Application of Geo-Informatics for Designing National Forest Inventory System and Forest Resources Potential Assessment of Bhutan

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KEY WORDS: Stratification, Sampling Statistics, Margin of Error, Anticipated n

ABSTRACT

Geo-Informatics plays an important role in designing the national forest inventory (NFI) system of Bhutan to collect data spatial explicitly and generate the estimates of resource quantity at the desired level of accuracy. Moreover, Bhutan has successfully conducted Forest Resources Potential Assessment (FRPA) using NFI and Geo-Informatics. This paper will discuss how integrated application of Geo-Informatics, Forestry and Sampling Statistics create National Forest Inventory (NFI) System of Bhutan to achieve desired level of statistical accuracy. Moreover, the paper will describe how NFI and Geo-Informatics are applied for National Forest Resources Potential Assessment and valuation of forest resources for National Level Forest Resources Planning.

INTRODUCTION

Bhutan is peaceful Himalaya kingdom which facilitates her people living in harmony with natural environment, Buddhist philosophy and traditional cultural values. Bhutan is mountainous landlocked country with abundant water resources, forest resources and rich biological diversity across the moderately inaccessible geologically fragile landscapes.

The total forest area excluding shrub lands is 27052.81 km^2 which represents 70.46% of total land cover of Bhutan. Due to the diversity of topographic terrain, rainfall patterns and temperature regimes, Bhutan retains six agro-ecological zones – alpine, cool temperate, warm temperate, dry subtropical, humid sub-tropical and wet sub-tropical zones. Eight major forest types (70% of total land use excluding shrubs and regrowth from fellow lands) – (1) Fir forests mixed with Rhododendron and Juniper (14% of forest types), (2) Mixed Conifer Forests dominated by the Spruce and Hemlock (20% of forest types), (3) Blue Pine Forests (5% of forest types), (4) Chir Pine Forests (4% of forest types), (5) Broadleaf mixed with conifer ecotones where oak mixed with blue pine, spruce and hemlock (6% of forest types), (6) Upland hardwood and cool broadleaved forests where evergreen oak associated (18% of forest types), (7) Lowland subtropical and tropical deciduous and semi-evergreen forests (18% of forest types) and (8) Alpine and temperate Scrub Forests (13% of forest types) are found in Bhutan. Other major land uses are Grasslands/Pasture (4% of total land use); Agriculture (3% of major land use), Horticulture, Shrub (10% of total land use) and other land use (12% of total land use).

The ALOS – AVNIR-2 multispectral images were selected for stratification of land cover stratification through digital image processing of multi-spectral ALOS images (AVNIR-2) from the 2006-2009 winter seasons, combined with other reference materials and extensive ground truthing exercises. Image segmentation and Multinomial Logistics Regression was applied for image classification using Erdas Imagine and R Statistics.

Bhutan is one of the top ten-biodiversity hot spots and one of the top ten countries with highest species richness per unit area in the world. Bhutan is the home to about 5,603 species of vascular plants of which 105 are endemic, 400 lichens, 369 orchids, 90 mushrooms, more than 700 birds species and 200 mammal species including 27 globally threatened mammals and more than 3000 wet lands and mountain lakes such as supra-snow lake, supra-glacier, glacier lakes, lake and marshes. The authors respects Bhutan as the laboratory of Nature because of her rich diversity of flora, fauna, landscapes, aesthetic beauty, forest structures, habitats, forest types and land covers.

In order to understand the spatiotemporal dynamics of ecosystems and forest stand structure for the sustainable forest resource management at the landscape and national scale, it is more important to have the reliable and accurate quantitative and qualitative resource information in Bhutan.

The forest information and data available in Bhutan however dates back to the late fifties and the first forest inventory at national scale, which was then referred to as the Pre Investment Survey was carried out in 1978-1981. Since then there has been many developmental activities like (road, infrastructures, transmission lines, urban expansion) which would have influenced the quantity and quality of forest. The changes so occurred have not been monitored and not accounted into the overall information on forest and its resources.

Therefore, National Forest Inventory (NFI) and Forest Resources Potential Assessment (FRPA) activities are proposed in order to fulfill the information needs for sustainable forest management which will provide the **socioeconomic benefits** to the community**, biodiversity conservation** through integrated management of intact matrix forest ensuring maintenance of all forest structures and habitats, the **productive capacity** of timber and non-timber products, **forest health** to avoid catastrophic outbreaks of pests or fires and poor logging and roading practices**, soil and water quality** improvement and **carbon sequestration**. Moreover, the authentic information and data from NFI & FRPA will ensure maintenance of 60% forest cover as per requirement by the Constitution of Bhutan.

Specifically, Bhutan NFI is demanded to provide the status and trend of national forests, information sought by resource planner, policy analysts, and other involved in forest resource decision making, plot level information on Land use, land cover, number of trees, basal area, timber volume, forest biomass, forest carbon, soil and soil carbon, Coarse Wood Debris, growth, mortality, and removals, potential forest productivity, aboveground forest biomass, below ground forest biomass, non-timber forest products, opportunities for the silvicultural treatment, forest stand structure, area and types of forest and wildlife habitats, and provide the answers in relation to the status and trend of forest ecosystems, distribution of plant species and their relationship to the environment, changes in forest structure and productivity resulting from disturbance, and improved prediction of forest growth and development on different sites and in response to management.

SAMPLING STATISTICS FOR BHUTAN NFI

According to the sampling with Fixed Area Plots, the following statistical proration are derived and implemented in R statistics. Sampling Strategies for Natural Resources and the Environment Page 207 to 246 (Gregoire, 2008) is an excellent reference for the following section.

"A" denotes the Area of study area such as a country, reserved forest, forest compartment or plantation etc. A contains m sample plots. The "**a"** denotes the area of a plot. The "y_i" denotes the measurement of individual quantity such as volume, biomass, and basal area of individual tree in the plot.

The population total T_y is derived as $\sum_{i=1}^{n}(yi)$ at the plot level.

The population mean per unit area is $\lambda_i = \sum_{i=1}^{n}(yi)\,/A$.

Inclusion probability (π) of a tree to a sample plot is derived as a/A. Inclusion zone has the same area of plot but orientation is different. The inclusion zone of circular plots and rectangular plots are straight forward. Therefore circular plots and rectangular plots are more common than other shapes like a star or an ell or a hexagon.

The clusters of 3 circular plots as east plot, north plot and elbow plots are selected for the straight forward calculation of inclusion probability and orientation of inclusion zone at the center of the each circular plot. The distance between east, north and elbow plots are 50 m. The size of east, north and elbow plot is 0.05 Ha. Therefore the total size of each cluster plot is 0.15 Ha.

Each cluster plot can provide the independent estimate of population total T_y. Therefore, inclusion probability of individual tree is $\pi_i = a_i/A$.

For the S^{th} plot, the independent estimate of population could be denote as $\hat{T}_{y\pi s}$ and the estimator is

$$\hat{\tau}_{y\pi s} = \sum_{U_i \in s} \frac{y_i}{\pi_i}.$$

Substituting $\pi_i = a_i / A$ into $\hat{\tau}_{y\pi s}$ yields $\hat{\tau}_{y\pi s} = A \sum_{U_i \in s} \frac{y_i}{a_i}$, which, barring edge trees, is identical to

$$\hat{\tau}_{y\pi s} = \frac{A}{a} \sum y_i = A \left(\frac{\text{plot total } y_i}{a} \right)$$

where the parenthesized term is the amount of the resource observed on the plot *prorated* to a per unit area (per acre, or per hectare, etc.) basis.

The $\hat{T}_{y\pi s}$ values varies from one plot to another provide the direct empirical evidence of how much the resource varies from one place to another with the study area A.

As there is m of these independent estimates $\hat{T}_{y\pi s}$ where s = 1,2,….m from m plots, average them together to get the unbiased estimator of T_y which will be denoted as $\hat{T}_{y\pi,rep.}$

$$\hat{\tau}_{y\pi,\text{rep}} = \frac{1}{m} \sum_{s=1}^{m} \hat{\tau}_{y\pi s}$$

Sample variance values among the $\hat{T}_{y\pi s}$ will be similar to the sample variance S^2_y of other context and it could be derived as follow.

$$s_y^2 = \frac{1}{(m-1)} \sum_{s=1}^{m} (\hat{\tau}_{y\pi s} - \hat{\tau}_{y\pi,\text{rep}})^2$$

As the plots are allocated at the simple random sample framework or systematically sufficient far apart to each other that there is no correlation between neighboring plots, the systematic layouts of plots is essentially equivalent to simple random sampling of plots. Therefore unbiased estimator of variance is derived as follow.

$$\hat{\mathrm{v}}(\hat{\tau}_{y\pi,\text{rep}}) = \frac{s_y^2}{m} = \frac{1}{m(m-1)} \sum_{s=1}^{m} (\hat{\tau}_{y\pi s} - \hat{\tau}_{y\pi,\text{rep}})^2$$

For Per Unit Area (density) estimation λ_y, the amount of y per unit area is denoted and estimated as follow.

$$\hat{\lambda}_{y\pi,\text{rep}} = \hat{\tau}_{y\pi,\text{rep}} / A$$

The variance is estimated as follow,

$$\hat{\mathrm{v}}(\hat{\lambda}_{y\pi,\text{rep}}) = \frac{1}{A^2} \hat{\mathrm{v}}(\hat{\tau}_{y\pi,\text{rep}})$$

Then the usual statistics is applied to derive the percent coefficient of variation (%CV), standard error percent (SE%), percent coefficient of variation (CV%), upper limit estimate and lower limit estimate based on the $\hat{T}_{y\pi,rep}$, S^2_y, $\hat{\lambda}_{y\pi,rep}$, $\hat{V}(\hat{\lambda}_{y\pi,rep})$ and $\hat{V}(\hat{T}_{y\pi,rep})$. R statistics package is applied to implement the plot sampling statistics for National Forest Inventory and Forest Resources Assessment.

PILOT NATIONAL FOREST INVENTORY

The purpose of Pilot NFI is estimating the forest resource quantity within the smallest administrative unit – Gewog. Gewog is similar to county in USA and commune in Switzerland. Gewog is the basic national planning unit for Bhutan. Statistical objective of the pilot NFI is to derive the reliability statistics of estimates such as %margin of error, % stand error, variance, % coefficient of variation and sample size within the Gewog. The national forest inventory will be designed based on the derived reliability statistics at the Gewog level NFI to the national scale NFI. Operational objective is to field test the data dictionary of NFI attributes integrated to GPS data collection system and data collection time and accessibility of sample plots at the rugged mountain terrain of Bhutan.

The forest management inventory data for certain Forest Management Units (FMUs) are available for designing the Pilot NFI at Toepisa Gewog. The area of pilot study site - Toepisa Gewog is 10279.21 Ha. The summary statistics of selected FMU for timber volume estimates are as follow.

Record	FMU	Region	Plot size (Ha)	FMU Area (Ha)	Number of Plots	SI %	MgErr%	CV%	Plot For 15% MgErr	SI% Required at 15% MgErr (3 Decimal)	SI% Required at 15% MgErr (1 Decimal)
1	Bitakha	West	0.05	7259.70	193	0.133	9.88	83.06	85	0.059	0.1
2	Chamgang	West	0.05	4692.85	178	0.190	7.56	61.03	47	0.050	0.1
4	Dongdechu	East	0.05	4856.00	147	0.151	9.87	72.32	65	0.067	0.1
5	Gidakom	West	0.05	13100.00	213	0.081	11.81	104.34	133	0.051	0.1
7	Helela	West	0.05	4692.85	177	0.189	7.54	60.69	47	0.050	0.1
8	Haa East Old	West	0.05	6951.92	240	0.173	6.95	65.21	54	0.039	0.0
9	Korilla	East	0.05	13832.30	327	0.118	12.42	138.92	225	0.081	0.1
10	Metapchu	West	0.05	10761.85	245	0.114	13.11	124.25	188	0.087	0.1
11	Wangdigang Old	East Central	0.05	9585.00	176	0.092	15.90	127.52	198	0.103	0.1
12	Selela2005	West	0.05	9253.00	102	0.055	9.83	59.78	45	0.024	0.0
14	Karshong Old	East Central	0.05	4715.77	217	0.230	11.87	105.82	137	0.145	0.1
15	Khalingkharungla Old	East	0.05	10074.70	129	0.064	12.01	82.32	84	0.042	0.0
16	Khotokha Old	West Central	0.05	9407.48	277	0.147	12.06	121.65	180	0.096	0.1

SI% = Sampling Intensity %

CV% = Coefficient of Variation %

MgErr% = Margin of Error %

It suggested 0.1% of sampling intensity is required in order to achieve the 10%~15% Margin of Error of timber volume estimates at the FMU level of area.

The sampling interval is calculated as 1.2 KM from cluster plot to another cluster plot as the following table. Bhutan is similar size to Switzerland. The sampling interval of Swiss National Forest Inventory is 1.4 KM. Therefore, the sampling intensity of Bhutan Pilot Inventory is higher than Swiss NFI.

Although 69 cluster plots fall within the study area (yellow boundary), only 58 cluster plots are accessible.

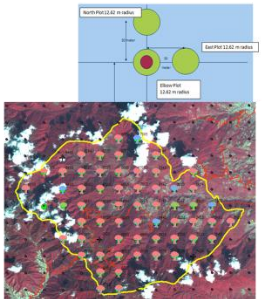
Total Study Area (Ha)	10279.21	Ha
0.1% Sampling Intensity	10.28	Ha
Cluster Plot Size	0.15	Ha
Total Number of Plots	68.53	
Area of Each Grid (Ha)	150.00	Ha
Area of Each Grid (Square meter)	1500000.00	Square Meter
Width or Height of Each Grid (meter)	1224.74	Meter
With or Height of Each Grid (KM)	1.22	KM
Sample Plot Distance (approximate)	1.20	KM

Pilot NFI Study Area

Cluster of 3 circular Elbow Plot, East Plot and North on an L-shaped transect spaced at 50 meter apart. Each plot has a radius 12.62m (approximately 0.05 Ha). One 3.57m subplot allocated in middle elbow plot for regeneration data collection.

Total 69 cluster plots. Each cluster plot has 0.15 Ha (0.05 * 3) are allocated at 1.2 km by 1.2 Km spacing within the Pilot Study Area.

Only 58 Cluster Plots are accessible



Based on the field sample data of 58 cluster plots and systematic sampling statistics, mean, lower limit and upper limit at 90% confidence interval of (1) the total number of trees, (2) total number of trees per hectare, (3) total timber volume, (4) timber volume per hectare, (5) total basal area and (6) basal area per hectare are estimated. Moreover, the reliability of estimates - % Margin of error, % Standard Error, % Coefficient of Variation, Variance and Estimated Variance were derived for evaluating the quality of estimate and designing the national level forest inventory. The following table presents the summary of aforementioned estimates and statistical reliability.

Species level estimates and forest strata level estimates with the study area were also derived by the Pilot NFI. In this paper, the total and per hectare estimate of all species and all strata will be focused for designing the National level forest inventory. In order to avoid minor imperfections of volume equations which prorate the basal area and/or height to volume introduce insignificant inaccuracies. However, in order to be perfect, basal area and basal area per hectare were selected as the target parameters and % Margin of error was selected as the indicator of acceptable error for designing the National level forest inventory. The most important parameter from the pilot NFI is % coefficient variation (%CV). According to the table %CV is 62.01 for the basal area estimate.
The advantage of GIS for application to National Forest Inventory or Multi-Resource Inventory is – it could derive the anticipated number of sample points (anticipated n) within the study area in order to calculate the statistical

acceptable errors based on %CV and sampling size statistics. It will balance the affordable budget with statistically acceptable errors for the survey before actual survey is conducted for the executive decision making.

The anticipated number of sample points (anticipated n) are derived at the national scale at 1.2 km, 1.5 km, 2 km, 3 km, 4 km, 5 km and 6 km sampling interval using GIS.

The sample size formula could be rearranged to calculate the prorated margin of error% as follow. The student t value is calculated based on 90% confidence interval.

% Margin of Error = (t*(%CV)) / (SQRT (Anticipated n))

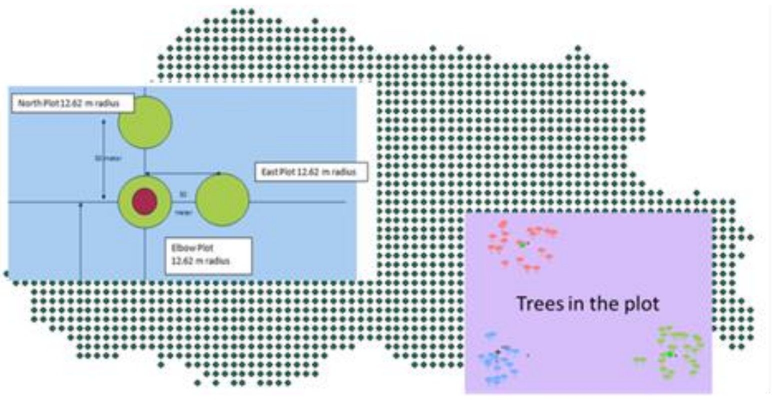
The anticipated number of sample points (anticipated n) are derived at the national scale at 1.2 km, 1.5 km, 2 km, 3 km, 4 km, 5 km and 6 km sampling interval using GIS. Then calculate the % Margin of Error

Sampling Interval	Anticipated n	%Margin of Error at National Level	%Margin of Error at Dzongkhag Level	% Margin of Error at Gewog Level
		%Margin of Error at National Level	%Margin of Error at Division Level	% Margin of Error at County Level
1.2 KM	26919	0.6	3	14
1.5 KM	17223	0.8	4	17
2 KM	9693	1	5	25
3 KM	4298	1.6	7	51
4 KM	2424	2.1	10	75
5 KM	1547	2.6	13	105
6 KM	1076	3.1	15	134

The approximate cost of sampling per cluster plot is estimated as 500 USD per cluster plot. The budget is estimated for the executive and financial decision.

Sampling Interval	Anticipated n	Anticipated n in the Forest	Anticipated n outside the Forest	Cost Per Cluster Plot	Total Cost for All Plots	Total Cost for Forest Plots	Total Plot for non-Forest Plots
				USD Per Cluster Plot	USD	USD	USD
1.2 KM	26919	18861	8058	500	9430500	4029000	4029000
1.5 KM	17223	11985	5238	500	5992500	2619000	2619000
2 KM	9693	6780	2913	500	3390000	1456500	1456500
3 KM	4298	2985	1313	500	1492500	656500	656500
4 KM	2424	1691	733	500	845500	366500	366500
5 KM	1547	1069	478	500	534500	239000	239000
6 KM	1076	750	326	500	375000	163000	163000

Although 14% Margin of error at the smallest Gewog level is achievable, the budget is more than 4 million USD. Therefore, 4 KM sampling interval is designated for Bhutan NFI in order to achieve acceptable 10% Margin of error of basal area as target parameter at the Dzongkhag (Division) level at an affordable budget (366500 USD) to collect 2424 sample plots data and providing very low % Margin of error 2.1% at the National level. Moreover, it provides flexibility to intensify the sample points within 4 KM interval until 0.5 KM interval systematically for important Gewogs for local level forest management planning.



Cluster of 3 circular Elbow Plot, East Plot and North on an L-shaped transect spaced at 50 meter apart. Each plot has a radius 12.62m (approximately 0.05 Ha). One 3.57m subplot allocated in middle elbow plot for regeneration data collection.

Total 2424 cluster plots (7272 plots). Each cluster plot has 0.15 Ha (0.05 * 3) are allocated at 4 km by 4 Km spacing throughout Bhutan.

RESULT OF ON GOING NATIONAL FORESS INVENTORY

Partially completed National Forest Inventory Reported important quantitative resource values related to forestry. The following table described the results of three Dzongkhags out of 20 Dzongkhags for the timber volume and number of trees estimates. One of the important data is National average and divisional (Dzongkhag) average value of mean volume of timber per hectare, number of trees per hectare and statistics of **reliability of information or statistical errors**. It is very important information for forest management planning and to avoid over exploitation of the timber resources.

	Lower Limit Volume (cu-m)/Ha	Mean Volume (cu-m)/Ha	Upper Limit Volume (cu-m)/Ha	MoErr%	SE%	CV%
FRPA	159.85	220.4	281.04	27.49	16.48	135.9
Haa NFI	195.93	250.95	306.37	22.1	13.25	112.43
Tsirang NFI	31	250	470	87.67	52	324
Paro NFI	128	196	263	34	20	145
FRPA&NFI	179.25	226.84	274.43	20.98	12.7	193.5
	Lower Limit Trees /Ha	Mean Trees /Ha	Upper Limit Trees /Ha			
FRPA	157.73	181.67	205.6	13.18	7.9	65.15
Haa NFI	168.66	202	235.22	16.48	9.89	83.9
Tsirang NFI	190	237	283	19.68	11.67	72.92
Paro NFI						
FRPA&NFI	176.57	193.59	210.61	8.79	5.32	81.09

The % margin of errors at each Dzongkhag is higher because of the inaccessibility to the plots due to the rugged terrains of Bhutan and inaccuracies of volume equations. Note that 10% Margin of error is designed for the basal area estimates.
Based on three Dzongkhags data, timber volume in conifer and broadleaf forests are also estimated. Summary of trees per hectare estimate and standing volume per hectare for broadleaf and conifer forests in Forest Production Area of Bhutan is described in following table.

Timber Volume (m^3)	Conifer	Broadleaf	Number of trees per hectare for All Trees	Trees/Ha
Total volume per hectare (m^3/ha)	103.11	139.09	Number of trees per hectare	193.59
Lower limit of volume per hectare (m^3/ha)	79.05	94.91	Lower limit of number of trees per hectare	176.57
Upper limit of volume per hectare (m^3/ha)	127.19	183.27	Upper limit of number of trees per hectare	210.61
Margin of Error (%) of total volume per hectare	23.35	31.76	Margin of error (%) of total number of trees per hectare	8.79
Percent coefficient of variation	215.32	292.95	Percent coefficient of variation	81.09
Standard error percent	14.14	19.23	Standard error percent	5.32

Although the complete data collection is expected to complete at the end of 2015-16, based on the available and accessible 323 cluster plots which contain 7637 were used to calculate the volume and number of trees estimation at species level.

Species	No. of tree per hectare			Standing volume per hectare		
	low	Ave.	Upper	Low	Ave.	Upper
Abies densa	6.83	13.68	20.53	17.33	40.11	62.88
Acer spp.	1.93	5.4	8.87	0.99	4.18	7.38
Alnus nepelensis	0	1.47	5.63	0	7.97	67.23
Beilschmiedia spp.	0	0.09	0.51	0	0.42	2.24
Betula spp.	1.32	5.92	10.52	0	3.92	18.22
Castanopsis spp.	0	7.24	16.47	0	19.74	65
Cupressus corneyana	0	1	9	0	0.27	4.03
Engelhardtia spicata	0	2.01	9.42	0	1.25	10.01
Juniperus spp.	0	0.182	6.16	0	0.76	4.2
Larix griffithii	0	0.34	1.9	0	0.75	7
Michelia spp.	0	0.86	2.3	0	1.34	4.21
Persea spp.	0	1.58	7.67	0	0.94	4.68
Phoebe spp.	0	0.2	1.31	0	0.2	2.42
Picea spinulosa	0.13	4.1	8.085	0	13.56	36.19
Pinus roxburghii	0	4.9	16.2	0	13.57	50.87
Pinus wallichiana	3.35	14.08	24.8	0	13.35	37.33
Quercus spp.	16.4	24.08	31.77	15.35	36.35	57.34
Schima walichii	0	3.1	7.59	0	1.39	3.42
Terminalia spp.	0	0.2	0.9	0	0.11	0.75
Tsuga dumosa	0.24	0.74	14.6	0	18.94	42.24
Abies densa(Eastern Region)	6.83	13.68	20.53	17.33	40.11	62.88
Acer spp. (East Region)	1.93	5.4	8.87	0.99	4.18	7.38
Picea spinolosa (Eastern Region)	0.13	4.1	8.085	0	13.56	36.19
Pinus roxburghii (East Region)	0	4.9	16.2	0	13.57	50.87
Pinus wallichiana (East Region)	3.35	14.08	24.8	0	13.35	37.33

Species	No. of Tree per hectare (%)			Standing Volume per hectare (%)			Sample size
	MoE	SE	CV	MoE	SE	CV	
Abies densa	50.03	30.3	461.46	56.8	34.39	523.83	476
Acer spp.	64.25	38.91	592.59	76.34	46.23	704.1	188
Alnus nepelensis	284.41	172.21	2623.1	743.59	450.26	6856.12	51
Beilschmiedia spp.	495	299	4562	432	262	3991	6
Betula spp.	77.68	47.04	716.42	109.7	66.42	1011.74	206
Castanopsis spp.	127.48	77.19	1175.74	229.19	138.78	2113.85	252
Cupressus corneyana	791.66	479.36	7301.46	1378	834.5	12710	35
Engelhardtia spicata	368	223	3397	704	426	6489	70
Juniperus spp.	235.05	142.23	2167	453.29	274.47	4180.67	64
Larix graffithii	452.83	274.2	4176.5	836.84	506.72	7718.2	12
Michelia spp.	167.35	101.33	1543.44	214.27	129.74	1976.25	30
Persea spp.	385	233.12	3550.83	398.08	241.04	3671.5	55
Phoebe spp.	549	332	5062	1293	783	11923	7
Picea spinulosa	96.76	58.59	892.46	166.79	101	1538.3	143
Pinus roxburghii	231.36	140.1	2133.8	274.89	166.45	2535.33	170
Pinus wallichiana	76.23	46.16	703.09	179.71	108.82	1657	490
Quercus spp.	31.92	19.33	294.42	57.76	34.98	532	838
Schima walichii	146.97	89	1355	145.78	88.3	1344.5	107
Terminalia spp.	344	208	3173	599	363	5527	7
Tsuga dumosa	96.8	58.6	892	123	74.49	1134	258
Abies densa (Eastern Region)	50.03	30.3	461.46	56.8	34.39	523.83	476
Acer spp. (Eastern Region)	64.25	38.91	592.59	76.34	46.23	704.1	188
Picea spinulosa (Eastern Region)	96.76	58.59	892.46	166.79	101	1538.3	143
Pinus roxburghii (Eastern Region)	231.36	140.1	2133.8	274.89	166.45	2535.33	170
Pinus wallchiana (Eastern Region)	76.23	46.16	703.09	179.71	108.82	1657	490

Margin of error%, Standard Error% and Coefficient of Variations % is presented as the reliability of estimates. Depending on the sample size, estimation errors are quite high at the individual species level. Therefore, the species level estimated data should be applied very cautiously at the present moment. Higher accuracy could be achieved if once the field work is completed when more plots data with more number of trees are available for estimation.

DISCUSSION SUMMARY

Geo-Informatics was applied for stratification of ALOS ANVIR-2 images in 2010 for National Forest Inventory and National Development Planning. ALOS AVNIR2 provided 10 meter fine resolution for high quality land cover and forest type stratification.

Trimble GPS system and its data dictionary capability was customized to collect the location and attributes of cluster plots, individual trees, soil, regeneration, shrubs data within the plots for statistical estimation. The Bhutan NFI proved that paper less data collection National Scale data collection is possible.

The geographic Information systems is essential tool for deriving the anticipated (n) number of plots at different sampling intensity and feed the data to R statistics for proration of sampling errors before actual field sampling work is carried out.

Theory of Sampling statistics and sampling with fixed Area Plots was successfully implemented and applied to design the sampling intensity and number of sample plots which will meet the acceptable errors of statistical estimation while allowing the budget affordable to conduct the nationally important survey.

The National Forestry Inventory of Bhutan targeted to accomplish the tasks at the end of 2016. The authentic and complete NFI data will provide higher accuracy of estimates for timber and non-timber resources planning and allocation.

The rugged terrain of the Himalaya is unavoidable obstacles for the accessibility to the sample plots and contributed significant impacts to the accuracy of information.

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