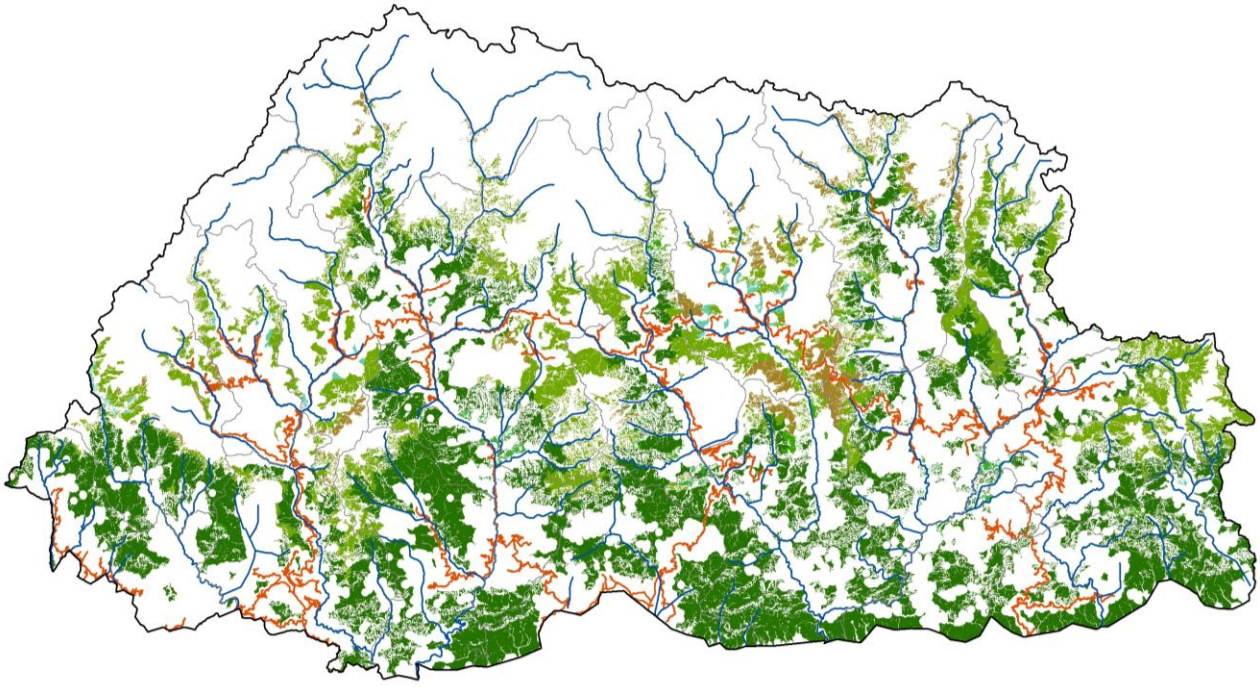
Forest Resources Potential Assessment of Bhutan 2013



Forest Resource Management Division
Department of Forests and Park Services
Ministry of Agriculture and Forests

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ROYAL GOVERNMENT OF BHUTAN
MINISTRY OF AGRICULTURE AND FORESTS
DEPARTMENT OF FORESTS AND PARK SERVICES
THIMPHU: BHUTAN
"Sustaining Forest Resources for Present and Future Generations"

FOREWORD

The Department of Forests and Park Services is pleased to bring out this report on Forest Resources Potential Assessment of Bhutan 2013. The report is anticipated to fulfill the information need and cater to the embellishment of detailed appraisal of the forest resources and trend in the changes over time. The report contains wealth of information on forest resources in Bhutan in terms of potential production forest discounting all the management regimes in place.

The constitution of Bhutan mandates maintaining 60% of total area of the country under forest cover for all times to come. Further, the National Forest Policy 2011requires bringing all the government reserve land under management regime focused on sustainable supply of forest products and ecosystem services and hence, judicious utilization of resources and streamlining the management on the basis of sustainability. Sustainability, by far is a pliant term and it is thus important how we define and on what basis. With increasing population, dependency on the natural resources is inevitable and social component cannot be ignored for the sake of conservation. The best conservation practice is integrating social needs with conservation.

Forest Resources Potential Assessment was carried out in 2013 with the objectives of assessing the resources in terms of growing stock so that it becomes easier for managers to align the resources distribution in a sustainable manner. The exercise has identified potential production areas that can be designated as Forest Management Units with further field verification. The results are based on eight spatial criteria developed by Department in consultation with relevant stakeholders. Further, the report has also detailed the growing stock of some important species which will prove useful while defining the market characteristics. As I understand, the report is comprehensive and covers all information that is deemed relevant and important for all users.

In particular, this report could be used by all Territorial Divisions in identifying potential areas in their respective Divisions for meeting timber requirements based on the principle of sustainable forest management. Besides, the report could also be used in Protected Areas for meeting rural timber requirements.

Therefore, I would like to heartily congratulate and extend my commend Forest Resources Management Division, particularly those involved in FRPA exercise and bringing up this informative report. Finally, I hope this report will be used meaningfully and will serve the purpose for which it is intended.

TASHI DELEK

Chencho Norbu
Director General

Acknowledgements

We would like to offer our sincere gratitude to Mr. Chencho Norbu, Director General, Department of Forests and Park Services for the continuous support and guidance besides providing invaluable advice in the process of preparing FRPA report. We also owe our deep respect and sincere gratitude to Mr. Kinley Tshering, Chief Forestry Officer, Forest Resources Management Division for his initiative, leadership, guidance and support while preparing this report, including data collection in the field.

We owe our deep appreciation and sincere thanks to Dr. Maung Moe Myint, Consultant for kindly agreeing to offer his services way below his regular consultancy charge for the benefit of the Department.

We would also like to acknowledge all staffs of Forest Resources Management Division, particularly Mr. Arun Rai, Sr.Forestry Officer, FRMD, Ms. Dimple Thapa, Dy.Chief Forestry Officer, FRMD, Mr. Santosh Katwal, Forestry Officer, FRMD, Mr. Ugyen Penjor, Forestry Officer, FRMD Mr. Phuntsho, Research Officer, FRMD including those involved in data collection in the field for their inputs.

Finally, we would like to thank our funding partners, viz the Royal Government of Bhutan (RGoB), European Union Renewable Natural Resources Support Project (EURNRSP) and Global Climate Change Alliance (GCCA) without whose support, this exercise would not have been possible.

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Acronyms

BC	Biological Corridor
CF	Community Forest
DEM	Digital Elevation Model
DoFPS	Department of Forests and Park Services
FMU	Forest Management Unit
FRMD	Forest Resources Management Division
FRPA	Forest Resources Potential Assessment
GIS	Geographical Information System
Ha	Hectare
Km	Kilometer
LCPA	Least Cost Path Analysis
M	Meter
NFI	National Forest Inventory
PA	Protected Area
PFPA	Potential Forest Production Area
WS	Working Scheme

Executive Summary

Bhutan is endowed with rich natural resources on which Bhutanese have depended on for generations and continue to do so. Under the visionary leadership of our monarchs, we have our forests and environment largely intact, given that we have one of the finest environment policies and legislations. However, given increasing population coupled with developmental activities, environment sector faces unprecedented pressure. Up keeping the Constitutional mandate of 60% for all times to come is a challenging task. Balanced sustainable use and conservation of forest and natural resources with emphasis on efficient and environment friendly technology is of utmost importance. Further science based participatory approach to forest governance and management is emphasized in the Policy. Thus all our objective of management must be in line with the policy.

The main objectives of carrying out FRPA was to assess resource potential of forest and to update with the results of FRPA 2004. It has been a decade since the last FRPA report and change in the total resource potential is seemingly reduced due to extraction of timber for the past ten years. It was carried out also to authenticate the total growing stock of the forest in the present scenario vis-à-vis the current system of sustainable forest management in Bhutan. With these results we anticipate to streamline the allocation of timber resources not only from territorial jurisdiction but also from protected area network for the rural supply.

To know the potential production capacity of forest, spatial multi-criteria analysis was carried at two different levels taking terrain into consideration (i.e. slope $\leq 45^{o}$ and $\leq 35^{o}$). This is because the potential production forest areas $\leq 35^{o}$ can be easily brought under sustainable forest management while potential production forest areas $\leq 45^{o}$ can be also brought under sustainable forest management but with certain management prescriptions. According to the analysis, 27.92% of the country's geographical area is potential for sustainable forest management having slope $\leq 45^{o}$. When considering slope $\leq 35^{o}$, only 23.25% of the country's geographical area is potential for sustainable forest management.

Further, the economic analysis shows that 11.27% of the total geographical area which is equivalent to 16% of the total forest has potential for sustainable forest management. Out of the total, only around 5.8% of the total geographical area can be sustainably managed for commercial purpose. The remaining 5.4% of the total geographical area can be sustainably managed for rural supply and may be subjected to commercial management with improved technology.

1. Introduction

Bhutan has pledged to keep its forest cover to 60% at all times to come. Records from Bhutan Land Cover Assessment 2010 divulges 70.46% of land is under forest cover of which 62.43% is Broadleaf, 22.69% is Mixed conifer, 3.98 is Chir pine, 2.96 is Blue pine, and 1.16% is broadleaf with conifer. Shrubs constitute 10.81%.

Bhutan being an agrarian country, forest and forest produce plays a vital role in the livelihoods of Bhutanese population. Rapid urbanization and accelerated infrastructure construction has led to increased timber demand. Timber demand is further coupled with rural timber supply. Commercial timber is extracted sustainably from designated Forest Management Units (FMUs) with appropriate silviculture system. Besides supplying commercial timber Department of Forests and Park Services (DoFPS) is also mandated to supply subsidized timber to rural households and renovation of Dzongs and Lhakhangs. Such timber supply is often made on *ad hoc* basic from any resource based area including protected area without proper scientific management. In contrary, our national forest policy emphasis on having scientific forest management plans for all government reserve forests to ensure sustainable supply of forest products or ecosystem services. Knowing the status of forest and potential resource based areas through periodic National Forest Inventory (NFI) incorporating geo-information and earth observation technique has become very crucial stepping stone towards sustainable management of Bhutan's forests.

The DoFPS has carried out Forest Resources Potential Assessment (FRPA) in 2004 to know the state of forest that can be brought under sustainable forest management. One of the key findings of FRPA, 2004 was that 16.8% of forest was available for timber production. However, national geographical area of the country was reduced to 38,394 km^2 and subsequently land cover and landuse map was updated in 2010. Again there was need to reassess the potential of forest based on new geographical area and updated land cover and landuse map. Therefore, Forest Resources Management Division, DoFPS revised FRPA in 2013 with technical assistance from Dr. Maung Moe Myint.

2. Objectives

FRPA 2013 was carried out with the following objectives:
1. To assess the Forest Resources Potential Area of Bhutan for sustainable management.
2. To estimate the growing stock of forest with potential forest area.
3. To streamline the allocation of timber resources from protected area network for rural supply.

3. Methodology

3.1 Identification of Potential Forest Production Area (PFPA).

Spatial criteria that indicate suitability of potential forest lands for sustainable management are derived based on Forest and Nature Conservation Act of Bhutan 1995, Forest Management Code

of Bhutan 2004, Forest and Nature Conservation Rules of Bhutan 2006, National Forest Policy of Bhutan 2011 and recommendations by DoFPS professionals. .

A total of 9 spatial criteria are derived in order to protect human habitats, infrastructure, aesthetics values, ecosystem function and hydrology. These include:

Only in forests lands below or equal an elevation of 4000m above mean sea level

1. Not within 200m either sides of roads (highways, feeder roads, farm roads, etc.).
2. Not within 30m from major drainages.
3. Not within 1 km from rural settlements.
4. Not within 1.5 km from towns.
5. Not within RAMSAR wetland sites.
6. Not within existing botanical, recreational parks and heritage forests.
7. Not within existing Forest Management Units and Working Schemes (WS).
8. Not within existing Community Forests (CFs).

The spatial analyses capability of geographic information system (GIS - ArcGIS); and FRMD ArcSDE/SQL Geodatabase of Bhutan which warehouse the highway, farm and feeder road, existing FMUs and WS, rural and urban settlements, wetlands, major drainage, major watersheds, CFs, botanical and recreational parks, Protected Areas (PAs), Biological Corridors (BC), digital elevation modal (DEM 30 Meter Resolution), slope and land cover map of Bhutan (2010) were applied in order to derive forest potential area. The minimum mapping unit for potential area is 100 hectare.

Spatial multi-criteria analysis was carried at two different levels taking terrain into consideration. Two slope criteria are established in order to segregate potential area into operable slopes and protection of terrain.

1. Slope less than or equal 45 degree.
2. Slope less than or equal 35 degree.

Further based on functionality of forest lands and objective of management, analysis was carried out in six different areas which resulted into six different scenarios. These six scenarios include;

1. Potential forest area of the country.
2. Potential forest area outside protected area network.
3. Potential forest area inside protected area network.
4. Potential forest area outside major watersheds.
5. Potential forest area inside major watersheds.
6. Potential forest area outside protected area networks and major watersheds.

3.2 Delineation of Potential Forest Production Units.

Potential forest area as a result of analysis, were delineated into smaller production units based on natural features. The boundary of production units approximately coincides with boundary of Chiwogs of Bhutan. Smallest production unit was taken as 100 hectare. Based on the management objectives, these production units could be merged or split into smaller units.

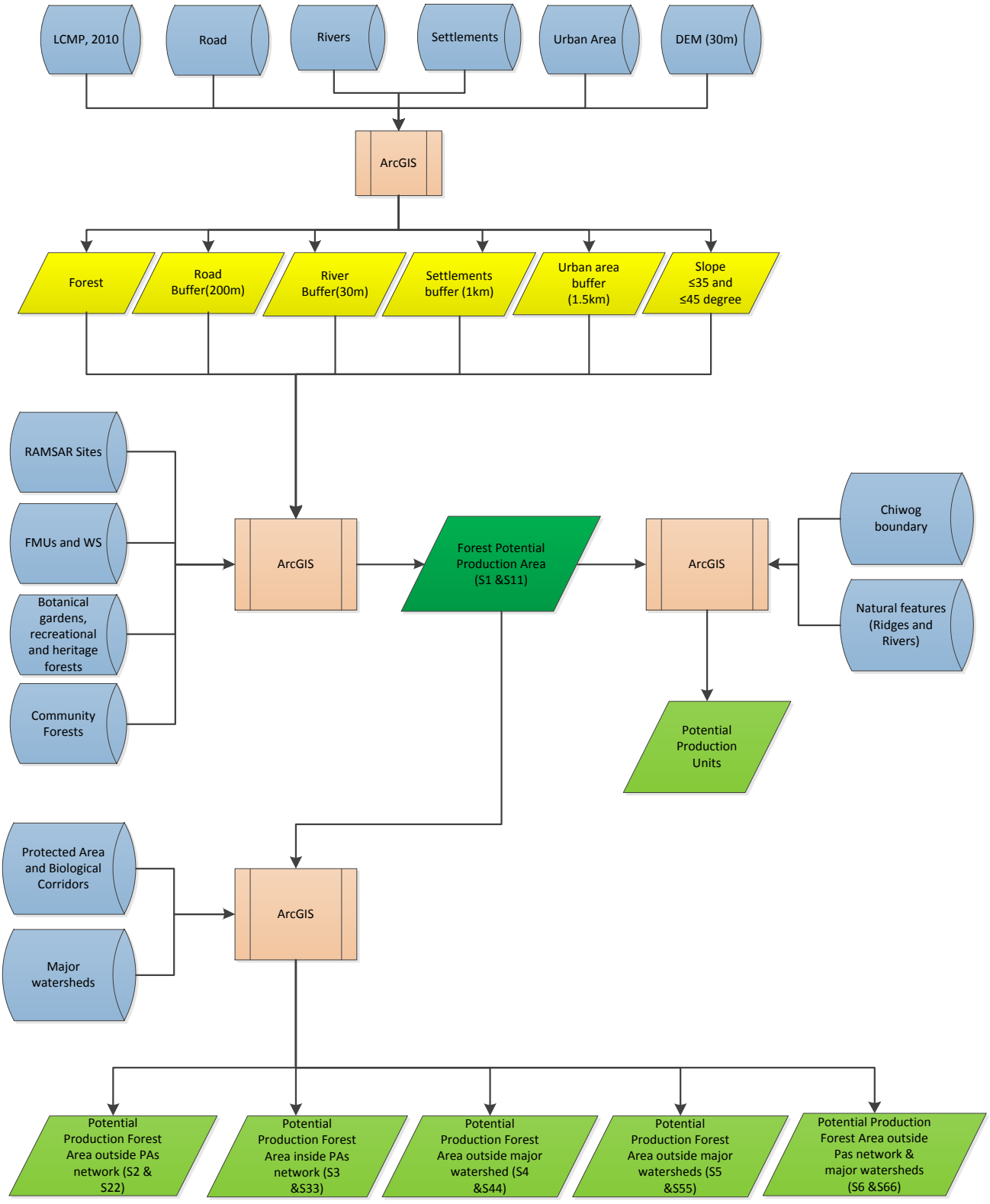

Figure 3-1 Flow chart illustrating the methodology in identifying potential forest production area and potential forest production units

3.3 Estimation of Growing Stock for Broadleaf and Conifer Forest in Potential Forest Production Area.

From the potential forest area, potential production units were delineated which was considered sampling framework for FRPA. Four sampling sites were randomly selected representing each forest type. Sampling design was based on existing NFI 1 km by 1 km systematic sampling cluster plots are generated within the 4km by 4km NFI sampling framework. For generating forest parameters, combine data of FRPA sample plots (Dagana, Trongsa, Thimphu and Trashigang) and available NFI data (Paro, Haa and Tsirang Dzongkhags) were used.

The R statistics code was written to estimate the mean, lower limit and upper limit of number of tree, basal area and timber volume. Forest parameter estimation were carried out at the plot level, per hectare level and total study area level with its statistical errors such as % margin of error, % standard error, % coefficient of variation, sample variance and estimated variance. The results are stored in ArcSDE/SQL Geodatabase server.

3.4 Estimation of Growing Stock of some important species within Potential Forest Production Area.

During forest resources potential assessment, an effort was also made to estimate parameters for some important species. Estimations of number of trees and standing volume with its sampling errors are estimated based on 232 Cluster Plots of 6737 trees using R Statistics Code. The results are also stored in ArcSDE/SQL Geodatabase.

4. Potential Forest Production Area

Based on slope less than or equal to 45^o, a total of 1071.83 thousand hectare of forest land was potential for forest management which is equal to 27.92% of country's geographical area and 39.62% to total forest land. Potential forest area feasible for sustainable management based on slope less than or equal to 35^o is 892.68 thousand hectare which is equal to 23.25% of country's geographical area and 33% to total forest land.

Details of potential area based on forest function and management objectives with slope ≤ 45^o is illustrated in following table and graphs.

Table 4-1 Details of potential forest production area in different management area (slope ≤ 45^o)

Category	Area (000ha)	Percentage to geographical area	Percentage to total forest land
Potential Production Forest area of Bhutan (S1)	1071.83	27.92%	39.62%
Potential Production Forest area outside Protected Area Network (S2)	514.73	13.41%	19.03%
Potential Production Forest area inside Protected Area Network (S3)	547.88	14.27%	20.25%
Potential Production Forest area outside Major Watersheds (S4)	806.52	21.01%	29.81%
Potential Production Forest area inside Major Watersheds (S5)	264.61	6.89%	9.78%
Potential Production Forest area outside Protected Area Network and Major Watersheds (S6)	423.62	11.03%	15.66%

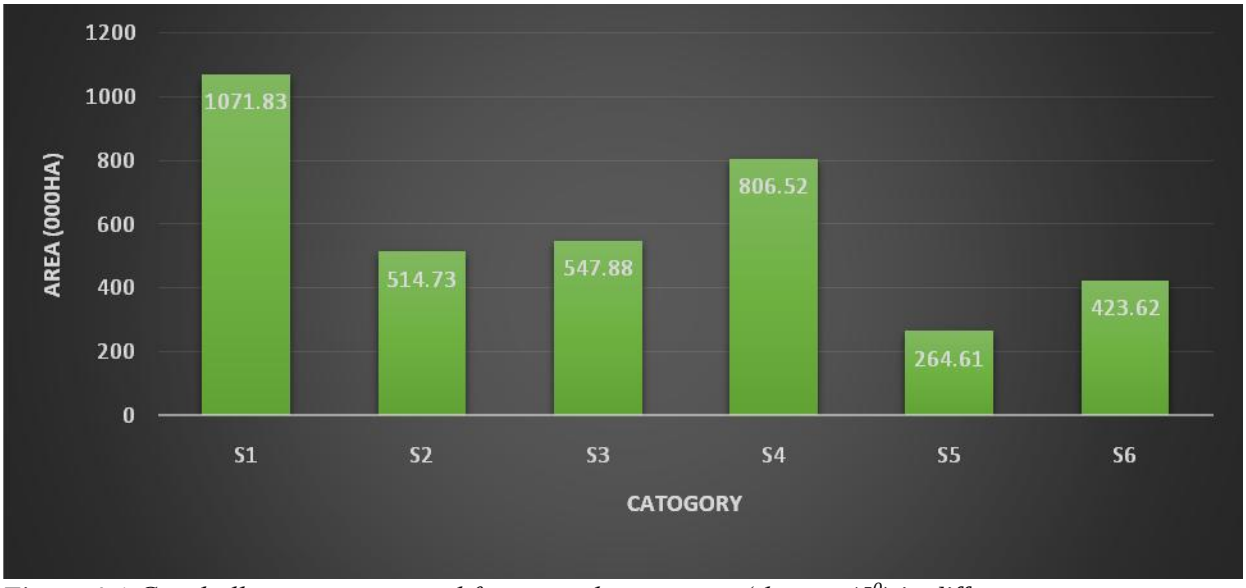

Figure 4-1 Graph illustrating potential forest production area (slope ≤ 45^0) in different management area

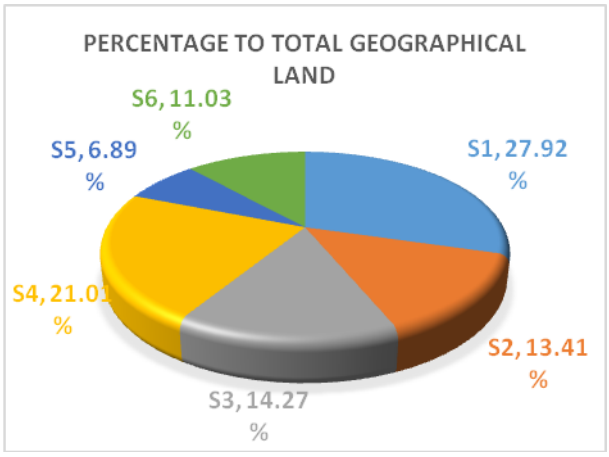

Figure 4-2 Pie chart illustrating percentage of potential forest production area (slope ≤ 45^o) to total geographical area

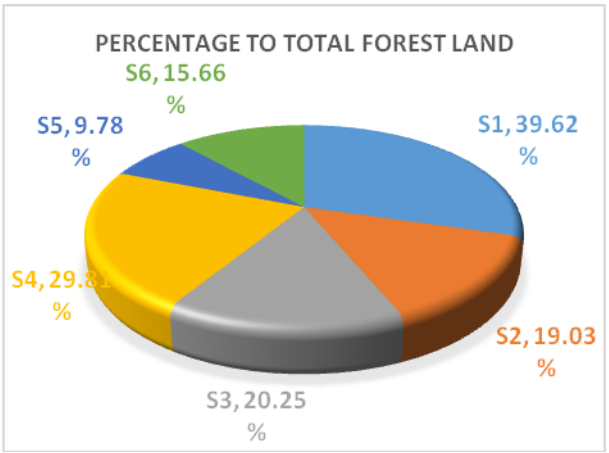

Figure 4-3 Pie chart illustrating percentage of potential forest production area (slope ≤ 45^o) to total forest land

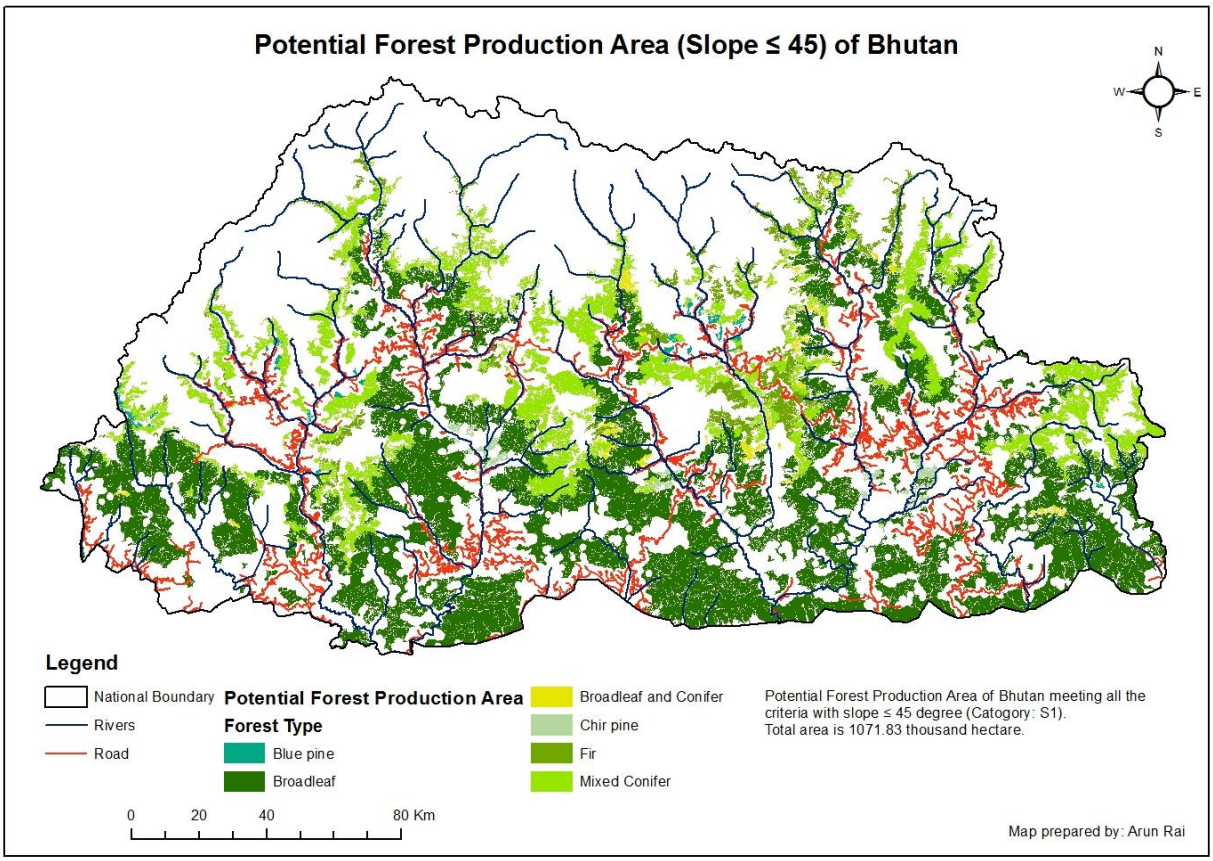

Figure 4-4 Map showing the potential forest production area of Bhutan (slope ≤ 45°)

Potential forest area based on forest function and management objectives with slope ≤ 35° is illustrated in following table and graphs in detail.

Table 4-2 Details of potential forest production area in different management area (slope ≤ 35°)

Category	Area (000ha)	Percentage to geographical area	Percentage to total forest land
Potential Production Forest area of Bhutan (S11)	892.68	23.25%	33.00%
Potential Production Forest area outside Protected Area Network (S22)	432.52	11.27%	15.99%
Potential Production Forest area inside Protected Area Network (S33)	452.54	11.79%	16.73%
Potential Production Forest area outside Major Watersheds (S44)	679.62	17.70%	25.12%
Potential Production Forest area inside Major Watersheds (S55)	212.48	5.53%	7.85%
Potential Production Forest area outside Protected Area Network and Major Watersheds (S66)	333.04	8.67%	12.31%

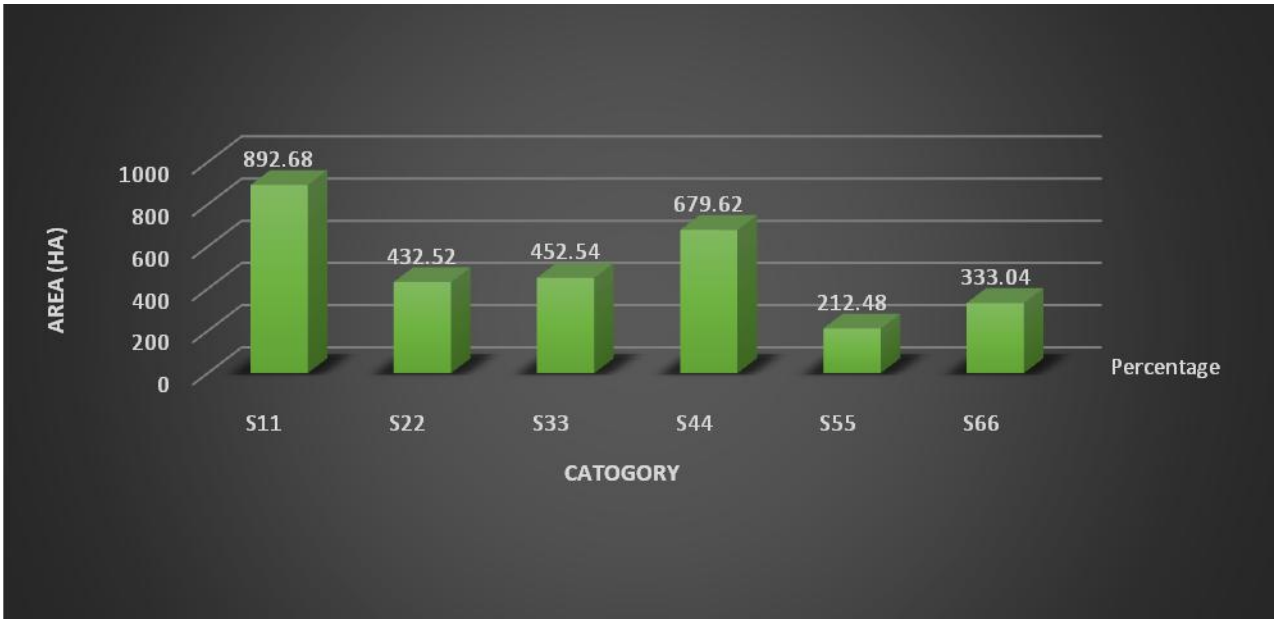

Figure 4-5 Graph illustrating potential forest production area (slope ≤ 35°) in different management area spelling category

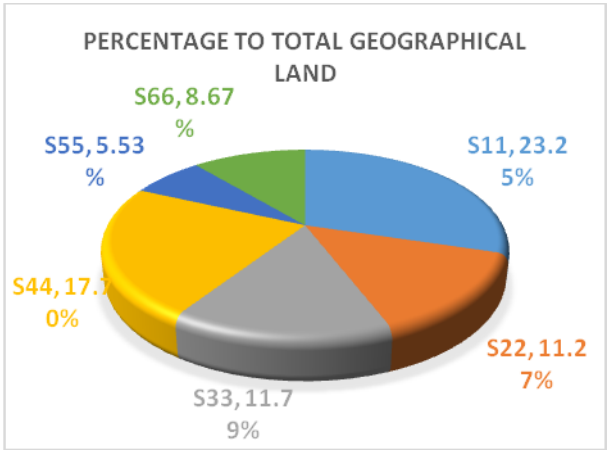

Figure 4-6 Pie chart illustrating percentage of potential forest production area (slope ≤ 35°) to total geographical area

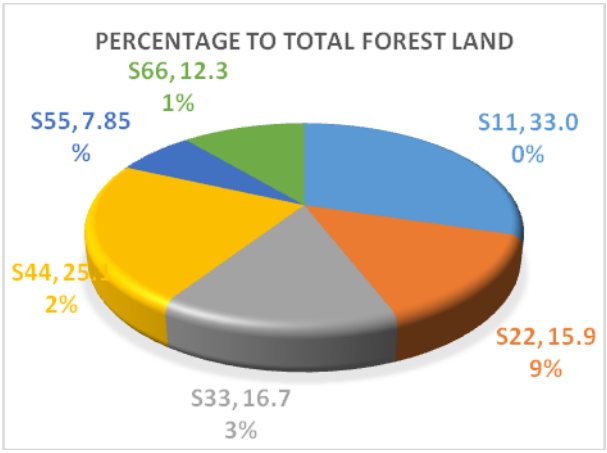

Figure 4-7 Pie chart illustrating percentage of potential forest production area (slope ≤ 35°) to total forest land

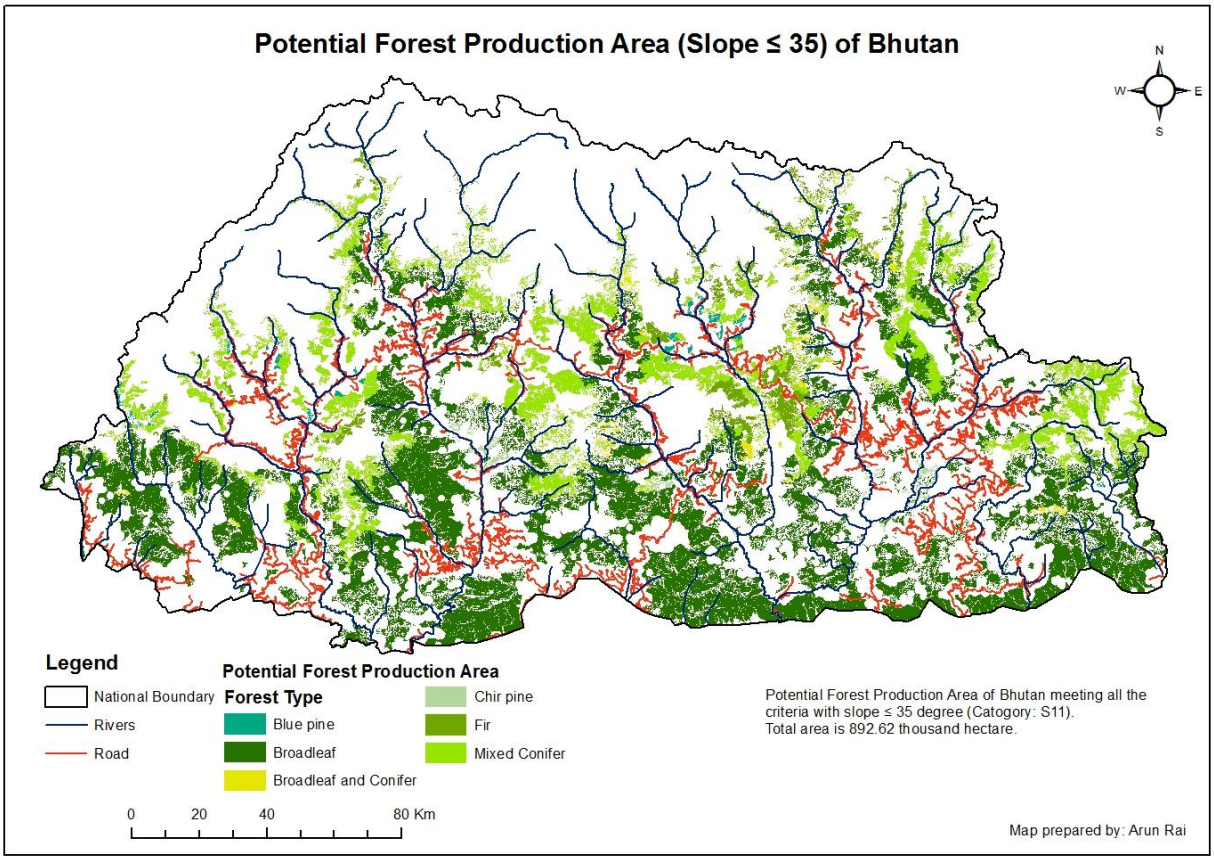

Figure 4-8 Map showing potential forest production area of Bhutan (slope ≤ 35°)

5. Distribution of Potential Forest Production Area in Protected Areas

Within the protected area, the total potential forest production area with slope ≤ 35° is approximately 452540 ha which is equivalent to 11.79% of total geographical area. These potential production areas have not been categorized according to park zonation. The forest potential of protected area was not intended for exploring into commercial logging instead it was geared to help protected area in sustainable management and allocation of resources with their jurisdiction.

Table 5-1 Distribution of Potential Forest Production Area in Protected Areas

Protected Area	Forest Type	Area (ha)
Bumdeling Wildlife Sanctuary	Broadleaf	16488.596
	Broadleaf and Conifer	598.72566
	Fir	3467.0351
	Mixed Conifer	22971.292
Jigme Dorji National Park	Broadleaf	12410.594
	Fir	2859.0525
	Mixed Conifer	21653.812
Jigme Singye Wangchuck National Park	Broadleaf	40891.014
	Broadleaf and Conifer	1366.4058
	Chirpine	2428.868
	Fir	585.96888
	Mixed Conifer	20804.975
Khaling Wildlife Sanctuary	Broadleaf	19367.825
Phibsoo Wildlife Sanctuary	Broadleaf	17170.188
Royal Manas National Park	Broadleaf	57516.256
Sekten Wildlife Sanctuary	Broadleaf	9452.2839
	Mixed Conifer	23959.316
Torsa Strict Nature Reserve	Bluepine	1060.7081
	Broadleaf	7367.1109
	Fir	406.91247
	Mixed Conifer	6884.2114
Wangchuck Centennial Park	Bluepine	198.83935
	Broadleaf	8021.1757
	Broadleaf and Conifer	1327.2896
	Fir	10630.075
	Mixed Conifer	17873.704
Biological Corridors	Broadleaf	69205.106
	Broadleaf and Conifer	1877.9752
	Chirpine	217.50305
	Fir	4524.3843
	Mixed Conifer	18065.976

6. Distribution of Potential Forest Production Area in Dzongkhag

Potential forest production area outside protected area with slope ≤ 35^{o} is about 432520 ha which equals to 11.27% of total geographical land.

Table 6-1 Distribution of Potential Forest Production Area in Dzongkhags

Dzongkhag	Forest Type	Area (ha)
Bumthang	Bluepine	3219.025
	Fir	2523.255
	Mixed Conifer	11111
Chukha	Broadleaf	40994.75
	Broadleaf and Conifer	239.7159
	Mixed Conifer	8466.326
Dagana	Broadleaf	48107.19
	Mixed Conifer	7956.707
Haa	Broadleaf	26792.8
	Fir	1166.249
	Mixed Conifer	5607.329
Lhuentse	Broadleaf	1668.292
	Broadleaf and Conifer	318.7448
	Chir pine	144.525
	Fir	87.72181
	Mixed Conifer	390.1074
Mongar	Broadleaf	22720.9
	Chir pine	1058.123
	Fir	256.7851
	Mixed Conifer	3384.071
Paro	Blue pine	783.4904
	Fir	78.2899
	Mixed Conifer	5976.912
Pemagyatshel	Broadleaf	18391.81
	Chir pine	1014.728
Punakha	Broadleaf	8051.965
	Chir pine	151.6024
	Mixed Conifer	691.8891

Dzongkhag	Forest Type	Area (ha)
Samdrupjongkhar	Blue pine	142.5734
	Broadleaf	30817.98
	Broadleaf and Conifer	396.1082
Samtse	Broadleaf	27945.73
	Broadleaf and Conifer	255.5414
	Mixed Conifer	428.4549
Sarpang	Broadleaf	11026.85
	Mixed Conifer	494.1625
Thimphu	Blue pine	909.2932
	Fir	2899.08
	Mixed Conifer	15716.05
Trashigang	Broadleaf	19043.95
	Chir pine	1296.402
	Mixed Conifer	11572.32
Trongsa	Broadleaf	4522.833
	Broadleaf and Conifer	216.2537
	Fir	209.1519
	Mixed Conifer	5301.567
Tsirang	Broadleaf	12203.03
	Chir pine	43.77182
	Mixed Conifer	1453.918
Wangdiphodrang	Broadleaf	24541.79
	Chir pine	1297.326
	Mixed Conifer	4600.618
Trashiyangtse	Broadleaf	7216.961
	Mixed Conifer	3630.574
Zhemgang	Broadleaf	22330.08
	Broadleaf and Conifer	422.7556
	Chir pine	65.08275
	Mixed Conifer	165.4733

7. Potential Forest Production Units.

Based on the natural features, forest potential production area was delineated into production units for ease of field truthing and management. A total of 478 units were delineated. Production units not only encompass net forest potential production area but also include other adjacent land use types. Area of production units ranges from minimum of 100 hectare to maximum of 52000 hectare. However, smaller units can be merged together to form bigger production units and vice-versa based on suitability and objective of management.

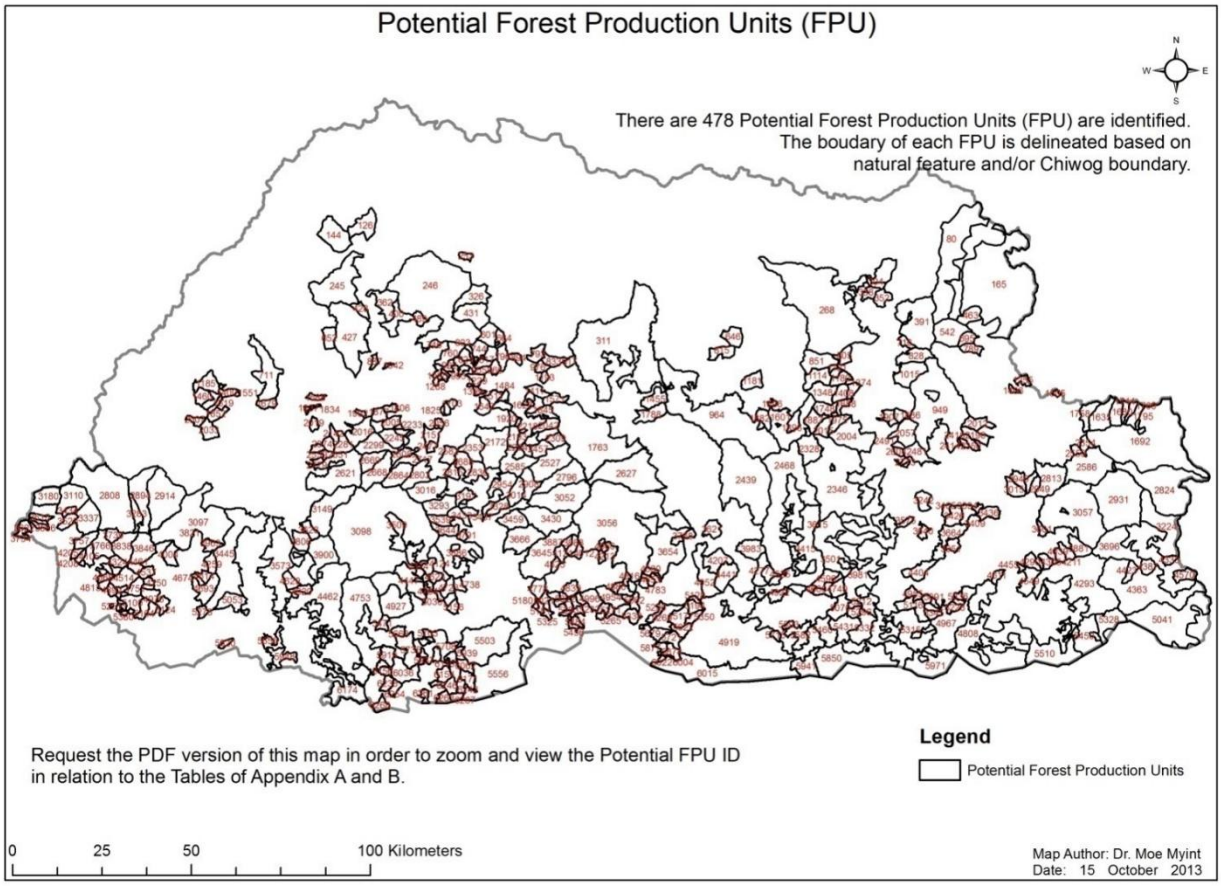

Figure 7-1 Map showing potential forest production units

8. Estimates of Quantity of Forest Resources for Production.

Forest landscape of Bhutan is predominated with broadleaf in the South and conifer in the North. During FRPA analysis, forest parameters for broadleaf and conifer were also estimated. The growing stocks such as standing volume (m^3), basal area (m^2) and number of trees with its corresponding sampling errors are derived based on FRPA field data and available NFI data in order to assess quantity and distribution of forest resources. A total of 86 cluster plots were enumerated with circular plot size of 0.05 hectare for collecting tree data. Sampling framework for FRPA is 478 Potential Production Units. Summary of standing volume per hectare for broadleaf and conifer is detailed in following table.

Table 8-1 Table illustrating standing volume per hectare estimation in conifer and broadleaf forest within potential forest production area

Volume (m^3)	Conifer	Broadleaf
Total volume per hectare	103.11	139.09
Lower limit of volume per hectare	79.05	94.91
Upper limit of volume per hectare	127.19	183.27
Estimated variance of total volume per hectare	212.47	715.68
Sample variance of total volume per hectare	49294.01	166036.97
Margin of Error (%) of total volume per hectare	23.35	31.76
Percent coefficient of variance	215.32	292.95
Standard error percent	14.14	19.23

Minimum of 79m^3 per hectare to maximum of 127m^3 per hectare with an average of 103m^3 per hectare standing volume could be estimated at 95% confidence for conifer species. Standard error and margin of error is 14.14% and 23.35% respectively. Similarly minimum of 95m^3 per hectare to maximum of 183 m^3 per hectare with an average of 139 m^3 per hectare standing volume is estimated for broadleaf species at 95% confidence level. Standard error of 19.23% and margin error of 31.76% were resulted during the estimation of broadleaf species. Therefore, when estimating the standing volume in potential production units which is also sampling frame, 103m^3 and 139m^3 per hectare could be used for conifer and broadleaf forest respectively. In order to prorate the total standing volume within potential production area, volume per hectare value (103m^3/ha for conifer and 139m^3/ha for broadleaf) could be multiplied with potential production area for forestry and timber volume planning at the national level.

Table 8-2 Table showing of number of tree per hectare estimation within potential forest production area

Number of Trees	Estimates
Number of trees per hectare	193.59
Lower limit of number of trees per hectare	176.57
Upper limit of number of trees per hectare	210.61
Percent coefficient of variation	81.09
Margin of error (%) of total number of trees per hectare	8.79
Standard error percent	5.32

Minimum of 177 and maximum of 211 trees per hectare with an average of 194 trees per hectare could be estimated at 95% confidence level. Corresponding errors for estimation were 5.32% of standard error and 8.79% of margin of error. In order to prorate the total number of trees within potential production area, trees per hectare value (194 trees/ha) could be multiplied with potential production area for forestry planning at the national level.

9. Estimation of growing stock of some important species

Choice of timber in the market is often made at species level. Bhutan forest yields variety of conifer and broadleaf species. Timber is generally sorted into different classes according to species, strength, durability and other associated characteristics. Royalty and price for timber of different class differs. Based on 7637 trees of 232 accessible cluster plots, standing volumes per hectare and number of trees per hectare of some important species are estimated.

Table 9-1 Table illustrating growing stock estimation per hectare of some important species

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

Low: lower limit; Ave.: Average/mean; Upper: upper limit

Table 9-2 Table illustrating errors for growing stock estimation of some important species

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

MoE: margin of error; SE: standard error; CV: coefficient variation

Depending on the sample size, estimation errors are quite high. Therefore, it is recommended that species level estimated data should be applied very cautiously. However the estimation could be improved by using more field data. Higher accuracy could be achieved if NFI data is used for estimation once the field work is completed.

10. Cost Benefit Analysis

10.1 Forest Road Construction.

Proximity of FMU from the accessible road plays a vital role in planning sustainable forest management. Isolated forest stands distanced by difficult terrain is often encountered to bring forest under sustainable management regime. Forest road is a major component when harvesting timber from FMUs. The construction of forest road is frequently confronted with extreme

topography. Optimal forest road planning in mountainous terrain is challenging and requires sophisticated method of path analysis. In order to minimize the environmental hazard, Least Cost Path Analysis (LCPA) method has been chosen to draw the forest road network in different potential areas from existing roads.

LCPA provides identification of the best way from one point to another based on cost surface. The accumulated cost surface consists of numerous criteria. In our analysis, land use and slope were two criteria taken into consideration to create cost surface. With LCPA using raster cost surface, road network was created for all potential areas outside protected area network. Proposed forest road starts from existing road and ends at the center of the potential FMUs.

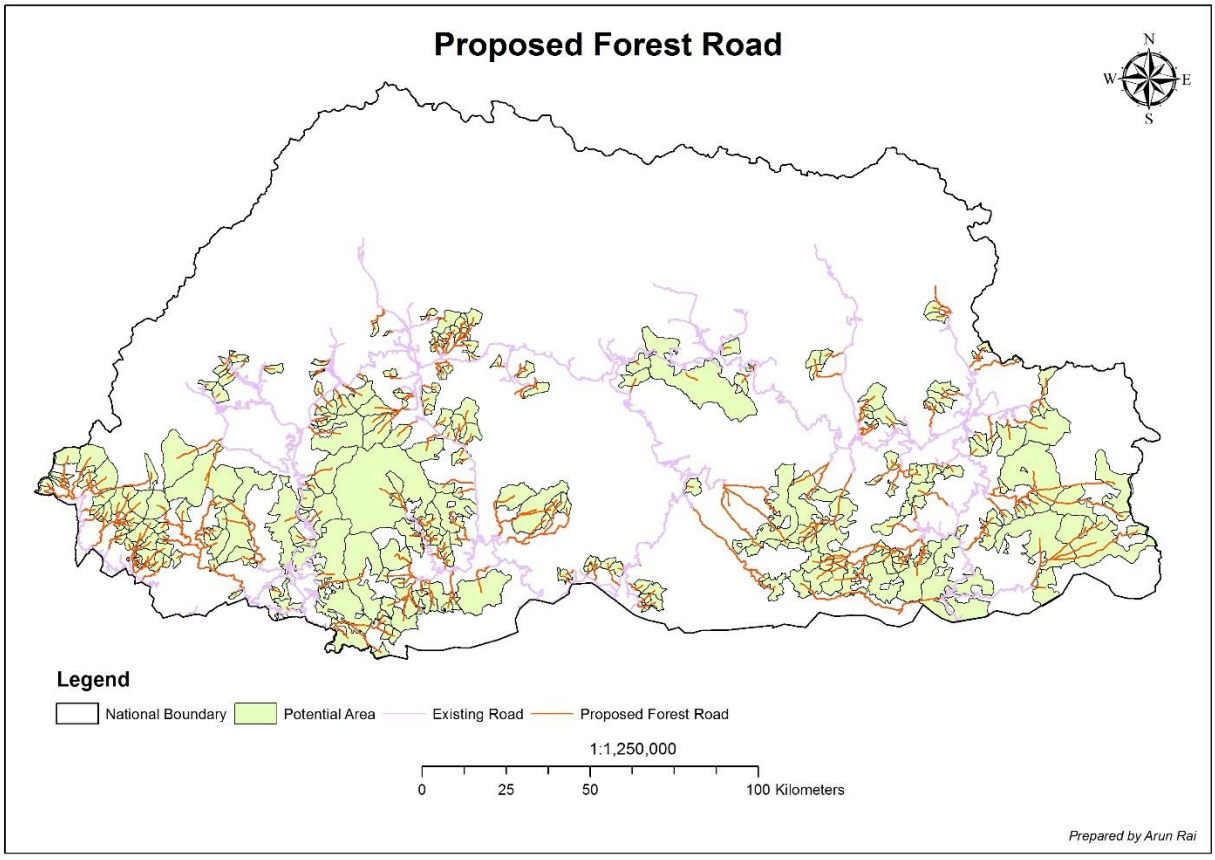

Figure 10-1 Map showing the proposed forest road

10.2 Revenue and Expenditure.

Prior to bringing any forest area under sustainable management, cost benefit evaluation is often considered necessary. For the analysis, potential area with slope $\leq 35^{0}$ has been considered. There are around 267 potential production areas outside protected network. The size of these area ranges from minimum of 100 hectare to maximum of 52000 hectare. Cost benefit analysis all the potential area was carried out to know the area that can be commercially managed.

Unit direct cost (Review of pricing structure for sand, stone and timber, 2014), unit indirect cost (Review of pricing structure for sand, stone and timber, 2014), and road construction cost were consider for carrying out cost benefit analysis. Cost of road construction from existing highway to the center of the potential area was estimated using the existing forest road construction rate

(Nu.2500000/km) from NRDCL. Total revenue generation is estimated from total available growing stock and current timber price in the market in different Dzongkhags.

11.27% of total geographical which is equivalent to 16% of total forest has potential for sustainable forest management outside protected area. Out of which only around 5.8% of the total geographical land can be sustainable managed at commercial level. Rest 5.4% of the total geographical land can be subjected to sustainable management for rural supply and can be subjected to commercial management with improved technology. Following graphs displays the total revenue and total expenditure in each potential production area.

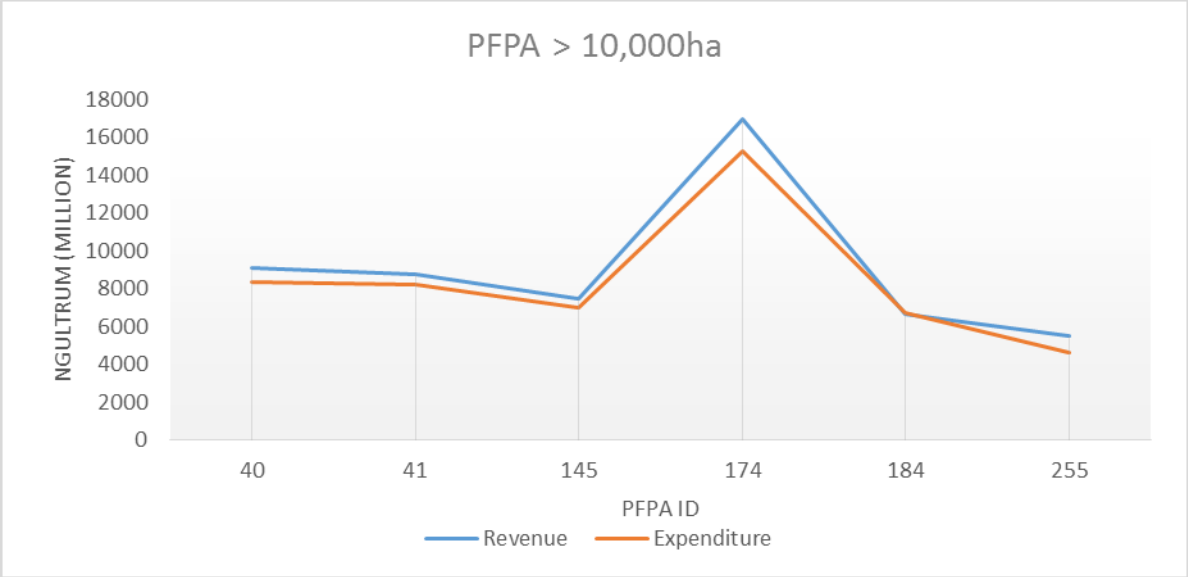

Figure 10-2 Graph showing revenue and expenditure for area > 10000 ha

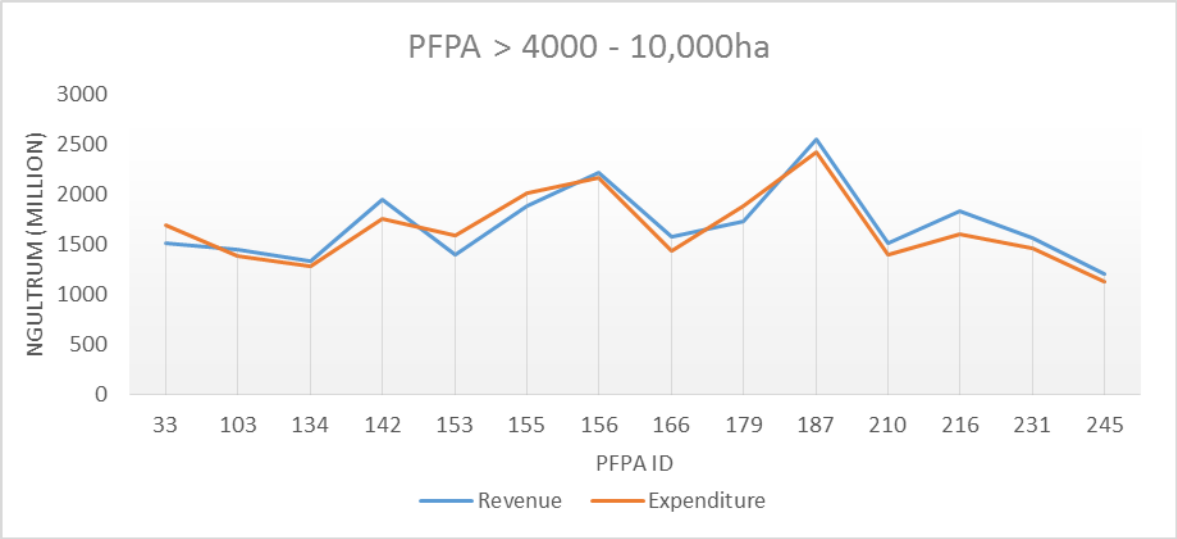

Figure 10-3 Graph showing revenue and expenditure for area > 4000 - 10000 ha

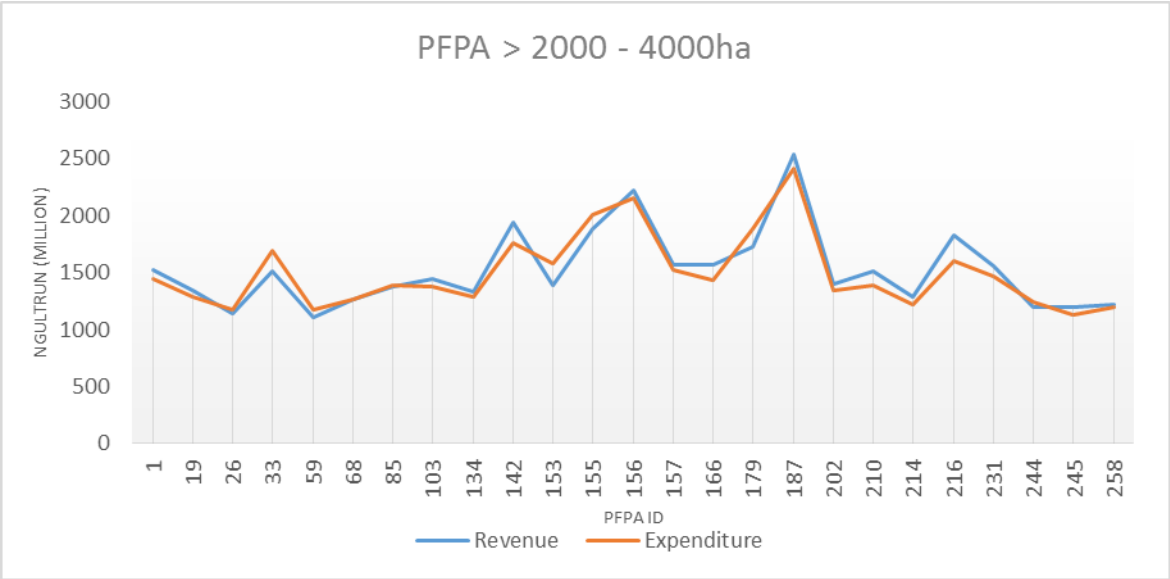

Figure 10-4 Graph showing revenue and expenditure for area > 2000 - 4000 ha

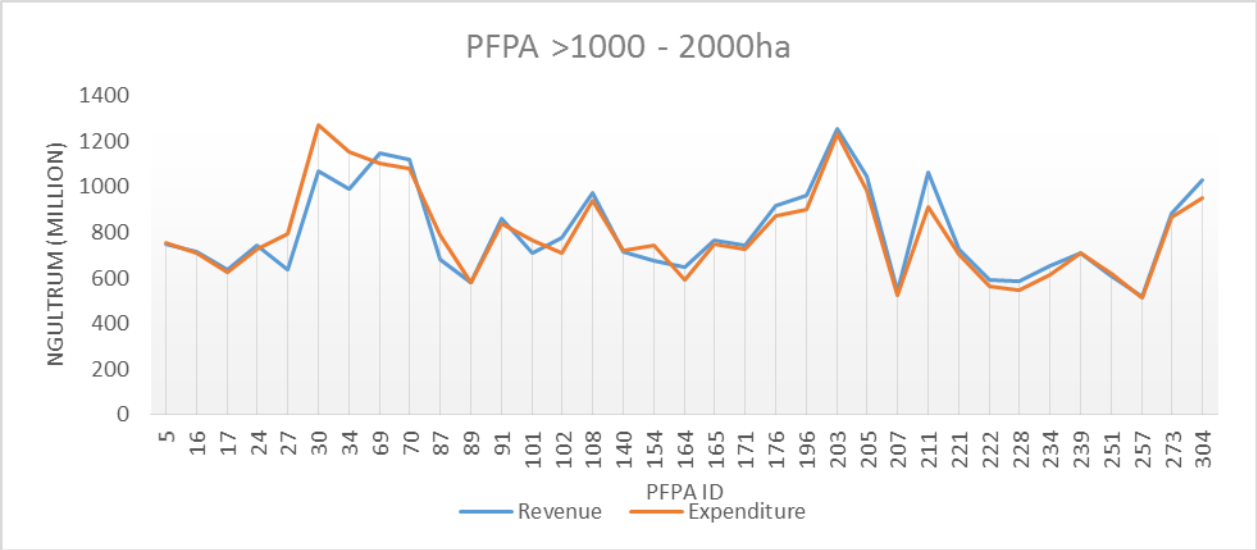

Figure 10-5 Graph showing revenue and expenditure for area >1000 - 2000 ha

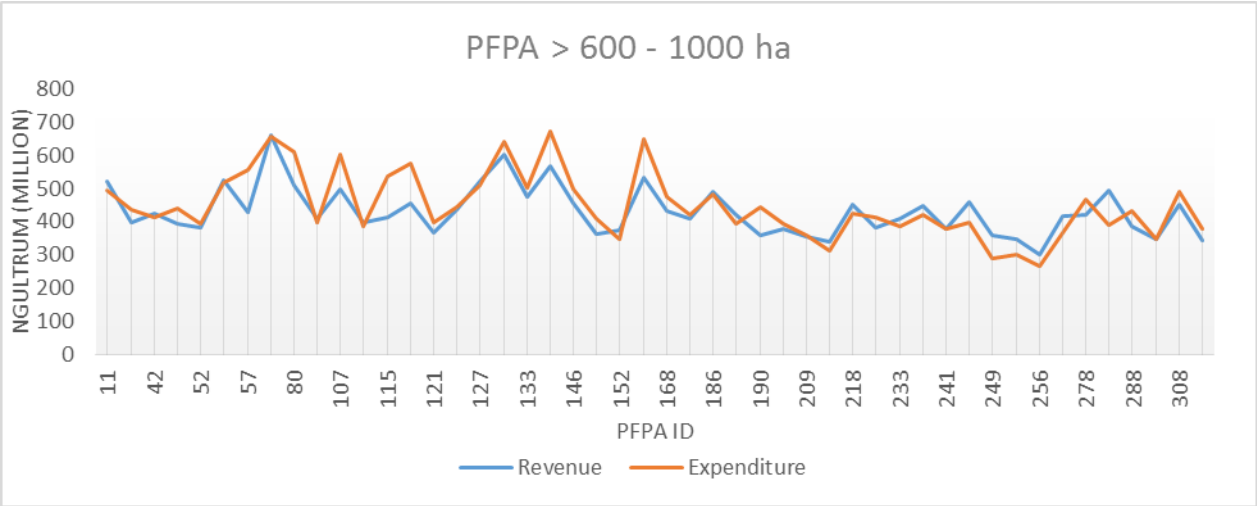

Figure 10-6 Graph showing revenue and expenditure for area > 600 - 1000 ha

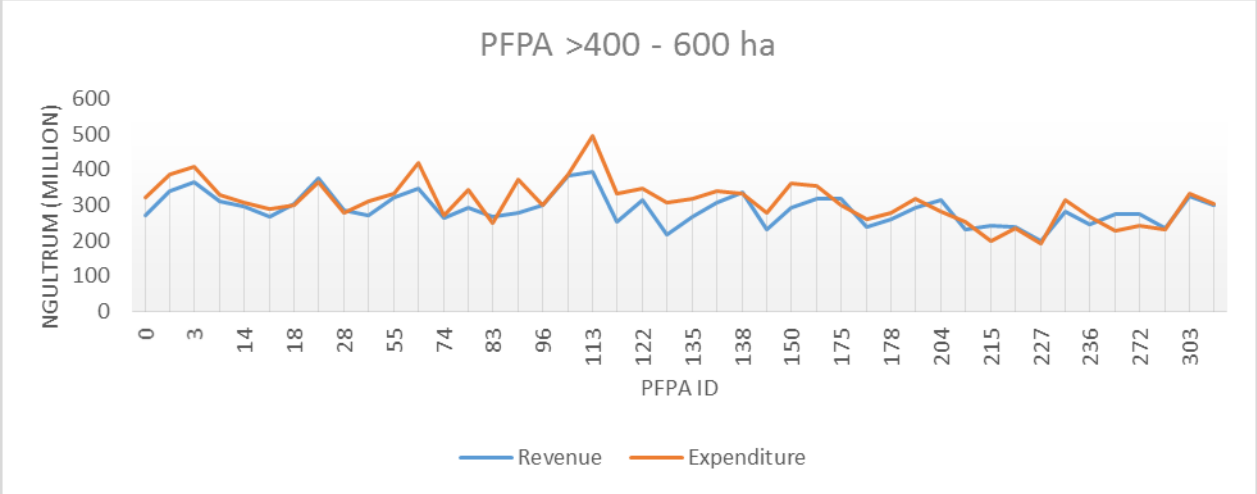

Figure 10-7 Graph showing revenue and expenditure for area > 400 - 600 ha

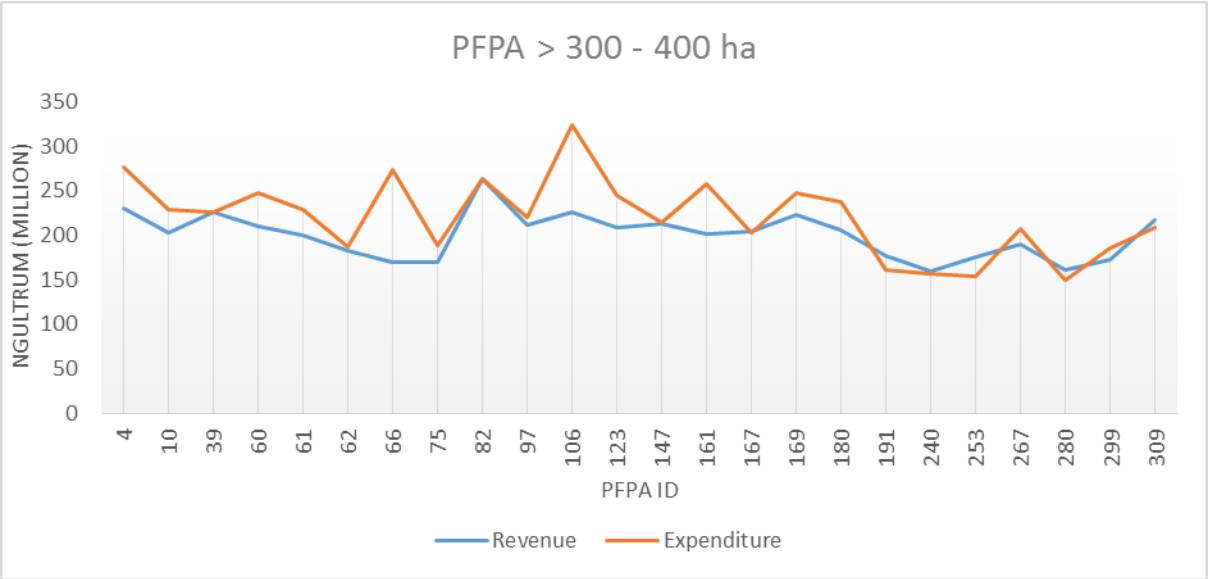

Figure 10-8 Graph showing revenue and expenditure for area > 300 - 400 ha

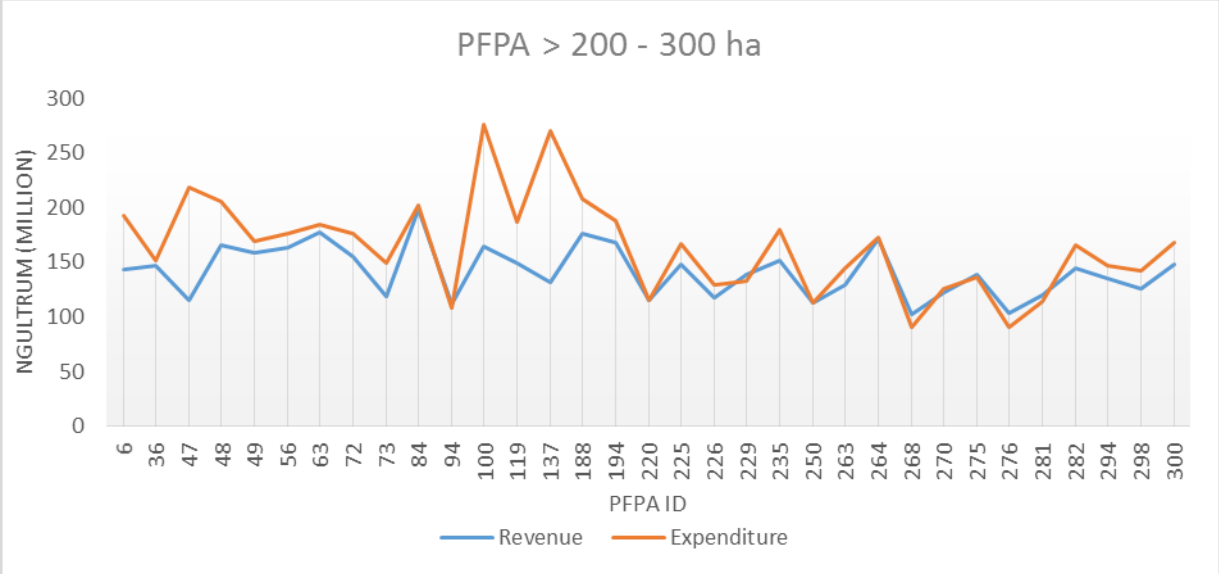

Figure 10-9 Graph showing revenue and expenditure for area > 200 - 300 ha

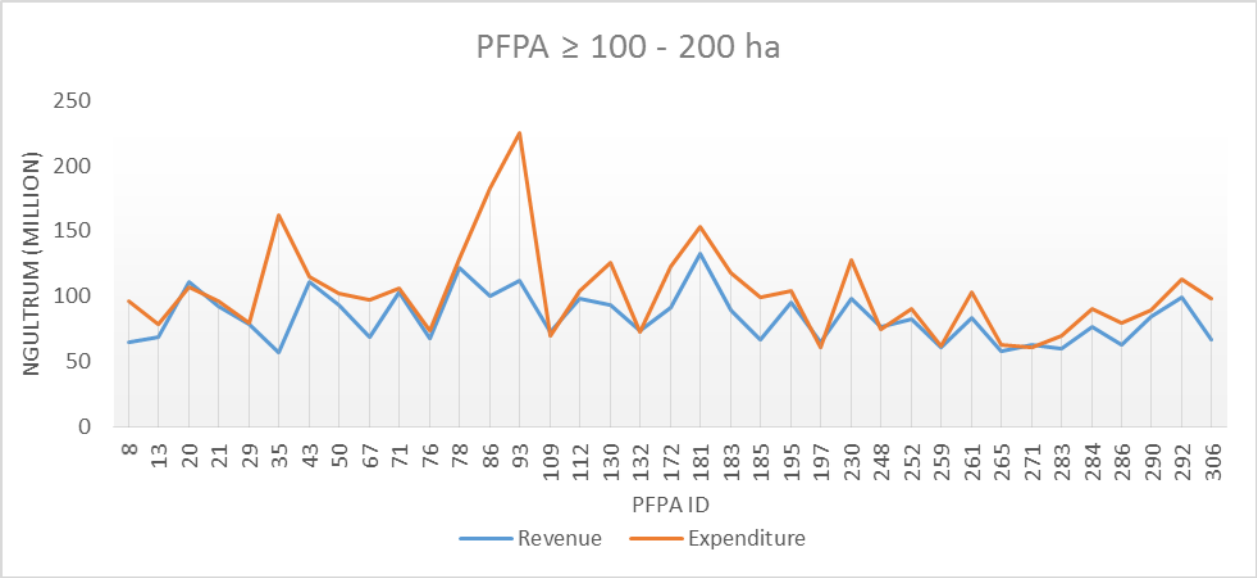

Figure 10-10 Graph showing revenue and expenditure for area > 100 - 200 ha

The size of potential production area ranges from minimum of 100 hectare to maximum of 52000 hectare. The boundary delineation of potential production area was carried out in the desktop using ArcGIS 10 taking the natural feature as reference. The bigger potential area can be divided to form a smaller manageable area and smaller potential area can be merged together to form an area suitable for establishment of FMU upon field validation.

11. Application of FRPA for forestry planning.

With increase in timber demand over the past few years and contrary pressure to maintain 60% of forest cover, it has been very crucial to have a reliable spatial data about the quantity of forest resources that can be brought under sustainable management. National Forest Policy of Bhutan emphasizing on having scientific management plan for any timber harvesting activities, knowing the potential forest production area is a stepping stone towards sustainable management. Quantity and spatial distribution of forest resources under different management zone is well represented in the analysis, which would enhance the policy maker in guiding sustainable forest management.

Protected area network of Bhutan is very unique with cluster of settlements within its territory. Forest resources not also act as refuge to wildlife but also a source of vital resources for population residing within the protected area for livelihood and socio economic benefit. From FRPA analysis, quantity and distribution of forest resources within protected area network is revealed. This result can be incorporated into the management plan of respective national parks, sanctuaries and reserves in proper forest resource allocation. Especially the area of rural timber allocation for population residing inside the protected area network can be easily managed.

DoFPS has mandate to make timber available and affordable to every Bhutanese population. Commercial timber is generally extracted from designated FMUs. With increased infrastructure development in urban areas, the demand for timber has escalated. Existing FMUs were not

enough to suffice the need of timber in the market. *Ad hoc* identification of resource based area was practiced to supply the immediate need of timber in the market. With the result from FRPA analysis, such practices can be avoided. Field truthing needs to be done in all potential production units and new area can be designated for established FMUs.

Bhutan being an agrarian country with around 70% (PHCB 2005) of population residing in rural area, forest is an inevitable natural resources for the rural population. Ranging from food to construction material is often derived from forest. Understanding the dire need of forest resources for rural population and challenges faced by DoFPS in managing the forest, concept of community forest has been introduced in Bhutan. Community forest is usually established near by the settlements and managed by community to derive forest produce for their daily needs. A total of 556 community forests has been established so far. Potential forest production area resulted from the FRPA analysis can be used for identifying potential community forest area near by the settlements.

Resource planning and management is not only confined to typical FMUs in Bhutan. With substantial area under state forest land which is not under any form of management regime per se brought under the regime of scientific management in the form of "Management of Forest Areas outside FMU system". The concept virtually aims to bring all state forest under scientific management. Forest Resource Potential Assessment is pivotal in typically identifying those areas which are not managed as a FMU, or under protected area network, or private or community forests. Aligning the idyll objective of National Forest Policy, it is paramount to understand which area falls under such state forest reserve land where the field Divisional in-charge will have a holistic knowledge of the resources within his/her jurisdiction. This not only pertains to the concept of allotting an area for timber extraction but also it will give an idea of the area that will need improvement and scientific intervention.

Bhutan has numerous Dzongs and Lhakhangs which need immediate attention for renovation besides new construction. Timber requirement for Dzongs is very high with specific size and species. Often such demand cannot be met from a single site. Besides, they are located in very secluded areas, often disconnected from motorable road. Timber requirement for such purposes need to be met from within the vicinity. Potential forest production area would enable DoFPS in locating such areas with less investment.

During FRPA analysis, different scenario has been developed especially in knowing the quantity and distribution of forest resources in different management area. Forest resources inside the protected area network and major watershed were also calculated. Areas that need immediate attention of conservation can be analyzed. Besides, DoFPS effort of conservation can be revealed and economic valuation can be analyzed for payment of environmental services.