Inventory with different sampling intensities: a tool for community forestry management in the middle hills of Nepal

Gopal P. Bhattarai[1]

The community forest management and planning for sustainable development and utilisation requires a good knowledge of forest related information such as growing stock, species diversity, increment, and yield. For this, information of existing growing stock of the forest is necessary and to get the better result of estimated growing stock needs better sampling methodology. In this context, the inventory results of total enumeration with that of Systematic Sampling and Simple Random Sampling using various sampling intensities were compared. Pokhareban Community Forest situated at Pangretar Village Development Committee, Ward No. 3 of Sindhupalchok District was selected for this study. The forest is basically in pole size stage and consists of Chilaune-Katus (*Schima-Castanopsis*) species, which is common type in the middle-hills of eastern, central and western development regions of Nepal.

In this study, Systematic Sampling (SS) method gave the better result compared to Simple Random Sampling (SRS). The finding of the study suggests that 10% sampling intensity (area wise) gives reliable estimate and therefore appropriate for the inventory of community forests in the middle hills of Nepal. The appropriate sampling intensity may vary with community forests as species composition differs, and will also depend upon financial and human resource constraints. Further studies should be carried out in different species composition, different stages of forest and different physiography to make a good prescription in this regard.

Key words: Community forestry, inventory, simple random sampling, systematic random sampling

Forest Resources Survey Office was established in 1963 with the co-operation of USAID and became a permanent organisation for carrying out forest resources inventory in Nepal (HMGN 1973). Later on, the Land Resource Mapping Project (LRMP) conducted a nation-wide land use and land capability survey in 1984. Based on these information, the project produced landuse and forest classification maps with forest type, maturity class and crown cover.

The Forestry Sector Master Plan (HMGN 1988) provided the nation-wide result of country's forest resources with a guideline to conduct forest inventory in future. Very recently, a national level forest inventory has been completed with the technical assistance of Forest Resource Information System Project of the Government of Finland.

So far, about 850 thousand hectares of the national forest area has been handed over as community forests to more than 11000 Community Forest User Groups (CFUGs). This constitutes little over fourteen percent of the total forest and shrub land area of the country (MIS 2002). The methodology applied for national forest inventory is not applicable for Community Forests (CF). This study, therefore, attempts to find out the appropriate methods to conduct the much-needed inventory works in community forests.

The study has the following objectives:

- to compare the inventory results of total enumeration with that of Systematic Sampling (SS) and Simple Random Sampling (SRS) using various sampling intensities (i.e. 0.6%, 1.05%, 2.1%, 5.01%, 10.06%, 14.86% and 20.1%). and
- to estimate the existing timber volume (in various diameter classes) in the Pokhareban CF.

[1] Assistant Forest Survey Officer, Forest Survey Section, Department of Forest Research and Survey, Babarmahal, Kathmandu, Nepal.

Methods

Upon consultation with District Forest Officer (DFO) of Sindhupalchok District, Pokhareban Community Forest (area 6.66 ha; altitude ranging 1,000m to 1,300m.) was selected for this study. The CF is situated at Pangretar Village Development Committee, Ward No. 3 of Sindhupalchok District. There are altogether 53 House Holds (HH) involved in protection and conservation of this forest. The forest is basically in pole size stage. The Forest is comprised of Chilaune-Katus (*Schima-Castanopsis*) species, which is a common type in the middle-hills of eastern, central and western development Regions of Nepal. The CF is relatively accessible and workable.

Upon fixing the boundary with the help of paint spray and marking ribbon; the forest inventory was initiated. From the Northeast corner of the CF, first sampling unit was fixed. The azimuth for every plot (square) was 210° North and 300° East. With the help of pocket computer and slope correction table, sloping distance was corrected instantly into horizontal distance in the field wherever necessary. Each and every unit was mapped on to the graph paper and sampling units were numbered. The sampling unit size was selected 10m × 10m. Altogether, 734 units including 123 units falling in the boundary (partial units) were surveyed. There were 611 units inside the boundary (full units). Total forest area was determined by calculating the area of each partial unit, and adding them to the area of full units.

The tally sheet of this inventory was divided into 4 different sections. The first part comprises general information of the forest inventory site. General information (e.g., sample plot number, altitude, average slope etc.) of each and every plot was also recorded. The second section was for the information of young regeneration or seedlings. For this purpose, the seedling was defined as the plant of only tree species whose height is >10 cm, shorter than 1.5m, and diameter less than 2 cm at 10cm above the ground. To forecast the future scenario of the forest, seedlings/regeneration were counted within the 1m × 1m nested plot and necessary information were also recorded. The third section was for established regeneration (Sapling). Sapling taller than 1.5m, greater than 2 cm and less than 10 cm diameter at breast height were counted and species-wise information of saplings were recorded. Tree tally sheet is the fourth section. All the trees greater than 10 cm diameter at breast height (dbh) were measured with the help of calliper and diameter tape. Tree height was measured using hypsometer (Sunto Clinometer). Height correction was made instantly for the leaning tree. All the data were recorded in the tally sheet.

After completion of the inventory as well as marking on the graph paper, a random table was produced using the computer. According to the random table, SRS units were selected for various sampling intensities of 0.6%, 1.05%, 2.1%, 5.01%, 10.06%, 14.86% and 20.1%. For this purpose, the required number of sampling units for the above mentioned intensities were 4, 7, 14, 34, 67, 99 and 134 respectively. However, if the selected sampling unit was found as partial (plot more than 30% area out from CF boundary) unit, then next unit (nearest unit from the rejected one) was chosen.

Similarly, sets of SS units were prepared. To do so, one random number was drawn for the first SS unit. Then various sets of systematic number were produced to get the sampling intensities of 0.6%, 1.05%, 2.1%, 5.01%, 10.06%, 14.86% and 20.1%. The number of units selected was similar as SRS units. For this purpose, the minimum distance in the row must be 40 m (for larger sampling intensities). If the condition of distance set prior between two sampling units was not fulfilled, that very unit was rejected.

Data processing

The data were processed in the Micro Soft Excel worksheet programme. For the total volume calculation of the measured trees, volume equation LN (V)=a+b×LN (d)+c×(LN (h) was used (Sharma and Pukkala 1990). Where, 'V' is the calculated total stem volume (m^3), 'd' stands for diameter (cm) in breast height, 'h' stands for height of the tree (m), LN refers to the natural logarithms and 'a','b','c', are the constants. The species not mentioned in the volume table was considered as Hill Miscellaneous and stem volume calculated accordingly. The total volume of the trees (species-wise and sampling intensity-wise) was calculated separately (Annex 1) and the findings were compared with enumeration result.

Results and discussion

Data were arranged in such a way that all sampling intensities provide preliminary glimpse as given in Table 1 and 2.

Total number of stems (> 10 cm dbh) was divided into three diameter classes for stem volume calculation as 10 to 19.9 cm, 20 to 49.9 cm and 50 cm and above. This method has also been followed during the national forest inventory. The first category represents as established regeneration and it does not produce the timber. However, small posts, rafts and fence post can be used from this class. It also gives an idea about the future condition of the forest. The second class represents about the pole size and small timber. This also depicts the scenario of the future harvestable timber with the help of which the removable small timber and the intensity for thinning may be estimated. The last category gives the harvestable timber in the forest. The existing stem number shows the proportion and condition of the forest.

In the Pokhareban Community Forest, following volume (m^3) has been calculated using the volume equation according to the diameter classes (Table 3).

In 1 ha area, there are about 572 trees. Therefore, the average tree spacing becomes 4.1m × 4.1m. The proportion of trees of different diameter class is about **220:49:1** (dbh class 10.0-19.9cm, 20.0-49.9cm and = 50.0cm respectively).

Table 1: Sampling plots summary (for Systematic Sampling Units)

SS	0.6%	1.05%	2.1%	5.01%	10.06%	14.86%	20.1%
0 plots	0	1	1	1	2	4	6
Avg. dbh (cm)	16.24	14.45	15.02	34.45	16	16.11	11.5
Max dbh (cm)	39.3	22.3	34	58.9	47.7	90	63.5
Min dbh (cm)	10	10.6	10	10	10	10	10
# > 30cm	3	0	3	11	12	22	24
# > 60 cm	0	0	0	0	0	1	1
Total # of trees	24	17	84	217	380	570	724
Avg. Ht. (m)	14.42	11.3	12.6	15.5	12.23	12.11	12.21
Max Ht. (m)	20	16	22	27.5	22	27.5	24
Min Ht. (m)	10	7	5	15.5	3	2	3
Max # tree/plot	12	4	3	15	15	16	16

Table 2: Sampling plots summary (for Simple Random Sampling Units)

SRS	0.6%	1.05%	2.1%	5.01%	10.06%	14.86%	20.1%
0 plots	0	0	1	2	5	3	4
Avg. dbh (cm)	17.26	15.47	15.11	15.2	16.5	16.48	15.81
Max dbh (cm)	36.2	39.9	29.1	43	63.5	51.2	58.9
Min dbh (cm)	10	10.3	10.1	10	10	10	10
# > 30cm	3	3	0	3	14	30	35
# > 60 cm	0	0	0	0	1	0	0
Total # of trees	25	55	80	159	368	619	762
Avg. Ht. (m)	12.96	13.5	11.46	11.92	12.51	12.41	12.25
Max Ht. (m)	19	19.5	20	20	24	22	23
Min Ht. (m)	4	5	3.5	4	4	2.9	2
Max # tree/plot	8	12	14	15	15	16	16

Table 3: Total Stem Volume (m^3) according to diameter class

Diameter classes	Total Stem Volume	Proportion of timber volume in CF %	Stem Volume (m^3)/ha	No of Stem in CF	Proportion of Stem	No of Stem/ha
dbh 10.0 - 19.9 cm	279.5	44.36	41.97	3105	81.41	466
dbh 20.0 - 50 .0 cm	309.3	49.08	46.45	695	18.22	104
dbh > 50 cm	41.4	6.56	6.22	14	0.37	2
Total	630.2	100	94.64	3814	100	572

Table 4: Number of stem/ha by diameter class in various inventories

Inventory and year	Number of stems/ha			
	10-19.9cm dbh	20-49.9cm dbh	50 cm dbh	Total number of stems/ha
Pokhareban CF, 1999	466	104	2	572
Forest Resources of the hilly region (1994–1998) [CDR (hilly area)], 1999	265	163	20	448
Forest Resources of Nepal, 1999	244	143	21	408
Commercial forest of Central Zone (hills), Forest Statistics of hill region (1973)	108	71	7	186

The number of stems/ha in hilly region of Central Development Region was found to be 265, 163, and 20 respectively (HMGN 1999a) (Table 4). In National Forest Inventory number of stems per hectare by diameter classes were found to be 244, 143 and 21 respectively (HMGN 1999b). Similarly, number of stem/ha on commercial forest land in the central zone (hills) were found to be 108, 71, 7 respectively (HMGN 1973).

All these results show that the total number of stems in CF is dense. Comparing the result of two inventories, biggest increase has occurred in diameter class 10.0- 19.9 cm. In case of second and third diameter classes, Pokhareban CF has relatively low stems. This result indicates that the CF being studied is in young stage i.e. in growing condition. Therefore, this forest urgently needs thinning and singling operation as silvicultural management.

In the study area, there is about 94.63 m^3 stem volume per hectare (volumes according to the diameter classes are 44.36 %, 49.08% and 6.56% respectively) whereas mean stem volume of Nepal is 178 m^3 per hectare (HMGN, 1999b). The mean stem volume in this CF is low compared to the national mean stem volume (because this forest is in young stage i.e. in growing condition). Total stem volume is directly proportional to number of stems, size of diameter at breast height and total tree height. In this CF, diameter of the stem is smaller and the volume is quite low. Hence the CF is relatively good in stocking.

Since Pokhareban CF comprises primarily *Schima wallichii*, which is moderately light demander species and it regenerates abundantly where sufficient light is admitted for the development of the seedlings (Troup 1921). It is moderately shade-tolerant, but in later life it benefits from full overhead light (Jackson 1994). Hence, mother trees could be removed to reduce the competition and to create large opening for light as well. It also helps to reduce the timber requirement for the users with least number of stem cuttings.

Comparative results of tree volume (m^3) estimation from Simple Random Sampling (SRS) and Systematic Sampling (SS) with 100% Enumeration in Pokhareban CF, Sindhupalchok (Area: 6.66 ha.)

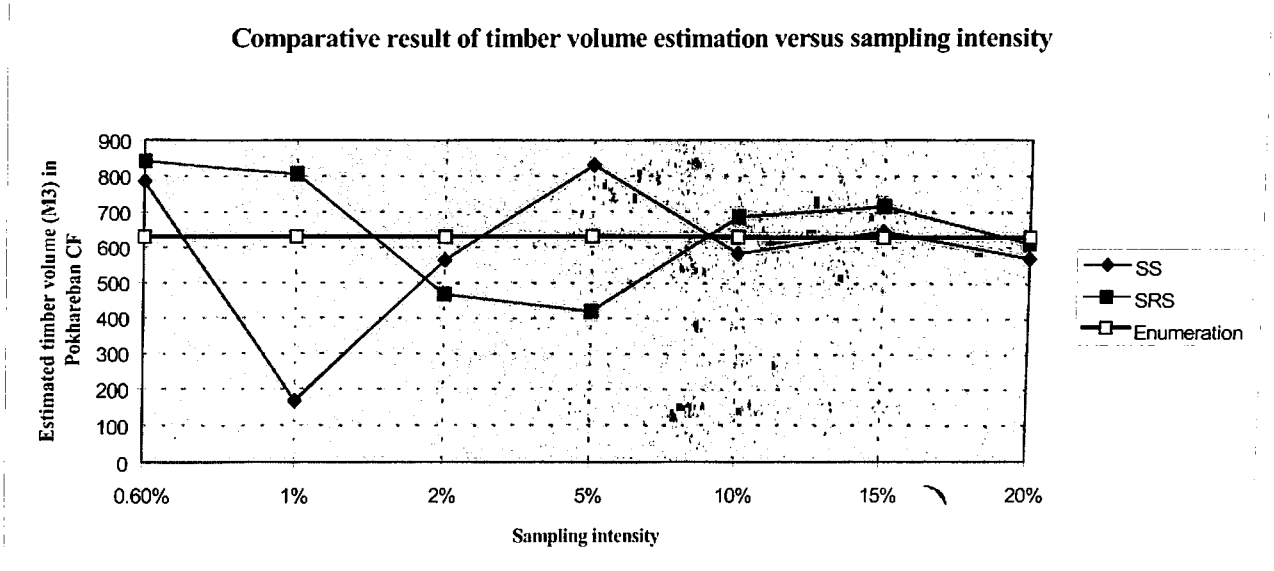

Figure 1: Comparative results of timber volume estimation by various sampling intensities

The volume estimation result from 1 % sampling intensity in Systematic Sampling method is too low compared to 100% enumeration and simple random sampling. It is because of the low number of encountered total trees. Altogether, there are only 17 trees in this intensity. The volume estimation is directly proportional to the number of the tree stem, its dbh and height. The maximum dbh and height observed with this intensity system was 22.3 cm and 16 m respectively. Furthermore, in this intensity, there was one zero-tree-plot.

The curve from Systematic Sampling was closer to the enumeration curve than that of Simple Random Sampling. If we compare with the results and resource used, 2% sampling intensity has given good result. However, on 5% sampling, there seem greater variations as SS overestimates the resource and SRS underestimates the volume. It is to be noted that existing community forestry in Nepal is not a homogeneous blocks of forest. Oversized trees are not uniformly scattered and therefore such occurrence happens. Considering these facts, if a small area of community forests is to be sampled, then 10 % sampling can give better estimates in most cases as can be seen from the figure 1.

Future priorities

SS method gave the better result compared to SRS. Considering the financial and human resource to be involved, 10% sampling intensity (area wise) will be an appropriate sampling intensity for the inventory of community forest in the middle hills of Nepal. However, further studies needed to reach a firm conclusion. Similar studies need to be carried out in different species composition, forests of different development stages and different physiography to make good prescription in this regard.

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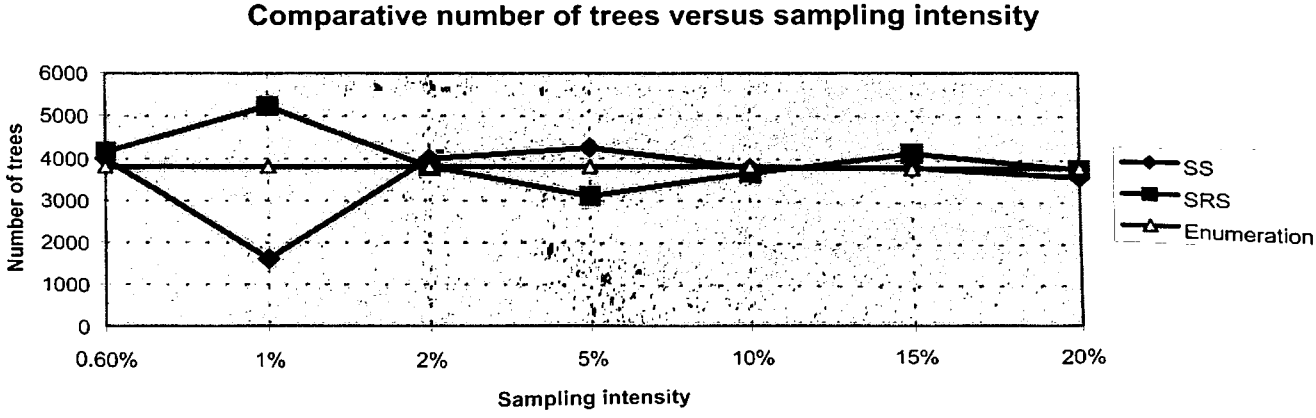

Figure 2: Comparative number of trees by various sampling intensity

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Annex 1

Total stem volume (m3) recorded from different sampling methods and with different sampling intensities.

	Total enumeration	dbh 10-19.9cm	dbh 20-49.9cm	dbh >50cm	SS 0.5% intensity	SS 1% intensity	SS 2% intensity	SS 5% Intensity	SS 10% intensity	SS 15% intensity	SS 20% intensity	SRS 0.5% intensity	SRS 1% intensity	SRS 2% intensity	SRS 5% Intensity	SRS 10% intensity	SRS 15% intensity	SRS 20% intensity
Local name	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m^3	Vol m3	Vol m3	Vol m3	Vol m3	Vol m3
0 plots	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amp	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphi	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Angeri	2.5	2.5	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.3	0.1	0.0	0.1	0.2	0.1	0.4	0.2
Ankhataruwa	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.3	0.1	0.0	0.1	0.0	0.4
Baklopate	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bhakimlo	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chilaune	397.6	142.6	222.6	32.4	3.0	1.0	7.8	24.7	35.9	56.7	69.6	2.9	4.7	5.4	12.2	41.8	67.1	77.0
Hade Baver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jhyanu	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Katus	121.3	100.9	19.1	1.3	1.1	0.0	1.1	9.1	9.7	19.1	21.7	1.5	2.8	2.1	4.8	10.2	19.4	29.8
Khirro	2.4	0.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.2	0.0	0.0	0.0	0.0	0.0	1.3	0.2
Kyamun	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Laligurans	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lankuri	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Latotooni	0.4	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mahuwa	21.2	11.9	9.2	0.0	0.1	0.1	0.2	1.1	3.6	3.9	6.1	0.0	0.0	1.0	0.1	2.7	4.3	1.1
Pipal	5.1	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Simal	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Siris	8.8	1.5	7.3	0.0	0.0	0.1	0.9	2.5	1.0	2.3	1.1	0.0	0.0	0.0	1.9	0.2	0.2	0.1
Unknown	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Uttis	67.7	17.1	47.9	2.6	0.5	0.5	1.8	4.8	7.9	6.4	13.9	0.5	0.7	1.1	2.2	13.9	13.2	14.0
Grand Total	630.2	279.5	309.3	41.4	4.7	1.8	11.9	42.4	58.8	96.1	114.7	5.1	8.5	9.8	21.4	69.1	106.4	123.1
Estimated volume (M3) in Pokhareban CF					784.64	166.94	564.49	831.10	584.30	646.47	569.99	841.30	805.90	468.11	420.09	686.74	715.80	611.79