

STATISTICAL MEASURES FOR REQUIRED OPTIMUM SAMPLE SIZE OF FOREST STANDS IN WEST BENGAL

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Abstract: : A survey has been taken up for statistical analysis on the sampled data collected from the 27 forests of West Bengal for determination of required optimum sample size in the forests including the nature of the vegetation pattern. Sampled data are analyzed in three phases separately applying probability measures of statistical methods. In the first phase, 9 sample spots of 2 forest patches of Garh Jangal and Aduria Forest, then 14 sample spots of the forest patches of 11 districts and overall, 27 sample spots from 19 districts situated all over the state of West Bengal are considered for statistical analysis. From the analysis, higher the survey spots, lower the required optimum sample size is revealed. Results obtained from the statistical analysis for the forest shows likely indications and positive trends that help to understand the vegetation categories, types of dominant timber trees and stem-diameters of the rest forest areas in the state.

Keywords: Optimum sample size, Random sampling, Stem diameter.

1. INTRODUCTION

Application of probability scale of statistical method may have some measures to interpret the required sample size for the entire study area. For determination of such required sample size in the forest areas, an attempt has been taken up for statistical analysis on the sampled data collected from 9 sample spots of 2 forest patches of Garh Jangal and Aduria forest under Bardhaman Forest Division, 14 sample spots of the forest patches of 11 districts and overall, 27 sample spots from 19 districts situated all over the state of West Bengal during the period from 2008 to 2020 consecutively.

The forest area of Bardhaman Forest Division is 339.31 sq km comprising 38 forest patches under the administrative control of Guskara forest range of Purba Bardhaman district and Panagarh & Durgapur forest ranges of Paschim Bardhaman district. Among 38 forest patches, pilot survey is conducted in two forest patches – Garh Jangal (forest area-3184.74 ha) and Aduria forest (forest area: 1777.14 ha) and the total coverage of survey area is 4961.88 hectares. The survey is conducted in the Garh Jangal and Aduria forest during October 2019 to September 2020. During the pilot survey,

total number of trees (10 cm and above diameter) enumerated are 4630 in 9 sampling units with the large representations of 4 timber tree species such as *Shorearobusta*, *Holarrhenaantidysenterica*, *Buchananialanzan* and *Acacia catechu*.

The total areas of forest in West Bengal (India) are 16901.51 sq km comprising numerous forest patches scattered all over 23 districts as recorded in the India State of Forest Report [1]. In such forest patches with rich and mixed floral diversity, an inventory survey is carried out with the random sample methodology for determination of optimum sample size for forests. Among them, pilot survey is conducted in 27 forest patches scattered in and around West Bengal. During the survey, the total number of trees (10 cm and above diameter at breast height) enumerated are 17380 in 27 sampling units in 27 forest patches with the large representations of numerous timber tree species of eight major forest types of West Bengal [2]. Such similarity pattern checks which is a criterion for determination of reliability of the data

sampled at random and in relatively lesser number of sample spots in the survey area of the forests is the objective of the present study.

2. RESULTS AND DISCUSSION

2.1 Data sampling in quadrats for Garh Jangal and Aduria forest

Number of data regarding categories of tree species including their diameter are collected in this inventory survey, though only timber trees of 10 cm and above diameter at breast height are inventoried, rest of the plant species including herbs and shrubs are considered as miscellaneous. For quantitative analysis, trees inside forests were sampled at random through 10m x 10m quadrats, equal to 0.1 hectare, and the collected data from 9 quadrats was transformed into the data for 1-hectare area after calculation with numerical conversion. Locations of all sampling units are indicated with the Latitude & Longitude taken on-spot from the Google Map (Table 1).

Table 1 : Collected data used for sample size determination

Name of the forests	Latitude & Longitude of the sampling spots	Trees/ha (above 10 cm diameter)	$\sum x^2$
Garh Jangal	23.603838N & 87.451219E	810	656100
	23.599647N & 87.451031E	730	532900
	23.596259N & 87.447513E	770	592900
	23.600971N & 87.432772E	320	102400
	23.595236N & 87.431461E	540	291600
Aduria Forest	23.578570N & 87.534175E	40	1600
	23.577743N & 87.529954E	610	372100
	23.578756N & 87.533068E	20	400
	23.579643N & 87.531399E	790	624100
	n = 9	$\sum x = 4630$	$\sum x^2 = 3174100$

2.1.1 Data Analysis and Results

Sampling units have been adopted considering quadrats of 0.1-hectare area in each spot of sampling in random sampling methodology. Each 0.1-hectare quadrat inside the forest is treated as a sampling unit during conducting the pilot survey. The data has been processed for calculation of sample size for the entire Garh Jangal and Aduria forest and the following formula is used after completing the forest vegetation survey

$$n = \frac{\left[\frac{(1.96)(c.v.)}{10} \right]^2}{1 + \frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2}$$

where, N is the total number of forests in West Bengal

No of sample quadrats, $n = 9$

$$\sum x = 4630$$

$$\bar{x} = 514.4444$$

$$\sum x^2 = 3174100$$

where, s=the standard deviation

$$s^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n}$$

$$s = 296.68$$

c. v. = Coefficient of variation

$$c. v. = \frac{s}{\bar{x}} \times 100$$

$$= 57.66$$

Where, x is the number of trees in a quadrat

and $\bar{x} = \sum x/n$ (i.e., mean of the variable tree/ha)

\bar{x} = Mean of the variable tree/ha = 514.4444

s = Standard deviation of tree/ha = 296.68

N = Total number of forests in West Bengal

For large N, the value of $\frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2$

is insignificant and the above formula for sample size will become,

$$n = \left[\frac{(1.96)(c.v.)}{10} \right]^2$$

$$n = \left[\frac{(1.96)(57.66)}{10} \right]^2$$

$$n = 127$$

In statistical analysis using probability methods, the sample size obtained in the result for Garh Jangal and Aduria forest has come out to be 127 quadrats and the result of the sampled data shows positive patterns. The present pilot survey is based on the data from 9 quadrats of the study areas which may throw some likely indication of vegetation pattern, number of stems having diameter classes of 10 cm and above, and types of dominant timber tree species.

2.2 Data sampling in quadrats for the 14 sample spots in 11 districts

Statistical measures are conducted where 14 forest patches scattered from east to west in the forest stands of Jungle Mahal are considered. During the pilot survey, the total number of trees (10 cm and above diameter at breast height) enumerated are 7980 in 14 sampling units in 14 forest patches with the large representations of several timber tree species (Table 2).

Table 2 Collected data used for sample size determination

District Name	Name of the forests	Trees (above 10 cm diameter) / ha	$\sum x^2$
Paschim Bardhaman	Garh Jangal	810	656100
	Aduria Forest	640	409600
Bankura	Joypur	780	608400
	Beliatore	800	640000
Jhargram	Mayur Jharna	870	756900
	Lalgarh	740	547600
Paschim Medinipur	Arabari	670	448900
Purulia	Bundwan	810	656100
Nadia	Bethuadahari	510	260100
Uttar Dinajpur	Kulik	450	202500
Dakshin Dinajpur	Dogachhi	370	136900
North 24 Parganas	Parmadan	430	184900
Howrah	Garh Chumuk	40	1600
Hugli	Garh Mandaran	60	3600
Total	n = 14	$\sum x = 7980$	$\sum x^2 = 5513200$

2.2.1 Data analysis and results

Number of data regarding categories of tree species including their diameters are collected in this inventory survey, though only timber trees of 10 cm and above diameter at breast height are inventoried, rest of the plant species including herbs and shrubs are considered as miscellaneous. For quantitative analysis, trees inside forests were sampled at random through 10m x 10m quadrats, equal to 0.1 hectare, and the collected data from 9 quadrats was transformed into the data for 1-hectare area after calculation with numerical conversion. List of all sampled forest patches and along with their occurrences in the districts of West Bengal are mentioned in Table 2.

Sampling units have been adopted considering quadrats of 0.1-hectare area in each spot of sampling in random sampling methodol-

ogy. Each 0.1-hectare quadrat inside the forest is treated as a sampling unit during conducting the pilot survey. The data has been processed for calculation of sample size for 14 forest patches and the following formula is used after completing the forest vegetation survey -

$$n = \frac{\left[\frac{(1.96)(c.v.)}{10} \right]^2}{1 + \frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2}$$

where, N is the total number of forests in West Bengal.

Number of sample quadrats, $n = 14$

$$\begin{aligned} \sum x &= 7980 \\ \bar{x} &= 570 \\ \sum x^2 &= 5513200 \end{aligned}$$

where, s = standard deviation

$$s^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n}$$

$$s = 262.48$$

c. v. = Coefficient of variation

$$c. v. = \frac{s}{\bar{x}} \times 100$$

$$= 46.04$$

Where, x is the number of trees in a quadrat and $\bar{x} = \sum x/n$ (i.e., mean of the variable tree/ha)

\bar{x} = Mean of the variable tree/ha = 570

s = Standard deviation of tree/ha = 262.48

N = Total number of forests in West Bengal

For large N , the value of $\frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2$ is

insignificant and the above formula for sample size will become,

$$n = \left[\frac{(1.96)(c.v.)}{10} \right]^2$$

$$n = \left[\frac{(1.96)(46.04)}{10} \right]^2$$

$$n = 81$$

In statistical analysis using probability methods, the sample size obtained in the result for 14 forest patches has come out to be 81 quadrats and the result of the sampled data shows positive patterns. The present pilot survey is based on the data from 14 quadrats of the study areas which may throw some likely indication of vegetation pattern, number of stems having diameter classes of 10 cm and above, and types of dominant timber tree species.

2.3 Data sampling in quadrats for the 27 sample spots from 19 districts of West Bengal

Number of data regarding categories of tree species including their diameters are collected in this inventory survey, though only timber trees of 10 cm and above diameter at breast height are inventoried, rest of the plant species including herbs and shrubs are considered as miscellaneous. For quantitative analysis, trees inside forests were sampled at random through 10m x 10m quadrats, equal to 0.1 hectare, and the collected data from 27 quadrats was transformed into the data for 1-hectare area after calculation with numerical conversion. List of all sampled forest patches along with their occurrences in 19 districts of West Bengal are enlisted in Table 3. Sampling units have been adopted considering quadrats of 0.1-hectare area in each spot of sampling in random sampling methodology. Each 0.1-hectare quadrat inside the forest is treated as a sampling unit during conducting the survey. The entire survey is conducted in both types of natural and stray forests patches during October 2008 to September 2020. After processing data for estimation of sample size for 27 Forest patches, following formula [3] is used after completing the survey of forest vegetation.

$$n = \frac{\left[\frac{(1.96)(c.v.)}{10} \right]^2}{1 + \frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2}$$

where, N is the total number of forests in West Bengal.

Number of sample quadrats, $n = 27$

$$\begin{aligned} \sum x &= 17380 \\ \bar{x} &= 643.70 \\ \sum x^2 &= 12523800 \end{aligned}$$

where, s = standard deviation

$$s^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n}$$

$$s = 222.46$$

c. v. = Coefficient of variation

$$c. v. = \frac{s}{\bar{x}} \times 100$$

$$= 34.55$$

Where, x is the number of trees in a quadrat and $\bar{x} = \sum x/n$ (i.e., mean of the variable tree/ha)

\bar{x} = Mean of the variable tree/ha = 643.70
 s = Standard deviation of tree/ha = 222.46
 N = Total number of forests in West Bengal

For large N, the value of $\frac{1}{N} \left[\frac{(1.96)(c.v.)}{10} \right]^2$ is insignificant, thus for determination of sample size the formula will become,

$$n = \left[\frac{(1.96)(c. v.)}{10} \right]^2$$

$$n = \left[\frac{(1.96)(34.55)}{10} \right]^2$$

$$n = 45$$

In statistical analysis using probability methods, the derived sample size from 27 forest patches has appeared to arise 45 quadrats and the result of the sampled data shows positive patterns. The collected data of the pilot survey is from 27 quadrats of the 27 forest areas which reflect similarity patterns of growing stocks, number of stems having diameter classes of 10 cm and above, and types of timber trees dominated in the forests.

Table 3: Data collected for computation of optimum sample size from 27 forest patches of West Bengal

District Name	Name of the forests	Trees (above 10 cm diameter)/ha	$\sum x^2$
Darjeeling	Mirik	830	688900
	Lava	920	846400
Kalimpong	Lolegaon	930	864900
	Chilapata	870	756900
AlipurDuar	Hatipota	650	422500
	Buxa	740	547600
Cooch Behar	Kodal Basti	590	348100
	Chapramari	670	448900
Jalpaiguri	Gorumara	710	504100
	Garh Jangal	810	656100
Paschim Bardhaman	Aduria Forest	640	409600
	Joypur	780	608400
Bankura	Beliatore	800	640000
	11 Mile	610	372100
Birbhum			

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Jhargram	Mayur Jharna	870	756900
	Lalgarh	740	547600
Paschim Medinipur	Arabari	670	448900
Purba Medinipur	Junput	770	592900
Purulia	Bundwan	810	656100
Nadia	Bethuadahari	510	260100
Uttar Dinajpur	Kulik	450	202500
Dakshin Dinajpur	Dogachhi	370	136900
24 Parganas (North)	Parmadan	430	184900
24 Parganas (South)	Dhanchi	530	280900
	Luthian	580	336400
Howrah	Garh Chumuk	40	1600
Hugli	Garh Mandaran	60	3600
Total	n = 27	$\sum x = 17380$	$\sum x^2 = 12523800$

3. Conclusion

Determination of required number of optimum sample size through the inventory study with the estimation of growing stock of standing trees in terms of tree density of major timber species for 9 sampling units taken up in Garh Jangal and Aduria forest are likely and possess similarity in pattern to 127 such quadrats (obtained in the result) for all 38 forest patches of two districts under Bardhaman Forest Division. The result of the survey and statistical analysis for optimum sample size determination should be at the accuracy/precision of $\pm 10\%$ at 95% probability level in terms of statistical random sampling methodology. The sample size obtained in the result interprets homogeneity of the vegetation pattern in all 38 forest patches of Bardhaman Forest Division.

Determination of required number of optimum sample size through the inventory study with the estimation of growing stock of standing trees in terms of tree density of major

timber species for 14 sampling units taken up in 14 forest are likely and possess similarity in pattern to 81 such quadrats (obtained in the result) for rest of the forest patches of West Bengal. The result of the survey and statistical analysis for optimum sample size determination should be at the accuracy/precision of $\pm 10\%$ at 95% probability level in terms of statistical random sampling methodology.

In statistical analysis using probability methods, the derived sample size from 27 forest patches has appeared to arise 45 quadrats and the result of the sampled data shows positive patterns. The collected data of the pilot survey is from 27 quadrats of the 27 forest areas which reflect similarity patterns of growing stocks, number of stems having diameter classes of 10 cm and above, and types of timber trees dominated in the forests. The survey result and statistical analysis for optimum sample size ascertainment might be $\pm 10\%$ accuracy at 95% probability level [3] in terms of statistical random sampling methodology. Determination of required number of

optimum sample size through the inventory study with the estimation of timber trees for 27 sampling units taken up in 27 forests are likely and possess similarity in patterns to 45 such quadrats (obtained in the result) for the rest of the forest patches of West Bengal. Pattern of vegetation is revealed by the presence of the growing stocks of standing trees in terms of tree density of major timber species in the forest stands.

Application of statistical measures for determination of optimum required sample size reveals that larger the area surveyed higher the data pool obtained minimizing the required optimum sample size for the forest stands. From this pilot survey it is noticed that the number of more surveys in the study areas enhances precision of data and reduces the probability level. Therefore, a survey to be conducted in the broader per-

spectives for the generation of more data pools for further interpretation on vegetation patterns and overall integrity monitoring of the forest stands is suggested.

REFERENCES

- [1] Forest Survey of India, India State of Forest Report 2019, Ministry of Environment, Forest & Climate Change, Government of India, p.187, 2019.
- [2] Champion, H. G. and Seth, S. K., A Revised Survey of Forest Types of India, Manager of Publication, Delhi, p.404, 1968.
- [3] Forest Survey of India, Report on Inventory of Trees in Non-Forest Areas, A Pilot Survey in 25 Villages of West Bengal, Forest Survey of India, Eastern Zone, Calcutta, p.29, 1997.