accurate planimetric and topographic maps by the use of precise and complicated instruments. We must study these developed methods of phtogrammetry. We must be trained for the interpretation of aerial photographs with the aid of the stereoscope. First we must use aerial photographs for the purpose of clarification of the boundaries of the property in which we are interested. Secondly, we must use them for the purpose of stratification of forest type. They are very important for sampling procedures. Thirdly aerial photographs supply the flame of sampling procedure and are more valuable than a detailed map. We must utilize them in the most effective way.

147. It is necessary to hasten the use of aerial photograph.

The value of the aerial photograph reaches the maximum point, when it is accompained with sampling methods. We do not know the true volue of aerial photographs until we obtain knowledge of sampling methods. At the present time, sampling works can not be considerd without aerial photographs. In Japan we should study the developed methods of estimating from the aerial photograph with ground check cruising. In this case we can take double sampling under cost consideration. According to the photogrammetric cruising supported by ground control, we can determine volume, area and so on. Systematic sampling can be used in spite of the appearance of the ground. These methods have the tendency of macrofication of forest mensuration and therefore stand density comes to be an important problem. The number of points and actual plot location can be obtained under the consideration of cost, compaering with the inventory errors. In Japan, we have many difficulties in the utilization of aerial photographs, such as steep mountaneous land, distributed small patched stands and so on. But we must study to obtain the technique of high performance cameras, altitude and so on. From a statistical point of view, we have gained a successful goal, then absolutly we must hasten the study of aerial photogrammetric utilization for forest mensuration. Aereal photography is concretely successful, although there are many difficulties. But the difficulties can be overcome.

CHAPTER 44. THE EXPECTED FUTURE DEVELOPMENT OF THE SAMPLING METHODS IN FORESTRY

148. General description.

In Japan, the inventory of Forestry has been carried out based on an older method except in the test case of sampling. Sampling methods are not sufficently understood by many foresters. Japanese foresters have been deciplined and educated on the foundation of the old German school. They are accustomed to every tree measurement and the standard sample plot method. It is very difficult to substitute new methods for old ones. But the developed methods should be carried out. At the present Japanese forestry inventory is entirely behind the times. In the age of progressive science, the older method should be abandoned rapidly.

149. Further progress of forest mensuration.

Based on new statistics, our forest mensuration should be expected to progress more and more. The foundation and reconstraction of mensuration will be soon perfectly established. The problem of predicting growth should especially be studied. At the present, no one method is generally preferable. SCHUMACHER said, in his text book, that the technique of forest mensuration is constantly changing. There have been many important additions to forest mensuration in the past 20 years in America and other countries, but it is too bad that we can not see this progress and great improvement being made in Japan. Our greatest source of error was an errorneous foundation for forest mensuration. If we take the new way, forest mensuration will be scientific and the goal of our study and research will be reached. Of course, in Japan, the education of forest mensuration should be improved on this basis and it will come to be the true foundation of forestry.

150. Application to management plan.

In the previous chapters, we treated and discussed many actual illustrations of sampling design for management plan. We recommended the various sampling procedures suitable for both private and national forest management plan. There are many suitable sampling methods. Perhaps circumstances will always demand new techniques. We should study more the developed methods accepted by the majority. Lastly we hope that management plan will develop into a science of prediction and a reliable test of results through statistical control.

—— The end ——