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Impact of biomass extraction on soil properties and foliar nitrogen content in a community forest and a semi-protected natural forest in the central mid-hills of Nepal

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Abstract: The impact of biomass removal on soil physical and chemical properties was compared between a community forest (CF) and a semi-protected natural forest (MF) belonging to the same vegetation type under similar climatic conditions and topographic features in the central mid-hills of Nepal. The impact of biomass extraction on soil and foliar nitrogen contents in CF was more pronounced than that in MF. Soil bulk density was significantly lower ($P < 0.05$) and soil C, N, exchangeable K and Mg concentrations were significantly higher ($P < 0.05$) in MF compared to CF. The foliar nitrogen content of dominant trees was higher ($P < 0.1$) in MF than CF. It is concluded that the biomass removal deteriorated forest soil characteristics including nutrient contents, and the state of foliar nitrogen content of trees.

Resumen: Se comparó el impacto de la remoción de biomasa en las propiedades físicas y químicas del suelo entre un bosque comunitario (CF) y un bosque natural semiprotegido (MF) que pertenece al mismo tipo de vegetación en condiciones climáticas y características topográficas similares, en las colinas medias centrales de Nepal. El impacto de la extracción de biomasa en el contenido de nitrógeno del suelo y foliar en el CF fue más pronunciado que en el MF. La densidad aparente del suelo fue significativamente menor ($P < 0.05$) y las concentraciones de C, N, K y Mg intercambiables en el suelo fueron significativamente mayores ($P < 0.05$) en el MF que en el CF. El contenido de nitrógeno foliar de los árboles dominantes fue mayor ($P < 0.1$) en el MF que en el CF. Se concluye que la remoción de biomasa deterioró las características del suelo del bosque, incluyendo el contenido de nutrientes y el estado del contenido de nitrógeno foliar de los árboles.

Resumo: O impacto da remoção de biomassa sobre as propriedades físicas e químicas do solo foi comparada entre uma floresta comunitária (CF) e uma floresta natural semi-protegida (MF) pertencentes ao mesmo tipo de vegetação e sob condições climáticas e características topográficas semelhantes nas colinas medianas centraisdo Nepal. O impacte da extração de biomassa no solo e nos teores de azoto foliar em CF foi mais acentuado do que na MF. A densidade aparente do solo foi significativamente menor ($P < 0,05$) e os teores em C, N, K de troca e Mg foram significativamente maiores ($P < 0,05$) em MF quando comparados com CF.O teor de azoto foliar das árvores dominantes foi maior ($P < 0,1$) em MF do que na CF. Conclui-se que a remoção de biomassa deteriorou as características dos solos florestais, incluindo o conteúdo de nutrientes, eo estado do teor de azoto foliar das árvores.

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Key words: Biomass, foliar nitrogen contents, mid-hills of Nepal, soil nutrients.

Introduction

The growing human population and its dependence on forests for fuel, fodder and timber have caused unsustainable exploitation of forest resources in Nepal since the mid-1950s (New Era 1997; Upreti 2001). This unsustainable way of extracting products from the forests led to rapid loss of vegetation (Upreti 2001), reduction of soil fertility (Maskey & Joshi 1998; Shrestha 2007), and caused serious environmental degradation (Karkee 2004). The Community Forestry Program was initiated in late 1970s to restore the degraded sites, increase the supply of forest products, and improve the environmental situation in the hills of Nepal (Acharya 2003). A Community Forest (CF) is controlled and managed by a Community Forest User Group (CFUG), a legally registered institution of the rural people, for fulfilling their need of forest products for domestic purposes (Gilmour & Fisher 1991). CFUGs carry out harvesting activities every year in their forests for timber, fuelwood, and leaf litter according to an operational plan. CFUGs conduct silvicultural operations (selective felling and pruning) once a year from mid November to late March. During this period fuelwood is collected (Shrestha 2004), and dead, dying trees are harvested for timber (Acharya 2002; Shrestha 2004). Fifty percent of the leaf litter produced by the forest is removed annually for composting (Acharya 2002; Mahat 1987).

Since wood contains very low amount of minerals, regular harvesting of wood depletes nutrients and acid neutralizing capacity of soil only at moderate rates. However, harvesting of other biomass fractions such as branches and leaves, and collection of litter have a much more severe impact on forest ecosystems (Glatzel 1991), especially on the soil nutrient contents ultimately impacting the distribution of tree species in a forest (Nizam *et al.* 2013). Deterioration of soil quality due to biomass extraction over a period of 20 years was noticed by Dahlgren *et al.* (2003). However, empirical data on the impact of biomass extraction on soil properties and foliar nutrient contents in montane forest ecosystems of Nepal are extremely rare (Gautam & Mandal 2013; Paudel & Sah 2003). Considering the removal of forest products from CF, it is hypothesized that deterioration of soil physical and chemical properties are more pronounced in CF than in semi-protected natural forest (MF). To test this hypothesis, we compared effects of biomass removal on soil physical properties, chemical properties and foliar nitrogen contents between a CF and a MF in the central mid-hills region of Nepal.

Materials and methods

Study site

The study site was located in Dhulikhel municipality area, the headquarters of Kavrepalanchok district, in central mid-hills region of Nepal (27° 37' N and 85° 33' E), and is 31 km east of Kathmandu (Fig. 1). Kavrepalanchok is one of the pioneer districts in implementing community forestry program in Nepal (Sharma 2000). The Gaukhureshwar community forest (hereafter referred to as CF) and an adjoining semi-protected natural forest (locally known as *Thulo ban*) owned by Dhulikehl municipality (hereafter referred to as MF) were selected for the study. Both the forests share same climatic conditions, topographic features and belong to montane subtropical *Schima-Castonopsis* forest type (Webb & Gautam 2001). Both the sites are located along the northern aspect of the hills with an altitudinal range of 1550 to 1700 m above mean sea level. The slope angle of the study sites varied from 15° to 35° with overall rugged topography.

Historically, the study site had a dense forest till 1933. Afterwards, the forest was exploited gradually. A series of natural calamities viz., earthquake and heavy rainfall also destabilized the forest. Additional pressure by population growth and urbanization led to severe degradation. Apparently, both the CF and MF were subjected to exploitation during 1934 - 1962, however, it is not clear which one of the two forests experienced greater pressure on the resources (Webb & Gautam 2001). Although the forests are classified as CF and MF on the basis of ownership on forest management and utilization, the ultimate right of land ownership of both the forests remains with the Government of Nepal as per Nepal Forest Act 1993.

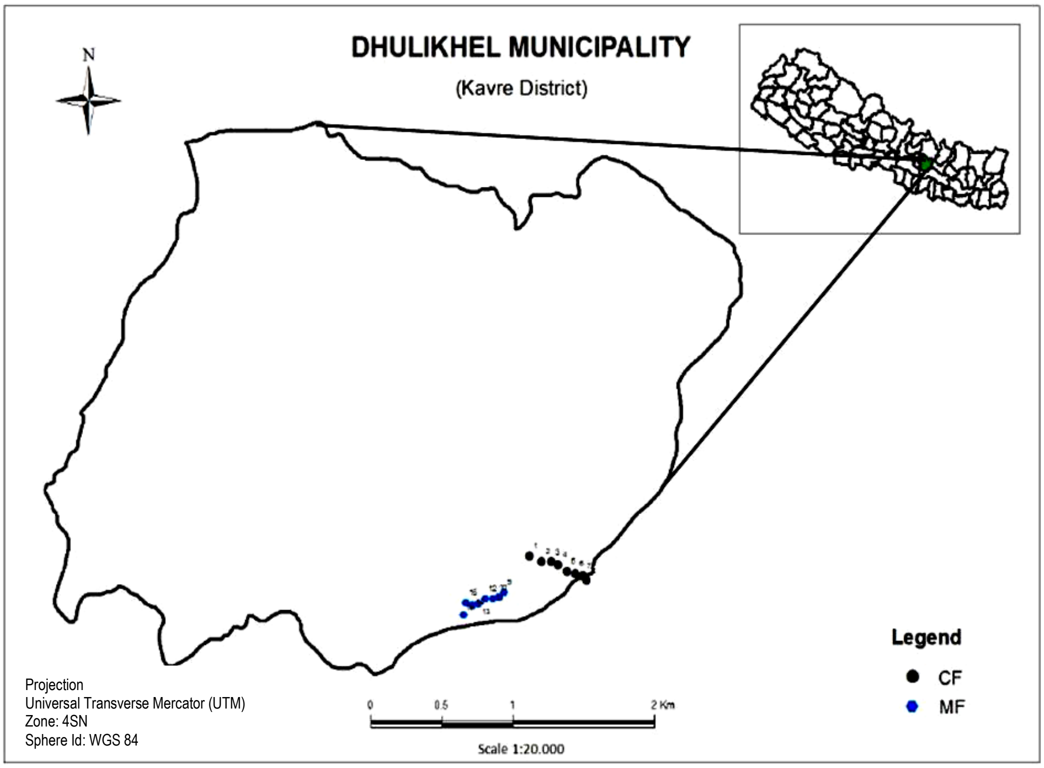

Fig. 1. Location map of the study sites

Gaukhureshwar community forest (CF)

The CF was cleared for grazing pasture in 1981 and only a few trees and bushes were left as remnants. In 1985, the local people made an effort to restore the forest with support from the District Forest Office, Kabhre by enrichment planting with *Pinus roxburghii* Sarg. and promoting natural regeneration. Later on, the District Forest Office, Kabhre formally handed over 21 ha of this forest to the local people by constituting a CFUG in 1992. Subsequently, secondary succession occurred (Webb & Gautam 2001) and *Pinus roxburghii* was replaced by naturally regenerated tree species such as *Castonopsis tribuloides* Sm, *Quercus glauca* Thunb., *Schima wallichii* (DC.) Korth. and *Rhododendron arboretum* Sm. (Baral & Katzensteiner 2009). The stands were about 20 years old in 2007. Now, the CFUG is managing this forest as a community forest and applying silvicultural treatments according to the operational plan (Personal communication with Badri Jangam 2007).

Dhulikhel municipality owned forest (MF)

The forest patch (*Thulo Ban*) in the study area has been protected by Dhulikhel municipality as a municipality owned forest. Since 1962, the MF got naturally reforested and the residents of Dhulikhel city started to protect it to conserve the watershed. After the establishment of Dhulikhel municipality in 1986, the municipality started contributing to the protection of MF by deploying watchmen, (Webb & Gautam 2001).

Geology

The bedrock of the area is mainly composed of metasandstone and siltstone with sub-ordinate amount of phyliite and slate of the Tistung formation (Stocklin & Bhattarai 1977). Current soil development partly takes place on residual soil and colluvial materials (Dahal *et al.* 2005). The parent rock material is mainly composed of phyllites, slates, limestone and shale where the erosion hazards and sediment production are high.

The soil was classified as a Ferralic Cambisol according to IUSS Working Group WRB (2006).

Climate

The summer from June to September is wet, and the winter between November and May is dry. Rainfall is received round the year, although less in winter. The average annual precipitation is 1632 mm and the annual average temperature is 17.4 °C (Fig. 2).

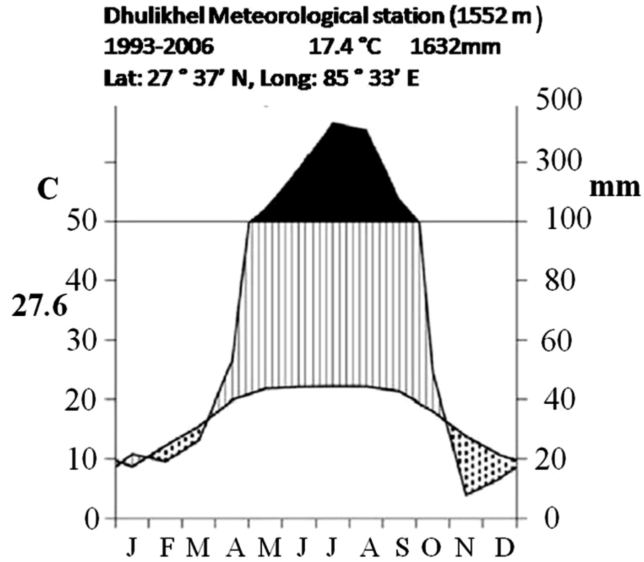

Fig. 2. Climatic diagram of the study sites located at Dhulikhel, Kavre district, Nepal. Data obtained from Department of Meteorology, Government of Nepal.

Data collection

Sampling design

An area of 5 ha in CF where silvicultural operations have been applied and a forest area of 5 ha from MF were selected for soil sampling and forest litter studies in comparable topographic positions during August, 2007. A transect was laid from downhill to uphill for collecting soil samples and carrying out litter sampling in each forest stand (CF and MF). In this transect, survey was done in 8 systematically placed 10 m x 10 m square plots. The sample plots were located at least 50 m apart and at least 20 m into the fragment interior from the edges or roads in each site. Soil and litter sampling was done in these 8 plots in each forest stand.

Forest litter inventory and quantification of amount of biomass extraction

Collection of forest biomass in the CF is undertaken through cleaning, thinning, pruning and litter raking, which are also considered as community forest management activities. The quantity of forest products extracted from the community forest was obtained from the records of CFUG. Forest user group members were interviewed to find out the quantity of leaf/litter extracted from CF and MF. Though collection of forest products in MF is not allowed, some illegal collection of forest products such as dry branches, tree stumps and litter was reported in some plots. However, it was not possible to get the detailed record of illegal collection from the MF. Amount of litter left on the forest floor was measured in 30 cm × 30 cm plots. Quantity of litter collected from the CF was calculated by interviewing the CFUG members.

Soil sampling

In each forest stand (CF and MF), eight sample plots were laid in a systematic way as described above. Pits of size, 50 cm length x 50 cm breadth x 30 cm depth were dug by shovel and soil samples were collected from 0 - 10 cm and 10 - 30 cm depths separately for chemical analysis. Five such representative soil pits were dug in 'W' shape in each of the 8 sample plots (n = 40) in each forest stand for collecting soil samples. Soil profile analysis of each soil pit was done using Munsell color chart (1975) and WRB guideline (2006). All samples were air-dried and passed through a 2-mm sieve for separating 'fine soil' and 'coarse soil'. A sharp edged iron cylinder (height 5 cm and diameter 7 cm) was forced manually into the soil for drawing the samples for bulk density determination in 0 - 10 cm and 10 - 30 cm soil depths separately in each sample plot.

Foliar sample collection

Foliar samples were taken to determine the foliar nutrient content of the two stands. The samples were collected in September i.e. after shoot growth was completed and before leaves began to change color. Five dominant and co-dominant trees were sampled from each sample plot (n = 8 plots* 5 trees/plot = 40). About, 60 to 70 leaves were plucked from these trees. Undamaged, fully expanded, healthy leaves were collected from the midsection of the current season's growth. The leaves were collected in plastic bags and protected from direct sunlight. The bags were labeled with date, sample number and tree location (tree number) and transported to the laboratory.

Litter sample collection

Five litter samples (200 g dry weight) were collected randomly and transported to laboratory for N and C analysis. These samples were collected from the litter loads transported by farmers for using as the animal bedding material.

Collection of other data

Climatic and other meteorological data were collected from the Department of Meteorology, Government of Nepal. Records of the forest management activities and the data related to the amount of forest products harvested/collected were

Table 1. Community forest management activities and quantity of forest products harvested.

Year	Management activities	Forest product extraction		
		Product	Unit*	Quantity
1993	Cleaning	Fuelwood with green foliage	Mg ha^{-1}	3.7
1994	Cleaning	Fuelwood with green foliage	Mg ha^{-1}	2.8
1997	Thinning/pruning	Fuel-wood	m^3	1.2
	(Average thinning intensity = 30 %)	Timber	m^3	0.4
		Foliage	Mg ha^{-1}	0.3
1999	Cleaning	Fuelwood with green foliage	Mg ha^{-1}	6.8
yearly	Litter raking (82 % of the total litter)	Litter	Mg ha^{-1} year^{-1}	3.2

The unit was transformed from local unit to SI unit considering 1 *bhari* = 40 kg for green foliage and fire wood, and 1 *bhari* = 25 kg for litter. Thinning intensity was determined consulting CF operational plan, and amount of litter raking was calculated from house hold survey.

taken from the records of CFUG office and District Forest Office.

Laboratory analysis

Soil bulk density of fine soil was determined following a standard laboratory procedure (ISO 11272 1993). Mineral soil samples were passed through a 2 mm-sieve and air-dried. Soil pH was determined in 1:3 soil suspensions in de-ionized H_2O (for active acidity) and 0.01 M $CaCl_2$ (for potential acidity) using a potentiometeric pH - meter (ÖNORM L 1083).

Total nitrogen contents of soil and foliar samples were determined by a Semi-micro-Kjeldahl analysis. Wet combustion of air-dry soil samples was carried out with H_2SO_4 (98 %) and catalyst containing K_2SO_4 and $CuSO_4$ at 400 °C. Automatic vapour distillation with saturated NaOH and titration of evolved NH_3 using a Kjeltec Auto 2300 (TECATOR) with automatic calculation device was used (ÖNORM L 1082). Total carbon in soil samples was determined by a C/S-Element Analyzer LECO S/C 444 using oven dried samples. Dry combustion at 1400 °C in pure O_2 atmosphere and infrared detection of evolved CO_2 was applied (ÖNORM L 1080). Exchangeable Na, K, Ca, Mg, Mn, Al and Fe in soil were determined by a 1 M Ammonium acetate extract with Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). Similarly, the nutrient (K, Ca, Mg, Cu, S, and P) contents of soil samples were determined in an aqua-regia extract by ICP-OES (Pavlíčková *et al.* 2003).

Cation exchange capacity was measured according to Cu-trien method of Meier & Kahr (1999). 500 mg of the sample were added to 35 ml of de-ionised water and dispersed with an ultrasonic rod. The suspension was then diluted to 50 ml and transferred to a glass beaker. Ten milliliter of the Cu-complex was added under stirring. After 3 minutes of reaction time the suspension was centrifuged at 3750 rpm for 3 min. The supernatant solution was carefully decanted. The extinction was measured at 620 nm in a 10 mm cuvette against water as the blank. The effective CEC was then calculated using equation (1).

$$CEC\ (mmol/100g) = (E_b - E_m) * 100/E_b/2.5 \quad (1)$$

where: Eb = Extinction without clay (blank)

Em = Extinction of the supernatant

2.5 is the correction factor for 500 mg sample.

The proportion of bases on the CEC is the % base saturation. Percent base saturation in soil was calculated using equation (2).

$$\%\ base\ saturation = ((mmol_c\ Ca^{2+} + mmol_c\ Mg^{2+} + mmol_c\ K^{+} + mmol_c\ Na^{+}) / CEC) * 100 \quad (2)$$

Statistical analysis

Mann-Whitney U test was employed to test the differences in soil bulk density, pH, and C and N contents between the two forests, as these parameters were not normally distributed. The total nutrient contents, exchangeable base cations, CEC, % base saturation of the soils and foliar nitrogen content in dominant tree species were subjected to independent-samples T-test to detect the differences between CF and MF. The level of significance used was α = 0.05. SPSS 15 statistical package was used for statistical analysis.

Results

Litter raking was much more prevalent than the other biomass extraction activities in the CF. Cleaning i.e. removal of unwanted shrubs and weeds, and thinning/pruning were the main silvicultural operations done after the forest was handed over to the community. Dead, dying, crooked, malformed and weak trees were preferentially removed in this system. For thinning purpose, on an average, people remove 30 % of pole sized trees and prune the branches up to 50 % of tree height as prescribed in the CF operational plan. Litter raking was free for the users during the winter. Grazing and illegal collection of forest products was completely prohibited. Litter collection takes place every year and was the most dominant form of biomass extraction from the CF. Other forms of extraction took place periodically (Table 1).

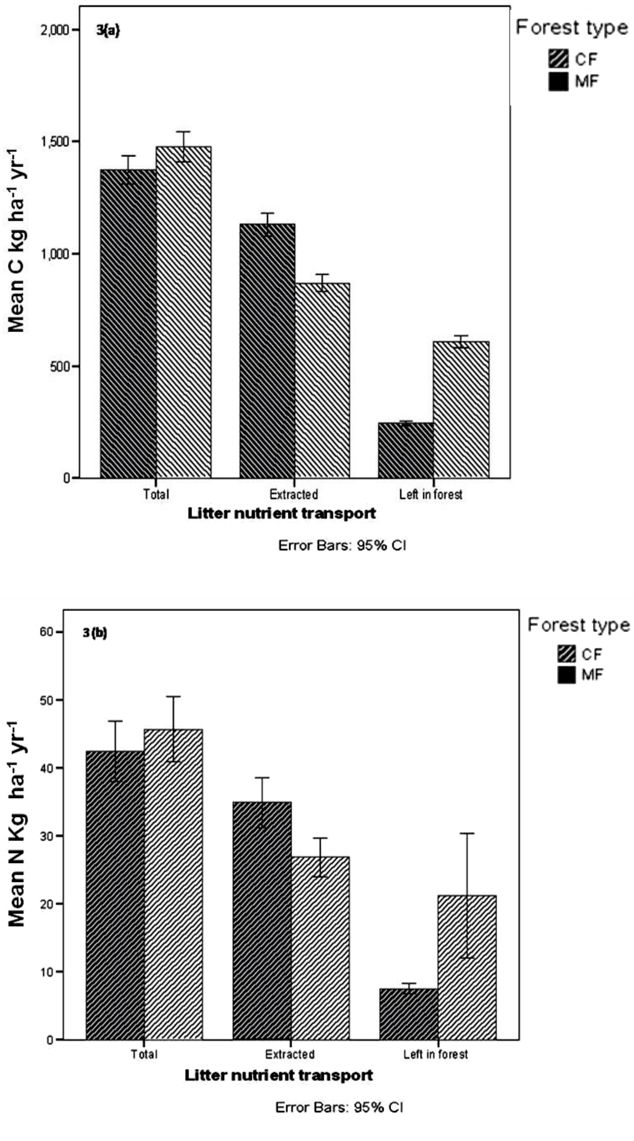

Fig. 3 (a,b). Amounts of C and N in the forest litter transferred by farmers from forest.

The quantity of litter fall on the forest floor was higher in MF (4.1 Mg ha^{-1} annum^{-1}) than CF (3.9 Mg ha^{-1} annum^{-1}). About 82 % of the total litter was transported by forest users from the CF for animal bedding and fertilizing their agricultural farmland (CFUG records). The amount of litter produced in the CF was not adequate to meet the requirements of all the members of CFUG. Therefore, some members enter into the MF illegally for collecting litter. Some people living in the city area also enter illegally into MF for collecting litter and dry wood. They transported 54 % of the total litter (2.3 Mg ha^{-1} year^{-1}) to their home and farmland and 46 % (1.8 Mg ha^{-1} year^{-1}) of total litter was left on the forest floor in MF.

The mean total C content in the forest litterfall was 1373.6 kg ha^{-1} yr^{-1} in CF whereas 1477.9 kg ha^{-1} yr^{-1} in MF. On the other hand, the average annual N content in forest litterfall was 42.4 kg ha^{-1} yr^{-1} in CF and 45.6 kg ha^{-1} yr^{-1} in MF. On the contrary, the total C and N extracted from forest during litter raking was 1130.1 and 34.9 kg ha^{-1} yr^{-1} from CF and 869.3 and 26.8 kg ha^{-1} yr^{-1} from MF respectively. It showed that significantly higher amounts of nutrients (608.5 kg ha^{-1} yr^{-1} and 21.2 kg ha^{-1} yr^{-1} of C and N) were left on the forest floor each year in MF than in CF (243.4 kg ha^{-1} yr^{-1} and 7.5 kg ha^{-1} yr^{-1} of C and N) which can have positive impact on nutrient cycling in the system (Fig. 3).

Soil properties and nutrient stock

Physical properties of soil

The soils in CF were heavily disturbed by erosion and human activities and were characterized by discontinuous horizons. The ‘A’ horizon was up to 5 - 15 cm, and then a B_1 horizon and a B_2 horizon could be distinguished. The soil colour found in CF was pale brown and grayish brown in the ‘A’ horizon; brownish yellow and light yellowish brown in the ‘B_1’ horizon; and reddish yellow and light yellowish brown in the ‘B_2’ horizon. The soil texture of CF was silt loam in ‘A’ and ‘B_1’ horizons and clay loam in ‘B_2’ horizon. On the other hand, the soil of MF was slightly disturbed from the litter raking and fuelwood collection. Three distinct soil horizons A, B_1 and B_2 were recognized at 5 - 15 cm, 15 - 25 cm and > 25 cm, respectively. The soil colour of the ‘A’ horizon was dark brown; B_1 was pale brown and well-structured, and ‘B_2’ was yellow and less structured. The soil texture was sandy clay loam in the ‘A’ horizon, silt loam in the ‘B_1’ horizon, and clay loam in the ‘B_2’ horizon. There was gradual increase of clay content with increasing soil depth (Fig. 4).

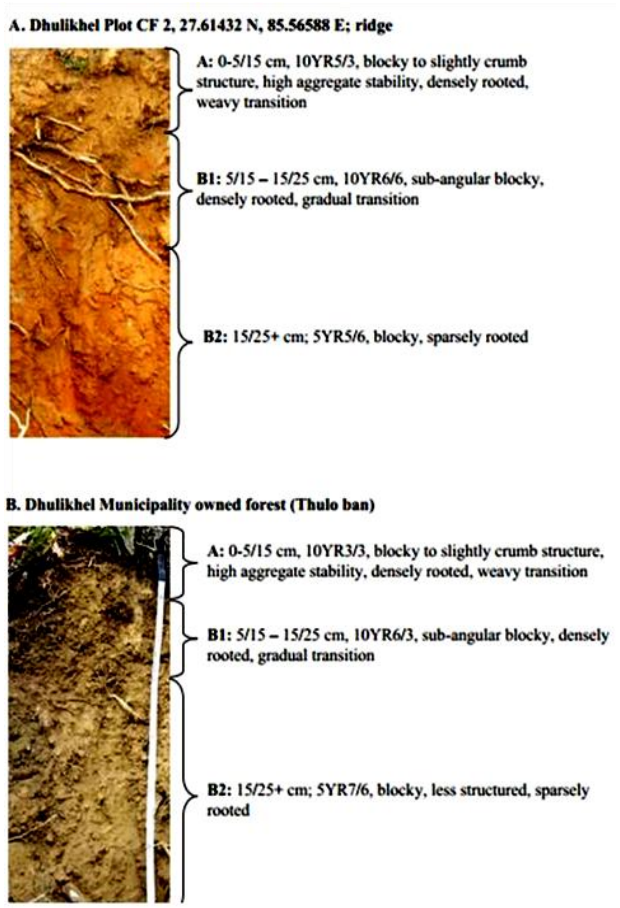

Fig. 4. The soil profiles of the study sites.

Mann-Whitney U test revealed that there was a significant difference (at α = 0.05) in soil bulk density between CF (0.99 g cm^{-3}) and MF (0.61 g cm^{-3}) in the 0 - 10 cm soil layer. However, there was no significant difference in soil bulk density between CF (1.02 g cm^{-3}) and MF (1.01 g cm^{-3}) in the 10 - 30 cm soil layer. There was also a significant difference in bulk density between the two soil layers (0 - 10 cm: 0.61 g cm^{-3} and 10 - 30 cm: 1.01 g cm^{-3}) in MF but no such difference existed between the soil layers (0 - 10 cm: 0.99 g cm^{-3} and 10 - 30 cm: 1.02 g cm^{-3}) in CF (Table 2).

Soil pH, C and N in soil

The soil pH values in both the forests were acidic. The soil pH of the 0 - 10 cm soil layer between CF (4.2) and MF (3.9) differed significantly ($P < 0.05$). Soil C and total N contents of the top 0 - 10 cm and 10 - 30 cm soil layers differed significantly between CF and MF ($P < 0.05$). There was 27.24 g kg^{-1} of C and 1.9 g kg^{-1} of N in 0 - 10 cm soil depth in the CF compared to 50.5 g kg^{-1} of C and 3.2 g kg^{-1} of N in the same soil depth of the MF. But the C/N ratio (ranged from 13.31 to 15.56) in both the soil layers did not differ significantly between CF and MF (Table 3).

Table 2. Soil bulk density at different soil layers in CF and MF.

Forest types	Soil Layer	Bulk density (g cm^{-3})
CF	0 - 10 cm	0.99 (.07)^{a}
	10 - 30 cm	1.00 (.05)
MF	0 - 10 cm	0.61 (.08)^{ab}
	10 - 30 cm	1.01 (.04)^{b}

The value indicated by "a" denotes significant difference between two forest types and the "b" denotes significant difference between soil layers within the forest type in Mann-Whitney U test at α = 0.05. The standard error of corresponding parameter is provided in parenthesis.

Exchangeable cations and base saturation

The concentrations of exchangeable base cations (Ca, Mg, K and Na) in 0 - 10 cm soil depth were higher in MF. The concentrations of exchangeable K, Mg and base cations in 0 - 10 cm soil depth were significantly higher in MF compared to CF ($P < 0.05$). However, there was no significant difference in exchangeable base cations in 10 - 30 cm soil depth between CF and MF except for Mg ($P < 0.05$) (Table 4). Concentrations of exchangeable cations in 0 - 10 cm soil depth, except for Al, were higher in MF than CF. Except for Al, there was a significantly higher amount of cations in 0 - 10 cm soil depth than 10 - 30 cm soil depth in both the forests. CEC was 23.16 and 29.7 mmol$_c$ kg^{-1} in 0 - 10 cm soil depth in CF and MF, respectively. According to Hazelton & Murphy (2007) rating, there was moderate (42.4 %) base saturation in 0 - 10 cm soil depth in MF but low (33.3 %) base saturation in the same soil depth in CF. However, there was low (22.5 %) and very low (17.4 %) base saturation in 10 - 30 cm soil depth in MF and CF, respectively (Table 4).

Foliar nitrogen content of different tree species

Foliar N content in dominant tree species was higher in MF than in CF. Foliar N content was higher in *Castonopsis tribuloides*, followed by *Quercus glauca* and *Schima wallichii* (Fig. 5).

Discussion

The results of this study supported the hypothesis that the biomass removal from the

Table 3. Mean soil pH, C and N contents and C/N ratio in the Community Forest (CF) and MF.

Forest type	Soil layer	pH (H_2O)	pH ($CaCl_2$)	Total C (g kg^{-1})	Total N (g kg^{-1})	C/N ratio
CF	0 - 10 cm	5.1 (0.06)	4.2 (0.03)[a]	27.2 (3.4)[ab]	1.9 (0.21)[ab]	14.1 (0.52)
	10 - 30 cm	5.0 (0.05)	4.1 (0.03)	13.1 (0.9)[b]	1.0 (0.04)[b]	13.3 (0.50)
MF	0 - 10 cm	5.0 (0.06)	3.9 (0.08)	50.6 (7.3)[ab]	3.2 (0.46)[ab]	15.6 (0.26)
	10 - 30 cm	5.1 (0.04)	4.1 (0.04)	19.0 (3.8)[b]	1.2 (0.13)[b]	15.1 (1.2)

The standard error of corresponding parameter is provided in parenthesis. The value indicated by "a" denotes significant difference between two forest types, "b" denotes significant difference between two soil layers within the forest type and "ab" denotes significant difference between forest types and soil layers both in Mann Whitney U test at $\alpha = 0.05$.

Table 4. Soil exchangeable cations and base saturation in CF and MF

Forest type	Soil layer	Na µg g^{-1}	K µg g^{-1}	Ca µg g^{-1}	Mg µg g^{-1}	Mn µg g^{-1}	Al µg g^{-1}	CEC $mmol_c$ kg^{-1}	Base cations $mmol_c$ kg^{-1}	% base saturation
CF	0 - 10 cm	6.0	73.7[a]	44.4	23.2[a]	13.6	13.0	23.2	6.3[a]	33.3
		(0.2)	(9.2)	(7.9)	(4.1)	(2.3)	(1.7)	(3.6)	(1.0)	(7.0)
	10 - 30 cm	5.9	32.2	16.4	9.6[a]	8.6	11.7	17.2	2.7	17.4
		(0.4)	(4.1)	(3.2)	(1.1)	(1.4)	(1.2)	(2.3)	(0.4)	(2.8)
MF	0 - 10 cm	7.3	108.2[a]	96.8	53.6[a]	20.8	10.2	29.7	12.3[a]	42.4
		(0.8)	(7.3)	(34.3)	(5.2)	(3.0)	(1.16)	(2.6)	(1.9)	(5.8)
	10 - 30 cm	5.2	42.7	13.9	14.9[a]	5.7	11.6	16.7	3.2	22.5
		(0.1)	(4.9)	(1.7)	(2.0)	(0.8)	(1.6)	(2.3)	(0.2)	(4.0)

Standard error of the corresponding value is provided in parenthesis
[a] Significant value at $\alpha = 0.05$ in independent samples T-test between CF and MF

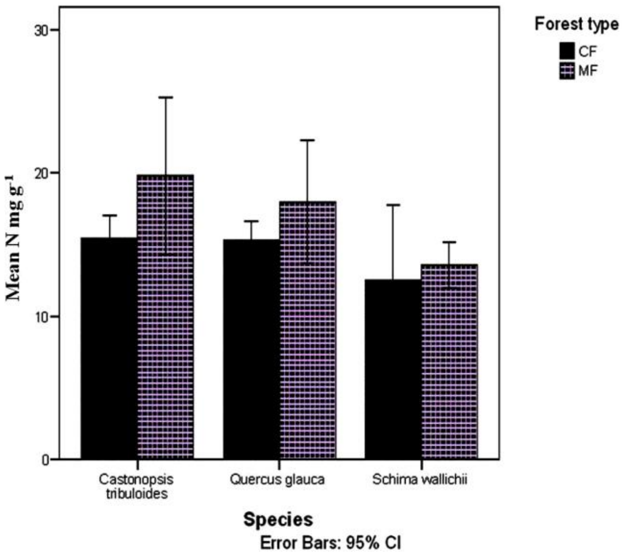

Fig. 5. Foliar nitrogen contents in dominant tree species.

forest ecosystem contributes to the loss of soil nutrients. Although the physical properties of a soil are the results of the nature of soil parent material, relief, climate and vegetation over a period of time (Brady & Weil 2001), the change in any one of these factors influences the soil development process (Anderson 1988). Forest management can change site productivity by altering root growth potential, water infiltration and soil erosion, and water and nutrient availability. As expected, the indicators of soil physical properties (the soil bulk density and the soil texture) were significantly different between the two forest stands under different management regimes. The physical properties of the soil and the state of soil nutrient contents in MF (where less biomass was extracted) showed improvement compared to CF, although both of the forests were heavily exploited in the past. It confirms that the less amount of biomass extraction from the forest improves physical and chemical characteristics of the soil due to reduced loss of top soil and increased supply of nutrients in the form of leaf litter and root biomass (Malla *et al.* 2001).

Soil compaction and associated disturbances reduce and disrupt soil porosity and increase soil bulk density (Gupta *et al.* 2010; Kozlowski 1999).

The rate of recovery of bulk density varies depending on the degree of soil disturbance and soil depth (Rab 2004). In a study by Page-Dumroesse *et al.* (2006), recovery on coarse-textured soils was evident in the surface (0 - 10 cm) soil, but the subsoil (10 - 30 cm depth) exhibited little recovery. A significantly lower bulk density in 0 - 10 cm compared to 10 - 30 cm soil layer in MF and significantly lower bulk density in MF compared to CF in 0 - 10 cm soil layer was observed. It may be due to the lower level of disturbance and higher organic matter accumulation on the ground surface in MF.

A study carried out in China showed that organic C and total N increased rapidly, and was highest in a 17 years old secondary forest. Later on it decreased and gradually remained at a constant level, suggesting that accumulation of organic C and total N in soil occurs mainly in the early successional stage (Jia *et al.* 2005). There was significantly lower organic C and total N in CF than MF, although the former was also a 17 year old successional forest. The lower organic C and total N in CF could be due to the higher rate of litter raking and biomass extraction. Moreover, the higher tree species richness in MF than CF (Baral & Katzensteiner 2009) might have contributed to higher organic C and total N in MF than CF. Kumar *et al.* (2010) reported a positive correlation between tree species richness and soil C, N and P.

Excessive removal of biomass and plant material from the soil causes soil acidification (Hazelton & Murphy 2007). There was a very low CEC in soils of both the forests which indicated the state of very low fertility and susceptibility to soil acidification. The % base saturation and base cations (K and Mg) were significantly higher in MF than in CF at 0 - 10 cm soil depth. This may be due to the extraction of timber in the latter forest that leads to the reduction in base cations (Schulze *et al.* 1996). Rosenberg & Jacobson (2004) also reported that the concentrations of exchangeable Ca and Mg in the organic layer were significantly lower in the repeatedly whole tree thinned plots than in the unthinned-plot. Moreover, litter raking substantially depleted the soil pool of exchangeable base cations (Ca^{2+}, Mg^{2+} and K^{+}) (Hofmeister *et al.* 2008). Soils with CEC < 30 $mmol_c kg^{-1}$ are considered low in fertility and susceptible to soil acidification. In this situation, avoiding whole-tree harvesting can improve the situation substantially for K, but the losses of Ca and Mg will still be significant (Akselsson *et al.* 2007). The significantly higher sulfur content in 0 - 10 cm soil depth in MF may be because of the higher microbial activity in this soil layer with higher organic matter content and lower soil bulk density (Swank *et al.* 1984). The rate of physical and chemical breakdown of organic matter in turn is related to several prevailing biotic and abiotic factors in the forest stand including the detritivore arthropods (Mukhopadhyay *et al.* 2014).

As foliar N content is related to soil N content (Johnson *et al.* 2002), the significantly lower leaf N content in *Castonopsis tribuloides* in CF compared to MF was perhaps due to lower soil N contents in CF than in MF. Foliar N content in *Castonopsis tribuloides*, *Quercus glauca* and *Schima wallichii* was lower in CF than MF. The values of foliar N content found in this study were lower than the values found in eastern hills of Nepal (Subba 1998).

Conclusions

The study showed that biomass extraction from the forest influenced soil bulk density, soil C, N, and the concentrations of exchangeable K, Mg and base cations (P and S) and foliar nitrogen contents of dominant tree species. As there was a tendency to extract higher amount of biomass (litter, branches and timber) from the CF, the soil nutrient contents were lower in CF than MF. The significant improvement of some soil attributes viz., soil bulk density, soil C, N, and some base cations in MF demonstrates the possibility of recuperation of soil properties if the intensity of biomass extraction is reduced. But caution must be taken when extrapolating results in this study to other forests in the central mid-hills of Nepal because of different soil and forest types and the limited sampling size of this study.

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