REDD$^+$ Pilot Project

Report on

Forest Carbon Stock

of Community Forests in three Watersheds (Ludikhola, Kayarkhola and Charnawati)

(Measurement period: March- June 2010)

Prepared by Asia Network for Sustainable Agriculture and Bioresources (ANSAB)

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Prepared by ANSAB and technically reviewed by Terra Global Capital

(ICIMOD, ANSAB and FECOFUN)

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Project Management Unit - REDD Pilot Project

Abstract

The Asia Network for Sustainable Agriculture and Bioresources (ANSAB), International Centre for Integrated Mountain Development (ICIMOD), and Federation of Community Forest Users' Nepal (FECOFUN) are jointly implementing the project "**Design and setting up of a governance and payment system for Nepal's Community Forest Management under Reducing Emissions from Deforestation and Forest Degradation (REDD)**" in 104 community forests of three watersheds of Nepal, namely; Kayarkhola of Chitwan district, Charnawati of Dolakha district and Ludhikhola of Gorkha district. The project is in operation since July 2009 with financial support of Norwegian Agency for Development Cooperation (NORAD). The watersheds cover an area of 27000 ha where community forest area alone stands at about 10266 ha. Estimating the current level of forest carbon stock in project sites is essential to generate baseline information so as to see the carbon stock change over the period whereby demonstrating the REDD incentive distribution and practice of governance process in community forest management system. Hence, this report primarily presents the information of current status of forest carbon stock in all three project watersheds. Consistency and better quality of the forest carbon measurement was ensured by giving training to forest technicians, local resource persons and government officials of all the project areas. The total number of permanent plots was determined by conducting 91 pilot plots in two preliminary forest strata; dense (more than 70% canopy cover) and sparse (less than 70% canopy cover) strata. Analysis was done using allometric equations suggested by Brown et al. (1987) and sampling intensity was calculated using method provided by UNFCCC (2009). In all 570 permanent plots were determined based on variance calculated with the help of information from a pilot inventory. Carbon at five pools was estimated. Tree, sapling and regeneration were measured as above ground biomass in circular plots of 8.92 m, 5.64 m and 1 m radii respectively. Herbs grass and leaf-litter and soil organic carbon were measured in circular nested plots of 8.92 m, 5.64 m, 1 m and 0.56 m radii respectively taking into consideration the procedures of IPCC and ensuring that the measurements meet the quality necessary to be eligible for the VCS standards.

Analysis of the DBH distributions of all strata follows a left-skewed trend, indicating most of the trees in all the strata are younger and there is potential to enhance forest carbon stock by stimulating tree growth through sustainable management of forest. Analysis of all carbon pools along with belowground biomass shows that forest carbon stocks in dense and sparse strata of Kayarkhola watershed are 296.44 t ha^{-1} and 256.70 t ha^{-1} respectively. The largest difference of carbon stock between two strata was found in Charnawati (62 t C/ha) where dense and sparse strata holds 228.56 t ha^{-1} and 166.75 t ha^{-1} respectively. Similarly, forest carbon stock in Ludikhola are 216.26 t ha^{-1} and 162.98 t ha^{-1} in dense and sparse strata respectively. The data of individual CFUG forest carbon shows that Nibuwatar, Chitramkaminchuli and Deujar of Kayarkhola; Charnawati, Bhitteri and Setidevi-Dadar of Charanawati; and Ludi-Damgade, Ghaledanda-Ranakhola and Gangate-Bahunechaur have highest forest carbon stock in respective watershed as the result of large dense area. There is general trend of increase in carbon stock with increase in altitude in Kayarkhola and Charnawati whereas the trend is reverse in Ludikhola. Aspectwise, East in Kayarkhola, South-East in Charnawati and North in Ludikhola recorded the highest forest carbon stock.

Considering the resource required and insignificant amout of carbon growth, measurement of carbon of herbs, grass and litter pool and soil can be avoided during next measurement as long as it is done in less than five years from the first measurement. Involvement of local communities will make the forest carbon measurement cheaper than conducted by technicainas; however, further capacity building of locals is required for data analysis, management and monitoring. Finally, for the purpose of long term monitoring, it is also crucial to ensure unbiased maintenance of established plots.

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List of acronyms

AGSB	above-ground sapling biomass
AGTB	above-ground tree biomass
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
BGB	below-ground biomass
CF	community forest
CFUG	community forest users' group
cm (or CM)	centimeter
CO_2	carbondioxide
dbh (or DBH)	diameter at breast height
DM	dry matter
FECOFUN	Federation of community forest Users' Nepal
FSC	Forest Stewardship Council
GHG	green house gas
GIS	geographic information system
GPS	global positioning system
ha (or Ha)	hectare
HGB	herb and grass biomass
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
kg (of KG)	kilogram
LHG	leaf litter, herb and grass
LLB	leaf litter biomass
LRP	local resource person
m (or M)	meter
Masl	meter above sea level
NORAD	The Norwegian Agency for Development Cooperation
PISP	permanent inventory sampling plot
PSP	pilot sampling plot
REDD	Reducing Emissions from Deforestation and Forest Degradation
SOC	soil organic carbon
t (or T)	ton (mega gram, 1000 kg, or metric ton)
tC	ton carbon
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Voluntary Carbon Standard

1. Introduction

1.1 Background

Asia Network for Sustainable Agriculture and Bioresources (ANSAB), International Centre for Integrated Mountain Development (ICIMOD), and Federation of Community Forest Users' Nepal (FECOFUN) are jointly implementing the project "**Design and setting up of a governance and payment system for Nepal's Community Forest Management under Reducing Emissions from Deforestation and Forest Degradation (REDD**)" in three watershed areas of Nepal, namely, Kayarkhola of Chitwan district, Charnawati of Dolakha district and Ludhikhola of Gorkha district with financial support from The Norwegian Agency for Development Cooperation (NORAD). This pilot project aims to demonstrate the feasibility of REDD payment mechanism in Community Forest (CF) by involving local communities including marginalized groups so that deforestation and forest degradation can be reduced by linking sustainable forest management practices with economic incentives. Further the project focuses on the concerns of indigenous, marginalized people, women, Dalit and local communities dependent on forests by involving them in designing and functioning of a national-level REDD governance and payment mechanism that supports community forestry at grassroots level. The specific objectives include; strengthening the capacity of civil society actors in Nepal to ensure their active participation in the planning and preparation of national REDD-strategies; establishing a Forest Carbon Trust Fund that is sustainable and creditable in the long run; and contributing to the development of REDD strategies that can effectively and efficiently monitor forest carbon flux in community managed forests.

The first year of project is much focused to develop biophysical and socio economic baseline information. One of the project partners, ANSAB led to collect baseline information of forest carbon and developed baseline report closely with Project Management Unit- PMU. The project developed forest measurement guideline incorporating international accepted methodologies and standards defined in IPCC, VCS and other complementary guideline including Pearson et al, Sandra Brown and MacDicken and relevant scientific literatures. The methodologies of forest carbon measurement guideline were fully used during forest inventory in collecting data. Local communities were involved in the carbon measurement process viewing to enhance the capacity of the local communities in the forest carbon measurement. This report summarizes the findings of the forest carbon in five different pools namely above ground (tree, sapline and seedling), herb, litter, soil and below ground. It further tries to suggest appropriate activities in enhancing forest carbon in the forest based on the findings of the first year carbon measurement.

The project employed the stock difference method to assess forest carbon that makes reference to traditional forest resource assessments and calculates changes in average carbon stock per unit area as the difference between carbon stock at time 2 and time 1. Based on the methods applied during the field measurements, a comprehensive guidelines have also been developed and published (Subedi et al. 2010), which are basis for different measurements and also form standards for measurements in subsequent years.

1.2 Objectives

The major objective of this report is to provide an overview of forest carbon stock available in all project watersheds. Specific objectives include:

- To assess the forest carbon at various levels and establish the baseline value
- To calculate forest carbon of individual community forest to support carbon payment in project demonstration phase (second year onwards)

1.3 Procedures for site/watershed selection

Ludikhola, Charnawati and Kayarkhola were three watershed areas selected for the operation of pilot project. Location map of project area is given in Figure 1.

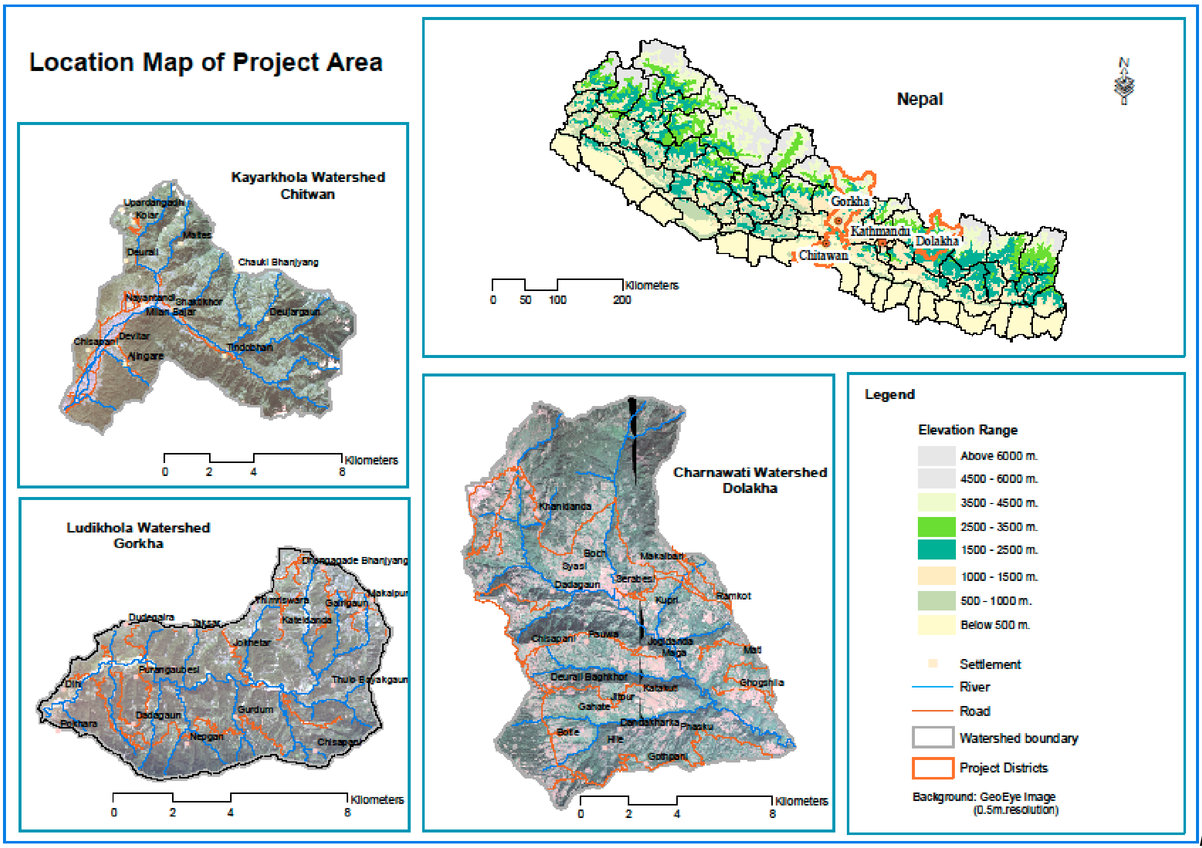

Figure 1: Map of project sites

Some of the critieria on which basis the project sites were selected have been briefly described as follows.

Ethnicity

Ethnicity is the major criterion for the selection of the project sites. The impact of REDD on the livelihood and customary rights of indigenous peoples (IPs) has been a matter of worldwide concerns for REDD initiaters and policy makers. Since this is the pilot project sought to demonstrate the project activities to acquire full range of experiences on indigenous people's rights and livelihood. The Charnawati Watershed in Dolakha is resided by rare *Thami* people, who are confined in Dolakha and Sindhupalchowk district in Nepal. *Thami* community is considered to have close connection with forest for their livelihood and culture. Similarly, Kayarkhola has good population of *Chepang* community, one of the most vulnerable ethnic groups in Nepal having practice of shifting cultivation for generations. There is perfect chance to show how REDD can preserve and promote customary rights of IPs like Chepang in Nepal. Likewise, Ludikhola is popular residence area of *Magar and Gurung* communities. There is a good representation from *Dalits* and elite castes i.e., *Brahmin, Chhetri* and *Newar* apart from the IPs in three watersheds. From this point of view, working in three watersheds, this project has opportunity to demo on REDD payment system in heterogenous communities with varied social and economic background.

Interest and readiness of the local people

In order to make REDD activities success it needs high level of interest, readiness and consent which is triggered by the enthusiasm, interest and acceptance of local communities, forest users as well as local level stakeholder. Without local support there is no REDD project in the current context when debate on REDD and forest dependent communities is mounting as huge concerns and issues globally. Since the project of this kind is first time being piloted in Nepal, hence it requires deep understanding, interests, support and finally consent from CFUGs and local stakeholders. These watershed units have good relation with FECOFUN (one of the project partners) including other two national partners ANSAB and ICIMOD. Local communities of these watersheds showed readiness to pilot this project keenly to see the impact of REDD provision from their forest and communities.

Forest Types

Various forest types and tree species with in the forest have varied carbon accumulation and storage capacity. As a pilot project it is very importanct to carry out the projects in different forest types and species to acquire wide range of ecologilcal insights and knowledge. Thus, three sites proposed for the project encompass the major forest types found in Nepal. The Charnawati watershed has combination of *Quercus*, *Chir*, *Rhododendron*, *Blue pine* and *Alder* species including some other associated species that are common in high hill forest types of the middle part of Nepal. The Ludikhola watershed bears *Schima Wallichi*, *Shorea robusta* and Pine whereas Kayarkhola watershed represents profound vegetation categories found in Mahabharat range in Nepal. *Shorea robusta* associated with *Acacia catecu*, *Mallatus phillipinensi and Terminalia tomentosa* are dominant species at lower altitude of Kayarkhola wheresas *Schima wallichi* abundantly appears in upper belt of the watersheds.Ludhikhola falls on hill but Kayarkhola lies in low hill and inner terai area.

Management Interventions

Community management system is one of the well established and stable forest management systems that remarkably contributing to enhance forest condition in Nepal. Forest and group management is entirely based on consensus of among forest users which are guided by formal deocuments; group constitutions and forest operational plan approved by District Forest authority. Practicing new idea of REDD payment system on such management system can expect to obtain full range of learning and experieices. Three proposed project watersheds represent ideal size of such community forest groups. More than 50 CFUGs are situated in Charnawati watershed, out of which 5 CFUGs are FSC sustainable forest management certified in 2005. Forest management system in Kayarkhola is very diverse where 15 CFUGs were already handed over to the local communities. Community forest in Kayarkhola has perfect interface with shifting cultivation customarily being practised by *Chepang* community for generations. Persistent charge to the Chepang community who highly depend on forest for their livelihoods is that their traditional shifting cultivation practice is responsible for forest degradation in the district. Hence the pilot project has good opportunity how REDD+ initiative perfectly implements in such mosaic nature of forest management system and diverse cultural groups.

Ecological Zones

Out of five major ecological zones represent in Nepal, the selected watershed sites represent three different ecological zones. The Kayarkhola watershed represents tropical and sub-tropical with huge altitudinal variation. Ludikhola watershed falls under the sub-tropical ecological zone whereas Charnawati watershed lies in temperate zones with diverse vegetation types.

Replicablility

Each watershed is selected in such a way that it would be representatives of other key watersheds in the country. The status of the forest, collection and use patterns are similar to other forest as well. During the selection of watershed areas, we considered about the replicable potentiality of the REDD implementing mechanism in other watershed areas with similar system of forest management. So these watershed areas have high potentiality of replication of the system that could be applied in other forest areas.

Accessibility

Since the project is on pilot scale and intending to design a payment mechanism under potential REDD mechanism, substantial visits and interventions of several national, international and regional organizations are expected. There involves frequent visits of project staffs and consultants that demands the project sites having good access to road and travel. All three watersheds can be reached within 5 hours of travel from Kathmandu.

1.4 General overview of all three watersheds

This section describes location of the pilot watersheds and their general vegetation/forest characteristics.

1.4.1 Physiography

The project areas are located in three different watersheds of Nepal covering different ecological ranging from tropical to temperate ecological region. The total area of three watersheds is 27,789 ha. Forest area represents nearly 65% of the total area of watersheds (Land cover analysis report 2010). Of the total forest area in the watersehds, about 60% (10,266.13 ha) is under community forest that is being managed by 104 CFUGs. Table 1 shows the summary of the project area.

Table 1: Physiography and demographic information of project watersheds

S.N.	Watershed (district)	Total Watershed area [ha]	No. of CFUG within WS	Total CF Area [ha]	Households*	Population*
1	Kayarkhola (Chitwan)	8,002	15	2,381.96	3935	22,090.00
2	Charnawati (Dolakha)	14,037	58	5,996.17	10270	48,504.00
3	Ludikhola (Gorkha)	5,750	31	1,888.00	3800	23,197.00
	Total	**27,789**	**104**	**10,266.13**	**18005**	**93,791.00**

Source: Land cover analysis (2010) and Socio-economic survey (2010)

*About 15% of the households estimated to be member of more than one CF, accordingly the actual number of Households and Population might be less (by about 15%) than reported in the table.

Charnawati watershed is located in the Dolakha district of the Central Development Region of Nepal. It covers hill and mountain physiography. Altitude ranges from 835 m-3549 m. This watershed is spread over 14037 hectare. There are 58 CFUGs within this watershed with total forest area of 5996.17 hectare. *Chhetri*, *Brahmin*, *newar*, *tamang*, *thami* and *dalits* represent the social diversity of this watershed.

Ludikhola watershed lies in the Gorkha district of the Western Development Region of Nepal. It represents the hill physiographic region, altitude ranging from 318 m to 1714 m. This watershed covers an area of 5750 hectare. There are a total of 31 CFUGs within this watershed managing 1888.00 ha forest area. This watershed is characterized by social diversity with presence of *Magar*, *gurung*, *tamang*, *dalit*, *Brahmin* and *chhetri*.

The Kayarkhola Watershed is located in the Chitwan district of the Central Development Region of Nepal. Altitude of this watershed ranges from 245 m to 1944 m, covering area of 8002 hectare. The 15 CFUGs of this watershed cover total 2381.96 hectare of forest area. The watershed is inhabited by socially and ethnically diverse forest-dependent indigenous communities such as Chepang and Tamang. These ethnic groups are some of the most marginalized ethnic groups in the country.

1.4.2 Vegetation/forest types

Due to differences in physio-climatic characteristics, watersheds under the present study constitute diverse ecology. Dominant forest types ranges from hill *Shorea robusta* forest through *Schima-Castanopsis* to *Rhododendron*. Even though *Shorea robusta* mixed sub-tropical hill deciduous forest forms major forest type in Kayarkhola (Chitwan) and Ludikhola (Gorkha), representing the lower altitudinal ranges among the three watersheds, associated species varies between these two watersheds. *Lagerestroemia* parviflora, *Mallatus phillipinensi* and *Terminelia tomentosa* are dominant associates in Kayarkhola (Chitwan) whereas *Schima wallichii* and *Castanopsis indica* are the most common associates in Ludikhola (Gorkha). On the other hand, even though *Shorea robusta* and *Schima-Castanopsis* forests are present in lower altitudes in Charnawati (Dolakha), the majority is formed by *Rhododendron* forests, extending high up to *Quercus* forest, representing the dominant higher altitudinal coverage by the watershed.

According to broader climatalogical categorization of forests, forests in Kayarkhola fall under tropical broadleaved, similarly forests in Charnawati falls within sub tropical to lower temperate (*Quercus*) forests and forests in Ludikhola falls within sub-tropical broad leaved forest (sal and chilaune).

1.4.3 Location, climate and land use

Table 2 presents information on location and climate and Table 3 presents information on land uses of all the project watersheds.

Table 2: Climatological information of watersheds

S.N.	Watershed	Geographical location		Altitude (m)*	Average tempzerature (°C)	Average rainfall (mm)
		Latitude (N)	Longitude (E)			
1	Kayarkhola (Chitwan)	27°40'07.79''-27°46'37.15''	84°33'25.88''-84°41'48.85''	245- 1944	29-32 (max), 16-19 (min)***	1436.32***
2	Charnawati (Dolakha)	27°35'16.12''-27°44'47.92''	85°56'18.41''-86°03'56.92''	835-3549	19.9 (max), 8.3 (min)****	2232.1*** *
3	Ludikhola (Gorkha)	27°55'02.85''-27°59'43.88''	84°33'23.13''-84°40'41.87''	318-1714	23.1**	1972-2000**

Source: *Land cover analysis (2010), **District Profile, Gorkha, ***Department of hydrology and meteorology (1971-1986), ****Meteorological data from Jiri station

According to Table 2, Charanawati watershed appears to cover the higher altitudinal ranges among the watersheds with least average temperature and highest average rainfall.

Table 3: Land use profiles of the watersheds

Land cover type	Area (ha) of different land use system			Total area (ha) of three watersheds
	Kayarkhola (Chitwan)	Charnawati (Dolakha)	Ludikhola (Gorkha)	
Close to open broadleaved (dense) forest	4119 (51.48%)	4991 (35.56%)	3873 (67.34%)	**27789**
Open Broadleaved (sparse) forest	1702 (21.27%)	2501 (17.82%)	996 (17.31%)	
Natural water bodies	31(0.39%)	1 (0.01%)	9 (0.17%)	
Bare Soil	30 (0.38%)	629 (4.48%)	241 (4.19%)	
Grassland and degraded forest	0.00	204 (1.45%)	0.00	
Clouds	81 (1.02%)	0.00	0.00	
Agriculture Land and built-up areas	2038 (25.47%)	5710 (40.68%)	632 (10.99%)	
Total area	**8002 (100%)**	**14037 (100%)**	**5750 (100%)**	

Source: Land cover analysis report (2010)

Table 3 reveals that forest forms major land use in all the watersheds. Within forest categories, the dense forest area is present in larger proportion in all watersheds compared to sparse forest area.

2. Methodology

2.1 Design of sampling and measurement techniques

This section describes the methodologies applied during the forest carbon measurement and tools for the data analysis. Methodologies defined in the forest carbon measruemnt guideline developed by the project were fully used at the forest inventory. For this, refer forest carbon measurement guideline of the project, Subedi et al. (2010) for much detail information.

2.1.1 Training local forest technicians and resource persons

With the aim of ensuring consistency in collection of data and field measurement, two ANSAB forest technicians, representatives from District Forest Office and FECOFUN from each watershed were thoroughly given a training of trainers (ToT) on techniques of forest carbon measurement at central level. These were principal local resource persons who assisted in the subsequent trainings and implementation of forest carbon stock inventory in the field.

2.1.2 Delineation of watershed (project) boundaries

The first step in forest carbon accounting is to establish the extent of the accounting area. Spatially, a well-documented boundary is required for both verification of accounting and avoidance of overlap, and thus double counting, between neighboring inventories. Therefore, spatial boundaries of the particular area need to be clearly defined to facilitate accurate measuring, monitoring, and verification. As watershed can be a natural entity of spatial project area, aforementioned three watersheds were selected and delineated. Spatial boundaries like rivers/creeks, mountain ridges were used for delineation. Similarly, spatially explicit boundaries were identified with a global positioning system (GPS).

Software such as geographical information system (GIS), ARC hydro extension of Arc GIS software or BASINS extension tool for ArcView software were used to identify watershed's spatial boundaries. Contour lines and data on drainage networks were used to define watershed boundaries and project areas. High resolution satellite image (Geo eye with 0.5m resolution) was used visually to verify the watershed boundaries.

2.1.3 Delineation of community forest boundaries

Individual forest blocks within the project area were mapped jointly by GIS experts, forest technicians, members of community forest users' group (CFUG) and representatives from the respective District Forest Office in a participatory way. Boundary delineation of 104 CFUGs of three watershed area was conducted in two months. High resolution satellite images printed in large scale (1: 7000) were used to find out the different land cover and natural boundaries and trace individual forest blocks easily. GPS coordinates and boundary references of forest operational plan were refered while mapping the boundary of individual CF. Boundary of the individual CFUG was first sketched on map in participatory way it was then digitized with GIS software and to develop map layers. GPS (GPS Map 60CSx, Garmin) tracking was used to verify the CF boundary and demarcate CF area from other land use system where natural boundary among the CFs and other land use systems were not clearly observable.

2.1.4 Strategies for stratification

Once the project area was delineated, basic information on features such as land use, land cover as well as vegetation and topographic data were collected. Data for the project area (e.g., watershed area) was then geo-referenced and traced onto a base map, specifying the details of the project area by indicating the different land-use categories (forest, water bodies, open land, agriculture land, and so forth.) and was developed with high-resolution satellite images. A stratum is an area of similar and homogenous nature of elements. Strata are thus areas different from each other in forest types, tree density, and species; basically established to increase accuracy of measurement by avoiding potential variation occur in the esults.

To make strata as homogeneous as possible, a forest within the project area was divided primarily into two layers or blocks; dense and sparse forest. Forest stratification was carried out using high resolution remote sensing imagery with the ERDAS Imagine, Definiens Developer and ArcGIS software. Forest with more than 70% of canopy coverage was considered dense and less than 70% as sparse. Detail of dense and sparse area in different watershed is given in Table 4.

Table 4: Area of different forest strata in three watersheds

S.N.	Watershed/district	Total watershed area [ha]	Total forest area [ha] in watershed	Total CF area [ha]	Categories of forest within CF	
					Dense forest area [ha]	Sparse forest area [ha]
1	Kayarkhola (Chitwan)	8,002	5821	2,381.96	1,902.72	479.19
2	Charnawati (Dolakha)	14,037	7492	5,996.17	3,899.25	2,097.00
3	Ludikhola (Gorkha)	5,750	4869	1,888.00	1,634.64	252.9
	Total	**27,789**	**18182**	**10,266.13**	**7,436.61**	**2,829.09**

Source: Land cover analysis report (2010)

2.1.5 Determination of potential leakage belt

Carbon leakage is defined as an increase in GHG emissions outside of the project area but directly attributable to the REDD project activities implemented inside of the project area (reference??). Any activity that reduces deforestation within a certain area may increase deforestation to an area outside of the project area. For example, the protection of forest land from grazing inside the project area can lead to the conversion of forest land into grazing land outside the project area. Similarly, closing down a forest for the collection of fuel-wood can increase fuel-wood collection in the immediate vicinity of the project area. Another example relates to logging: if logging was occurring within the project area, project actions can lead to a displacement to outside of the project area (Aukland et al., 2003). Focus Group discussions and detail study of map of the project area was conducted to identify possible leakage area within and outside the project area. Apart from this, elements suggested in the study on drivers of forest degradation and leakage analysis carried out by the project were refered during the leakage belt analysis. This led to correct demarcation of each leakage belt, which is crucial for accounting GHG benefits of the REDD project since it is an area where leakage will be monitored and deducted from the actual Net Emission Reductions (NERs). Similarly, socio-economic survey was done to make further clear how leakage could occur in the project area.

2.1.6 Pilot inventory for optimal sampling intensity

A preliminary inventory was conducted to estimate the variance of the carbon stock in each forest stratum and to provide a basis for calculating the number of permanent plots required for detail inventory. It was carried out by laying 9 to 32 circular plots randomly in each stratum. Altogether, pilot measurements were carried out in 91 temporary circular plots (stratum-wise detail is given in Table 5).

As random selection is important to cover the natural variability present within the different stratum, all the plots were randomly distributed using Hawth's Analysis Tools for ArcGIS (www.spatialecology.com). Figure 2 shows locations of temporary plots laid out on the ground for pilot inventory.

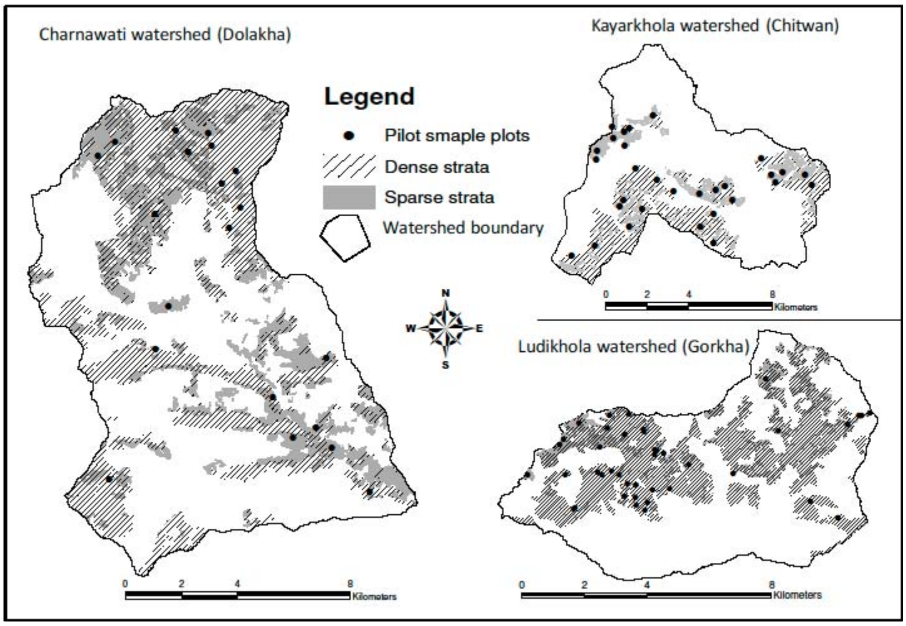

Figure 2: Distribution of temporary sampling plots (PSP)

Diameter at breast height (DBH) ware measured of all the trees above and equal to 5 cm within 250 m^2 circular plots (8.92 m horizontal radius), except in Gorkha, where size of the temporary pilot plot was 100m^2 (5.64 m horizontal radius).

Eq. (i) was used for estimating biomass on the basis of measured DBH which generally recommended for moist climate with annual rainfall (1500 - 4000 mm), suggested by Brown et al. (1989, p. 886).

$$y = 38.4908 - 11.7883\text{DBH} + 1.1926\ \text{DBH}^2 \text{.................. Eq. (i)}$$

Carbon fraction 0.47 was used to derive carbon stock per tree from the estimated biomass. Finally, carbon stock per plot, per ha (tC ha^{-1}) and mean forest carbon stock per ha for each of the stratum was estimated as summarized in Table 5.

For calculating tree carbon stocks (Q,tC ha^{-1}) from the pilot inventories, total number of permanent sample plots required at stratum i(n_i) level was estimated by using Eq. (ii) (UNFCCC 2009, p. 4):

$$n_i = \frac{\sum_{i=1}^{L} N_i \cdot st_i}{\left(N \cdot \frac{E_1}{Z^{\alpha}/_2}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2} \cdot N_i \cdot st_i \qquad \text{..................Eq. (ii)}$$

Where,

L = total number of strata (dimensionless);

N_i = maximum total number of sample plots in stratum i;

st_i = standard deviation of Q for stratum i;

N = maximum possible number of sample plots in the project area;

E_1 = allowable 10% error of the estimated Q (expressed as fraction); and

$Z^{\alpha}/_2$ = value of the statistics Z (embedded as inverse of standard normal probability cumulative distribution).

Table 5: Summary statistics of values used to determine total number of required permanent inventory sample plots (PISP) and derived and laid out number of permanent inventory sample plots for forest carbon monitoring.

Stratum	Total area under CF [ha]	No. of pilot sample plots (PSP)	Size of pilot sampling plots (PSP) [m^2]	Mean tree carbon stock (Q) [tC ha^{-1}]	Standard deviation	Required no. of permanent sampling plot (PISP)	Total number of plot laid on the ground	Number of extra reserved plots
Chitwan (Kayarkhola) dense	1,902.72	13	250	162.01	90.95	113	154	41
Chitwan (Kayarkhola) sparse	479.19	17	250	72.57	54.57	17	26	9
Dolakha (Charnawati) dense	3,899.24	10	250	220.71	146.51	148	164	16
Dolakha (Charnawati) sparse	2,097.00	10	250	89.19	81.79	45	41	-4
Gorkha (Ludikhola) dense	1,634.64	32	100	108	64.82	135	144	9
Gorkha (Ludikhola) sparse	252.9	9	100	66.16	71.39	23	41	18
Total	**10,265.69**	**91**	**-**	**-**	**-**	**481**	**570**	**89**

Source: Pilot field survey (2009)

As dense strata had higher standard deviation of forest carbon stock derived from pilot inventory (except Gorkha) and higher proportion of area coverage compared to sparse strata, dense strata in all watersheds were eligible for having higher number of permanent inventory sampling plots (PISP). From the calculation, as shown on Table 5, Charnawati dense has the highest number of PISP whereas Kayarkhola sparse has least.

2.1.7 Permanent plot distribution and layout

This section describes how the number of permanent sample plots were determined and laid out in the field. This chapter also illustrates the software used and field process applied during laying out plots in the forest.

Figure 3: Laying out 0.56 m plot

2.1.7.1 Number of permanent sample plots in each community/strata/watershed

Altogether 481 permanent plots were enough for carrying out the forest carbon inventory in three watersheds. However, samplings measurements were done in 570 plots (including in 89 extra plots) in three watersheds, 180 in Kayarkhola, 205 in Charnawati and 185 in Ludikhola, to enhance the output and to account the outliers that may come during the measurement. Out of these plots 108 plots were distributed in sparse forest strata and 462 in dense strata, detail is given in Table 5.

Plots were randomly distributed using Hawth's Analysis Tools for ArcGIS (www.spatialecology.com) and co-ordinates were loaded on the GPS set (GPS Map 60CSx, Garmin) as the centre of the nested plots. With the help of the GPS apparatus, the plot centre was navigated. However, due to inaccessible and steep terrain in few cases, establishing permanent plot or even reaching the given location was impractical, in such cases; a systematic method of shifting plot’s centre was followed, with the help of a random compass bearing table.

2.1.7.2 Size and shape of sample plots

Circular plot size was applied for the inventory because of its easiness to establish especially in sloping terrains and also reduce the edge effect problem that normally occurs in reatangular plots. As illustrated in Figure 4, several sub- plots were established within each plot for specific purposes: inside the plot of 8.92 m radius, a sub-plot of 5.64 m radius was established for saplings, a sub-plot with 1 m radius was established for counting regeneration. Sub-plot with 0.56 m radius was further set up for collecting sample of leaf litter, herb, grass and soil. Slope correction in each permanent plot was done whenever required.

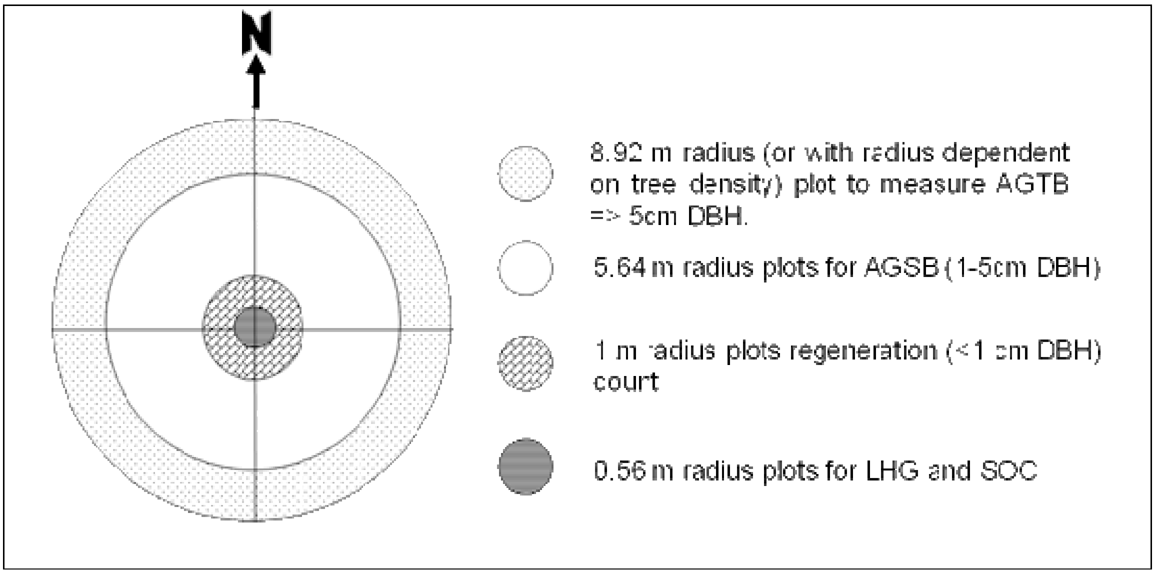

Figure 4: Sampling design of circular plot (default size)

2.1.8 Involvement of local communities in measurement process

As this project intends to increase the capacity of local communities in carrying out forest carbon measurement and monitoring, representatives from community forest users, watershed REDD network and FECOFUN were actively involved in the whole process of forest carbon measurement. It was also important as local people have better idea of their forest. This helped technicians to navigate permanent plots easily. Altogether 351 people from communities participated in the measurement work and earned knowledge and skills on forest carbon measurement Members from REDD watershed Networks[1], LRPs (Local resource person) and CF (community forest) members (Details is given in Table 6) took part in the measurement work.

Table 6: Number of local communities participated in forest carbon measurement

District (watershed)	Female				Male				Grand total
	BC	D	J	Total	BCN	D	J	Total	
Chitwan (Kayarkhola)	8		8	16	26	5	62	93	109
Dolakha (Charnawati)	21	1	18	40	82	4	28	114	154
Gorkha (Ludikhola)	10	1	6	17	46	6	19	71	88
Grand Total	**39**	**2**	**32**	**73**	**154**	**15**	**109**	**278**	**351**
BCN = Brahmin, Chhettri and Newar, D = Dalit, and J = Janajati									

Source: Annual progress report (2010)

[1]REDD watershed network is network representatives form CFUGs under the respective watershed. It works as a coordinating body among CFUGs at watershed level.

2.1.9 Equipments and materials

All the required equipments and materials were collected before going to field. All instruments and pieces of equipment were prepared, checked and calibrated beforehand. The field inventory team ensured that every instrument was functioning to avoid troubles and disturbances during field inventory. A complete checklist of instruments was prepared so that no material gets left behind; this checklist was also useful during the fieldwork as the team moves from one location to the other.

2.1.10 Human resource management

An ideal team of 3-5 members for pilot inventory and 6-8 members for detail inventory was formed well in advance to their first field operation to ensure perfect and complete data collection. One forest technician for pilot work and two forest technicians having detail knowledge of carbon measurement methodology were assigned in detail inventory. They ware also capable to operate all the equipments properly as well as comprehend the importance of tiniest detail of the work. Short orientation to the team members was conducted prior to the field departure. During the orientation, community members were trained on methodologies, tasks of each team member were clarified and detail plan was done.

2.2 Field measurement and analysis

As described in section 2.1.7.2, nested circular plots with horizontal diameters ranging from 0.56 m to 8.92 m were laid out for quantifying different carbon pools. Details of field measurement techniques and methods for estimating forest carbon stock of different pools are described in the succeeding sections.

2.2.1 Forest carbon pools

Descriptions of different carbon pools considered under this study are provided in this section. As suggested by IPCC (2003), carbon stock of four carbon pools including above ground (tress, sapling and herbs), below ground, leaf litter and soil organic matters were estimated. Estimation of dead wood is not significant in the project area (community forest) because of frequent removal of dead wood materials by local communities for fuelwood purpose. Since IPCC 2006 prescribes estimating harvested wood product during national carbon inventory, the project has applied conservative approach to avoid carbon of this pool.

2.2.1.1 Aboveground tree biomass (AGTB)

The DBH (at 1.3m) and height of individual tree greater than or equal to 5 cm DBH were measured in each permanent circular plot with 250 m^2 area (with 8.92 m horizontal radius) using diameter tape, clinometers and linear tape or vertex-IV/transponder. Trees were first marked starting from the edge and working inwards to prevent accidental double counting. All the trees marked were then numbered from inward to edge starting from North towards clockwise direction. Each tree was recorded individually, together with its species name. Trees on the border was included if > 50% of their basal area falls within the plot and excluded if <50% of their basal area falls outside the plot. Trees overhanging into the plot were excluded, but trees with their trunk inside of the sampling plot and branches out were included. For trees of unusual shape, a standard forestry practice was adopted. For stems that fork from the ground, each individual stem is measured separately; to indicate that they are part of the same tree, however, they are numbered by adding a letter suffix. For example, stems 12a and 12b would both be part of tree number 12. Care was taken to ensure that the diameter tape is put around the stem exactly at the indicated point of measurement.

Table 7: Species ranking on the basis of frequency, categorization and wood specific gravity (ρ) [gm cm^{-3}] values for the purpose of estimating AGTB [wood specific gravity source from MPFS (1988)]

Stratum	Rank 1 tree species	Rank 2 tree species	Rank 3 tree species	All other species
Chitwan (Kayarkhola) dense	sal (*Shorea robusta*), 0.88	botdhangero (*Lagerstroemia parviflora*), 0.85	sindure (Mean of terai/lower slope mixed hardwood forest), 0.72	Mean of terai/lower slope mixed hardwood forest, 0.72
Chitwan (Kayarkhola) sparse	sal (*Shorea robusta*), 0.88	parijat (Mean of terai/lower slope mixed hardwood forest), 0.72	saj (*Terminelia tomentosa*), 0.95	Mean of terai/lower slope mixed hardwood forest, 0.72
Dolakha (Charnawati) dense	guras (*Rhododendron arboretum*), 0.64	angeri (Mean of upper slope mixed hardwood forest), 0.594	khasru (*Quercus spp.* Mean of upper slope mixed hardwood forest), 0.594	Mean of upper slope mixed hardwood forest, 0.594
Dolakha (Charnawati) sparse	guras (*Rhododendron arboretum*), 0.64	khote sallo (*Pinus roburghii*), 0.65	chilaune (*Schima wallichii*), 0.69	Mean of upper slope mixed hardwood forest, 0.594
Gorkha (Ludikhola) dense	sal (*Shorea robusta*), 0.88	chilaune (*Schima wallichii*), 0.69	katus (*Catanopsos spp*), 0.74	Mean of terai/lower slope mixed hardwood forest, 0.72
Gorkha (Ludikhola) sparse	sal (*Shorea robusta*), 0.88	chilaune (*Schima wallichii*), 0.69	bhalayo (Mean of terai/lower slope mixed hardwood forest), 0.72	Mean of terai/lower slope mixed hardwood forest, 0.72

According to the framework of the project, site specific allometric equations could not be developed for the project sites, therefore, Eq (iii) suggested by Chave (2005, p. 93)(for moist forest stand) was selected after thorough review of literatures.

$$AGTB = 0.0509 * \rho D^2 H \quad \text{... Eq. (iii)}$$

where,

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

Even though wood specific gravity (ρ) is a component in Eq (iii), due to the fact that the wood specific gravity of all the tree species encountered during the field measurements were not readily available, the specific value were used only in cases of three most frequently encountered species in each stratum (if available), for remaining tree species, a general value was used according to associated forest types (see Table 77 for detail).

After taking the sum of all the individual biomass weights (in kg) of a sampling plot and dividing it by the area of a sampling plot (250 m^2), the biomass stock was attained in kg m^{-2}. This value was then converted to t ha^{-1} by multiplying it by 10. Since the project areas are part of the tropical and sub-tropical region, the biomass stock was converted into carbon stock after multiplication with the IPCC (2006) default carbon fraction of 0.47.

2.2.1.2 Aboveground saplings biomass (AGSB)

Nested sub plots of 5.64 m radius were established for measuring saplings. Saplings with diameter > 1 cm to < 5 cm were measured at 1.3 m above ground level. National allometric biomass equations were used to determine the aboveground sapling biomass (AGSB) (<5cm DBH). These tables are developed by the Department of Forest Research and Survey (DFRS), and the Department of Forest, Tree Improvement and Silviculture Component (TISC), Nepal (Tamrakar 2000). In case of tree species other than given equations in the biomass table, equations were applied according to given associations of species (forest type). The biomass value was derived from stem compartment only. The following regression model [Eq. (iv)] was used for an assortment of species to calculate biomass.

$$\log(AGSB) = a + b\ log(D) \qquad \text{.. Eq. (iv)}$$

where;

$\log$	=	natural log [dimensionless];
$AGSB$	=	aboveground sapling biomass [kg];
a	=	intercept of allometric relationship for saplings [dimensionless];
b	=	slope allometric relationship for saplings [dimensionless]; and
D	=	over bark diameter at breast height (measured at 1.3m above ground) [cm].

Used variables (i.e. a and b) for all tree species is presented in Annex 1. Biomass stocks were converted to carbon stocks using the IPCC (2006) default carbon fraction of 0.47.

2.2.1.3 Regeneration count

A nested plot of 1 m radius was laid out for evaluating status of regeneration (<1 cm dbh). All regenerations in the plot of this size were counted, identified and recorded.

2.2.1.4 Leaf litter, herbs, and grasses (LHG)

One circular sub plot of 1 m^2 (0.56 m radius) was established at the centre of each nested plot. All the litters (dead leaves, twigs, etc.) and live components (herb and grass) within the 1 sub plots were collected separately in a destructive manner.

Figure 5: Collecting leaf litters

Fresh samples were weighed in the field with 0.1 g precision. A well- mixed subsample of about 100 g is then placed in a marked bag. Subsample is taken to the laboratory and oven dried until constant weight to determine water content to determine oven-dry-to-wet mass ratio to convert the total wet mass to oven-dry mass. A. For herb, grass and litter, the amount of biomass per unit area was calculated by:

$$LHG = \frac{w_{field}}{A} \cdot \frac{w_{subsample,dry}}{w_{subsample,wet}} \times 10 \qquad \text{.. Eq. (v)}$$

where;

LHG	=	biomass of Leaf Litter, Herb, and Grass [t ha^{-1}];
w_{field}	=	weight of the fresh field sample of leaf Litter, herb, and grass, destructively sampled within an area of size A [kg];
A	=	size of the area in which leaf litter, herb, and grass were collected [m^2];
$w_{subsample,dry}$	=	weight of the oven-dry sub-sample of leaf litter, herb, and grass taken to the laboratory to determine moisture content [g]; and
$w_{subsample,wet}$	=	weight of the fresh sub-sample of leaf litter, herb, and grass taken to the laboratory to determine moisture content [g].

The carbon content in LHG, $C(LHG)$ is calculated by multiplying LHG with the IPCC (2006) default carbon fraction of 0.47.

2.2.1.5 Soil organic carbon (SOC)

Figure 6: Collection of soil sample

Soil organic carbon was determined through collecting samples from the default depth of 30cm prescribed by the IPCC (2006). Near the centre of the plot a single pit of about 30 cm depth were dug. For the purpose of estimating bulk density three individual soil samples of approximately 300 cm^3, one each from three depths (0-10 cm, 11-20 cm, and 21-30 cm) were collected with the help of standardized 300 cm^3 metal soil sampling corer. Similarly, one composite sample of approximately 100 g was collected mixing soils from all the three layers for determining concentrations of organic carbon. The composite soil samples collected in the field were prepared by removing stones and plant residues > 2mm (plant residues <2mm dia is considered as soil organic matter) as well as by grinding. All material collected in the cores and composite soil sample were placed into appropriately labelled sample bags. Subsequently, 3 samples of 300cm^3 of three depths and one composite sample (100g) were taken to the laboratory and oven dried (105^0 C) until constant weight to determine water content. The carbon stock of soil organic carbon was calculated as given by Eq. (vi) (Pearson et al. 2007, p. 30):

$$SOC = \rho \times d \times \%C \qquad \text{... Eq. (vi)}$$

where:

SOC	=	soil organic carbon stock per unit area [tha^{-1}];
ρ	=	soil bulk density [gcm^{-3}];
d	=	the total depth at which the sample was taken [cm]; and
$\%C$	=	carbon concentration [%].

As we only had one composite sample of soil (0-30 cm) for carbon concentration analysis for the purpose of SOC analysis, the bulk density was also derived for the depth of 0-30 cm, averaging the bulk densities from the available layers (0 – 10 cm, 11 – 20 cm and 21 – 30 cm).

2.2.1.6 Belowground biomass (BGB)

One of the most common descriptors of the relationship between root (belowground) and shoot (aboveground) biomass is the root-to-shoot ratio, which has become the standard method for estimating root biomass from the more easily measured shoot biomass. Belowground biomass estimation is much more difficult and time consuming than estimating aboveground biomass. Measurements of root biomass are indeed highly uncertain, and the lack of empirical values for this type of biomass has for decades been a major weakness in ecosystem models (Geider et al. 2001). To simplify the process for estimating below ground biomass, it is recommended to follow MacDicken (1997) root-to-shoot ratio value of 1:5 that is to estimate belowground biomass as 20% of aboveground tree biomass.

2.2.1.7 Total forest carbon stock

The forest carbon stock is calculated by summing the carbon stock of the individual carbon pools of that stratum using the following formula. It should be noted that any individual carbon pool of the given formula can be ignored if it doesn't contribute significantly to the total forest carbon stock.

Forest carbon stock of a stratum:

$$C(LU) = C(AGTB) + C(AGSB) + C(HG) + C(BB) + C(L) + SOC \quad \text{..........Eq. (vii)}$$

where;

C (LU) = carbon stock for a land use category [tC ha^{-1}];
C (AGTB) = carbon stock in aboveground tree biomass [tC ha^{-1}];
C (AGSB) = carbon in aboveground sapling biomass [tC ha^{-1}];
C (HG) = carbon in herbs and grass [tC ha^{-1}];
C (L) = carbon in leaf litter [tC ha^{-1}];
C (BB) = carbon in belowground biomass [tC ha^{-1}];
SOC = soil organic carbon [tC ha^{-1}];

The total forest carbon stock is then can be converted to tons of CO_2equivalent by multiplying by 44/12, or 3.67 (Pearson et al, 2007).

2.2.2 Leakage analysis

Local communities may save their own community forest on the expenses of nearby forest area. This is further triggred by the fact that REDD+ concept which is performance based deal. With this, local communities tempt to keep their forest untouch enhancing carbon stock to be eligible for the REDD benefits. As a resut of this, activity shifting outside to the project (community forest are) might be a tendency to conserve their forest in the expense of other. In order to monitor the leakage activities thereby verify the leakae ree carbon, the project identified leakagebelt through community consultation as well as GIS analysis in the watersheds. Table 8 and Figure 7 below show the leakage areas of the three watersheds.

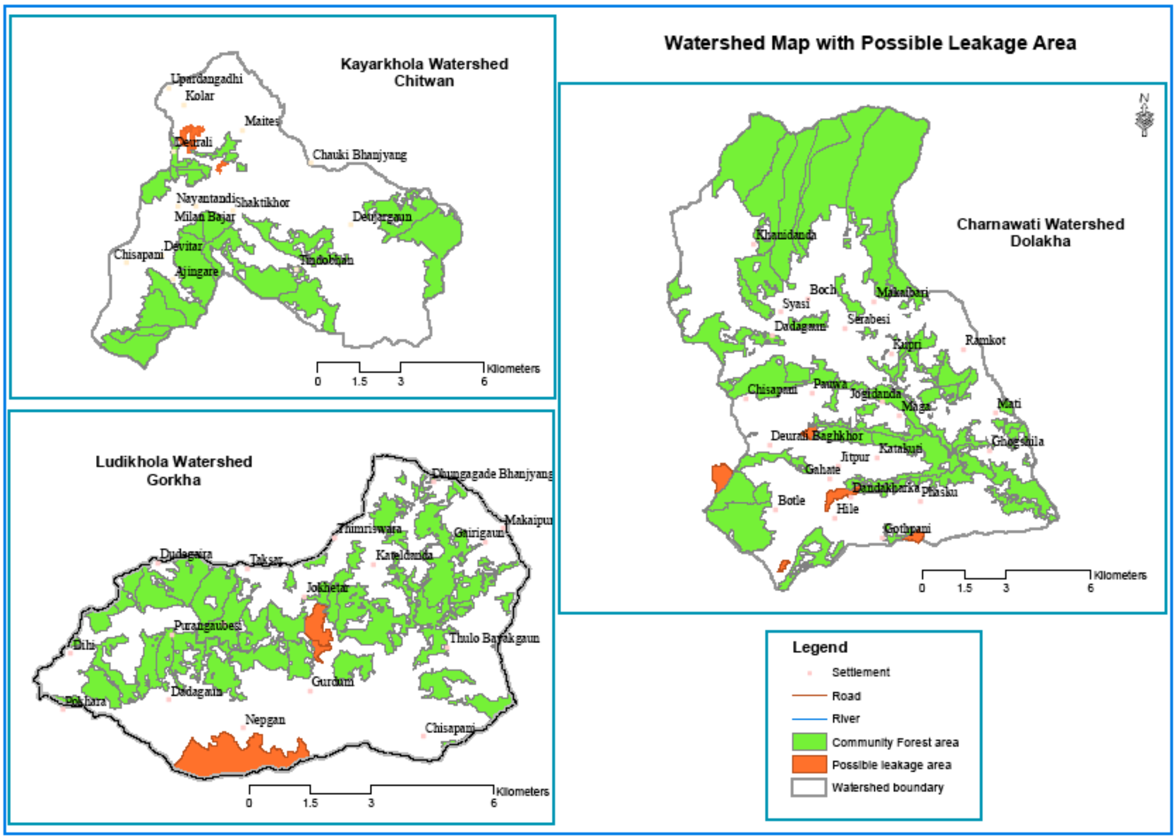

Figure 7: Map showing possible activity leakage zone

Table 8: Possible leakage area in three watersheds

S.N.	Watershed (district)	Total watershed area [ha]	Total CF area [ha]	Possible leakage area [ha]
1	**Kayarkhola (Chitwan)**	8,001.93	2,381.96	41
2	**Charnawati (Dolakha)**	14,038.84	5,996.17	130
3	**Ludikhola (Gorkha)**	5,750.49	1,888.00	269
	Total	**27,791.26**	**10,266.13**	**440**

Source: Land cover analysis report (2010)

For further analysis of the leakage, 6, 3 and 5 permanent plots in Ludikhola, Kayarkhola and Charnawati have been established respectively. Similar measurements and analysis of carbon stock measurement were carried out in these plots too. The analysis of this belt will help us in monitoring leakage activity within the watershed.

3. Results and discussions

Results and analysis of measurement from the field and lab are presented in the subsequent sections. Analysis was done using R-statistical software (R Development Core Team 2009).

3.1 Diameter distribution

As evident from plotted diagrams of DBH distribution, the DBH distributions follow a left-skewed trend in all strata, indicating most of the trees in all the strata are younger and there is potential to enhance forest carbon stock by encouraging tree growth. It could also be inferred from the diagrams that there are few trees in most strata that seem to be outliers (at the extreme right) in terms of measured diameter; DBH records of these trees need to be identified from the pool data and need to be checked for the correctness of entry or even for the field measurement.

3.2 Aboveground tree biomass (AGTB)

Based on pre-analysis, plots with extreme biomass values were identified. Within these plots with extreme biomass values, individual tree with potential outlier variable values (i.e. DBH and height) were identified. Out of the total 21,170 trees measured in the three watersheds, 43 trees were identified as trees with potential outlier variable values (Annex 2). All final analysis excludes measures of these potential outlier trees. Each stratum has few plots with outlier tree biomass values. The frequency of outlier plots seems to be highest in Ludikhola dense followed by Charnawati dense and Charnawati sparse (Annex 2). In order to re-include identified potential outlier trees in the analysis, measures of these trees need to be reconfirmed from the remeasurements in the field.

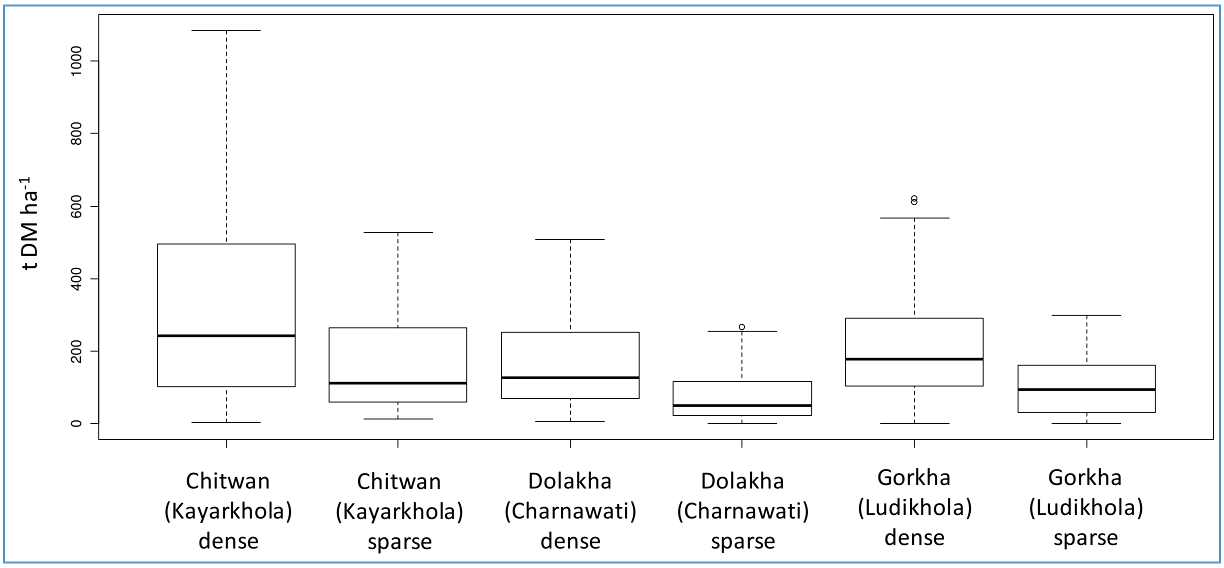

Figure 8: Box-and-whisker plot of AGTB in different strata showing five-number summaries and outliers

Plots in Kayarkhola dense have most spreading biomass values followed by Ludikhola dense and Kayarkhola sparse (figure 8). Sparse strata in Charnawati and Ludikhola have the least spread of AGTB values.

Table 9: *Summary statistics of sampling of trees in different strata*

Stratum	Variable [unit]	No. of plots	Mean	Standard deviation	Half width of confidence interval	Maximum	Minimum	Median	Sampling precision
Chitwan (Kayarkhola) dense	Biomass[t DM ha^{-1}]	154	322.65	267.72	42.62	1,084.71	1.20	242.45	6.69
	Tree density [ha^{-1}]	154	1,092.21	740.82	117.94	4,160.00	120.00	960.00	5.47
	Basal area [m^2 ha^{-1}]	154	31.19	18.53	2.95	90.95	0.71	27.36	4.79
Chitwan (Kayarkhola) sparse	Biomass[t DM ha^{-1}]	26	197.73	173.89	70.23	526.57	12.00	110.51	17.25
	Tree density [ha^{-1}]	26	903.08	669.63	270.47	3,120.00	240.00	700.00	14.54
	Basal area [m^2 ha^{-1}]	26	23.22	13.70	5.53	58.62	5.22	19.30	11.57
Dolakha (Charnawati) dense	Biomass[t DM ha^{-1}]	164	165.24	122.01	18.81	508.39	4.83	126.83	5.77
	Tree density [ha^{-1}]	164	1,600.49	1,013.64	156.30	4,720.00	160.00	1,320.00	4.95
	Basal area [m^2 ha^{-1}]	164	33.84	19.28	2.97	121.97	3.04	30.18	4.45
Dolakha (Charnawati) sparse	Biomass[t DM ha^{-1}]	41	77.64	70.63	22.30	266.25	0.00	48.09	14.21
	Tree density [ha^{-1}]	41	1,110.24	854.20	269.62	3,560.00	0.00	720.00	12.02
	Basal area [m^2 ha^{-1}]	41	20.06	15.93	5.03	60.70	0.00	15.02	12.41
Gorkha (Ludikhola) dense	Biomass[t DM ha^{-1}]	144	202.21	136.95	22.56	622.00	0.40	177.43	5.64
	Tree density [ha^{-1}]	144	1,899.86	1,036.75	171.39	6,360.00	120.00	1,680.00	4.56
	Basal area [m^2 ha^{-1}]	144	27.27	12.75	2.10	64.61	0.27	26.49	3.90
Gorkha (Ludikhola) sparse	Biomass[t DM ha^{-1}]	41	107.85	84.72	26.74	298.32	0.00	93.00	12.27
	Tree density [ha^{-1}]	41	1,371.43	864.08	269.27	4,280.00	0.00	1,180.00	9.72
	Basal area [m^2 ha^{-1}]	41	17.68	10.17	3.21	39.51	0.00	18.71	8.98

Referring to Table 9, Kayarkhola dense seems to have the highest per ha mean AGTB and Charnawati sparse has the lowest. However, it should also be noted that the standard deviation in the Charnawati dense is also the highest. In terms of mean tree density per hectare, Ludikhola dense tends to have the highest value followed by Charnawati dense. The tree density per ha is the lowest in Kayarkhola sparse strata. Mean basal area is highest in Charnawati dense whereas it is lowest in Ludikhola sparse. The minimum value column suggests at least one plot in Charnawati sparse and Ludikhola sparse has no tree.

Figure 9 illustrates the status of the forest based on three observable varialbles i.e. biomass, tree density and basal area in three watersheds. Kayarkhola is with higher mean biomass, least mean tree density and moderate mean basal area. It characterizes that the forest in Kayarkhola has relatively taller and mature trees with larger diamenter class. With lower mean biomass, moderate mean tree density and higher mean basal area of forest in Charnawati explicitely signifies the majority of shorter trees. Unlike two watersheds, less mean biomass, moderate tree density and basal area further symbolizes forest with young tress. Such forest dimensions of the forest in watersheds were perfectly synchronized with the general characteristic of dominant trees and climatic variations in the watersheds.

Overall, all the dense strata have higher AGTB values for all the given variables (i.e. biomass, tree density and basal area) than that of the sparse justifies the strategy of stratification. However, most of the sparse strata have sampling precision values greater than predetermined acceptable limit (i.e. less than 10%), which suggests sparse stratum might need to be splitted into further strata to make homogenous layer

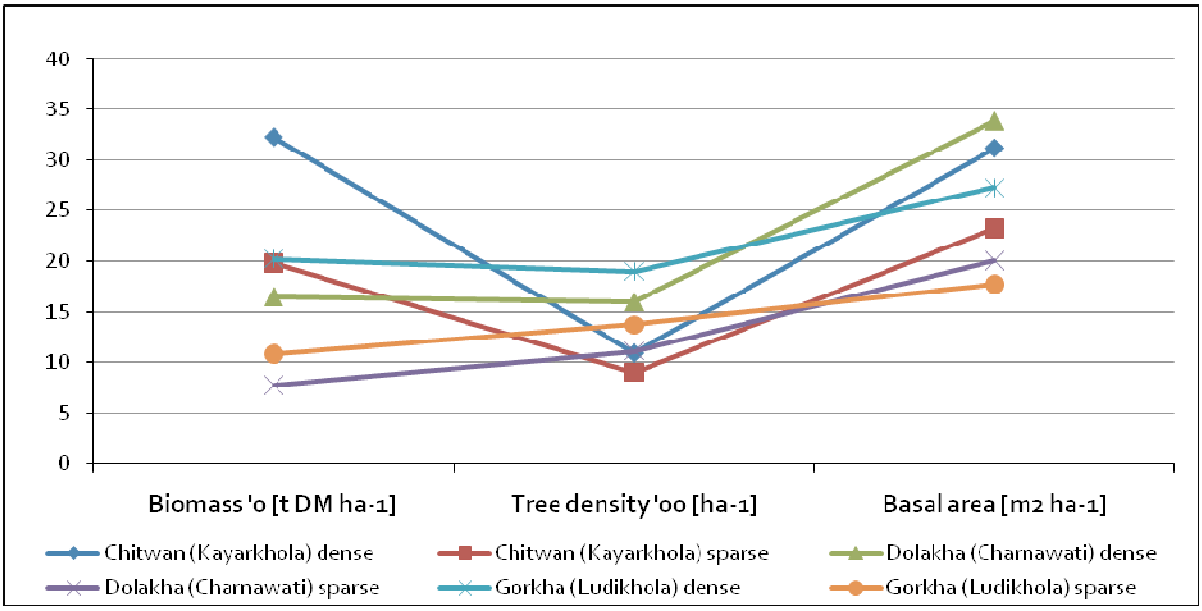

Figure 9: Rank of strata on the basis of key tree variables in the plot

3.3 Aboveground sapling biomass (AGSB)

Figure 10 suggests Ludikhola sparse has the highest spread of plots in terms of AGSB followed by Charnawati dense. Kayarkhola sparse and Kayarkhola dense have least spread AGTB values.

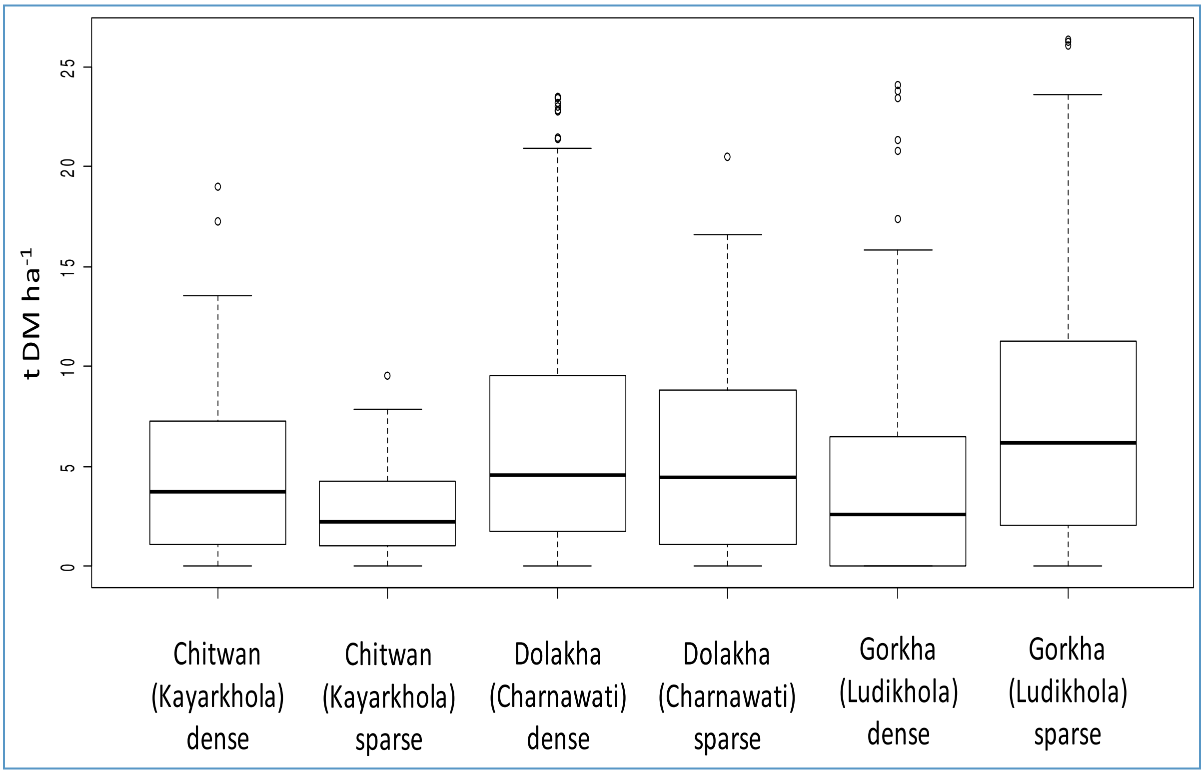

Figure 10: Box-and-whisker plot of AGSB in different strata showing five-number summaries and outliers

Table 10: Above ground per ha saplings values in different strata

Stratum	Variable [unit]	No. of plots	Mean	Standard deviation	Half width of confidence interval	Maximum	Minimum	Median	Sampling precision
Chitwan (Kayarkhola) dense	Biomass [t DM ha^{-1}]	154	4.54	3.88	0.62	18.96	0.00	3.74	6.89
	Tree density [ha^{-1}]	154	1,685.06	1,494.60	237.94	6,200.00	0.00	1,300.00	7.15
	Basal area [m^2 ha^{-1}]	154	1.06	0.94	0.15	4.63	0.00	0.81	7.18
Chitwan (Kayarkhola) sparse	Biomass [t DM ha^{-1}]	26	2.93	2.65	1.07	9.50	0.00	2.19	17.72
	Tree density [ha^{-1}]	26	1,184.62	1,261.01	509.33	5,800.00	0.00	800.00	20.88
	Basal area [m^2 ha^{-1}]	26	0.70	0.63	0.25	2.27	0.00	0.50	17.70
Dolakha (Charnawati) dense	Biomass [t DM ha^{-1}]	164	6.74	6.54	1.01	23.46	0.00	4.56	7.57
	Tree density [ha^{-1}]	164	2,070.73	1,999.48	308.30	13,900.00	0.00	1,500.00	7.54
	Basal area [m^2 ha^{-1}]	164	1.49	1.31	0.20	5.09	0.00	1.10	6.87
Dolakha (Charnawati) sparse	Biomass[t DM ha^{-1}]	41	5.29	4.91	1.55	20.51	0.00	4.45	14.49
	Tree density [ha^{-1}]	41	1,670.73	1,677.09	529.35	6,700.00	0.00	1,100.00	15.68
	Basal area [m^2 ha^{-1}]	41	1.35	1.35	0.43	5.40	0.00	1.09	15.57
Gorkha (Ludikhola) dense	Biomass [t DM ha^{-1}]	144	4.33	5.41	0.89	24.07	0.00	2.58	10.42
	Tree density [ha^{-1}]	144	1,507.69	1,951.38	322.58	11,500.00	0.00	1,000.00	10.82
	Basal area [m^2 ha^{-1}]	144	1.16	1.45	0.24	7.38	0.00	0.74	10.44
Gorkha (Ludikhola) sparse	Biomass [t DM ha^{-1}]	41	8.19	7.97	2.52	26.37	0.00	6.15	15.21
	Tree density [ha^{-1}]	41	3,000.00	3,677.22	1,145.90	18,600.00	0.00	2,100.00	18.91
	Basal area [m^2 ha^{-1}]	41	2.03	1.96	0.62	7.07	0.00	1.52	15.02

Table 10 reveals that overall per ha values of all AGSB variables (i.e. biomass, tree density and basal area) are highest in Ludikhola sparse and least in Kayarkhola sparse. Minimum values column suggests all strata have at least one plot without any sapling. Except in Kayarkhola dense and Charnawati dense, sampling precision values are above 10%, reaching up to 20.88%, which might be due to the fact that the pilot survey was targeted to sampling trees, not to the saplings. Hence, the sample size (or plot size) for sapling survey might need to be optimized in order to achieve higher accuracy.

3.4 Herb and grass biomass (HGB)

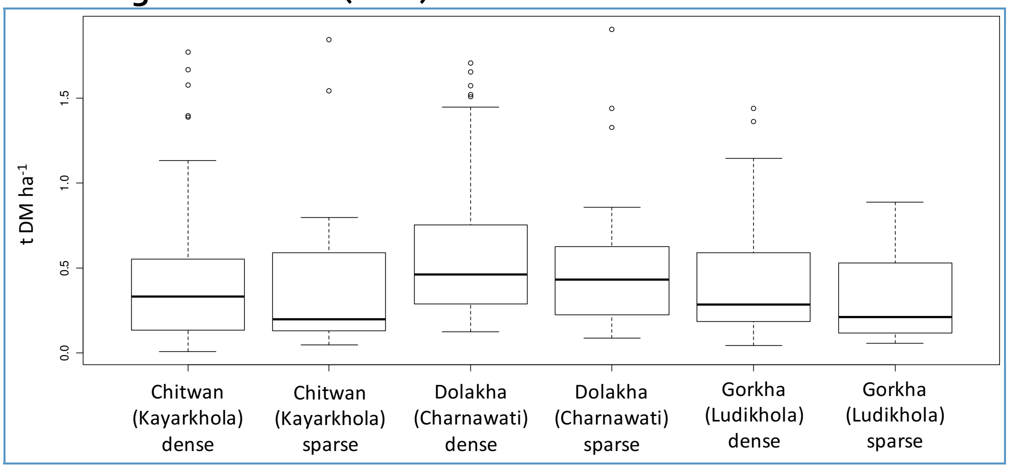

Figure 11: Box-and-whisker plot of HGB in different strata showing five-number summaries and outliers

According to Figure 10, all dense strata (i.e. Charnawati dense, Kayarkhola dense and Ludikhola dense) seems to have the higher spread of HGB whereas all sparse strata seems to have little spread in terms of HGB values. That means dense of all watersheds have larger carbon stock in herbs and grass biomass pool.

Table 11: Per ha Dry Matter value of f herbs and grass in different strata

Stratum	No. of plots	Mean [t DM ha^{-1}]	Standard deviation	Half width of confidence interval	Maximum	Minimum	Median	Sampling precision
Chitwan (Kayarkhola) dense	99	0.42	0.37	0.07	1.77	0.01	0.33	9.04
Chitwan (Kayarkhola) sparse	15	0.48	0.54	0.30	1.84	0.05	0.20	28.91
Dolakha (Charnawati) dense	120	0.56	0.37	0.07	1.71	0.12	0.46	6.01
Dolakha (Charnawati) sparse	26	0.54	0.44	0.18	1.90	0.08	0.43	15.99
Gorkha (Ludikhola) dense	82	0.40	0.32	0.07	1.44	0.04	0.28	8.78
Gorkha (Ludikhola) sparse	34	0.30	0.23	0.08	0.89	0.06	0.21	13.28

According to summary presented in Table 11, per ha mean value of dry matter and carbon stock of HGB is recorded highest in Charnawati dense and lowest in Ludikhola sparse. Considering the ranges of sampling precision, sampling in all sparse strata needs to be optimized to achieve desired precision (i.e. 10%). As the mean herbs, grass biomass (HGB) contains about 0.50 tDM ha^{-1}, it might be necessary to evaluate the significance of monitoring the HGB pool also reviewing efforts required for herb, shrub and grass sampling and expenditures for lab analysis.

3.5 Leaf litter biomass (LLB)

Charnawati sparse has plots with the most spread leaf litter biomass (LLB) values. There is not similar pattern in Charnawati and Kayarkhola where LLB in dense strata of these two watersheds is recorded higher than in sparses starta. Kayarkhola sparse appears to have the least spread LLB values (figure 11).

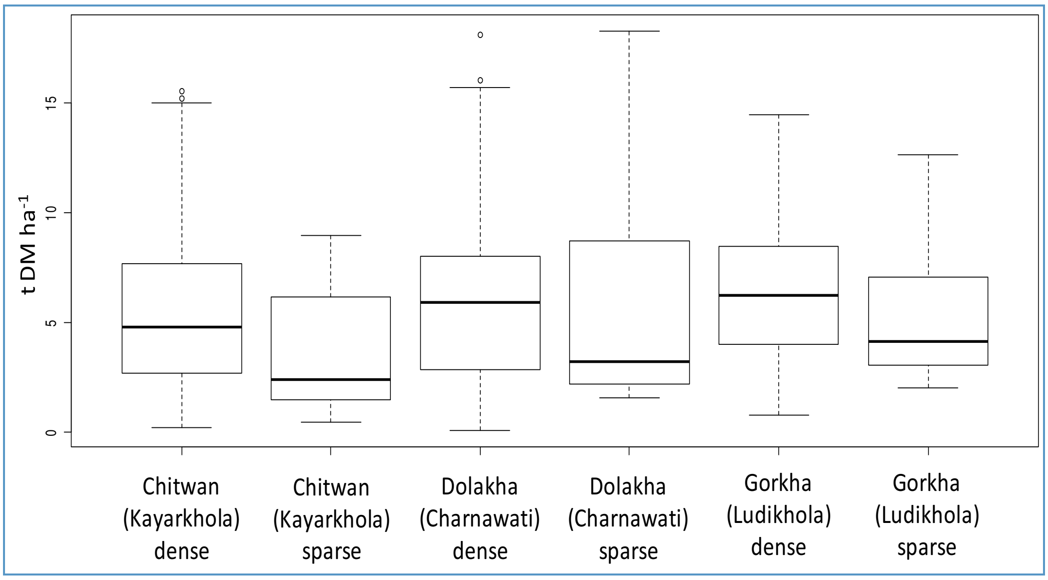

Figure 12: Box-and-whisker plot of LLB in different strata showing five-number summaries and outliers

Table 12: Summary statistics of leaf litter biomass sampling in different strata

Stratum	No. of plots	Mean [t DM ha^{-1}]	Standard deviation	Half width of confidence interval	Maximum	Minimum	Median	Sampling precision
Chitwan (Kayarkhola) dense	80	5.39	3.69	0.82	15.52	0.19	4.77	7.66
Chitwan (Kayarkhola) sparse	13	3.66	2.94	1.77	8.96	0.42	2.40	22.26
Dolakha (Charnawati) dense	88	6.45	4.05	0.86	18.09	0.06	5.89	6.69
Dolakha (Charnawati) sparse	9	5.83	5.48	4.22	18.26	1.54	3.19	31.34
Gorkha (Ludikhola) dense	98	6.34	3.41	0.68	14.46	0.79	6.21	5.44
Gorkha (Ludikhola) sparse	19	5.23	2.80	1.35	12.62	2.00	4.10	12.28

As evident from Table 12, all dense strata are ahead of their sparse counterparts in terms of mean LLB. Charnawati dense has highest value followed by Ludikhola dense. Mean LLB ranges from 3.66 to 6.45 t DM ha^{-1}. Similarly, sampling precision for all sparse strata are higher than 12% up to above 30%, indicating sample size in sparse strata might need to be optimized for enhanced accuracy in estimation of LLB.

3.6 Soil organic carbon (SOC)

In Figure 13, Kayarkhola sparse tends to have the maximum spread of plots in terms of soil organic carbon (SOC), followed by Charnawati sparse and Charnawati dense. Ludikhola (both dense and sparse) appears to have plots with least spread of SOC values.

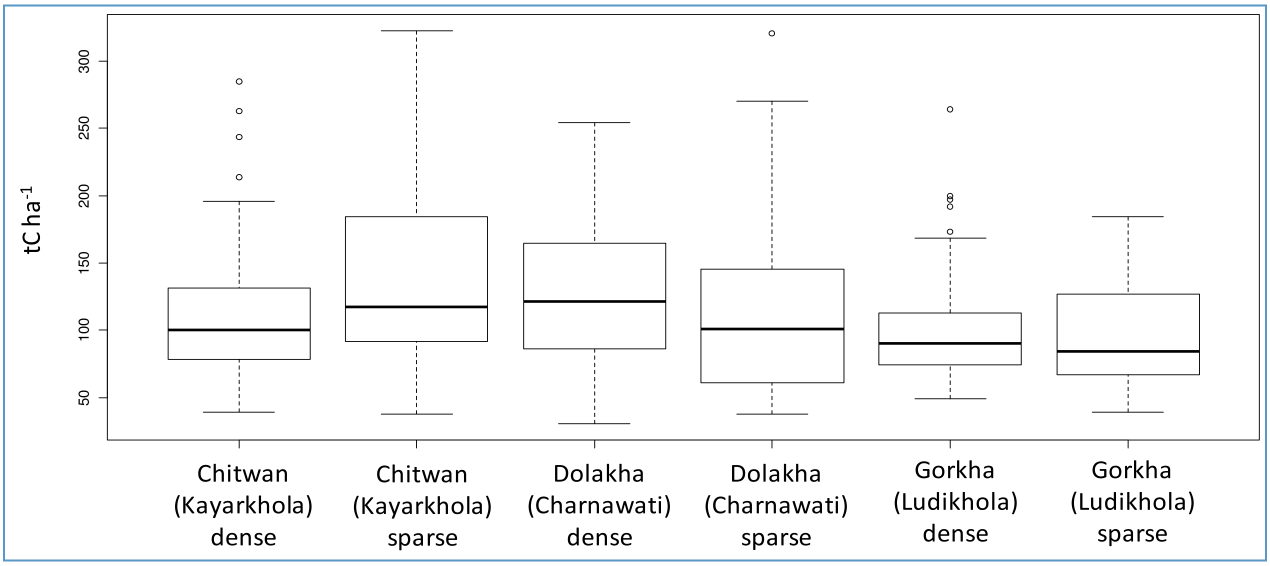

Figure 13*: Box-and-whisker plot of SOC in different strata showing five-number summaries and outliers*

According to Table 13, sparse stratum in Kayarkhola seems to have the highest mean SOC. The lowest mean SOC value is in Ludikhola sparse. Except Kayarkhola sparse, sampling precision of SOC estimates in all strata are below 10%, suggesting adequacy of existing sampling frame for SOC estimate.

Table 13: Summary statistics of soil organic carbon sampling of in different strata

Stratum	No. of plots	Mean [tC ha^{-1}]	Standard deviation	Half width of confidence interval	Maximum	Minimum	Median	Sampling precision
Chitwan (Kayarkhola) dense	134	109.60	42.06	7.19	285.14	39.47	100.54	3.32
Chitwan (Kayarkhola) sparse	22	141.85	76.91	34.10	322.83	37.86	117.21	11.56
Dolakha (Charnawati) dense	149	128.90	52.42	8.49	254.31	30.53	121.45	3.33
Dolakha (Charnawati) sparse	40	117.48	70.51	22.55	320.79	37.64	101.23	9.49
Gorkha (Ludikhola) dense	134	97.01	33.91	5.79	263.99	48.87	90.48	3.02
Gorkha (Ludikhola) sparse	39	95.70	36.10	11.70	184.80	39.11	84.06	6.04

3.7 Belowground biomass (BGB)

Mean BGB is derived as 20% of AGTB. Thus the trend of BGB is same as AGTB, i.e. highest in Kayarkhola dense followed by Ludikhola dense and lowest in Charnawati sparse. Summary of BGB is given in Table 14.

Table 14: Mean below around biomass in all strata

Stratum	Below Ground Biomass [t ha^{-1}]
Chitwan (Kayarkhola) dense	64.53
Chitwan (Kayarkhola) sparse	39.55
Dolakha (Charnawati) dense	33.05
Dolakha (Charnawati) sparse	15.53
Gorkha (Ludikhola) dense	40.44
Gorkha (Ludikhola) sparse	21.57

3.8 Strata level total forest carbon stock in project watersheds

This section attempts to analyze the data strata wise in all the project watersheds. This will give idea how forest carbon stock varies among dense and sparse strata, different altitudinal ranges and in different aspects.

3.8.1 Forest carbon stocks in Kayarkhola watershed

Subsequent sub-headings give the details of forest carbon stock in different category of stratification.

3.8.1.1 Forest carbon stock summary in dense and sparse strata of Kayarkhola

As indicated in Figure 14, among different carbon pools, tree holds almost half of the total forest carbon stock in Kayarkhola dense whereas soil organic carbon represents more than half of the total forest carbon stock (51%) in Kayarkhola sparse. Proportion of carbon stock in sapling pool is same in both strata being 1%, where as carbon stocks in herb and litter pools are consistently low and similar in all strata, litter being 1% and herb being 0%. Carbon stock in below ground pool is 10% to 7 % in dense and sparse strata respectively.

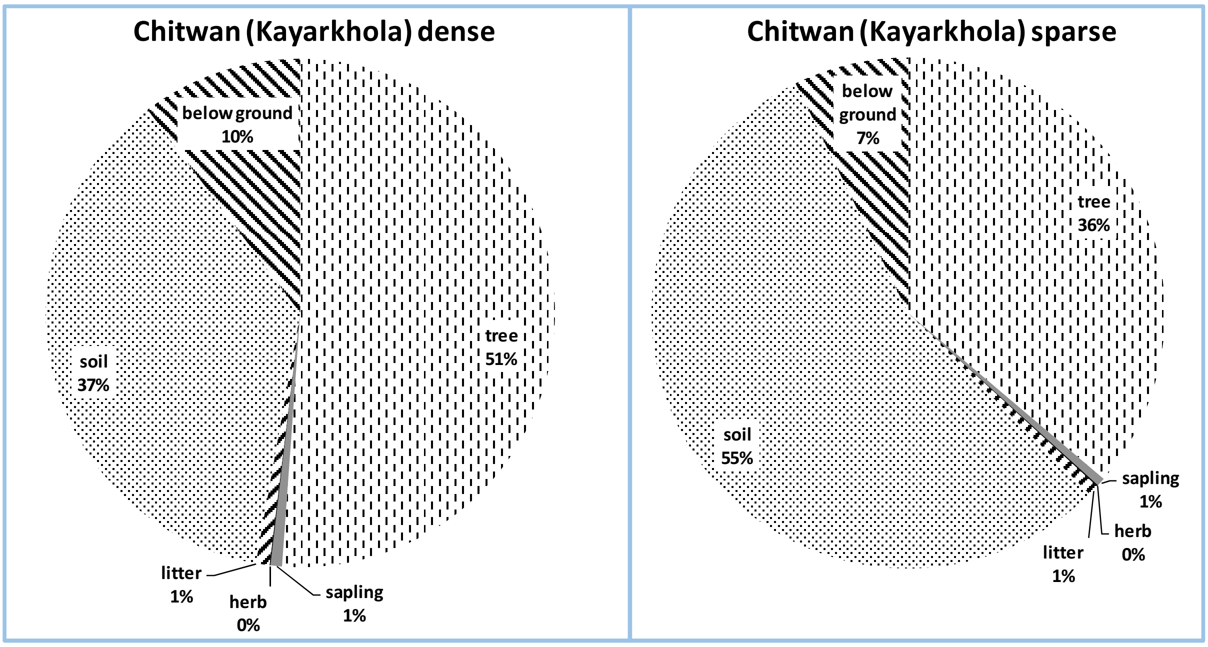

Figure 14*: Strata wise proportion of each carbon pool in Kayarkhola*

3.8.1.2 Altitude wise forest carbon stock summary in Kayarkhola

Forest carbon stocks in all pools except tree and below ground seem almost consistent along the altitudinal gradients in Kayarkhola. The per ha mean of forest carbon stock increases along the altitudinal gradient until reaching at the highest at the altitudinal range of 681 - 840 meter above sea level (masl) then begin to decrease. Lowermost altitudinal range (i.e. <360 masl) holds the lowest per ha mean of forest carbon stock in Kayarkhola.

Figure 15 shows altitudinal variations in per ha mean forest carbon stock in each pool in Kayarkhola watershed.

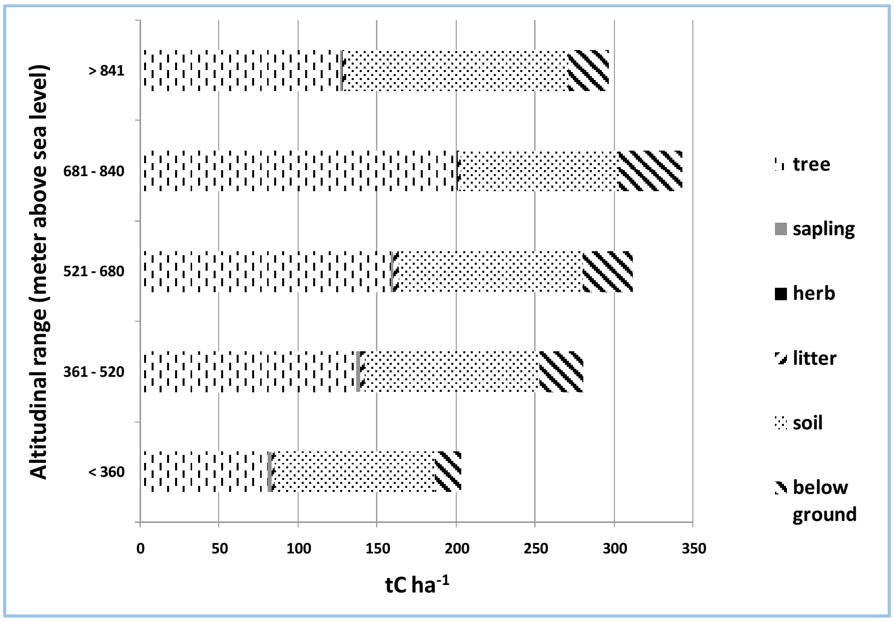

Figure 15: Altitude-wise forest carbon stock summary in Kayarkhola

3.8.1.3 *Chitwan (Kayarkhola) aspect wise forest carbon stock summary*

Figure 16 shows variations of per ha mean forest carbon stock in all aspects in Kayarkhola watershed.

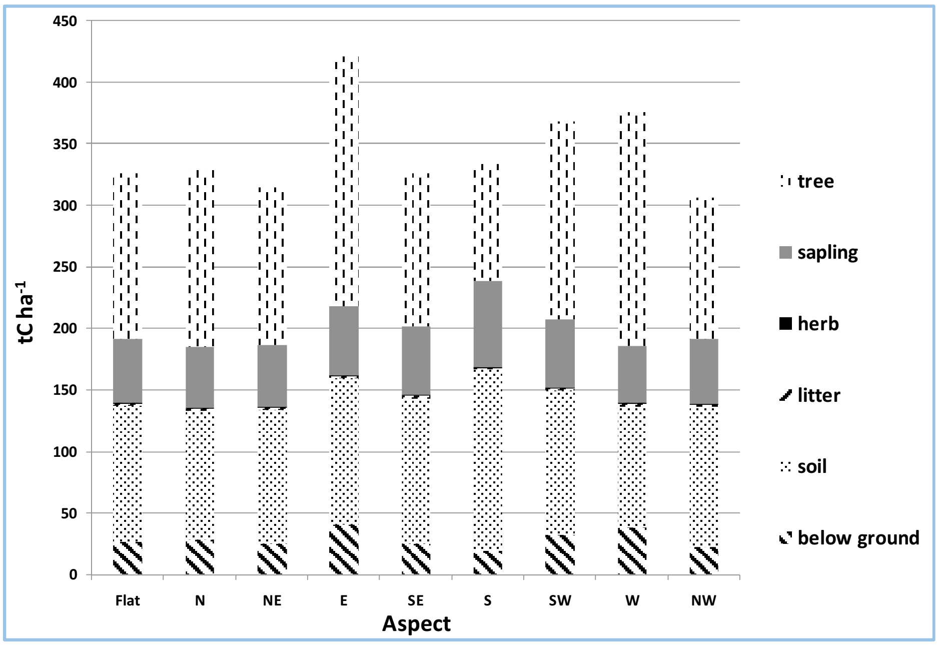

Figure 16: Aspect wise summary of forest carbon stock in each pool in Kayarkhola

It appears tree growth is favored on east facing slopes in Kayarkhola watershed as forest carbon stock in tree pool (as well as total forest carbon stock in all pool) seems the highest on eastern aspect, followed by West and South-West. North-West, followed by North-East aspects appear to hold the least amount of per hectare forest carbon stock.

3.8.2 Forest carbon stocks in Charnawati watershed

Subsequent sub-headings give the details of forest carbon stock in different category of stratification in Charnawati.

3.8.2.1 *Forest carbon stock summary in dense and sparse strata of Charnawati*

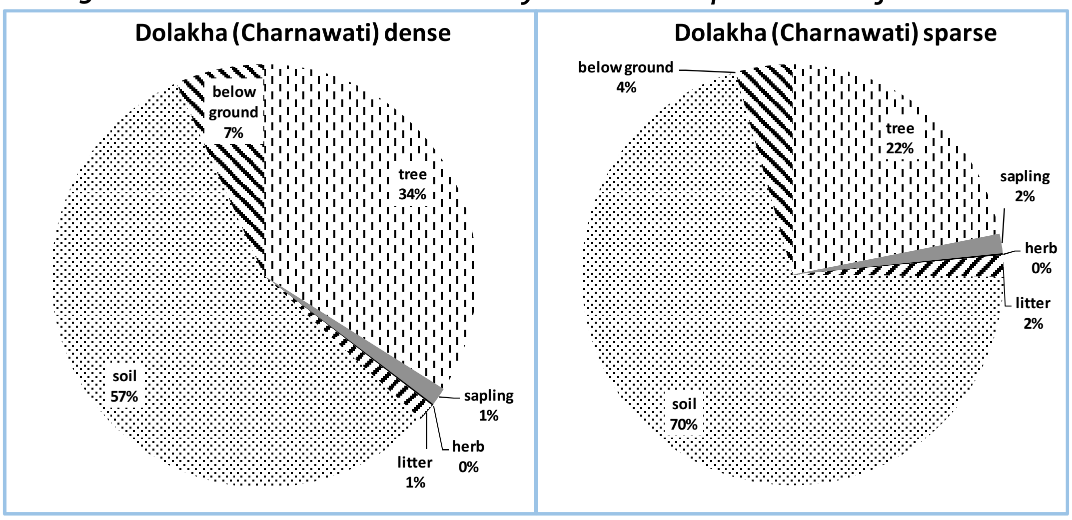

Figure 17: Strata wise proportion of each carbon pool in Charnawati

Carbon pool in soil seems consistently dominant among all pools in both strata in Charnawati, followed by tree. Herbs and litter pool represent insignificant (0%) carbon stock in both strata in this watershed.

3.8.2.2 Altitude-wise carbon stock summary in Charnawati

Figure 18 shows altitudinal variations per ha mean carbon stock in each pool in Charnawati watershed.

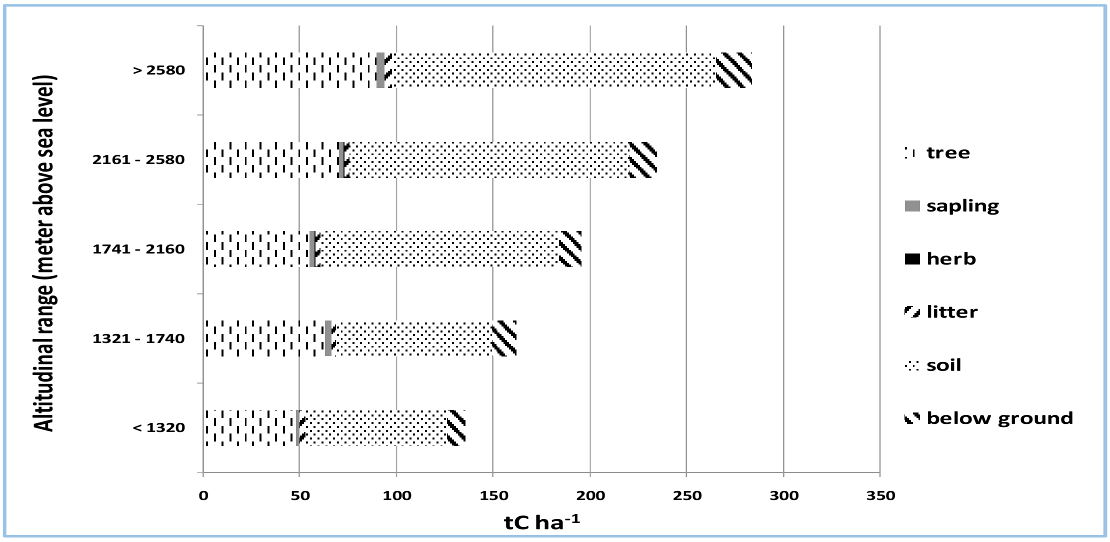

Figure 18: Altitude-wise forest carbon stock in Charnawati

Forest carbon stock seems increasing proportionately to altitudinal range in Charnawati, forest carbon stock in above 2580 masl altitude is the highest where as <1320 masl being the least.

3.8.2.3 Aspect-wise forest carbon stock summary in Charnawati

Figure 19 shows variations of per ha mean forest carbon stock in all aspects in Charnawati watershed.

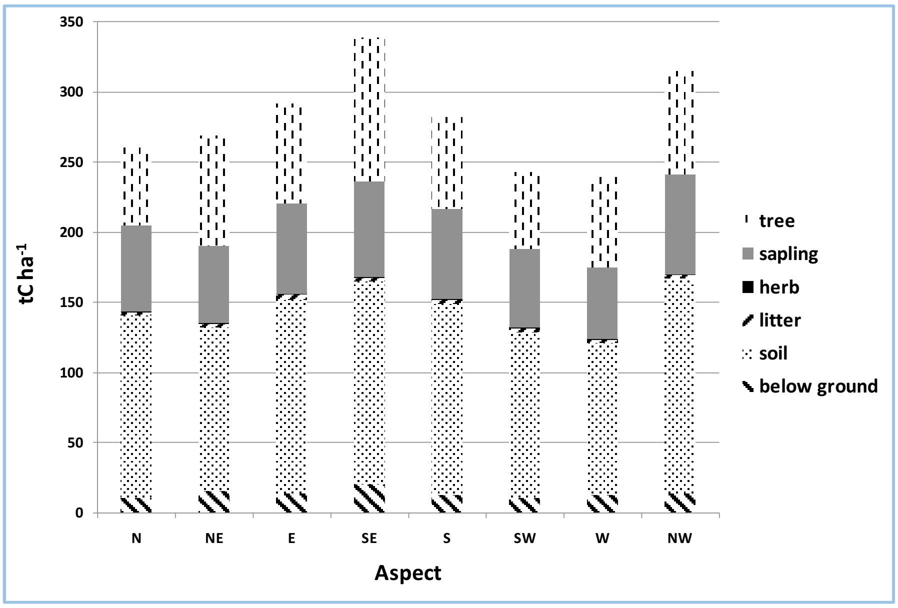

Figure 19: Aspect-wise forest carbon stock of Charnawati

Forest carbon stock seems to be increasing gradually from North aspect until South-East, where it reaches the highest. It then decreases gradually to the lowest level on West before reaching at the second highest on North-West aspect.

3.8.3 Forest carbon stocks in Ludikhola watershed

Subsequent sub headings give the details of forest carbon stock in different category of stratification.

3.8.3.1 Gorkha (Ludikhola) stratum-wise forest carbon stock summary

Carbon stock in soil seems to have more than half of the total forest carbon stock in sparse stratum in Ludikhola, where as soil and tree pool in dense strata hold 45% and 44% of the total forest carbon stock. Herb and litter pools seem to have consistently lower proportion of carbon stocks, being 0% and 1% in dense and 0% and 2% in sparse stratum respectively.

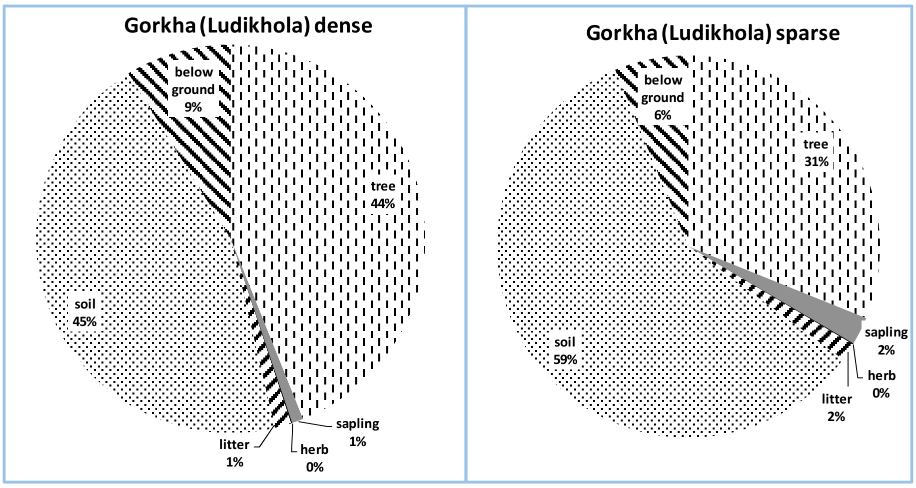

Figure 20: Strata-wise proportion of each carbon pool in Ludikhola

3.8.3.2 Altitude-wise forest carbon stock summary in Ludikhola

Figure 21 shows altitudinal variations in per hectare mean carbon stock in each pool in Ludikhola watershed.

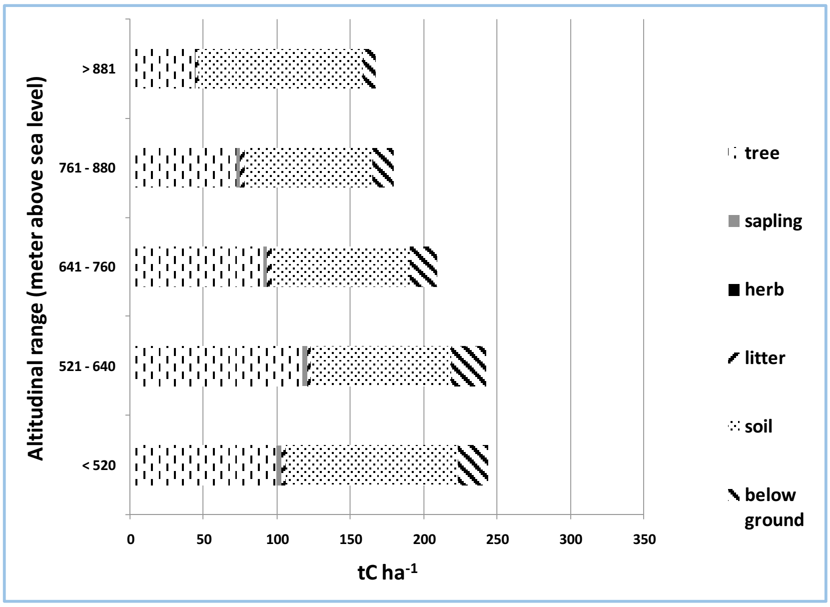

Figure 21: Altitude-wise forest carbon stock summary in Ludikhola

Forest carbon stock appears to be decreasing with respect to increasing altitudinal gradient in Ludikhola, >881 masl being the altitudinal range with the lowest forest carbon stock where as <520 with the highest per hectare mean stock of forest carbon.

3.8.3.3 Aspect-wise forest carbon stock summary in Ludikhola

Figure 22 shows variations of per hectare mean forest carbon stock in all aspects in Ludikhola watershed.

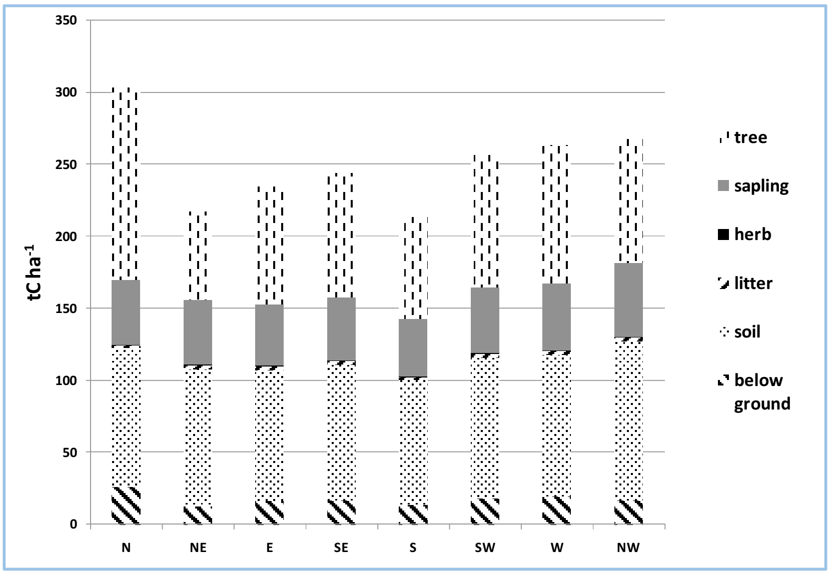

Figure 22: Aspect-wise summary of forest carbon stock in each pool in Ludikhola

North aspect leads all other aspects in Ludikhola in terms of aspect-wise per hectare forest carbon stock, followed by North-West and then by West. South aspect holds the least forest carbon stock followed by North-East and East aspects in increasing order.

3.9 Comparison of strata level mean forest carbon stock in all carbon pools

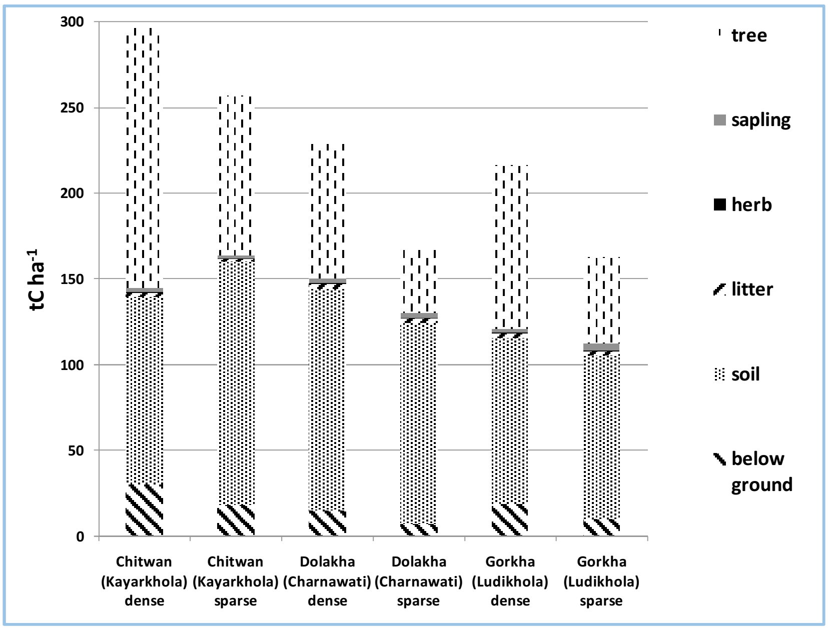

Figure 23: Total mean of forest carbon stock in each pool in all strata

Figure 23 provides overview of total forest carbon stock in dense and sparse strata in all watersheds. Overall, Kayarkhola dense and sparse appear to have the highest amount of forest carbon stock, followed by Charnawati dense and then by Ludikhola dense. Ludikhola sparse, on the other extreme, holds the least amount of per unit forest carbon, followed by Charnawati sparse and Ludikhola dense in increasing order.

3.10 Forest carbon stock in leakage zone

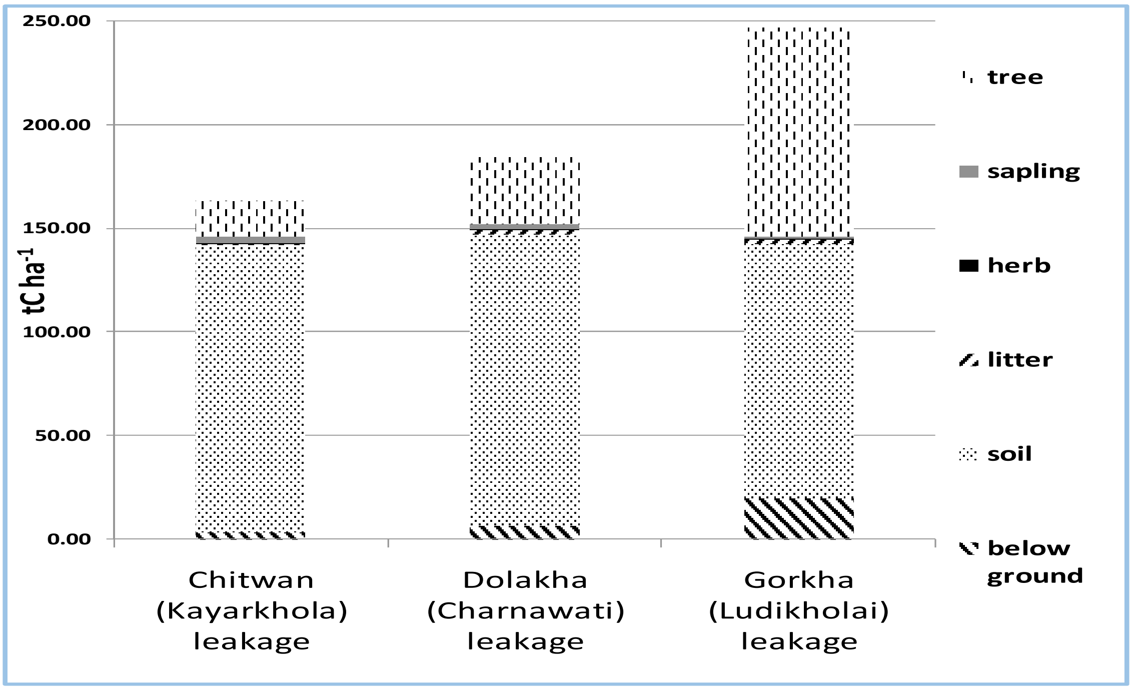

Figure 24: Forest carbon stock in leakage zone

Figure 24 presents summary of mean carbon stock in different pools in leakage zone of all watersheds. Ludikhola leakage zone seems to have the highest mean forest carbon stock followed by Charnawati and hence Kayarkhola has the least amount of mean forest carbon stock. Mean carbon stock in soil pool appears to be least in Ludikhola leakage.

3.11 Status of forest carbon stock at CF level

Stock of carbon in each CF is presented in Annex 3. Accordingly, total and strata-specific forest carbon stock, Nibuwatar, Chitramkaminchuli and Deujar seem to be the three CFs with highest total forest carbon stock in Kayarkhola. Similarly Charnawati, Bhitteri and Setidevi-Dadar appear to be the three CFs in Charnawati with the highest stock of total forest carbon. Ludi Damgade, Ghaledanda-Ranakhola and Gangate-Bahunechaur are the three CFs with highest stock of forest carbon in Ludikhola. The determinant factor for a CF to have the higher forest carbon stock is its area within dense stratum, as dense stratum has much higher mean forest carbon stock in all watersheds.

3.12 Comparison of mean and total forest carbon stock at different spatial scales

Table 15 compares strata specific mean and total forest carbon stock, and watershed total and weighted mean of forest carbon stock. It also gives weighted mean of forest carbon stock among three watersheds.

Table 15: Comparison of mean and total forest carbon stock at different spatial scale

Stratum	Mean carbon stock [tC ha^{-1}]	Area [ha]	Total carbon stock [tC]	total carbon stock [tC]	Weighted mean carbon stock [tC ha^{-1}]	Weighted mean carbon stock [tC ha^{-1}]
Chitwan (Kayarkhola) dense	296.44	1,902.72	564,040.24	687,046.43	288.44	226.25
Chitwan (Kayarkhola) sparse	256.70	479.19	123,006.19			
Dolakha (Charnawati) dense	228.56	3,899.25	891,222.13	1,240,894.72	206.95	
Dolakha (Charnawati) sparse	166.75	2,097.00	349,672.59			
Gorkha (Ludikhola) dense	216.26	1,634.64	353,501.40	394,718.84	209.12	
Gorkha (Ludikhola) sparse	162.98	252.90	41,217.44			

Notwithstanding the mean and weighted forest carbon stock is highest in Kayarkhola (both dense and sparse strata), due to largest area coverage, Charnawati stores about double total forest carbon stock than Kayarkhola. Per hectare average forest carbon stock is highest in Kayarkhola dense, where as it is lowest in Ludikhola sparse. Dense and sparse strata in Ludikhola appear to have lower forest carbon stock comparing respectively to Charnawati dense and sparse. However, higher weighted mean forest carbon stock in Ludikhola than Charnawati, implies that Ludikhola have higher proportion area within dense stratum compared to Charnawati. The difference between forest carbon stocks in dense and sparse strata is highest in Charnawati, where as it is lowest in Kayarkhola, which indicates there is high chance to increase biomass through enrichment plantation, forest restoration and sustainable management of forest in Charnawati compared and vice versa in Kayarkhola.

3.13 Frequency (occurrence) of plant species

Altogether 403 plant species were recorded during the inventory in all watersheds. However, the total number of plant species is likely to reduce once botanical names of all plant species are confirmed because in many cases, same plant species might have different local names in different communities and sites. Table 17 summarizes top three plant species in tree, sapling and regeneration categories that occurred most frequently.

Table 16: Rank of three mostly observed plant according to their frequency of occurrence and category

Stratum	Plant frequency rank	Plant category		
		Tree	Sapling	Regeneration
Chiwan (Kayarkhola) dense	1	sal (*Shorea robusta*)	sal (*Shorea robusta*)	sal (*Shorea robusta*)
	2	botdhangero (*Lagerestroemia parviflora*)	sindure (*Mallotua philippinensis*)	sindure (*Mallotua philippinensis*)
	3	sindure (*Mallotua philippinensis*)	saj (*Terminalia alata*)	saj (*Terminalia alata*)
Chiwan (Kayarkhola) sparse	1	sal (*Shorea robusta*)	sal (*Shorea robusta*)	sal (*Shorea robusta*)
	2	parijat (*Nyctanthes arbor-tristis*)	sindure (*Mallotua philippinensis*)	sindure (*Mallotua philippinensis*)
	3	saj (*Terminalia alata*)	ankhle (*Chirita urticifolia*)	jamuno (*Syzygium cumini*)
Dolakha (Charnawati) dense	1	guras (*Rhododendron spp.*)	guras (*Rhododendron spp.*)	ashare (*Lagerstroemia indica*)
	2	angeri(*Lyonia ovalifolia*)	ashare (*Lagerstroemia indica*)	jhigune (*Eurya acuminata*)
	3	khasru (*Quercus spp.*)	angeri (*Lyonia ovalifolia*)	guras (*Rhodendron spp.*)
Dolakha (Charnawati) sparse	1	guras (*Rhododendron spp.*)	guras (*Rhododendron spp.*)	badkaule (*Casearia graveolens*)
	2	khote sallo (*Pinus roxburghii*)	angeri (*Lyonia ovalifolia*)	angeri (*Lyonia ovalifolia*)
	3	chilaune (*Schima wallichii*)	kalikath (*Mucana nigricans*)	khote sallo (*Pinus roxburghii*)
Gorkha (Ludikhola) dense	1	sal (*Shorea robusta*)	sal (*Shorea robusta*)	sal (*Shorea robusta*)
	2	chilaune (*Schima wallichii*)	chilaune (*Schima wallichii*)	latikath (*Cornus oblonga*)
	3	katus (*Castanopsis indica*)	katus (*Castanopsis indica*)	chilaune (*Schima wallichii*)
Gorkha (Ludikhola) sparse	1	sal (*Shorea robusta*)	sal (*Shorea robusta*)	sal (*Shorea robusta*)
	2	chilaune (*Schima wallichii*)	buddharyo (*Lagerestroemia parviflora*)	latikath (*Cornus oblonga*)
	3	bhalayo (*Rhus wallichii*)	khatire	chilaune (*Schima wallichii*)

Referring to Table 16, *Shorea robusta* appears to be the most dominant species in all strata among the all plant categories in Kayarkhola and Ludikhola. The second most common plant species are *Mallotua philippinensis* in Kayarkhola where as *Schima wallichii* in Ludikhola.

Comparatively, Charnawati watershed seems to different dominant floristic composition compared to the other two watersheds. *Schima wallichii* is the only among the top three most frequent species that exists commonly in Ludikhola and Charnawati.

4. Future prospects

- Identified outlier trees from pre-analysis (as presented in Annex 2) need special attention during next measurements. During remeasurements, the attempt should be to make sure that the outliers are the result of measurement or other human errors. Most importantly, during analysis of year two tree measurements, it should be made sure that the tree biomass change is based on the same set of trees so that there shouldn't be an accidental high growth of forests. In any case, the analysis should clearly indicate why particular trees were considered "outliers", and if they were included in the analysis or not. The presence of multiple outliers in one plot could be an indication that the stratification should be revisited as some forest strata might contain larger trees than other areas.

- Analyzed values in sparse strata have a general tendency to show higher estimates of errors. Therefore, the stratification strategy might need to be evaluated and further stratification might need to be carried out splitting sparse stratum into two or more strata.

- REDD+ is more about payment for performance, i.e. CFs will be paid based on the amount of forest carbon stock they increase over the certain period of time. The carbon stock in herbs, grass and litter pool is negligible. Possibility of enhancing stock in these pools is thus very less. It takes long time to acquire significant change in soil organic carbon. The benefit from these pools should be analyzed very minutely in the second measurement as cost, time and effort (sampling and lab analysis) involved in quantifying is rather higher than tree, and sapling. It might be practical to ignore these minor pools in measurement and monitoring that will be carried out by communities. However, some default values can be established with the help of findings of second measurement, and can be used in future.

- As measurements was confined only towards quantification of carbon pools, it might also be necessary to quantify other environmental variable, e.g. wildlife, fungi, and other flora and fauna if the ultimate goal of the project is to incorporate biodiversity perspectives.

- Use of other standard tools and equipment (e.g. GPS enabled camera and Densiometer) might need to be considered in succeeding measurements for better estimates quality assurance/ quality control (QA/QC).

- Considering frequent dead wood collection by adjacent communities, deadwood pool was completely ignored during the measurement. However, dead standing trees and stumps might need to be considered in the future.

- The pace of amending CF operational plan in Nepal currently lags behind due to burden of CF inventory tasks, and it is not feasible if forest carbon stock quantification is recommended independently. On the other hand, participation of local communities in the forest carbon measurement seems to be inexpensive for monitoring, reporting and verification (MRV). But challenge of QA/QC arises, which can be tackled by building the capacity of locals and developing guidelines in local languages. As project like these requires long term monitoring, due to enhanced awareness among local people by their participation, possibilities of unbiased maintenance of permanent plots in long term could also be ensured. Therefore, a common meeting point between existing CF inventory methods and standard forest carbon stock quantification must be sought for so that communities will be able to do both amendments to their CF operational plan and quantify forest carbon stocks in their forests with minimal external inputs and maintaining international standards.

- The identification of the leakage belt for the current measurement was only preliminary. In future, to become compatible with the international carbon market, standard procedures might need to be followed to quantify carbon stock in leakage and reference zone, particularly to assess implication of project activities.

- Further to this report, integrating information from analysis of socio-economic conditions of communities adjacent to forests, particularly the status of local-level drivers of deforestation and forest degradation and leakage, forest carbon enhancement activities need to be implemented for higher increment in the forest carbon stock and thus higher incentives to the local communities from the rapidly expanding global carbon market.

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Annexes

Annex 1: Species parameters details used to estimate sapling biomass (Tamrakar, 2000)

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 acuminata	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	sallo	-3.985	2.744	0.990
Pinus wallichiana	ghoge 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 2: Details of outlier trees.

District	Plot no.	Strata	Tree number	Species	DBH [cm]	Height [m]
Chitwan	5	sparse	10	saj	95.80	18.82
Chitwan	10	sparse	15	Harra	52.80	27.40
Chitwan	10	sparse	21	sal	58.00	33.90
Chitwan	128	dense	13	sal	70.30	45.46
Chitwan	140	dense	1	chilaune	170.30	27.61
Chitwan	140	dense	3	sal	93.60	38.57
Chitwan	140	dense	14	saj	71.50	47.61
Chitwan	190	dense	4	sal	67.30	47.80
Dolakha	2	dense	22	thingre salla	77.00	26.40
Dolakha	5	dense	19	thingre salla	99.00	38.20
Dolakha	13	dense	9	thingre salla	127.10	21.80
Dolakha	15	dense	4	gobresallo	74.50	26.90
Dolakha	15	dense	37	gobresallo	58.90	28.60
Dolakha	17	dense	1	khasru	125.50	24.30
Dolakha	29	dense	3	thingre salla	72.00	25.30
Dolakha	29	dense	32	gobresallo	64.00	26.60
Dolakha	38	dense	30	thingre salla	101.00	25.67
Dolakha	90	dense	9	thingre salla	71.50	31.80
Dolakha	96	dense	1	gobresallo	190.50	32.50
Dolakha	103	dense	8	thingre salla	118.50	31.80
Dolakha	223	sparse	29	thingre salla	84.50	17.00
Dolakha	232	sparse	6	Khote sallo	85.00	38.54
Dolakha	235	sparse	1	chilaune	26.60	27.92
Dolakha	235	sparse	4	mauwa	31.10	29.18
Dolakha	235	sparse	25	chilaune	27.70	20.14
Dolakha	235	sparse	26	chilaune	27.70	20.14
Dolakha	247	sparse	1	Khote sallo	42.00	26.22
Dolakha	247	sparse	10	Khote sallo	31.00	56.40
Dolakha	247	sparse	11	Khote sallo	40.00	32.03
Dolakha	247	sparse	14	Khote sallo	36.00	27.46
Dolakha	248	sparse	8	khasru	83.00	22.00
Gorkha	20	sparse	43	sal	49.00	25.20
Gorkha	20	sparse	58	sal	45.80	26.90
Gorkha	21	sparse	6	sal	77.00	31.81
Gorkha	31	sparse	1	sal	57.90	24.25
Gorkha	31	sparse	22	sal	41.50	17.77
Gorkha	37	sparse	3	sal	70.00	17.30
Gorkha	64	dense	23	sal	64.50	91.87
Gorkha	103	dense	10	sal	51.30	52.32
Gorkha	104	dense	10	sal	60.20	54.33
Gorkha	141	dense	6	sal	50.00	31.39
Gorkha	142	dense	2	sal	73.40	30.00
Gorkha	180	dense	23	bar	133.80	23.23

Annex 3: CF level summary of carbon stock

S.N.	District (Watershed)	CF name	Total CF area [ha]	Area in dense strata [ha]	Area in sparse strata [ha]	Total carbon stock in dense strata [tC]	Total carbon stock in sparse strata [tC]	Total carbon in CF	Weigtage average per hectare carbon [tC ha^{-1}]
1	Chitwan (Kayarkhola)	Nibuwatar	329.18	315.21	13.97	93440.51	3586.04	97026.55	294.75
2	Chitwan (Kayarkhola)	Chitramkaminchuli	314.02	233.05	80.96	69085.09	20782.11	89867.20	286.19
3	Chitwan (Kayarkhola)	Deujar	278.87	184.06	94.82	54562.55	24339.92	78902.47	282.93
4	Chitwan (Kayarkhola)	Devidhunga	253.86	211.64	42.22	62738.33	10837.71	73576.04	289.83
5	Chitwan (Kayarkhola)	Kalika	213.77	206.15	7.57	61110.88	1943.19	63054.07	295.03
6	Chitwan (Kayarkhola)	Indreni	172.17	155.57	16.61	46117.00	4263.72	50380.72	292.60
7	Chitwan (Kayarkhola)	Batauli	155.77	91.29	64.49	27061.91	16554.33	43616.24	279.99
8	Chitwan (Kayarkhola)	Dharapani	147.16	142.19	4.96	42150.65	1273.21	43423.86	295.10
9	Chitwan (Kayarkhola)	Janapragati	118.84	97.18	21.66	28807.93	5560.04	34367.97	289.20
10	Chitwan (Kayarkhola)	Pragati	115.48	70.78	44.70	20981.95	11474.31	32456.26	281.06
11	Chitwan (Kayarkhola)	Kankali	91.60	78.48	13.12	23264.53	3367.85	26632.38	290.75
12	Chitwan (Kayarkhola)	Samfrang	63.90	26.84	37.06	7956.42	9513.16	17469.58	273.39
13	Chitwan (Kayarkhola)	Satkanya	58.28	55.95	2.33	16585.76	598.10	17183.86	294.85
14	Chitwan (Kayarkhola)	Jharana	34.53	23.47	11.07	6957.42	2841.63	9799.05	283.70
15	Chitwan (Kayarkhola)	Jamuna	34.53	10.86	23.67	3219.33	6076.00	9295.32	269.20
16	Dolakha (Charnawati)	Charnawati	819.35	733.67	85.67	167689.59	14285.37	181974.96	222.10
17	Dolakha (Charnawati)	Bhitteri	542.64	377.67	164.97	86321.27	27508.55	113829.82	209.77
18	Dolakha (Charnawati)	Setidevi Dadar	421.71	192.63	229.08	44028.03	38198.82	82226.85	194.98
19	Dolakha (Charnawati)	Dhande	343.69	229.51	114.18	52457.42	19039.38	71496.80	208.03
20	Dolakha (Charnawati)	Shankadevi	305.26	247.40	57.86	56546.41	9648.09	66194.49	216.85
21	Dolakha (Charnawati)	Srijana	264.20	209.90	54.29	47975.31	9052.79	57028.10	215.86
22	Dolakha (Charnawati)	Tharlange	203.97	183.92	20.05	42037.25	3343.31	45380.56	222.49
23	Dolakha (Charnawati)	Eklepakha	197.33	157.83	39.58	36074.05	6599.92	42673.97	216.17
24	Dolakha (Charnawati)	Golmeshor	215.18	100.95	114.23	23073.40	19047.72	42121.12	195.75
25	Dolakha (Charnawati)	Majhkharka Lisepani	174.18	145.73	28.44	33308.44	4742.34	38050.78	218.47

S.N.	District (Watershed)	CF name	Total CF area [ha]	Area in dense strata [ha]	Area in sparse strata [ha]	Total carbon stock in dense strata [tC]	Total carbon stock in sparse strata [tC]	Total carbon in CF	Weigtage average per hectare carbon [tC ha^{-1}]
26	Dolakha (Charnawati)	Botlesetidevi	172.10	113.69	58.42	25985.29	9741.47	35726.76	207.58
27	Dolakha (Charnawati)	Napkeyanmara	152.46	82.56	69.90	18870.14	11655.74	30525.88	200.22
28	Dolakha (Charnawati)	Gairi jungle	131.08	125.98	5.11	28794.33	852.09	29646.41	226.15
29	Dolakha (Charnawati)	Jugedarkha	125.60	101.50	24.10	23199.11	4018.65	27217.76	216.70
30	Dolakha (Charnawati)	Sitakunda	141.31	15.72	125.59	3593.01	20941.98	24534.99	173.63
31	Dolakha (Charnawati)	Thansa deurali	124.37	59.08	65.29	13503.48	10887.03	24390.51	196.11
32	Dolakha (Charnawati)	Bhakare	104.43	76.26	28.17	17430.19	4697.31	22127.50	211.89
33	Dolakha (Charnawati)	Kopila	96.07	88.24	7.83	20168.37	1305.64	21474.01	223.52
34	Dolakha (Charnawati)	Salleri	92.27	26.69	65.58	6100.34	10935.39	17035.73	184.63
35	Dolakha (Charnawati)	Jyamire	70.01	58.38	11.64	13343.49	1940.96	15284.45	218.29
36	Dolakha (Charnawati)	Kamalamai	71.81	15.31	56.50	3499.29	9421.31	12920.60	179.93
37	Dolakha (Charnawati)	Chyanedada	64.86	33.07	31.79	7558.57	5300.94	12859.51	198.27
38	Dolakha (Charnawati)	Timure tinsalle	67.10	23.49	43.62	5368.94	7273.58	12642.52	188.39
39	Dolakha (Charnawati)	Pauwa	58.64	41.92	16.72	9581.35	2788.04	12369.39	210.94
40	Dolakha (Charnawati)	Charnawati 1	55.12	43.12	11.99	9855.62	1999.32	11854.94	215.11
41	Dolakha (Charnawati)	Mahabhir	50.26	48.00	2.26	10971.01	376.85	11347.86	225.78
42	Dolakha (Charnawati)	Lodini	50.67	46.64	4.03	10660.16	672.00	11332.16	223.65
43	Dolakha (Charnawati)	Simpani	64.40	8.05	56.35	1839.93	9396.30	11236.23	174.48
44	Dolakha (Charnawati)	Bhumethan Shivajung	46.67	16.71	29.97	3819.28	4997.46	8816.74	188.88
45	Dolakha (Charnawati)	Chhitakunda	51.51	0.00	51.51	0.00	8589.23	8589.23	166.75
46	Dolakha (Charnawati)	Dimal	38.20	34.66	3.54	7921.98	590.29	8512.27	222.83
47	Dolakha (Charnawati)	Bichaur	47.71	7.29	40.42	1666.22	6739.99	8406.21	176.19
48	Dolakha (Charnawati)	Devithan	43.94	14.36	29.58	3282.16	4932.43	8214.59	186.95
49	Dolakha (Charnawati)	Mahankal Sahele	39.38	26.69	12.69	6100.34	2116.04	8216.38	208.64
50	Dolakha (Charnawati)	Thumkadada	40.78	20.56	20.22	4699.25	3371.66	8070.91	197.91
51	Dolakha	Budabhimsen	41.97	9.12	32.85	2084.49	5477.70	7562.19	180.18

S.N.	District (Watershed)	CF name	Total CF area [ha]	Area in dense strata [ha]	Area in sparse strata [ha]	Total carbon stock in dense strata [tC]	Total carbon stock in sparse strata [tC]	Total carbon in CF	Weigtage average per hectare carbon [tC ha^{-1}]
	(Charnawati)								
52	Dolakha (Charnawati)	Kuprisalleri	42.03	1.61	40.42	367.99	6739.99	7107.97	169.12
53	Dolakha (Charnawati)	Sanobothle	35.06	18.27	16.79	4175.84	2799.71	6975.55	198.96
54	Dolakha (Charnawati)	Barkhe dadapari	35.40	11.61	23.78	2653.61	3965.29	6618.90	187.03
55	Dolakha (Charnawati)	Laliguras	35.53	10.33	25.20	2361.05	4202.07	6563.12	184.72
56	Dolakha (Charnawati)	Chyanse Bhagawati	30.32	23.82	6.50	5444.36	1083.87	6528.23	215.31
57	Dolakha (Charnawati)	Mathani	28.28	22.52	5.77	5147.23	962.14	6109.37	215.96
58	Dolakha (Charnawati)	Simsugure	33.35	3.87	29.47	884.54	4914.09	5798.63	173.92
59	Dolakha (Charnawati)	Pokhari	23.60	18.00	5.60	4114.13	933.79	5047.92	213.89
60	Dolakha (Charnawati)	Gothpani	23.50	17.40	6.09	3976.99	1015.50	4992.49	212.54
61	Dolakha (Charnawati)	Maithan harisiddi	28.35	3.51	24.85	802.26	4143.71	4945.96	174.40
62	Dolakha (Charnawati)	Dhade Singhadevi	29.17	0.17	29.01	38.86	4837.38	4876.24	167.11
63	Dolakha (Charnawati)	Kalchhe	21.49	16.34	5.14	3734.71	857.09	4591.80	213.77
64	Dolakha (Charnawati)	Thutemane	23.60	8.63	14.97	1972.50	2496.23	4468.73	189.35
65	Dolakha (Charnawati)	Ramite	13.60	13.17	0.43	3010.17	71.70	3081.87	226.61
66	Dolakha (Charnawati)	Sundarimai	12.98	4.51	8.47	1030.82	1412.36	2443.18	188.23
67	Dolakha (Charnawati)	Bhasmepakha	10.93	6.16	4.77	1407.95	795.39	2203.34	201.59
68	Dolakha (Charnawati)	Palung Mahila	10.28	0.32	9.96	73.14	1660.82	1733.96	168.67
69	Dolakha (Charnawati)	Chuchhedhunga	8.90	0.00	8.90	0.00	1484.06	1484.06	166.75
70	Dolakha (Charnawati)	Amalekharka CF	6.60	1.51	5.09	345.13	848.75	1193.88	180.89
71	Dolakha (Charnawati)	Bhirmuni Devithan	5.98	0.00	5.98	0.00	997.16	997.16	166.75
72	Dolakha (Charnawati)	Gahate baghkhor	5.54	0.19	5.35	43.43	892.11	935.53	168.87
73	Dolakha (Charnawati)	Palekoban	1.49	1.03	0.45	235.42	75.04	310.46	209.77
74	Gorkha (Ludikhola)	Ludi Damgade	270.71	221.44	49.28	47887.82	8031.61	55919.44	206.56
75	Gorkha (Ludikhola)	Ghaledanda Ranakhola	181.66	146.56	35.09	31694.54	5718.94	37413.48	205.96
76	Gorkha (Ludikhola)	Gangate Bahunechaur	173.62	156.79	16.83	33906.84	2742.94	36649.78	211.09

S.N.	District (Watershed)	CF name	Total CF area [ha]	Area in dense strata [ha]	Area in sparse strata [ha]	Total carbon stock in dense strata [tC]	Total carbon stock in sparse strata [tC]	Total carbon in CF	Weigtage average per hectare carbon [tC ha^{-1}]
77	Gorkha (Ludikhola)	Bhalukhola	107.59	106.48	1.10	23026.98	179.28	23206.26	215.71
78	Gorkha (Ludikhola)	Kuwadi	92.27	83.75	8.52	18111.48	1388.58	19500.06	211.34
79	Gorkha (Ludikhola)	Taksartari	89.31	83.08	6.23	17966.58	1015.36	18981.94	212.54
80	Gorkha (Ludikhola)	Birienchok	83.57	69.88	13.69	15112.00	2231.19	17343.18	207.53
81	Gorkha (Ludikhola)	Thokane Bhanjyang	76.18	73.54	2.65	15903.50	431.89	16335.39	214.40
82	Gorkha (Ludikhola)	Baghepani	68.16	67.55	0.60	14608.12	97.79	14705.91	215.79
83	Gorkha (Ludikhola)	Lamidanda	61.59	58.98	2.61	12754.80	425.38	13180.18	214.00
84	Gorkha (Ludikhola)	Siraute	60.34	56.20	4.14	12153.61	674.73	12828.34	212.60
85	Gorkha (Ludikhola)	Kyamundanda	58.72	56.60	2.12	12240.11	345.52	12585.63	214.33
86	Gorkha (Ludikhola)	Mahalaxmi	63.96	38.05	25.92	8228.56	4224.42	12452.98	194.67
87	Gorkha (Ludikhola)	Shikhar Bhanjyang	55.49	55.40	0.10	11980.61	16.30	11996.90	216.16
88	Gorkha (Ludikhola)	Sandan Bisauni	50.62	48.65	1.98	10520.88	322.70	10843.57	214.17
89	Gorkha (Ludikhola)	Kharko Pakho Bekhpari	51.15	44.35	6.80	9590.97	1108.26	10699.23	209.17
90	Gorkha (Ludikhola)	Chisapani	50.04	45.15	4.88	9763.98	795.34	10559.32	211.06
91	Gorkha (Ludikhola)	Shikhar	50.84	42.47	8.38	9184.41	1365.77	10550.18	207.48
92	Gorkha (Ludikhola)	Kharkandepakha	47.82	45.82	2.00	9908.87	325.96	10234.83	214.03
93	Gorkha (Ludikhola)	Goldanda	45.99	45.63	0.36	9867.78	58.67	9926.45	215.84
94	Gorkha (Ludikhola)	Shikhar Danda	30.36	16.28	14.09	3520.65	2296.38	5817.03	191.54
95	Gorkha (Ludikhola)	Badahare	25.78	10.69	15.09	2311.78	2459.36	4771.14	185.07
96	Gorkha (Ludikhola)	Punche	18.13	15.44	2.69	3339.00	438.41	3777.41	208.35
97	Gorkha (Ludikhola)	Ludi	17.44	5.75	11.69	1243.47	1905.23	3148.70	180.54
98	Gorkha (Ludikhola)	Ram Laxman	13.25	12.78	0.47	2763.76	76.60	2840.36	214.37
99	Gorkha (Ludikhola)	Laxmi Mahila	8.72	8.09	0.63	1749.51	102.68	1852.19	212.41
100	Gorkha (Ludikhola)	Patal Chanpe Mahila	8.16	7.44	0.72	1608.95	117.35	1726.29	211.56
101	Gorkha (Ludikhola)	Anapswanra Bhawanipakha	9.14	4.21	4.93	910.44	803.49	1713.93	187.52
102	Gorkha (Ludikhola)	Sitalu Pakha	5.69	4.12	1.57	890.98	255.88	1146.85	201.56
103	Gorkha (Ludikhola)	Bhangeristan Ghantari	5.24	3.15	2.09	681.21	340.63	1021.83	195.01
104	Gorkha (Ludikhola)	MajhiKhola Simredanda	6.00	0.33	5.67	71.36	924.09	995.46	165.91