Baseline Forest Carbon Assessment in Eastern Nawalparasi, Nepal

ANSAB

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LIST OF ACRONYMS AND ABBREVIATIONS

ANSAB	Asia Network for Sustainable Agriculture and Bioresources
BMU	German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BZCFUG	Buffer zone community forest users' group
CFUG	Community forest users' group
CO2e	Carbon dioxide equivalent
DBH	Diameter at breast height
GLAD	Global Land Analysis and Discovery Laboratory, University of Maryland
GIS	Geographic information system
GPS	Global positioning system
ha	Hectare
IKI	International Climate Initiative of the German Federal Government
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
LRP	Local resource person
m	Meter
MHS	Manfred-Hermsen-Stiftung for Nature Conservation & Environmental Protection
QA/QC	Quality Assurance and Quality Control
t	Metric ton
TISC	Tree Improvement and Silviculture Division
tC	Carbon in Metric ton
tCO2e	Carbon dioxide equivalent (in Metric ton)

EXECUTIVE SUMMARY

This study report presents a comprehensive assessment of forest carbon stock in the four municipalities of eastern Nawalparasi, namely Kawasoti Municipality, Madhyabindu Municipality, Hupsekot Rural Municipality, and Binayee-Tribeni Rural Municipality, with the underlying purpose of generating the baseline of forest carbon stock in order to observe the changes taking place as a result of sustainable forest management activities induced by the project.

ANSAB and Manfred-Hermsen-Stiftung (MHS), with funding support from the International Climate Initiative (IKI) and MHS are implementing the project 'Nature Conservation and Agroforestry Production in Rural Communities' in the four municipalities. This project contributes to biodiversity conservation and climate change mitigation, and enhances livelihoods and the development perspectives of local communities through improved community-based management of forests and farms.

The project activities are focused on approximately 20,000 ha of forests within the four municipalities, but it is expected that adjacent forest areas will also benefit from these activities. Hence the total area of forests within the four municipalities is being considered in the present assessment. The study applied standard methodologies for sampling, forest carbon inventory, and analysis, following the IPCC and forest carbon stock measurement guidelines (Subedi et al. 2010). Field assessments were conducted from October to December 2021, with data analysis beginning in early 2022. Permanent plots of three nested concentric circles with horizontal radius ranging from 1 to 12.62 m were laid out to quantify different carbon pools, specifically seedlings, saplings, and trees. Carbon stock was calculated using the above-ground carbon pool, which included saplings and trees.

The total land area of the four municipalities is 81,906 ha, of which 48,298 ha (or about 59%) is covered by forests. About 70 percent of the forest area, or 33,659 ha, is made up of dense forest strata, which are strata with more than 70 percent canopy cover. The other 30 percent, or 14,639 ha, is made up of sparse forest strata (strata having less than 70 percent canopy cover). A total of 56 permanent sample plots were randomly placed in each stratum, with 45 sample plots in the dense forest stratum and 11 sample plots in the sparse forest stratum.

The study estimated the mean forest carbon stock in the project area to be 561.62 $tCO2e\ ha^{-1}$, with a total forest carbon stock of 27.125 million tCO2e. The dense strata account for more than 81% of total forest carbon, while the sparse strata account for about 19% of total carbon stock.

The study has used the reference level estimated by the Emission Reduction Program of the Government of Nepal in the TAL (Terai Arc Landscape) region to estimate the reference scenario in the project area. As our project area lies in the TAL region, this reference emission level has been used. This assessment has identified the drivers of deforestation in the project area that are similar to the drivers identified in the TAL region. Based on the document, the reference emission level for the TAL program area covering a total forest area of 1,173,550 ha is 895,710.08 $tCO2e\ yr^{-1}$, or 0.76 $tCO2e\ yr^{-1}\ ha^{-1}$. With this figure, we estimated the carbon stock to decline by 36,863.37 $tCO2e\ yr^{-1}$ in the project area. This value was used to establish the baseline reference scenario for the project area. The project aims to increase the forest carbon stock in the project area by 665,000 tCO2e in three years through improved forest management practices in line with the National Forest Stewardship Standards (NFSS). This increment in forest carbon stock is based on ANSAB's previous study in forest areas of adjoining districts, where sustainable forest management activities incl. improved silviculture operations and counteracting the drivers of deforestation and degradation, contributed to sequester 13.689 tCO2e/hectare/year. By conducting the present assessment, we established more confidence that the initial assumptions made regarding the increase in carbon stock can be achieved. The project plans to reach the target by capacitating the community forest user groups on sustainable forest management, revising forest management plans in line with the NFSS, and providing sustainable forest management on the ground to address the major drivers of deforestation and forest degradation.

A field-level assessment will be carried out in the third year to measure the change in forest carbon stock after the project's intervention.

1. INTRODUCTION

1.1 Background

ANSAB along with the German foundation Manfred-Hermsen-Stiftung for Nature and Environment (MHS), has been jointly implementing the project "Nature Conservation and Agroforestry Production in Rural Communities" in the Kawasoti, Madhyabindu, Hupsekot, and Binayee-tribeni municipalities of the Nawalparasi (East) district in southern Nepal. This project is funded by the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection (BMU) and co-funded by MHS, and is being implemented for three years starting on September 1, 2021.

The project aims to contribute to climate protection and biodiversity conservation and build resilience for ecosystems and forest user communities by bringing over 20,000 ha of forests and 1,000 ha of farm land under improved management and benefiting 30,000 ha indirectly through incentives and demonstration effects. Reduction of emissions and sequestration of carbon are achieved by fostering sustainable forest management and forest biodiversity and by addressing the drivers of deforestation and forest degradation, including forest fires and overexploitation of forest resources.

In this regard, ANSAB has carried out the current study to establish a baseline for the carbon stock of forests in the project area in order to quantify the changes in forest carbon stock induced by the project.

1.2 Objectives

The overall goal of this study is to assess the forest carbon stock in the Kawasoti, Madhyabindu, Hupsekot, and Binayee-Tribeni Municipalities of the eastern Nawalparasi district, where the project "Nature Conservation and Agroforestry Production in Rural Communities", is being implemented. The specific objectives of the study are to:

- Quantify the current stock of forest carbon in the project area and adjoining forest areas of the four municipalities
- Establish a reference scenario for measurement of the change in forest carbon stock induced by the project through sustainable forest management and related activities.

1.3 Organization of the report

The study's context, purpose, and goals are covered in Chapter 1. Chapter 2 gives an overview of the major types of vegetation, forest cover, and climate in the project area. The methodology is described in detail in Chapter 3 along with the study's sampling design, field setup, field inventory and analysis, and the quality assurance and quality control procedures used. Lastly, Chapter 4 encompasses the study's findings and discussion.

2. GENERAL OVERVIEW OF THE PROJECT AREA

The project area connects the Chitwan National Park with the Himalayan foothills and lies within an ecologically highly sensitive region that is part of a global biodiversity hotspot. The project area involves four different municipalities, namely Kawasoti, Madhyabindu, Hupsekot, and Binayee-tribeni of Nawalparasi (East) district, Nepal. A map of the project area is presented in Figure 1.

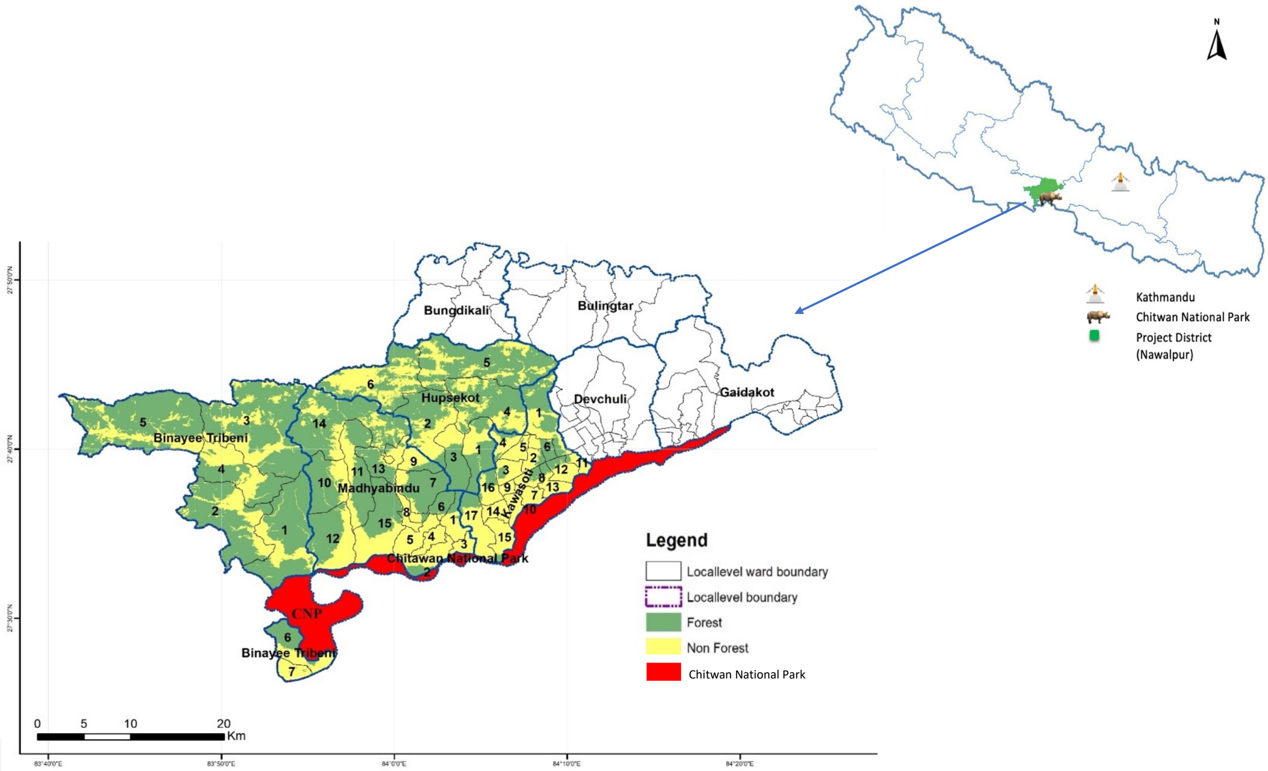

Figure 1: Map of Nawalparasi (East) district showing details of four municipalities

2.1 Forest coverage

The total area of the four municipalities is 81,906 ha, including 48,298 ha (about 59%) of forest area. Respective values, including the population by municipality, are presented in Table 1.

Table 1: Area and population of the project area

Municipalities	Total area (ha)	Forest Area (ha)	Non-Forest area (ha)	Forest cover (in %)	Population
Kawasoti	10,833	2,938	7,895	6.08	62,481
Madhyabindu	23,365	13,430	9,935	27.81	54,424
Binayee-tribeni	28,772				
Hupsekot	18,936	11,799	7,137	24.43	25,065
Total	**81,906**	**48,298**	**33,608**	**100**	**175,089**

Source: DFO Nawalparasi (East)

2.2 Forest types

The four municipalities cover a variety of ecological zones, including tropical, subtropical, and temperate zones. According to the Forest and Vegetation Types of Nepal (2002), there are six distinct dominant forest types in the project area (Table 2).

Table 2: Forest types in the project area

Forest Type	Total area (ha)	Percentage (%)
Hill Sal Forest	26,841.77	55.58
Lower Temperate Oak Forest	296.99	0.61
Lower Tropical Sal and Mixed Broad Leaved Forest	15,361.77	31.81
Riverine Khair-Sissoo Forest	381.61	0.79
Schima-Castanopsis Forest	3,944.07	8.17
Upper Tropical Riverine Forest	1471.50	3.04
Total	**48,298**	**100**

Source: TISC, 2002

3. METHODOLOGY

The study has applied standard methodologies and stepwise procedures for the sampling, inventorying of forest carbon, following the Forest Carbon Stock Measurement Guidelines developed by ANSAB, ICIMOD, and FECOFUN in 2010 (Subedi et al. 2010). Details of the methodology are presented below.

3.1 Sampling design

3.1.1 Project area base map development

To create a base map, land use and forest cover data maps were overlaid on the spatial boundaries of the four municipalities. Data from the Department of Survey (DoS, 2010) was used for municipal land use, and data from the Department of Forest Research and Survey (DFRS, 2015) for forest coverage. Figure 2 shows the resulting base map, including the project area's forest, non-forest, built-up, and other land use categories.

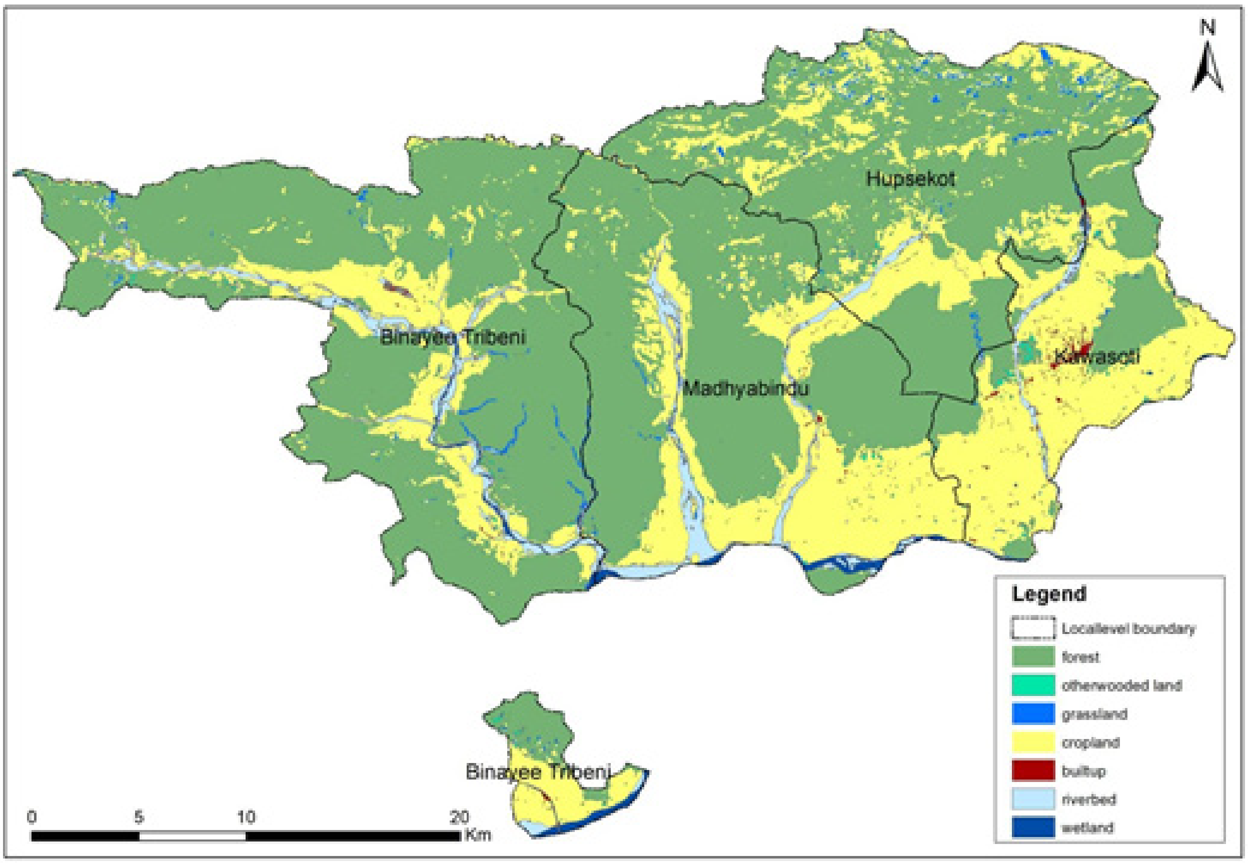

Figure 2: Project area base map

3.1.2 Forest stratification

The Global Canopy Cover data prepared by the Global Land Analysis and Discovery (GLAD) laboratory in the Department of Geographical Sciences at the University of Maryland (https://glad.umd.edu/) was used for the stratification of the forest cover map. Tree canopy cover data of 2019 was overlaid by forest cover map of the project area for stratification. Masked canopy cover data was reclassified into two strata[1]: canopy cover having more than 70 percent and canopy cover having less than 70 percent. The stratified map is presented in Figure 3, and Table 3 shows the areas by Municipality, with circa 70% of the total forest under the dense strata and the remaining 30% in the sparse strata.

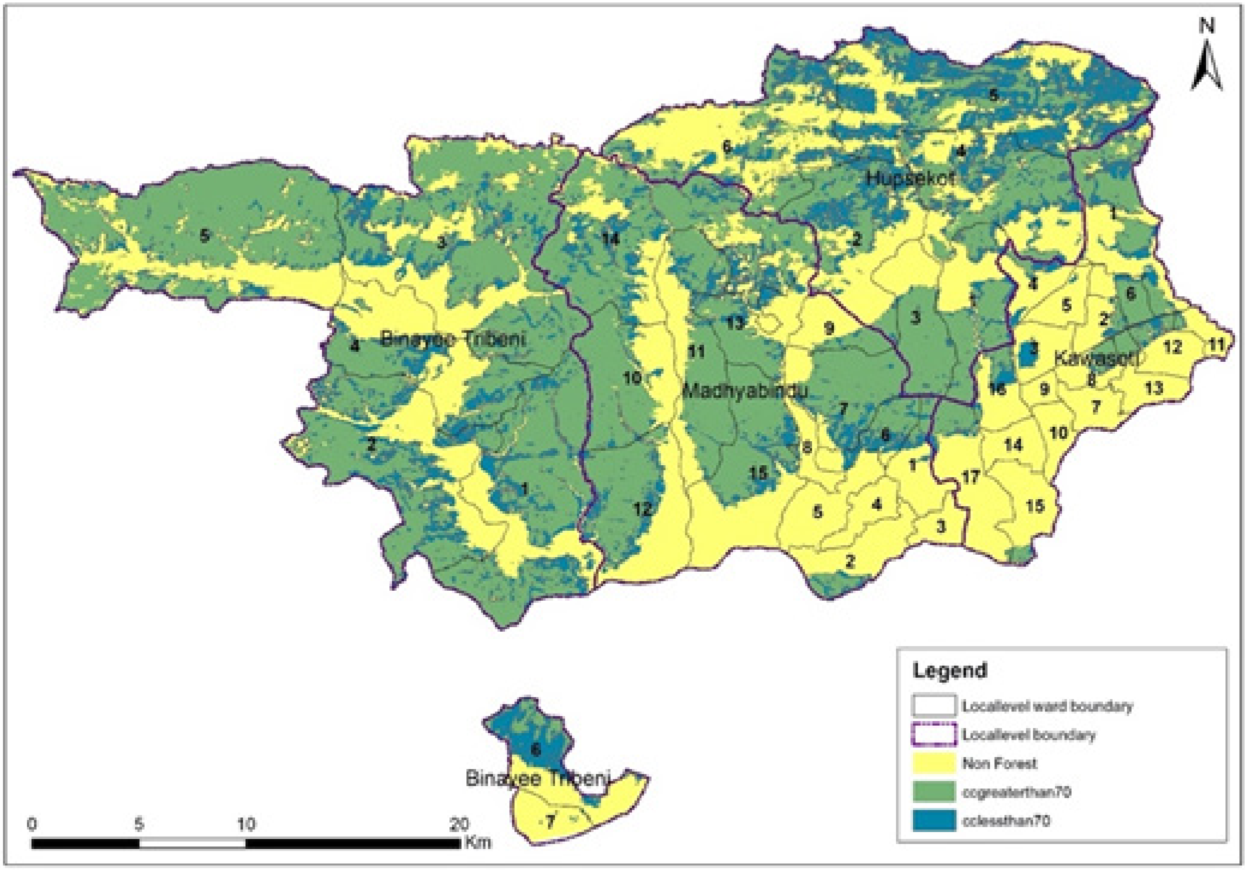

Figure 3: Stratified map of the project area

Table 3: Forest strata of the project area

Municipalities	Total forest area (ha)	Forest area in Dense strata (ha)	Forest area in sparse strata (ha)
Kawasoti	2,938	1,923	1,015
Madhyabindu	13,430	10,405	3,025
Hupsekot	11,799	6,298	5,501
Binayee-tribeni	20,131	15,033	5,098
Total	**48,298**	**33,659**	**14,639**

[1]The forest strata are areas distinctly different from each other in forest types, density, and species; and as such they have different amounts of carbon stored.

3.1.3 Permanent plot estimation and distribution on the map

For calculating the total number of permanent sample plots required in each stratum, we used the following equation (UNFCCC, 2009).

$$n_i = \frac{\sum_{h=1}^{L} N_i \cdot st_i}{\left(N \cdot \frac{E_1}{Z^{\alpha}/_2}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot N_j \cdot st_i$$

Where,

L = total number of strata (dimensionless);
Ni = maximum total number of sample plots in stratum;
sti = standard deviation for stratum;
N = maximum possible number of sample plots in the project area;
E1 = allowable 10% error; and
Zα/2 = value of the statistics Z (embedded as inverse of standard normal probability cumulative distribution).

A total of 61 concentric nested circular permanent sample plots, including 47 plots for dense strata and 14 plots for sparse strata have been estimated for the detail forest carbon assessment in the project area (Table 4).

Table 4: Total number of permanent sample plots by municipality

S.N	Municipality	Number of plots by strata		
		Dense strata	Sparse strata	Total
1	Kawasoti	2	2	4
2	Madhyabindu	16	3	19
3	Hupsekot	10	2	12
4	Binayee-Tribeni	19	7	26
Total		**47**	**14**	**61**[(2)]

After calculating the number of permanent sample plots, the sample plots were distributed on the base map to identify the area for conducting the forest carbon inventory. The permanent plots were distributed randomly in both the dense and sparse forest strata using the Hawth's analysis tools from the ArcGIS software. Figure 4 depicts the distribution of the permanent sample plots throughout the project area.

[2]Out of 61 sample plots, 56 plots were established as permanent sample plots during field level assessment. The remaining 5 plots were dropped because they were in the high-risk area of tiger attack, with recent human casualties.

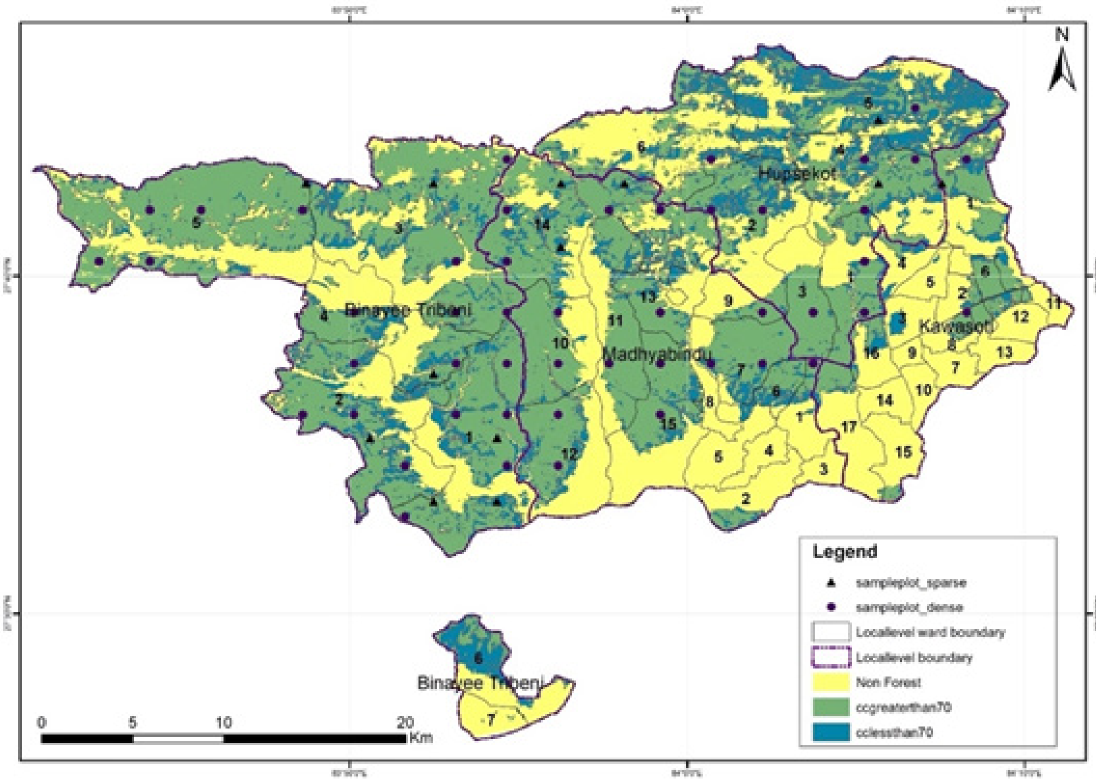

Figure 4: Distribution of permanent sample plots in the project area

3.2 Field Measurement

3.2.1 Formation of survey team and orientation for field measurement

For the field measurement of forest carbon, three survey teams were formed. Each team included five members, led by a forest technician and supported by four local resource persons for detailed forest carbon assessments. The forest technicians were previously trained on the forest carbon assessment process and also involved with ANSAB in forest carbon measurement. They had detailed knowledge of the measurement techniques, were able to operate all equipment properly, and possessed comprehension about the importance of all relevant details. Before initiating the assessment, an orientation was provided to the teams, including the forest technicians and local resource persons, on the data collection format, survey equipment, responsibilities of crew members, and details to be considered during the field work for achieving higher accuracy and precision in the measurements. The members of the survey team, along with their roles and responsibilities are presented in Table 5.

Table 5: Roles and responsibilities of the forest carbon measurement team

Team Member	Roles and Responsibilities
Forest Technician-1	Navigation to the plot center, determine the plot edge and trees within the plots, measurement of tree height, supervision of the team and assurance of the quality of work and inventory, quality assurance and calibration of equipment before going to the field and after laying out each plot
Local resource person-1	Marking trees to be measured, laying out inner/core plots for sapling and seedling records, counting of seedlings in the innermost sub-plot
Local resource person-2	Inserting the iron rod in the center of the plot to make the permanent plot
Local resource person-3	Diameter measurement of tree and saplings
Local resource person-4	Record keeping of all the measurements carried out within the plot

3.2.2 Arrangement of equipment and materials

The equipment and materials as presented in Annex 1 were used to measure forest carbon stock. The equipment, data collection sheet and other materials were developed, collected and checked before initiating field measurement. This approach ensured that every instrument was functioning, and a complete set and number of data collection sheet, equipment and other materials was prepared before moving to the field sites.

3.2.3 Laying out the permanent plots

Size and shape of the sample plot

Permanent plots were set up to measure the carbon pools. Figure 5 shows how these plots were made, with three concentric circles having radii ranging from 1 m to 12.62 m. As such, these "subplots" were created to measure specific carbon stocks. The 12.62-m-radius for trees, the 5.64-m-radius for saplings, and the 1-m-radius for regeneration/seedlings of the selected tree species.

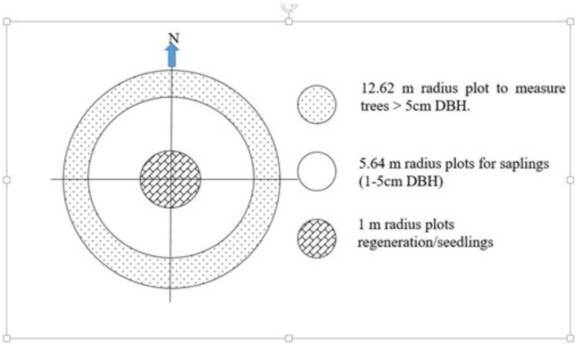

Figure 5: Size and shape of the permanent plot, composed of three nested concentric circles

Plot navigation, center point marking, and slope correction of the permanent plot

The sample plots were located in the field using GPS devices. By applying standard forestry practices, a total of 5 inaccessible plots were relocated in 50 meters of the plot vicinity.

After reaching the plot center, each plot was marked and an iron rod (0.5 feet) was inserted into the soil just at the center of the plot to facilitate periodic monitoring. The distance of at least one permanent reference point (stone or tree or any other permanent object) was recorded for each plot and a rough layout sketch of each plot incl. references, their distances, and bearings to the center produced. In addition, easily recognizable landmarks on the plot layout sketch were marked.

Once the center point of the plot was marked on the ground, the slope of the sample plot was corrected using Survey Master/Clinometer for slope determination and slope correction factor to convert plot's radius distance into actual surface length/distance. In addition, care was taken to complete slope correction mostly in the hilly terrain.

3.2.4 Measurement of carbon pools

This study has monitored the above ground forest carbon pools, including seedlings, saplings, and trees. Below ground biomass, commonly known as root biomass, was estimated using the default root-to-shoot ratio, as suggested by MacDicken (1997), which indicates that the below ground biomass represents nearly 20% of the above ground biomass.

Details of the field measurement techniques and methods of estimation of the forest stock in the above ground pools are presented below:

A. Seedlings/Regeneration count

The main objective of counting the regeneration/seedlings is to assess the status of natural regeneration and forest health in the particular forest and contribute to the development of measures for managing the forest in a sustainable manner for providing quality timber and other ecosystem services. The circular plot with a 1 m radius was laid out, and the number of regenerations of the desired tree species were counted within that plot. Regeneration consists of those plants that have a height less than 1 m.

B. Measurement of saplings

Saplings are plants with a DBH (diameter at breast height) of less than 5 cm. In order to record them, the 5.64-meter-radius circular plot was laid out, and the number of saplings was counted and measured. The first sapling was measured north of the plot's center, and subsequent measurements were taken in a clockwise direction. Each sapling's diameter was measured with a digital caliper at 1.3 m (breast height) from ground level.

C. Measurement of trees

All trees having DBH equal to or greater than 5 cm are considered trees in the estimation of above ground biomass. The trees were counted and measured within the nested plot of 500 square meters with a radius of 12.62 m. The tree height was measured using Vertex IV and transponder, and the tree DBH was measured using a diameter tape. To collect height and diameter variables precisely, the survey followed the standard principles of tree diameter and height measurement. Similarly, the diameter and height of irregular trees were measured according to the principles illustrated in Figure 6. The survey considered and counted two trees if forking was <1.3 m in height from ground level (DBH) and single trees if forking was >1.3 m in height.

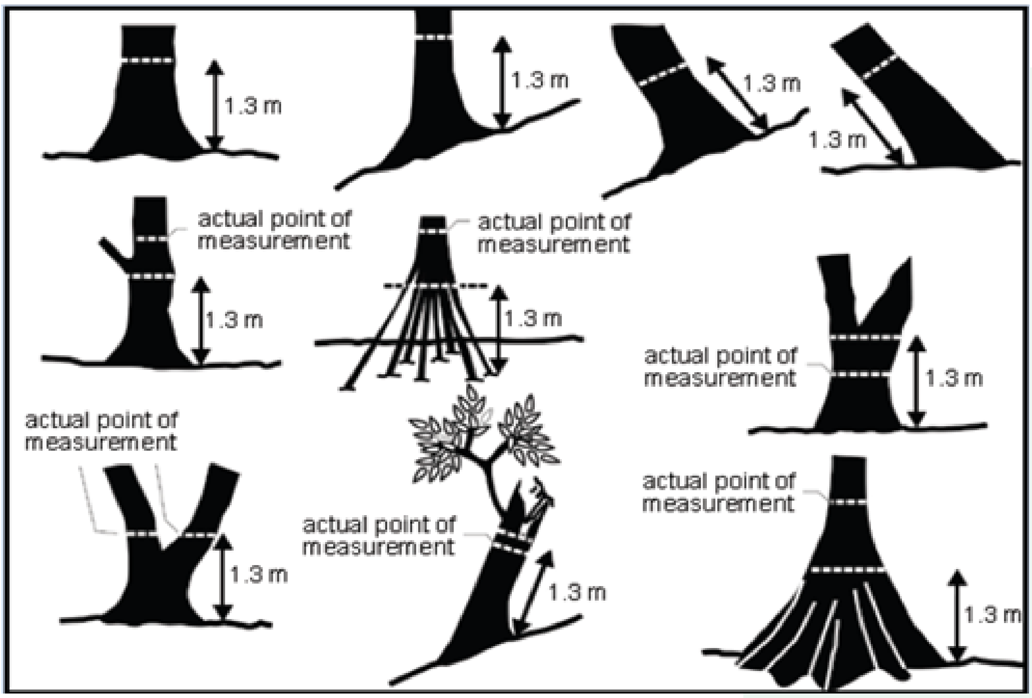

Figure 6: Standard forestry practices while measuring tree diameter at breast height

Individual trees with DBH equal to or greater than 5 cm were measured using diameter tape. In cases of deformed trunks at breast height, the diameter was measured from the nearest (above or below the breast height) well-formed point of the stem. Each tree was marked with temporary signs to prevent accidental double counting. Clinometers and highly sensitive hypsometers (Vertex IV and Transponder T3) were used to measure the heights of trees. Special attention was given to measure the height of leaning trees with the use of Vertex IV. This was done because a transponder attached to the tree trunk of a leaning tree would have resulted in a biased estimate of tree´s height unless the lean was exactly at 90o to the observer. Each tree was recorded individually with its species name. Border trees were included if they had > 50% of the basal area within the plot and excluded if they had > 50% of the basal area outside the plot. Trees overhanging the plot were also excluded, but trees with their trunk inside the sampling plot and branches outside were included.

3.3 Data compilation, entry and analysis

After field measurement, all the data sheets were indexed and entered into MS Excel. The data was afterwards exported and analyzed using the software R. The above-ground biomass (saplings and trees) was calculated, and the below-ground biomass (root biomass) was estimated following the forest carbon measurement guidelines (Subedi et. al, 2010). Then all the carbon pools were summed up to estimate the total biomass in a particular stratum and per hectare of forest area. The biomass was converted into carbon and carbon dioxide equivalent (CO2e) using fractions of 0.47 by the IPCC (2006) and 3.67 by Pearson et. al (2007), respectively. The equations and formulas employed are provided below.

3.3.1 Sapling biomass

National allometric biomass equations developed by the Department of Forest Research and Survey, Nepal (Tamrakar 2000) were used to determine the sapling biomass (≤5 cm DBH).

The regression equation model presented below was applied to calculate sapling biomass.

$$\log(AGSB) = a + b\log(D)$$

Where,

Log = natural log (dimensionless)
AGSB = above ground sapling biomass (kg)
a = intercept of allometric relationship for saplings (dimensionless)
b = slope allometric relationship for saplings (dimensionless) and
D = diameter at breast height of the sapling (at 1.3m above ground) (cm)

The variables of the previously developed regressions i.e., slope (a) and intercept (b) for all saplings have been used. The details of species parameters used for estimation of sapling biomass species parameters are presented in Annex 2.

3.3.2 Tree biomass

According to the ecological condition of the forest, the above-ground biomass calculations were performed based on the following equation from Chave et al. (2005, p. 93):

AGTB=0.0509*ρD^2 H

Where,

AGTB = aboveground tree biomass (kg)
p = wood specific gravity (kg m^{-3});
D = tree diameter at breast height (DBH) [cm]; and
H = tree height (m)

The wood´s specific gravity (ρ) was used according to associated forest types as mentioned in the Master Plan for Forestry Sector (GoN, 1988).

3.3.3 Total forest carbon stock calculation

The total forest biomass of each pool was converted to carbon by multiplying by the IPCC (2006) recommended default carbon fraction of 0.47. Then, the following equation was used to estimate total forest carbon stock by adding all carbon pools with total forest carbon stock (in tons) per unit area.

C(LU)=C(AGTB)+C(SB)+C(BB)

Where,

TC (LU) = carbon stock for a land use category [tC ha^{-1}];
C (AGTB) = carbon stock in above ground tree biomass [tC ha^{-1}];
C (SB) = carbon in sapling biomass [tC ha^{-1}]; and
C(BB) = carbon in belowground biomass [tC ha^{-1}]

The carbon stock was converted to tons of CO2 equivalent (CO2e) by multiplying it by 44/12, or 3.67 (Pearson et al. 2007).

3.3.4 Establishment of baseline reference scenario

The baseline reference scenario was established for the project area, based on the reference level estimated by the Emission Reduction Program of the Government of Nepal in the TAL (Terai Landscape Landscape) region (ERPD 2018). As the project area also lies in the TAL region, this reference emission level has been used. Based on the document, the reference emission level for the TAL program area covering a total forest area of 1,173,550 ha is 895,710.08 tCO2e yr^{-1}, or 0.76 tCO2e yr^{-1} ha^{-1}. With this figure, we estimated the carbon stock to decline by 36,863.37 tCO2e yr^{-1} in the forest area of 48,298 ha included in this assessment. This value was used to establish the baseline reference scenario for the project area.

3.4 Quality assurance and quality control

An adequate quality assessment of an inventory requires both internal and external control procedures. Internal control activities are intended to ensure accuracy, documentation and transparency of the inventory operations. The provisions for quality assurance (QA) and quality control (QC) were implemented during the whole study periods to ensure that the reported carbon stocks are reliable and meet minimum measurement standards. The QA/QC provisions were applied at the following stages: (1) collecting reliable field measurements; (2) verifying data entry and analysis techniques.

3.4.1 QA/QC for field measurement

Rigorous orientation and hands on training of the field staff, forest technicians and the local resources persons were conducted before moving to the field and continued during the fieldwork. The hands-on training ensures that measurements executed by different teams or at different times are consistent and comparable. All the forest technicians and local resource persons involved in the carbon assessment were fully trained in all aspects of field data collection and data entry. Field crews provided extensive training so as to be fully cognizant of all procedures and to ensure that accurate data was collected.

3.4.2 QA/QC for data entry and analysis

The orientation and hands-on training were conducted to the forest technicians and local resources person's regarding the data entry of the collected data. Data entry was done immediately after collecting the data in the field. Data entry into spreadsheets is often a significant source of error. Ongoing communication between all personnel involved in measuring and analyzing data is critical for resolving apparent anomalies before final analysis of the monitoring data is completed. Special attention was paid to units used in the field (a standard forestry measurement system was used for all tree DBH and height. All measurements contained in spreadsheets were clearly indicated. Errors were reduced through spot checks of the entered data by the forest technicians.

In this study we identified and verified a total of 4 outlier trees (Annex 3) from different municipalities and we did not consider them in the analysis due to the higher values of diameter and tree height that might cause a significant error in the baseline carbon stock.

4. RESULT AND DISCUSSIONS

4.1 Vegetation parameters

4.1.1 Dominant tree species

Out of the 56 permanent sample plots established across the project area, 54 plots belonged to natural forest area while 2 plots fell in plantation forests. The study recorded a total of 99 different species of trees, with seedlings of 63 species, saplings of 99 species, and trees of 88 species in the project area. Sal (Shorea robusta) is the dominant tree species in the project area. A list of the identified tree species in the project area is presented in Annex 4. The fact that there are more seedlings and saplings present on the forest floor indicates that the area is undergoing regeneration.

4.1.2 Tree diameter and height

The mean diameter and height of the trees were 15.30 (±0.27) cm and 11.07 (±0.15) m, respectively. A similar study was carried out by ANSAB in Chitwan (adjoining district) in 2013, where the average tree diameter was 12.6 cm and the height was 9.18 m. The measured trees in this study have a lower mean tree diameter and height than recorded on average in the Terai forests. This may be mainly due to number of species covered by this study. In our study, 99 species were covered, whereas only 10 important timber species were covered in the study of DFRS.

4.1.3 Tree stem distribution pattern

Figure 7 presents the distribution of trees based on their diameter. The figure shows that trees with DBH classes of 5-10 cm have the highest percentage (49.5%), with the number of trees decreasing as DBH classes increase. This lower number of trees in the high DBH classes, suggests a younger and regenerating forest in the project area. It also indicates a larger potential to enhance forest carbon sequestration by fostering forest maturation through sustainable management practices.

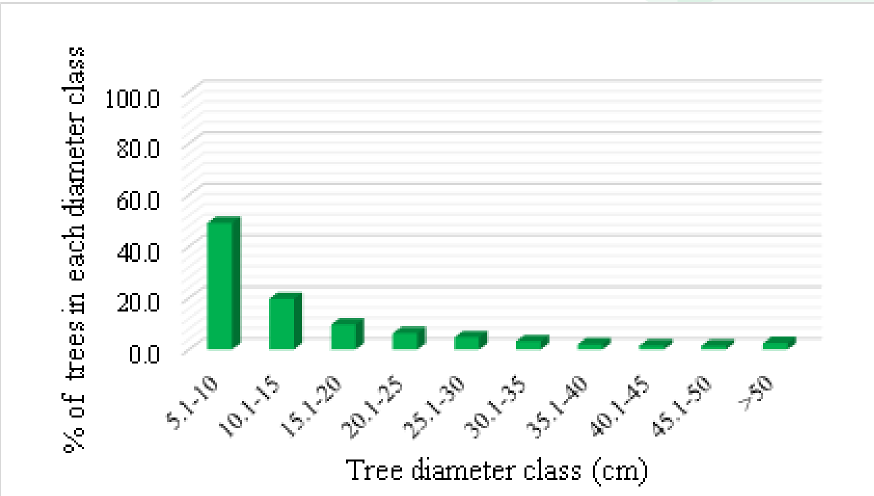

Figure 7: Tree diameter class distribution in project area

4.1.4 Density of seedlings, saplings and trees

The mean density of seedlings, saplings and trees in the project area is presented in Table 6.

Table 6: Mean density of the seedlings, saplings and trees per hectare

Strata	Mean density (no. of plants per hectare)		
	Seedlings	Saplings	Trees
Dense	15,598	5,842	867
Sparse	11,971	3,454	498
Average	**13,522**	**4,648**	**793**

When the mean density of the seedlings and saplings in the project area is compared to the recommended standard value in the National Community Forest Inventory Guideline, 2061 (MoFSC/CPFD, 2000), we find that the forests' regeneration status is excellent. According to the guideline, the regeneration status of forest is excellent if the number of seedlings per hectare is more than 5,000, it is good if the number is 2000-5000, and it is fair if the number of regenerations per hectare is less than 2000. Similarly, when compared to the number of saplings, the regeneration status is excellent if the number of saplings per hectare is more than 2000, it is good if the number per hectare is 800-2000, and it is fair if the number per hectare is less than 800.

The mean density of trees (793 plants per hectare) in the project areas is also higher than the average mean tree density in the Terai forests (583 plants per hectare - DFRS, 2015), suggesting the density of trees is also good in the project sites.

4.1.5 Sapling and tree basal area

Table 7 presents the basal areas for the saplings and trees in the two forest strata. The basal area for saplings was found to be 0.98 m^2 ha^{-1} in dense and 0.56 m^2 ha^{-1} in sparse forest strata. Similarly, the basal area for trees was found to be 23 m^2 ha^{-1} in dense strata and 21.7 m^2 ha^{-1} in sparse forest strata. The mean basal area of a sapling was 0.77 m^2 ha^{-1}, and the mean basal area of a tree was 22.74 m^2 ha^{-1}.

Table 7: Sapling and tree basal area

Forest Strata	Sapling basal area (m^2ha^{-1})	Tree basal area (m^2ha^{-1})
Dense	0.98	23.02
Sparse	0.56	21.66
Mean	0.77	22.74
Standard Error	±0.14	±0.18

The mean tree basal area (22.74 m^2 ha^{-1}) in our project site is slightly higher than the mean tree basal are in the Terai forest (18.38 m^2 ha^{-1}), but slightly lower than the national average (24.46 m^2 ha^{-1}) (DFRS, 2015). According to DFRS (2015), the highest value of tree basal area is in High Mountains and High Himalayan region (28.48 m^2 ha^{-1}), and the lowest in the Middle Mountains (16.53 m^2 ha^{-1}) of Nepal. The total basal area figures in the Terai, Churia, and Middle Mountains are roughly comparable. The basal area values of all DBH classes are high in the High Mountains and High Himalaya.

4.2 Sapling and tree biomass stock

A total of 2,182 trees and 3,009 saplings of 99 different species have been recorded and measured for the estimation of the biomass stock. It is estimated that the total forest biomass stock in the project area is 290.60 t ha^{-1} (379.58 t ha^{-1} in dense and 201.56 t ha^{-1} in sparse strata), as shown in Table 8.

Table 8: Forest biomass stock in trees and saplings by the forest strata

Forest Strata	Tree Biomass ($t\ ha^{-1}$)			Sapling Biomass ($t\ ha^{-1}$)	Total Forest Biomass ($t\ ha^{-1}$)
	Above ground	Below ground	Total		
Dense	313.15	62.63	375.78	3.80	379.58
Sparse	166.27	33.25	199.52	2.04	201.56
Mean	**239.71**	**47.94**	**287.65**	**2.92**	**290.57**

The mean biomass value in the project area (290.57 t ha^{-1}) is higher than the mean biomass stock in the Terai forest (208.73 t ha^{-1}) (DFRS, 2015), whereas the mean tree biomass (287.65 t ha^{-1}) is lower compared to similar adjoining forests of the Chitwan district (321 t ha^{-1} with 398.8 t ha^{-1} in dense and 243.4 t ha^{-1} in sparse strata) (Subedi et al. 2015). However, this comparison is made with two separate studies.

4.2.1 Summary statistics of the sapling biomass

According to the results of the analysis, the dense plots had the highest spread value of sapling biomass. Figure 8 shows that there were only a few plots with extremely high sapling biomass values (higher than values found in the dense strata), suggesting a potential for the enhancement of biomass in the strata through better forest management activities.

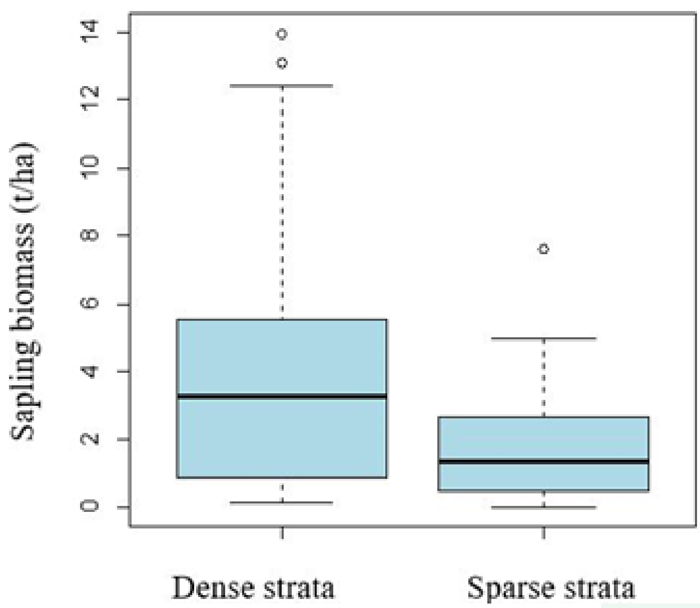

Figure 8: Box and whisker plot of sapling biomass

Table 9 provides the summary statistics of the sapling biomass. The table shows that the sampling precision of the baseline carbon assessment is 4.2% in dense and 5.5% in sparse, the values being within the acceptable limit of <10% as indicated by UNFCC (2009).

Table 9: Summary statistics of sapling biomass

Strata	No. of plots	Mean t ha^{-1}	Standard deviation	Half width of confidence interval	Maximum t ha^{-1}	Minimum t ha^{-1}	Median t ha^{-1}	Sampling precision (%)
Dense	45	3.80	3.60	1.10	14.00	0.20	3.30	4.20
Sparse	11	2.05	2.40	1.60	7.60	0.00	1.40	5.50

4.2.2 Summary statistics of the tree biomass

The distribution of tree biomass is greater in dense plots than in sparse plots. As shown in Figure 9, the tree biomass values in the dense strata are more uniformly distributed, and there are plots with higher tree biomass values.

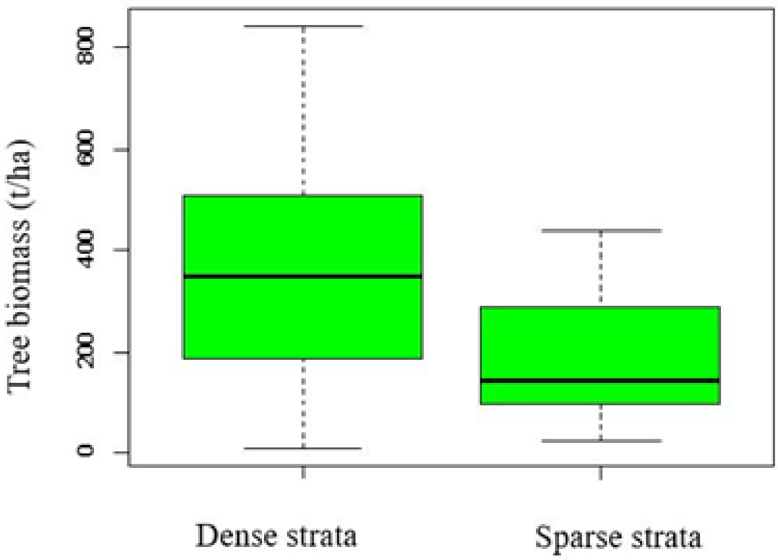

Figure 9: Box and whisker plot of tree biomass

Table 10 provides the summary statistics of the tree biomass values and indicates that the sampling precision of the baseline carbon assessment is good enough (8.9% in dense and 9.2% in sparse), with the values lying within the acceptable limit, indicating that the sampling design for the baseline carbon assessment was done correctly.

Table 10: Summary statistics of tree biomass

Strata	No. of plots	Mean t ha^{-1}	Standard deviation	Half width of confidence interval	Maximum t ha^{-1}	Minimum t ha^{-1}	Median t ha^{-1}	Sampling precision (%)
Dense	45	375.70	224.10	68.10	841.70	8.39	349.80	8.10
Sparse	11	199.50	147.23	98.90	439.10	25.58	142.20	9.20

4.3 Forest carbon stock

Table 11 presents the forest carbon stock in the project area. The weighted mean forest carbon stock was determined at 153.03 tC ha^{-1} (or 561.62 tCO2e ha^{-1}). Consequently, the total forest carbon stock in the project site was found to be 7.39 million tC ha^{-1} (or 27.125 million tCO2e.). Out of the total forest carbon, the dense strata have over 81% of the total carbon stock, and the sparse strata have about 19% of the total carbon stock. Total carbon stock in the dense and sparse forest strata in four municipalities is presented in Annex 5.

The total tree carbon was found to be 176.61 tC ha^{-1} in dense strata and 93.77 tC ha^{-1} in sparse strata. Likewise, the total sapling carbon was found to be 1.78 tC ha^{-1} in dense and 0.96 tC ha^{-1} in sparse strata.

Table 11: Forest carbon stock in the project area

Forest Strata	Carbon stock in tree (tC ha^{-1})			Carbon stock in sapling (tC ha^{-1})	Mean Forest carbon stock		Total forest carbon stock in the project area	
	Above ground	Below ground	Total		tC ha^{-1}	tCO2e ha^{-1}	tC (million)	tCO2e (million)
Dense	147.18	29.43	176.61	1.78	178.39	654.69	6.00	22.036
Sparse	78.14	15.62	93.77	0.96	94.73	347.66	1.39	5.089
Total	**225.32**	**45.05**	**270.38**	**2.74**	**153.03**	**561.62**	**7.39**	**27.125**

4.4 Drivers of deforestation and forest degradation

Deforestation and forest degradation are two important dimensions of environmental change that are directly related to global warming and pose serious threats to biodiversity and livelihoods of forest dependent local communities. Deforestation refers to the complete loss of forest cover. Forest degradation relates to the loss of biomass (carbon) and reduction in the capacity of forests to produce ecosystem services.

Based on the field assessment and the various parameters recorded in the sample plots, the drivers of deforestation and forest degradation have been identified and prioritized based on their occurrence at the plots. Altogether six major drivers of deforestation and forest degradations were observed, which include forest fire incidences, lopping, grazing, fire wood collection, timber extraction, and soil erosion. Figure 10 shows the presence of the six drivers of deforestation and forest degradations in the permanent sample plots.

These drivers of deforestation and forest degradation in the project area are present since a long time because of the socio-economic conditions and dependency of local people on the forest resources. It was observed that out of the 56 sample plots, 53 plots showed the presence of at least one of the six drivers of deforestation and forest degradation. As shown in the figure, it was found that fire wood collection (covering 82% of occurrence) was the most frequent driver followed by lopping (79% occurrence), soil erosion (48% occurrence), timber harvesting (41% occurrence), grazing (39% occurrence) and forest fires (38% occurrence).

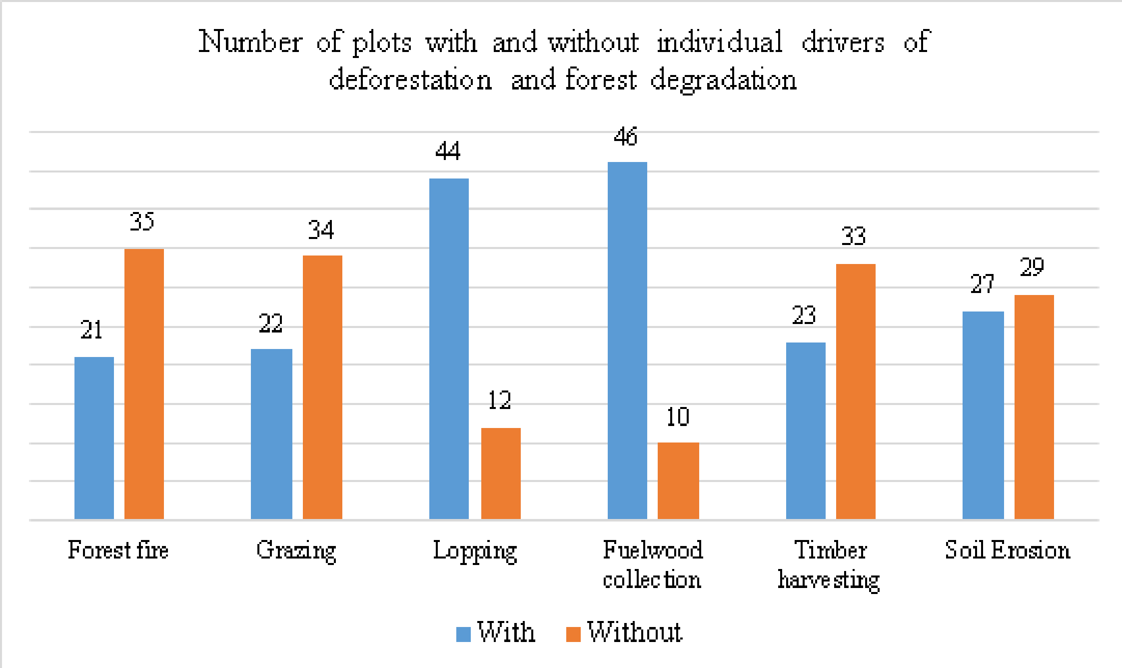

Figure 10: Occurrence of main drivers of deforestation and forest degradation in the sample plots

4.5 Baseline reference scenario and projected increase in carbon stock

The six main drivers identified above represent the principal cause of deforestation and degradation in the project area, and hence also the cause of the decline in forest carbon stock. Our current assessment shows that these drivers of deforestation and degradation are similar to the drivers identified in the Terai Arc Landscape (TAL) region, and we assume that the rate of change in forest carbon stock in TAL could be used in our project area to set up the baseline scenario. Consequently, the baseline reference scenario is projected with a total forest carbon stock in the project area of 27.08 million tCO2e, 27.05 million tCO2e, and 27.014 million tCO2e for the years 2022, 2023 and 2024 respectively.

The project aims to increase the forest carbon stock in the project area by 665,000 tCO2e in three years through improved forest management practices in line with the National Forest Stewardship Standards (NFSS). This increment in forest carbon stock is based on ANSAB's previous study in forest areas in the adjoining district, where the carbon sequestration due to sustainable forest management interventions was 13.689 tCO2e yr^{-1} ha^{-1} (ANSAB et. al 2013). Major sustainable forest management interventions carried out during the previous project were improved silviculture operation (e.g thinning, pruning, bush clearing, etc.), forest fire control, grazing management, alternative energy promotion, enrichment plantation, and assisted natural regeneration. These interventions focus on addressing the drivers of deforestation and degradation (similar to the drivers we have identified during the field visit in the study), and improving forest operation (similar to what we have planned in this project). We therefore established a higher degree of confidence that the assumptions initially made regarding the increase in forest carbon stock through the project´s interventions can be achieved.

This project plans to achieve the increment by capacitating the community forest user groups on sustainable forest management, revising of forest management plans in line with the NFSS, and providing sustainable forest management on the ground to address the major drivers of deforestation and forest degradation. A field-level assessment will be carried out in the third year to measure the changes in forest carbon stocks after the project's intervention.

Figure 11 depicts a baseline reference scenario for the project area based on a declining carbon stock of 0.76 $tCO_2e\ yr^{-1}\ ha^{-1}$ vs. the targeted increase in total forest carbon stock of 13.689 $tCO_2e\ yr^{-1}\ ha^{-1}$.

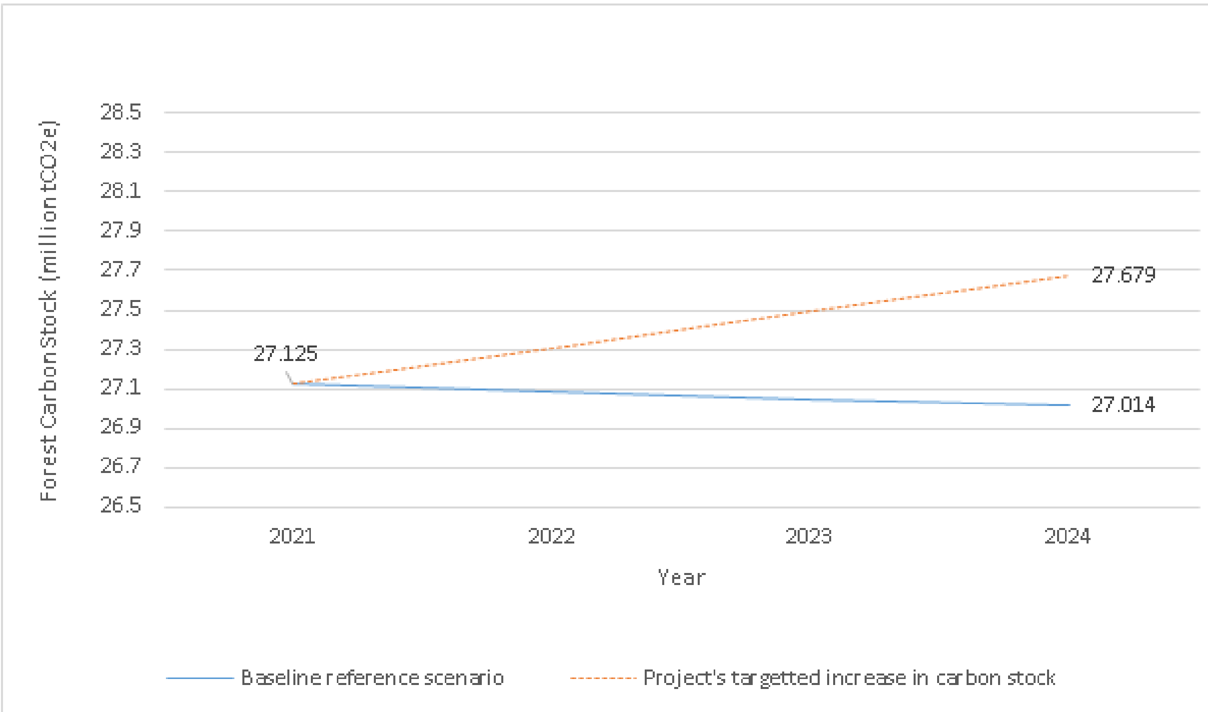

Figure 11: Baseline reference scenario vs. projected increase in forest carbon stock

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ANNEXES

Annex 1: List of equipment and materials used in the forest carbon assessment

S.N.	Particulars	Purpose
A	**Equipment**	
1	GPS	Boundary survey, stratification and locating plots
2	Linear tape	For locating plot boundary and distance measurement
3	Iron rod	Invisible reference of the permanent plot
4	Weighing machine	For weighing sample
5	Linear tape	For measuring distance between tree and measurer
6	Diameter tape	For measuring diameter of the tree at breast height
7	Clinometer	For measuring the ground slope, top and bottom angle to the tree
8	Vertex IV and Transponder	For measuring tree height and establishing circular plots without the use of tapes and clinometers.
B	**Materials**	
1	Base map	Plot navigation
2	Rope	For plot boundary delineation
3	Chalk	For marking the trees within the boundaries temporarily before permanent tagging and ensure that it is measured.
4	Hammer	Fixing metal pipe /iron rod inside the ground

Annex 2: Details of species parameters used for estimation of sapling biomass

Scientific name	Local name	Intercept (a)	Slope (b)	R square
Alnus neplensis	Utis	-2.348	2.102	0.978
Casearia graveolens	Barkamle	-1.627	1.520	0.990
Castanopsis indica	Katus	-0.710	1.720	0.970
Engelhardia spicata	Mauwa	-2.142	1.938	0.987
Eurya acuminate	Jhigune	-1.743	1.797	0.981
Ficus neriifolia	Dudilo	-0.986	1.750	-
Ficus semicordata	Khanyo	-1.370	2.010	0.940
Fraxinus floribunda	Lakuri	-2.130	2.082	0.971
Litsea monopetala	Kutmero	-1.880	2.260	0.940
Lyonia ovalifolia	Angari	-2.833	2.010	0.990
Maesa macrophylla	Bhokate	-1.769	1.650	0.766
Melastoma melabathricum	Chulese	3.670	1.050	0.980
Myrica esculenta	Kafal	-2.535	1.403	0.848
Myrsine capitellata	Setokath	-1.859	1.932	0.979
Phyllanthus embilica	Amala	-2.046	1.889	0.968
Pinus roxburghii	Khote sallo	-3.985	2.744	0.990

Pinus wallichiana	Gobre sallo	-1.816	1.816	0.990
Pyrus pahia	Mayal	-1.863	1.814	0.953
Quercus spp.	Baj	-0.532	0.988	0.786
Quercus spp.	Khasru	2.763	1.166	0.999
Rhododendron spp.	Laligurans	-2.533	1.393	0.698
Rhus wallichii	Bhalayo	-1.954	1.899	0.956
Schima wallichii	Chilaune	-2.220	2.520	0.980
Shorea robusta	Sal	-2.608	2.996	0.982
Wendlandia coriacea	Tilke	-1.280	1.432	0.999
all other species	Mixed species	-0.280	1.510	0.930

Annex 3: List of the outlier tree in the study sites

Local Level	Strata	Plot	Species	DBH (cm)	Tree height (m)
Binayee-tribeni	Dense	27	*Terminalia tomentosa*	82	42.2
Madhyabindu	Dense	34	*Shorea robusta*	77.2	38.3
Madhyabindu	Dense	36	*Shorea robusta*	83.5	45.1
Hupsekot	Dense	40	*Shorea robusta*	78.8	41.4

Annex 4: List of identified tree species in the project sites

S.N	Local Name	Scientific Name
1	Amba	*Psidium guava*
2	Emli	*Tremendus indica*
3	Ashare	*Lagerstroemia indica*
4	Asna	*Termenellia tomentosa*
5	Bhelar	*Trewia nudiflora*
6	Bakaino	*Melia azedarach*
7	Bayar	*Zizyphus mauritiana*
8	Barro	*Temenellia balerrica*
9	Bhalayo	*Rhus wallichii*
10	Bhatii	*Flemingia semialata*
11	Bhorla	*Bauhinia vahlii*
12	Chaiuri	*Madhuca longifolia*
13	Chulethro	*Brassiopsis hainla*
14	Chilaune	*Schima wallichii*
15	Chaite	*Cassia floribunda*
16	Chulesi (rato)	*Osbeckia rostrata*
17	Curry Patta	*Murrya koenigii*
19	Cyamunna	*Syzyzium operculata*
20	Dhaiyero	*Woodfordia fruticosa*

21	Bot Dhayero	*Lagerstroemia parviflora*
22	Dudhe	*Euphorbia hirta*
23	Dhudhilo	*Ficus neriifolia*
24	Dumri	*Ficus sarmentosa*
25	Dabdabe	*Lannea coromandelica*
26	Dhursul	*Colebrookea oppositifolia*
27	Gabujo	*Millettia extensa*
28	Guyalo	*Callicarpa macrophylla*
29	Gayo	*Bridelia retusa*
30	Hadachur	*Viscum articulatum*
31	Harro	*Terminalia chebula*
32	Amali	*Choerospondias axillaris*
33	Jhigune	*Euria cerasifolia*
34	Jamun	*Syzygium cumini*
35	Kalo Bhaskas	*Justicia adhatoda*
36	Kanju	*Holoptelea integrifolia*
37	Karipatta	*Gmelina arborea*
38	Katus	*Castanopsis lancifolia*
39	Khaksi	*Streblus asper*
40	Khirro	*Holarrhena pubescens*
41	Khair	*Acacia catechu*
42	Kumbhi	*Careya herbacea*
43	Kutmero	*Litsea glutinosa*
44	Kusum	*Schleichera oleosa*
45	Kyamuna	*Cleistocalyx operculatus*
46	Lathikath	*Miliusa velutina*
47	Latikath	*Cornus oblonga*
48	Latimauwa	*Madhuca latifolia*
49	Lapsi	*Choerospondias axillaris*
50	Mahuwa	*Engelhardia spicata*
51	Mal	*Macaranga denticulata*
52	Khosrette	*Ficus hispida*
53	Neem	*Azadirachta indica*
54	Padari	*Stereospermum personatum*
55	Piyari	*Buchanania latifolia*
56	Saj	*Terminalia alata*
57	Sajan	*Celtis australis*
58	Sakhuli	*Cinnamomum bejolghota*
59	Sal	*Shorea robusta*
60	Siris	*Albizia odoratissima*

61	Sati sal	*Dalbergia latifolia*
62	Sindhure	*Mallotus philippensis*
63	Sikakai	*Acacia rugata*
64	Sissoo	*Dalbergia sissoo*
65	Simal	*Bombax ceiba*
66	Tanki	*Bauhinia purpurea*
67	Thot	*Wendlandia coriacea*
68	Tendu	*Diospyros tomentosa*
69	Tejpat	*Cinnamomum tamala*
70	Thotee	*Ficus hispida*
71	Tuni	*Toona ciliata*
72	Patpate	*Magnolia pterocarpa*
73	Lakuri	*Fraxinus floribunda*
74	Rajbriksha	*Cassisa fistula*
75	Sandan	*Desmodium oojenense*
76	Khanyu	*Ficus semicordata*
77	Rakchan	*Daphniphyllum himalense*
78	Gullar	*Ficus racemosa*
79	Aanp	*Mangifera indica*
80	Kavro	*Ficus lacor*
81	Kaulo	*Persea duthiei*
82	Ipil Ipil	*Leucaena leucocephala*
83	Pipal	*Ficus religiosa*
84	Karma	*Adina cardifolia*
85	Chiuri	*Diploknema butyracea*
86	Teak	*Tectona grandis*
87	Setosiris	*Albizia chinensis*
88	Dabe	*Gardneria angustifotia*
89	Palas	*Butea monosperma*
90	Kadamba	*Anthocephalus chinensis*
91	Khamari	*Gmelina arborea*
92	Kalikath	*Miliusa velutina*
93	Arjun	*Terminalia arjuna*
94	Angeri	*Lyonia ovalifolia*
95	Amala	*Phyllanthus emblica L*
96	Phaledo	*Erythrina stricta*
97	Setosiris	*Albizia procera*
98	Badahar	*Artocarpus lakoocha*
99	Dumri	*Ficus racemosa*

Annex 5: Total carbon stock in the dense and sparse forest strata in four municipalities

Municipality	Strata	Area of strata (ha)	Forest Carbon		
			tC	tCO2e (million)	tCO2e (million)
Binayee-tribeni	Dense	15,033	2,681,736.87	9.842	11.614
	Sparse	5,098	482,933.54	1.772	
Hupsekot	Dense	6,298	1,123,500.22	4.123	6.036
	Sparse	5,501	521,109.73	1.913	
Kawasoti	Dense	1,923	343,043.97	1.259	1.612
	Sparse	1,015	96,150.95	0.353	
Madhyabindu	Dense	10,405	1,856,147.95	6.812	7.864
	Sparse	3,025	286,558.25	1.052	
Total		**48,298**	**7,391,181.48**		**27.125**

Rich Biodiversity and Prosperous Communities

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