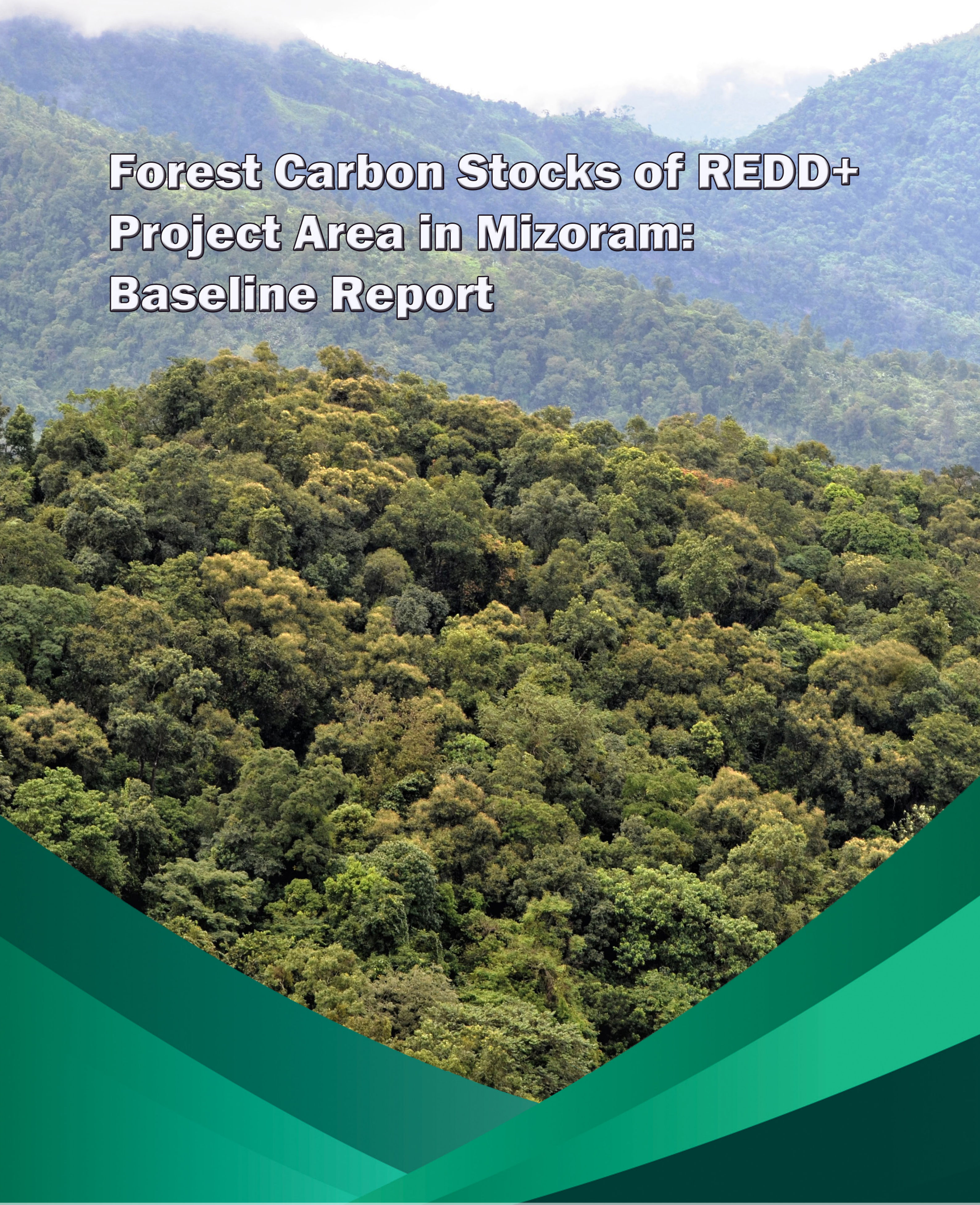
Forest Carbon Stocks of REDD+ Project Area in Mizoram: Baseline Report



ICIMOD

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

NORWEGIAN MINISTRY OF FOREIGN AFFAIRS

Forest Carbon Stocks of REDD+ Project Area in Mizoram: Baseline Report

2018

Indian Council of Forestry Research and Education

(An Autonomous Body of Ministry of Environment, Forest and Cimate Change, Government of India)

P.O. New Forest, Dehradun - 248006 (INDIA)

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

NORWEGIAN MINISTRY OF FOREIGN AFFAIRS

Published by:

Biodiversity and Climate Change Division
Directorate of Research
Indian Council of Forestry Research and Education
P.O. New Forest, Dehradun- 248006 (Uttarakhand), INDIA

Authors:

Dr. R.S. Rawat, Scientist Incharge, Biodiversity and Climate Change Division
Dr. Gurveen Arora, Research Associate, Biodiversity and Climate Change Division
Dr. Jaiyati Rawat, Senior Consultant, Biodiversity and Climate Change Division
Sh. V.R.S. Rawat, REDD+ Expert Consultant, Biodiversity and Climate Change Division
Sh. M.Z. Singson, Head, FRCBR, Aizawl
Sh. H. Ramchhanliana, Consultant, FRCBR, Aizawl

Citation: Rawat, R.S., Arora, G., Rawat, J., Rawat, V.R.S., Singson, M.Z. and Ramchhanliana, H. (2018). Forest Carbon Stocks of REDD+ Project Area in Mizoram: Baseline Report. Indian Council of Forestry Research and Education, Dehradun (INDIA).

Contents

Abbreviation Used

Executive Summary

1 Introduction 1

2 Methodology and Procedure 3

2.1 Project area
2.2 Forest types of project area
2.3 Soil
2.4 Climate
2.5 Sampling design
2.6 Estimation of forest carbon stocks
2.7 Data Analysis

3 Results 9

3.1 Aboveground biomass and carbon stock
3.2 Belowground biomass and carbon stock
3.3 Deadwood biomass and carbon stock
3.4 Litter biomass and carbon stock
3.5 Bulk density and Soil Organic Carbon Density
3.6 Total biomass and Carbon stock

4 Discussion 11

5 Conclusion 13

References 15

Annexure 1: Plot Description Form 17

Annexure 2: Allometric Equation for Volume Estimation 20

Abbreviation Used

AGB	Above Ground Biomass
BGB	Below Ground Biomass
C	Carbon
D&FD	Deforestation and Forest Degradation
FAO	Food and Agriculture Organization of United Nations
GHG	Greenhouse Gas
GIZ	Deutsche Gessellschaft fur Internationale Zusammenarbeit
GPS	Global Positioning System
Gt	Giga tones
ha	Hectare
ICFRE	Indian Council for Forestry Research and Education
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
km^2	Square kilometer
LULUCF	Land Use, Land Use Change and Forestry
Mg/ha	mega gram per hectare (1Mg =1 tonne)
Mg/m^3	mega gram per cubic metre ($1mg/m^3$ = $1gm/cm^3$)
MRV	Measurement, Reporting and Verification
msl	mean sea level
Pg	Peta gram
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SOC	Soil Organic Carbon
t/ha	tonnes per hectare
tC/ha	tonnes carbon per hectare
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

Acknowledgement

International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ), Germany

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany

Forest Research Centre for Bamboo and Rattan (FRCBR), Aizawl, Mizoram

Department of Environment, Forest and Climate Change, Mizoram

Guidance and Support

Dr. Suresh Gairola, Director General, ICFRE

Mr. S.D. Sharma, Dy. Director General (Research), ICFRE

Dr. Bhaskar Singh Karky, Resource Economist, ICIMOD

Mr. Kai Windhorst, Chief Technical Advisor, GIZ

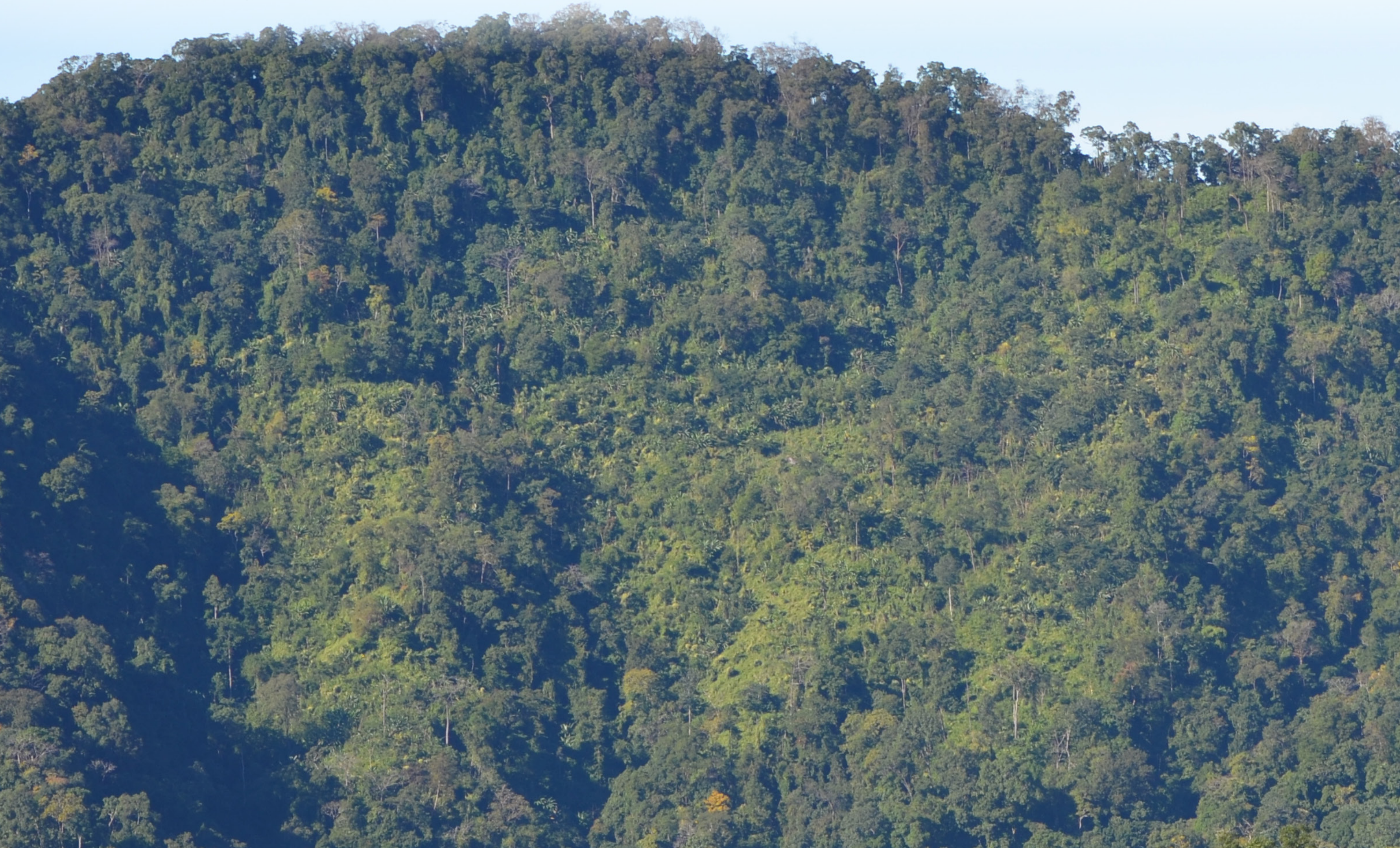
Mr. K. Kire, APCCF, Department of Environment, Forest and Climate Change Mizoram

Mr. Nabin Bhattarai, Research Associate, ICIMOD

Field staff of FRCBR, Aizawl

Layout & Design

Mr. Umang Thapa, BCC Division, ICFRE



Executive Summary

The quantification of forest biomass and carbon stocks plays a crucial role in regulation of global carbon cycle. Understanding of the spatial distribution of biomass and carbon stocks is a prerequisite for implementation of REDD+ activities. The REDD+ pilot project area in Mamit district of Mizoram was selected for the implementation of activities of REDD+ Himalaya Project. Four types of forests (Secondary moist bamboo brakes forest, *Cachar* tropical moist evergreen forest, East Himalayan Moist Mixed Deciduous forest and Pioneer Euphorbiaceous Scrub) are found in the project area which are broadly classified in two forest groups (Tropical Semi-Evergreen forest and Tropical Moist Deciduous forest). In the project area, 90 sample plots were randomly laid out and data were collected for estimation of forest carbon stocks. During the study, all the five carbon pools (aboveground biomass, belowground biomass, deadwood biomass, litter biomass and soil organic matter) were assessed.

The aboveground carbon stock ranged from 82.51 tC/ha to 112.24 tC/ha and belowground carbon stock ranged from 4.29 tC/ha to 30.30 tC/ha. The soil carbon stock ranged from 51.19 tC/ha to 103.25 tC/ha. The cumulative effect of five carbon pools showed the highest forest carbon stocks in East himalayan moist mixed deciduous forest (216.81 tC/ha) followed by Cachar tropical semi-evergreen forest (192.78 tC/ha) and minimum in pioneer euphorbiaceous scrub (85.15 tC/ha). Secondary moist bamboo brakes showed total carbon stock of 104.27 tC/ha.

Overall the forest carbon stocks was reported highest in East Himalayan moist mixed deciduous forest (1122.30 million tonnes) followed by Cachar tropical semi-evergreen forest (909.58 million tonnes) and secondary moist bamboo brakes (860.61 million tonnes) and pioneer euphorbiaceous scrub (23.55 million tonnes), respectively. The precise estimation of carbon stocks are vital to know the affect of various land use land cover change brought by developmental activities, forest fire, shifting cultivation and other drivers of deforestation and forest degradation in the REDD+ project pilot area.

1 Introduction

Natural forests, being as a source as well as sink of carbon, seek attention from all over the world for their status of maintaining and enhancing in terms of quality and quantity by managing it sustainably. Inventory and monitoring of carbon stock changes in forests, forest area and land use and land cover changes provides an improved understanding of global carbon balance. Globally, forest carbon stocks declined by 13.6 Pg C between 1990 and 2015 (Kohl *et al.*, 2015). FAO (2015) reported that emissions from forest degradation are significant and account for emission of 1.0 Gt CO_2 yr^{-1} on average over the period of 2011–2015. Whereas, the reduction in net annual natural forest loss was reported from 8.5 million ha per year (1990 to 2000) to 6.6 million ha per year (2010 to 2015). Reduction in natural forest is an important proxy of deforestation and forest degradation. The forest degradation and deforestation activities have a major impact on the forest carbon stocks.

Carbon uptake in a terrestrial sinks is an important process in a global carbon balance and hence limiting the concentration of carbon dioxide in the atmosphere. According to Kyoto Protocol, the terrestrial ecosystem involves five carbon pools. It has been estimated that world's forest stored about 234 Pg C in the aboveground compartment, 62 Pg C in the belowground compartment, 42 Pg C in the dead woody compartment, 23 Pg C in litter compartment, and a maximum carbon sink of 398 Pg C in the forest soils (Kindermann *et al.*, 2008). These carbon pools are dynamic and change with changes in land-use.

India is one of the 12 mega diversity countries and has about 2% of the forest area. As per India State of Forest Report 2017, the total forest cover of the country is 80.20 million hectare which is 24.39% of the total geographic area of the country (FSI, 2017). Mizoram, being one of the densely forested hill states of the country, having 88.48% area of the state under forest cover, but the open forests area is also highest (67.05%) among the north east states. As per India State of Forest Report 2017, the forest carbon stocks in Mizoram is 95.041 million tonnes which is 1.34% of the total forest carbon stocks of the country (FSI, 2017). Table 1 shows the forest carbon stocks in different carbon pools of Mizoram. However, deforestation and forest degradation activities (such as shifting cultivation and other developmental activities) in the state have resulted in decline of 531 km^2 of the forest cover in two years (FSI, 2017).

Table 1: Forest carbon stocks in different carbon pools (in 000' tonnes) of Mizoram

Forest Cover area (km^2)	Above Ground Biomass	Below Ground Biomass	Dead Wood	Litter	Soil Organic Carbon	Total
18,186	15,359 (8.45)	3,173 (1.74)	633 (0.35)	2,652 (1.46)	73,224 (40.26)	95,041 (52.26)

**carbon stock value tonnes/ha is given in parenthesis*

(Source: FSI, 2017)

The objective of this report is to generate the baseline information of forest carbons stocks of the REDD+ pilot area are under Mamit district of Mizoram.

2 Methodology

2.1 Project area

Mizoram state is among the eight states lies in the Northeastern part of the country. Geographically it lies between 21°58' to 24°35'N latitudes and 92°15' to 93°29' E longitudes. The state has 8 districts viz. Aizawl, Champhai, Kolasib, Lunglei, Mamit, Lawngtlai, Saiha and Serchhip and 23 sub-divisions. Mamit district was selected as a REDD+ pilot project area in consultation with Department of Environment, Forests and Climate Change, Government of Mizoram.

Mamit is a fourth largest district of Mizoram state. It is situated between 23°15'21.25" - 24°15'16.80" N latitude and 92°15'44.54" - 92°40'39.63" E longitude with an altitude ranging from 40 m to 1485 m above msl. It is situated in the western part of Mizoram and located at a distance of 96 km from the state capital, Aizawl. Its geographical area is 3025 sq.km. The project area constitutes 12 villages having 1583 households with the total population of 8174 under Mamit District (Rawat *et al*., 2017).

2.2 Forest types of project area

In the project area, four forest type are found as per the Champion and Seth (1968) classification of forest types. The detail is given in Table 2 along with their area in hectares. The map of forest types are given in Figure 1.

Table 2. Forest types of project area

S. No.	Forest Type	Area (ha)
1	2/2S1 Secondary Moist Bamboo Brakes	8254.55
2	2B/2S1 Pioneer Euphorbiaceous Scrub	276.62
3	2B/C2 Cachar Tropical Semi-Evergreen Forest	4718.24
4	3C/C3b East Himalayan Moist Mixed Deciduous Forest	5176.44

Following are the description of each forest type:

(1) **2/2S1 Secondary Moist Bamboo Brakes:** The project area is dominated by this forest type with total area of 8254.55 ha. *Bambusa tulda*, *Dendrocalamus hamiltonii, Dendrocalamus longispathus* and *Melocanna baccifera*, etc. are the dominant species of this forest type. Due to the disturbances caused by the shifting cultivation, the majority of area in the state is predominated by the bamboo species.

(2) **2B/2S1 Pioneer Euphorbiaceous Scrub:** This forest type is generally found in the degraded and exposed forest areas present on the higher slopes and on top of the hills. Vegetation has stunted and species like *Albizia chinensis*, *Betula cylindrostachya*, *Bruinsmia polysperma*, *Castanopsis tribuloides*, *Colona floribunda*, *Macaranga* spp., *Mallotus* spp., *Schima wallichii* and *Wendlandia budleioides* etc are the major speccices of this forest type.

(3) **2B/C2 Cachar Tropical Semi-Evergreen Forest:** Species like *Careya arborea, Dipterocarpus turbinatus, D. tuberculatus, Emblica* spp., *Terminalia chebula, Melanorrhoea usitata, Duabanga grandiflora, Xylia dolabriformis, Dillenia pentagyna, Lagerstroemia parviflora, Terminalia tomentosa, Gmelina arborea, Wendlandia grandis, Woodfordia fruticosa* and *Licuala peltata* etc. are the major species of this forest type.

(4) **3C/C3b East Himalayan Moist Mixed Deciduous Forest:** The dominant species of this forest type are *Aglaia spectabilis, Albizia procera, Albizia stipulata, Artocarpus lakoocha, Dillenia pentagyna, Lagerstroemia parvifora, Neolamarckia cadamba, Salmalia malabarica, Schima wallichii, Syzigium cuminii, Terminalia bellerica* and *Terminalia chebula*, etc.

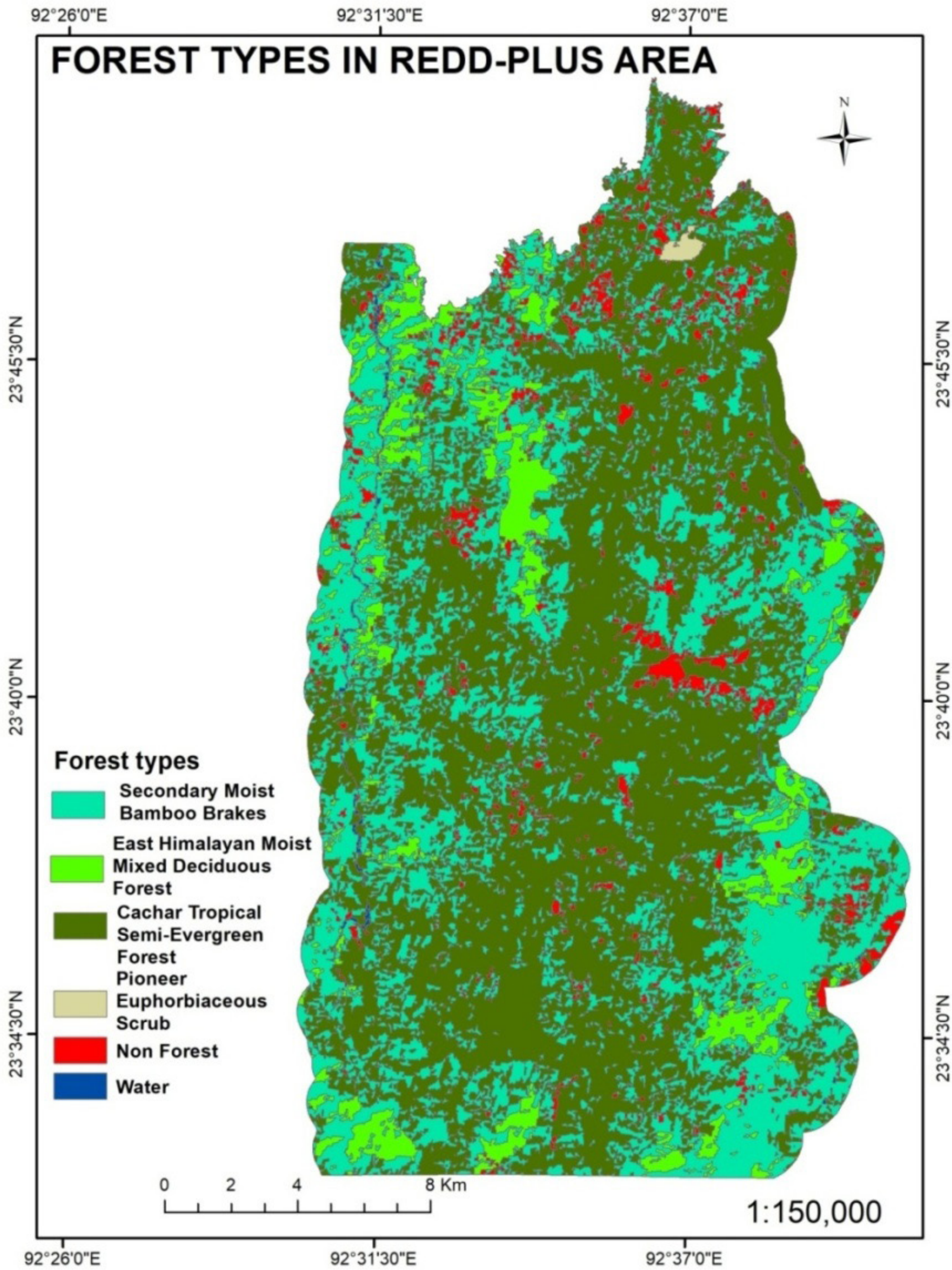


Figure 1. Forest type map of REDD+ project area

2.3 Soil

The soil of Mamit district has been derived from parent rock such as ferruginous sandstone, shale, alluvial and colluvial materials. Soil formations have been categorized into hill, valleys and terraces. The hill includes colluvial soil, formed along the steep sided slopes because of accumulation of soil forming materials on slope surface. The soils in hills are rich in humus. In valleys, soils occur as a mixture of colluvial and alluvial materials. It is restricted to the rolling valleys along the river courses. Terraces are the remnants of deposits of cobbles and pebbles (Source: http://cgwb.gov.in/District_Profile/Mizoram/MAMIT.pdf).

2.4 Climate

The relevant thermo-characteristics of Mamit district is that temperature do not fluctuate much throughout the year. Owing to its tropical condition, it enjoys the moderate climate. This district experiences neither too hot nor too cold throughout the year. It falls under the influence of the south-west monsoon. Less rainfall is found in North-east monsoon as compared to other seasons. The district receives annual rainfall between 2000-3100 mm from both North-east and South-west monsoons. The area receives an adequate amount of rainfall which is responsible for a humid tropical climate characterized by short winter and long summer and heavy rainfall.

2.5 Sampling design

In the present study, non-destructive approach was followed for estimation of aboveground biomass and other carbon pools. A total of 90 plots were sampled in four forest types *i.e.* Pioneer Euphorbiaceous Scrub, Secondary Moist Bamboo Brakes, *Cachar* Tropical Semi-Evergreen Forest and East Himalayan Moist Mixed Deciduous Forest. Number of plots in each forest type were laid randomly proportional to size (area) of each forest type. The size and shape of the plot is a trade-off between accuracy, precision, time and cost for measurement. The size of each plot was taken to be 0.1 ha and rectangular plot was opted for the estimations of the five carbon pools. The plot of 0.1 ha was laid out to by measuring 22.36 m horizontal distance *i.e.* half of the diagonal in all the four directions at 45^{o} in north-east, at 135^{o} in south-east, at 225^{o} in the south–west, and at 31.5^{o} in north-west corners of the plot from true north (Rawat *et al.*, 2017). Initial plot information was recorded in plot description form as given in Annexure I and sample plot layout shown in Figure 2 and directions for plot layout in Box 1.

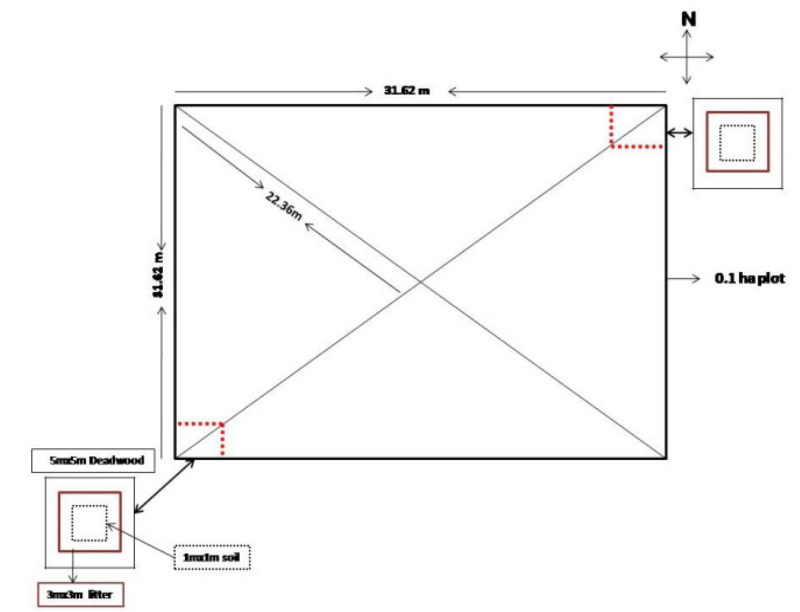


Figure 2. Sample plot layout

2.6 Estimation of forest carbon stocks

The field inventory and the methodology for assessment of five carbon pools of the project area are presented below:

2.6.1 Estimation of forest carbon stocks

To measure the biomass of vegetation in a plot requires precision and accurate measurement especially in a situation of uneven aged stands with variable tree size distribution present in a given study area. Within the plot, all trees having diameter above 10 cm were enumerated using for height and diameter breast height (DBH) for biomass estimation using allometric equations developed by FSI, 1996. All the precautions were taken during tree measurements. Allometric equations were used for volume estimation of each tree within the plot. For volume estimation of each tree, these allometric models were fitted to the data using DBH and both DBH, height in combination. These allometric equations used are either site specific or site specific and species specific. The volume equations for different species found in the study area are given in Annexure II. The estimated volume was converted to biomass by multiplying with basic wood density and biomass expansion factor (Kaul *et al.*, 2009; IPCC, 2003). The value of aboveground biomass was extrapolated on per hectare basis (equation 1). Similarly, carbon stock was estimated by multiplying the total aboveground biomass by a conversion factor (equation 2) that represents the average carbon content in biomass using IPCC Good Practice Guidance for LULUCF (IPCC, 2003) based conversion factors. In the present study, conversion factor was taken to be 0.5 as carbon fraction of dry matter to convert the aboveground biomass into carbon stock on per hectare basis (IPCC, 2003).

AGB = volume x D x BEF *equation 1*

Carbon (t/ha) = AGB x carbon % *equation 2*

where:

AGB	=	Aboveground biomass (Mg/ha)
D	=	Basic wood density (tonnes dry matter/m^3 of merchantable volume)
BEF	=	Biomass expansion factor

2.6.2 Estimation of belowground biomass

Belowground biomass has a relationship with aboveground biomass usually called as root-to-shoot-ratio method (Kaul *et al.*, 2009). The formulae for the estimation of below ground biomass and carbon stock used the conversion factor given by IPCC, 2003 are given below (equation 3 & 4):

BGB = 0.27 x AGB *equation 3*

Carbon (t/ha) = BGB x carbon % *equation 4*

where:

AGB	=	Aboveground biomass (Mg/ha)
BGB	=	Belowground biomass (Mg/ha)

2.6.3 Estimation of deadwood biomass

For dead wood biomass, a quadrat of 5×5 m was laid in two corners diagonally of sample plot. More than 5 cm diameter dead wood which includes wood lying on the surface, dead roots, and stumps were collected, weighed and recorded as fresh weight. The height and diameter of lying and standing deadwood was measured in the sample plot. The biomass of deadwood was measured by calculating the volume of the wood by using the following equations 5 and 6 (Rawat *et al.*, 2017):

$$Volume\ (m^3) = 1/3\ \pi h\ (r_1^2 + r_2^2 + r_1 \times r_2) \quad \text{equation 5}$$

where:

h	=	height of the standing dead wood (m)
r_1	=	radius at the base(m)
r_1	=	radius at the top (m)

Further, the overall biomass was converted to carbon stock for deadwood in a similar manner as aboveground carbon stock.

$$Biomass = volume \times wood\ density \quad \text{equation 6}$$

2.6.4 Estimation of litter biomass

Two quadrats of 3×3 m were laid in two corners diagonally of the each plot inside the plot boundary. Thus, a total of 90 plots in each forest type below 5 cm diameter were sampled. In each quadrat, the fresh weight of the litter was measured. The sample material was taken after the proper marking and packing of the polybag to the laboratory for further analysis where it was washed by floatation method and was oven dried at 65°C. After the attainment of the constant weight by the sample material, the dry weight of the material was taken. This was extrapolated on per hectare basis for even representation. Below equation 7 used for estimation of dry mass of leaf litter on hectare basis. Further, the biomass of litter was converted to carbon stock using the conversion factor (0.5) of carbon fraction of dry matter.

$$Leaf\ litter = (fresh\ weight - dry\ weight) / (fresh\ weight) \times 10,000 \quad \text{equation 7}$$

2.6.5 Estimation of soil organic carbon stocks

Soil sample within the plot inside the plot boundary was collected from two corners by laying out 1×1 m quadrat. Soil sample was taken from 0-30 cm depth as per IPCC Good Practice Guidance for LULUCF (IPCC, 2003). At sampling point, forest floor and litter from an area 1×1 m is removed and a pit of 30 cm wide, 30 cm deep and 50 cm in length was dug out. Soil from three sides of the pit of 0 to 30 cm depth was scraped with the help of *khurpee* and bulked. The soil was mixed thoroughly and 500 gm was collected for soil analysis. The soil sample was collected kept in a polythene bag and tightly closed with the thread. A label showed the sample details inside and outside the bag.

2.6.5.1 Soil organic carbon estimation

Soil samples were dried at room temperature in the laboratory. After drying, the samples were ground and sieved through 100 mesh sieve (2 mm sieve). The sieved samples were used for soil organic carbon estimation. Soil organic carbon was estimated by standard Walkley and Black method (1934).

2.6.5.2 Bulk density estimation

The core sampler (of known volume) was used for the collection of the sample of bulk density at two depths from 0-15 cm and 15-30 cm depths. The core sampler with the help of hammer was inserted. Precaution was taken while removing the core sampler so that the core may not drop down. The soil in the core was kept in the oven for drying at 65°C till it attains constant weight. The dry weight was measured by following the formula:

Bulk density of the soil = dry weight of the soil (gm)) / (Volume of the core (cm^3)   *equation 8*

2.6.5.3 Percent coarse fragment estimation

Percent coarse fragment (>2 mm size) in soils was estimated by morphological examinations of soils at 0-30 cm depth. Small amount of soil (approx. 100-200 g) from pit were taken out and placed on palm and was visually examined to know that how much quantity of coarse fraction (more than 2 mm size) exists in the sample.

2.6.5.4 Soil organic carbon stock estimation

The soil organic carbon stock was calculated by using the formula (equation 9) given below (Batjes, 1996):

Soil organic carbon stock (tC/ha) = CiDiEi (1-Gi)   *equation 9*

where,

Ci = Soil organic carbon content (%)

Di = Bulk density (Mg m^{-3})

Ei = Soil depth (m)

Gi = Volume fraction of coarse elements

Box 1: Plot layout

i. With the help of GPS and project sampling map, the centre of the plot was located in the particular forest type within the project area.

ii. For future validation and verification, the centre and boundaries of the plot were marked with the help of permanent paint.

iii. After laying the plot with the help of the ropes, the trees in one direction were measured

iv. Each tree as per the suitability of field conditions and to avoid duplicacy of the tree within the plot was marked.

v. The diameter of each tree at breast height (*i.e.* 1.37 cm) was measured and recorded it in the permanent data records along with the species name.

vi. The height of the tree using clinometer was measured.

vii. If a tree lied on the plot boundary, 50 % of the tree trunk lies inside or outside the boundary was checked. Trees who are more than 50 % of the trunk lies outside of the boundary were excluded.

2.7 Data analysis

Data collected from 90 sample plots under different forest types were compiled in Microsoft excel by ensuring its quality assurance and control by reducing the uncertainty. The relevant data were subjected to further analysis by summing the values obtained under different carbon pools in each forest type. The conversion of the data was done from plot basis to per hectare basis and further with the area covered by different forest type.

3 Results

Biomass is an important parameter to assess the assimilation of carbon by plants via photosynthesis process. It is a function of DBH, height and wood density at a given location (Dasgupta *et al*., 2015). The present study has estimated biomass carbon density present in five carbon pools in each forest type of the project area.

3.1 Aboveground biomass and carbon stock

The aboveground biomass ranged from 31.78 Mg/ha to 165.02 Mg/ha and carbon stock ranged from 15.89 tC/ha to 82.51 tC/ha. Among the four forest types, the maximum aboveground biomass was found in East himalayan moist mixed deciduous forest (165.02 Mg/ha) followed by Cachar tropical moist evergreen forest (140.82 Mg/ha) whereas minimum aboveground biomass was found in secondary moist bamboo brakes (31.78 Mg/ha). The pioneer euphorbiaceous scrub showed 45.31 Mg/ha aboveground biomass. The Table 3 has shown the aboveground carbon stock on per hectare basis in different forest types.

3.2 Belowground biomass and carbon stock

Belowground biomass comprises of coarse and fine roots. Maximum belowground biomass was found in *Cachar* tropical moist evergreen forest (60.60 Mg/ha) and minimum was observed in secondary moist bamboo brakes (8.58 Mg/ha).

The pattern of belowground carbon stock was observed highest in *Cachar* tropical moist evergreen forest (30.31 tC/ha) followed by east Himalayan moist mixed deciduous forest (27.86 tC/ha) and minimum was observed in secondary moist bamboo brakes (4.29 tC/ha). The pioneer euphorbiaceous scrub showed below ground biomass and carbon stock 12.23 Mg/ha and 6.11 tC/ha.

3.3 Dead wood biomass and carbon stock

Among the four forest types, the maximum biomass and carbon stock was observed in *Cachar* tropical semi-evergreen forest which is 6.08 Mg/ha and 3.04 tC/ha, respectively. This was followed by east Himalayan moist mixed deciduous forest which showed biomass and carbon stock as 5.54 Mg/ha and 2.77 tC/ha, respectively. The values observed for dead wood biomass and carbon stock in different types of forest are compiled in Table 3. Minimum deadwood biomass was observed in secondary moist bamboo brakes with 3 Mg/ha and carbon stock 1.5 tC/ha.

3.4 Litter biomass and carbon stock

Little variation in litter biomass and carbon stock of litter was found in all forest types found in Mizoram. The maximum litter biomass was observed in *Cachar* moist evergreen forest (0.88 Mg/ha) followed by east Himalayan moist mixed deciduous forest (0.84 Mg/ha). The minimum litter biomass was observed in pioneer euphorbiaceous scrub with 0.70 Mg/ha value. Secondary moist bamboo brakes forest type showed 0.72 Mg/ha litter biomass. Similar pattern was observed in carbon stored by litter in different forest type given in Table 3.

3.5 Bulk density and soil organic carbon density

The bulk density of different forest type varied from 1.03 to 1.23 Mg/m^3, the highest bulk density was found in east Himalayan moist mixed deciduous forest (1.23 Mg/m^3) and the lowest was found in Pioneer Euphorbiaceous scrub (1.03 Mg/m^3).

The soil organic carbon density was quantified in the order of East himalayan moist mixed deciduous forest (103.25 tC/ha > Cachar tropical moist evergreen forest (88.59 tC/ha) > Secondary moist bamboo brakes (82.22 tC/ha) > Pioneer euphorbiaceous scrub (51.19 tC/ha).

Table 3. Carbon stocks in different forest types in five carbon pools of project area

Forest type	**Aboveground carbon (t C/ha)**	**Belowground carbon (tC/ha)**	**Dead-wood carbon (tC/ha)**	**Litter carbon (tC/ha)**	**Soil organic carbon (tC/ha)**	**Total carbon stock (tC/ha)**	**Total carbon stock (million tonnes)**
Secondary moist bamboo brakes	15.89	4.29	1.50	0.36	82.22	104.27	860.61
Pioneer euphorbiaceous scrub	22.65	6.11	4.50	0.70	51.19	85.15	23.55
Cachar tropical moist evergreen forest	70.41	30.31	3.04	0.44	88.59	192.78	909.58
East Himalayan moist mixed deciduous forest	82.51	27.86	2.77	0.42	103.25	216.81	1122.30

3.6 Total biomass and carbon stock

Cumulative effect of five carbon pools in different forest types was studied and found in the range of (85.15 - 216.81 tC/ha). The highest carbon stored was observed in East himalyan moist mixed deciduous forest (216.81 tC/ha) followed by East himalayan moist mixed deciduous forest (192.78 tC/ha) and minimum in pioneer euphorbiaceous scrub (85.15 tC/ha). Secondary moist bamboo brakes showed total carbon stock as 104.27 tC/ha.

After extrapolation to different forest type's area, the total carbon stock was showed in the order of East himalayan moist mixed deciduous forest > Cachar moist evergreen forest > secondary moist bamboo brakes > pioneer euphorbiaceous scrub.

4 Discussion

In forestry sector, regional terrestrial carbon accounting is important especially to address the issue of climate change mitigation through REDD+. The central idea of REDD+ is performance based payments that can be established through reducing emissions and enhancing carbon stocks (Angelsen and Rudel, 2013). A project level approach was followed for measurement, reporting and verification (MRV) where finer temporal and geographical scales of measurement of carbon stock and changes are emphasized for credit flow.

In this perspective, current study has attempted to study the carbon stock estimation in five carbon reservoirs as per IPCC Good Practice Guidance for LULUCF (IPCC, 2003) in four forest types of Mamit district, Mizoram. Aboveground biomass constitutes the major portion of the reservoir in the plants. In current study, the aboveground biomass ranged from 31.78 Mg/ha to 165.02 Mg/ha and carbon stock ranged from 15.89 tC/ha to 82.51 tC/ha. Similar finding was observed by Chabbra *et al*. (2002). Borah *et al*., 2013 studied aboveground biomass and carbon stock of forest in *Cachar* district, Assam and reported biomass ranges from 32.47 Mg/ha to 261.64 Mg/ha and carbon stock ranged from 16.24 Mg/ha to 130.82 Mg/ha. The estimates of the current study fall under the similar range. The potential of forest to sequester carbon is influenced by the forest type, age of the forest, size and class of tree etc. (Terakunpisut *et al*., 2007). Comparable values were found by other researchers such as Flint and Richards 1996; Singh *et al*., 2018 and Gogoi *et al*., 2017. Ramachandran *et al*., 2007 also reported biomass in a range of 57.50-307.30 t/ha in different forest types of natural forest area in a part of Eastern Ghats of Tamil Nadu.

In relation to area, the maximum contribution in carbon storage was found maximum in East himalayan moist mixed deciduous forest (38.48%) followed by Cachar tropical moist evergreen forest (31.19%) and minimum was observed in Pioneer euphorbiaceous scrub (0.80%). The contribution in carbon storage by Secondary moist bamboo brakes was found to be 29.51%. Soil being a significant part of global carbon stock, in this study the soil organic carbon density ranged from 51.19 tC/ha - 103.25 tC/ha which is comparable with Gogoi *et al*., 2017 and Vanlafakawma *et al.,* 2014. Singh *et al*., 1991 also reported soil organic carbon stock in the range from 82.1 - 134.1 Mg C ha^{-1} which is alomost similar with the present study. The variability in the soil carbon stock may be due to disturbance brought by shifting cultivation, other anthropogenic activities which includes developmental and other drivers of deforestation and forest degradation etc.

Understanding of spatial distribution of biomass is a prerequisite to find out the sources and sinks of carbon (C) as a result of forest to degraded land and *vice versa* as well as their temporal variations (Yavasli, 2012). Therefore, the precise assessment of CO_2 emissions as a result of land use changes, forest fire, degradation, and other anthropogenic activities are required and are one of the few challenging issues for understanding global carbon cycle and hence for making policies.

5 Conclusion

With the formulation of National REDD+ Strategy and Forest Reference Level for India, in addition to this baseline forest carbon stocks report can prove an effective step to explore the REDD+ initiatives. The forest based carbon stocks permanence helps in achieving the long term climate change mitigation goals. This report will serve as pioneer step in implementation of REDD+ activities in the project area to achieve the over arching objective of National REDD+ Strategy and will help in providing incentives to local communities through implementation of REDD+ activities.

References

Angelsen, A. and Rudel, T.K. (2013). Designing and implementing effective REDD + policies: A forest transition approach. *Review of Environmental Economics and Policy*, 7 (1): 91-113.

Batjes, N.H. (1996). Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science*, 47:151-163.

Borah, N.,Nath, A.J. and Das, A.K. (2013). Aboveground biomass and carbon stocks of tree species in tropical forests of Cachar District, Assam, Northeast India. *International Journal of Ecology and Environmental Sciences*, 39 (2): 97-106.

Champion, H.G. and Seth, S.K. (1968). A revised survey of the forest types of India. Government of India Publications, Delhi, India.

Chhabra, A., Palria, S. and Dadhwal, V.K. (2002). Growing stock-based forest biomass estimate for India. *Biomass and Bioenergy*, 22:187-194.

Dasgupta, S., Singh, T.P. and Rawat, R.S. (2015). Assessment of above ground biomass and soil organic carbon stock in the forests of India. In: M.S.R. Murthy, S. Wesselman, H. Gilani (ed.) *Multi-scale forest biomass assessment and monitoring in the Hindu Kush Himalayan region: a geospatial perspective*. ICIMOD, Kathmandu, Nepal, pp.20-29.

Flint, P.E. and Richards, J.F. (1996). Trends in carbon content of vegetation in South and Southeast Asia associated with change in land use. pp. 201-300. In: V.H. Dale (ed.) *Effects of Land-Use Change on Atmospheric CO_2 Concentrations, South and Southeast Asia as a Case Study*. Springer-Verlag, Berlin.

FAO (2010). Global Forest Resources Assessment 2010. FAO Forestry Research Paper, 63, Rome.

FSI (1996). Volume Equations for Forests of India, Nepal and Bhutan. Forest Survey of India, Dehradun.

FSI (2017). Indian State of Forest Report 2017. Forest Survey of India, Dehradun.

Gogoi, A., Sahoo, U.K. and Singh, S.L. (2017). Assessment of biomass and total carbon stock in a tropical wet evergreen rainforest of Eastern Himalaya along a disturbance gradient. *Journal of Plant Biology and Soil Health*, 4(1):1–8.

IPCC (2003). *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F., Eds., Institute for Global Environmental Strategies (IGES), Kanagawa.

Kaul, M., Dadhwal, V.K. and Mohren, G.M.J. (2009). Land use change and net C flux in Indian forests. *Forest Ecology and Management*, 258: 100–108.

Kindermann, G.E., McCallum, I., Fritz, S. and Obersteiner, M.A. Global forest growing stock, biomass and carbon map based on FAO statistics. *Silva Fennica*, 42(3):387-396.

Kohl, M., Lasco, R., Cifuentes, M., Jonsson, O., Korhonen, K.T., Mundhenk, P., Navar, J.D.J. and Stinson, G. (2015). Changes in forest production, biomass and carbon: Results from the 2015 UN FAO Global Forest Resource Assessment. *Forest Ecology and Management*, 352:21-34.

Ramachandran A., Jayakumar, S., Haroon, R. M., Bhaskaran, A. and Arockiasamy, D. I. (2007). Carbon sequestration: estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. *Current Science*, 92(3):323-331.

Rawat, V.R.S., Rawat, R.S. and Verma.N. (2017). *Training manual on REDD+ Measurement, Reporting and Verification*. Indian Council of Forestry Research and Education, Dehradun (India).

Singh, O.P., Datta, B. and Rao, C.N. (1991). Pedochemical characterization and genesis of soils in relation to altitude in Mizoram. *Journal of the Indian Society of Soil Science*, 39: 739-750.

Singh, S.L., Sahoo, U.K., Gogoi, A. and Kenye, A. (2018). Effect of land use changes on carbon stock dynamics in major land use sectors of Mizoram, Northeast India. *Journal of Environmental Protection*, 9: 1262-1285.

Terakunpisut, J., Gajaseni, N., Ruankawe, N. (2007). Carbon sequestration potential in aboveground biomass of thong pha phum national forest, Thailand. *Applied Ecology and Environmental Research* 5(2): 93-102.

Vanlafakawma, D.C., Lalnunmawia, F. and Tripathi, S.K. (2014). Soil carbon pools of bamboo forests of Mizoram, India. *Science Vision*,14 (1):46-50.

Walkley, A.E. and Black, J.A.(1934). An examination of the Degitjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*, 37:29-38.

Yavasli, D.D. (2012). Recent approaches in aboveground biomass estimation methods. *Aegean Geographical Journal*, 21(1):39–49.

Annexure I

Plot Description Form

Name of Division: ……………….. Date: ……………….. Time: ………………..

S. No.	Description	Inputs			
1	Quadrat No.				
2	Range				
3	Block				
4	Compartment				
5	Grid				
6	Latitude				
7	Longitude				
8	Altitude				
9	Identification Point of Plot	Locality	Landmark	Distance from Road (km)	Nearby Village
10	Legal Status	Reserve Forest ☐	Protected Forest ☐	Community Forests ☐	
11	Land Use	Closed Forest ☐	Dense Forest ☐	Open Forest ☐	Scrub ☐
12	Slope				
13	Aspect				
14	Humus	Shallow ☐	Medium ☐	Deep ☐	No Humus ☐
15	Regeneration Status	Adequate ☐	Inadequate ☐	Absent ☐	
16	Fire Incidence	Heavy ☐	Moderate ☐	Light ☐	None ☐
17	Faunal Sighting, if any		Species		
		Mammals			
		Birds			
		Reptiles			
		Amphibians			

18 Tree – DBH and Height Measurements (31.62m X 31.62m Central Plot/Lateral Plot)

Plot No.: …………………

S. No.	Species Name		DBH (cm)	Height (m)
	Common Name	Botanical Name		
1				
2				
3				

19	Shrub and Regeneration (3m X 3m Plot)						
	S. No	Species Name		Collar dia at base (cm)	DBH (cm) if any	Height (m)	Remarks, if any, about the conditions of shrub vegetation.
		Botanical Name	Loca Name				
	Plot No. ……………………….. Sub Plot No: ………………………..						
	1						
	2						
	3						
	Plot No. ……………………….. Sub Plot No: ………………………..						
	1						
	2						
	3						
	Plot No. ……………………….. Sub Plot No: ………………………..						
	1						
	2						
	3						
	Plot No. ……………………….. Sub Plot No: ………………………..						
	1						
	2						
	3						
	Plot No. ……………………….. Sub Plot No: ………………………..						
	1						
	2						
	3						

20	Herbs and Seedlings (1m X 1m Plot)				
	S.No.	Species Name		Height (m)	Remarks, if any, about the condition of herbal vegetation
		Botanical Name	Local Name		
	Plot No. ……………………….. Sub Plot No: ………………………..				
	1				
	2				
	3				
	Plot No. ……………………….. Sub Plot No: ………………………..				
	1				
	2				
	3				
	Plot No. ……………………….. Sub Plot No: ………………………..				
	1				
	2				
	3				

	Plot No. ……………………….. Sub Plot No: ………………………..				
	1				
	2				
	3				
	Plot No. ……………………….. Sub Plot No: ………………………..				
	1				
	2				
	3				
21	Litter Sample Collection				
	Sample No: ………………… Fresh Weight: ……………………… Sample No: ………………… Fresh Weight: ……………………… Sample No: ………………… Fresh Weight: ………………………				

22	Soil Sample Collection	
	Erosion	Slightly ☐ Moderate ☐ Severe ☐ Gullied ☐
	Physiographic	Hill Top ☐ Hill slope ☐ Plateau ☐ Plain ☐ Valley ☐
	Moisture	Wet ☐ Moist ☐ Dry ☐
	Soil Sample for Moisture	Sample No: ………………… Fresh Weight: ……………………… Sample No: ………………… Fresh Weight: ……………………… Sample No: ………………… Fresh Weight: ………………………

	Soil Sample No.Carbon Estimation:…….	Soil Sample No. Bulk Density 0-10 cm:…………	Soil Sample No. Bulk Density 10-20 cm:……………	Soil Sample No. Bulk Density 20-30 cm:……………

Sample Collected By: ………………..

Date: …………………………………

Annexure II

Allometric equations for volume estimation (FSI, 1996)

S. No.	Species name	Volume estimation
1	Albizzia species	$\sqrt{V}=-0.07109+2.99732*DBH-0.26953*\sqrt{DBH}$
2	Castanopsis tribuloides	$\sqrt{V}=0.3464+3.99269*DBH-1.64666*\sqrt{DBH}$
3	Ficus species	$\sqrt{V}=0.03629+3.95389*DBH-0.84421*\sqrt{DBH}$
4	Gmelina arborea	$V=0.01156+0.21230*DBH+5.10448*DBH2$
5	Macaranga indica	$\sqrt{V}=-0.07109+2.99732*DBH-0.26953*\sqrt{DBH}$
6	Syzygium cuminii	$\sqrt{V}=-0.05923+2.33654*DBH$
7	Schima wallichi	$\sqrt{V}=-0.07109+2.99732*DBH-0.26953*\sqrt{DBH}$
8	Sterospermum species	$\sqrt{V}=0.49746+5.98454*DBH-2.84986*\sqrt{DBH}$
9	Rest of the species	$-0.17114+2.00564*DBH+0.54361*\sqrt{DBH}$