National Forest Inventory Report

Stocktaking Nation's Forest Resources

Volume I

Department of Forests and Park Services

We dedicate this report to
His Majesty The Fourth Druk Gyalpo Jigme Singye Wangchuck
and
His Majesty The Fifth Druk Gyalpo Jigme Khesar Namgyal Wangchuck
for their farsighted and visionary leadership in the field of
environmental conservation

We also dedicate this report to the Birth of our Gyalsey.

དཔལ་ལྡན་འབྲུག་གཞུང་ས་ཚན་དང་ནགས་ཚལ་ལྷན་ཁག།
ROYAL GOVERNMENT OF BHUTAN
Ministry of Agriculture and Forests
Tashichhodzong
Thimphu:Bhutan

MINISTER

Message

I am truly happy to be part of the publication of National Forest Inventory (NFI) report and avail the opportunity to pay my humble gratitude and respect to Their Majesties – Fourth and Fifth Kings for their visionary leadership in conservation and forest governance. It is with their sheer leadership and blessing we have huge forests and pristine environment while it is fast decreasing globally. It is also an opportunity to dedicate to the Birth of our Gyalsey, under whose leadership we look forward to steer forward our sacred country and continue our leadership in conservation.

Forests play an important role in ensuring food security, alleviating poverty, providing environmental services, and green growth and development opportunities, among others. For Bhutan with fragile mountainous ecosystem, the forests play even greater role given adverse impacts of climate change. Bhutan has also committed to remain carbon neutral for all times to come, therefore, forest is expected to take center stage and play key role in fulfilling this commitment. While the contribution from the forestry sector to gross domestic product (GDP) remains largely underestimated, the efforts are on to valuate and quantify it. The current NFI information and results will therefore, help us in our endeavor to truly valuate the role of forests in national development.

I am happy that many years after the Pre-Investment Survey (PIS), we have successfully completed the first NFI which is more comprehensive and holistic, designed to collate wide range of information not limiting to tree and timber. The current NFI vis-à-vis PIS is the first inventory lead and carried out by our own national experts, which adds an added dimension to celebrate. The national-expert-driven process has helped us building institutional capacity which will enable periodic inventory over time to monitor sacred constitutional mandate of 60% forest cover in perpetuity.

Therefore, I would like to commend the efforts and hard work of our colleagues in the Department of Forests and Park Services, particularly those involved in NFI as field crew and coordinating team. While I am deeply saddened by the loss of one of our senior most crew leaders, I appreciate the enthusiasm and commitment of all who have been involved to see through the NFI, despite this tragic event.

Hence, as I congratulate the team for this unprecedented achievement, I hope the results and estimates presented in this report will be useful to wide range of user stakeholders aside from the policy makers.

Trashi Delek

Yeshey Dorji

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ROYAL GOVERNMENT OF BHUTAN
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SECRETARY

Message

I am immensely glad to note that the Department of Forests and Park Services (DoFPS) is coming out with the report on first National Forest Inventory (NFI) of Bhutan. It is a matter of privilege that we have carried out the NFI which is largely very expensive both in terms of financial and human resources particularly technical capacity. Moreover, I am pleased to note this was undertaken by our own colleagues in the Department which is yet another milestone.

Forests, as we all know is our national heritage and plays vital role in sustaining livelihood of 69% of the Bhutanese populace residing in remote Bhutan depending largely on agriculture. Therefore, this is the most important sector and we depend on forest on a day to day basis. Nevertheless, despite such dependence, we have managed to maintain our forest intact. This has been possible as we have one of the best environmental policies and legislations under the visionary leadership of Their Majesties. While quality of forest and forest cover elsewhere in the world is fast degrading and dwindling, we have huge pristine forest cover, a true example of living in harmony with the nature.

The estimates and result from our current NFI is testimony to this. While we take pride in being custodian of this heritage, we endeavor to maintain this and handover to our future generations, as our visionary monarchs have repeatedly reminded us that the pristine environment that we have today has not been inherited from our forefathers but rather borrowed from our future generations. Therefore, it is our sacred duty to carry forward this responsibility in letter and spirit, and handover to our future generation.

Effort such as this current NFI, therefore, is not an end; rather it is a new beginning for future periodic inventories. Hence, I would like to congratulate the Department in general and NFI team in particular including field crew for this commendable work.

In conclusion, I hope that the NFI will be of immense help to all stakeholders apart from the DoFPS and the Ministry.

Trashi Delek

Rinzin Dorji

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ROYAL GOVERNMENT OF BHUTAN
Ministry of Agriculture and Forests
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DIRECTOR

Foreword

Let me congratulate and commend the Forest Resources Management Division (FRMD)for successfully carrying out the first field based inventory after Pre-Investment Survey (PIS) which was carried out with the help of government of India from 1974-81. I understand this is a technical exercise that is massively expensive requiring enormous investments in the form of technical human resources besides financial inputs. The exercises such as this are critically important not just for the Department but for the nation too.

The information, data and results generated from National Forest Inventory (NFI) are remarkably important and establish the baseline data for future monitoring and measurement purposes. It will guide our national policies on forests conservation, governance and management besides enabling science-based forest management. Our forests are not only source of timber which is a valued resource and raw material for construction of houses, culturally important structures like Dzongkhags and Lhakhangs that has huge cultural sentiments and beliefs attached, it is also home for many rare and endangered wildlife species including flagship animals such as Royal Bengal Tiger, Snow Leopard, Golden Langur, Takin and critically endangered birds like White Bellied Heron. The forests are also providing numerous intangible ecosystem services and acts as major terrestrial sink of carbon. It also prevents soil erosion and loss of fertile top soils, which again is a very important service provided by our forests, where loss of soil and other resources through soil erosion and landslide is a huge concern in a mountainous terrain like ours.

Unfortunately, despite valuable contributions from forests, it remains underestimated and underrepresented when it comes to contribution to the national exchequer. Therefore, we foresee being able to valuate and quantify the role of forestry sector, for which the results from NFI will form the key building blocks. The information and result generated from NFI are our valued assets that will be useful and benefit us understanding the actual role of forest in our development process aside from environmental conservation and ecological values the forest provides us.

Therefore, let me once again commend the work of dedicated team of young officers from FRMD led by Mr. Lobzang Dorji, Chief Forestry Officer, FRMD and NFI field team for excellently coordinating and carrying out the first NFI for Bhutan. What makes us more proud is the fact that we have been able to show that we have developed our own capacity over the time to carry out such a massive technical task. Therefore, congratulations once again and I wish the team a great success as they continue their effort working on second volume of NFI report.

Trashi Delek!

Phento Tshering

Acknowledgement

The National Forest Inventory (NFI) of Bhutan has been successfully conducted with the concerted effort of many people. Had it not been for their unwavering support and commitment, carrying out NFI would have remained a distant dream and plan for the Department. Therefore, everyone associated with NFI, either directly or indirectly deserves to be acknowledged.

Firstly, the Ministry of Agriculture and Forests (MoAF) and the Department of Forests Park Services (DoFPS) merit a special mention here. Both the Ministry and Department recognized the importance of NFI; and provided guidance and necessary support from the inception of NFI in 2009 till the completion.

NFI also received guidance and advice from NFI Core team chaired by Hon'ble Secretary, Ministry of Agriculture and Forests. Their inputs have been invaluable to make some critical decisions in taking NFI forward.

NFI is a very expensive exercise requiring a lot of technical expertise. We greatly acknowledge the USDA Forest Service Experts; Professor Timothy Gordon Gregoire, Yale University, USA; Dr. Moe Maung Myint, the then Research Scientist, Yale University, USA; Dr. Julian Fox, Forestry Officer, FAO; Dr. Javier Garcia Perez, Statistician, FAO; Mr. Stefano Ricci, Software Engineer, FAO and Mino Togna, Software Engineer, FAO for their valuable inputs in terms of statistics, data management, computer programming and data analytical softwares. Their expert inputs and contributions have been critical to see through NFI.

Most importantly, we would like to acknowledge the hard work of the NFI field crew members and especially Mr. Langa Tshering, senior crew leader whom we lost to a tragic accident during field work. They have worked under difficult terrain and harsh weather conditions risking their own lives. From the commencement of field work in 2012, they have been in the field toiling under sun and rain; and at times spent time in the forest without food or water. For all these they deserve a special mention here. Their family members too deserve appreciation for continued support and for motivating them.

NFI is very intensive even in terms of financial inputs. Over the last 7 years since its inception in 2009 with preparatory phase, financial support was received from various donors and sponsors for different aspects of NFI:

- Netherlands Development Agency(SNV) for the technical assistance in inventory designing and piloting
- Bhutan Trust Fund for Environment Conservation for supporting the preparatory phase and initiating the enumeration phase for six western Dzongkhags
- European Union (EU) through Renewable Natural Resources (RNR) Sector Support Programme (EU-RNR SSP) for supporting the field enumeration
- European Union (EU) through Global Climate Change Alliance (GCCA) for supporting the capacity building of NFI field crews
- FAO through the United Nations Reducing Emission from Deforestation and Forest Degradation Targeted Support program (UN REDD-TS) for supporting the institutional capacity building
- UNDP through Low Emission Capacity Building project (LECB) for supporting human resources capacity building in forest carbon assessment
- Forest Carbon Partnership Facility (FCPF) for the World Bank facilitated REDD+ Readiness Preparation Proposal that has supported field enumeration and continues to support the remaining

activities of NFI and NFMS

- Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Germany, fund being delivered through ICIMOD in partnership with GIZ for supporting the forest carbon assessment field works under the on-going REDD+ Himalayas Project. This report is being printed under this project.

Therefore, entire amalgamation of aforementioned donors, experts including NFI field crew and coordinating team are acknowledged sincerely for their support. Their contributions in terms of technical, financial and hard works are recorded deep in the hearts of many. They have been part of the Department's history and another milestone achieved.

Forest Resources Management Division

Executive Summary

Nearly thirty years after the Pre-Investment Survey (PIS) carried out from 1974-81, the current National Forest Inventory (NFI) was launched with preparatory phase in 2009 and actual field work carried out between July, 2012 - December, 2015. Following the completion of field enumeration, data analysis was carried out in phased manner and results are being reported in two volumes. Therefore, this report constitute volume I of NFI and contains information on scope of the report, history of NFI, methodologies and estimates of forest cover, tree count, basal area and growing stock.

Scope, History and Methodology

- This report focuses only on the traditional forestry parameters such as forest cover, basal area, tree count and growing stock.
- The national estimates have higher precision with lower margin of error and precision decreases as the estimates are calculated at smaller sampling size (e.g dzongkhag, forest type).
- NFI data were collected from a systematic cluster samples comprising of 2424 cluster plots laid at 4 km x 4 km grid spread across the country. Each cluster plot comprised of three plots called Elbow (L), North (N) and East (E) laid at 50 meters apart forming a L-shaped sample plot.
- 1685 of the total 2424 cluster plots were enumerated during field enumeration.
- All trees having a minimum diameter at breast height (dbh) of 10 cm were enumerated.
- Total of 50,899 individual trees and 460 plus species were measured and recorded during field enumeration from 1685 cluster plots.
- The data management and analysis was performed using Open Foris Collect and Open Foris Calc and customized R-modules.

Forest Cover

- Forest cover in this report is estimated based on forest defined in National Forest Policy 2011. Forest occupies a total of 2,730,889 ha which is 71% of the total geographical area of the country.
- Forest cover area is the highest in Wangdue Phodrang dzongkhag with 292,824 ha and the lowest in Tsirang dzongkhag with 48,857 ha.
- Dagana, Pemagatshel and Zhemgang dzongkhags have the highest forest cover percent of 83 % each and Gasa dzongkhag the least with 36%.
- The majority of forest fall under Cool Broad-leaved Forest with 986,765 ha (26%) and least under Dry Alpine Scrub Forest with 2654 ha (<1%).
- By land cover class, Broad-leaved Forest constitutes 1,927,913 ha (50%) and Coniferous Forest constitutes 770,032 ha (20%).

Tree count

- A total of 816,524,026 trees are estimated to be found in Bhutan's forest including trees found in non-forest categories with stem density 213 trees per ha.
- Trashigang dzongkhag has the highest number of tree count with 82,773,731 trees and Gasa dzongkhag has the lowest number of tree count with 9,766,164 trees
- Tsirang dzongkhag has the highest stem density with 283 trees per ha and Gasa dzongkhag has the lowest stem density with 91 trees per ha.
- Maximum tree count is recorded in Cool Broad-Leaved Forest with 296,492,852 trees and the lowest in Dry Alpine Scrub Forest with 469,746 trees.
- Stem density is the highest in Evergreen Oak Forest with 367 trees per ha and the lowest in Dry Alpine Scrub Forest with 113 trees per ha.
- The total tree count of 28 major genus is estimated at 482,943,993 trees.
- Maximum tree count is found in diameter class of 10-20 cm with 287,507,073 trees and the minimum in diameter class of 90-100 cm with 10,311,675 trees.

- Maximum tree count is found in height class of 10-15 m with 282,468,672 trees and the minimum in height class of >=40 m with 3,788,271 trees.

Basal area

- The total basal area of our forest is estimated to be 114,791,541 m^2 with average basal area of 30 m^2 per ha.
- The total basal area is the highest in Trashigang dzongkhag with 9,956,439 m^2 and the lowest in Gasa dzongkhag with 961,167 m^2
- Lhuntse dzongkhag has the highest basal area per hectare with 56 m^2 per ha and the lowest in Gasa dzongkhag with 9 m^2 per ha.
- Total basal area is maximum in Cool Broad-Leaved Forest with 49,177,533 m^2 and the minimum in Dry Alpine Scrub forest with 19,481 m^2.
- The basal area per hectare is the highest in Hemlock Forest with 60 m^2 per ha and the lowest in Dry Alpine Scrub Forest with 5 m^2 per ha.
- The total basal area of 28 major genus of trees is 80,347,953 m^2.
- The diameter class of >=100 cm contributes the maximum basal area with 33,040,958 m^2 and the minimum from diameter class of 10-20 cm with 5,235,586 m^2
- Maximum basal area is estimated to be in height class of 10-15 m with 24,922,738 m^2 and the minimum in height class of >=40 m with 2,566,680 m^2.

Growing stock

- Growing stock is estimated using 29 general volume equations developed during PIS.
- The total growing stock of our forest is 1001 million m^3 and average growing stock is 261 m^3 including all trees whether or not they fall under our forest definition.
- Mongar dzongkhag has the highest total volume with 86,817,118 m^3 and Gasa dzongkhag has the least with 7,277,898 m^3 .
- Lhuntse dzongkhag has the highest volume per hectare with 566 m^3 while Gasa dzongkhag has the least with 68 m^3.
- The Cool Broad-Leaved Forest has the highest total volume with 438,025,418 m^3 and Dry Apline Scrub Forests has the least with 95,854 m^3.
- The volume per hectare is highest in Hemlock Forest with 583 m^3 and lowest in Dry Alpine Scrub Forest with 23 m^3.
- The 28 major genus of trees contribute 738,883,514 m^3 of volume.
- The diameter class of >=100 cm has the highest volume estimate of 337,804,979 m^3 while the diameter class of 10-20 cm has the least 26,588,104 m^3.
- The height class of 15-20 m has volume estimate of 201,311,590 m^3 which is the highest while the lowest volume estimates is in height class of >=40 m with 43,658,495 m^3.

The result reported here gives an overall insight of forest and will help government, department and other stakeholders in formulation of policies and legislations and decision making towards sustainable forest management.

Acronyms and abbreviations

.dbf	Database file
.ssf	Standard storage file
BA	Basal Area
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BTFEC	Bhutan Trust Fund for Environmental Conservation
CI	Confidence Interval
cm	Centimeter
dbh	Diameter at Breast Height
DoFPS	Department of Forests and Park Services
EU	European Union
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FPED	Forest Protection and Enforcement Division
FRMD	Forest Resources Management Division
GCCA	Global Climate Change Alliance
GI	Galvanized Iron
GIS	Geographic Information System
GIZ	Deutsche Gesellschaftfür Internationale Zusammenarbeit -German Corporation for International Cooperation
GPS	Global Positioning System
GS	Growing Stock
ha	Hectare (unit of area)
ICIMOD	International Centre for Integrated Mountain Development
Km	Kilometer
LECB	Low Emission Capacity Building Project
m^3	Cubic meter (unit of volume measurement)
MoAF	Ministry of Agriculture and Forests
MoE	Margin of Error
NBC	National Bio-diversity Center
NECS	National Environment Commission Secretariat
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NFP	National Forest Policy
NRED	Nature Recreation and Eco-tourism Division
NSSC	National Soil Services Center
PIS	Pre-Investment Survey
REDD	Reducing Emission from Deforestation and forests Degradation
RGoB	Royal Government of Bhutan
RNR SSP	Renewable Natural Resources Sector Support Programme
R-PP	REDD+ Readiness Preparation Proposal
RS	Remote Sensing
RSPN	Royal Society for Protection of Nature
SFED	Social Forestry and Extension Division
SNV	Netherlands Development Agency
UN REDD -TS	UN REDD Targeted Support
UN	United Nations
WB	World Bank
WCD	Wildlife Conservation Division
WMD	Watershed Management Divison

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Chapter 1
Introduction

1.1 Scope of National Forest Inventory Report

This report is the first volume of Bhutan's National Forest Inventory (NFI). The field work began in July, 2012 and completed in December, 2015. The report focuses only on the traditional forestry parameters related to trees and presents the following estimates:

i. Forest cover

1. Total forest cover
2. Forest cover by dzongkhag
3. Forest cover by forest type
4. Forest cover by land use class

ii. Tree Count

1. Total tree count
2. Tree count per hectare
3. Tree count by dzongkhag
4. Tree count per hectare by dzongkhag
5. Tree count by forest type
6. Tree count per hectare by forest type
7. Tree count by diameter class
8. Tree count per hectare by diameter class
9. Tree count by height class
10. Tree count per hectare by height class
11. Tree count by major tree species

iii. Basal Area

1. Total basal area
2. Basal area per hectare
3. Basal area by dzongkhag
4. Basal area per hectare by dzongkhag
5. Basal area by forest type
6. Basal area per hectare by forest type
7. Basal area by diameter class
8. Basal area per hectare by diameter class
9. Basal area by height class
10. Basal area per hectare by height class
11. Basal area by major tree species

iv. Growing stock

1. Total volume
2. Volume per hectare

3. Volume by dzongkhag
4. Volume per hectare by dzongkhag
5. Volume by forest type
6. Volume per hectare by forest type
7. Volume by diameter class
8. Volume per hectare by diameter class
9. Volume by height class
10. Volume per hectare by height class
11. Volume by major tree species

This report is intended to present up-to-date information on tree resources in the country, which will serve as a tool for strengthening the science-based forest management. It will promote development of effective forest governance and resources utilization plans and programs based on sustainable forest management principles and best practices.

The second volume of NFI report will present the results and estimates on biodiversity, forest biomass and forest carbon, forest health, forest disturbances, wild life presence–absence, non-wood forest produce, information on herbs and shrubs. The two volume combined will present the comprehensive state of forest resources in Bhutan.

These reports are the second such report presented since the first nation wide forest inventory referred to as Pre-Investment Survey (PIS).

1.2 History of National Forest Inventory in Bhutan

Realizing the need for a comprehensive assessment of forest resources, with help of Forest Survey of India, Government of India, the Pre-Investment Survey (PIS) was carried out from 1974 to 1981, covering a total area of 29,176.4 square kilometer. The survey focused on "assessing the availability of raw materials for wood based industries". It generated estimates for number of stems per hectare, volume table, volume per hectare, total growing stock, regeneration status and increment etc. The report of the PIS proposed the potential availability of timber resources for setting up wood based industries in Bhutan based on information gathered.

Volume equations for 28 major timber species and one general volume equation for others were developed during PIS along with forest type maps at 1:50, 000 scale for the country. In essence PIS was the first national forest inventory for Bhutan which was followed by number of assessments using the remote sensing technologies but no field inventory has been done since then, owing to various reasons such as lack of financial and technical capacities. The remote sensing (RS) based forest resources assessment provided qualitative estimates such as forest extent and coverage but lacked capacity to make quantitative assessments of the rich forest resources.

The information generated from PIS and RS exercises could not maintain the pace with unprecedented infrastructure development and the result do not necessarily reflect the actual scenario of those factors affecting forest resources in the country. Therefore, the comprehensive national forest inventory was necessary to understand the spatial and temporal dynamics of forest resources in the country. Thus the current NFI was initiated in 2009.

1.3 Current NFI

As opposed to conventional National Forest Inventories that focus mainly on timber resource assessments, the current NFI of Bhutan is a multipurpose forest ecosystem health monitoring inventory. Therefore, other parameters such as information on biodiversity, forest health (pest and disease), forest disturbance and soil carbon were collected.

The preparatory phase for the current NFI began in 2009 and lasted until mid-2012. This phase involved developing sampling design, piloting the sampling design, preparing field manuals, procuring field gears and equipment, selecting and training NFI field crews.

The field work for current NFI took three and half years to complete data collection from all twenty dzongkhags. The main purpose of NFI is to generate updated information on forest resources of country to support formulation of policies and legislations aiming at forest management, use and conservation as desired by various stakeholders and other line agencies. While NFI fieldwork has been completed, the field and laboratory work for biomass and allometric equation development is on-going. These equations will be used for generating biomass and carbon stock estimates of our forests, which will be reported in volume II of NFI report.

1.4 Limitation of estimates

The current NFI has been designed to obtain estimates at a national level with precision at 15% margin of error and 90% confidence interval. Therefore, the estimates generated at Dzongkhag level and other categories such as by land cover class, forest types and major tree species will have lesser precision level than estimates generated at the national level. These estimates may serve to provide a broad guidance and use of the estimates for forest management planning at Forest Management Unit (FMU) and Community Forest (CF) designed to harvest timber will require intensified resource assessments.

Further, the sampling design was aimed at achieving 15% Margin of Error (MoE) with 90% Confidence Interval (CI) for basal area estimates at dzongkhag level; due to inaccessibility of 30% of cluster plots, the targeted level of precision could not be achieved.

Chapter 2
Field Methodology

2.1 Sampling design

The National Forestry Inventory uses a systematic cluster samples comprising of 2424 cluster plots laid at 4 km x 4 km grid spread across the country. The centre of all NFI plots are monumented with galvanized iron (GI) pipe for the purpose of relocating the plots during the future forest inventories.

The each cluster plot consists of 3 circular plots of 12.62 m radius placed on a "L" shaped transect at 50 m apart and referred to as the Elbow, North and East plot (Figure 1) and the layout of 2424 cluster plot is illustrated in Figure 2

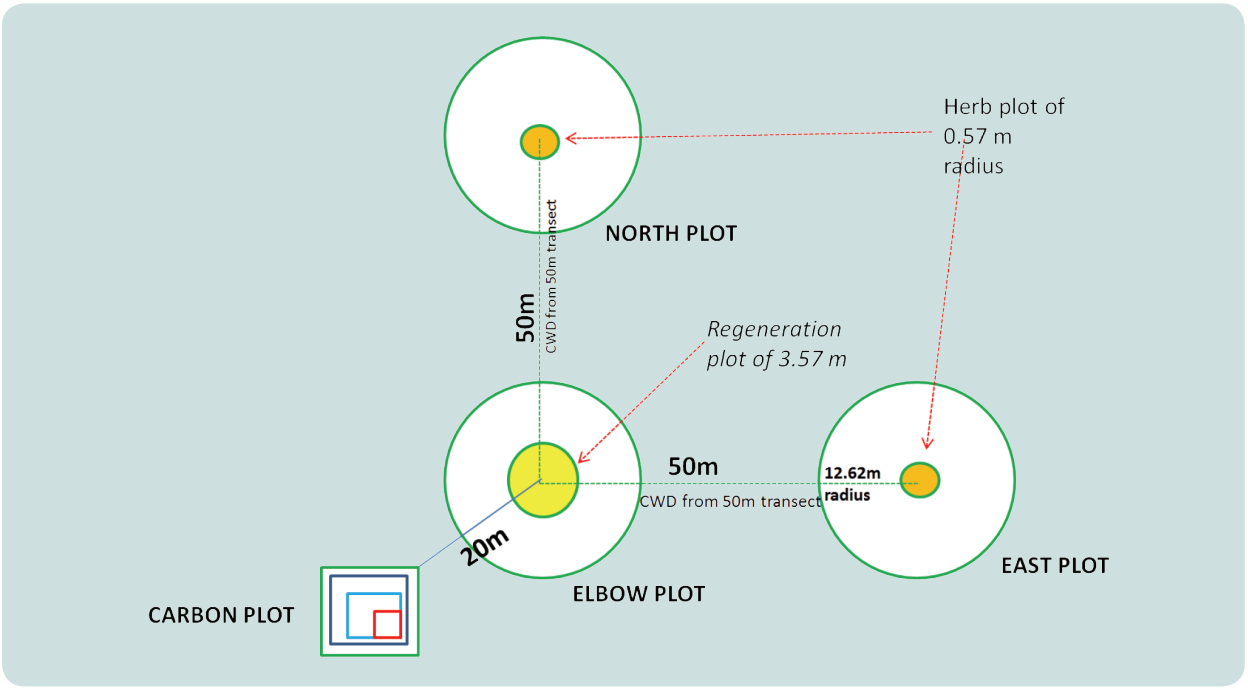

Figure 1: NFI plot design

Therefore, all trees having a minimum dbh of 10 cm irrespective of their conditions are enumerated from the plots. For regeneration and herbs, smaller sub-plots are embedded within Elbow, East and North plots. A sub-plot of 3.57 m radius for regeneration is laid within Elbow plot and 0.57 m radius sub-plots for herbs are laid within North & East Plots.

The NFI design has been developed to generate estimates for basal area at 15% margin of error with 90% confidence interval at national and dzongkhag level. Although the cluster plot consists of three disjoint plots, it is treated as a single sampling unit in the analysis. For statistical purposes, the size of the NFI is expressed as the total number, 2424, sampling units distributed across Bhutan.

The details of the sampling design and field data collection methodology is described elaborately in the Field Manual, National Forest Inventory of Bhutan, published by Forest Resources Management Division in 2012.

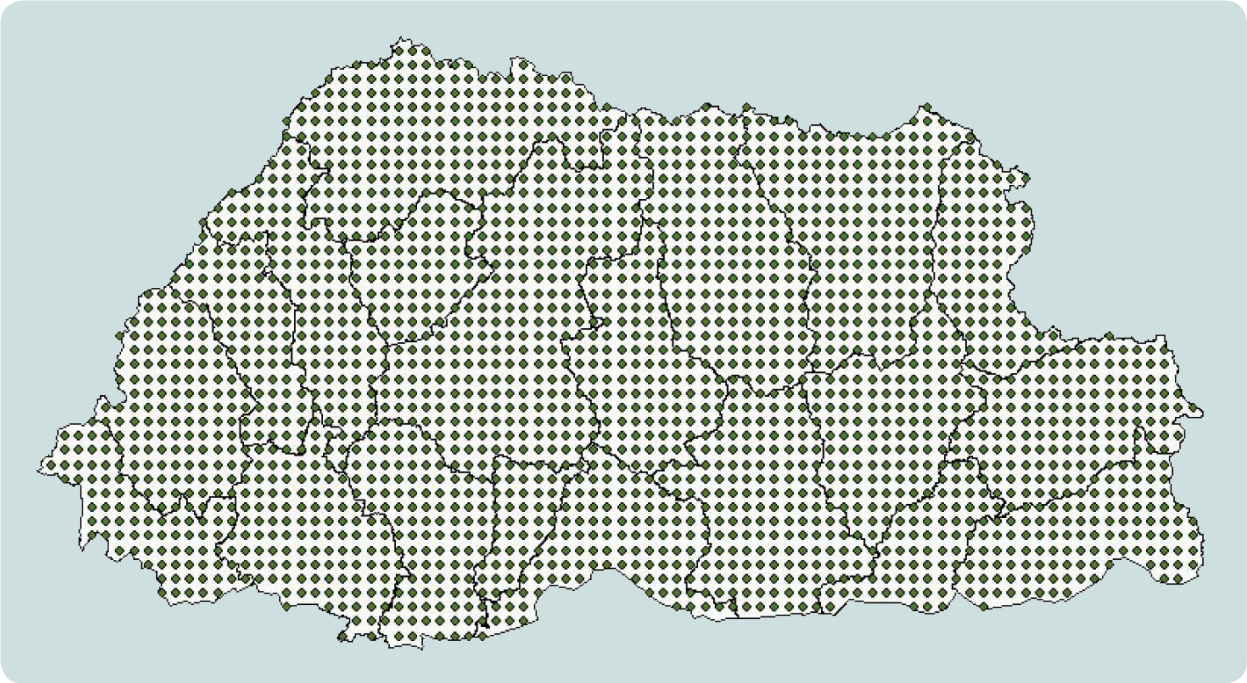

Figure 2: Layout of 2424 cluster plots

Chapter 3
Data Management

This chapter briefly describes and presents the data flow from field data collection to data analysis and result generation. The details of each components of the data management are described in Data Management Protocol, National Forest Inventory of Bhutan.

3.1 Data Collection

The NFI data collection is done using Trimble Global Positioning System (GPS) device. Upon completion of the enumeration of each cluster plot, the data is transferred to laptops and backed–up in external hard drives provided to the field crew for data security. Upon completing enumeration in each dzongkhag, the data is transferred onto the centralized data server maintained at FRMD.

However, under unavoidable circumstances such as plot falling in valleys resulting into poor or no GPS signals and at the times when GPS drains out of battery, the information are recorded in paper forms. The paper form data are digitized at FRMD.

3.2 Data conversion and migration

The data collected using Trimble GPS are in standard storage file (.ssf) format. These are then converted into Database file (.dbf) format using Pathfinder Office software, to make it compatible with Open Foris Collect tools, which has been adopted for NFI data management. Open Foris Collect is an open source data management tool developed by FAO.

The converted files (.dbf) are then migrated to Collect platform with the help of customized data migratory tool (software program) developed by FAO experts.

3.3 Data sorting and cleaning

The migrated data are then launched in Collect platform. From Collect platform, the data is then exported as comma separated values (csv) files. These csv files are cleaned, sorted and prepared for final analysis.

The data validation is also executed in Collect platform with a set of validation rules developed in Collect survey design itself.

3.4 Data analysis

The NFI data analysis is done using Calc, which is a robust, modular browser-based tool for analysis and generating result. It is also developed by FAO. This tool allows development of customized R modules (R is an open source statistical software) to perform customized analysis and generates reports in calc using Saiku, which is an open source software for web-based analytic solution. The maps presented in this report are prepared in Arc GIS 10.3.1 version and graphs prepared in R version 3.2.4.

Chapter 4
Results

1685 of the total 2424 cluster plots have been enumerated, while remaining could not be accessed owing to various reasons such as security issues, difficult terrain, rivers, snow and glaciers. Table 1 shows the status of accessibility of cluster plots in each dzongkhag and Figure 3 shows overview of accessible plots.

All statistical estimates presented in this report have been generated using NFI data collected over the period of three and a half years and analyzed with the help of Open Foris toolkit (Collect and Calc) developed by Food and Agricultural Organization of United Nations (FAO) and R statistical program.

R modules have been developed with the help of FAO expert to enable customized data analysis and generate results for Bhutan.

All estimates are generated at cluster plot level and are rounded to nearest whole number or to maximum of one decimal place.

Table 1: Overview of the accessible and inaccessible cluster plots

SN	Dzongkhag	Total Plots	Accessible	Inaccessible	Accessibility (%)
1	Bumthang	167	126	41	75
2	Chukha	113	94	19	83
3	Dagana	107	93	14	87
4	Gasa	201	48	153	24
5	Haa	121	84	37	69
6	Lhuntse	181	64	117	35
7	Mongar	120	92	28	77
8	Paro	81	73	8	90
9	Pemagatshel	63	56	7	89
10	Punakha	70	51	19	73
11	Samdrup Jongkhar	119	100	19	84
12	Samtse	80	75	5	94
13	Sarpang	104	88	16	85
14	Thimphu	114	80	34	70
15	Trashigang	137	132	5	96
16	Trashiyangtse	90	58	32	64
17	Trongsa	113	73	40	65
18	Tsirang	42	41	1	98

SN	Dzongkhag	Total Plots	Accessible	Inaccessible	Accessibility (%)
19	Wangdue Phodrang	251	143	108	57
20	Zhemgang	150	114	36	76
	TOTAL	**2424**	**1685**	**739**	**70**

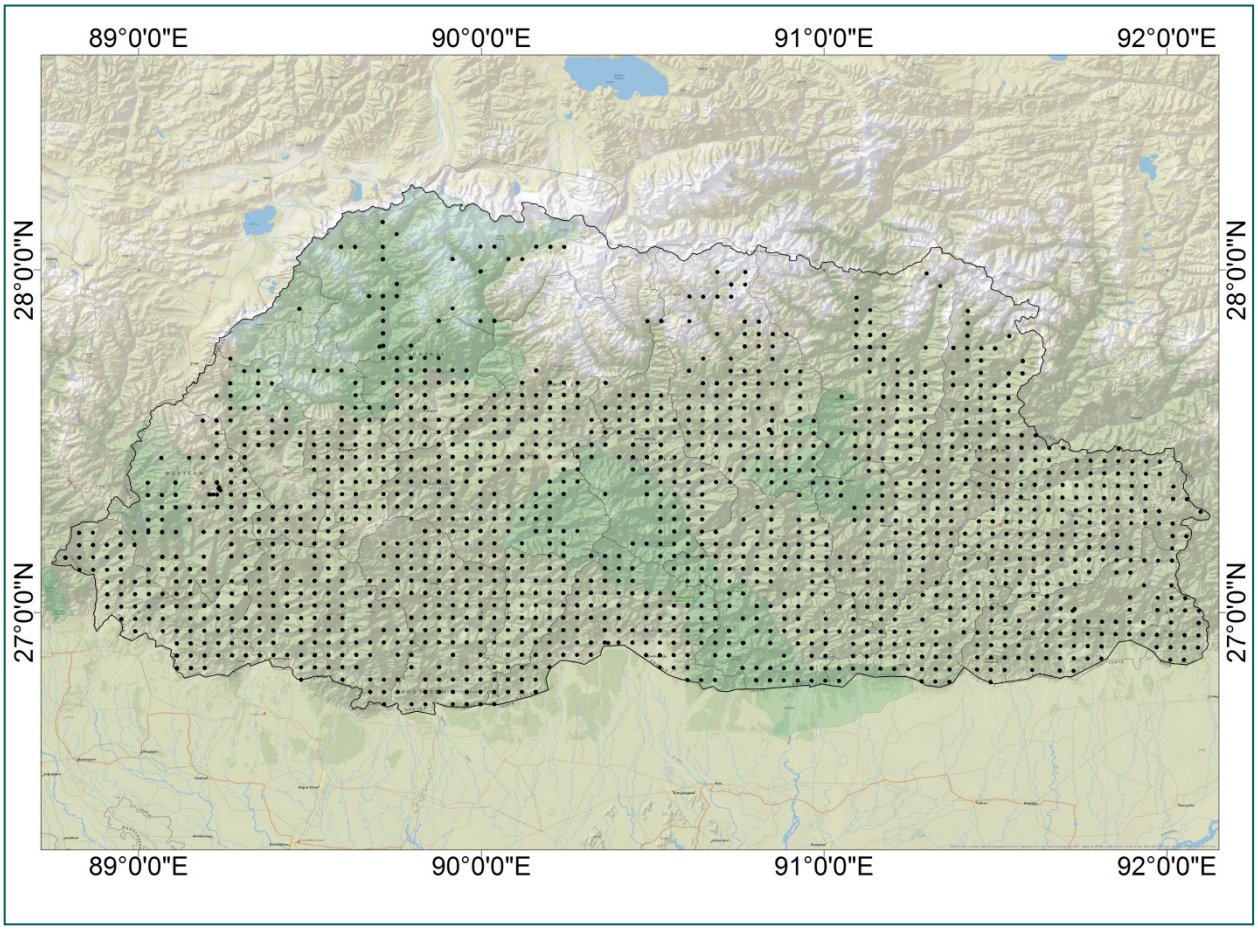

Figure 3: Overview of accessible cluster plots

4.1 Forest cover

Forest cover estimate is based on the forest defined in the National Forest Policy of Bhutan (NFP, 2011) which states that land with trees spanning more than 0.5 ha with trees higher than 5 meters and a canopy cover of more than 10%. The crown cover at each sample plot was measured using crown densitometer equipment while the height and diameter of trees were measured using Laser Ace Hypsometer and diameter tape (in cm) respectively. These measurements were used for estimating the forest cover. It is estimated that 2,730,889 ha of total geographical area, equivalent to 71 % of the country is under forest cover.

4.1.1 Forest cover estimates by different categories

The Table 2 provides forest cover by forest and non-forest while Table 3 and Table 4 provide distribution of forest cover by dzongkhag and forest type respectively. The Table 5 provides forest cover under different land use land cover classes. For details of forest type and land use land cover classes refer, Annexure II and III respectively.

Table 2: Forest cover by forest and non-forest

Sl. No.	Particulars	Area (ha)	Forest cover (%)	Margin of Error (%)	90% Confidence interval	
					Lower	Upper
1	Forest	2,730,889	71	2	69	73
2	Non-forest[1]	1,108,511	29	5	27	30
Total area (ha)		**3,839,400**				

Table 3: Forest cover by dzongkhag

SN	Dzongkhag	Dzongkhag Area (ha)	Forest Area (ha)	Forest Cover (%)	MoE%	90% Confidence interval	
						Lower	Upper
1	Bumthang	269,091	144,842	54	13	47	60
2	Chukha	186,149	151,164	81	7	75	86
3	Dagana	170,608	141,861	83	7	77	88
4	Gasa	310,398	112,272	36	28	26	48
5	Haa	188,635	129,500	69	11	61	75
6	Lhuntse	283,091	213,792	76	12	66	83
7	Mongar	192,536	158,031	82	7	76	87
8	Paro	127,461	72,574	57	16	48	65
9	Pemagatshel	101,217	83,745	83	10	75	89
10	Punakha	109,878	79,316	72	14	62	80
11	Samdrup Jongkhar	185,881	133,622	72	9	65	77
12	Samtse	129,216	77,299	60	13	52	67
13	Sarpang	163,928	127,397	78	9	71	83
14	Thimphu	177,841	94,256	53	16	45	61
15	Trashigang	218,253	159,998	73	8	67	79
16	Trashiyangtse	143,496	99,860	70	14	60	78
17	Trongsa	179,607	142,571	79	10	72	85
18	Tsirang	63,163	48,857	77	13	68	85
19	Wangdue Phodrang	399,641	292,824	73	8	67	78
20	Zhemgang	239,308	198,036	83	6	78	87

[1]**Non-forest** - Those areas without trees (including water bodies, agriculture land, meadows etc) or with trees less than 5m in height and/or less than 10% canopy cover.

Table 4: Forest cover by forest type

Forest Type	Forest Area (ha)	Forest cover (%)	MoE (%)	90% Confidence interval	
				Lower	Upper
Subtropical Forest	241,804	6	3	6	7
Warm Broadleaved Forest	693,683	18	2	17	18
Chirpine Forest	98,563	3	7	2	3
Cool Broadleaved Forest	986,765	26	1	25	26
Evergreen Oak Forest	31,464	1	0	0.8	0.8
Blue Pine Forest	137,230	4	4	3	4
Spruce Forest	40,183	1	7	1.0	1.1
Hemlock Forest	88,327	2	6	2.2	2.4
Fir Forest	352,552	9	2	9.0	9.3
Juniper- Rhododendron Scrub	57,242	1	12	1.3	1.6
Dry Alpine Scrub	2,654	0	56	0.0	0.1

Table 5: Forest cover by land use land cover class

Land use land cover class	Forest Area (ha)	Forest cover (%)	MoE(%)	90% Confidence interval	
				Lower	Upper
Broad-leaved Forest	1,927,913	50.0	2	49.3	51.1
Coniferous Forest	770,032	20.0	3	19.4	20.6
Plantation	3,842	0.1	47	0.1	0.1
Scrub Forest	24,592	0.6	32	0.4	0.9
Rocky outcrop	7,685	0.2	58	0.1	0.5
Snow/glacier	768	0.00	83	0.0	0.1
Marshy area	768	0.00	82	0.0	0.1
Water bodies	0	0.00	44	0.0	0.0
Settlement	3,074	0.1	71	0.0	0.2
Agriculture	16,523	0.4	35	0.3	0.7
Horticulture	13,064	0.3	33	0.2	0.5

4.2 Tree count

The number of trees per unit area is an important of measure of stand density. Only trees above 10 cm dbh were recorded during the field enumeration and therefore, tree count estimate includes trees with dbh more than or equal to 10 cm. A total of 816,524,026 trees are estimated with margin of error of 3% and 213 trees per hectare with 3% margin of error. These estimates are generated based on trees enumerated without segregating country into forest and non-forest.

4.2.1 Tree count by forest and non-forest

Tree count estimates have also been generated by segregating the country into forest and non-forests. Therefore, Table 6 provides estimates of total tree count in forest and non-forest area, while the Table 7 shows the estimates of tree count per hectare.

Table 6: Total tree count by forest and non-forest

Particular	Tree count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	765,026,264	4%	738,020,077	792,032,451
Non-forest	51,497,762	12%	45,216,114	57,779,410

Table 7: Tree count per hectare by forest and non-forest

Particular	Tree count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	280	3%	273	287
Non-forest	46	12%	41	52

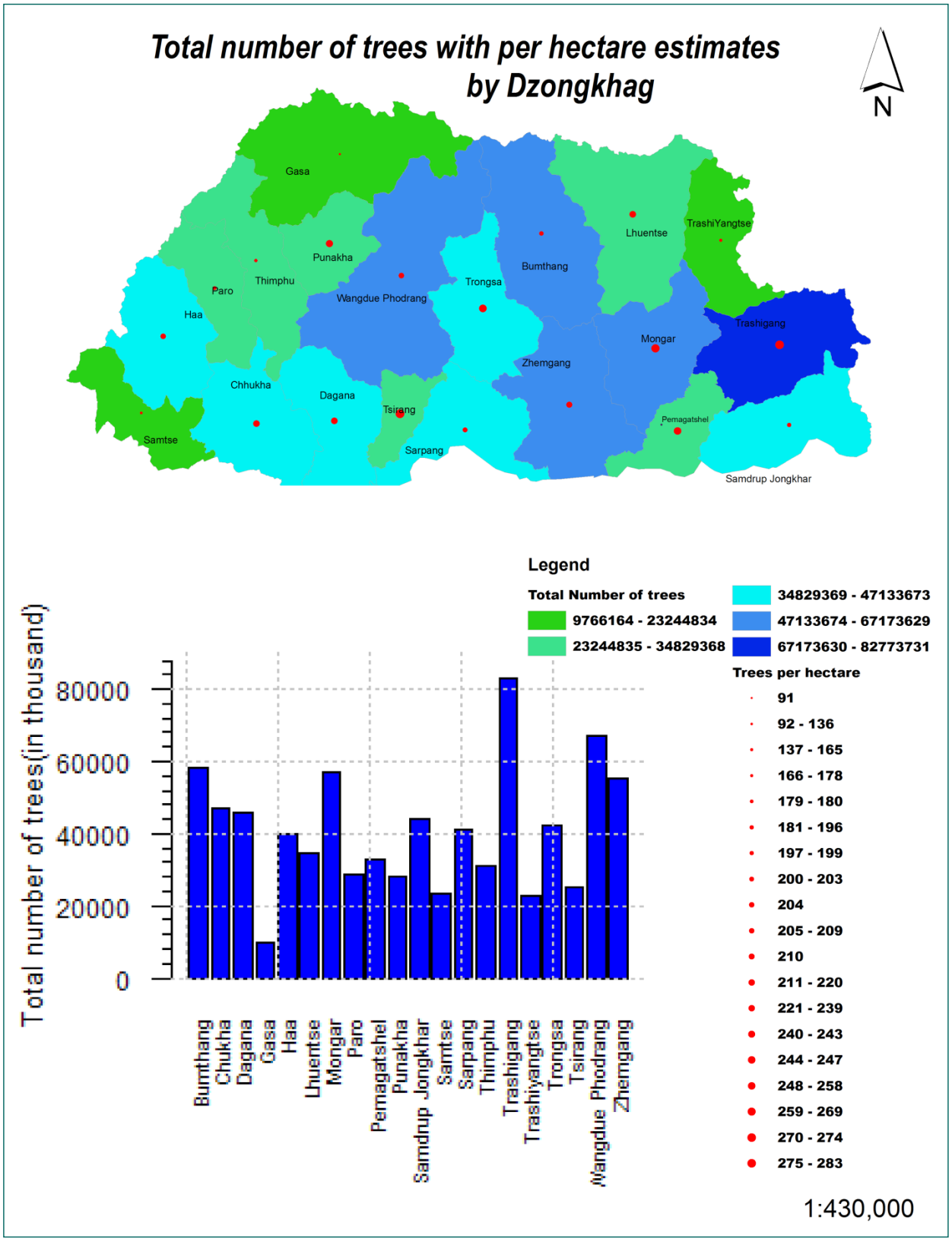

Figure 4: Tree count by Dzongkhag

4.2.2 Tree count by Dzongkhag

The Table 8 provides estimates of total tree count by dzongkhag while the Table 9 shows the estimates of tree count per hectare. These estimates are graphically depicted in Figure 4.

Table 8: Total tree count by dzongkhag

Dzongkhag	Tree count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Bumthang	58,104,507	20	46,319,129	69,889,885
Chukha	47,133,673	20	37,747,564	56,519,782
Dagana	45,565,329	20	36,630,945	54,499,713
Gasa	9,766,164	43	5,593,411	13,938,917
Haa	40,019,299	23	30,715,540	49323059
Lhuntse	34,829,368	25	26,278,186	43,380,549
Mongar	56,801,342	20	45,314,427	68,288,257
Paro	28,495,378	28	20,624,394	36,366,361
Pemagatshel	32,867,043	28	23,823,757	41,910,329
Punakha	27,843,795	29	19,777,399	35,910,191
Samdrup Jongkhar	44,193,975	20	35,414,755	52,973,194
Samtse	23,244,834	22	18,126,789	28,362,878
Sarpang	41,026,980	20	32,649,143	49,404,816
Thimphu	31,351,734	28	22,724,472	39,978,997
Trashigang	82,773,731	18	67647,032	97,900,430
Trashiyangtse	23,032,690	26	17,008,748	29,056,633
Trongsa	42,163,461	22	33,037,276	51,289,646
Tsirang	25,063,204	31	17,342,018	32,784,390
Wangdue Phodrang	67,173,629	17	55,690,690	78,656,569
Zhemgang	55,073,890	17	45,627,899	64,519,881

Table 9: Tree count per hectare by dzongkhag

Dzongkhag	Tree count per ha (No)	Margin of Error (%)	90 % Confidence interval	
			Lower	Upper
Bumthang	199	15	170	228
Chukha	220	11	196	245
Dagana	220	10	198	242
Gasa	91	36	59	124
Haa	209	15	177	242
Lhuntse	239	14	206	273
Mongar	269	12	237	300

Dzongkhag	Tree count per ha (No)	Margin of Error (%)	90 % Confidence interval	
			Lower	Upper
Paro	180	20	144	215
Pemagatshel	258	17	214	302
Punakha	243	18	200	287
SamdrupJongkhar	196	12	173	219
Samtse	136	12	120	152
Sarpang	203	11	180	226
Thimphu	165	21	130	201
Trashigang	274	12	241	307
Trashiyangtse	178	15	151	204
Trongsa	247	11	219	274
Tsirang	283	16	236	329
WangduePhodrang	204	11	182	227
Zhemgang	210	9	192	228

4.2.3 Tree count by Forest Type

The Table 10 provides estimates of total tree count while the Table 11 shows the estimates of tree count per hectare in different forest types

Table 10: Total tree count by forest type

Forest Type	Tree count (No)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Subtropical Forest	58,680,325	17	48,872,802	68,487,847
Warm Broadleaved Forest	176,821,358	9	160,435,513	193,207,202
Chirpine Forest	20,888,529	27	15,285,344	26,491,714
Cool Broadleaved Forest	296,492,852	8	273,663,611	319,322,094
Evergreen Oak Forest	11,539,075	42	6,662,226	16,415,923
Blue Pine Forest	49,194,493	23	37,828,174	60,560,811
Spruce Forest	10,660,196	36	6,866,757	14,453,634
Hemlock Forest	25,298,077	25	18,862,504	31,733,649
Fir Forest	108,602,166	14	93,697,702	123,506,629
Juniper- Rhododendron Scrub	17,289,671	32	11,761,075	22,818,266
Dry Alpine Scrub	469,746	90	44,854	894,637
Others	40,587,540	15	34,654,221	46,520,859

Table 11: Tree count per hectare by forest type

Forest Type	Tree count per ha (No)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Subtropical Forest	225	8	206	244
Warm Broadleaved Forest	239	5	227	251
Chirpine Forest	189	15	161	217
Cool Broadleaved Forest	292	4	280	305
Evergreen Oak Forest	367	15	312	421
Blue Pine Forest	343	13	299	388
Spruce Forest	256	13	221	290
Hemlock Forest	275	9	250	300
Fir Forest	301	7	280	321
Juniper- Rhododendron Scrub	283	16	238	329
Dry Alpine Scrub	113	50	56	169
Others	41	14	36	47

4.2.4 Tree count by diameter classes

The diameter has been classified into 10 classes of 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm and >=100 cm.

The Table 12 provides estimates of total tree count by different diameter classes irrespective of forest and non-forest for the entire country. The Tables 13 and 14 show the tree count estimates in different diameter classes within forest and non-forest areas respectively.

The tree count per hectare for different diameter classes irrespective of forest and non-forest area is depicted in Table 15, while the Tables 16 and 17 provide the tree count per hectare in forest and non-forest areas respectively. The comparison of tree count per hectare and total tree count among forest, non-forest and entire country is illustrated in Figures 5 and 6 respectively.

Table 12: Total tree count by diameter class

Diameter Class (cm)	Tree Count (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	287,507,073	6	271,030,273	303,983,872
20-30	202,331,578	5	192,708,105	211,955,050
30-40	112,587,427	5	107,005,557	118,169,298
40-50	67,575,186	6	63,654,069	71,496,303
50-60	44,042,444	6	41,264,922	46,819,965
60-70	31,404,770	7	29,133,301	33,676,240

Diameter Class (cm)	Tree Count (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
70-80	21,161,284	8	19,493,329	22,829,240
80-90	16,054,694	9	14,567,898	17,541,490
90-100	10,311,675	11	9,227,380	11,395,970
>=100	24,063,100	12	21,249,963	26,876,238

Table 13: Tree count by diameter class within forest

Diameter Class (cm)	Tree Count (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	269,884,034	5	255,775,519	283,992,548
20-30	188,875,637	4	181,239,463	196,511,811
30-40	105,086,650	4	100,796,173	109,377,126
40-50	63,226,250	5	60,096,314	66,356,187
50-60	41,549,761	5	39,295,230	43,804,292
60-70	29,465,175	6	27,705,739	31,224,612
70-80	19,896,002	7	18,526,902	21,265,102
80-90	15,160,662	8	13,913,294	16,408,031
90-100	9,864,659	9	8,929,292	10,800,026
>=100	22,532,639	11	20,078,487	24,986,790

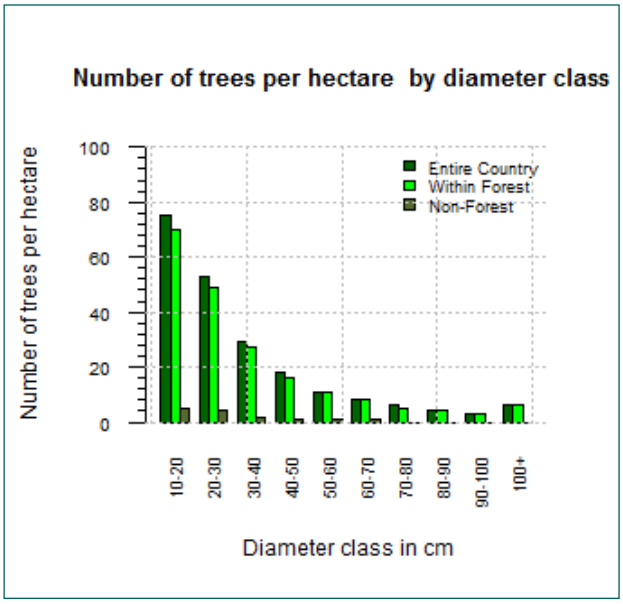

Figure 5: Comparison of tree count per hectare by diameter class

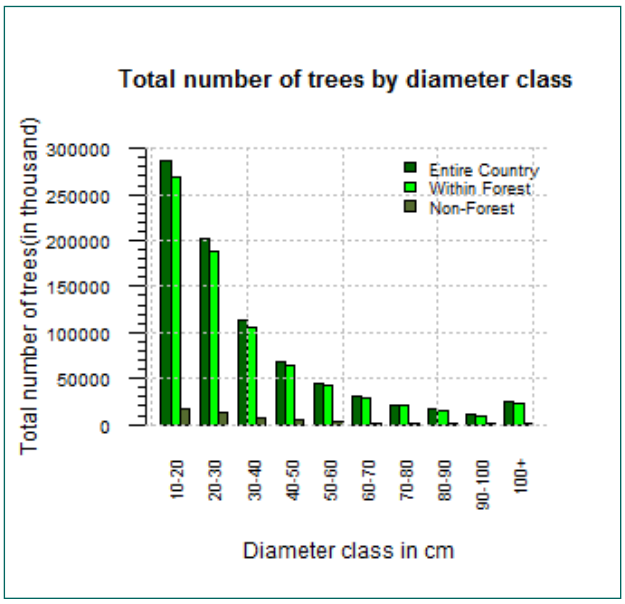

Figure 6: Comparison of total tree count by diameter class

Table 14: Tree count by diameter class within non-forest

Diameter Class (cm)	Tree Count (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	17,623,039	13	15,254,753	19,991,324
20-30	13,455,940	15	11,468,642	15,443,239
30-40	7,500,777	17	6,209,384	8,792,171
40-50	4,348,936	18	3,557,756	5,140,116
50-60	2,492,683	21	1,969,692	3,015,674
60-70	1,939,595	26	1,427,562	2,451,628
70-80	1,265,283	24	966,427	1,564,138
80-90	894,032	27	654,605	1,133,459
90-100	447,016	33	298,088	595,944
>=100	1,530,462	23	1,171,476	1,889,447

Table 15: Tree count per hectare by diameter class

Diameter Class (cm)	Tree Count per ha (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	75	6	71	79
20-30	53	5	50	55
30-40	29	5	28	31
40-50	18	6	17	19
50-60	11	6	11	12
60-70	8	7	8	9
70-80	6	8	5	6
80-90	4	9	4	5
90-100	3	11	2	3
>=100	6	12	6	7

Table 16: Tree count per hectare by diameter class within forest

Diameter Class (cm)	Tree Count per ha (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	70	5	67	74
20-30	49	4	47	51
30-40	27	4	26	28
40-50	16	5	16	17
50-60	11	5	10	11
60-70	8	6	7	8

Diameter Class (cm)	Tree Count per ha (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
70-80	5	7	5	6
80-90	4	8	4	4
90-100	3	9	2	3
>=100	6	11	5	7

Table 17: Tree count per hectare by diameter class within non-forest

Diameter Class (cm)	Tree Count per ha (No)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	5	13	4	5
20-30	4	15	3	4
30-40	2	17	2	2
40-50	1	18	1	1
50-60	1	21	1	1
60-70	1	26	0	1
70-80	0	24	0	0
80-90	0	27	0	0
90-100	0	33	0	0
>=100	0	23	0	0

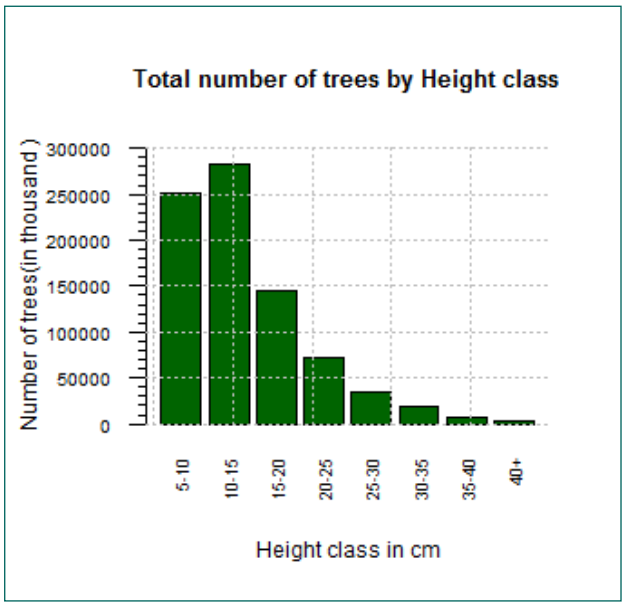

Figure 7 Total tree count by height class

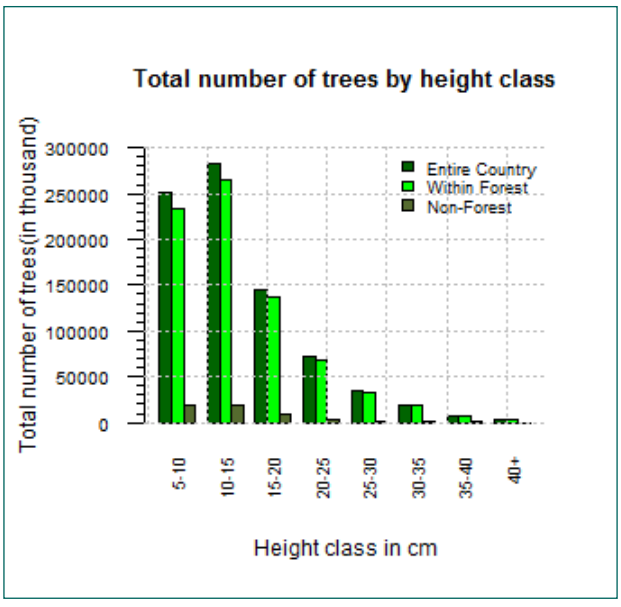

Figure 8: Comparison of total tree count by height class

4.2.5 Tree count by height classes

The height has been classified into 8 classes of 5-10 m, 10-15 m, 15-20 m, 20-25 m, 25-30 m, 30-35 m, 35-40 m and >=40 m.

The Tables 18 provides estimates of total tree count by different height classes irrespective of forest and non-forest for the entire country. The Tables 19 and 20 show the tree count estimates in different height classes within forest and non-forest areas respectively.

The tree count per hectare in different height classes irrespective of forest and non-forest for entire country is tabulated in Table 21, whereas the Tables 22 and 23 provide tree count per hectare within forest and non-forest area respectively. The total tree count and comparison of tree count by different height classes among forest, non-forest and entire country are illustrated in Figures 7 and 8 respectively.

Table 18: Total tree count by height class

Height Class (m)	Tree Count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	250,707,804	6	236,347,149	265,068,459
10-15	282,468,672	5	269,104,525	295,832,818
15-20	145,280,210	6	137,175,616	153,384,803
20-25	72,984,838	6	68,261,631	77,708,044
25-30	35,526,410	9	32,504,808	38,548,012
30-35	18,918,628	11	16,811,314	21,025,941
35-40	7,379,553	16	6,183,912	8,575,193
>=40	3,788,271	23	2,934,913	4,641,630

Table 19: Tree count by height class within forest

Height Class (m)	Tree Count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	232,827,163	5	221,148,360	244,505,966
10-15	264,307,698	4	253,346,138	275,269,259
15-20	137,006,625	5	130,450,754	143,562,496
20-25	69,014,729	6	65,126,849	72,902,610
25-30	33,518,626	7	31,043,689	35,993,562
30-35	18,115,514	10	16,263,268	19,967,760
35-40	7,053,761	15	5,989,927	8,117,596
>=40	3,712,506	21	2,914,807	4,510,205

Table 20: Tree count by height class within non-forest

Height Class (m)	Tree Count (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	17,880,641	15	15,198,789	20,562,493
10-15	18,160,973	13	15,758,388	20,563,559
15-20	8,273,585	19	6,724,862	9,822,308
20-25	3,970,108	21	3,134,783	4,805,434
25-30	2,007,784	27	1,461,119	2,554,449
30-35	803,114	32	548,046	1,058,181
35-40	325,791	40	193,985	457,598
>=40	75,765	73	20,106	131,425

Table 21 Tree count per hectare by height class

Height Class (m)	Tree Count per ha (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	65	6	62	69
10-15	74	5	70	77
15-20	38	6	36	40
20-25	19	6	18	20
25-30	9	9	8	10
30-35	5	11	4	5
35-40	2	16	2	2
>=40	1	23	1	1

Table 22 Tree count per hectare by height class within forest

Height Class (m)	Tree Count per ha (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	61	5	58	64
10-15	69	4	66	72
15-20	36	5	34	37
20-25	18	6	17	19
25-30	9	7	8	9
30-35	5	10	4	5
35-40	2	15	2	2
>=40	1	21	1	1

Table 23 Tree count per hectare by height class within non-forest

Height Class (m)	Tree Count per ha (No)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	5	15	4	5
10-15	5	13	4	5
15-20	2	19	2	3
20-25	1	21	1	1
25-30	1	27	0	1
30-35	0	32	0	0
35-40	0	40	0	0
>=40	0	73	0	0

4.2.6 Tree count by major trees

While 460 plus tree species were recorded during NFI enumeration, the tree count estimates for 28 major genus of trees in Bhutan are reported in the Table 24.

Table 24: Total tree count by major tree species

Species	Tree Count (No)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Abies densa	55,717,896	14	47,955,070	63,480,723
Acer spp.	25,623,868	12	22,447,926	28,799,810
Ailanthus integrifolia	1,439,543	60	574,020	2,305,066
Alnus spp.	8,349,350	24	6,307,176	10,391,525
Aphanamixis polystachya	1,636,533	42	956,985	2,316,082
Beilschmiedia spp.	7,728,074	20	6,214,481	9,241,667
Betula spp.	18,683,755	15	15,840,658	21,526,851
Bombax ceiba	568,241	40	343,393	793,089
Castanopsis spp.	36,594,702	16	30,872,039	42,317,366
Cupressus spp.	242,449	104	-9,152	494,051
Duabanga grandiflora	2,000,207	35	1,307,647	2,692,768
Engelhardtia spicata	7,364,400	22	5,779,055	8,949,744
Juniperus spp.	13,910,533	31	9,617,817	18,203,249
Larix griffithii	598,547	49	304,355	892,739
Magnolia spp.	10,735,961	15	9,079,971	12,391,951
Persea spp.	22,025,010	15	18,747,179	25,302,841
Phoebe hainesiana	30,306	165	-19,559	80,172
Picea spinulosa	8,947,897	29	6,354,653	11,541,141
Pinus roxburghii	16,850,231	29	11,970,398	21,730,064

Species	Tree Count (No)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Pinus wallichiana	37,375,086	24	28,305,156	46,445,016
Quercus spp.	86,016,491	9	78,413,921	93,619,062
Rhododendron spp.	89,100,144	10	80,062,949	98,137,339
Schima wallichii	15,872,857	19	12,906,194	18,839,520
Sterculia vilosa	1,022,833	36	659,584	1,386,083
Symplocos cochinchinensis	606,123	87	79,014	1,133,232
Terminalia myriocarpa	181,837	55	82,401	281,273
Tetrameles nudiflora	780,384	37	493,375	1,067,392
Tsuga dumosa	12,940,735	25	9,750,074	16,131,397

4.3 Basal Area

Stand basal area is the tree cross-sectional area at breast height summed over all the trees in a stand and expressed per unit ground area (West, 2009). It indicates the extent of area covered by tree stems and is easily measureable attribute for assessing stand density. Basal area of tree is reported to be positively correlated to its crown cover. It, therefore serves as an important measurement for understanding the competition among trees growing in an area. Basal area is a useful index for understanding forest-wildlife habitat relationships and making timber harvest decisions (basal_area_guide.pdf, Mississippi Wildlife, Fisheries and Parks).

The total basal area for the country is estimated to be 114,791,541 m^2 and an average of 30 m^2 per hectare with 5% margin of error for both estimates. These estimates are generated based on trees enumerated without segregating the country into forest and non-forest.

4.3.1 Basal area by forest and non-forest

Basal area estimates have also been made by segregating the country into forest and non-forests. Therefore, basal area estimate by forest and non-forest areas at a national level is tabulated in Table 25 while the Table 26 provides the basal area per hectare by forest and non-forest area.

Table 25: Basal area by forest and non-forest

Particular	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	107,911,592	5	102,072,451	113,750,733
Non-forest	6,879,950	15	5,860,445	7,899,454

Table 26: Basal area per hectare by forest and non-forest

Particular	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	40	5	38	41
Non-forest	6	14	5	7

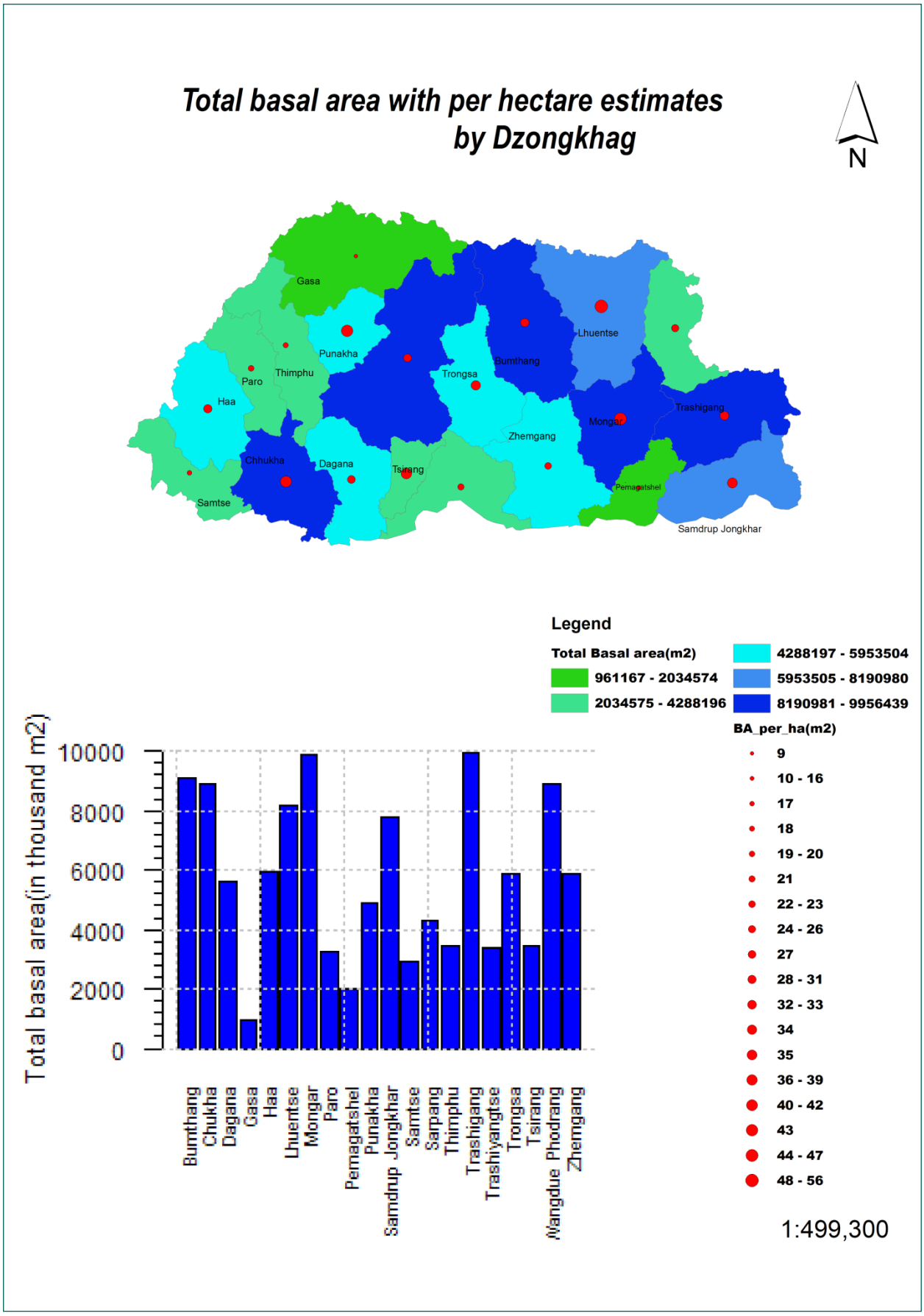

Figure 9: Basal area estimates by Dzongkhag

4.3.2 Basal area by Dzongkhag

The Table 27 provides the estimates of total basal area by dzongkhag, whereas the basal area estimates per hectare by dzongkhag is tabulated in Table 28. These estimates are graphically depicted in Figure 9.

Table 27: Total basal area by dzongkhag

Dzongkhag	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Bumthang	9,113,332	25	6,801,503	11,425,161
Chukha	8,930,964	29	6,381,958	11,479,969
Dagana	5,602,927	21	4,414,932	6,790,922
Gasa	961,167	41	565,705	1,356,630
Haa	5,953,504	25	4,489,559	7,417,449
Lhuntse	8,190,980	31	5,673,870	10,708,090
Mongar	9,901,153	25	7,462,217	12,340,089
Paro	3,233,250	29	2,293,943	4,172,557
Pemagatshel	2,034,574	28	1,472,638	2,596,510
Punakha	4,917,451	44	2,752,450	7,082,453
Samdrup Jongkhar	7,774,159	25	5,805,259	9,743,059
Samtse	2,951,339	25	2,213,717	3,688,961
Sarpang	4,288,196	22	3,341,781	5,234,612
Thimphu	3,435,862	30	2,419,802	4,451,922
Trashigang	9,956,439	21	7,906,993	12,005,885
Trashiyangtse	3,391,081	28	2,438,757	4,343,404
Trongsa	5,888,173	25	4,392,785	7,383,562
Tsirang	3,480,965	45	1,917,726	5,044,205
Wangdue Phodrang	8,881,214	21	7,059,102	1,070,3326
Zhemgang	5,904,811	18	4,850,756	6,958,866

Table 28: Basal area per hectare by dzongkhag

Dzongkhag	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Bumthang	31	21	25	38
Chukha	42	23	32	52
Dagana	27	13	24	31
Gasa	9	34	6	12
Haa	31	17	26	37
Lhuntse	56	23	43	69
Mongar	47	18	38	55

Dzongkhag	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Paro	20	22	16	25
Pemagatshel	16	17	13	19
Punakha	43	38	27	59
Samdrup Jongkhar	35	20	28	41
Samtse	17	17	14	20
Sarpang	21	14	18	24
Thimphu	18	24	14	22
Trashigang	33	15	28	38
Trashiyangtse	26	18	21	31
Trongsa	34	17	28	40
Tsirang	39	37	25	54
Wangdue Phodrang	27	16	23	31
Zhemgang	23	10	20	25

4.3.3 Basal area by Forest Type

The Table 29 provides the estimates of total basal area by forest type, whereas the basal area estimates per hectare by forest type is tabulated in Table 30.

Table 29: Total basal area by forest type

Forest Type	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Subtropical Forest	4,779,091	17	3,966,631	5,591,552
Warm Broadleaved Forest	19,916,536	11	17,753,440	22,079,633
Chirpine Forest	3,035,458	44	1,711,116	4,359,800
Cool Broadleaved Forest	49,177,533	10	44,310,479	54,044,588
Evergreen Oak Forest	1,309,743	45	722,964	1,896,522
Blue Pine Forest	4,799,319	39	2,929,359	6,669,279
Spruce Forest	1,965,564	49	997,476	2,933,653
Hemlock Forest	5,477,464	28	3,960,499	6,994,429
Fir Forest	17,175,922	15	14,590,927	19,760,918
Juniper- Rhododendron Scrub	1,579,923	38	984,981	2,174,864
Dry Alpine Scrub	19,481	108	-1536	40,498
Others	5,555,506	17	4,600,493	6,510,518

Table 30: Basal area per hectare by forest type

Forest Type	Basal area per ha (m^2)	Margin of Error (%)	90%Confidence interval	
			Lower	Upper
Subtropical Forest	18	9	17	20
Warm Broadleaved Forest	27	8	25	29
Chirpine Forest	27	37	17	38
Cool Broadleaved Forest	49	7	45	52
Evergreen Oak Forest	42	22	32	51
Blue Pine Forest	34	34	22	45
Spruce Forest	47	39	29	66
Hemlock Forest	60	16	50	69
Fir Forest	48	9	43	52
Juniper- Rhododendron Scrub	26	23	20	32
Dry Alpine Scrub	5	80	1	8
Others	6	17	5	7

4.3.4 Basal area by diameter classes

The diameter has been classified into 10 classes of 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm and >=100 cm.

The Table 31 provides estimates of total basal area by different diameter classes irrespective of forest and non-forest for the entire country. The Tables 32 and 33 show the basal area estimates in different diameter classes within forest and non-forest areas respectively.

The basal area per hectare for different diameter classes irrespective of forest and non-forest area is depicted in Table 34, while the Tables 35 and 36 provide the basal area per hectare in forest and non-forest areas respectively. For graphical summaries of these estimates, refer Figures 10 and 11.

Table 31: Total basal area by diameter class

Diameter Class (cm)	Basal area (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	5,235,586	6	4,947,515	5,523,657
20-30	9,429,362	5	8,984,062	9,874,663
30-40	10,538,991	5	10,012,241	11,065,740
40-50	10,527,956	6	9,914,233	11,141,680
50-60	10,321,214	6	9,667,693	10,974,735
60-70	10,276,988	7	9,533,633	11,020,342
70-80	9,156,739	8	8,432,797	9,880,681
80-90	9,010,929	9	8,169,586	9,852,272
90-100	7,252,753	11	6,487,498	8,018,008
>=100	33,040,958	13	28,764,681	37,317,235

Table 32: Basal area by diameter class within forest

Diameter Class (cm)	Basal area (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	4,908,416	5	4,664,830	5,152,002
20-30	8,810,575	4	8,456,815	9,164,336
30-40	9,837,539	4	9,433,455	10,241,623
40-50	9,854,280	5	9,362,884	10,345,677
50-60	9,739,159	5	9,208,157	10,270,160
60-70	9,646,519	6	9,069,602	10,223,435
70-80	8,599,766	7	8,007,965	9,191,567
80-90	8,513,907	8	7,805,610	9,222,205
90-100	6,936,433	10	6,276,470	7,596,395
>=100	31,064,932	12	27,277,453	34,852,411

Table 33: Basal area by diameter class within non-forest

Diameter Class (cm)	Basal area (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	327,170	14	282,685	371,655
20-30	618,787	15	527,247	710,327
30-40	701,452	17	578,786	824,118
40-50	673,676	18	551,349	796,002
50-60	582,055	21	459,536	704,575
60-70	630,469	26	464,031	796,907
70-80	556,973	24	424,832	689,115
80-90	497,021	27	363,975	630,067
90-100	316,320	33	211,028	421,613
>=100	1,976,026	25	1,487,228	2,464,823

Table 34: Basal area per hectare by diameter class

Diameter Class (cm)	Basal area per ha (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	1	6	1	1
20-30	2	5	2	3
30-40	3	5	3	3
40-50	3	6	3	3
50-60	3	6	3	3
60-70	3	7	2	3

Diameter Class (cm)	Basal area per ha (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
70-80	2	8	2	3
80-90	2	9	2	3
90-100	2	11	2	2
>=100	9	13	7	10

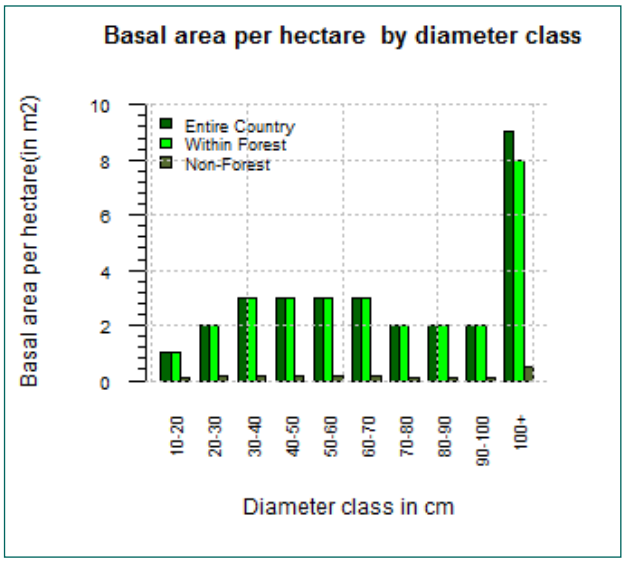

Figure 10: Comparison of basal area per hectare by diameter class

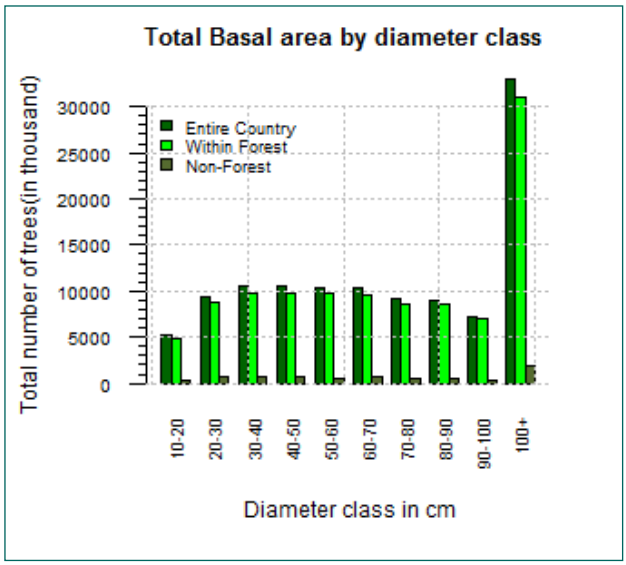

Figure 11: Comparison of total basal area by diameter class

Table 35: Basal area per hectare by diameter class within forest

Diameter Class (cm)	Basal area per ha (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	1	5	1	1
20-30	2	4	2	2
30-40	3	4	2	3
40-50	3	5	2	3
50-60	3	5	2	3
60-70	3	6	2	3
70-80	2	7	2	2
80-90	2	8	2	2
90-100	2	10	2	2
>=100	8	12	7	9

Table 36: Basal area per hectare by diameter class within non-forest

Diameter Class (cm)	Basal area per ha (m^2)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	0.1	14	0.1	0.1
20-30	0.2	15	0.1	0.2
30-40	0.2	17	0.2	0.2
40-50	0.2	18	0.1	0.2
50-60	0.2	21	0.1	0.2
60-70	0.2	26	0.1	0.2
70-80	0.1	24	0.1	0.2
80-90	0.1	27	0.1	0.2
90-100	0.1	33	0.1	0.1
>=100	0.5	25	0.4	0.6

4.3.5 Basal area by height classes

The height has been classified into 8 classes of 5-10 m, 10-15 m, 15-20 m, 20-25 m, 25-30 m, 30-35 m, 35-40 m and >=40 m.

The Table 37 provides estimates of total basal area by different height classes irrespective of forest and non-forest area for the entire country. The Tables 38 and 39 show the basal area estimates in different height classes within forest and non-forest areas respectively.

The basal area per hectare in different height classes irrespective of forest and non-forest for entire country is tabulated in Table 40, whereas the Tables 41 and 42 provide basal area per hectare within forest and non-forest area respectively.

Table 37: Total basal area by height class

Height Class (m)	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	12,572,187	11	11,198,272	13,946,102
10-15	24,922,738	8	22,953,175	26,892,301
15-20	24,240,942	7	22,468,634	26,013,249
20-25	21,033,059	8	19,297,846	22,768,272
25-30	14,595,493	10	13,110,914	16,080,071
30-35	10,064,858	16	8,498,772	11,630,943
35-40	4,795,585	23	3,713,243	5,877,928
>=40	2,566,680	28	1,839,212	3,294,148

Table 38: Basal area by height class within forest

Height Class (m)	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	11,469,743	10	10,340,619	12,598,867
10-15	23,393,533	7	21,690,858	25,096,208
15-20	22,925,599	7	21,420,417	24,430,782
20-25	19,879,182	7	18,417,535	21,340,829
25-30	13,684,261	9	12,485,948	14,882,574
30-35	9,509,274	14	8,159,772	10,858,775
35-40	4,534,226	21	3,570,442	5,498,011
>=40	2,515,773	27	1,843,648	3,187,897

Table 39: Basal area by height class in non-forest

Height Class (m)	Basal area (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	1,102,444	22	857,653	1,347,234
10-15	1,529,205	17	1,262,317	1,796,092
15-20	1,3153,43	20	1,048,218	1,582,468
20-25	1,153,877	24	880,311	1,427,443
25-30	911,232	31	624,966	1,197,498
30-35	555,584	39	338,999	772,168
35-40	261,359	45	142,800	379,917
>=40	50,907	109	-4437	106,251

Table 40: Basal area per hectare by height class

Height Class (m)	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	3	11	3	4
10-15	6	8	6	7
15-20	6	7	6	7
20-25	5	8	5	6
25-30	4	10	3	4
30-35	3	16	2	3
35-40	1	23	1	2
>=40	1	28	0	1

Table 41: Basal area per hectare by height class within forest

Height Class (m)	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	3	10	3	3
10-15	6	7	6	7
15-20	6	7	6	6
20-25	5	7	5	6
25-30	4	9	3	4
30-35	2	14	2	3
35-40	1	21	1	1
>=40	1	27	0	1

Table 42: Basal area per hectare by height class within non-forest

Height Class (m)	Basal area per ha (m^2)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	0.3	22	0.2	0.4
10-15	0.4	17	0.3	0.5
15-20	0.3	20	0.3	0.4
20-25	0.3	24	0.2	0.4
25-30	0.2	31	0.2	0.3
30-35	0.1	39	0.1	0.2
35-40	0.1	45	0.0	0.1
>=40	0.0	109	0.0	0.0

4.3.6 Basal area by major trees

As with the tree count estimates, the basal area estimates for 28 major genus of trees in Bhutan are reported in the Table 43.

Table 43: Basal area by major tree species

Species	Basal area (m^2)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Abies densa	16,094,918	18	13,165,804	19,024,033
Acer spp.	3,990,626	21	3,147,308	4,833,944
Ailanthus integrifolia	117,796	60	47,583	188,008
Alnus spp.	1,719,579	45	947,999	2,491,159
Aphanamixis polystachya	107,304	50	53,129	161,479
Beilschmiedia spp.	689,571	25	516,002	863,141
Betula spp.	2,510,130	20	2,007,568	3,012,692
Bombax ceiba	428,100	44	239,746	616,453
Castanopsis spp.	4,729,598	17	3,947,347	5,511,849

Species	Basal area (m^2)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Cupressus spp.	89,125	73	23,653	154,596
Duabanga grandiflora	615,047	55	278,939	951,156
Engelhardtia spicata	884,283	36	568,309	1,200,256
Juniperus spp.	1,274,774	37	803,832	1,745,716
Larix griffithii	104,565	70	30,971	178,158
Magnolia spp.	2,520,473	21	1,999,605	3,041,340
Persea spp.	4,775,978	23	3,697,252	5,854,705
Phoebe hainesiana	185,542	84	29,469	341,615
Picea spinulosa	1,717,181	42	1,003,512	2,430,850
Pinus roxburghii	3,294,583	44	1,856,921	47,322,45
Pinus wallichiana	4,593,705	41	2,702,335	6,485,074
Quercus spp.	16,811,310	11	15,026,390	18,596,229
Rhododendron spp.	6,212,397	15	5,255,734	7,169,060
Schima wallichii	1,788,229	35	1,169,092	2,407,366
Sterculia vilosa	432,594	67	142,660	722,528
Symplocos cochinchinensis	18,615	73	4,971	32,259
Terminalia myriocarpa	44,286	93	3,199	85,374
Tetrameles nudiflora	323,469	46	175,559	471,378
Tsuga dumosa	4,274,175	28	3,064,809	5,483,540

4.4 Growing stock

The forest management code of Bhutan, 2004 defines growing stock as the standing volume of all living trees in a given area of forest. For this national estimate, the growing stock is the standing volume for all trees having dbh of 10 cm and above. The volume estimates are based on the 29 general volume equations developed during PIS.

The growing stock per hectare is estimated to be 261 m^3 and the total growing stock of country is 1001 million m^3 with 6% margin of error for both estimates. These estimates are generated without segregating the country into forests and non-forests.

4.4.1 Total volume by forest and non-forest

Volume estimates have also been generated by segregating the country into forest and non-forests. Therefore, the Tables 44 provides estimates of total volume in forest and non-forest area while the Table 45 shows the estimates of volume per hectare.

Table 44: Total volume by forest and non-forest

Particular	Total Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	944,261,791	6	88,666,3574	1,001,860,008
Non-forest	56,726,859	16	47,612,870	65,840,848

Table 45: Volume per hectare by forest and non-forest

Particular	Volume per ha (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Forest	346	6	327	365
Non-forest	51	16	43	59

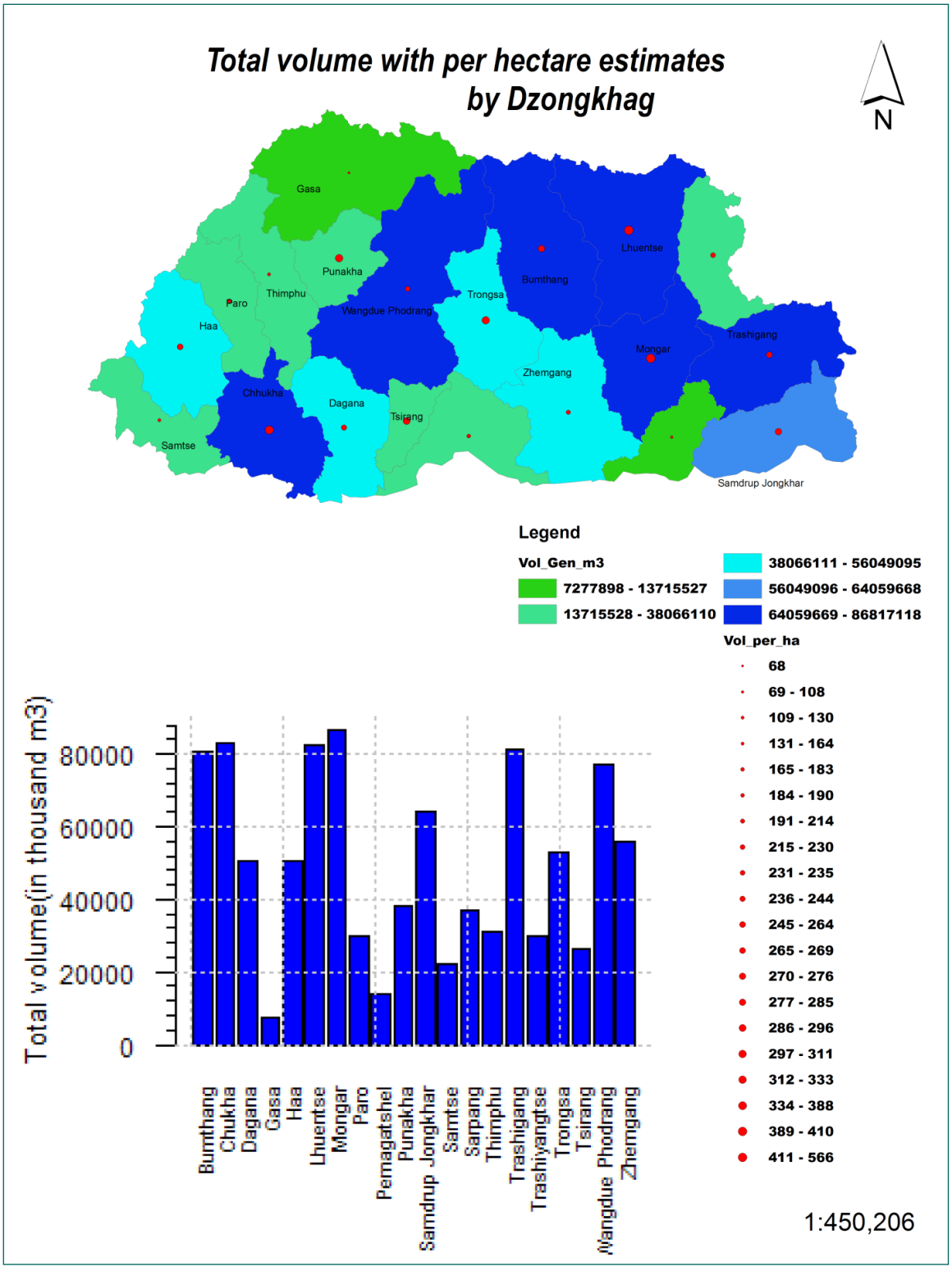

Figure 12: Volume estimates by Dzongkhag

4.4.2 Volume by Dzongkhag

The Table 46 provides the estimates of total volume estimates by dzongkhag whereas the volume estimates per hectare by dzongkhag is tabulated in Table 47. These estimates are graphically depicted in Figure 12.

Table 46: Total volume by dzongkhag

Dzongkhag	Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Bumthang	80,762,631	28	57,990,766	103,534,495
Chukha	82,958,251	34	54,568,982	111,347,521
Dagana	50,545,703	23	38,953,617	62,137,790
Gasa	7,277,898	44	4,056,847	10,498,950
Haa	50,497,520	25	37,820,925	63,174,114
Lhuntse	82,316,715	33	55,414,249	109,219,182
Mongar	86,817,118	27	63,643,891	109,990,344
Paro	30,123,103	32	20,427,131	39,819,074
Pemagatshel	13,715,527	30	9,631,699	17,799,356
Punakha	38,066,110	41	22,390,803	53,741,416
Samdrup Jongkhar	64,059,668	24	48,890,186	79,229,151
Samtse	22,145,634	26	16,468,418	27,822,850
Sarpang	36,959,686	23	28,361,025	45,558,347
Thimphu	31,038,099	32	21,186,049	40,890,150
Trashigang	81,428,565	22	63,254,178	99,602,953
Trashiyangtse	29,750,481	32	20,145,561	39,355,402
Trongsa	53,083,953	29	37,861,744	68,306,161
Tsirang	26,232,194	49	13,281,737	39,182,651
Wangdue Phodrang	77,160,697	20	61,372,361	92,949,034
Zhemgang	56,049,095	19	45,371,591	66,726,599

Table 47: Volume per hectare by dzongkhag

Dzongkhag	Volume per ha (m^3)	Margin of Error (%)	90% Confidence Interval	
			Lower	Upper
Bumthang	276	24	209	344
Chukha	388	30	272	504
Dagana	244	16	206	282
Gasa	68	37	43	94
Haa	264	18	217	312
Lhuntse	566	26	420	711

Dzongkhag	Volume per ha (m^3)	Margin of Error (%)	90% Confidence Interval	
			Lower	Upper
Mongar	410	21	325	496
Paro	190	26	141	239
Pemagatshel	108	20	86	130
Punakha	333	34	219	447
Samdrup Jongkhar	285	17	235	334
Samtse	130	18	107	153
Sarpang	183	16	154	212
Thimphu	164	26	120	207
Trashigang	269	18	222	317
Trashiyangtse	230	24	174	285
Trongsa	311	22	243	379
Tsirang	296	42	172	420
Wangdue Phodrang	235	16	198	272
Zhemgang	214	12	188	239

4.4.3 Volume by Forest Type

The Table 48 provides the estimates of total volume estimates by forest type whereas the volume estimates per hectare by forest type is tabulated in Table 49.

Table 48: Total volume by forest type

Forest Type	Volume (m^3)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Subtropical Forest	40,138,915	19	32,659,421	47,618,409
Warm Broadleaved Forest	167,010,550	11	148,327,316	185,693,784
Chirpine Forest	23,213,144	43	13,137,474	33,288,815
Cool Broadleaved Forest	438,025,418	11	391,882,941	484,167,894
Evergreen Oak Forest	10,704,461	47	5,720,295	15,688,627
Blue Pine Forest	47,630,853	50	24,017,835	71,243,870
Spruce Forest	16,724,318	46	9,113,333	24,335,302
Hemlock Forest	53,694,358	29	38,280,478	69,108,238
Fir Forest	147,584,360	16	124,452,068	170,716,653
Juniper- Rhododendron Scrub	11,313,793	42	6,546,253	16,081,332
Dry Alpine Scrub	95,854	110	-9389	201,097
Others	44,852,628	18	36,697,314	53,007,942

Table 49: Volume per hectare by forest type

Forest Type	Volume per ha (m^3)	Margin of error (%)	90% Confidence interval	
			Lower	Upper
Subtropical Forest	154	12	135	173
Warm Broadleaved Forest	226	8	207	244
Chirpine Forest	210	37	132	287
Cool Broadleaved Forest	432	8	396	468
Evergreen Oak Forest	340	26	252	428
Blue Pine Forest	332	46	181	484
Spruce Forest	401	36	256	546
Hemlock Forest	583	18	478	688
Fir Forest	409	10	367	450
Juniper- Rhododendron Scrub	185	29	132	239
Dry Alpine Scrub	23	82	4	42
Others	46	18	38	54

4.4.5 Volume by diameter classes

The diameter has been classified into 10 classes of 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm and >=100 cm.

The Table 50 provides estimates of total volume estimate by different diameter classes irrespective of forest and non-forest for the entire country. The Tables 51 and 52 show the volume estimates in different diameter classes within forest and non-forest areas respectively.

The volume per hectare for different diameter classes irrespective of forest and non-forest area is depicted in Table 53, while the Tables 54 and 55 provide the volume per hectare in forest and non-forest areas respectively. For graphical summaries of these estimates, refer Figures 13, 14 and 15.

Table 50: Total volume by diameter class

Diameter Class (cm)	Volume (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	26,588,104	6	25,097,280	28,078,928
20-30	58,219,008	5	55,314,990	61,123,026
30-40	74,366,025	5	70,491,156	78,240,894
40-50	82,462,862	6	77,517,182	87,408,542
50-60	87,773,859	7	81,994,499	93,553,220
60-70	92,103,408	8	85,116,029	99,090,787
70-80	84,528,987	8	77,645,611	91,412,362
80-90	85,893,893	9	77,995,632	93,792,154
90-100	71,247,266	11	63,409,949	79,084,582
>=100	337,804,979	14	291,703,733	383,906,224

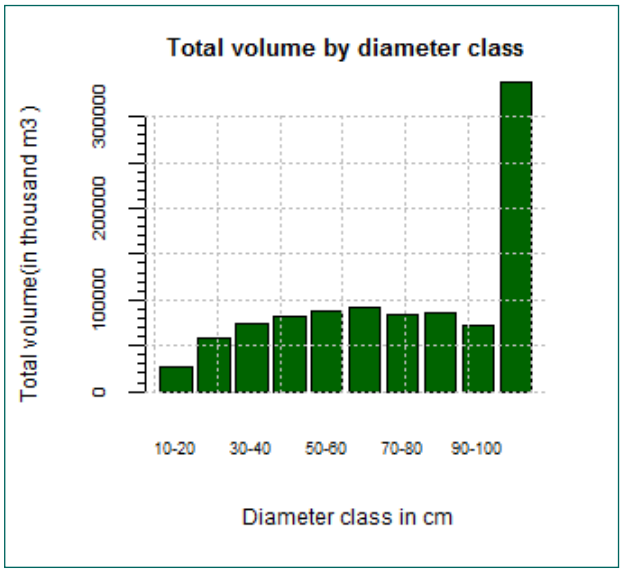

Figure 13: Total volume by diameter class

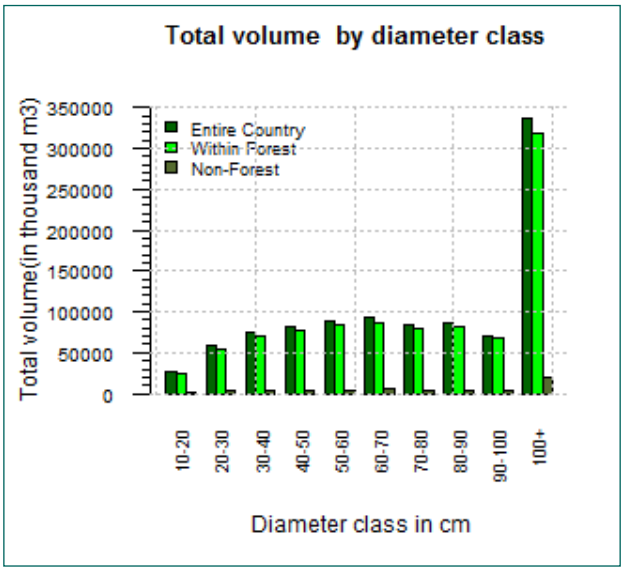

Figure 14: Comparison of total volume by diameter class

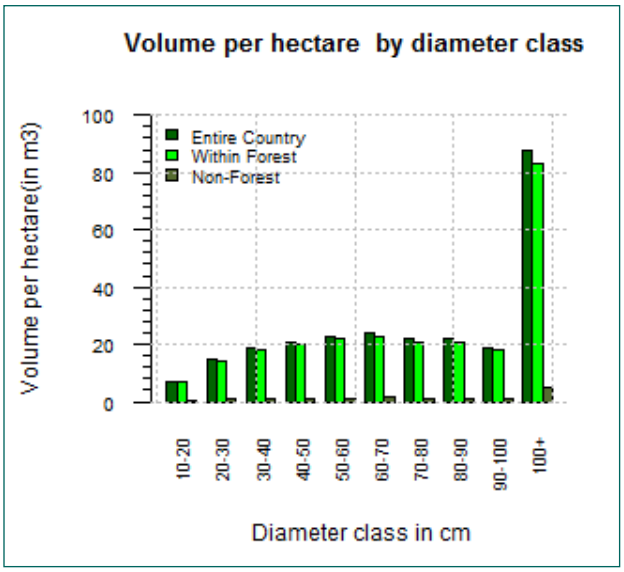

Figure 15: Comparison of volume per hectare by diameter class

Table 51: Volume by diameter class within forest

Diameter Class (cm)	Volume (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	24,964,767	5	23,695,477	26,234,057
20-30	54,633,847	4	52,288,536	56,979,158
30-40	69,703,136	4	66,659,181	72,747,090
40-50	77,707,422	5	73,631,604	81,783,241
50-60	83,148,950	6	78,355,227	87,942,674
60-70	86,719,083	6	81,232,159	92,206,006
70-80	80,045,648	7	74,291,502	85,799,793

Diameter Class (cm)	Volume (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
80-90	81,525,554	8	74,785,167	88,265,941
90-100	67,988,983	10	61,283,226	74,694,739
>=100	317,824,143	13	277,010,847	358,637,439

Table 52: Volume by diameter class within non-forest

Diameter Class (cm)	Volume (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	1,623,338	14	1,401,804	1,844,871
20-30	3,585,162	16	3,026,454	4,143,869
30-40	4,662,890	18	3,831,976	5,493,804
40-50	4,755,440	18	3,885,578	5,625,301
50-60	4,624,909	21	3,639,271	5,610,546
60-70	5,384,325	28	3,883,870	6,884,780
70-80	4,483,339	25	3,354,108	5,612,569
80-90	4,368,339	27	3,210,465	5,526,213
90-100	3,258,283	35	2,126,723	4,389,843
>=100	19,980,836	26	14,692,886	252,687,85

Table 53: Volume per hectare by diameter class

Diameter Class (cm)	Volume per ha (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	7	6	7	7
20-30	15	5	14	16
30-40	19	5	18	20
40-50	21	6	20	23
50-60	23	7	21	24
60-70	24	8	22	26
70-80	22	8	20	24
80-90	22	9	20	24
90-100	19	11	17	21
>=100	88	14	76	100

Table 54: Volume per hectare by diameter class within forest

Diameter Class (cm)	Volume per ha (m^3)	Margin of Error (%)	90 % confidence interval	
			Lower	Upper
10-20	7	5	6	7
20-30	14	4	14	15
30-40	18	4	17	19
40-50	20	5	19	21
50-60	22	6	20	23
60-70	23	6	21	24
70-80	21	7	19	22
80-90	21	8	19	23
90-100	18	10	16	19
>=100	83	13	72	93

Table 55: Volume per hectare by diameter class within non-forest

Diameter Class (cm)	Volume per ha (m^3)	Margin of Error (%)	90 % Confidence interval	
			Lower	Upper
10-20	0.4	14	0.4	0.5
20-30	0.9	16	0.8	1.1
30-40	1.2	18	1.0	1.4
40-50	1.2	18	1.0	1.5
50-60	1.2	21	0.9	1.5
60-70	1.4	28	1.0	1.8
70-80	1.2	25	0.9	1.5
80-90	1.1	27	0.8	1.4
90-100	0.8	35	0.6	1.1
>=100	5.2	26	3.8	6.6

4.4.6 Volume by height classes

The height has been classified into 8 classes of 5-10 m, 10-15 m, 15-20 m, 20-25 m, 25-30 m, 30-35 m, 35-40 m and >=40 m.

The Table 56 provides estimates of total volume by different height classes irrespective of forest and non-forest area for the entire country. The Tables 57 and 58 show the volume estimates in different height classes within forest and non-forest areas respectively.

The volume per hectare in different height classes irrespective of forest and non-forest for entire country is tabulated in Table 59, whereas the Tables 60 and 61 provide volume per hectare within forest and non-forest area respectively.

Table 56: Total volume by height class

Height Class (m)	Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	147,587,570	8	135,866,377	159,308,764
10-15	188,428,530	7	174,663,895	202,193,165
15-20	201,311,590	8	184,957,435	217,665,744
20-25	168,860,259	10	151,440,809	186,279,709
25-30	130,437,327	15	110,440,115	150,434,538
30-35	70,134,971	22	54,660,763	85,609,179
35-40	49,692,320	11	44,279,500	55,105,141
>=40	44,536,083	28	31,893,984	57,178,182

Table 57: Volume by height class within forest

Height Class (m)	Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	138,528,992	7	128,401,740	148,656,243
10-15	178,198,602	7	166,514,535	189,882,669
15-20	190,173,747	7	176,496,285	203,851,208
20-25	158,491,692	9	144,403,234	172,580,150
25-30	123,366,737	14	106,105,905	140,627,570
30-35	66,330,936	21	52,577,195	80,084,677
35-40	45,512,590	10	41,010,816	50,014,364
>=40	43,658,495	27	31,972,450	55,344,540

Table 58: Volume by height class within non-forest

Height Class (m)	Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	9,058,578	18	7,464,636	10,652,520
10-15	10,229,928	20	8,149,360	12,310,496
15-20	11,137,843	24	8,461,150	13,814,536
20-25	10,368,567	32	7,037,576	13,699,559
25-30	7,070,589	39	4,334,210	9,806,968
30-35	3,804,035	45	2,083,568	5,524,502
35-40	4,179,730	22	3,268,684	5,090,777
>=40	877,588	109	-78467	1,833,642

Table 59: Volume per hectare by height class

Height Class (m)	Volume per ha (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	13	11	12	14
10-15	38	8	35	41
15-20	49	7	45	53
20-25	52	8	48	57
25-30	44	10	39	49
30-35	34	15	29	39
35-40	18	22	14	22
>=40	12	28	8	15

Table 60: Volume per hectare by height class within forest

Height Class (m)	Volume per ha (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	12	10	11	13
10-15	36	7	33	39
15-20	46	7	43	49
20-25	50	7	46	53
25-30	41	9	38	45
30-35	32	14	28	37
35-40	17	21	14	21
>=40	11	27	8	14

Table 61: Volume per hectare by height class within non-forest

Height Class (m)	Volume per ha (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
5-10	1	22	1	1
10-15	2	18	2	3
15-20	3	20	2	3
20-25	3	24	2	4
25-30	3	32	2	4
30-35	2	39	1	3
35-40	1	45	1	1
>=40	0	109	0	0

4.4.7 Volume by major tree species

As with the estimates for tree count and basal area, the estimates for 28 major genus of trees in Bhutan are reported in the Table 62.

Table 62: Total volume by major tree species

Species	Volume (m^3)	Margin of Error (%)	90% Confidence interval	
			Lower	Upper
Abies densa	150,849,177	20	121,310,404	180,387,950
Acer spp.	34,556,461	21	27,166,392	41,946,529
Ailanthus integrifolia	1,023,279	59	418,575	1,627,984
Alnus spp.	18,067,583	50	9,110,048	27,025,119
Aphanamixis polystachya	862,555	54	392,693	1,332,417
Beilschmiedia spp.	6,214,392	28	4,477,063	7,951,722
Betula spp.	22,725,357	21	17971744	27,478,969
Bombax ceiba	3,644,572	48	1,886,485	5,402,660
Castanopsis spp.	41,451,068	18	34,041,133	48,861,003
Cupressus spp.	687,598	75	170,533	1,204,663
Duabanga grandiflora	6,442,472	61	2,506,328	10,378,616
Engelhardtia spicata	7,334,435	31	5,069,115	9,599,754
Juniperus spp.	8,652,133	42	5,018,214	12,286,053
Larix griffithii	871,225	75	213,860	1,528,591
Magnolia spp.	25,062,080	24	19,038,383	31,085,778
Persea spp.	45,433,542	24	34,327,563	56,539,520
Phoebe hainesiana	1,793,240	110	-176780	3,763,260
Picea spinulosa	16,435,038	41	9,733,366	23,136,711
Pinus roxburghii	28,694,088	42	16,534,615	40853561
Pinus wallichiana	49,020,050	49	24,958,241	73,081,859
Quercus spp.	167,106,952	11	148,045,603	186,168,301
Rhododendron spp.	36,415,725	18	29,953,653	42,877,797
Schima wallichii	16,059,934	42	9,375,585	22,744,284
Sterculia vilosa	4,866,251	75	1,228,023	8,504,478
Symplocos cochinchinensis	173,241	88	20,964	325,518
Terminalia myriocarpa	774,273	92	62,188	1,486,357
Tetrameles nudiflora	3,040,422	48	1,590,099	4,490,745
Tsuga dumosa	40,626,371	27	29,614,694	51,638,048

Chapter 5
Way forward

The NFI plots are permanent sample plots which are geo-referenced and will be re-visited for future periodic inventories. These plots have been marked with galvanized iron pipe at the centre of each plot to enable re-locating them in future.

The estimates and result presented in this report volume I will mainly guide in answering some of the questions relating to sustainable forest management. However, a major chunk of work is still left to be completed that includes working on volume II of the NFI report.

The volume II of NFI report will contain estimates and results on biomass, forest carbon, soil carbon, biodiversity information apart from information on regeneration, increment, sapling, wildlife, non-wood forest produce, forest disturbance and forest health.

All these information when combined with results presented in this Volume I will present a comprehensive picture of state of Bhutan's forest. The quality assurance and quality control (QAQC) exercise which involves revisiting 10% of the NFI sample plots will be continued to assess the sources of variablity for improving the qiality of data of our upcoming reports and the quality of future inventories.

Most importantly, the current initiative on NFI, while offering us the baseline information on our forest, establishes a foundation for periodic inventories in future. The periodic inventories are imperative for monitoring 60% forest cover mandate as enshrined in the constitution of Bhutan.

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Annexure I: List of National Forest Inventory Team Members

a. NFI Coordination Team

Sl.	Name	Designation	Office
	Lobzang Dorji	Chief Forestry Officer (2014-)	FRMD
1	Dr. D.B Dhital	Chief Forestry Officer (2009)	FRMD
2	Kinley Tshering	Chief Forestry Officer (2009-2014)	FRMD
4	Kezang Yangden	Sr. Forestry Officer	FRMD
5	Younten Phuntsho	Sr. Forestry Officer	FRMD
6	Santosh Katwal	Sr. Forestry Officer	FRMD
7	Ugyen Penjor	Forestry Officer (2015-2016)	FRMD
8	Dorji Wangdi	Sr. Forestry Officer (2016-)	FRMD

b. NFI Core Team (Advisory)

Sl.	Name	Designation	Office
1	Secretary		MOAF
2	Director		DoFPS
3	Chief Forestry Officer(s)		FRMD, SFED, FPED, WCD, NRED, WMD
4	Thinley Namgyel	Chief Environment Officer	NECS
5	Chukey Wangchuk	Chief Program Officer (2009-2015)	BTFEC
6	Rebecca Pradhan	Ecologist	RSPN
7	Rinchen Yangzom	Dy. Chief Biodiversity Officer	NBC
8	Representative from NSSC		NSSC

c. NFI Crew

Sl.	Name	Designation	Office
1	Late Langa Tshering	Sr. Forest Ranger II (Crew Leader)	Gedu Division
2	Kezang Dorji	Sr. Forest Ranger I	Samtse Division
3	Karma Tenzin	Forest Ranger II	Gedu Division
4	Basant Thapa	Forester	Gedu Division
5	I K Bhujel	Forester	Samtse Division
6	Tashi	Sr. Forest Ranger II (Crew Leader)	Paro Division
7	Tshering Wangchuk	Forester	Paro Division
8	Tshering Phuntsho	Sr. Forester	Wangdue Division

Sl.	Name	Designation	Office
9	Tashi Phuntsho	Forester	Wangdue Division
10	Tenzin Dorji	Sr. Forester	Wangdue Division
11	Tenzin Jamtsho	Forest Ranger I (Crew Leader)	Paro Division
12	Nidup Dorji	Forest Ranger II	Paro Division
13	Phurpa Tshering	Sr. Forester	Paro Division
14	Tularam Suberi	Forester	Sarpang Division
15	Guman Singh Biswa	Sr. Forester	JKSNR
16	Jamyang Tenzin	Sr. Forest Ranger II (Crew Leader)	UWICE
17	Kezang Phuntsho	Forester	Thimphu Division
18	Dorji Wangchuk	Forester	Thimphu Division
19	Sonam Wangpo	Forester	Thimphu Division
20	Chengala	Forester	Thimphu Division
21	Sonam Wangdi	Sr. Forest Ranger (Crew Leader)	RMNP
22	Rinchen Dorji	Forester	RMNP
23	Singye	Sr. Forester	RMNP
24	Phurba Dorji	Sr. Forester	Zhemgang Division
25	Harkey Ghalley	Sr. Forester	Zhemgang Division
26	Yeshey Nedup	Sr. Forest Ranger II (Crew Leader)	WCNP
27	Tandin Wangchuk	Forester	PNP
28	Chimi Tshewang	Forester	JSWNP
29	Sangay Tshering	Sr. Forester	JSWNP
30	Sangay Penjor	Forester	JDNP
31	Gyeltshen	Forester	Tsirang Division
32	Dawa Wangdi Sherpa	Sr. Forester	Tsirang Division
33	Sangay Lhajay	Sr. Forester	Sarpang Division
34	Dorji Dukpa	Forester	Sarpang Division
35	Tashi Tobgay	Forest Ranger II (Crew Leader)	JDNP
36	Gembo Tshering	Forester	Mongar Division
37	Dawa Norbu	Sr. Forester	Mongar Division
38	Rinchen Khandu	Forest Ranger I (Crew Leader)	SWS
39	Lhakpa Tshering	Sr. Forest Ranger II	BWS
40	Tashi Dorji	Forester	JDNP
41	Tshering Wangchuk	Forester	JSWNP

Sl.	Name	Designation	Office
42	Rinchen Dorji	Forester	Trashigang Division
43	Phurpa Dorji	Sr. Forester (Crew Leader)	SWS
44	Nidup Dorji	Sr. Forester	Trashigang Division
45	Chedup	Forester	Trashigang Division
46	Pema Namgyal	Forester	SWS
47	Tenzin Rabgay	Forest Ranger (Crew Leader)	JDNP
48	Karma Nidup	Forest Ranger	Samdrup Jongkhar Division
49	Karman Subba	Sr. Forester	Samdrup Jongkhar Division
50	Karma Gyeltshen	Forester	JDNP
51	Namgay Dorji	Forester	JDNP
52	Lha Tshering	Forest Ranger I (2012-2015) (Crew leader)	Mongar Division
53	Late Wangchuk	Sr. Forest Ranger II (2012-2014)	Samdrup Jongkhar Division
54	DB Chettri	Sr. Forest Ranger I (2012-2014) (Crew Leader)	Tsirang Division
55	Sonam Drupchu	Sr. Forest Ranger II (2012-2014) (Crew leader)	Mongar Division
56	Phuntsho	Sr. Forest Ranger II (2012-2014) (Crew leader)	SWS
57	Karma Dorji	Forest Ranger I (2012-2014) (Crew leader)	Wangdue Division
58	Dorji Wangdi	Sr. Forest Ranger II (2012-2013)	BWS

d. NFI Data Management and Analysis Team

Sl.	Name	Designation	Office
1	Kezang Yangden	Sr. Forestry Officer	FRMD
2	Younten Phuntsho	Sr. Forestry Officer	FRMD
3	Santosh Katwal	Sr. Forestry Officer	FRMD
4	Dorji Wangdi	Sr. Forestry Officer	FRMD

e. External Experts for Data Analysis

Sl.	Name	Designation	Office
1	Javier Garcia Perez	Forest Statistician	FAO, ROME
2	Stefano Ricci	Software Engineer	FAO, ROME

f. NFI External Advisor

Sl.	Name	Designation	Office
1	Timothy G. Gregoire	Professor	Yale FES, USA

g. NFI QAQC team I

Sl.	Name	Designation	Office
1	Tshedar	Sr. Forest Ranger	FRMD
2	Dorji Wangchuk	Forester	FRMD
3	Norbu Wangchuk	Forester	FRMD
4	Sangay Tshering	Field Assitant	FRMD
5	Gyeltshen	Field Assitant	FRMD
6	Pema Tenzin	Field Assitant	FRMD
7	Tshering Sherpa	Field Assitant	FRMD
8	Norjay	Field Assitant	FRMD

h. NFI QAQC team II

Sl.	Name	Designation	Office
1	Tashi Tobgay	Forest Ranger II	JDNP
2	Dorji Wangchuk	Forester	Thimphu Division
3	Dorji Dukpa	Forester	Sarpang Division
4	Sangay Lhajay	Sr. Forester	Sarpang Division
5	Rinchen Dorji	Forester	RMNP

Annexure II: Forest Type

Sl. No	Forest Type	Code	Characteristics	Characteristic species
1	Subtropical Forest	STFr	• Contain many tropical genera and species, forming dense jungle • Scattered Sal trees in Sarbang areas • Altitudinal range: 200-1000 m (-1200m)	*Acraocarpus fraxinifolius, Ailanthus grandis, Bombax ceiba, Crateva regiliosa, Dellinia pentgyna, Duanbanga grandiflora. Gmelina arborea, Leea asiatica, Musa, Pnadanus, Pterospermum aceriflolium, Shorea robusta, Tetremeles nudiflora, Thunbergia*
2	Warm Broad-leaved Forest	WBFr	• Type of Subtropical forest, but occurs at higher altitude with lower rainfall • Contains mixture of Evergreen and deciduous broad leaved species • Many of the tropical genera e.g. Duabanga, Pterospermum and Tetrameles are absent • Altitudinal range: 1000-2000m(-2300m)	*Alangium chinensis, Altingia excels, Bischofia javanica Calicarpa arborea, Castanopsis indica, Cordia oblique, Dendrocalamus hookeri Dichroa febrifuga, Engelhardia spicata, Eoudia fraxinifolia, Macaranga pustulata, Maesa spp., Mussaenda roxburghii, Pouzolzia sanguine, Raphidophora eximea, Schima wallichi, Wandlandia puberula*
3	Chirpine Forest	CPFr	• Low-altitude xerophytic forest occurring in the deeper dry valleys of Bhutan • Almost no other tree species occur in such forest other than Chirpine • Altitudinal range:900-1800 m(-2000m)	*Buddleja asiatica, B.bhutanica, Cycas pectinata, Cymbopogon flexuosus, Euphobia royleana, Ficus obligodon, Grewia sapida Indigofera dosua, Rhus paniculata, Zizyphus incurve*

Sl. No	Forest Type	Code	Characteristics	Characteristic species
4	Cool Broad-leaved Forest	CBFr	• Found on moist exposed slopes • Mixed forest in which oaks are LESS COMMON and other trees, both deciduous and evergreen, e.g. Lauraceae, Exbucklandia etc., are more abundant together with dense shrubs, climbers and epiphytes • Altitudinal range:2000-2900m	*Acer campbelli, A. sterculiaceum, Alnus nepalensis, Betula alonoides, Brassiopsis alpine, Chirita lachensis, Corylopsis himalayana, Elatostema monandrum, E. obtusum, Exbucklandia populnea, Ilex fragilis, Lecanthus peduncularis, Lindera neesiana, L. pulcherrima, Persea clarkeana, Pilea bracteosa, Rosa moschata, Rubus lineatus, Schisandra grandiflora, Symplocus dryiphila*
5	Evergreen Oak Forest	EOFr	• Characteristic feature of some parts of Central Bhutan(for e.g. Trongsa and hills above Mongar) • Composition varies according to altitude and rainfall • At lower levels, Castanopsishystrix and C.tribuloides are often dominant, higher up Quercus lamellose becomes commoner • With increasing dryness , more xerophytic Quercusspecies,e.g. Q.lanata, Q.grifithii and Q.semicarpifolia and Pinuswallichiana are seen • Not much shrub layer, whilst shady humid floors are dominated by small herbs • Altitudinal range: (1800-)2000-2600m	*Acer campbelli, Castanopsis hystrix, C. tribuloides, Elatostema hookerianum, E. sessile, Galeola lindleyana, Juglans regia, Pilea symmeria, Quercus lamellose, Skimmia arborescens, Symplocus lucida*

Sl. No	Forest Type	Code	Characteristics	Characteristic species
6	Blue Pine Forest	BPFr	• Temperate equivalent of Chirpine forest and occupies the dry valleys of Bhutan • Bluepine dominant with Quercus species in some places • Xerophytic shrubs occurs and herbs mostly appear during the monsoon season • Altitudinal range: 2100-3000(-3200)m	*Berberis asiatica, Berchemia edgeworthii, Cotoneaster griffithii, Eleagnus parviflora, Euonymus grandiflorus, Indigofera heterantha, Jasminium humile, Prinsepia utilis, Lyonia ovalifolia, Quercus griffithii, Q.semicarpifolia, Rhododendron arboretum, Rosa sericea, Spirea canescens, Zanthoxylum armatum*
7	Spruce Forest	SPFr	• Spruce forest with Hemlock and Fir forests occupy the montane cloud-forest zone of Bhutan • Often mixed with each other but separate forests can frequently be recognized • Spruce are found at lower altitude than Hemlock and Fir • Altitudinal range:2700- 3100(-3200)m	*Acer cappadocicum, A.pectinatum, Berberis praecipua, Enkianthus deflexus, Larix grifithiana, Lindera heterophylla, Osmanthus suavis, Picea brachytyla, P. spinolosa, Salix daltiniana, Salvia campanulata, Taxus baccata*
8	Hemlock Forest	HMFr	• Appears at higher altitude than Spruce where Tsugadumosa is dominant species mixed with Spruce and Fir • Shrubby and arborescent rhododendrons are frequent with dense growth of ferns, lichens and bryophytes • Altitudinal range: 2800-3100m	*Arundinaria griffithiana, Betula utilis, Buddleja colvilei, Daphne bholua, Gaultheria fragmentissima, Larix griffithiana, Litsea sericea, Maddenia himalaica, Magnolia globosa, Panax pseudo-ginseng, Rhododendron falconeri, R.hodgsonis, R. keysii, Rubus calophyllus, R. pentagonus, Sorbus thibetica, Tsuga dumosa, Viburnum mullaha*

Sl. No	Forest Type	Code	Characteristics	Characteristic species
9	Fir Forest	FIFr	• Occurs in the highest ridges of Bhutan below tree line, where huge tracts are covered by no other tree species than Fir (Abiesdensa) and some Hemlock and Birch in places. • Luxuriant undergrowth of Rhododendrons and other shrubs with many small herbs on mossy ground layer are found. • As tree lines are approached, the firs become stunted and are mixed with Junipers and smaller Rhododendron species • Altitudinal range: 3300- 3800m	*Abies densa, Arundinaria maling, Betula utilis, Bryicarpum himalaicum, Daphne bholua, Juniperus pseudosabina, Maddenia himalaica, Primula denticulate, Prunus rufa, Rheum acuminatum, Rhododendron cinnabarinum, R. hodgsonii, Ribes tikare, Rubus fragariodes, Skimmia laureola, Sorbus foliolosa, Viburnum nervosum*
10	Juniper-Rhododendron Scrub	JUSc	• Moist scrub vegetation occurring above treeline throughout Northern and Central Bhutan • Consists of scattered shrubs of Junipers, Rhododendron and Potentillaarbuscula but with rich herb layer appearing during the monsoon • Damp grassy meadow commonly found in this zone • Altitudinal range: 3700-4200m	*Gaultheria trichophylla, Juniperus recurva, J. squamata, Morina nepalensis, Pedicularis megalantha, Phlomis tibetica, Potentilla arbuscula, Primula sikkimensis, Rhododendron lepidotum, Thalictrum chelidonii, Trollius purnilus*
11	Dry Alpine Scrub	DASc	• More xerophytic vegetation found • Higher altitude than Juniper-Rhododendron Scrub • Altitudinal range: 4000-4600m	*Aconitum orochryseum, Astragalus acaulis, Chesneya nubigena, Cremanthodium thomsonii, Ephedra gerardiana, Meconopsis calderiana, Rheum nobile, Rhododendron anthopogon, Salix lindleyana, Saussurea gossypiphora, S. obvallata, Saxifraga moorcroftiana, Tanacetum gossypinum, Thermopsis barbata*

Sl. No	Forest Type	Code	Characteristics	Characteristic species
12	Not sure	NS	• When the data collector is not sure or doesn't know, which category of Forest type to record the plot into, it may be recorded as :"Not Sure"	-

Source: Flora of Bhutan Volume II

Annexure III: Land Cover Category

Sl.No	Land Use Type	Definition	Land use land cover categories (Reclassified for NFI reporting)
1	Coniferous forests	Forest In which more than 75 percent of tree cover consists of coniferous (Fir, Spruce, Pine) species.	Coniferous forests
2	Broadleaf forests	Forest In which more than 75 percent of tree cover consists of broadleaf and hardwood species.	Broadleaf forests
3	Coniferous plantation	Plantations of more than 75 percent coniferous species	Plantation forest
4	Broadleaf plantation	Plantations of more than 75 percent broadleaf species	
5	Scrub forests	Forest areas characterized by less than 10 percent tree cover; or where vegetations are stunted or dwarfed.	Scrub forests
6	Meadow	Open areas of predominantly grassy vegetation cover and herbaceous plants.	Meadow
7	Chuzhing	Irrigated, bench terraced and land cultivated mainly for rice	Agriculture
8	Kamzhing	Rainfed, cultivated land which may be terraced or unterraced.	
9	Mixed agriculture		
10	Apple orchard	Self explanatory	Horticulture
11	Citrus orchard	Self explanatory	
12	Areca nut	Self explanatory	
13	Cardamom Plantation	Self explanatory	
14	Other horticulture		
15	Urban	Towns and areas of habitation(near houses but besides roads or other concrete surfaces).	Settlement
16	Rural	Areas of habitation in villages (near houses, footpaths, or areas which are not forest, or meadows or agricultural fields)	
17	Impervious surface	Man-made surfaces like roads, concretes, pavements	

Sl.No	Land Use Type	Definition	Land use land cover categories (Reclassified for NFI reporting)
18	Snow/glacier	Only those areas which appear to remain permanently under snow or glacier should be identified as one.	Snow/glacier
19	Rocky outcrop	Areas of rocky outcrop and rocky barren lands, sometimes associated with sparse trees/scrub cover	Rocky outcrop
20	Scree	Scree, or talus, is accumulation of broken rock fragments at the base of crags, mountain cliffs, or valley shoulders.	
21	Lake	A lake is a body of relatively still fresh or salt water of considerable size, localized in a basin, which is surrounded by land apart from a river, stream, or other form of moving water that serves to feed or drain the lake. (Source:en.wikipedia.org/wiki/Lake). Lakes can be Alpine lake, Sub-alpine lakes, Glacier lakes, Supra Glacial lake, Supra snow lake or Tsho.	Water bodies
22	Reservoir	Any water body held within man-made structure.	
23	River		
24	Marshy area	Poorly drained or waterlogged areas of permanent swamp or marsh	Marshy area
25	Landslide	Areas in which there is clear evidence of erosion	Others
26	Gully	Gullies are vast gaps, crevices created by erosion of soil on hillside by running waters.	
27	Others-		

Source: LUPP, 1995