International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 3, Issue 01, January 2016
Available at http://internationaljournalofresearch.org

The Global Terrestrial Carbon Stocks, Status of Carbon in Forest and Shrub Land of Nepal, and Relationship between Carbon Stock and Diversity

Gokul Gaudel[1]; Zhang Wen Hui[1*]; Dang Quang Hung[2] & Le Thi Hien[3]

[1]College of Forestry, Northwest A&F University, Yangling 712100, Shaanxi, China. Email: gokul6gaudel@gmail.com Cell No.: +8613201750996

1*. College of Forestry, Northwest A&F University, Yangling 712100, Shaanxi, China. (Corresponding Author, Professor at Northwest A&F University, Yangling, 712100, Shaanxi, China.)

[2]College of Forestry, Northwest A&F University, Yangling 712100, Shaanxi, China.

[3]College of Forestry, Northwest A&F University, Yangling 712100, Shaanxi, China. Email: 2025140709@qq.com

Abstract

Forest management strategy may affect the global carbon stock, biodiversity and global carbon cycle. It is necessary to understand how different management practices can aid in greenhouse gas reduction efforts instead of monetary benefits. Developing countries are required to produce robust estimates of forest carbon stocks for successful implementation of climate change mitigation policies related to Reducing Emissions from Deforestation and Degradation (REDD). Thus, community forest of Nepal has greater potentiality to gain monetary benefits through carbon credits from REDD + mechanism. The study found some evidence to select the best management practices for community forestry and helps to participate in the reducing emission from deforestation and degradation and enhancement of carbon stock (REDD+) mechanism. The study focused on description of the global terrestrial carbon stocks, status of carbon in forest and shrub land of Nepal and relationship between carbon stock and biodiversity. Position of Nepal in global carbon stock is comparatively better than many others nation in the world. As Nepal is rich in biodiversity and there is positive linkage between biodiversity and carbon stock, Nepal can be benefitted through carbon market.

Key Words: Carbon stock; Biodiversity; Community forestry; REED+

1. Introduction

Forests play an important role in global carbon cycle and function as both sources and sinks of carbon dioxide (CO_2) depending on the specific management regime and activities (IPCC, 2000). Forest management has been usually focused on increasing the forest productivity and growing stock for supply of forest products along with producing other services such as carbon stock and biodiversity because deforestation, forest degradation, carbon sequestration climate change, and biodiversity are closely interlinked with each other (Thompson, Ferria, Gardner, Guariaguata, Koh, Okabe, Pan, Schmitt, Tylianakis, Barlow, Kapos, Kurz, Parrotta, Spalding, & Vliet, 2012). The ability of forest ecosystem to provide both tangible and intangible services relies on conditions, stocking, site quality and practices of forest management. As forests act as the greatest means of terrestrial carbon sink, deforestation and forest degradation cause emission of carbon from forest and consequently effect on environment and biodiversity in the tropics (FAO, 2010). Deforestation in forest singly contributes about emission of 5.9 Giga tons (Gt) CO_2 annually in the world (IPPC, 2007) and halting of it can reduce about 17.4% atmospheric CO_2 emissions (IPPC, 2009). It is estimated that if current rate of deforestation and clearing tropical forests continues, it could release an additional 87 to 130 Giga tons carbon (G t C) of CO_2 to the atmosphere by 2100 (Ross and Sheikh, 2010) which consequently influences climate change and reduction of biodiversity. Worldwide, about 8000 tree species (about 9% of the total number of tree species) are under the threat of extinction because of deforestation and impacts of climate change (Singh, Sah, Tyagi, & Jina, 2005). In Nepal, net emissions of CO_2 were estimated to be 9747 G t for the base year 1994/95 among them net emissions of CO_2 from the Land-use change and Forestry sectors were about 8117 Gt in the base year 1994/95 (MOPE, 2004).In year 2008 the carbon emission of Nepal was reported 3542.32 Kilotons. According to the definition of The World Bank Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring (http://www.tradingeconomics.com). Carbon dioxide emissions of Nepal in 2010 and 2011 were reported 4331 and 4334 Kiloton respectively (http://data.worldbank.org). Carbon stocks and sequestration are closely interlinked with biodiversity as different plant species have different capacity of sequestering and storing carbon from the atmosphere. In general, large and slow growing trees with high wood densities tend to store more carbon in the long term. Changes in biodiversity may also directly and indirectly affect the likelihood of tree survival and carbon stock of forest. Generally carbon stock is positively correlated with biodiversity in natural forest but the degree of relationships exists between carbon dynamics and biodiversity in tropical forests is uncertain due to forest types, site quality, succession and forest management practices (Talbot, 2010). However, within similar type and condition of forests they are mostly influenced by management model and practices. Gelman, Hulkkonen, Kantola, Nousiainen, Nousiainen, and Poku-Marboah (2013) found that carbon sequestration in terrestrial forest ecosystem can be increased by application of certain proper management practices such as prolonged rotations, increased thinning, continuous forest cover, supporting litter production and natural ecological conditions, keeping the right water level and cleaning the high emission ditches in peat lands. Kapos, Kurz, Gardner, Ferreira, Guariguata, Koh, Mansourian, Parrotta, Sasaki, Schmitt, Barlow, Kanninen, Okabe, Pan, Thompson, and Vliet (2012) also highlighted that management activities such as restoration, reforestation and protection from degradation, fire, grazing and overharvesting of timber and non-timber resources enhances both carbon stocks and biodiversity but with varying impacts on biodiversity whereas conversion of natural forest and plantation forest reduces the biodiversity. It has been found that enhancing carbon sequestration is a low-cost option to mitigate from burning issues of climate change. At the same moment, carbon sequestration is also appropriate from environmental and a socioeconomic point of view because removal of CO_2 from the atmosphere helps in amelioration of the climate, the improvement of soil quality, and the increase in biodiversity (Batjes and Sombroek, 1997). It can also provide socioeconomic benefits through increased yields and monetary incomes from potential carbon trading schemes (McDowell, 2002). Carbon sequestration projects enhance local participation in sustainable forest management practices (Tschakert, 2001). Thus, reduction of carbon emission from deforestation and forest degradation through carbon credit (REDD) mechanism is gaining popularity. The Copenhagen Accord (COP15 of December, 2009) shifted the crucial role of reducing emission from deforestation and degradation(REDD) into REDD+ highlighting the need to enhance removal of greenhouse gas emission by proper management of forest, and commits to provide funding for such actions in developing countries (UNFCCC, 2009). Proper management practices of forest through REDD+ mechanism can help not only in reducing carbon emission but also in

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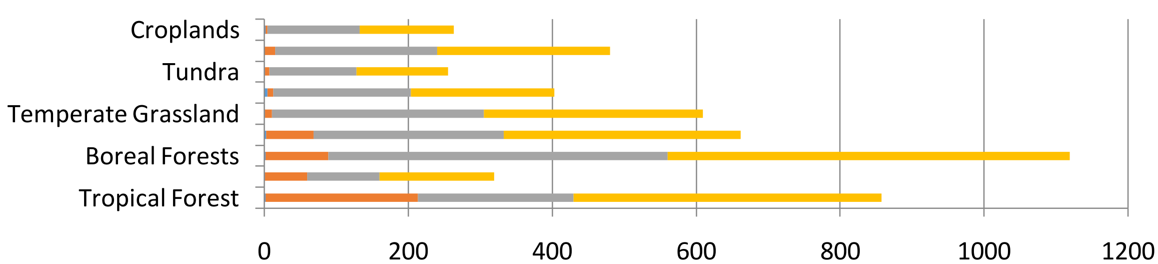
conserving biodiversity. Dynamics of REDD+ mechanism have major focus on monitoring, reporting and verification (MRV) as well as reference emission level (REL) which need sufficient records of carbon stock. Besides, there is another significant growing concern about the relationship between carbon stock and biodiversity since it can help in biodiversity promotion through REDD+ mechanism

2. Global Terrestrial Carbon Stocks

Globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above-ground, and 40% of terrestrial below-ground biomass carbon storage (Kirschbaum, 1996). The Soil Organic Carbon (SOC) pool represents a dynamic equilibrium of gains and losses. Of the five principal global carbon pools, the ocean pool is the largest with 38.4 trillion metric ton (mt) on the surface layer, followed by the fossil fuels (4.13 trillion mt), soils (2.5trillion mt to a depth of one meter), biotic (620 billion mt) and atmospheric pools (800 billion mt). If the fluxes among terrestrial reserves are combined, annual total carbon flows across the reserves result to an average around of 60 billion mt, whereas in managed ecosystems (croplands, grazing lands, and plantations) account about 57 percent of the total (Lal 2009). It is estimated that around 1200 to 1800 gigaton (Gt) of carbon are stored in soils worldwide and it represents twice of the amount that is stored in all terrestrial plants on the Earth's surface in the form of organic carbon, which is a major source of green house gases (GHGs), particularly in the form of CO_2, and CH_4 (Lal 2004). The soil pool is 3.3 times the size of the atmospheric pool (760 Gt) and 4.5 times the size of the biotic pool (560 Gt) (Lal, 2005).Though there is wide variation in soil carbon estimates, the available data clearly indicates that the total amount of carbon stored in soil is many times higher than the total carbon reserve in the atmosphere. The global carbon stocks in vegetation and soil up to depth of 1 m is shown in Table 1 with figure.

Table1: <u>Global Carbon Stocks in Vegetation and Soil Carbon Pools Down to a Depth of 1 Meter</u>



	Tropical Forest	Temperate Froests	Boreal Forests	Tropical Savannas	Temperate Grassland	Deserts & Semi-Deserts	Tundra	Wetlands	Croplands
Area (109 ha)	1.76	1.04	1.37	2.25	1.25	4.55	0.95	0.35	1.6
Golbal Carbon Stock (G t C) Vegetation	212	59	88	66	9	8	6	15	3
Global Carbon Stock (G t C) Soil	216	100	471	264	295	191	121	225	128
Global Carbon Stock (G t C) Total	428	159	559	330	304	199	127	240	131

Source: Intergovernmental Panel on Climate Change (IPCC, 2000).

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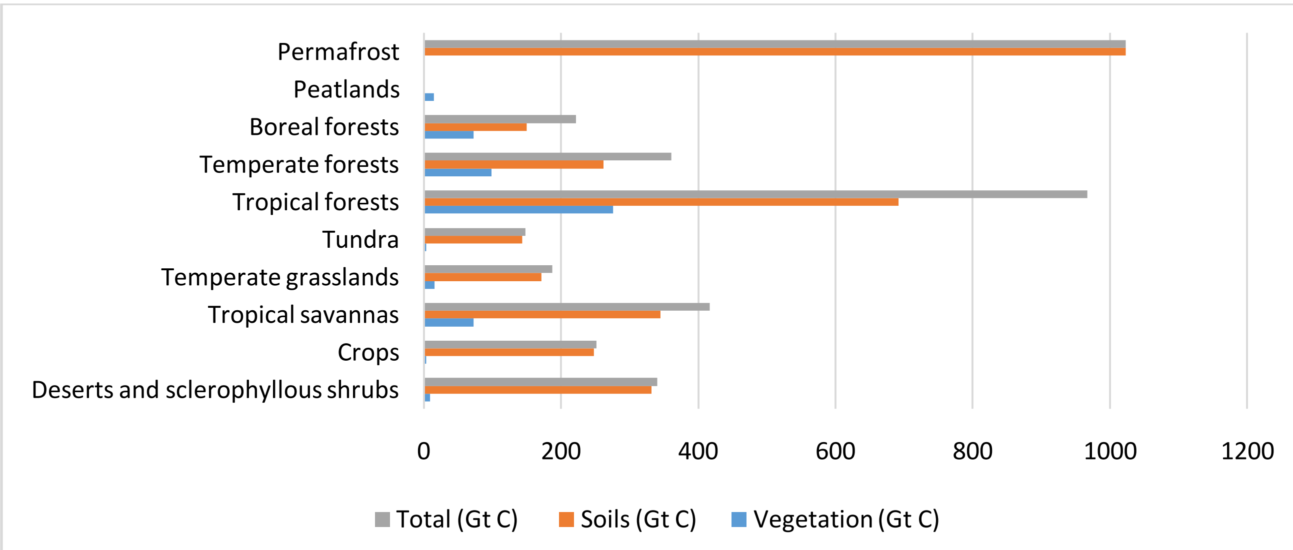
The above estimates consider only the first 1 m of soils and are thought to underestimate soil carbon content in some biomes.

Eglin, Ciais, Piao, Barre, Belassen, Cadule, Chenu, Gasser, Reichstein, and Smith (2011) recalculated carbon storage values which includes soil carbon stock estimates down to a depth of 3 m is shown in Figure -1. In comparison to IPCC (2000) in Table 1 with figure Eglin et. al. (2011) research shows significantly higher estimates in nearly all biomes, including an approximately threefold increase in soil organic carbon stocks estimates for tropical forests.

Figure 1: <u>Global Carbon Stocks in Vegetation and Soil Carbon Pools Down to a Depth of 3 Meter</u>



Source: Overview on Response of Global Soil Carbon Pools to Climate and Land-Use Changes (Eglin et al., 2011).

Eglin et al. (2011) provided mean values for soil carbon and ranges for vegetation carbon and then they were averaged to generate the estimates which are shown here (Fig. 1) for vegetation and total carbon respectively.

Trumper, Bertzky, Dickson, Vander, Jenkins, and Manning (2009) have improved and updated the result of spatial resolution of soil carbon stocks which is shown in Table-2. United Nation Environment Program and World Conservation Monitoring Center (UNEP-WCMC) have produced a spatially explicit, top-down assessment of global carbon stocks (Trumper et al. 2009) that integrates remotely-sensed land cover classifications (GLC, 2000) with IPCC Tier I default values for ecosystem carbon stocks, combined with a spatially-explicit soil database for better account for soil carbon stocks. Even though carbon density estimates based on this product are not yet available.

Table 2: Summary of Global Carbon Stocks

	Total (Gt C)
Tropical, Sub-tropical Forests	547.8
Tropical and Sub-tropical Grasslands, Savannahs and Shrub Lands	285.3
Deserts and Dry Shrub Lands	178
Temperate Grasslands, Savannas and Shrub Lands	183.7

Temperate forest	314.9
Boreal Forest	384.2
Tundra	155.4
Rocks and Ice	1.47
Lakes	0.98

Source: UNEP-WCMC (Trumper et al., 2009).

Studies outlined in the GRID-Arendal/UNEP (2013) indicate that the largest amounts of carbon are stored in the tropics and in high latitude ecosystems compared to other ecosystems. The carbon stock also varies within the same ecosystem from place to place due to variation in site quality, stocking and composition of forest, human activities and land use management practices. Study conducted by Saatchi, Harris, Brown, Lefsky, Mitchard, Salas, Zutta, Buermann, Lewis, Hagen, Petrova, White, Silman, and Morel (2011) in tropical region across three continents such as Africa, Latin America and South East Asia reported a wide variation in both above ground biomass carbon density and total biomass carbon density across the continents as shown in Table -3.

Table 3: Carbon Stocks in Tropical Regions across Three Continents

Region	Forest Area (Million ha.)	AGB Carbon Density (tons ha^{-1})	Total Biomass Carbon Density (tons C ha^{-1})
		Mean ± SD	Mean ± SD
Africa			
Tropical Rain Forest	252.9	107 ± 51	135 ± 64
Tropical Moist Deciduous Forest	110.6	38 ±18	53 ± 32
Tropical Shrub Land	1.6	41 ± 25	49 ± 23
Tropical Dry Forest	36.1	38 ± 18	82 ± 49
Tropical Mountain System	22.7	64 ± 39	49 ± 19
Sub-tropical Humid Forest	1.5	38 ± 15	41 ± 21
Sub-tropical Dry Forest	0.7	31 ± 16	45 ± 14
Sub-tropical Mountain System	1.1	34 ± 11	45 ± 14
Africa Total	**427.2**	**80 ± 78**	**102 ± 98**
Latin America			
Tropical Rain Forest	587.1	115 ± 34	146 ± 42
Tropical Moist Deciduous Forest	179.3	54 ± 42	69 ±53
Tropical Shrub Land	0.9	55 ± 41	71 ± 51
Tropical Dry Forest	47.6	27 ± 23	36 ± 29
Tropical Mountain System	71.8	86 ± 50	110 ± 62
Sub-tropical Humid Forest	20.4	51 ± 38	66 ± 48
Sub-tropical Dry Forest	5.3	55 ± 51	71 ± 64
Sub-tropical Mountain System	7.2	21 ± 23	27 ± 29
Latin America Total	**919.8**	**94 ± 110**	**119 ± 138**
South East Asia			
Tropical Rain Forest	261.6	121 ± 50	153 ± 62
Tropical Moist Deciduous Forest	55.6	105 ± 49	133 ± 61
Tropical Shrub Land	2.5	64 ± 39	82 ± 49

International Journal of Research
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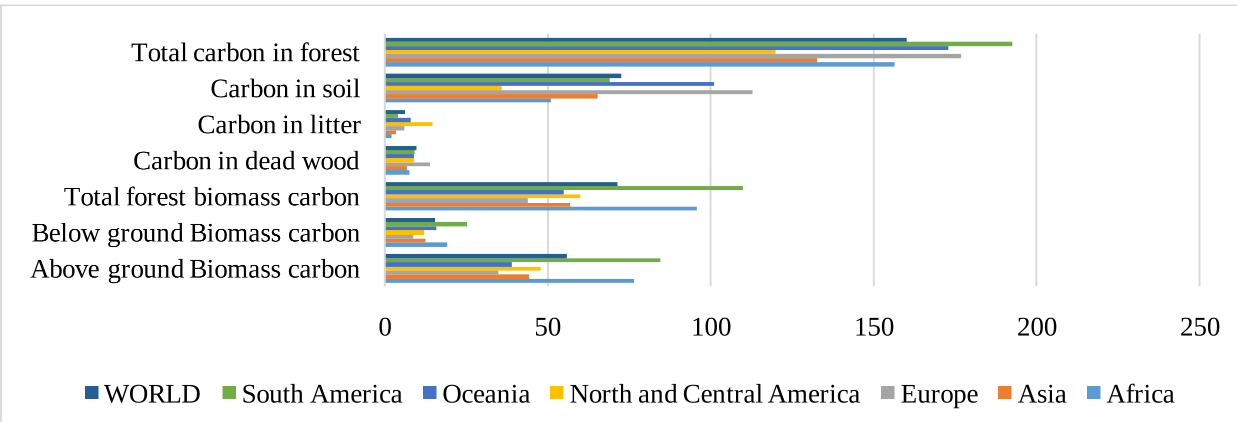
Tropical Dry Forest	17.6	83 ± 50	106 ± 63
Tropical Mountain System	53.6	128 ± 34	162 ± 42
Sub-tropical Humid Forest	0.8	88 ± 34	112 ± 42
Sub-tropical Mountain System	7.7	101 ± 41	128 ± 52
South East Asia Total	**399.5**	**118 ± 114**	**149 ± 142**
All Total	**1,746.5**	**94 ± 110**	**122 ± 221**

Source: Benchmark Map of Forest Carbon Stocks in Tropical Regions across Three Continents (Source: Saatchi et al., 2011)

Another study by FRA (2005) on region basis calculated the carbon content in different pools and found that most of the carbon content (about 45%) is found in soil. The comparison of all the carbon pools of forest in Africa, Asia, Europe, America and world on region basis is shown in Figure-2.

Figure 2: Carbon Stock per Hectare in Year 2005 on Region Basis

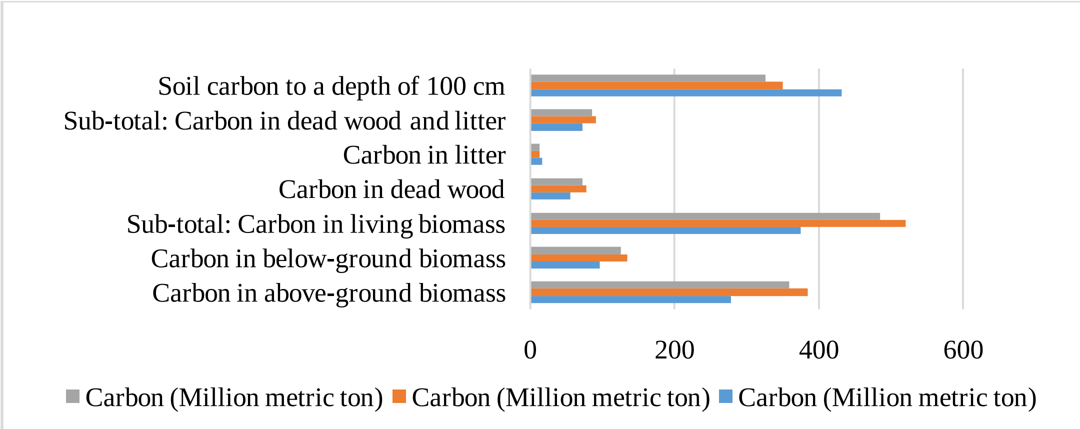


(Source: Forest Resources Association, 2005)

3. Status of Carbon in Forest and Shrub Land and of Nepal

Rendering to Forest Resources Association (2005), total forest carbon storage in South Asia is about 33,301 Mt (Million tons), beyond which, around 10004 Mt forest carbon is stored in India, 291 Mt is in Pakistan, 35 Mt is in Bangladesh, 676 Mt is in Bhutan and 897 Mt is in Nepal. Besides that, around 226 Mt of carbon is stored in other wooded land in Nepal. Food and Agriculture Organization's (FAO, 2006) estimation of organic carbon distribution in above-ground and below-ground biomass, deadwood and litter and soil up to 1 m depth in Nepal's forest and shrub land is about 1123 million ton. The study showed that the SOC pool holds 496 million metric tons in forest and shrub land. The carbon stock per hectare on year basis in Nepal is shown in Figure-3 and on legal basis is shown in Table-4.

Figure 3: Carbon Stock per Hectare on Year Basis in Nepal.



(Source: FAO, 2006)

Table 4: Carbon Stock per Hectare on Different Management Regimes in Nepal.

National Forest							
Category of Forest	**Area (million Ha)**	**AGB (tons)**	**BGB (tons)**	**Dead wood biomass (tons)**	**Total biomass in million (tons)**	**Carbon in million (tons)**	**Per ha Carbon (tons)**
Government Managed	3.9	767.82	268.74	155.486	1192.06	596.0296	152.8
Community	1.2	236.36	82.689	47.841	366.7874	183.3937	152.8
Leasehold	0.014	2.756	0.9647	0.558	4.27919	2.139593	152.8
Religious	0.00054	0.107	0.0374	0.0216	0.165971	0.082986	153.7
Protected	0.71	139.84	48.924	28.306	217.0159	108.508	152.8
Total National Forest	5.824	11474	401.36	232.21	1780.31	890.15	153
Private Forest	0.002	0.012	0.004	0.00232	0.0178	0.00892	3.88
Grand Total	5.826	1147	401.36	232.216	1780.33	890.162	

(Source: FAO 2006)

A large number of studies regarding the carbon estimation were found in Nepal but these were mostly done in low land and mid hills (Jati, 2012).Very few research works were found regarding the slope gradient studies in available literatures. Some of the studies in Nepal are explained below.

Shrestha (2009) carried out the study to quantify total carbon sequestration in two broadleaved forests (*Shorea* and *Schima-Castanopsis* forests) of Palpa district. Total biomass carbon in *Shorea* and *Schima-Castanopsis* forest was found 101.66 and 44.43 t/ha respectively. Soil carbon sequestration in *Schima-Castanopsis* and *Shorea* forest was found 130.76 and 126.07 t/ha respectively. Total carbon sequestration in *Shorea* forest was found 1.29 times higher than *Schima-Castanopsis* forest. The study found that forest types play an important role on total carbon sequestration.

Baral, Malla, and Ranabhat (2009) assessed the aboveground carbon stock in the five major forest types, representing two physiographic regions and four districts of Nepal. Results indicated variation in age of the stand (18-75 years), aboveground carbon stock per hectare (34.30-97.86 dry wt. t/ha) and rate of carbon sequestration (1.30-3.21 tons/ha/yr), according to different forest types. The rate of carbon sequestration by different forest types dependent on the growing nature of the forest stands. Tropical riverine and *Alnus nepalensis* forest types demonstrated the highest carbon sequestration rates in Nepal.

ANSAB, ICIMOD and FECOFUN (2012) jointly studied at 105 Community Forestry (CF) of three different watersheds having an area of 10,266 ha of Chitwan (Khayarkhola Watershed), Dolakha (Charnawati Watershed) and Gorkha (Ludhikhola Watershed) district. In 2010 it was found that the carbon stock in dense and sparse forest of Khayarkhola Watershed to be 296.44 and 256.70 t/ha where as it was 228.56 and 166.76 t/ha for Charnawati Watershed of Dolakha and in Ludhikhola Watershed it was 216.26 t/ha and 162.98 t/ha for dense and sparse forest respectively. In 2011 it was found that the carbon stock in dense and sparse forest of Khayarkhola Watershed to be 298 and 257 t/ha where as it was 231 and 168 t/ha for Charnawati Watershed of Dolakha and in Ludhikhola Watershed it was 221 t/ha and 166 t/ha for dense and sparse forest respectively. Likewise, in 2012 it was found that the carbon stock in dense and sparse forest of Khayarkhola Watershed to be 300 and 258 t/ha where as it was 233 and 171 t/ha for Charnawati Watershed of Dolakha and in Ludhikhola Watershed it was 224 t/ha and 170 t/ha for dense and sparse forest respectively. From the above information it can be concluded that the carbon stock content of study area is increasing every year.

Aryal (2010) tried to estimate the status of carbon stock at ToudolChhap Community Forest at Sipadol, Bhaktapur. The study was focused in two forest types, Pine forest and mixed broad leaf forest. The carbon content of pine forest i.e. 113.29 t/ha was found to be higher than that of mixed broad leaf forest i.e. 31.4 t/ha. But, SOC was found higher in mixed broad Leaf forest (70.51 t/ha) than in the pine forest (53.75 t/ha). Also, in both forest type, SOC decreases with increasing depth. Therefore, total carbon stock of pine forest and mixed broad leaf forest was found to be 167.04 t/ha and 101.91 t/ha respectively. In addition, CO2 equivalent was estimated to be 612.48 and 373.67 t CO2/ha for pine forest and mixed broad leaf forest. It was found that both forest types have high potential to store carbon in biomass and soil with efficient management.

Bhusal (2010) estimated total carbon content in 14 hector sampled area of the Nagmati Watershed (Shivapuri National Park) soil and was found to be 9782.11±25.18 t/ha corresponding to a total of 167442.26±42076.82 tonnes of carbon content in the Nagmati Watershed (1406 ha). According to the estimation, the total carbon content of Shivapuri National Park (5860.8 ha i.e. 40% of total area of park which is forest) excluding soil is 699961.20±175894.32 tonnes.

Chhetri (2010) studied the carbon stock status of Syalmati Watershed of Shivapuri NationalPark andcalculated that the Syalmati watershed had storage of 226.8±23.8 t/ha above ground biomass, 27.9±5.8 t/ha below ground biomass and 0.28 ±0.06 t/ha litter biomass. Therefore, total biomass in the forest of Syalmati was estimated to be 254.8±52.69 t/ha. It was concluded that the more the forest matures, less carbon is sequestered.

Jati (2012) carried out the comparative study of the carbon assessment in Kumvakarna Conservation Community Forest (KCAP), Taplejung. He carried out the comparative study in Preserved Forest (PF) and Managed Forest (MF) and found out the tree biomass carbon to be 109.10 t/ha and 177.44 t/ha respectively. It was concluded that PF was less efficient for carbon storage since it stored 93.88 t/ha less carbon than

MF though the disturbances such as fuel wood collection, grazing, timber harvesting and fodder collection were found more in MF.

Mandal (2006) conducted research on carbon stock of collaborative forests of Nepal. Three collaborative forests were selected as study sites in Mahottari district of Nepal. The soil samples were collected from 0–0.1, 0.1–0.3, and 0.3–0.6 m depths. Research revealed the estimated carbon stocks of 197.10, 222.58, and 274.66 ton ha^{-1} in Banke-Maraha, Tuteshwarnath, and Gadhanta-Bardibas collaborative forests respectively.

DFRS/FRA (2014), estimated total carbon stock in the Churia forest was to be 160.65 tg (116.94/ha). Tree,litter/debris and soil components comprised 84.73, 0.31 and 31.90 t/ha carbon respectively.

DFRS/FRA (2014), estimated total carbon stock in the Terai forest was to be 185.18 (123.12/ha). Tree,litter/debris and soil components comprised 89.18, 0.28 and 33.66 t/ha carbon respectively.

4. REDD + Mechanism and Community Forest

Nepal has a historic successful community forestry management system. It is the largest successful community based management system and constitutes about 26% of the national forest. Out of total community forests about 11% of forest area is under Terai community forest and 19% of forest falls under Inner- terai region (DoF, 2012). The trend of handing over community forest is still running due to its higher potentiality on conservation of forest and biodiversity, fulfillment of basic needs of forest product to local people, conservation of watersheds and income generation from sale of forest products for community and rural development. Community forest users group has been generating income only from trading the forest products (firewood, timber and non-wood products) but has not been getting benefit from environmental services such as carbon sequestration, biodiversity conservation, watershed function and amelioration of climate though it has greater potentiality (Kanel and Niraula, 2004; Mandal, 2006).

The concept of REDD (Reducing Emission from Deforestation and Forest Degradation) is not a new idea. Excessive felling and smuggling of trees in tropical forest during 1980s and 1990s compelled foresters and environmental scientist to combat deforestation but it gained popularity at the international level, when it was discussed at the various events organized by United Nation Framework Convention on Climate Change (UNFCCC), especially at COP 3 in Kyoto held in 1997. Kyoto protocol only established policy to reduce the greenhouse gas emission through reforestation and afforestation but was unable to include the carbon dioxide reduction through deforestation and forest degradation. The Coalition for Rainforest Nations (CfRN), a group of tropical countries lobbying for the inclusion of forest conservation put forward the REDD policy in consecutive UNFCCC and finally get value in Bali Action Plan, 2007 (COP 13 held in Bali of Indonesia in 2007). This initiative was formally adopted as a measure contributing to climate change mitigation. Under the REDD mechanism, countries will need to measure and monitor the emissions of CO2 resulting from deforestation and degradation within their borders. REDD has proliferated as REDD+ from Copenhagen accord (COP15 of December 2009). REDD+ includes Reducing Emissions from Deforestation and forest Degradation, Conservation of forest carbon stocks, and Sustainable management of forests and Enhancement of forest carbon stock. Cancun and Durban conference on climate change have also emphasized on promotion of REDD+ policy (UNFCCC, 2011). This forest-carbon offsetting mechanism of REDD+ would compensate developing countries for their effort to conserve and mange forests. The Government of Nepal has embraced the promise of REDD+ and is actively engaged in developing policies through the leadership of the REDD Forestry and Climate Change Cell (REDD Cell), an independent entity under the Ministry of Forests and Soil Conservation (MoFSC). It is created to formulate policies and facilitate 'REDD readiness' activities which received financing from the World Bank's Forest Carbon Partnership Facility (FCPF). In Nepal, handover of national forest to community forest user groups (CFUGs) as community managed forests evolved in the late 1970's through an interaction of multiplicity of factors such as deforestation, excessive dependence of the people over forest resources, political turmoil, population growth, regulatory enforcement and adjustments, and a paradigmatic shift in global development thinking. In Nepalese context, community forest has received highest priority of all the programs of Nepal's forestry sector since 1978 and constitutes more than 18,000 community forests occupying 1.65 million ha (about 4 2.6% of total forest area). It has been renowned worldwide as a very successful community based forest management system in terms of decreasing deforestation, conservation of forest and biodiversity and supply of forest produce. The sustainable management of community forest has carbon sequestration rate of 2.79 t ha-1yr-1 (Banskota, Karki, & Skutsch, 2007) which shows greater potentiality of the carbon sink in the community forests instead of providing tangible benefits. Thus, community forest of Nepal has greater potentiality to gain monetary benefits through carbon credits from REDD + mechanism. The promotion of carbon stock, sustainable forest management and carbon enhancement are necessary for getting benefit from REDD+ for reducing emission. A broad set of management actions such as various forms of forest restoration, reforestation, afforestation, enrichment planting and another proper management practices are necessary to maximize benefits from REDD+ mechanism. While any or all of these actions may potentially form part of REDD+ programs and strategies, selection of appropriate management practices in existing national and community forests are key to minimizing negative impacts, and ensuring positive outcomes for both carbon and biodiversity. The monetary benefits from carbon trade (US $ 8-15 per ton CO2) through REDD+ mechanism could also contribute to improve the rural livelihoods, protecting good forest governance, reducing biodiversity loss and increasing adaptation strategy to climate change.

5. Relationship between Carbon and Diversity

Nepal comprises only 0.09% of the global landmass but rich in both physical diversity and biodiversity. It contains typical topography from Terai to Mountains and Himalayas, climate and vegetation. Nepal possesses a large diversity of flora and fauna at genetic, species and ecosystem levels. Nepal constitutes a total of 118 types of ecosystem, 75 types of vegetation, 35 types of forests, 342 endemic plant species and 160 endemic animals (MoFSC, 2002).

Generally carbon stock of natural forest increases with increase in biodiversity up to climax stage because forests with rich biodiversity fill the gaps in forest and contains larger stocking and canopy cover. Though majority of studies show that there is a positive relationship between species richness and carbon stock, the relationship is not universal due to influence of species composition and application of management practices (Thompson, Mackey, McNulty, & Mosseler, 2009). Study shows that species richness has greater effect in carbon sequestration than species composition in a natural tropical forest of Panama (Ruiz-Jaen and Potvin, 2010) while species composition has greater positive effect on soil carbon due to fast litter decomposition than species richness (Giesselmann, Martins, Brändle, Schädler, Marques, & Brandl, 2010 and Barantal, Fromin, Schimann, & Hättenschwiler, 2011). The impacts of changes to forest management on both carbon stocks and biodiversity are often complex and non-linear due to several anthropogenic factors, succession and site quality (Thomson, Ferria, Gardner, Guariaguata, Koh, Okabe, Pan, Schmitt, Tylianakis, Barlow, Kapos, Kurz, Parrotta, Spalding, & Vliet, 2012). The relationship between carbon stock and biodiversity under different types of management in different locality is listed in Table-7.

Table 5: Relationship between Carbon and Biodiversity under Different Types of Management

Ecological Zone	Location	Forest Stand Type	Type of Relationship (Biodiversity Vs. Carbon)	Positive (+) Negative (-) Neutral (0)	Reference
Tropical Humid	Australia	Planted (Commercial)	Higher tree growth rates with increase sp. richness	+	Erskine et al (2006)
Tropical Rain Forest	Australia	Planted (Commercial)	Two species resulted in superior growth rates than either species alone	+	Bristow et al. (2006)
Tropical Rain Forest	Panama	Planted (Experimental)	Significant effects of tree species richness on total litter production; litter decomposition not affected by tree species richness	+	Scherer-Loren-Zen et al (2007)
Tropical Rain Forest	Australia	Planted (Experimental & Natural)	No relationship between diversity and production in old forests	0	Firn et al. (2000)
Tropical Rain Forest	Panama	Natural	No relationship between tree-species diversity and above-ground carbon stocks	0	Kirby and Potvin (2007)
Tropical Rain Forest	Panama	Planted (Experimental)	Tree biomass higher in pairs and plots with higher species richness	+	Murphy et al. (2008)
Tropical Rain Forest	Panama	Planted (Experimental)	No significant differences in root or microbial biomass	0	Murphy et al. (2008)
Tropical Rain Forest	Panama	Planted (Experimental)	Soil respiration 19-31% higher in monoculture than in pairs and plots with higher species	-	Murphy et al. (2008)
Various (Review)	Tropics	Planted (Experimental)	Mixed Plantations had higher diameter growth rate	+	Piotto (2008)
Tropical Rain Forest	Panama	Planted (Experimental)	Species diversity explained 23% of productivity and 30% of mortality	+	Healy et al. (2008)
Tropical Rain Forest	Borneo	Natural	Tree diversity negatively correlated with organic carbon	-	Silk et al. (2009)

(Source: International Union of Forest Research Organizations (IUFRO); Thompson et al., 2012)

6. Conclusion

Globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above-ground, and 40% of terrestrial below-ground biomass carbon storage. Though there is wide variation in soil carbon estimates, the available data clearly indicates that the total amount of carbon stored in soil is many times higher than the total carbon reserve in the atmosphere. Studies indicate that the largest amounts of carbon are stored in the tropics and in high latitude ecosystems compared to other ecosystems. The carbon stock also varies within the same ecosystem from place to place due to variation in site quality, stocking and composition of forest, human activities and land use management practices. In comparison to other South Asian countries Nepal is one of the richest countries for carbon stock. A large number of studies regarding the carbon estimation were found in Nepal but these were mostly done in low land and mid hills. The community based management system is one of the successful forest management systems of Nepal. It has higher potentiality on conservation of forest and biodiversity as well as it helps to fulfill demand of forest products for forest user group. Community forest users group has been generating income only from trading the forest products (firewood, timber and non-wood products) but has not been getting benefit from environmental services such as carbon sequestration, biodiversity conservation, watershed function and amelioration of climate though it has greater potentiality. In Nepal, some Community forests are highly active in management and others are focused on protection while some are passive or inactive. It is necessary to analyze the effect of different management practices and test which types of existing management practices are suitable for promotion of carbon stock and biodiversity in community forest. Nepal comprises only 0.09% of the global landmass but rich in both physical diversity and biodiversity. Though majority of studies show that there is a positive relationship between species richness and carbon stock, the relationship is not universal due to influence of species composition and application of management practices.

Sustainable forest management policy with stocking enhancement activities such as enrichment planting, regeneration promotion activities should be implemented in CF to maximize carbon stocks and diversity instead of getting direct benefits from forest products. Maximization of carbon stocks in community forest should provide intangible benefits through REDD+ mechanism. The REDD+ program should have parallel focus on carbon sequestration and biodiversity promotion. Baseline information of carbon stocks and biodiversity should be maintained at different levels i.e. local, regional and national. That helps to assess the periodic change in carbon and biodiversity.

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