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Soil Properties in Two Forest Sites in Cox's Bazar, Bangladesh

Md. Akhtaruzzaman[1,*], K. T. Osman[1] and S. M. Sirajul Haque[2]
[1]*Department of Soil Science, University of Chittagong, Chittagong-4331, Bangladesh*
[2]*Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh*

Abstract

Soil samples were collected from three depths (0-10 cm, 10-40 cm and 40-80 cm) of two forest sites including one plantation dominated by teak with some other minor species and another degraded natural forest in Cox's Bazar, Bangladesh to compare their soil properties. Some vegetation parameters were also studied. For this study 10x10 m and 2×2 m quadrats were used for the tree and undergrowth parameters, respectively. Soil samples were also collected from these quadrats. Between the two forest types, the highest levels of organic carbon, total nitrogen, available phosphorus, exchangeable bases and cation exchange capacity (CEC) were found in soils of the plantation. The soils were acidic in nature and exchangeable Al concentrations were low. Teak dominated forest plantation had higher soil fertility index (SFI) than the degraded natural forest site. Steps for reforestation and appropriate protection are needed to improve the situation.

Key Words: Forest plantation, degraded natural forest, soil properties, soil fertility index

Introduction

The area under investigation comprises mostly of low hills of Dupi Tila formation. These hills are of Tertiary sedimentary rocks occurring in stratigraphic succession. The Dupi Tila formation mostly comprises unconsolidated sediments of the late Miocene and pliocene time. The sediments consist mainly of medium sands mixed with clays and silts, locally coarse sands and some gravel. The mottled zone is locally underlain by a concretionary or a plinthitic layer (SRDI 1976). Most soils have developed from sandstones or sandy sediments and the sand fraction of the soil is dominated by quartz, feldspars and mica, while the clay fraction is dominated by kaolinite with minor amounts of illite and vermiculite. Total amount of weatherable minerals is generally less than 10 percent (Huizing 1971). These areas were covered in the past by tropical rain forests and mixed evergreen forests. The natural forests have largely been deforested leaving some remnants here and there. Afterwards, large scale plantations, mostly of teak, were raised by the Forest Department. These forests are also highly disturbed. In this study, soil properties of two forest sites including one plantation dominated by teak with some other minor species and another degraded natural forest in Cox's Bazar, Bangladesh were determined and compared.

Materials and Methods

The sites under study consisted of a forest plantation and a degraded natural forest at Chakaria and Medakacchapia of Cox's Bazar District, Bangladesh (Table 1; Fig. 1). Cox's Bazar has a tropical monsoon climate like other parts of the

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Corresponding author: Md. Akhtaruzzaman

Department of Soil Science, University of Chittagong, Chittagong-4331, Bangladesh
Tel: 880-1711471838, Fax: 880-031-2606014, E-mail: akhtarsoilcu@gmail.com, akhtarcu@yahoo.com

Table 1. General description of locations under study

Forest type Location	Geographic position	Elevation (m) Slope	Tree species
Teak dominated forest plantation Chakaria, Cox's Bazar	21°42′44″N 92°04′52″E	16 Nearly level (0-2%)	*Tectona grandis*, *Syzygium grande*, *S.fruiticosum*, *Dipterocarpus* spp.
Degraded natural forest Medakacchapia, Cox's Bazar	21°37′47″N 92°04′36″E	14 Gentle slope (0-8%)	*Dipterocarpus turbinatus*, *D.alatus*, *D.costatus*, *Hopea odorata*, *Artocarpus chaplasha*, *Albizia procera*

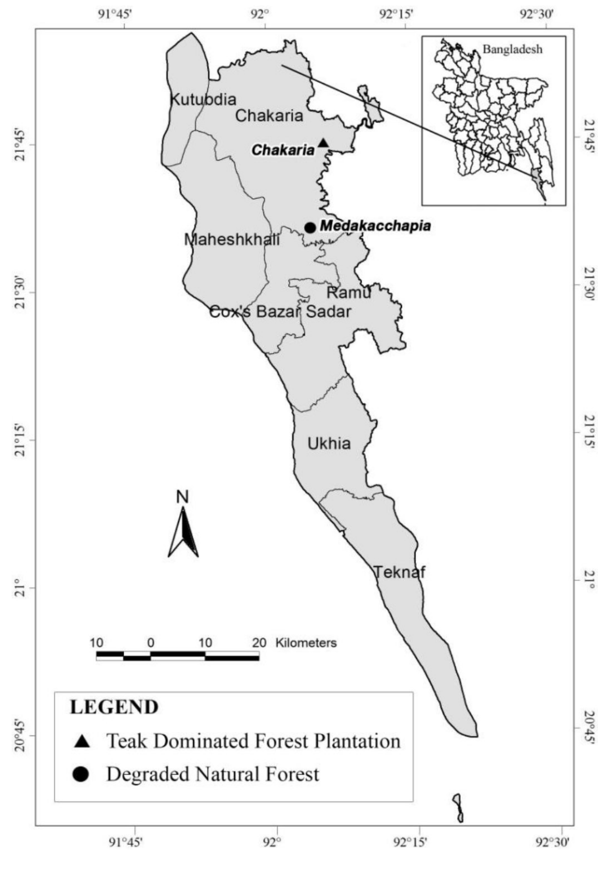

Fig. 1. Map of the study area.

country. The monsoon usually begins in June and ends in October. The mean annual precipitation of 3,627 mm and mean annual temperature of 25.7°C were recorded. Mean relative humidity throughout the year ranged from 70 to 90 % (Wikipedia 2015).

The both forests were composed of some evergreen and some deciduous tree species. The forest plantation was covered mainly with teak (*Tectona grandis*) planted in 1952 with minor proportion of jam (*Syzygium* spp.) and garjan (*Dipterocarpus* spp.). On the other hand, the degraded natural forest site was dominated by *Dipterocarpus* spp. (Table 1). Herbs, shrubs, climbers (vines) were present as undergrowth at both sites. For the study of vegetation, 10x10 m quadrats were laid randomly in the sites. There were 5 quadrats in each site. For undergrowth study, 2x2 m quadrats were selected in the forest types. The number of trees, diameter at breast height and height were determined. Basal area, density and timber volume were estimated. The basal area of a tree and basal area per hectare were also calculated from the following formula given by (Shukla and Chandel 1980):

$$\text{Basal area ha}^{-1} = \frac{\Sigma \frac{\pi}{4} D^2}{\Sigma \text{area of all quadrats}} \times 10{,}000$$

Where, D = Diameter at breast height in cm.

Shannon-Wiener diversity index (H) is computed by using the Shannon-Wiener information index (Shannon-Weaver 1963).

For litter collection, 10 quadrats with 1x1 m were laid in a single forest site. In each site, three soil pits were dug from surface to 80 cm. Pits were of 100x150 cm in lateral dimensions.

Soil samples were collected from three different depths like 0-10 cm (surface), 10-40 cm (middle) and 40-80 cm (bottom) from each pit dug in the quadrats. Soil samples were dried in the air, ground and passed through a 2 mm sieve for physical analysis. Another portion was screened through 0.5 mm sieve for chemical analysis. Particle size distribution of the soils and sediments was determined by hydrometer method (Day 1965). Field moisture content was determined gravimetrically after drying soil samples in an oven at 105°C for 24 hours. Soil pH was measured in soil-water suspension (1:2.5) using a corning glass electrode. Organic carbon and total nitrogen were determined by wet-oxidation method of Walkley-Black (1934) and micro-Kjeldahl method (Jackson 1973), respectively. Cation exchange capacity (CEC) was determined by saturation with 1N ammonium acetate (pH 7.0) and replacement with 1N NaCl solution (Black 1965). Exchangeable calcium and magnesium were determined by EDTA extraction followed by determination in an AAS, and potassium and sodium were determined using a flame photometer (Jackson 1973). Available phosphorus was extracted with Bray and Kurtz reagent-II and determined spectrophotometrically using $SnCl_2$-reduced molybdophosphoric blue colour method (Jackson 1973). The statistical analysis was done by Minitab (1996). The SFI was calculated based on the following equation (Moran et al. 2000):

Soil Fertility Index (SFI)=pH+organic matter (%, dry soil basis)+available P (mg kg^{-1})+exch K ($cmol_c kg^{-1}$)+exch Ca ($cmol_c kg^{-1}$)+exch Mg (cmolckg^{-1})−exch Al (cmolckg^{-1}).

Results

Physical properties of soil

Physical properties of soils in two forest sites under study were shown in Table 2. In the surface soils, silt contents were 13% at degraded forest and 17% at the forest plantation and decreased to 6% and 12% in the bottom layers, respectively. The clay contents were 21% in surface soil of degraded forest and 25% in the forest plantation. In the middle layer clay contents were 33% and 34%, respectively and further increased to 36% and 44%, respectively in the deepest layers. The field moisture contents in the surface soil were 13.06% and 16.66% at degraded forest and planted forest sites, respectively.

The bulk density values for the surface soil were 1.30 g cm^{-3} in planted forest site and 1.35 g cm^{-3} in degraded natural forest site. The other two soil depths of degraded forest site also contained higher values of bulk density. The bulk density showed the increasing trend with depth of at both forest sites (Table 2). Total porosity values were 43% and 45% at top soils in degraded natural forest and forest plantation sites, respectively. In middle and the lowest layer it varied between 41% and 43%. Porosity in soils of the plantation site was higher than that of the degraded natural forest site. Porosity decreased with depths in soils of both sites (Table 2).

Chemical Properties of soil

Soil organic carbon in the surface soil ranged from 1.24% in degraded forest to 1.61% in forest plantation (Table 3). It decreased to 0.16% and 0.22%, respectively in the bottom layers. Total N content at the surface soils ranged from 0.14% (degraded natural forest) to 0.18% (planted forest) while in middle layers it varied between 0.08% and 0.09% in planted forest and degraded natural forest sites, respectively. On the other hand, in the lowest layer, total N varied between 0.04% and 0.05% in degraded natural forest and planted forest sites, respectively. The C: N ratio differed between 8.86 (degraded forest) and 8.94 (teak forest) in surface soils.

In surface soils, available phosphorus contents ranged from 4.34 mg kg^{-1} in degraded forest to 9.17 mg kg^{-1} at planted forest site (Table 3). The soils at three depths of the plantation site had higher contents of available phosphorus as compared to the degraded forest site but significantly higher value was observed at soils of surface and middle layers of the two sites. The pH_{H2O} in surface soils ranged

Table 2. Soil physical properties in forest plantation and degraded natural forest sites

Soil physical parameters	Soil depth (cm)	Forest plantation	Degraded natural forest
Silt (%)	0-10	$17^a \pm 4.51$	$13^b \pm 3.00$
	10-40	$20^a \pm 2.31$	$11^b \pm 2.57$
	40-80	$12^a \pm 1.80$	$6^a \pm 2.00$
Clay (%)	0-10	$25^a \pm 5.00$	$21^a \pm 1.00$
	10-40	$33^a \pm 7.00$	$34^b \pm 3.00$
	40-80	$44^a \pm 5.00$	$36^b \pm 1.00$
Field moisture (%)	0-10	$16.66^a \pm 2.6$	$13.06^a \pm 3.2$
	10-40	$17.48^a \pm 1.4$	$18.00^a \pm 1.1$
	40-80	$18.69^a \pm 3.8$	$14.71^a \pm 2.6$
Bulk density (g cm^{-3})	0-10	$1.30^a \pm 0.10$	$1.35^a \pm 0.15$
	10-40	$1.44^a \pm 0.10$	$1.45^b \pm 0.15$
	40-80	$1.46^a \pm 0.20$	$1.50^a \pm 0.10$
Total porosity (%)	0-10	$45^a \pm 0.7$	$43^a \pm 1.2$
	10-40	$41^a \pm 1.5$	$43^a \pm 1.7$
	40-80	$40^a \pm 2.3$	$40^a \pm 1.9$

Mean±standard deviation. Values with different lowercase (a−b) letters are significantly different in the same soil layers at different land-use systems ($p < 0.05$).

Table 3. Soil chemical properties in forest plantation and degraded natural forest sites

Soil chemical parameters	Soil depth (cm)	Forest plantation	Degraded natural forest
Organic C (%)	0-10	$1.61^a \pm 0.72$	$1.24^b \pm 0.14$
	10-40	$0.41^a \pm 0.30$	$0.51^a \pm 0.10$
	40-80	$0.22^a \pm 0.10$	$0.16^a \pm 0.13$
Total N (%)	0-10	$0.18^a \pm 0.06$	$0.14^b \pm 0.10$
	10-40	$0.08^a \pm 0.05$	$0.09^b \pm 0.01$
	40-80	$0.05^a \pm 0.05$	$0.04^a \pm 0.03$
C/N ratio	0-10	$8.94^a \pm 1.33$	$8.86^a \pm 0.54$
	10-40	$5.13^a \pm 0.48$	$5.67^a \pm 1.20$
	40-80	$4.40^a \pm 0.29$	$4.00^a \pm 0.57$
Available P (mg kg^{-1})	0-10	$9.17^a \pm 0.13$	$4.34^b \pm 0.25$
	10-40	$1.18^a \pm 0.64$	$1.10^b \pm 0.52$
	40-80	$0.65^a \pm 0.45$	$0.45^a \pm 0.60$
pH_{H2O}	0-10	$5.40^a \pm 0.40$	$5.36^a \pm 0.92$
	10-40	$4.64^a \pm 0.87$	$4.24^a \pm 0.53$
	40-80	$4.43^a \pm 0.95$	$4.11^a \pm 0.61$
pH_{KCl}	0-10	$4.71^a \pm 0.53$	$4.62^a \pm 0.88$
	10-40	$3.50^a \pm 0.89$	$3.38^a \pm 1.43$
	40-80	$3.63^a \pm 0.26$	$3.48^a \pm 0.74$
Total exchangeable bases ($cmol_c kg^{-1}$)	0-10	$2.89^a \pm 0.64$	$2.44^b \pm 0.40$
	10-40	$1.18^a \pm 0.32$	$0.94^a \pm 0.41$
	40-80	$1.17^a \pm 0.61$	$0.71^a \pm 0.37$
Cation exchange capacity ($cmol_c kg^{-1}$)	0-10	$13.07^a \pm 1.67$	$10.29^a \pm 0.43$
	10-40	$11.05^a \pm 0.53$	$10.17^b \pm 1.88$
	40-80	$12.97^a \pm 0.52$	$8.33^a \pm 1.26$

Mean ± standard deviation. Values with different lowercase (a−b) letters are significantly different in the same soil layers at different land-use systems ($p < 0.05$).

from 5.36 to 5.40 in degraded forest and planted forest sites, respectively (Table 3). In middle depths, pH_{H2O} varied between 4.24 and 4.64 and in bottom soils between 4.11 and 4.43. On the other hand, pH_{KCl} in the surface soils was found between 4. 62 and 4.71. In middle and lower depths, pH_{KCl} ranged within 3.38 and 3.50 as well as 3.48 and 3.63, respectively.

Total exchangeable bases (TEB) in the surface soils ranged from 2.44 $cmol_c kg^{-1}$ to 2.89 $cmol_c kg^{-1}$ in degraded forest and teak planted forest sites, respectively. In middle and bottom soils exchangeable bases varied between 0.94 $cmol_c kg^{-1}$ (degraded forest) and 1.18 $cmol_c kg^{-1}$ (planted forest) as well as 0.71 $cmol_c kg^{-1}$ (degraded forest) and 1.17 $cmol_c kg^{-1}$ (planted forest), respectively. The degraded forest soils had the lower contents of TEB as compared to the teak plantation forest soils. Total exchangeable bases were found higher at surface soils in both sites under study and decreased with depth. Significant difference in TEB was observed only in surface soils for the two forest types.

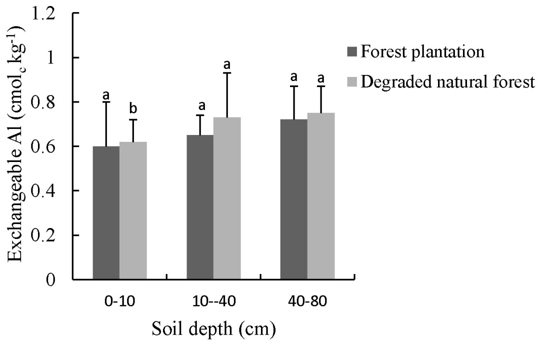

Fig. 2. Exchangeable Al of soils in forest plantation and degraded natural forest sites.

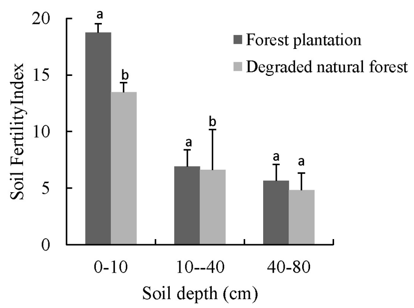

Fig. 3. Soil Fertility Index (SFI) in forest plantation and degraded natural forest sites.

The cation exchange capacity (CEC) at the surface soils was between 10.29 $cmol_c kg^{-1}$ in degraded forest and 13.07 $cmol_c kg^{-1}$ in plantation forest. CEC was lower in all depths under the degraded forest site than in the plantation site and significant variation was observed only at middle layers of both sites. Plantation forest type showed the lower contents of exchangeable Al in three depths in comparison to other degraded forest type (Fig. 2). Exchangeable Al was observed increased with soil depth of both sites. Only surface soils of the two studied sites showed the significant variation. Soil Fertility Index (SFI) for forest plantation and degraded forest was shown in Fig. 3. The planted forest had the higher SFI values in all the three depths compared to degraded forest site. Higher SFI were found in surface soils than that of other two (middle and bottom) layers and significant variation was observed in soils of surface and middle layers of the studied forest types.

Vegetation parameters

Results of vegetation composition and diversity were given in Table 4. In context of overstory layer, the planted forest site had 2.0 times more tree individuals than the degraded forest site under study. On the contrary, tree height, diameter at breast height (DBH), basal area, diversity index and species richness of tree species in degraded natural forest site were higher than in teak forest sites. Tree height and DBH varied significantly between the two forest sites (Table 4). The parameters of undergrowth layer (number of undergrowth species, species richness, and diversity index) in degraded natural forest site were found higher than in planted forest site (Table 4). The invasive undergrowth species like *Chromolaema odorata* (assam pata), *Eupatorium odoratum* (assam lata), *Diplazium esculentum* (dekhi shak), *Melastoma malabathricum* (bantejpata), *lantana camara* (chotra), *Mimosa pudica* (lazzaboti) etc. are abundant in the open areas of degraded natural forest site. A higher amount of litterfall was recorded in soils under teak plantation site than in soils under the degraded natural forest site.

Table 4. Values of vegetation parameters in forest plantation and degraded natural forest sites

Vegetation parameters	Forest plantation	Degraded natural forest
Overstory layer		
No. of trees ha^{-1}	$375^a \pm 86.6$	$183^a \pm 14.43$
Tree height (m)	$16.00^a \pm 4.88$	$24.14^b \pm 6.96$
Diameter at breast height (cm)	$38^a \pm 3.39$	$67.67^b \pm 2.84$
Basal area(m^2 ha^{-1})	$42.53^a \pm 2.49$	$66.47^a \pm 3.20$
Diversity index (H)	$0.74^a \pm 0.013$	$1.14^a \pm 0.17$
Species richness	$4^a \pm 0.70$	$6^a \pm 0.35$
Undergrowth layer		
No. of undergrowth ha^{-1}	$31{,}667^a \pm 7{,}806$	$31{,}841^a \pm 6{,}063$
Species richness	$17^a \pm 4.15$	$21^a \pm 6.20$
Diversity index (H)	$1.59^a \pm 4.07$	$1.85^a \pm 7.18$
Litterfall (kg ha^{-1})	$1{,}417^a \pm 160.7$	$1{,}367^a \pm 252.0$

Mean±standard deviation. Values with different lowercase (a−b) letters are significantly different in the same soil layers at different land-use systems ($p < 0.05$).

Discussion

Physical properties of soil

Many researchers (Duiker et al. 2003; Celik, 2005; Gol and Dengiz 2008) reported that soil aggregates are positively correlated with soil organic matter. Loss of organic matter by erosion deteriorates soil aggregates and finally the finer particles are either lost by erosion or leached downward making texture of the surface soil coarser. The forest plantation soil was relatively finer because the natural forest was more disturbed by human activity. In forest sites under study, clay content increased with depth with concomitant increase in moisture content. Similar results were also reported by Gupta et al. (2010).

Moisture content was also comparatively higher in soils under the forest plantation might be due to higher contents of organic matter and clay.

Forest degradation might have caused higher loss of organic matter accumulation on the soil surface, soil aggregation and increase bulk density. Han et al. (2010) reported an increase in bulk density with depth in some other types of soils. Bulk density is closely related to soil organic matter (Perie and Ouimet 2008). It is well documented that organic matter increases soil porosity with decreasing soil bulk density because porosity is inversely related to bulk density (Meng et al. 2005; Tejada et al. 2008; 2009).

Soil disturbance may cause soil compaction and Weidelt (1996) observed that soil compaction may be likely to hamper seed germination and establishment of dipterocarp seedlings.

Chemical properties of soil

Higher content of organic carbon in the forest plantation was probably related to higher litterfall. In the degraded forest site, lower litterfall and removal of organic matter by erosion can be the possible reasons of lower organic carbon.

The values of organic carbon in the present study are similar to the values recorded by Chowdhury et al. (2007) in mixed forests of Chittagong Hill Tracts. Optimum climatic condition in the study area promotes higher decomposition of organic matter and loss of organic carbon. Lal (1987) reported that high temperature and humidity of the tropical region result in rapid decomposition of organic matter. Chen and Li (2013) found that human disturbance in the forest decreased soil carbon. It is known that tropical soils are composed of low activity clays (kaolinite) and have relatively low organic matter concentrations, low pH values and abundant Fe-oxides (Rieuwerts 2007). Soil N is supposed to be the most limiting nutrient in a majority of ecosystems (Fenn et al. 1998). Higher amount of total N in the forest plantation soil was due to higher content of organic matter content. The variation in C: N ratio was greatly influenced by the vegetation type and composition (Fisher and Binkley 2000) and climatic condition (Callesen 2007). Cote et al. (2000) concluded that both organic C and N were significantly affected by the factors such as stand type, stand age, and the interaction between age, species composition, and soil properties. Higher contents of available phosphorus in teak plantation forest might be due to higher content of organic matter in soil. Gupta and Sharma (2008) also reported that organic C and P were positively correlated because these parameters were closely related with soil humus.

The soils under study were low in available phosphorus. Similar observation was also reported by SRDI (2002) and Chowdhury et al. (2007). Low pH and higher contents of sesquioxides, and low P containing minerals in the parent materials were the causes of low available phosphorus (Soromessa et al. 2004; Uzoho and Oti 2004).

The variation in soil pH might be linked to the status of base cations in soil. The soils were, however, acidic in both sites. These soils are highly weathered, leached, and drained. These findings are supported by the works of other investigators (SRDI 1976; CERDI 1983; Islam et al. 2006).

Relatively lower concentrations of total exchangeable bases in the degraded forest soils indicated that removal of basic cations from the soil to the greater extent. Higher contents of base cations (Ca, Mg, and K) in teak leaf litter have been found under naturally growing teak forests (Yadav and Sharma 1968) and teak plantations (Singh et al. 1985) which might have contributed to the higher pH of teak dominated plantation soil. Boley et al. (2009) also found higher concentrations of Ca in the teak plantations over undisturbed forests which play the vital role in increasing soil pH. These findings need more study in future.

In this study, higher CEC was observed in soils of teak forest. The variation of CEC is linked with nature and amount of organic matter, types of clay minerals and pH in soil (Bortoluzzi et al. 2006; Abdu et al. 2008; Zhang et al. 2013).

Exchangeable Al content in soil is closely related to soil pH (Mladkova et al. 2004) and clay type (Shade 2003; Hattori et al. 2005; Rodgers 2005) and weathering stage of soil (Tanskanen 2006).

Exchangeable Al with the value of 1 $cmol_c\ kg^{-1}$ in soil solution are considered as toxic level, which causes adverse effects to plant growth (Amacher et al. 2007). However, exchangeable Al concentration in all soil depths of the sites under study was below the above toxic value.

The higher soil fertility index of teak plantation site was associated with higher amount of organic matter. The Reasons for low soil fertility at degraded natural forest site could be explained by the loss of litter influx after canopy removal, accelerated soil erosion, rapid organic matter decomposition and nutrient mineralization in soil. A decline in SFI was also recorded with increasing soil depth. The result was similar to the other findings reported by Lu et al. (2002) and Akbar et al. (2010).

Vegetation parameters

Higher number of tree species in teak planted forest might be related to more protection and the plantation programme in the site. Conversely, in the natural forest, illegal felling reduces the number of trees. In degraded natural forest, ages of the native tree species were more than the other plantation site. Tree height and DBH of tree species is directly related to the age of trees.

However, lower diversity in a forest could be due to the lower rate of evaluation and diversification of communities and severity in the environment (Connell and Oris 1964). Shukla et al. (2014) reported that Shannon-Wiener index of a reserve forest in eastern Himalayas in India was 4.77. Brown et al. (2015) reported that clear-felling created a 리 ush of vigorous plant growth, this was not long-lasting, and the end result was reduced plant biodiversity.

The opening of the canopy by illegal removal of trees in the degraded forest forest stands promoted the growth of herbs, shrubs, grasses or vines as undergrowth. Undergrowth is scarce in teak forests and it is suggested that teak suppresses undergrowth (Boley et al. 2009; Carle et al. 2009).

The possible reason of higher litter accumulation in planted forest was the higher number of teak plantation which favoured more litterfall than that of degraded natural forest. The changes in the quantity of total litter fall are attributed to variations in the age, density and locality conditions (Hosur and Dasog 1995). Previous studies, however, suggested that stand age is a key factor affecting litterfall (Celentano et al. 2011). Gazell et al. (2012) reported that the tree species richness probably play an effective role on litterfall production, when forest becomes more mature. The amount of litter production depends mainly on plant species, climate, soil fertility, vegetation type, land use type and time (Fernandes et al. 1997).

Conclusions

Physical and chemical properties of soil were studied and compared between two forest types including one mixed plantation dominated by teak and a degraded natural forest. Vegetation parameters were also assessed. It was found that the plantation soil was relatively more fertile despite disturbances in both the sites. The degraded natural forest was more eroded due to higher interferences. The degradation of soil and forest resources are likely to increase if human disturbances continue. Some immediate steps such as reforestation and appropriate protection should therefore be required.

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