Indian Forester, 142 (1) : 47-61, 2016
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

THE RANDOMIZED BRANCH SAMPLING - A COST EFFECTIVE ESTIMATION METHOD OF ABOVE GROUND BIOMASS

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ABSTRACT

Forest ecosystem plays an important role in global cycling and storing and United Nations Framework Convention on Climate Change (UNFCC) and its Kyoto Protocol recognized the role of forests in carbon sequestration and storage. Modelling forest dynamics, predicting future yield, and exploring alternatives sustainable management options require accurate tree wood volume and biomass estimation. In order to achieve best biomass estimation, it is important to use appropriate biomass sampling technique that is unbiased. Here we described a randomized branch sampling a technique recently been popularized in forestry to sample above ground biomass of tree species (Gregoire *et al.,* 1995) in relatively most cost effective and statistically reliable manner.

Key words: Randomised, Branch, Sampling, Bhutan.

Introduction

Forest ecosystems play a very important role in the global carbon cycle, storing about 80% of all aboveground and 40% of all below-ground terrestrial organic carbon (IPCC, 2001). Forest can sequester more carbon than any other terrestrial ecosystem (IPCC, 2001; Lal, 2005; Gibbs *et al*., 2007). They can store more CO_2 Ca. 4500 Gt than the atmosphere (3000 Gt) Prentice (2001). Forest became more relevant as a sink of CO_2 in the face of climate change. Carbon sequestration is a complementary service of forest and sustainably managed forests are reliable sinks of greenhouse gases (GHGs) (Levy *et al*., 2004) or (2000). United Nations Framework Convention on Climate Change (UNFCC) and its Kyoto Protocol recognized the role of forests in carbon sequestration and storage (Brown, 2002). It is a common knowledge that the process of photosynthesis, the atmospheric CO_2 is utilized by the leaves for the manufacture of food in the form of glucose and it gets converted to other forms of food material, i.e. starch, lignin, hemicelluloses, amino acids, protein, etc. and is diverted to other tree components for storage and during the productive season, CO_2 from the atmosphere is taken up by vegetation and stored as plant biomass.

The estimation of biomass at different scales is required for varieties of reasons pertinent to ecological, environmental analysis or resource management. For example it may well serve to indicate a forest areas capacity to produce timber, conservation areas for wildlife reserves, even putting aside carbon forests or it may indicate site responses to certain management actions such as harvesting of forest resources, irrigation of certain plant species in a plantation,. The measurement of above ground biomass (AGB) involves sampling and oven drying of samples to reduced moisture content to tolerable smallest level, however for large trees, the processes is hard owning to utterly large amount of biomass from a single individual tree and biomass fraction from below ground may be small but the task of obtaining such below ground biomass for purpose of measurement is challenging because of its difficult in accessing it. Furthermore, the actual measurement of biomass involves killing of sample plants. It is for such reasons a well planned sampling of AGB decreases the amount of effort required, without eliminating the population of interest (Gregoire and Valentine, 2008) There are numerous ways in which such a sample can be selected, however there is no particular way to collect the samples that is best for all populations, conditions and information needs.

There is no single method for estimating biomass stocks, but a number of methods depending on the scale considered (Gibbs *et al*., 2007). On a national or larger scale, mean values per biome are usually employed (FAO, 2006). However, in absence of reliable techniques for obtaining realistic estimates for carbon pool have a direct bearing on the implementation of climate change related programs such as REDD Plus, PES etc especially in monitoring, verification and reporting (MRV) requirements of such international initiative to combat climate change.

The paper describes a randomized branch sampling a technique recently been popularized in forestry to sample above ground biomass of tree species in relatively most cost effective and statistically reliable manner.

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In this paper we are presenting randomized branch sampling (RBS) a relatively old method, however getting more popular in recent times as an unbiased estimator of above ground biomass (AGB). The AGB is defined as trees components such as bole, segments, twigs, needles, cones, dead branches and epicormic branches excluding the underground roots. RBS is a sampling scheme which can be implemented to estimate many different attributes of an object displaying a branched or forked form.

RBS was originally introduced by Jessen (1955) to estimate the amount of fruits on a fruit tree, where the method of sampling provides an efficient means to estimate many characteristics of trees, besides fruit. Later it was used to sample trees for estimation of volume, biomass and mineral contents of trees (Valentine *et al*., 1984; Gregoire *et al.,* 1995). RBS can be used alone or can be combined with importance sampling (IS) to estimate the above-ground woody components of a tree from measurements taken on a single disk (Valentine *et al*., 1984). This method of sampling is useful in any forest sampling in which estimates of the biomass components are needed for individual trees. Because RBS avoids weighing the fresh weight of all biomass components in the field, it permits larger first stage samples than the tradional method of sampling for individual-tree biomass, thereby increasing the precision of the inventory (Gregoire and Valentine, 1996). In an effort to seek a reliable field and laboratory methodology which could provide unbiased estimates of AGB the RBS (Gregoire *et al.,* 1995) had been adopted by DoFPS for aboveground tree biomass estimation and to develop species specific allometric equations (DoFPS, 2013). This was done in collaboration with Yale University, USA and Professor Tim Gregoire was engaged in developing field guidelines including template in Microsoft excel to implement RBS for estimating AGB of tree species in Bhutan.

The RBS scheme is design-unbiased and the average estimates obtained from all possible samples is equal to the targeted variables (Gregoire *et al*., 1995). It was found to be cost-effective and it overcame many of the difficulties identified in biomass measurements such as comparatively less amount of samples, avoidance of fresh weight measurements in the field due owning to its probabilistic selection method (Gregoire *et al*., 1995; De Gier, 2003). It had been proven useful in any forest sampling in which estimates of the biomass components are needed for individual trees and thereby increasing the precision (Gregoire and Valentine, 1996).

In traditional method of biomass estimation, (Table 1) the fresh weights of individual trees was determined by weighing all components of the tree, but for larger trees it would have been laborious and time consuming to which RBS offers an alternative (Gregoire *et al*., 1995). All the material that is not the part of the path can be discarded which is one of the big advantages of RBS (Parresol, 1999).

In order to execute the RBS smoothly field data template was developed in collaboration with Yale University, USA. The template was developed in Microsoft excel spread sheets, basically there were three sheets named General, Path 1 and Path 2, if necessary more paths could be added. In General sheet general attributes of sample trees (outlined in Table 4 later) were recorded; in addition certain estimates such as basal area, ground basal area were customized to generate values automatically upon entry of measured values. The General sheet was also designed to conduct importance sampling for selecting sample biomass from main stem (explained later in bole sampling section). The Path1 and Path 2 and even could add more paths if required were designed to select the paths for sampling of branches, foliage and other crown characteristics.

Sampling methods

While executing RBS and other samplings to obtain reliable estimates for AGB, certain rules were followed and are outlined here. After felling the desired sample tree all dead first-order branches were removed from the tree and its total weight was recorded and approximately 10% of the total weight was sub-sampled. The DBH was measured at 1.3 meter above the ground and always measured in the up slope side of the stem. Any tree with a main stem which forked beneath breast height was treated as two trees and the data template was filled out for each. All H measurements were recorded in meter to two decimal places. All diameter measurements were recorded in cm to one decimal place, effectively the diameters were measured to the nearest mm but were recorded in cm.

Sample trees : For the purpose of illustration we are demonstrating the field, laboratories and computation of AGB of trees species using data from a study of biomass in bluepine forest of central Bhutan. The data were collected from 36 bluepine trees from 11 community forests (CFs) in central Bhutan. The sample trees were selected from smallest to largest diameter spreads across those CFs (Table 2) from multi-aged stands, trees with deformities were not sampled, each tree was cut according to the convenient of feller adjusted against terrain and slope(stump height varied from 0.14 m to 1.14 m) and total height (H) was measured to two decimal places. The DBH outside bark (dob) was measured at 1.3 m and recorded to the nearest two

Table 1: Comparison between traditional and RBS methods of biomass sampling

Traditional methods	Randomized branch sampling
• All components of sampled tree needs measurement of fresh weights and sub-sampled from each component. • All branches needed to be sever from main stem and hence it was costly and time consuming.	• No need to take fresh weights of components which saves time and cost. • It involves the probabilistic selection procedures of a path from the base of a tree to a terminal branch. Only the section of the path needed to be sampled from the tree for dry weights.
• Needs conversion of estimates of trees volume/ hectare to biomass/hectare by means of biomass expansion factor (BEF), where $$BEF = \frac{\text{Total AGB density of the trees}}{\text{oven} - \text{dry biomass density of the inventoried trees volume}}$$	• No need of BEF ins tead in employing RBS probability is used to select the samples e.g. discs from the stem, or a branch along a path), then biomass is estimated for the entire stem or branching network, by dividing the measured oven -dried biomass in the sample by the probab ility that was used to select those samples.

decimal places. After each tree was felled the RBS was employed with at least two sampling paths for each tree. Selection of tree size classes was done based diameter classes by replicating three to five trees from each diameter class. 36 sample trees were destructively felled from 11 CFs spread across Bumthang district in central Bhutan.

A portable computer customized with RBS template was used to direct the entire sampling procedures. Prior to implement the actual RBS, vital attributes of the trees were recorded, an example from a sampled tree is shown in (Table 4).

Randomized branch samplings: Here we illustrate application of RBS to select the branches and foliage from the butt of felled tree to its terminal segment (Fig. 1) following RBS manual developed to conduct biomass sampling of forest trees in Bhutan (DoFPS, 2012) or 2013.

In RBS “branch” was defined as entire stem system that develops from single bud (lateral or terminal) whereas segment was a part of branch between two consecutive nodes (Fig. 1). Path (P in Fig. 1) was defined as a sequence of connected branch segments (Valentine *et al.,* 1984, Gregoire *et al.,* 1995). Figure 1 showed 18 possible paths from butt to the terminal of the tree. The entire aboveground of the tree was considered a branch for the purpose of RBS in which case possible paths in a tree equals number of terminals shoots (Gregoire *et al.*, 1995). Nevertheless the starting point need not be the butt of main stem and terminus need not be terminal shoot, it entirely depends on the subject of investigations. In our case we were interested in estimating the AGB of trees and we considered taking butt as the starting point. The detailed of the path selection and theoretical background were outlined by many authors, Valentine *et al.* (1984); Gregoire *et al*. (1995); De Gier (2003). Ducey *et al*. (2009), and thus not reported or reviewed. Here we illustrated RBS with an example from the bluepine data from central Bhutan, recently collected for estimating its biomass and development of biomass equation.

Selection probabilities in RBS: A tree without deformities was felled at a convenient height (H) and stump height was recorded, the height of the tree was taken from the ground. Any broken tops or branches while felling were aligned with the tree at the point of breakage. The measurement begun with DBH at 1.3 m above ground in cm to one decimal place and measurement of H was taken and recorded. The first node was located where one or more branches departed the main stem (Fig. 1, P1N1) , if branches did not occur in neat whorls then a node was located by including number of branches emanating from the main stem over a short section of the stem (strictly within 50 cm), otherwise , each emanating branch was considered next

Table 2: The basic statistics of trees harvested for the purpose of estimating biomass from 11 community forests in central Bhutan.

Variable	Mean	Standard Deviation	Range
DBH (cm)	35.29	25.34	2.6 - 95.80
Height (m)	23.02	12.52	3.35 - 51.50
Live crown height (m)	12.89	8.21	1.2 - 30.70

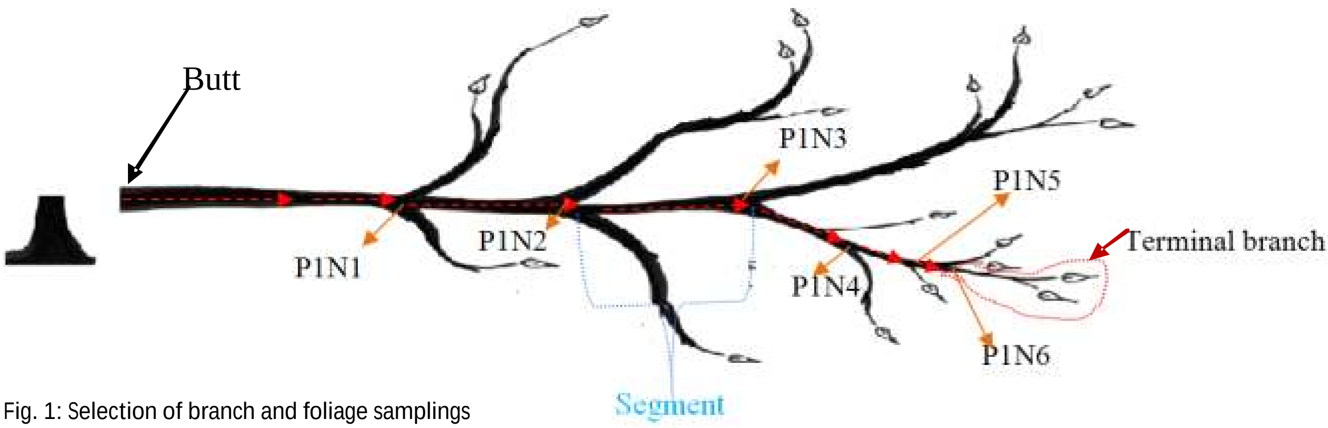

Fig. 1: Selection of branch and foliage samplings

node. The location of the first node was flagged and marked with P1N1 on the flagging (P1N1 was an abbreviation for Path 1, Node 1).

To select the sample from the branches ,the diameter (d in Table 3) of each branch emanating from P1N1 (Fig. 1) , including the diameter of the main stem was measured and recorded to the nearest 1/10th of cm in designated cells in excel spread sheet (prepared and customized for conducting RBS for forest trees species in Bhutan). For the purpose of RBS, the main stem at any node was treated like any other lateral branch emanating from the node. As each branch diameter was recorded on the spreadsheet, the cells immediately to the right (2, 3, and 4, on Table 3) were automatically been populated with values. The "q" value is the conditional probability of selecting a branch, and it is computed in a way that is intended to be approximately proportional to the that branch's biomass.

After all the branch diameters at P1N1 node have been recorded, a random number "u" was drawn from 0 to 1 using pocket calculator or using RAND# function in excel and recorded manually (0.709 in Table 3). A branch was selected from column 4 in Table 3 whose q cumulative value was the first to exceed the "u" random number value, in this case 7th branch with q cum value of 1 (Table 3) was selected since 1 > 0.709, and that was the branch that was selected to continue the path. The selected branch was the main bole and the selected branch was marked as "x" in next column of that row. It has to be noted that the q-cum value corresponding to the final diameter at the node should have value of 1, otherwise, checking for the erroneous entry of data should be done before proceeding further.

At each node because of many emanating branches, it may be confusing to locate the branch that was selected previously. For that reason, it was strongly suggested that branches be measured in a systematic fashion, in a clockwise direction beginning with the uppermost lateral branch emanating from the main stem.

The selection of branch along path 1 was continued from node 1 (P1N1) to node 2 (P1N2) (Fig. 1). P1N2 was established at the point where one or more branches emanated from it (Fig. 1). The sequence of measurements and recordings of branch diameter (d) was repeated as in P1N1 for Node 2. The column labeled 4 in Table 3 was populated with values with each entry of d. Once all branches were measured, the data recorder, generated a random number "u" and looked for q cumulative column, a branch whose q cumulative exceeded the u was selected to continue the path to node 3. In our example from Table 3, the 5th branch whose q cum value was 1.00 (1>0.856) was selected to continue to node 3 and this branch was marked P1N2 and flagged. When the path veered off from the main stem, it was marked with "z" to indicating the diversion of path from the main stem, in our example on node 17th, the path veered off from the main stem (Table 3).

The process of selecting the branch from Path 1 was continued until the selected branch was sufficiently small that it could be clipped from the tree in its entirety, that was the terminal branch for Path 1 (Fig. 1).

When Path 1 had been fully selected; all the nodes and selected branch segments were labeled and flagged and process of selecting Path 2 begun. The portion of Path 2 overlapped with Path 1 that branch segments selected in Path 1 remained on the tree until all paths on that tree have been selected. The clipping of branches from the tree was done until all subsequent paths on that tree were determined.

As mentioned earlier the entire RBS protocol was developed in Microsoft excel spread sheet, the Path 1 was copied and saved as Path 2, taking all precautions that Path 2 sheet was working and sheet was active , the process of selecting branches on Path 2 begun. Returning to Node 1 and the diameters that have already been

Table 3: Selection of branches by RBS (col 1= diameter of branch (d) in cm, col 2 = branch diameter squared to 2.5, col 3 = conditional probability (q) = $\frac{d^{2.5}}{Total^{d2.5}}$, col 4,conditional cumulative q (q cum), u, is random number generated either with pocket calculator or using Rand# function in excel. The spread sheet in excel was fully customized to calculate the estimates automatically. Data from a bluepine tree from central Bhutan, 2014.

Path	Node	No.of branches	1=d (cm)	2 =d $^{2.5}$	(3)=q	4=q cum	Random number u	Remarks
1	1	1	6.9	125.061	0.01	0.01	0.709	
	1	2	5.0	55.902	0.00	0.01		
	1	3	5.0	55.902	0.00	0.02		
	1	4	3.0	15.588	0.00	0.02		
	1	5	2.6	10.900	0.00	0.02		
	1	6	5.3	64.668	0.00	0.02		
	1	7	46.0	14351.410	0.98	1.00		x
			$\Sigma d^{2.5}$=	14679.432				
	2	1	3.9	30.037	0.00	0.00	0.856	
	2	2	2.1	6.391	0.00	0.00		
	2	3	12.0	498.831	0.04	0.04		
	2	4	10.9	392.253	0.03	0.07		
	2	5	43.5	12480.246	0.93	1.00		x
			$\Sigma d^{2.5}$=	13407.758				
	17	1	3.4	21.316	0.06	0.06	0.088	
	17	2	5.1	58.739	0.16	0.22		x,z
	17	4	9.5	278.169	0.78	1.00		
			$\Sigma d^{2.5}$=	358.224				

recorded for it from Path 1, the only additional work that needed to be done was to generate and manual recording a new random number "u" As done when selecting Path 1, the selection of branch was exactly the same as in P1N1, a branch was selected when q cumulative had exceeded the random number "u". (Table 3) at this point it has to be noted that nothing other than the new random number needed to be entered for Node 1 of Path 2. If different branch was selected at this node than was selected for Path 1, then different labeling with flagging was done and in the worksheet, erasing of the former "x" (Table 3, remarks column) in designated cell and placing it in the row corresponding to the newly selected branch was required, otherwise if the same branch was selected for Path 1, the recorder needed to scroll down the worksheet to Node 2 and repeated the procedures like in P2N1.

At second and subsequent nodes, RBS was applied in the same fashion as was done for Path 1. In all occasions, a branch eventually was selected at a node which made Path 2 departed from the previously selected Path 1. All branch segments from Path 1, those were not on the main stem but were selected in Path 2, were labeled as part of Path 2 so as to include their dry weight correctly in the RBS-based estimate of branch biomass from Path 2.

Sometimes it is expected that Path 2 duplicates the Path 1 completely, if such situation arises, Path 2 had to be ignored and new Path 2 had to be begun all over again. The RBS selection of Path 2 should be preserved and nothing should be done deliberately to interfere with the random selection process for the purpose of making Path 2 differ from Path 1.

Depending on the situation and confidence of the crew, a third path could be selected, in a situation when Path 1 or Path 2 was short or perhaps resulted in a terminal branch with very little foliage. However, normally two paths per tree were recommended (Gregoire *et al*., 1995). In such circumstance, a new worksheet for Path 3 can be created, and the Path can be selected in a fashion identical to that used for Path 2.

After all paths have been selected, all segments of the paths that are not on the main stem were clipped, labeled, and bagged for eventual drying. The sampling on main stem was done differently and will be elaborated later section.

The records of conditional selection probabilities (*q*) were recorded, in our case the pre developed data Microsoft excel template in a computer stored such values (data templates with guidelines were developed in Microsoft excel spread sheet to conduct the RBS in Bhutan) and these probabilities (values) were used to compute the biomass (*b*) of the tree components when the oven-dried weights of the samples came back from the laboratory (see computation of foliar biomass section).

The epicormic and dead branches were sampled outside RBS, using traditional methods of samplings.

Subsampling of large-diameter branch segments

On broad-leaved trees, the selected branch segments by RBS may turned out to be too bulky to transport to the laboratory for drying, such branches may be sub-sampled. Prior to sub-sampling of such branches, distance between two nodes were taken and recorded (the Path 1 and Path template provided space to record such measurement) a disc measuring not less than 5 cm was extracted at the midpoint of the branch segment after the disc was extracted its thickness was recorded to $1/10^{th}$ of cm. The disc must be labeled and brought to laboratory for drying. Many discs from the selected branches could be extracted in this way and bring lesser samples for laboratory drying.

Sampling the bole of a felled trees

For sampling the bole/ main stem from a felled tree, the foremost task was to obtained the total height of the tree (H) to nearest meter (Table 4) and marked the centriod height (Hc) estimated as 1/3 of H. Hc divided the bole into a lower stratum and an upper stratum, labeled as Stratum I and II (Fig. 2). The discs were cut at two randomly selected locations in each stratum, the locations denoted by the symbols θ_1 and θ_2, for the two discs in Stratum I were heights measured from the ground.

Stratum I was the bole below the centriod and Stratum II was the bole above it. Two discs each from lower section and from upper section of the tree bole for estimating bole biomass were extracted. It had been generally accepted that for most single stemmed trees, approximately one-half the volume of the bole/stem was accumulated between the ground and a one-third of its H.

The length (L) of the first segment of the bole was computed as Hc and the length (L1) of the second segment was computed as H-Hc and a selection method was applied that ensured, if one disc was near the base of the section, the other one was chosen antithetically (Gregoire *et al*., 1995) to ensure that it was chosen near the top. The selection of disc samples from bole section was obtained using equations 1 to 4 (Table 4 and Fig. 2).

$$SI\theta 1 = H - \sqrt{(H^2 - 2) * (u) * Hc * (H - 0.5 * Hc)} \quad \text{Equation 1}$$

$$SI\theta 2 = H - \sqrt{(H^2 - 2) * (1 - u) * Hc * (H - 0.5 * Hc)} \quad \text{Equation 2}$$

$$SII\theta 1 = H - \sqrt{(H^2 - 2) * (u * 0.5) * H^2 * Hc * (H - 0.5 * Hc)} \quad \text{Equation 3}$$

$$SII\theta 2 = H - \sqrt{(H^2 - 2) * (1 - u * 0.5) * H^2 * Hc * (H - 0.5 * Hc)} \quad \text{Equation 4}$$

Where S was stratum, I refers to bole length from base of the tree to centriod height, II refers to length of bole from centriod height (Hc) to tip of the tree, H was total height of the tree, u was randomly number generated number using pocket calculator or using rand# function in excel (Table 5). The uniform random, u, used to select the two disc locations in the lower stratum is a different random number than those used to select a branch at a node. While the same u was used in equations 1 and 2, a different u was selected to be used for equations 3 and 4.

As mentioned earlier the data collection template prepared for RBS-Bhutan, generated the disc locations

Table 4: The general attributes of felled tree, all attributes were customized in Microsoft Excel spread sheet.

Sl No	Attributes	Measured and Estimated values
1.	Total tree height (H) in meter	34.65
2.	Diameter at breast height (D) in centimeter	71.70
3.	Estimated basal area (PI()D^2)= Pi()*77.47^2/4/10000 in meter square	0.4038
4.	Centroid height (Hc) from the ground (1/3 of H) in meter	11.55
5.	Ground diameter above bark in cm	88.10
6.	Ground x-sectional area (B) = Pi*9.8^2/4/10000 in meter square	0.61
7.	Height to base of live crown in meter	18.30
8.	Diameter at base of the tree to live crown in cm	45.90
9.	Breast height dib in cm (two readings and averaged	69.50
10.	Fresh Weight of all dead branches (g) of the felled tree in gram	34200.00

Table 5: Antithetic selection of height for discs sample from the bole of a felled chirpine tree.

Section of Bole	Height reference	Rand# (u)	Θ_1 (m)	Θ_2 (m)
Stratum I	0 to Hc	0.764	8.36	2.35
Stratum II	Hc to H	0.747	6.33	2.01

automatically according to the algorithms (equations 1-4) (Table 5). Using the data from the bluepine (Table 4) and using equations 1 to 4, the position of the four sample disc from the main bole of a bluepine tree whose H was 34.65 m, centriod height (Hc) was 11.55 m (Table 5)

In these ways discs samples from the bole of 36 blue pine trees were extracted and brought to the laboratory for oven drying. The samples were oven-dried (OD) at 72 degree Celsius until constant weights were obtained and these ODs were used to estimate the inflated bole biomass. The computation of biomass of bole and foliage are shown in the next sections of this paper.

Biomass Estimation

Dry weight computations

The dry weights from each section were obtained from $SI\theta_1$, $SI\theta_2$, $SII\theta_1$ and $SII\theta_2$ after drying the discs samples in the laboratory. The computations was done to obtain the inflated estimates of total dry weights of the particular sample tree by following the procedures suggested by Gregoire *et al.* (1995) and is illustrated in the following section.

Bole biomass estimation

Lower stratum : The biomass for lower section of the bole was calculated employing the equations 6, 7 and 8 where *f(H)* was the density function derived from the equation 5. For the purpose of estimation let the two heights where discs were cut in stratum I (0 to *Hc*) be $SI\theta_1$ and $S1\theta_2$ (Fig. 2, 5) and because of the way those were selected, $SI\theta_1 < SI\theta_2$ *or* $SI\theta_1 > SI\theta_2$. The probability density function (Gregoire and Valentine, 2008); that was used to select those heights was

$$f(H) = \frac{S(H)}{\int_0^{H_c} S(H)dH} = \frac{A(1-\frac{h}{H})}{AH_c\frac{H-0.5H_c}{H}} = \frac{H(1-\frac{h}{H})}{H_c(H-0.5H_c)} = \frac{(H-h)}{H_c(H-0.5H_c)} \quad \text{equation 5}$$

Where, A= cross-sectional area, H= Total tree height, Hc=Centriod height and h= height of the disc that was selected from base of the tree.

Let the biomass per unit length of bole be w_{I1}/t_{I1} for the first disc and be w_{I2}/t_{I2} second disc where w_{I1} was dry weight of disc one ($SI\theta_1$ *in Fig. 2*) and t_{I1} = the thickness of the disc one (average disc thickness) and the estimate of stem biomass from the disc cut at θ_{I1} (Fig. 2) was computed as equation 6.

$$= \frac{w_{I1}/t_{I1}}{f(\theta_{I1})} \quad \text{equation 6}$$

and the estimated stem biomass from the disc cut at θ_{I2} ($SI\theta_2$ in figure 1) was computed using equation 7

$$= \frac{w_{I2}/t_{I2}}{f(\theta_{I2})} \quad \text{equation 7}$$

Because there was no reason to regard one as more important than the other, two estimated values of stem biomass were averaged as in equation 8

$$\widehat{W}_I = 0.5(\widehat{W}_{I1} + \widehat{W}_{I2}) \quad \text{equation 8}$$

Upper stratum : The biomass for upper section of the bole was calculated using the equations 10, 11 and 12 where *f (h)* was the density function derived from the equation 9. Total bole biomass was estimated using equation 13.

For the computation purpose, let the two heights where discs were cut in stratum II (*Hc* to *H* in Fig. 2) be θ_{II1} and θ_{II2} and because of the way those were selected, $\theta_{II1} < \theta_{II2}$ *or* $\theta_{II1} > \theta_{II2}$. The probability density function that was used to select those heights was as in equation 9 (Gregoire *et al.*, 1995);

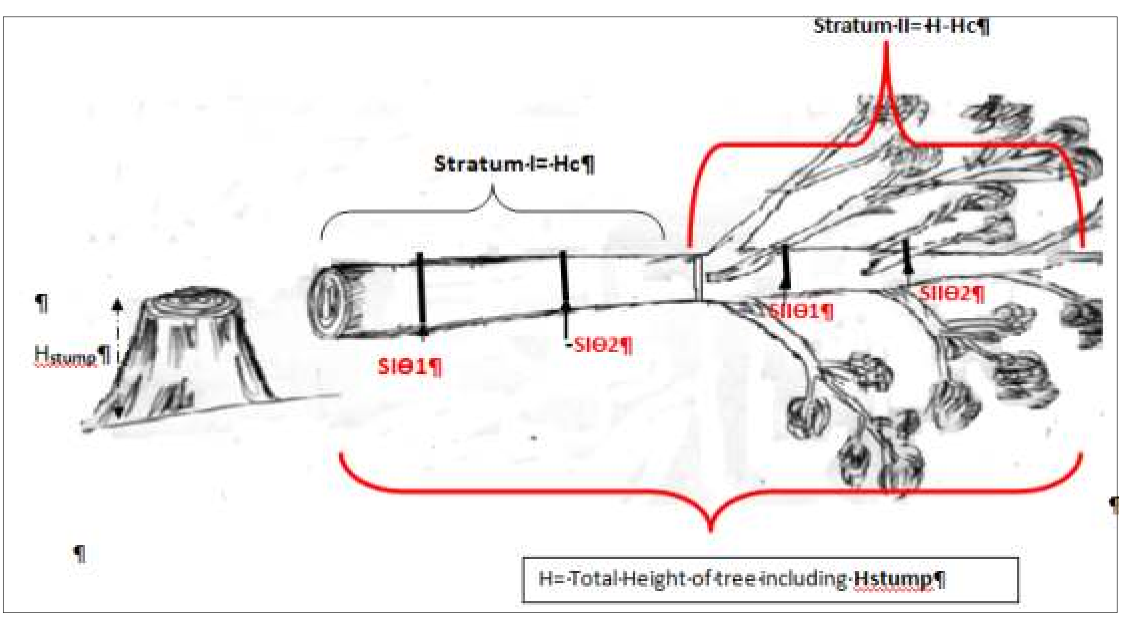

Fig. 2: Sampling bole part of the felled tree

$$= g(h) = \frac{S(h)}{\int_{hc}^{H} S(h)dh} = \frac{B(1-\frac{h}{H})}{B\frac{0.5H^2 - Hc(H-0.5Hc)}{H}} = \frac{H-h}{0.5H^2 - Hc(H-0.5hc)} = \frac{H-(Hc+h)}{0.5H^2 - Hc(H-0.5Hc)}$$

equation 9

Therefore the weight of bole of upper section stem biomass from the disc cut at and the estimates of stem biomass from the disc cut at (SIIθ_1 and SIIθ_2 in Figure 2) was estimated using equation 12 ;

$$\widehat{W_{II1}} = \frac{w_{II1}/t_{II1}}{g(\theta_{II1})} \quad \text{equation 10}$$

$$\widehat{W_{II1}} = \frac{w_{II2}/t_{II2}}{g(\theta_{II2})} \quad \text{equation 11}$$

$$\widehat{W_{II}} = 0.5(\widehat{W}_{II1} + \widehat{W}_{II2}) \quad \text{equation 12}$$

The two estimates for the lower stratum and the upper stratum were summed to obtain the final estimate of biomass for the whole bole/stem, as in equation 13;

$$\widehat{W_{bole/stem}} = \widehat{W_I} + \widehat{W_{II}} \quad \text{equation 13}$$

An example of estimation using data from a chirpine tree is provided as annex. (Table)

Computation of Foliar biomass (branch, leaves, fruits, dead branches and epicormic branches): An estimate of the biomass (b) (excluding bole/stem) of the sampled tree was computed by dividing each b (b_1, b_2,...b_R) by the probability (Q_1, Q_2 ...Q_R) of selecting that segment and by adding (see Table 4) those probabilities adjusted values together as shown in equation 14 (Gregoire *et al.,* 1995).

$$= \widehat{B_{foliage}} = \sum_{r=1}^{R} \frac{\hat{b}}{Q_r} = \frac{b_1}{Q_1} + \frac{b_2}{Q_2} + \frac{b_3}{Q_3} + \cdots + \frac{b_R}{Q_R}. \quad \text{equation 14}$$

Table 6 provides information needed to compute biomass of branches of an entire tree; an example will be illustrated later in this section.

For the purpose of estimation of foliage biomass an example is illustrated using data from a bluepine tree from central Bhutan (only the 22 segments of Path1 data were used in this worked example, as other procedures for computation are same and highlighted on Table 8).

Table 7 provides the information needed to compute $\hat{b}_{branch}$ and other foliage components and computed as follows.

$$\hat{b}_{branch} = \sum_{r=1}^{R} \frac{b_r}{Q_r} = 0_1 + 0_2 + \cdots 0_{16} + \frac{0.547}{0.06} + \frac{0.324}{0.05} + \frac{0.117}{0.05} + \frac{0.158}{0.05} + \frac{0.078}{0.04}$$

=9.56 +6.11+2.38+ 3.48+1.99 =23.52 kg, where $\hat{b}_{branch}$ is an unbiased estimator of branch biomass of the entire tree provided by Path 1 and biomass of branch segments for Path 2 was also estimated similarly 45.78 kg and total estimated biomass was 68.22 kg for that tree (highlighted in Table 8) and this total branch biomass of that tree was estimated at. Estimates for components of the foliage parts such as twigs, leaves and fruits were computed following the same procedures and the results of the 36 sample bluepine trees are provided in Table 8 (the example data used in this paper is highlighted).

The unbiased estimate of branches, leaves, fruits biomass) could be determined using equation [15]

$$\hat{b} = \frac{1}{m}\sum_{i=1}^{m} \hat{b}i \quad \text{equation 15}$$

where, m is the number of paths that were sampled on the tree, and is the estimated biomass from the *i*th path. The variance was estimated using equation [16] when two paths (m>1) were selected

$$Var(\hat{b}) = \frac{1}{m(m-1)}\sum(\hat{b}i - \hat{b})^2 \quad \text{equation 16}$$

In most instances epicormic branches (*eb*) and dead branches (*dr*) were prevalent, in such cases *eb* and *dr* sub-sampled after taking their total fresh weights (about 10% of the total weight was suggested).

Multiple path computation : If $\hat{f}_{foliage1}$ is the estimate of tree foliage from path 1, and $\hat{f}_{foliage2}$ is the estimate of tree foliage from path 2, then the estimator of tree foliage would be estimated as their average, i.e. $\hat{F}_{foliage} = (\hat{f}_{foliage1} + \hat{f}_{foliage2})/2$ and if three paths were selected then $\hat{F}_{foliage} = (\hat{f}_{foliage1} + \hat{f}_{foliage2} + \hat{f}_{foliage3})/3$ and so on. Total biomass of a tree was estimated as the sum of the components (bole, foliage (branch, twigs,

Table 6: Conditional and unconditional probabilities computation to estimate the biomass of the sampled biomass.

Node of a tree	Conditional selection probability	Unconditional selection probability	Measured biomass (b)
1	q_1	$Q1=q_1$	b_1
2	q_2	$Q2=q_1q_2$	b_2
..	..	--	...
r	q_r	$Qr= q_1q_2...q_r$	b_r
..			
R	q_R	$Q_R= q_1q_2...q_R$	b_R

Table 7: Branch diameter and selection probabilities of bluepine tree from central Bhutan (br = branch, t = twig and n= needles). The yellow highlights indicates the branch that was selected at each node.

Node (r)	Br. Diameter (cm)	u	Conditional selection probability (*qr*)	unconditional selection probability (*Qr*)	Dry wt Bole (kg)	Dry wt Foliage (Kg)		
						br	t	n
Butt	71.1	0	1.00	1.00		0	0	0
1	6.9, 5.0, 5.0,3. 0, 2.6, 5.3, 46.0	0.709	0.98	1.00X0.98= 0.98		0	0	0
2	3.9,2.1,12.0, 10.9,43.5	0.856	0.93	0.98x0.93 =0 91		0	0	0
3	7.5, 41.0	0.946	0.99	0.99x.91 = 0.90		0	0	0
4	9.5, 7.5, 41.0	.605	0.96	0.90x0.96 =0.86		0	0	0
5	6.5, 9.5 32.5	0.608	0.98	0.86x0.98 =0.85		0	0	0
6	9.4,23.0	0.371	0.94	0.85x0.94=0.79	0	0	0	0
7	6.9, 30.0	0.478	0.78	0.79x.78=0.78	0	0	0	0
8	8.0, 27.0	0.455	0.95	0.78x0.95 =0.74	0	0	0	0
9	8.0. 26.0	0.268	0.95	0.71x 0.95=0.71	0	0	0	0
10	8.5, 25.0 (skipped to 17th branch, where it departed main stem)	0.655	0.94	0.71x0.94=0.66 On 16th branch sum to 0.35	0	0	0	0
17	3.4,5.1, 95	0.088	0.78	0.35x0.78 =0.06	0.00 estimated separately	0.547	0.00	0.00
18	1.5,0.8,4.5	0.207	0.93	0.06x0.93 =0.05		0.324	0.00	0.00
19	0.9, 1.2, 3.8	0.507	0.92	0.05x0.92=0.05		0.117		
20	1.4, 3.8	0.553	0.92	0.05x		0.158		
21	1.4, 2.9	0.176	0.86	0.86=0.04		0.078		
22	1.5,1.0, 2.4	0.543	0.70	0.04x0.70=0.03		0.00	0.147	0.118

Table 8: The estimated biomass of blue pine trees from central Bhutan using RBS methods (source Tashi, 2014) the highlighted tree (sample ID 26) was used to illustrate the computation of branch biomass (segment refers to branch).

Sample ID	Basal Diameter (cm)	Dbh (cm)	Basal area at dbh(m^2)	Basal area at base (m^2)	Live crown height (m)	Total height (m)	Stump Height (m)	Bole biomass (Kg)	Segment biomass (kg)	Twigs (kg)	Needles (kg)	Cones (kg)	Total foliar biomass (kg)	Epicormic branches (kg)	Dead branches (kg)	Total Biomass (kg)
1	64	55.7	0.2437	0.322	17.4	32.55	0.80	1685.200	65.274	67.691	14.725	0.000	147.690	0.000	15.509	1848.399
2	39.5	30.3	0.0721	0.123	17.3	28.1	0.60	336.509	11.945	3.381	1.772	0.227	17.325	0.000	2.946	356.779
3	26.6	21.9	0.0377	0.056	6.85	17.92	0.30	162.117	26.097	11.109	4.124	0.000	41.330	0.000	7.491	210.938
4	20	17	0.0227	0.031	4	11.28	0.30	46.015	5.824	8.434	4.456	0.000	18.714	0.000	0.171	64.899
5	98.5	71.2	0.3982	0.762	30.35	48.81	0.80	3365.150	144.992	25.578	9.414	8.935	188.919	0.000	86.344	3640.413
6	37.5	31.3	0.0769	0.129	5.5	18.82	0.70	248.373	32.795	35.031	11.897	0.000	79.724	0.000	9.213	337.310
7	56	44.8	0.1576	0.246	16.3	28.24	0.75	793.159	52.759	39.691	9.203	3.218	104.871	0.000	33.343	931.374
8	10.9	8.5	0.0057	0.009	6.25	10.62	0.45	14.479	0.000	0.594	0.322	0.000	0.916	0.000	0.397	15.792
9	7	4.6	0.0017	0.004	2.27	6.15	0.16	2.287	0.000	0.534	0.233	0.000	0.768	0.000	0.018	3.073
10	51.8	42.5	0.1419	0.211	13.4	25.85	0.80	788.302	74.061	19.513	12.620	9.136	115.330	0.000	37.802	941.434
11	43.1	35.6	0.0995	0.146	15.31	23.69	0.70	401.556	48.883	9.172	5.479	7.031	70.565	0.000	14.728	486.849
12	32.2	24.1	0.0456	0.081	16.9	26.51	0.30	232.271	15.515	7.432	4.469	0.000	27.416	0.000	1.756	261.443
13	17.1	13.3	0.0139	0.023	9.5	15.27	0.39	35.873	3.492	1.394	0.971	0.000	5.857	0.000	3.129	44.858
14	8.1	6	0.0028	0.005	3.33	7.52	0.27	4.559	0.939	0.179	0.313	0.000	1.431	0.000	0.482	6.472
15	4.7	2.6	0.0005	0.002	1.8	3.35	0.14	0.633	0.000	0.067	0.071	0.000	0.138	0.000	0.050	0.821
16	82.3	66.7	0.3494	0.532	16	34.54	0.86	2567.810	394.692	76.589	20.439	0.000	491.721	0.000	15.017	3074.548
17	58.2	47.6	0.178	0.266	18.35	30.3	0.72	862.876	82.578	20.761	2.110	0.000	105.450	0.000	22.194	990.520
18	46	37	0.1075	0.166	18.2	33.33	0.75	559.037	32.329	7.584	3.047	0.000	42.960	0.000	4.078	606.075
19	31.5	27	0.0573	0.078	14.4	25.2	1.14	268.453	14.382	3.178	2.147	0.000	19.708	0.000	2.881	291.041
20	20.2	14.5	0.0165	0.032	3	10.9	0.19	24.251	7.464	4.875	2.499	0.000	14.838	0.000	2.133	41.222
21	84	59.8	0.2809	0.554	25.2	35.2	0.80	1446.910	81.348	15.515	4.740	4.024	105.627	0.000	59.114	1611.652
22	36	28.5	0.0638	0.102	16.9	26.5	0.50	274.888	17.434	9.616	5.351	1.423	33.824	0.000	1.924	310.636
23	16.2	12	0.0113	0.021	8.65	13.2	0.24	27.244	0.000	1.186	1.133	0.000	2.319	0.000	1.320	30.882
24	8.7	6	0.0028	0.006	3.25	6.15	0.30	2.751	0.000	0.494	0.331	0.000	0.824	0.000	0.269	3.844
25	7.2	3.8	0.0011	0.004	1.46	3.38	0.32	1.579	0.000	0.234	0.078	0.000	0.313	0.000	0.016	1.908
26	88.1	71.7	0.4038	0.61	18.3	34.65	1.40	2499.890	45.874	15.320	3.924	4.806	69.924	16.119	27.483	2613.416
27	15.1	10	0.0079	0.018	1.2	8.5	0.24	10.157	0.000	3.492	3.306	0.000	6.798	0.000	0.105	17.060
28	67.9	57.2	0.257	0.362	18.5	33.3	1.10	1500.770	142.109	25.675	20.873	0.000	188.657	0.000	42.682	1732.109
29	72.5	65.8	0.34	0.413	22.35	37.2	1.30	2342.200	15.485	5.530	2.864	0.000	23.879	5.847	6.804	2378.730
30	82	73.5	0.4243	0.528	20.4	31.7	0.62	1969.340	122.036	19.440	14.648	51.086	207.209	0.984	244.022	2421.556
31	46.5	40	0.1257	0.17	15.2	27.82	0.67	481.172	21.936	8.227	9.552	0.000	39.715	0.000	17.868	538.755
32	20	15.3	0.0184	0.031	7.45	16.25	0.27	59.420	0.000	2.743	2.126	0.000	4.870	0.000	0.449	64.738
33	69.2	60.6	0.2884	0.376	15.3	26.56	0.45	1393.600	254.494	32.940	21.705	12.797	321.936	0.000	17.290	1732.827
34	69.7	62.7	0.3088	0.382	19.95	31.53	0.33	1165.800	130.753	54.358	14.035	0.000	199.146	0.000	47.408	1412.354
35	7.2	5.5	0.0024	0.004	2.85	6.2	0.21	3.258	0.000	0.379	0.289	0.000	0.668	0.000	0.393	4.319
36	114.5	95.8	0.7208	1.03	30.7	51.5	1.01	5190.530	186.125	46.831	24.144	0.000	257.099	0.000	117.967	5565.595

leaves fruits) epicormic branches (eb) and dead branches (*dr) was*

$$\hat{B}_{total} = \hat{B}_{bole} + \hat{B}_{branch} + \hat{B}_{foliage} + \hat{B}_{er} + \hat{B}_{dr} \quad \text{equation 17.}$$

The step by step procedures for laboratory and computations of biomass are provided in the annex.

Conclusion

Over past decades many biomass sampling method were developed to estimate the biomass of trees for various reasons, as pointed earlier in the introduction part , that single sampling method is not sufficient to sample biomass from a tree. Here we have demonstrated that a method called randomized branch sampling along importance sampling developed by (Valentine *et al*., 1992); Furnival *et al*. (1986); Gregoire *et al*. (1995); Gregoire and Valentine (2008) could be used to estimate the biomass of the trees. The use of probability proportional to size (Gregoire and Valentine, 2008) in sampling of biomass could improve the biomass estimation in a reliable manner. However the comparison of different methods is anticipated in future so as to validate this method further empirically.

Acknowledgement

We would like to thank Bhutan Trust Fund for Conservation of Environments for financial support to conduct the sampling of the trees and Prof. Timothy G. Gregoire from Yale University for introducing the RBS methods in Bhutan. Most of the text in this paper came from his works (RBS manual, his lecture notes, and other literature he had provided).

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ou ikfjr=k fo'o pØ.k vkj Hk.Mkj.k e ,d egRoi.k Hkfedk vnk djr g vkj tyok; ifjoru ij l;Dr jk"V : ij[kk lEeyu vkj blds D;kVk ikVkdky u dkcu iFkDdj.k ,o Hk.Mkj.k e ouk dh Hkfedk dk ekU;rk nh gA ou xfrdh dh ekMfyx] Hkkoh mit d Hkfo";dFku vkj odfYid ik"k.kh; ic/ fodYik dh [kkt dk ifj'k¼ o{k dk"B vk;ru vkj toek=kk vkdyu dh vko";drk gkrh gA lokRre toek=kk vkdyu gkfly dju d fy, ,lh mi;Dr toek=kk ifrp;u rduhd dk mi;kx dju egRoi.k g] tk fu"i{k gkA ;gk ge ,d eknfPNdhÑr "kk[kk ifrp;u dk o.ku dj jg g] ;g og rduhd g ftl vi{kkÑr dkiQh ykxr iHkkoh vkj lkf[;dh; :i l fo"oluh; rjhd l o{k itkfr;k d HkE;ifjd toek=kk dk lEiy yu d fy, okfudh e gky gh e ykdfi; cukb xb gA

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Annex: Laboratory procedures and estimation of above ground biomass of trees using RBS.

1. Oven drying procedures

When the tree samples are collected employing RBS in the field, the sample should be labeled properly, clipped/cut, bagged (usually a big sack is suggested to accommodate all samples /tree).The samples should be bagged separately by components (disc, branches, twigs, leaves/needles, Epicormic branches, dead branches, fruits in case of broad leaves and cones in case of conifer) first then if possible should be accommodated in single big bag per tree if not use of another sack is suggested. The samples should be transported immediately from the field for oven-drying in the designated laboratory. The following steps and procedures should be followed while drying the samples.

- The sample tree components (discs, segments, terminals, dead branches, Epicormic branches, leaves/needles and fruits/cones) will separately stacked in the laboratory (check for proper labeled by tree ID). Before putting the samples in the oven , the labeled for sample identity were cross checked and verified carefully in order to avoid erroneous results.
- Sample components especially discs, branches should be resized to desirable size if the oven cannot accommodate the bigger size samples. While resizing components care must be taken not to lose sawdust, barks splint (label them by tree id and by component before putting them in the oven for drying)
- Bigger samples especially of discs and braches should be dried first then other lighter components such as twigs, leaves/needles and fruits.
- Once the samples are ready with proper label, size and by component, place the samples in an electric oven.
- Set the temperature of the oven to 70 degree (can be dried upto 105 degree) before placing the samples in the oven (this temperature may be ok for all components)
- The samples should be dried till constant weight is obtained.
- Use reliable electronic balance to weigh the dried samples (supplied in the laboratory mentioned its name in the data sheet)
- Data recording should be done either in paper or in PC, later is preferable as shown in Table 1.Create excel sheet and enter the data
- Once the samples are oven-dried and constant weight obtained maintained a data sheet as in Table 2 for disc samples and Table 3 for other segments.

Table 1: Laboratory recording sheet for oven dried samples of tree biomass

TreeID	Component (tick appropriate)	Date started	Time Started	Wt (gram)				End date and time
				1	2	3	4	
	Disc, branch, twigs, leaves/cones, dead branch, Epicormic branch, fruits/cones							
PW12052014927APBC	Disc ((SIΘ1)	12.5.2014	9:30 am	4500	2500	2400	2400	13/5/2014 9:30 AM

Table 2: data record sheet for od wt of disc samples

TreeID	Component	Stratum	OD wt (g)
	Disc	I (θ1)	
		I(θ2)	
		II (θ1)	
		II(θ2)	

Table 3: Data record sheet for other trees component (branch, twigs, leaves/cones, dead branch, Epicormic branch, fruits/cones)

TreeID	Component	Path	Node	OD wt (g)	Remarks

2. Estimation of biomass

When all the biomass component for a whole tree is obtained estimate the biomass by following the table 4 and 5 for bole biomass and table 4.

When all the components oven dried weight is taken and all estimates are done enter the final data on Table 8.

Table 4: Bole biomass estimation

Disc	Disc wt [kg]	Disc thickness[m]	(V) Wt. per m	(VI) H	(VII) Hc	(VIII) 0-Hc (1)	(IX) 0-h_c (2)	(H) h_c-H(1)	(I)h_c-H(2)	(J)Density function				(K)Final - F	(L) Total disc biomass	(M) Avg. biomass (lower and upper)	(N)Total Bole Biomass
SIϴ1	82	0.0555	1477.5	37.47	12.49	1.51				35.96	6.25	31.23	390	0.092205	16023.821	8556.240	9737.54
SIϴ2	4.2	0.0555	75.676	37.47	12.49		10.36			27.11	6.25	31.23	390	0.069513	1088.6585		
SII? 1	3.28	0.0568	57.746	37.47	12.49			8.76		16.22	312.00			0.051987	1110.7838	1181.300	
SIϴ2	5.38	0.055	97.818	37.47	12.49				0.6	24.38	312.00			0.078141	1251.8167		

Table 5: Definitions of functions of Table 4.

Reference in table 1	Entries /functions
Tree ID	Tree iD refers to name of the file in RBS template for BHUTAN in general sheet of field manual
Disc	Disc refers to disc taken from bole/stem from sample tree (ϴ-I1, disc 1 from stratum I), (ϴ-I2, disc 2from stratum I), (ϴ-II1, disc1 from str atum II), (ϴ-II2 , disc 2 from stratum II)
(I) OD Wt	Oven-dried weights of discs from stratum I and stratum II
(II) Disc Thickness (cm)	Refers to RBS template of Bhutan in general sheet (average of disc thickness)
(A)Converted Kg	Conversion of (I) oven dried wt to KG =(I)/1000
(B) Converted meter	Conversion of disc thickness from cm to meter =(II)/100
© OD wt per m	Conversion of OD wt of disc per meter =(A)/(B)
(D) H	Total height of tree in meter from RBS Template of sample tree
(E) h_c	Centroid height in meter (1/3 of H (D) from RBS template of sample tree
(F) o-h_c (ϴ1)	Refer to RBS template general sheet = (D) H- $\sqrt{H^2 - 2 * Rand\# * h_c * (H - 0.5 *}$
(G)0-h_c (ϴ2)	Refer to RBS template general sheet = (D) H- $\sqrt{H^2 - 2 * (1 - Rand\#) * h_c * (H - 0.5 *}$
(H) h_c-H (ϴ1)	Refer to RBS template general sheet = (D) H- $\sqrt{H^2 - 2 * Rand\# * 0.5 * H^2 - (h - c) * (H - 0.5 *}$
(I)h_c-H (ϴ2)	Refer to RBS template general sheet = (D) H- $\sqrt{H^2 - (1 - Rand\#) * 0.5 * H^2 - (h\_c) * (H - 0.5 *}$
(J) Density Function	(1 = H-h_c), (2 = 0.5*(h_c)) ,(3 = H- 0.5*(h_c)),(4= E*H-0.5*h_c), (5= D-G), (6= 0.5* h_c),(7 = H-0.5*h-c), (8=H*H-0.5*h_c), (9=(D)-((E)+(H)), (10= 0.5*(H)^2 –h_c*(H-0.5*h_c)), (11= D-(E+I)) and (12 = , 0.5*H^2-h_c*(H-0.5*h_c))
(K) Final-F	J1/J4 from density function
(L) Total disc biomass	C/(K)
(M) Avg.biomass (upper and lower	S1= 0.5 (? 1+? 2) and S2 = 0.5 (? 1+? 2), where s = stratum
(N) Total bole biomass	S1+S2

Table 6: biomass estimation of branch, foliage, Epicormic branches, dead branches and fruits or cones

Tree id	Path	Node	Branch OD wt (g)	(O) Branch OD wt (g/Q)	(P) Foliage OD wt(g/Q)	(Q) Epicormic branches OD wt(g)	(R) Dead branches OD wt (g)	(S) Fruits/cones OD wt (g)	Remarks if any
			1	2	3	4	5	6	

Table 7: Entries definition of Table 6.

Components in Table 5	Definition
Branch OD wt (g)	Oven dried weight obtained from laboratory for a particular tree ID
(O) Branch OD wt (g/Q)	Estimation of branch biom ass = Branch OD wt /Q1 = where Q = d^2.5 / ?d^2.5 (Sum of all the branch diameter squared of the first node) and in the subsequent Q1 be multiplied Q 2, Q3 from other nodes until the final segment whose biomass is tagged for OD. Use the OD wt of this segmen t to estimate the OD of that branch, if more segments from other nodes are selected, use the same procedures at the end sum all the OD of the selected braches to find the total branch estimates
(P) Foliage OD wt(g/Q)	Follow same in (O)
(Q) Epicormic branches OD wt(g)	Direct OD will be entered in Table 7 in Epicormic column for that tree ID
(R) Dead branches OD wt (g)	Direct OD will be entered in Table 7 in Epicormic column for that tree ID if all dead branches are Oven-dried otherwise estimates needs to be work out according to sample proportion (e.g. if the total dead wood sample in the field weigh 10 kg, if 10% of the dead branches were samples then after oven -drying the constant weight is 0.75 kg, then estimates =0.75(OD wt) /1 kg (sample)* 10 =7.5 Kg should be entered in Table 7 in dead brach column.
(S) Fruits/cones OD wt (g)	Follow same procedures as in (O)

Table 8 : Final biomass Data sheet Landscape format?

Tree Id	DBH (cm)	H (tree total height) meter	X-sectional area (m^2) at DBH	x-sectional at ground	Bole biomass (Kg)	Branch biomass (Kg)	Twigs Biomass Kg	Epicormic braches biomass Kg	Dead braches biomas Kg	Leaves/needle biomass Kg	Fruit /cones biomass Kg	Total tree biomass KG