STRATIFIED TWO-STAGE SAMPLING (SELF-WEIGHTED) FOR ASSESSMENT OF VILLAGE FOREST RESOURCES

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ISLAM, S. S. 2004. Stratified Two-Stage Sampling (Self-Weighted) for assessment of village forest resources. The paper examines the suitability of Stratified Two-Stage Sampling (Self-Weighted) as a field sampling design in assessing village forest resources in Bangladesh. A study population of 900 households was formed consisting of 14 administrative units comprising of several local councils, each having a group of villages in the district of Chittagong in Bangladesh. The study concentrates on tree and bamboo resources as they contribute a major share of the village forest economy. Seven parameters defined under five variables were calculated for complete enumeration (total homestead area = 97 ha, total area of compact tree garden = 49 ha, total volume of trees = 9490 m^3, total volume of compact trees = 8308 m^3, total number of bamboos = 53 229, volume of compact trees per hectare = 170 m^3 and number of households with bamboo plantation = 407). Stratified Two-Stage Sampling design was tested with collected field data using a computer. The parameters were estimated through the sampling technique using self-weighted method considering 250 sample households (estimated total homestead area = 78 ha, estimated total area of compact tree garden = 50 ha, estimated total volume of trees = 9432 m^3, estimated total volume of compact trees = 8183 m^3, estimated total number of bamboos = 53 546, estimated volume of compact trees per hectare = 165 m^3 and estimated number of households with bamboo plantation = 413). The estimates were compared with the enumerated values on the basis of percentage standard error, percentage accuracy, percentage bias and 95% confidence level. The sampling design under the study was found to be a suitable inventory technique and is recommended for application in the field to assess village wood and bamboo resources in Bangladesh.

Key words: Sampling techniques – village forest resources – tree density – bamboo abundance – Bangladesh

ISLAM, S. S. 2004. Pensampelan Dua Peringkat Bersusun Lapis (Swacondong) untuk penilaian sumber hutan di kampung. Kertas ini mengkaji kesesuaian Pensampelan Dua Peringkat Bersusun Lapis (Swacondong) sebagai corak pensampelan di lapangan untuk menilai sumber hutan di kampung di Bangladesh. Sebanyak 900 keluarga di wilayah Chittagong di Bangladesh dikaji. Kajian melibatkan 14 unit tadbir yang merangkumi beberapa majlis tempatan, setiapnya mengandungi beberapa kampung. Kajian tertumpu kepada sumber-sumber pokok dan buluh memandangkan kedua-dua sumber ini banyak menyumbang kepada ekonomi hutan kampung. Tujuh parameter yang ditakrifkan di bawah lima pemboleh ubah dihitung untuk pengiraan lengkap (jumlah kawasan rumah ladang = 97 ha, jumlah kawasan kebun pokok padat = 49 ha, jumlah isi padu pokok = 9490 m^3, jumlah isi padu pokok padat = 8308 m^3, jumlah buluh = 53 229, isi padu pokok padat sehektar = 170 m^3 dan bilangan keluarga yang mempunyai ladang buluh = 407). Corak Pensampelan

Dua Peringkat Bersusun Lapis diuji dengan komputer menggunakan data lapangan. Parameter dianggar menggunakan teknik pensampelan cara condong kepada sendiri dengan mengambil kira 250 sampel rumah tangga (anggaran jumlah kawasan rumah ladang = 78 ha, anggaran jumlah kawasan kebun pokok padat = 50 ha, anggaran jumlah isi padu pokok = 9432 m^3, anggaran jumlah isi padu pokok padat = 8183 m^3, anggaran jumlah buluh = 53 546, anggaran isi padu pokok padat sehektar = 165 m^3 dan anggaran bilangan keluarga yang mempunyai ladang buluh = 413). Nilai anggaran dibanding dengan nilai yang dikira berdasarkan peratusan ralat piawai, peratusan ketepatan, peratusan cenderung dan paras keyakinan 95%. Corak pensampelan yang dikaji didapati sesuai sebagai teknik inventori dan disyorkan diguna pakai di lapangan untuk menilai sumber-sumber kayu dan buluh di kampung di Bangladesh.

Introduction

Bangladesh (20° 34'–26° 38' N, 88° 01'–92° 41' E), bounded by India on the west, north and north-east and Myanmar on the south-east and the Bay of Bengal on the south, has 2.14 million ha under forest and 0.27 million ha under village forest resources. These two forest areas cover about 16% of the total land area of the country. However, much of the forest land is barren—only 0.93 million ha (6.5%) are covered with trees (Anonymous 1989). Most of the village forest resources (75%) are in the northern and southern regions of the country (Davidson 1984). The village woodlot is normally a mixture of short-boled and heavily-branched fruit trees, smaller trees, canes, bamboos and shrubs providing timber, fuelwood, food and fodder to the village community. A total of 85% population of the country lives in rural areas. They are directly or indirectly dependent on these resources for their livelihood. The village woodlot area being about $\frac{1}{10}$th of the national forest area, supplies the bulk of sawn timber, firewood and bamboo to the nation. Accordingly, the government has been emphasising on the conservation of the resources in all the five-year plans

Despite the importance of village woodlot resources previous surveys have found divergent results for the contribution of the resources (Table 1). Table 1 shows that different authors/organisations estimated different values for the same parameters at about the same time period using Multi-Stage Sampling method. The difference in estimation might have occurred due to time duration and choice of sampling method. The variation in the estimates due to time factor is obvious. However, variation of the contribution of village woodlot resources due to sampling method should be avoided and a search for appropriate sampling design is necessary for accurate and precise estimates. Without reliable estimates, proper planning as well as monitoring of these valuable resources is not possible. Since Multi -Stage Sampling method had been used to estimate the village woodlot parameters by different authors/organisations, it was, therefore, decided to choose Stratified Two Stage Sampling method for testing. It was intended to examine the suitability of the chosen sampling design as a field sampling design in assessing village forest resources in Bangladesh.

Table 1 Contribution of village woodlot resources to the total national production

Source	Contribution of resource (%)			Sampling method
	Sawlogs	Fuelwood	Bamboo	
Bangladesh Energy Study (1976)	48	48	77	Stratified two-stage sampling
Hammermaster (1981)	48	70–80	70–80	Stratified two-stage sampling
Douglas (1982)	85	90	90	Stratified three-stage (self-weighted) sampling
Byron (1984)	75	–		Collected from different homestead woodlot surveys
BBS (1990)		85		Stratified two-stage systematic sampling

Materials and methods

Chittagong district, consisting of 14 rural administrative units comprising several local councils, each having a group of villages, was considered as the area of study. It is one of the 64 districts in Bangladesh and situated at the south-east corner of the country. It has a total land area of 0.52 million ha having a population of 5.29 million with 575 040 households living in 1290 villages. It has, however, almost a similar type of homestead condition, household occupation and species composition as in other rural areas in the country except for some differences in geographical and climatic conditions.

A target population was first formed in the study area. A preliminary survey was conducted with a sample of 45 households. It was mainly conducted for estimating population size and pretesting a field sheet. A field sheet was finally prepared. It contained homestead area, compact tree garden area, diameter at breast height measurement of trees (species wise) in both compact and scattered areas number of bamboo clumps with culms (species wise), general information and economic status of a household. The size of the target population for the study was estimated by the formula of Chacko (1965).

$$n = (ts)^2/d^2$$

$$d = py$$

where

p = specified precision (12% margin of error)
y = mean volume of standing trees
s = estimated standard deviation
t = Student's t at 1 – a probability level with n – 1 degrees of freedom

A total of seven parameters and five variables were considered for the study. The seven parameters were (a) total homestead area (ha), (b) total area (ha) of compact tree garden, (c) total volume (m^3) of trees, (d) total volume (m^3) of compact trees, (e) total number of bamboos, (f) volume (m^3) of compact trees

per hectare and (g) number of households with bamboo plantation. The variables were (a) area of compact tree garden (x_2), (b) homestead area (x_4), (c) volume of standing trees (y_2), (d) volume of standing compact trees (y_3) and (e) number of standing bamboos (y_4) of a household.

A total of 11 major tree species and three common bamboo species were assessed for data collection in the study area. The 11 tree species were *Mangifera indica, Artocarpus heterophyllus, Tectona grandis, Syzygium cumini, Lagerstroemia speciosa, Gmelina arborea, Samanea saman, Albizia lebbeck, Albizia procera, Dalbergia sissoo* and *Erythrina indica.* The minor tree species were grouped as others. The three common bamboo species were *Bambusa vulgaris, Melocanna baccifera* and *Bambusa tulda.* The uncommon bamboo species were grouped as others.

The target population of 900 households was estimated by the given formula. Homestead area (courtyard + pond + ditch) and area under compact tree garden of a household were measured in hectares and recorded in the field sheet. A total of 17 333 trees of the selected species were tallied as per designed field sheet. The diameter at breast height measurement of all standing trees except *Cocos nucifera* and *Borassus flabellifer* was taken. Volume of all trees were estimated by available local volume tables (Aleem 1981, Islam 1984, Islam 1988). A total of 53 229 bamboos were also tallied and their numbers recorded in the field sheet. The five variables were thus generated through computer. In this way, data on area, trees and bamboos were collected in the field sheet and complete enumeration was carried out. The seven parameters were calculated on the basis of enumerated values of the target population.

Stratified Two-Stage Sampling (Self-Weighted) was chosen for testing its suitability as field sampling design for assessing village wood and bamboo resources in Bangladesh. It was applied on the target population for estimating the parameters. The self-weighting technique was followed at estimation stage. Stratification was done on the basis of location, landuse system and homestead wood and bamboo resources so that each stratum was internally homogeneous. The 14 rural administrative units were thus stratified as stratum I, stratum II, stratum III, stratum IV, stratum V, stratum VI and stratum VII. The 22 villages and 900 households were distributed among the seven strata. A total of 250 households were considered to estimate the parameters by the chosen sampling design. The parameters of total homestead area, total area under compact tree garden, total volume of trees, total volume of compact trees and total number of bamboos were estimated by the formula of total estimate (Obaidullah 1980). Volume of compact trees per hectare and number of households with bamboo plantation were estimated by the formula of ratio (Obaidullah 1980) and proportion (Islam 1994) estimate respectively.

The study was to compare the estimates done by chosen sampling design with the enumerated values of the parameters with regard to percentage standard error (%SE), percentage accuracy (%AC), percentage bias (%bias) and 95% confidence interval (%CI). In percentage accuracy, the estimates are unbiased whereas the estimates in percentage bias are biased. The cost of the surveys was not considered in the study as the surveys were compared through computer. The percentage

standard error of the estimate was calculated by (SE/estimate) 100. Similarly the percentage bias of the estimate was calculated by the same formula. The percentage accuracy was calculated by the formula 100 – {(population value – estimate)/ population value}100. The 95% confidence interval was estimated by the usual formula. The samples of 14 villages (600 households) and 250 households randomly selected from seven strata were first stage and second stage units respectively. The distribution of the sample villages and the sample households and the self-weighting nature were given in Table 2.

Table 2 Distribution of sample villages and sample households and self-weighting nature in Stratified Two-Stage Sampling

Stratum	Total villages (N_h)	Total HH in N_h	Total villages selected (n_h)	fa $= \frac{n_h}{N_h}$	Total HH in n_h (M_h)	Total HH selected (m_h)	fb $= \frac{m_h}{M_h}$	f = fa.fb
I	3	143	2	0.6667	79	31	0.3924	0.2616
II	3	117	2	0.6667	87	35	0.4023	0.2682
III	3	144	2	0.6667	97	39	0.4021	0.2681
IV	3	128	2	0.6667	85	34	0.4000	0.2667
V	4	145	2	0.5000	86	45	0.5233	0.2616
VI	3	89	2	0.6667	72	29	0.4028	0.2685
VII	3	134	2	0.6667	94	37	0.3936	0.2624
Total	22	900	14		600	250		

HH = households

Results and discussion

The size of the target population was estimated to be 900 households through the preliminary survey of 45 households. It was estimated for the variable y_2 (volume of standing trees of a household) at 12% margin of error (6% standard error). The five variables were generated. Complete enumeration was carried out and the mean, standard deviation and coefficient of variation of each of the variables were calculated for the target population. Average area of both compact tree garden (0.05 ha) and homestead land (0.11 ha) showed very small figure with high coefficients of variation (6.75 and 1.33). The averages for volume of standing trees (10.54 m^3) and number of bamboos (59) were reasonable with also high coefficients of variation (1.11 and 4.31). Here the standard deviations of all variables were larger than the means. It is an indication that the target population was heterogeneous and the stratification was justified.

The seven parameters of the target population were calculated and presented in Table 3. Total area of compact trees was about half that of total homestead area. This means that village people had limited areas for compact tree plantation. The volume (m^3) of compact trees per hectare was not promising perhaps because of two reasons. One reason was that the smaller trees (less than 20 cm diameter at breast height) were not tallied. Another reason could be the dense spacing. Total number of bamboos and number of households with bamboo plantation were not

Table 3 The calculated values of the parameters of the target population

Parameter	Value
Total area (ha) of compact tree garden (Σx_2)	49
Total homestead area (ha) (Σx_4)	97
Total volume (m^3) of trees (Σy_2)	9490
Total volume (m^3) of compact trees (Σy_3)	8308
Total number of bamboos (Σy_4)	53 229
Volume (m^3) of compact trees per hectare ($R_1 = \Sigma y_3 / \Sigma x_2$)	170
Number of households with bamboo plantation ($NP = N_1$)	407

encouraging. Only 407 households out of 900 were interested to plant bamboos. The village people had limited bamboo plantation in comparison with their daily demand. The target population was actually a variable population.

The seven parameters were estimated on the basis of 250 sample households using Stratified Two-Stage Sampling (Self-Weighted). The total, ratio and proportion estimates of the parameters with corresponding percentage standard error, percentage accuracy, percentage bias and 95% confidence interval were presented in Table 4.

Table 4 The comparative results of Stratified Two-Stage Sampling (Self-Weighted) and complete enumeration

Parameter	Population value	Estimate	Stratified Two-Stage (Self-Weighted) % SE	% AC	95% CI
Σx_2	49	50	3	99	(47, 52)
Σx_4	97	78	2	81	(75, 82)
Σy_2	9490	9432	3	99	(8946, 9918)
Σy_3	8308	8183	3	98	(7727, 8638)
Σy_4	53 229	53 546	4	99	(48 738, 58 355)
R_1	170	165	10	0 3[a]	(133, 197)
NP	407	413	7	99	(356, 469)

[a] indicates % bias

Σx_2 = Total area of compact tree garden (ha)
Σx_4 = Total homestead area (ha)
Σy_2 = Total volume of trees (m^3)
Σy_3 = Total volume (m^3) of compact trees
Σy_4 = Total number of bamboos
R_1 = Volume (m^3) of compact trees per hectare
NP = Number of households with bamboo plantation

Table 4 also contains enumerated values of the parameters. The estimates of all the parameters except R_1 had small standard errors. The estimate of R_1 had a standard error 10 which might be accepted in the present homestead condition of Chittagong. Therefore, all estimates were found to be reliable. The percentage accuracies of all the estimates showed very high value except the estimate of x_4 which had 81% accuracy. These indicate that the estimated values are very close to the population values. The bias estimate of R_1 was also negligible. All population

values lay within the intervals estimated at 95% confidence except for x_4. It may lie between another 95% confidence interval estimated by a separate sample. In view of all these measures of reliability of the estimates, Stratified Two-Stage Sampling (Self-Weighted) yields reliable estimates.

The present Stratified Two-Stage Sampling (Self-Weighted) may be easily applied for conducting village woodlot survey. It will provide quick estimates with improved precision and accuracy as well as reduced cost. The selected sampling design was tested with field data through computer. There was no scope of having non-sampling error in the field. Sampling error was, however, obvious. It is now necessary to discuss about sampling units, frame, sampling intensity, stratification and self-weighting technique. They will be considered while sampling village forest resources in Bangladesh by the selected sampling design. The sampling units may change depending on the situation. The administrative units and the villages may be considered as first and second stage units. The frames of administrative units and villages are always available. However, the frame of the households is not readily available. It may be available from local councils. The sampling intensity was taken to be 25% for the study. It was large in comparison with sample sizes in typical woodlot surveys. Proportion allocation was followed in distributing sample households among seven strata. Stratification was mainly done on geographical proximity which covers the variables under the study. The results of the estimates showed that stratification on geographical proximity was reasonable. It would help to avoid post stratification which involves money, manpower and time. Self-weighting technique was applied at the estimation stage for estimating the parameters to avoid large amount of computation. In village forest survey, it is always desired that the weight is constant so that (a) tabulation becomes simpler and (b) analysis becomes easier. It may be emphasised that the criteria discussed above had direct contribution on the reliability of the estimates yielded by the selected sampling design. Therefore, Stratified Two-Stage Sampling (Self-Weighted) may be recommended for the assessment of village forest resources in Bangladesh.

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