ISSN: 1991-2951 (Print)
ISSN: 2091-2781 (Online)

Our Nature

Journal homepage: http://nepjol.info/index.php/ON

Variation in carbon stock in litterfall, fine root and soil in Sal (*Shorea robusta* Gaertn.) forests of eastern Nepal

Krishna Prasad Bhattarai[1*] and Tej Narayan Mandal[2]

[1]*Department of Botany, Mechi Multiple Campus, Tribhuvan University, Bhadrapur, Nepal*
[2]*Department of Botany, Post Graduate Campus, Tribhuvan University, Biratnagar, Nepal*
[*]*E-mail: krishnaprbhattarai@gmail.com*

Abstract

Global climate change is a major problem generated by increasing concentration of carbon dioxide in the atmosphere. Forests and their soils are major sink of carbon and thus constitute an effective role in the global carbon cycle. Present study was conducted to quantify and compare the amount of carbon stock in litterfall, fine root and soil between Tarai Sal forest and Hill Sal forest of eastern Nepal. Carbon stock in litter and fine root was estimated by ash content method and in soil by multiplying the value of soil organic carbon, bulk density and soil depth. Carbon stock in litterfall was higher (3.94 Mg ha^{-1}) in TSF than HSF (3.26 Mg ha^{-1}) and in fine root (0-5 mm size) in 0-30 cm soil depth it was higher in HSF (2.76 Mg ha^{-1}) than TSF (2.19 Mg ha^{-1}). In soil (0-30 cm depth) the value was higher in HSF (58.23 Mg ha^{-1}) than TSF (50.81Mg ha^{-1}). Tarai Sal forest accumulated higher carbon stock in the litterfall and lower in fine root than Hill Sal forest which was mainly attributed to the amount of litterfall and fine root biomass rather than organic carbon concentration. In Tarai Sal forest the carbon stock in soil was relatively low than Hill Sal forest that may be due to the higher net uptake and mineralization of carbon in the situation of higher growth rate of plant. These outcomes verified that the forest plays important role for mitigation of global warming by storing the atmospheric carbon dioxide in plant parts and the soil. So, it concludes that conserving the considerable quantity of carbon in forests is inevitable for proper forest management.

Key words: Fine root biomass, Litter mass, Sequestered carbon, Tarai and Hill Sal forest

DOI: http://dx.doi.org/10.3126/on.v16i1.22124

Manuscript details: Received: 14.06.2018 / Accepted: 13.10.2018

Citation: Bhattarai, K.P. and T.N. Mandal 2018 Variation in carbon stock in litterfall, fine root and soil in Sal (*Shorea robusta* Gaertn.) forests of eastern Nepal, *Our Nature* 16(1): 68-73. DOI: http://dx.doi.org/ 10.3126/on.v16i1.22124

Introduction

Global climate change is a current issue caused by the increasing concentration of green house gases including carbon dioxide in the atmosphere. Forests and their soils are major sink of atmospheric carbon and thus the influence of forests in the global carbon cycle is now widely recognized (Basu, 2009). They sequester and store more carbon than any terrestrial ecosystems, i.e., they store more than 80% of all terrestrial above ground carbon and more than 70% of all soil organic carbon (Jandl, *et al*., 2006). Forests have a great role in climate change improvement (Maraseni *et al*., 2005; Pan *et al*., 2011) by reducing CO_2 levels of the surrounding by sequestering atmospheric carbon into the plant biomass through the process of photosynthesis and by increasing the organic carbon content in the soil (Brown and Pearce, 1994). Increased level of soil organic carbon improves soil quality by increasing ion exchange

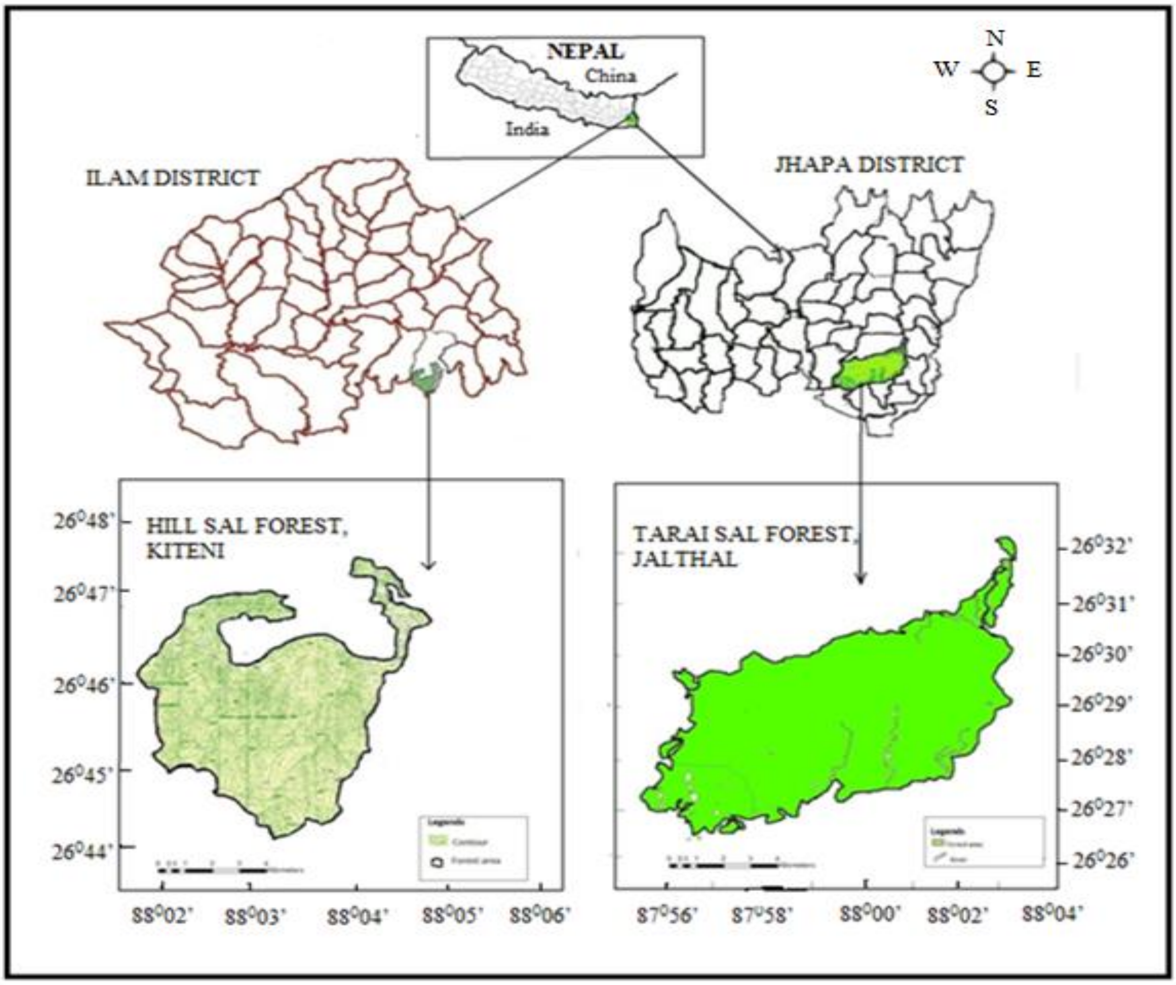


Figure 1. Location map of study area of Hill Sal forest lies at Kiteni, Ilam district and Tarai Sal forest lies at Jalthal, Jhapa district in eastern Nepal

capacity, aggregation, water holding capacity, infiltration and microbial diversity (Lal, 2004).

Tropical forests are one among the rich and complex terrestrial ecosystems which store approximately 55% of the worlds living terrestrial carbon (Pan *et al*., 2011). Carbon is stored in the forests mainly in tree components like stem, branches, leaves, fine root, litter and in forest soil. Total carbon stock and carbon increment vary according to vegetation types, growth age and topographic aspects. However, it decreases due to forest fire, fuel-wood, livestock feed, disease, drought and illegal logging. Despite its importance, studies on the carbon stock in different forest ecosystems in Nepal is still limited (Shrestha and Singh, 2008). So in the present study an attempt has been made to quantify and compare the amount of carbon in litterfall, fine root and soil of Sal forests located in Tarai and Hill region of eastern Nepal.

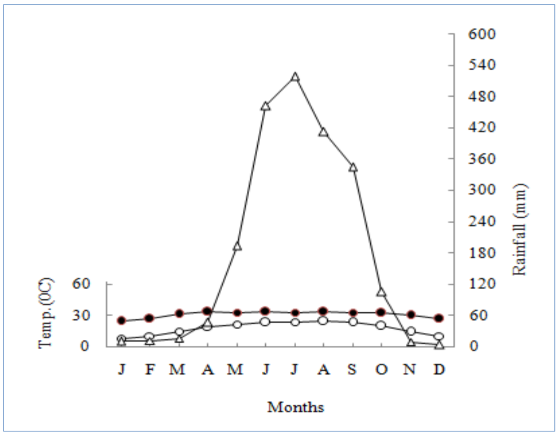
Materials and methods

Study area

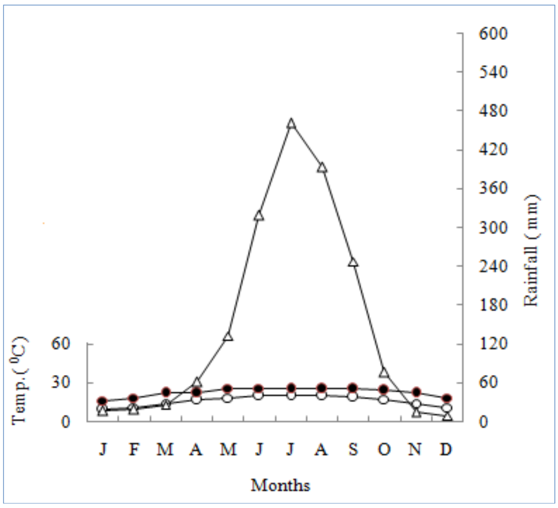
The study was carried out in the Sal forest of Jhapa and Ilam districts of eastern Nepal (Fig. 1). Sal forest of Jhapa district is addressed as Tarai Sal forest (TSF) and of Ilam district as Hill Sal forest (HSF). The main part of TSF is located at Jalthal near Kechana (extreme low land of Nepal). The forest floor has ridge and furrow with altitudinal variation from 62 to 129 m above msl. It lies in between 87°55′ and 88°03′E longitude and 26°26′ and 26°31′N latitude. On the other hand the main part of HSF is located at Kiteni, Kolbung in Ilam district. The forest is situated on the southern foot hills (Siwalik Hills) representing the Sub Himalayan tract of Nepal Himalayas (Gansser, 1964). Altitude ranges from 500 to 850 m above msl. It is situated in between 88°02′ and 88°04′E longitude and 26°44′ and 26°47′N latitude.

Climate

The climate of the study area is tropical monsoon type. The year is divisible into dry and warm summer season (March to middle May), humid and warm rainy season (middle May to October) and dry and cool winter season (middle November to February). Based on the data of the period 2001 to 2014, the mean monthly minimum temperature of Tarai Sal forest ranged from 10.05ºC to 23.99ºC and maximum temperature ranged from 23.92ºC to 33.35ºC (Fig. 2a). Likewise, the mean monthly minimum temperature of Hill Sal forest ranged between 9.36ºC and 19.88ºC and maximum temperature between 16.45ºC and 25.91ºC (Fig. 2b). The average annual rainfall of Tarai Sal forest was 2130.4 mm and Hill Sal forest was 1776.07 mm (Figs. 2a, 2b).



(2a)



(2b)

Figure 2. Ombrothermic representation of the climate of (2a) Tarai Sal forest of Jalthal and (2b) Hill Sal forest of Kiteni. (○= monthly mimimum temperature, ●= monthly maximum temperature, Δ= mean monthly rainfall of the period 2001-2014)

Vegetation

Tarai Sal forest contains dense deciduous vegetation and it is one of the most complex ecosystems of eastern Nepal. It is a Sal *(Shorea robusta* Gaertn.) dominated mixed tropical forest. The other main associates are *Lagerstroemia parviflora* Roxb., *Dillenia pentagyna* Roxb., *Terminalia bellerica* (Gaertn.) Roxb, *T. chebula* Retz., *Sizygium cuminii* (L.) Sekeels, *Duabanga grandiflora* (Roxb. ex DC.) Walp, *Artocarpus chamsala* Roxb. The forest is peculiar in containing some sub tropical species like *Schima wallichii* DC. Korth, *Castanopsis indica* (Roxb.) Miq, *Michelia champaca* L. and *Madhuca longifolia* (Koenig) Mac (Bhattarai, 2017). Hill Sal forest contains upper tropical deciduous and semi-deciduous vegetation. It is also Sal *(S. robusta* Gaertn.) dominated mixed forest. The important associates are *Schima wallichii* DC. Korth, *Lagerstroemia parviflora* Roxb., *Dillenia pentagyna* Roxb., *Cassia* sp., *Duabanga grandiflora* (Roxb. ex DC.) Walp. This forest is also a habitat for rare and threatened species like *Michelia champaca* L., *Cycas pectinata* Griff. and *Cyathia spinulosa* Wallich ex Hooker.

Estimation of litterfall

Litterfall samples were collected from the litter traps (1m × 1m) which were fixed at thirty permanent plots in each forest. Sampling plots were selected and established randomly. Collection was done at two months interval for one year from March 2013 to February 2014. The collected samples were brought to the laboratory, separated into leaf and non-leaf (small branches, reproductive parts and miscellaneous) components. Litter samples were oven dried at 80ºC for 24 h and the mean bi-monthly dry weight value for each site was estimated.

Estimation of fine root biomass

Fine root (0 - 5 mm diameter) biomass (FRB) was determined from thirty soil monoliths (10cm × 10cm × 30cm depth) taken out from permanent plots in each forest in summer, rainy and winter season during 2012 and 2013. Soil monoliths were washed over a sieve with fine jet of water to retrieve the fine roots which were oven dried at 80ºC. Fine root size < 2 mm and 2-5 mm in 0-15 cm and 15-30 cm soil depth were separated and estimated separately. Summer, rainy and winter season values were averaged to obtain a mean annual FRB.

Estimation of carbon stock in litter and fine root

Carbon present in litter and root litter was estimated by ash content method. Carbon concentrations were assumed to be approximately 50% of ash free weight (McBrayer and Cromack, 1980). In this method oven dried plant component (litter and fine root) was burnt in Muffle furnace at 400ºC temperature. Ash content (inorganic elements in the form of oxides) left after burning was weighed and carbon concentration was calculated by using the following equation: % Carbon = (Initial dry weight of litter - Ash weight) × 100/2. The carbon stock in litter and fine root was calculated by multiplying carbon concentration with dry weight.

Estimation carbon stock in soil

Soil samples were collected in two soil depth (0-15 cm and 15-30 cm) from thirty plots used for fine root and litter collection in each forest site. Soil was collected from three pits (10 cm × 10 cm × 30 cm each) at each plot and mixed together and pooled as one replicate (Singh *et al.*, 2001). Bulk density (BD) was determined by inserting metallic tube in soil and thereafter estimating dry weight of a unit volume of soil (Brady and Weil, 2013) while soil organic carbon (SOC) was determined by dichromate oxidation method (Kalembasa and Jenkinson, 1973). Carbon stock (CS) in soil (Mg ha^{-1}) was calculated using the formula: CS = SOC × soil depth × BD.

Statistical analysis

Statistical tests were carried out in SPSS (IBM Statistics, ver. 20) packages. The data were checked for normality (Kolmogorov-Smirnov test) before statistical analysis. Student t-test was used to test the significant difference in the amount of litterfall, fine root biomass and soil organic carbon due to forest types (TSF and HSF).

Results and discussion

Carbon stock in ecosystem may differ considerably between the forest types due to differences in vegetation, microclimate, stand age, and elevation (Dar and Sundarapandian, 2015; Thapa-Magar and Shrestha, 2015). In addition, forest type and mineral factor strongly affect the organic carbon pools in seasonally dry tropical forests (Toriyama *et al.*, 2015). Comparatively carbon stock in litterfall was higher (3.94 Mg ha^{-1}) in Tarai Sal forest than Hill Sal forest (3.26 Mg ha^{-1}) (Table 1). Contribution of leaf litter was higher (69%) than non-leaf litter (31%) in carbon stock in both forests. Carbon stock in litterfall was basically depends upon the annual litterfall which was significantly (df value 58, $p<0.00$) higher in TSF (8.82 Mg ha^{-1}) than in HSF (7.18 Mg ha^{-1}). Difference in Carbon stock in litterfall is primarily related to the variation in quantity of organic compound and litterfall which was higher in TSF (Bhattarai and Mandal, 2018). Similar trend of carbon stock was observed in community forests under $REDD^{+}$ (Pandey *et al.*, 2014)

Annual fine root biomass (FRB) was higher in HSF (6.27 Mg ha^{-1}) than TSF (5.04 Mg ha^{-1}) (Table 2). The variation in annual FRB was significant (df value 58, $p<0.001$). Variation in carbon stock in fine root mainly depends upon carbon concentration and fine root biomass. Carbon stock in fine root (0-30 cm soil depth) was higher (2.76 Mg ha^{-1}) in HSF than TSF (2.19 Mg ha^{-1}). Higher value of carbon stock in Hill Sal forest was mainly due to the higher amount of fine root biomass which accumulates more organic matter due to lower decomposition rate (Bhattarai and Mandal, 2016). In the Tarai Sal forest carbon stock is less due to having low fine root biomass whereas its organic carbon concentration is high. The amount of carbon in fine root might also be the results of numerous external factors such as soil nutrients and climate as well as internal factors. Moreover, variation of carbon stock mainly depends upon forest site, fine root biomass and nutrient content in fine root. Girardin *et al*. (2011) found consistent results in which an increase in fine root carbon stock were observed in tropical forest in the Peruvian Andes located at high altitude.

In the present study carbon stock in forest soil was higher in Hill Sal forest than Tarai Sal forest (Table 3). Contribution in carbon stock of soil was higher in upper soil layer (61.4% in TSF and 55.47% in HSF) than lower soil layer. A similar relationship in between carbon stock and forest types was also observed in community forest having the dominant species *S. robusta* Gaertn. of Chitwan (in the Tarai) and Gorkha (in the Hills) districts of central Nepal (Pandey and Bhusal, 2016) and in tropical Amazonian and Andean forests (Girardin *et al*., 2013). The difference in soil carbon of forest is primarily related to the variation in quantity of soil organic matter and bulk density (Bhattarai and Mandal, 2016).

Table 1. Carbon stock (Mg ha^{-1}) in litterfall on the forest floor in Tarai Sal forest and Hill Sal forest of eastern Nepal

Components	Tarai Sal forest			Hill Sal forest		
	Litterfall (Mg ha^{-1})	OC (%)	Carbon stock	Litterfall (Mg ha^{-1})	OC (%)	Carbon stock
Leaf litter	6.16±0.06	44.40	2.73	5.01±0.12	45.10	2.26
Non leaf litter	2.66±0.05	45.40	1.21	2.17±0.08	46.05	1.00

Table 2. Carbon stock (Mg ha^{-1}) in fine root in Tarai Sal forest and Hill Sal forest of eastern Nepal

Fine root size	Tarai Sal forest			Hill Sal forest		
	FRB (Mg ha^{-1})	OC (%)	Carbon stock	FRB (Mg ha^{-1})	OC (%)	Carbon stock
<2 mm	3.50±0.08	43.30	1.51	4.48±0.14	43.75	1.96
2-5 mm	1.54±0.13	44.25	0.68	1.79±0.09	45.25	0.80

Table 3. Carbon stock (Mg ha^{-1}) in soil in Tarai Sal forest and Hill Sal forest of eastern Nepal

Soil depth	Tarai Sal forest			Hill Sal forest		
	SOC (%)	BD (g cm^{-3})	Carbon stock	SOC (%)	BD (g cm^{-3})	Carbon stock
0-15 cm	1.30 ± 0.004	1.60± 0.09	31.20	1.03 ± 0.007	2.09± 0.12	32.30
15-30 cm	1.44 ± 0.004	0.91 ± 0.05	19.61	1.13 ± 0.004	1.53 ± 0.11	25.93

In TSF, the carbon stock in soil was relatively low, this may be due to the higher net uptake and mineralization of carbon in the situation of higher growth rate of plant. In addition, the reduction in carbon stock in TSF may be due to high rate of litter decomposition (Bhattarai, 2016). In contrast, HSF contained relatively higher level of carbon stock in soil which may be due to lower uptake and mineralization of carbon in the situation of lower growth rate of plants. Thus, accumulation of soil carbon in HSF was at higher rate. On the other hand, disturbance activities like removal of litter mass and even forest biomass by local people may also cause the variation in carbon stock which results in the significant loss of stand biomass as well as carbon uptake capacity of vegetation (Gautam and Mandal, 2016).

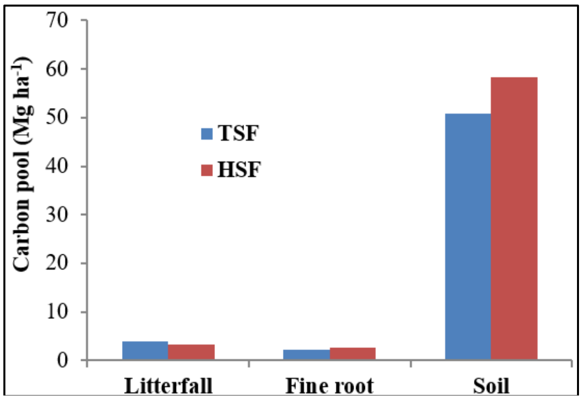


Figure 3. Comparison of carbon pool in litter fall, fine root (0-5 mm diameter) and soil (0-30 cm depth) in between TSF and HSF.

In conclusion, Tarai Sal forest accumulated higher carbon stock in the litterfall and lower in fine root than Hill Sal forest which was mainly attributed to the amount of litterfall and fine root biomass rather than organic carbon concentration (Fig. 3). Hill Sal forest indicated relatively higher level of carbon stock in soil which may be due to lower net uptake and mineralization of carbon.

These outcomes verified that the forest plays important role for mitigation of global warming by storing the atmospheric carbon dioxide in plant parts and in the soil. So, conserving the considerable quantity of carbon in forests through proper forest management is essential to reduce the emission of carbon as per the objective of REDD^{+}.

Acknowledgements

We are grateful to the Head, Department of Botany and to the Campus Chief of Post Graduate Campus, T.U., Biratnagar, Nepal for providing laboratory and library facilities. The first author is grateful to the Institute of Science and Technology, Tribhuvan University, Kathmandu for study leave and to the University Grants Commission, Nepal for the research fellowship.

References

Basu, P. 2009. A green investment. If growing forests in India can generate lucrative carbon credits, then why isn't everyone planting trees? News feature. *Nature* ***457*(*8*)**: 144-146.

Bhattarai, K.P. 2016. *Decomposition, nutrient release in leaf litter and N-mineralization in Sal (Shorea* *robusta Gaertn.) forests of Jhapa and Ilam districts, Eastern Nepal*. Tribhuvan University, Kathmandu, Nepal. (Ph.D. thesis).

Bhattarai, K.P. 2017. Enumeration of flowering plants in Tarai Sal (*Shorea robusta* Gaertn.) forest of Jalthal, eastern Nepal. *Journal of Plant Resources* ***15*(*1*):** 14-20.

Bhattarai, K.P. and T.N. Mandal 2016a. Relationship between soil microbial biomass and fine roots in Tarai and Hill Sal (*Shorea robusta* Gaertn.) forests of eastern Nepal. *International Journal of Ecology and Environmental Sciences* ***42*(*S*):** 19-28.

Bhattarai, K.P. and T.N. Mandal 2016b. Effect of altitudinal variation on the soil characteristics in Sal (*Shorea robusta* gaertn.) forests of eastern Nepal. *Our Nature* ***14*(*1*):** 30-38. DOI: http://dx.doi.org/10.3126/on.v14i1.16438

Bhattarai, K.P. and T.N. Mandal 2018. Comparative study on litter production and nutrient return to soil in Tarai and Hill Sal (*Shorea robusta* Gaertn.) forests of eastern Nepal *Banko Janakari* ***28*(*1*):** 11-19.

Brady, N.C. and R. Weil 2013. *The nature and properties of soils*. Pearson Education, New York.

Brown, K. and D. Pearce 1994. The economic value of non-market benefits of tropical forests: carbon storage. In *The economics of project appraisal and the environment: New horizon in environment economics* (Weiss, J. Ed.). E. Elgar, Aldershot. pp. 102-119.

Dar, J.A. and S. Sundarapandian 2015. Variation of biomass and carbon pools with forest type in temperate forests of Kashmir Himalaya, India. *Environmental Monitoring Assess* ***187***. DOI: 10.1007/s10661-015-4299-7.

Gansser, A. 1964. Geology of Himalayas. In *Geology of the Himalayas* (De Sitter, L.U. Ed.). Interscience Publisher, London. pp. 145- 273.

Gautam, T.P. and T.N. Mandal 2016. Effect of disturbance on biomass, production and carbon dynamics in moist tropical forest of eastern Nepal. *Forest Ecosystems* ***3***: 11. DOI: 10.1186/s40663-016-0070-y.

Girardin, C.A.J., L.E.O.C. Aragão, Y. Malhi, W. Huaraca Huasco, D.B. Metcalfe, L. Durand, M. Mamani, J.E. Silva-Espejo and R.J. Whittaker 2013. Fine root dynamics along an elevational gradient in tropical Amazonian and Andean forests. *Global Biogeochemical Cycle* ***27***: 252-264.

Girardin, C.A.J., Y. Malhi, L.E.O.C. Aragao, M. Mamani, W. Huaraca Huasco, L. Durand, K.J. Feeley, J. Rapp, J.E. Silva-Espejo, M. Silman, N. Salinas and R.J. Whittaker 2011. Net primary productivity allocation and cycling of carbon along a tropical forest elevational transect in the Peruvian Andes. *Global Change Biology* ***16*(*12*):** 3176-3192.

Jandl, R., K. Rasmussen, M. Tome and D.W. Johnson 2006. *The role of forests in carbon cycles, sequestration and storage. Forest management and carbon sequestration*. Federal research and training centre for forests, natural hazard and landscape, Vienna, Austria 4.

Kalembasa, S.J. and D.S. Jenkinson 1973. A comparative study of titremetric and gravimetric methods for the determination of organic carbon in soil. *Journal of Science Food Agriculture* ***24***: 1085-1090.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma* ***123*:** 1-22.

Maraseni, T.N., G. Cockfield and A. Apan 2005. Community based forest management systems in developing countries and eligibility for clean development mechanism. *Journal of Forest Livelihood* ***4***: 31-42.

McBrayer, J.F. and K.J. Cromack 1980. Effect of snowpack on oak- litter breakdown and nutrient release in a Minnesota forest. *Pedobiologia* ***20*:** 47-54.

Pan, Y., R.A. Birdsey, J. Fang, R. Houghton, P.E. Kauppi, W.A. Kurz, O.L. Phillips, A. Shvidenko, S.L. Lewis, J.G. Canadell, P. Ciais, R.B. Jackson, S.W. Pacala, A.D. McGuire, A.D., Piao, A. Rautiainen, S. Sitch and D. Hayes 2011. A large and persistent carbon sink in the world's forests. *Science* ***333*:** 988-993.

Pandey, H.P. and M. Bhusal 2016. A comparative study on carbon stock in Sal (*Shorea robusta*) forest in two different ecological regions of Nepal. *Banko Janakari* ***26*(*1*):** 24-31.

Pandey, S.S., T.N. Maraseni and G. Cockfield 2014. Carbon stock dynamics in different vegetation dominated community forests under REDD+: A case from Nepal. *Forest Ecology and Management* ***327*:** 40-47.

Shrestha, B.M. and B.R. Singh 2008. Soil and vegetation carbon pools in a mountain watershed of Nepal. *Nutrient Cycling in Agroecosystems* ***81*:** 179-191.

Singh, K.P., T.N. Mandal and S.K. Tripathi 2001. Patterns of restoration of soil physicochemical properties and microbial biomass in different landslide sites in the Sal forest ecosystem of Nepal Himalaya. *Ecological Engineering* ***17*:** 385-401.

Thapa-Magar, K.B. and B.B. Shrestha 2015. Carbon stock in community managed Hill Sal (*Shorea robusta*) forests of Central Nepal. *Journal of Sustainable Forestry* ***34*(*5*):** 483-501.

Toriyama, J., M. Hak, A. Imaya, K. Hirai and Y. Kiyono 2015. Effects of forest type and environmental factors on the soil organic carbon pool and its density fractions in a seasonally dry tropical forest. *Forest Ecology and Management* ***335*:** 147-155.