Nepalese Journal of Biosciences 2: 10-16 (2012)

Effect of disturbance on fine root biomass in the Tropical moist forest of eastern Nepal

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Abstract

Fine root biomass (<5 mm diameter) was estimated in 0-15 cm and 15-30 cm soil depths of disturbed and undisturbed stands of tropical moist forest in eastern Nepal. The value of root mass was higher (4.28 t ha^{-1}) in the undisturbed stand than the disturbed stand (2.04 t ha^{-1}). The biomass of smaller fine roots (<2 mm diameter) was 1.51 and 3.2 t ha^{-1} in the disturbed and undisturbed stands respectively. Most of the fine roots were present in the surface soil layer (0-15 cm), in both the disturbed and undisturbed stands (67% in the disturbed and 64% in the undisturbed). The nitrogen stock in the fine roots was more (38.61 kg ha^{-1}) in undisturbed stand than the disturbed stand (16.93 kg ha^{-1}). More nitrogen was confined in the fine roots of <2 mm diameter in both undisturbed (28.8 kg ha^{-1}) and disturbed (13.59 kg ha^{-1}) stands.

Key words: Forest, disturbance, fine root biomass, nitrogen stock

Introduction

In many tropical countries, forest destruction and conversion to agricultural land is continuing at high rate. In the periphery of most tropical forest of Nepal, selective logging and the creation of small-scale crop plantations are significant causes of deforestation. Because the area of disturbed forest increases rapidly, we need a better understanding of the ecological consequences of forest disturbance in the aboveground as well as the belowground system. Research on the structure and functioning of disturbed tropical forests mostly focuses on aboveground aspects only. However, some studies reported the effect of anthropogenic disturbance on the belowground system of tropical forests (Leuschner *et al*. 2006; Barbhuiya *et al*., 2012). Moreover, effect of landslide disturbance on the fine root biomass, production and turnover rate has been studied in five age series (1 year to 58 year-old) landslide damaged sites in the sal forest ecosystem of Nepal Himalaya (Mandal, 1999).

Fine roots (<5 mm in diameter) are responsible for water and nutrient uptake and synthesis of certain growth hormones. Therefore, they have a key role in nutrient and water cycling and soil carbon sequestration in terrestrial ecosystems due to the large carbon input into soil from fine roots and the stabilization of the associated carbon derived from roots (Guo *et al.,* 2007). Fine roots which are dynamic components of below-ground biomass represent about 30% of the above-ground biomass (Noordwijik *et al.*, 1996) and between 40-85% of the net primary production according to soil type (Hoffmann & Usoltsev, 2001). High fine root densities increase the hydraulic contact between plants and the soil, water uptake rates and therefore contribute to higher transpiration rates (Williams *et al.*, 1998).

One of the important factors that may be critically related to root function is soil depth. Soil bulk density, clay content, moisture, nutrient content, temperature, and soil microbial biomass composition generally change with soil depth, and root life span is likely affected by these soil properties (Jackson *et al*., 2000; Joslin *et al*., 2006). The activity of fine roots in the forest is suggested to be under strong genetic control (Espeleta *et al*., 2009), but fine roots also show variation in their biomass and vertical distribution in response to environment and stand age (Yuan & Chen, 2010).

Fine roots also are important sources of detritus within the forest soils and thereby sustain soil biological activity (Pollierer *et al*., 2007) and also influence soil organic matter and nutrient dynamics (Hendricks *et al*., 2006). Increased nutrient availability might increase carbon input to soils through enhanced fine root turnover (King *et al*., 2002). The contribution of fine roots to the carbon and nutrients stock in the soil is equivalent or even higher to that of litterfall that returns carbon and nutrients from canopy to the soil (Hendrick & Pregitzer, 1993).

Fine roots can fluctuate considerably in biomass, production, and turnover throughout the season or between years, depending on different sites (Wang & Guo 2008; Barbuhiya *et al*., 2012). Despite the importance of fine roots, their sampling is more time consuming and the methods are usually less precise. Thus, fine roots remain one of the most challenging but important areas of study in terrestrial ecosystems. Therefore, the studies of fine root dynamics and turnover rate are still essential at present. The main objective of the present study was to evaluate the effect of disturbance on fine root biomass and nitrogen stock in fine root in tropical moist forest (Charkoshe jungle) of eastern Nepal.

Materials and Methods

Study area

The present study was conducted in the sal bearing tropical forest (Charkoshe jungle), located in the bhabar belt of Sunsari district, eastern Nepal (Longitude 86°53'E to 87°21'E and latitude 26°24'N to 26°52'N), within the altitude range of 220 to 370 m above m.s.l. It falls under the tropical moist forest according to the life zone classification of Holdridge *et al.* (1971). The sampling area was selected at the central core part (which was treated as undisturbed forest stand) and peripheral part of the forest (disturbed stand).

Climate

The climate is tropical monsoon type. The year is divisible into three distinct seasons: (i) dry and warm summer season (March to May); (ii) wet and warm rainy season (June to October); and (iii) dry and cool winter (November to February). Based on the data for 2007-2011, mean monthly minimum temperature ranged from 9.3-25.5°C and maximum temperature ranged from 22.4-34.5°C. The average annual rainfall was 1814.9 mm; of which more than 79% occurred from June to September (Fig. 1). Relative humidity was higher from June to October. Data on rainfall, temperature and humidity were obtained from the Department of Meteorology, Koshi Basin, Dharan in Sunsari district, Nepal.

Soil

The study area is bordered by Siwalik hills in the north and Gangetic alluvial plains in the south. The area has been formed from soft erodible sediments of the Siwaliks and is identified by the presence of boulder beds mixed with sand, silt, clay forming a porous nature. Topsoil of the study area is typical loam.

Vegetation

The forest is dominated by *Shorea robusta* Gaertn. Other main associates are *Lagerstroemia parviflora* Roxb., *Terminalia alata* Heyne ex Roth., *Mallotus philippensis* (Lam.) Mull.-Arg., *Adina cordifolia* Benth. & Hook f. ex Bran, *Dillenia pentagyna* Roxb., *Terminalia bellerica* (Gaertn.) Roxb., *Schleichera oleosa* Lour. Merr., *Croton roxburghii* N.P. Balakr., *Careya arborea* Roxb. The forest is also the habitat of some rare (e.g. *Dalbergia latifolia* Roxb., *Desmodium oojeinensis* (Roxb.) H. Ohashi, *Pterocarpus marsupium* Roxb. etc.) and commercially as well as medicinally important plants (e.g. *Acacia catechu* (L.) Willd., *Cassia fistula* L., *Holorrhena antidysenterica* Wall., *Terminalia chebula* Retz. etc.).

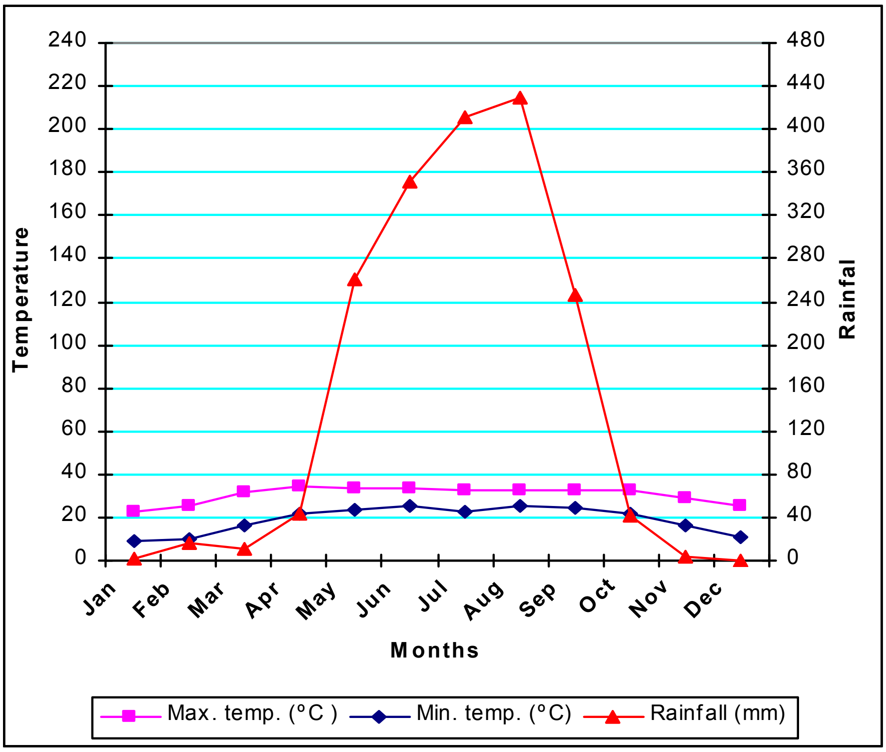

Figure 1. Ombrothermic representation of the climate in tropical moist forest region of eastern Nepal.

Estimation of fine root biomass

Fine roots (<5 mm diameter) were collected during summer season (May, 2011) from one soil monolith (10×10 cm^2) within two depth ranges (0-15 and 15-30 cm) in thirty five randomly located sites at each stand. Soil monoliths were washed over a sieve with fine jet of water to retrieve the fine roots. They were oven dried at 80°C to constant weight and weighed to find the dry matter content. Oven dried fine roots were categorized in <2 mm diameter and 2-5 mm diameter fraction. The root biomass was estimated diameterwise and depthwise.

Nitrogen concentration and Stock

The fine roots of <2 mm and 2-5 mm of all sample size were mixed separately. The concentration of nitrogen was analyzed diameterwise by micro Kjeldahl method following

Jackson (1958). Concentration of nitrogen was multiplied with the biomass of fine roots in each diameter class and thus stock of nitrogen in fine root was estimated.

Results

Spatial variation in root mass

Data on fine root biomass estimated during the summer season are presented in table 1. The total fine root mass (<5 mm diameter) was higher (4.28 t ha^{-1}) in the undisturbed stand and lower (2.04 t ha^{-1}) in disturbed stand. The biomass of smaller fine roots (<2 mm diameter) was 1.51 and 3.2 t ha^{-1} in the disturbed and undisturbed stands respectively. Similarly, the biomass of larger fine roots (2-5 mm diameter) was almost double in the undisturbed stand (1.09 t ha^{-1}) than the disturbed one (0.53 t ha^{-1}).

Vertical distribution of root mass

Most of the fine roots were present in the surface soil layer (0-15 cm), in both the disturbed and undisturbed stands (67% in the disturbed and 64% in the undisturbed). The sub-surface soil layer (15-30 cm) had 33-36% of total fine root mass (Tab. 1). In the vertical distribution also, the biomass of small fine roots (<2 mm) was higher in surface soil layer in both undisturbed (2.0 t ha^{-1}) and disturbed stand (1.03 t ha^{-1}) than the sub-surface layer.

Table 1. Fine root biomass (t ha^{-1}) in tropical moist forest of eastern Nepal. Values are mean ±SE

Diameter	Disturbed stand			Undisturbed stand		
	Soil depth (cm)		Total	Soil depth (cm)		Total
	0-15	15-30		0-15	15-30	
< 2 mm	1.03±0.05	0.48±0.02	1.51	2.0±0.09	1.19±0.05	3.2
2-5 mm	0.34±0.02	0.19±0.01	0.53	0.74±0.08	0.35±0.05	1.09
Total (0-5 mm)	1.37±0.08	0.67±0.04	2.04	2.74±0.13	1.54±0.07	4.28

Nitrogen stock in fine roots

The nitrogen stock in the fine roots was more (38.6 kg ha^{-1}) in undisturbed stand than the disturbed stand (16.9 kg ha^{-1}). More nitrogen was confined in the fine roots of <2 mm diameter in both disturbed (13.6 kg ha^{-1}) and undisturbed (28.8 kg ha^{-1}) stands. The nitrogen stock in the fine roots of 2-5 mm diameter varied from 19.7-25.4% of total nitrogen stock in fine roots (Tab. 2).

Table 2. Nitrogen stock in fine root biomass (kg ha^{-1}) in tropical moist forest of eastern Nepal

Diameter	Disturbed site			Undisturbed site		
	Soil depth (cm)		Total	Soil depth (cm)		Total
	0-15	15-30		0-15	15-30	
< 2 mm	9.27	4.32	13.59	18.09	10.71	28.8
2-5 mm	2.14	1.2	3.34	6.66	3.15	9.81
Total (0-5 mm)	11.41	5.52	16.93	24.75	13.86	38.61

Discussion

Spatial variation in fine root biomass

Fine root biomass was higher in undisturbed stand than the disturbed stand. It may be attributed to differences in site quality and species composition of the vegetation. The higher fine root biomass in the undisturbed stand may reflect the higher density and basal area of trees, greater accumulation of surface litter and soil nutrients. Lower root mass in disturbed stand may be attributed to lower organic matter and nutrients. Leuschner *et al.* (2006) reported that disturbed forest may contain a biomass of fine roots only 60% or less of the global average in undisturbed tropical moist forests.

Vertical distribution of fine root biomass

In this study, the fine root biomass decreased with increased soil depth. More than 64% of the fine root biomass was retrieved in the upper 15 cm soil layer. This high density of fine roots in the top few centimeters of soil is important for the conservation of nutrients in the forests. Usually, fine root biomass decreases with increased soil depth in many forest types (Borken *et al.*, 2007; Sakai *et al.*, 2007; Zhou & Shangguan, 2007; Borja *et al.*, 2008). Thus, the vertical distribution of fine roots is a basic strategy that helps plants to acquire below-ground nutrients. The greater proportion of roots near the surface in the highly disturbed stand reflected the greater proportion of herbs in the vegetation. This result was similar to observations in a pasture-land of tropical evergreen forest in Mexico (Jaramillo *et al*., 2003). The biomass of small fine roots (<2 mm) was higher in surface soil layer in both undisturbed (2.0 t ha^{-1}) and disturbed stands (1.03 t ha^{-1}) than the sub-surface layer. Mandal (1999) also reported higher value (2.3 t ha^{-}) of <2 mm diameter size fine root in summer season than greater diameter size in Plateau sal forest in eastern Nepal.

Nitrogen stock in fine root

The nitrogen (N) stock in the fine roots of both stands was significantly higher in surface soil than in deeper soil. This difference in fine root N content may be related to the trend in the soil N content. The positive relationship between fine root N and soil N was also found in previous study (Helmisaari *et al*., 2007). The N stock of fine roots was suggested to be positively related to root respiration (Pregitzer *et al.*, 1998), but negatively related to root longevity (Yuan & Chen, 2010). The higher fine root N stock at undisturbed stand indicated that soil nutrient absorption in this stand was enhanced by higher root metabolism, while the lower fine root N stock at disturbed stand was associated with longer longevity of fine roots, which was an optimization of nutrient-poor conditions.

In the present study, nitrogen stock also changed with the diameter of fine roots. More nitrogen concentration was found in the fine roots of <2 mm diameter than larger fine roots. Similar trend was described in previous study (Mandal, 1999; Comas & Eissenstat, 2009).

Acknowledgements

We are grateful to the Head, Department of Botany and Campus Chief, Post Graduate Campus, Biratnagar for providing laboratory and library facilities. Financial support by the University Grants Commission, Nepal, is thankfully acknowledged.

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