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Plant diversity and soil characteristics of *Shorea robusta* and *Castanopsis hystrix* forests and slash and burn habitats of Arun Valley, Eastern Nepal

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Abstract

Arun valley is under the influence of broad-leaved *Shorea robusta* forests, *Schima wallichii* & *Castanopsis hystrix* forests, and *Castanopsis hystrix*, *Eurya accuminata*, *Quercus lamellosa* and *Rhododendron arboreum* forests respectively at tropical, subtropical and temperate zone. Of the total 184 plant species observed, 137 species were recorded from *Shorea robusta* forest site, 64 species from slash and burn site and 42 species from *Castanopsis hystrix* forest site. Thus, a diversity (species richness) remained the highest (137) in *Shorea robusta* forest site. Maximum âw diversity (1.71) and Simpson's diversity index (0.91) were obtained in *Shorea robusta* forest site followed by slash and burn site and *Castanopsis hystrix* forest site. Sandy loam soil texture was common while loam-sandy loam was observed in *Shorea robusta* forests. Concentration of Nitrogen (0.281 - 0.438 %) was high in slash and burn site where as the value (0.112–0.127%) was lower in *Shorea robusta* forest site. Soil was slightly acidic (pH 5.78 ± 1.28) and fertile (OM 11.67 ± 7.42) in all the sites.
***Keywords**:* Plant diversity, soil pH, *Castanopsis hystrix* forest, Slash and Burn, Arun valley

INTRODUCTION

Nepal, where the terrain is hilly and mountainous and soils are developed from micaceous parent material (Vetaas, 2000); soil erosion and soil fertility are critical issues with respect to sustainable agriculture and forest management. The manner in which soils are used and managed has marked impacts on productivity and sustainability of forests, which ultimately influences biodiversity. Sustainability of forest biodiversity focuses on the quality of soil resources and the relationship that exists between its use, management and the environment (Larson & Pierce 1994). Lack of vegetation cover intensifies erosion through structural weakness and an absence of armoring of their soil surface (Baral *et al.* 2000). Therefore, the temperament of vegetation always has some bearing on the nature of the soil and *vice–versa* (Eyre 1963).

Vegetation has long been recognized as an important means of controlling erosion (Morgan 1986) and binding the soil into a resistant root mat and decreasing the erosive energy of flowing water by reducing its velocity (Striffler 1979). Particularly, the trees, upper stratum of multistoried forest vegetation, play an important role in the amelioration of soils under forestry and agricultural land use systems through the regular supply of organic matter and essential nutrients released from decomposed leaf and root biomass (Rhoades 1997).

While, the vegetation of Arun valley is largely disturbed by accelerating anthropogenic activities such as grazing, felling, encroachment, habitat fragmentation, firing, slash and burn, land clearing, relegation of natural vegetation and plantation of commercial crops, etc.; natural disasters: flooding, soil erosion, etc. are the common disturbance regimes (Kunwar 2000; Chaudhary & Kunwar 2002). The problem with the chronic form of forest disturbance is that plant species or ecosystems often do not get time to recover (Singh 1998; Kunwar & Sharma, 2004). In this regard, study of a and â diversity components can be the useful means for measuring and monitoring the effects of anthropogenic disturbance regimes (Halffter 1998). Though the different forest types, and slash and burn practices offer a good promise in the tract but the intimate knowledge about the nature and property of the soil supporting biodiversity, vegetation and traditional agroforestry practices is very meager. The information given in this paper, therefore, aims to understand some important characteristics of the soil supporting to different forests and slash and burn practices at Arun valley, eastern Nepal. It also deals with diversity of vegetation in relation to soil characteristics.

MATERIALS AND METHODS

Study site

The study area is located in the Arun valley, stretching from 86°45’ to 87°34’E longitude, 26°25’ to 27°55’ N latitude and 450 – 2620 msl altitude. The particular sites selected for study were *Shorea robusta* forests (SR) – at Hookse, Satighat, Kartikeghat, and Bumlingtar in the lower Arun valley that began from Arun river bank (450 - 850 m); *Castanopsis hystrix* forests (CH) - at Chichila, Mudhe, Num, Seduwa and Tashigaun (1570 - 2200 m); and slashed and burnt habitats (SB) – at Chichila-Diding, Mudhe and Tamku (1500 - 2620 m). The climate ranges from tropical to temperate and the average monthly temperature is 1.8°-28.5° C. Arun valley falls in the Eastern Himalayan regime where the monsoons starts early and lasts longer. Soil is brown podzolic and acidic in nature (Shrestha 1989).

Quantitative analysis

Fieldwork was carried out during the period 1997 - 1999. A total of 172 square quadrat plots (each plot measuring 20 m ´ 20 m) were studied comprising 62 plots in SR site, 60 in CH site and 50 in SB site. Only the tree species with >10 cm DBH (diameter at breast height) at 1.37 m from the ground and height >1.37 m), saplings (DBH <10 cm and height <1.37 m) and seedlings (DBH= 0 and height <1.37 m) (West *et al.,* 1981; Vetaas, 2000) were identified and counted.

Diversity analysis

Simpson’s diversity index (D) was analyzed following Simpson (1949). The â diversity was calculated following Whittaker (1972), and Colwell and Coddington (1994). Similarity index (Community coefficient) was calculated applying Sorenson’s index modified by Gregsmith (1964).

D = “ pi^2

Where, D = Simpson’s diversity index,

pi = Proportion of individuals of the i^{th} species

âw = (S/Sc) – 1

Where, âw = Whittaker’s Beta diversity,

S = Total number of species

Sc = The mean species richness

$$\hat{a}cc = \frac{(Sj + Sk - 2Vjk) \times 100}{(Sj + Sk - Vjk)}$$

Where, âcc = Colwell and Coddington’s Beta diversity

Sj and Sk are the number of species in sample plot j and k respectively

Vjk = Number of species in common between the two plots

IS = 2C/(A+B)

Where, IS = Index of Similarity,

C = Number of common species in both stands,

B = Number of species in one stand,

A = Number of species in another stand

Soil analysis

About one kg soil samples from four corners of each plot at the depth of 15cm were collected by following Tribedi & Goel (1984). The samples were blended homogenously, packed tightly in a polythene bag, and preceded for physiochemical analysis following (PCARR, 1980) in research laboratory of Central Department of Botany (CDB), Tribhuvan University and the Soil Division of Nepal Agricultural Research Council (NARC), Khumaltar, Nepal. Correlation analysis was done following Bailey (1995).

RESULTS

Vegetation composition

Forests at lower elevation of Arun valley are mainly dominated by *Shorea robusta* as upper canopy cover. However, its dominance gradually decline with increasing elevation and then dominated by *Schima wallichii* and *Castanopsis hystrix*. As given in Table-1 the IVI found at SR forest site was led by *Shorea robusta* (138.24) followed by *Schima wallichii* (28.39). The highest value of IVI (183.29) was recorded that of *Castanopsis hystrix* in CH forest site. *Castanopsis hystrix* also remained frequent in SB site where its IVI value was 155.42 followed by *Eurya accuminata* 101.74 (**Table 1**).

Table.1: Top five dominant tree species based on IVI value

Name of species	SR site	SB site	CH site	Total IVI	Av. IVI
Castanopsis hystrix	-	155.42	183.29	338.71	112.9
Shorea robusta	138.24	-	-	138.24	46.08
Eurya accuminata	-	101.74	33.91	105.65	35.21
Schima wallichii	28.39	-	-	28.39	9.46
Lagerstroemia parviflora	22.52	-	-	22.52	7.50
Boehmeria platyphylla	-	19.15	-	19.15	6.38
Lyonia ovalifolia	-	13.83	-	13.83	4.61
Viburnum erubescense	-	-	13.45	13.45	4.48
Holoptelia integrifolia	13.42	-	-	13.42	4.47
Castanopsis tribuloides	-	-	12.36	12.36	4.12
Quercus lamellosa	-	-	12.28	12.28	4.09
Terminalia alata	10.21	-	-	10.21	3.40
Alnus nepalensis	-	6.10	-	6.10	2.03

Of total 184 plant species observed, 137 were recorded from SR site, 64 from SB site and 42 from CH site. Therefore, diversity (species richness) remained the highest in SR site. Maximum âw diversity and Simpson's diversity index (D) were obtained in SR site followed by SB site and CH site (**Table 2**).

Table. 2. Diversity indices of different sites

Diversity indices/sites	SR site	CH site	SB site
a	137	42	64
âw	1.71	0.51	0.79
D	0.91	0.57	0.60

Highest value of âcc diversity was found between SR site and CH site and the least between CH and SB sites, i.e. SR and CH sites were heterogeneous while the CH and SB sites were homogeneous. Invariably, all the sites of the present investigation showed remarkable degree of dissimilarity in their plant species composition and structure (**Table 3)**.

Table. 3. Similarity index and beta diversity (âcc) between different sites

Sites	**SR site**	**CH site**	**SB site**
SR Forest site	-	0.111	0.169
CH Forest site	94.08*	-	67.5*
SB site	90.76*	0.490	-

* âcc - Beta diversity value, Colwell and Coddington (1994)

Soil physio-chemical properties

Physico-chemical characters of soils in all three-survey sites are summarized in **Table 4**. The soil texture was sandy loam (sand, silt and clay, 49-61%, 27-37% and 6-19% respectively). The percentage of sand and silt increases at higher altitude sites. The soil at SR site was loamier than other two sites.

Table. 4. Physicochemical properties of soil

Soil parameters/Habitat	**SR site**	**CH site**	**SB site**
Physical properties			
Soil Texture			
Sand (%)	49.88 – 59.57	61.41 – 63.90	50.03 – 64.03
Silt (%)	27.81 – 34.89	28.29 – 29.80	28.73 – 36.73
Clay (%)	12.62 – 18.89	06.46 –0 8.22	06.60 – 09.29
Chemical properties			
N (%)	0.112 – 0.127	0.280 – 0.400	0.281 – 0.438
P (Kg/ha)	97.62 – 225.00	61.56 – 70.36	76.62 – 112.44
K (Kg/ha)	272.62 – 436.81	352.80 – 471.75	266.33 – 425.40
pH	04.10 – 04.32	06.74 – 06.90	05.82 – 0 6.81
OM %	03.14 –03.15	14.90 – 18.45	12.29 – 18.11

Concentration of all chemical components of soil decreased with increase in altitude excepting that of Phosphorus, which showed the significant reverse trend. Concentration of Nitrogen (0.281 - 0.438 %) was high in SB site where as low in SR site (0.112–0.127%). Similarly, the concentration of Phosphorus (97.62–225.00) kg/ha was high in SR site and low (61.51–70.36) kg/ha in CH site. The CH site was richer in bearing the concentration of Potassium (352.80–471.75) kg/ha.

Correlation analysis

Nitrogen attributed less significant relation with potassium ($r < 0.323$) and silt content ($r < -0.077$). It revealed significant positive relation with soil organic matter ($r < 0.965$) while negative relation with phosphorus ($r < -0.934$) and clay texture. In addition, it showed significant negative relation with biodiversity indices. Very contrasting relation was obtained between nitrogen and pH. Phosphorus contributed to retain the significant negative relationship with other soil characters except with silt and clay. The clear strong positive relation was rendered between Phosphorus and biodiversity indices. Sandy soil texture played quite negative relation with biodiversity indices whereas clay with biodiversity indices was reversing (**Table 5**). Value less than 0.5 were considered as insignificant, hence not interpreted.

Table. 5 Correlation analysis between soil characters and biodiversity indices

	P	**K**	**PH**	**OM**	**Sand**	**Silt**	**Clay**	**α**	**âw**	**D**
N	- 0.934	-	0.967	0.965	0.673	-	- 0.995	- 0.957	- 0.956	- 0.999
P		- 0.642	- 0.993	- 0.995	- 0.890	-	0.973	0.997	0.997	0.930
K			0.553	0.558	0.917	- 0.967	-	- 0.583	- 0.585	-
PH				0.999	0.839	-	- 0.992	- 0.999	- 0.999	- 0.965
OM					0.842	-	-0.991	- 0.999	- 0.999	- 0.963
Sand						- 0.786	-0.767	- 0.859	- 0.860	- 0.667
Silt							-	-	-	-
Clay								0.987	0.987	0.989
α									0.999	0.954
â										0.953
D										

DISCUSSION

Plant diversity

Lower Arun valley is characterized with lush forests of *Shorea robusta* (Sal). The highest IVI value of Sal at SR site indicated that all the available resources are being utilized by the Sal. However, Sal species gradually declined above 1000 m. It is mainly confined at low land Terai (Giri *et al.* 1999) and luxuriantly grown within 1000 m (Chaudhary *et al.* 1999; Kunwar & Chaudhary 2004) in Arun valley. It also confined to the ridges, spurs and on the southern aspects of the valley. The occurrence of Sal supplemented with palms, cycads, tree ferns, bananas, *Pandanus* etc. characterize the lower belt of Arun valley (Chaudhary & Kunwar 2002).

With increasing elevation, the domination of *Shorea robusta* and *Schima wallichii* gradually declined, and appeared the *Castanopsis hystrix* and *Eurya acuminata* both possessing the highest share of IVI. Latter two species are the most frequent in upper subtropical and temperate zones of Arun valley (Carpenter 2001; Shrestha 1989). In CH site, trees of *Schima wallichii* were associated with *Castanopsis indica* at lower elevation and while at the upper elevation i.e. closure to temperate zone *C. tribuloides* combined with *C. hystrix*. The influence of *Quercus lamellosa* and *Rhododendron arboreum* was noticed only at temperate zone (2000-3000m).

The SB site also entailed the similar vegetation composition but the extent of tree species was maintained only in six years and ten years fallows. One year and three year fallows possessed only herbaceous, weedy and shrub species (*Saxifraga brachypoda, Cyperus rotundus, Eupatorium adenophorum*, *Maesa chisia*, *Coix* sp., etc.). Clear cutting and burning operation during slash and burn practices alter above ground vegetation, surface soil temperature and atmosphere. The complete denudation of forests and loss of several plant communities is due to very short fallow cycle, which cause significantly the soil erosion, loss of fertility, reduction of crop yield, lowers the water table, and threats the biodiversity and finally deteriorates the physico-chemical properties of soil due to lack and changing nature of vegetation (Aweto 1981).

Highest diversity indices of plant species were noticed at SR site followed by SB site due to the luxuriant growth of understorey and middlestorey because of the presence of moderate disturbances. There was better development of herbaceous layer taking place under the sparse tree crown cover because of the ample germination and establishment of tree seedlings. The opportunity for the recruitment of shrubs and herbs was provided by open canopy in the sites because of the moderate disturbances (Vetaas & Chaudhary 1998; Kunwar *et al.* 2001) and so did light penetration to the soil surface (Khera *et al.* 2001). Moreover, grazing brings about increase in number of plant species especially synanthropic plants of limited cover (Jankowski 1997).

The undergrowth plant species of the Sal forest has been considered as an important component in the conservation and quality control of soil (Rashid *et al.* 1997). Species richness of plant species strongly correlates with Nitrogen mineralization rate (Hutchinson *et al.* 1999) however, high species richness was obtained in low Nitrogen containing SR site. The decrease in soil Nitrogen caused by disturbance will likely cause change in species composition. High species richness of a stand correlates positively with less fertile stands (Hutchinson *et al.*, 1999) and negatively with protection and controlled grazing stands (Zhang 1998).

Very low species diversity at CH site was due to the presence of dense canopy and mature stands. The growth of herbs and seedlings are relatively checked and reduced the biodiversity where the canopy coverage is very high. The species diversity increases as the ecosystem develops and decreases with maturity (Gupta & Shukla 1991). Moreover, the diversity was negatively correlated with increasing elevation, which was concurred with the findings of Kunwar & Chaudhary (2004).

Low value of âcc in between CH and SB sites was due to the commonality of species and low rate of turnover. The value is an indication of lesser impact of altitudinal and vegetational difference on the significant turnover of species among the study sites. Verma *et al.* (2001) put forth that not only macro-environment but also plants may change the micro-environment and soil fertility, which in turn affects the species turnover. Invariably, all the sites showed remarkable degree of dissimilarity in their vegetation composition and structure. This may be the reflection of the difference in altitude, local environmental factors and vegetation types. The similarity in plant species composition found between CH and SB sites was due to presence of similar factors i.e. elevation, forest types and microclimate.

Soil properties

Arun valley exhibits considerable variation in the forest types (Chaudhary & Gupta 1997), which ultimately affect the soil composition and structure. The reduced canopy cover of forests has a direct effect on the seed production, but it may also indirectly effect regeneration through changes in the understorey vegetation and soil properties (Vetaas 2000) particularly to soil texture (Kovaco 1975). Soil texture and soil types were similar in all study sites while loam - sandy loam type was obtained in SR site. Such soil texture is also reported earlier (Gupta & Shukla 1991) from Sal forests in India and Terai forests in Nepal. The sandy-loam texture is very common in Terai, Siwalik and Dun valleys, which support dense forests of Sal and other valuable timber species (Shah 1999). The finding of loamy texture at lower elevation to sandy loam at higher elevation was argued with the findings of Trapp (1993).

Soil texture affects the size and turnover of soil microbial biomass (Gupta & Malik 1996), which ultimately affects the plant growth through the influence under water supply. The supply of water to plants usually is greater in moderate fine texture soil (Jackson 1987). The finer texture was found higher at SR site at lower elevation. The higher value of diversity indices found at SR site was due to the presence of high water availability/soil moisture. According to El-Demerdash (1996) silt content of soil plays negative correlation with diversity, however it showed positive correlation in the present study (**Table 6**). Sand and clay played significant positive correlation with diversity indices.

The higher organic matter concentration found at SB site was due to the absence of human interferes after abandonment. There was a tradition of long fallow cycling, which can contribute to revitalize the soil nutrients and vegetation to some extent. The clearing of natural vegetation and intensive cultivation cause huge soil organic matter loss (Srivastav & Singh 1989). The recovery of organic matter loss may start as the fallow progresses due to the formation of humus through high production of annual herbs, litterfall and consequent decomposition of litter and deposits in 10 years fallow (Singh *et al.* 2001).

The concentration of organic matter varied widely from 3.14% at SR site to 18.45% at CH site. The higher contents of organic matter found in CH site may be due to the presence of matured forest stands with closed canopy, which facilitated rapid decomposition, and checked soil moisture. High organic matter content is maintained in dense forest soils by the fall of huge amounts of litter on the soil surface and its rapid decomposition due to favorable condition like moisture and temperature (Aweto 1981). However, the organic matter exhibited the strong negative correlation with diversity indices due to an account of light unavailability in dense forests at ground layer. The shrub and herb layers are suppressed under the close canopy. The stands with high organic matter related to poor regeneration (Seth & Bhatnagar 1959), ultimately reduce the species richness. Organic matter content was found in increasing trend with increasing elevation and this is supported by Hanalt & Whittaker (1976) while pH opposed the trend. There was positive correlation of organic matter with nitrogen ($r < 0.965$) which coincided with finding of Gupta *et al.* (1989) in Dhankuta Nepal.

The soil was slightly acidic (pH 5.78 ± 1.28) which is considerably better for plant growth. The acidic nature of soil may be attributed to the high rainfall and adequate moisture, which is sufficient to remove basic cations out of the surface horizons of the soils (Miller 1965). Shrestha (1992) and Jaishy *et al.* (1999) respectively implied that the soil is acidic in Terai and eastern Nepal. The acidic soil ranged from 4.5 – 5.5 is ideal for saplings and ground cover vegetation (Singh & Singh 1989) and for Sal forests (Banerjee *et al.* 1989) which ranged within the present study findings. There was higher pH content in sites CH and SB and it was due to the influence of high litter deposition and decomposition.

The range of Nitrogen concentration was higher than that of Paudel & Sah (2003). The higher level of Nitrogen at CH and SB sites is due to the presence of close tree canopy combined with dense forest. The total Nitrogen content declines immediately after burning (Singh *et al.* 2001). This could be attributed to the conversion of organic Nitrogen to volatile form during pyrolysis and suppression of nitrogen fixing microbial populations. However, long cycled fallow (SB sites) in study area accounted to have high Nitrogen value. The concentration of Nitrogen absorbs rapidly in first five years, which may be due to less litter production and rapid utilization of N by fast growing species (Singh *et al.* 2001). From the results, it is argued that the existing fallow cycle at study areas is considerable healthy and providing adequate cycling for vegetation and soil nutrient recovery. The lower value of Nitrogen concentration at SR site was due to the dominance of single species (*Shorea robusta*) as observed by Bhatnagar (1965) in *Shorea robusta* forests in India.

There were no significant relationship between saplings and soil variables in Oak forests except for a weak response to total Nitrogen (Vetaas 2000); and adequate support from high level Nitrogen to regenerate tree species (Singh & Singh 1987), however Nitrogen showed significant negative correlation ($r < 0.956$-0.999) with plant species diversity in the present study. Janssens *et* *al.* (1998) reported that excess Nitrogen is known for its negative effect on the diversity of plant community but its availability would be controlled by Phosphorus.

The highest value of phosphorus was found at the SR site, where had also good plant regeneration and species richness. Bhatnagar (1965) observed higher Phosphorus in good regeneration areas. Available Phosphorus induces slight increase in plant growth and species richness particularly in ground cover (Chiarucci *et al.* 1998). It correlated significantly positive to the diversity and species richness. It is supported by Morgan (1998) that alien species and herbs are slightly positively correlated with soil Phosphorus. It also attributed significant relation with Potassium ($r < -0.642$) as similar to the findings of Shrestha and Jha (1998). The low value entailed at CH site may be attributed to the rapid utilization by large sized trees for the production of above ground biomass (Kunwar 2000). The acidic nature of soils and inherited low Phosphorus levels across Hindu-Kush Himalaya influence the forest vegetation (Pierzynski *et al.* 1994).

The concentration of exchangeable cations in the soil increases considerably after burning of the slashed and other vegetation (Singh *et al.* 2001). However, there was least Potassium in SB site. It may be due to the fact that the increase in Potassium exists for a while after the burning and thereafter abruptly declines due to surface runoff and percolation losses, which was concurred with the findings of Singh *et al.* (2001) and vigorous growth of above ground biomass resulting in low turnover nutrients (Ramakrishnan & Toky 1983). The loss will be much higher for Potassium exchangeable cations as compared to other cations (Singh *et al.* 2001). The high content of organic Nitrogen and Potassium at CH forest site is probably due to higher organic matter and its input from the tree cover (Malla *et al.* 2001). Enhance of cations occurs as increasing the vegetation (Grubb & Edward 1982). Soil K increased as the soil pH decreased in study sites is supported by Black (1968).

CONCLUSION

Shorea robusta, Schima wallichii, Castanopsis hystrix, and *Eurya accuminata* respectively remained abundant with increasing elevation in Arun valley. Diversity of plant species composition was remarkably seen in *Shorea robusta* forests. Understorey vegetation was overshadowed by trees and shrubs entailed the rapid decomposition of leaf litter and ground vegetation, resulted the soil slightly acidic (pH 5.78 ± 1.28), loamier and fertile (OM 11.67 ± 7.42).

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