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Response of vegetation along landscape positions and soil regimes in Sal (*Shorea robusta* Gaertn.) forests of Uttarakhand-India

Sunil Prasad[1*], JMS Tomar[2]
[1] Ecology and Biodiversity Services (EBS), Indraprasth-1, Ring Road Dehradun-Uttarakhand, India
[2] ICAR-Indian Institute of Soil and Water Conservation (IISWC), Dehradun-Uttarakhand, India

Abstract
The present study was designed to analyze the relationships among vegetation, soil characters, and landscape position in Sal forests of foothills of Himalaya. We used two types of landscape positions i.e. hilltops and hill base. Various geological and environmental processes were primary factors influencing soil properties on hill base and hilltops. Soils on the hilltop were chronologically older and resulted from pedologenesis whereas the soils at hill base are new and somehow made up through sedimentation processes. The present study showed that lower areas (hill base) of sal forests are subject to mild disturbance due to tree biomass extraction in these areas. The western aspect was found moister than the eastern aspect and it is more conducive for the development of the herbaceous community and the study indicated a higher pH value in forest soil that is hazardous for the regeneration of the sal forest. Hilltop is the best-suited place for tree species development where tree density showing a positive correlation with nitrogen content in the soil.

Keywords: *Shorea robusta*, landscape position, soil, hilltops, hill base

Introduction

Heterogeneity in floral composition and landscape characteristics can influence many environmental cycles and ecosystem processes, including soil nutrient and water interactions (Fu *et al.*, 2004) [9]. Differences in soil characteristics are very common that significantly influence the growth and development of vegetation. Distribution of plant species depends on the type of resources accessible for plants and in larger words; we can say that forest dynamics somehow depend on the variations of available resources. Soil characteristics influence forest distribution not only at a larger spatial scale but also prove its importance at a smaller spatial scale. At smaller spatial scales, soil resources continue to show considerable spatial heterogeneity, often down to the smallest scale at which measurements are taken (Jackson and Caldwell, 1993) [10]. Small-scale heterogeneity can have a large impact on the performance of individual plants (Miller *et al.*, 1995) [11], and hence, on the structure and dynamics of plant populations and communities.

In India, the extent of Sal (*Shorea robusta*) forest ranges from Uttarakhand in the north up to Andhra Pradesh in the south and Tripura in the east; covering Himachal Pradesh, Haryana, Uttar Pradesh (UP), Bihar, West Bengal, Odisha, Madhya Pradesh, Chhattisgarh, Maharashtra, Jharkhand, Sikkim, Assam and Meghalaya (Chitale and Behera, 2012; Champion and Seth, 1968) [12, 13]. The species is widely distributed having large niche throughout the Bhabar and Tarai areas of the Uttarakhand state. A Sal forest apart from providing timber provides fuel-wood and fodder, seeds for oil and tannin, and gum from the bark. It forms a key component for a diverse range of products including oil, soap, and cocoa butter equivalent (CBE) in chocolate manufacturing purposes.

In Uttarakhand, *Shorea robusta* forests are extensively distributed all through the Bhabar and Tarai areas. There is a series of sal forests in Doon Valley of Uttarakhand viz., Dry Shiwalik Sal, Moist Shiwalik Sal, High-level alluvium Sal, and Wet Sal i.e. wet Bhabar Sal. A large network of small catchments that are the source of various springs and all the Himalayan Rivers cross these forests to catch their connecting plains. Doon-valley is one of the prominent niches of sal forests that are currently being exposed due to the biotic pressure on forests and the alteration of hydrological regimes. The result of these changes may influence the soil-plant relationships. Landscape position plays a vital role in nutrients accumulation and thus finally plays a big role in plant community composition and development. On the other hand, soil nutrient profile at various landscape positions is greatly influenced by their plant associates. The present study is focused on the comparison of plant species composition and soil physio-chemical profiling of Sal forest along with landscape position in Doon Valley, Uttarakhand.

Methodology

Study area

The present study has been carried out in Barkot Forest Range (30^{0} 03'52"- 30^{0}10'43" N and 78^{0}09'49" - 78^{0} 17'09" E) lies about 35 km away from Dehradun, on the Dehradun-Rishikesh route. The main forest type is Sal Mixed Moist Deciduous Forest and the whole area possesses the relatively flat, gentle, and undulating topography. The whole study area lies in the Doon Valley with altitude ranges between 330 m and 565 m above mean sea level.

Hill Top and Hill Base

The whole study has been carried out in two landscape position i.e. hill base and hilltop. (a) All the area within 10 m distance from the summit has considered as Hill Top and (b) the area up to 10 m from the base is regarded as hill base. These two landscape positions have been marked as per the sketch diagram given below.

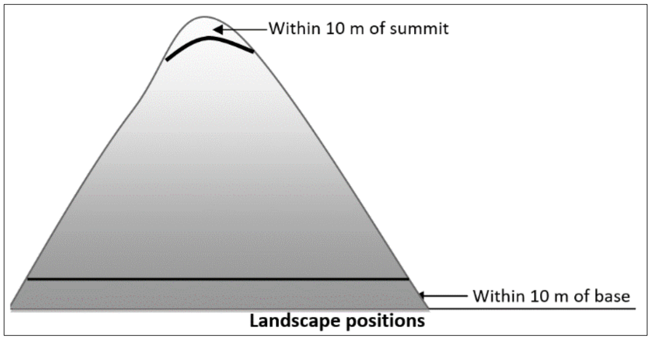

Fig 1: Sketch diagram showing hill base and hill top positions

Vegetation Sampling

A primary vegetation survey has been carried out to understand the community composition and profile of vegetation in the study area. Quadrat based sampling has been carried out and the size and number of quadrats needed were determined using the species-area curve method (Mishra, 1968) [6]. The sampling consisted of randomly placed quadrats of 10 x 10 m^2 for trees, 5 x 5 m^2 for shrubs, and 1 x 1 m^2 for herbs around the same sampling locations. All the quadrats were spatially distributed to minimize the autocorrelation among the vegetations. In this study a total of 60 quadrats (N-60) were laid down for the tree (30 in each aspect) and 120 for shrubs (60 in each aspect) and 300 for herbs (150 in each aspect). The data on vegetation were quantitatively analyzed for density, frequency, and abundance as per Curtis and McIntosh (1950) [7]. The Importance Value Index (IVI) for trees was determined as the sum of relative density, relative frequency, and relative dominance (Curtis, 1959) [7].

Soil Sampling

The soil samples were collected from 10-30 cm depth, packed in polythene bags, and brought to the laboratory for physio-chemical analysis. A total of 24 soil samples (6 in each landscape position and 12 in each aspect) have been collected.

Soil Analysis: Water holding capacity was calculated as WHC (%) = gain in weight at the saturated point/dry weight of the soil X 100 (Mishra, 1968) [6]. Bulk density (g/cm^{-3}) has been measured by Cylindrical Core Method whereas soil moisture percentage was calculated based on dry soil weight. Moisture (%) = Weight of moist soil-weight of oven-dry soil/weight of oven-dry soil X 100. pH was directly read with the help of a dynamic digital pH meter (Soil: Water ratio as 1: 2.5). Total nitrogen (g/kg) was determined in the soil by method, (Kjeldahl, 1883) [15].

Results

Species composition along with landscape position

In the eastern aspect, 25 species were recorded in hill base as compared to 26 plant species in hilltop. The western aspect was comprised of 28 plant species in the hill base and 25 species at hilltop (Table 1).

Table 1: Species composition at different landscape positions and aspects

	Hill Base	**Hill Top**
	Eastern Aspect	
Species	*Shorea robusta* (T), *Lepidagathis sp.*, *Chlorodendron viscosum* (S), *Uvaria cordata* (S), *Crotolaria sp.* (S), *Sida rhombifolia* (S), *Periploca calophylla* (S), *Vigna Sp.* (S), *Grewia oppositifolia* (S), *Hemigraphis latiprosa* (S), *Carissa spinarum* (S), *Tinospora sinensis* (S), *Jasminum abyssinicum* (S), *Lantana camara* (S), *Murraya koenigii* (S), *Urena lobata* (S), *Ageratum conzoides* (H), *Adiuntum incisum* (H), *Desmodium pulchellum* (H), *Oxalis corniculata* (H), *Oplismenus burmannii* (H), *Cyathea dealbata* (H), *Thalypteris parasitica* (H), *Pogostemon benghalensis* (H), *Lipocarpha chinensis* (H), *Centella asiatica* (H)	*Shorea robusta*(T), *Mallotus philippensis* (T), *Terminalia alata* (T), *Lepidagathis sp.* (S), *Chlorodendron viscosum* (S), *Crotolaria sp.* (S), *Sida rhombifolia* (S), *Periploca calophylla* (S), *Vigna Sp.* (S), *Grewia oppositifolia* (S), *Hemigraphis latiprosa* (S), *Carissa spinarum* (S), *Jasminum abyssinicum* (S), *Lantana camara* (S), *Murraya koenigii* (S), *Urena lobata* (S), *Ageratum conzoides* (H), *Adiuntum incisum* (H), *Desmodium pulchellum* (H), *Oxalis corniculata* (H), *Oplismenus burmannii* (H), *Cyathea dealbata* (H), *Thalypteris parasitica* (H), *Pogostemon benghalensis* (H), *Lipocarpha chinensis* (H), *Centella asiatica* (H)
	Western Aspect	
Species	*Shorea robusta* (T), *Lantana camara* (S), *Jasminum abyssinicum* (S), *Chlorodendron viscosum* (S), *Murraya koenigii* (S), *Urena lobata* (S),*Carissa spinarum* (S), *Hemigraphis latiprosa* (S), *Celebrookia oppositifolia* (S), *Sida rhombifolia* (S), *Solanum torvum* (S), *Crotolaria sp.* (S), *Aniosmeles indica* (S), *Eupatorium adenophorum* (H), *Ageratum conzoides* (H), *Reinwardtia tetragyna* (H), *Oplismenus burmannii* (H), *Cyathea dealbata* (H), *Thalypteris parasitica* (H), *Bidens pilosa* (H), *Desmodium pulchellum* (H), *Emilia sonchifolia* (H), *Pogostemon benghalensis* (H), *Adiuntum incisum* (H), *Oxalis Corniculata* (H), *Cynodon dactylon* (H), *Dioscorea deltoides* (H), *Solanum nigrum* (H)	*Shorea robusta* (T), *Lantana camara* (S), *Jasminum abyssinicum* (S), *Chlorodendron viscosum* (S), *Murraya koenigii* (S), *Urena lobata* (S), *Carissa spinarum* (S), *Hemigraphis latiprosa* (S), *Celebrookia oppositifolia* (S), *Sida rhombifolia* (S), *Aniosmeles indica* (S), *Bauhinia sp.* (S), *Lepidagathis sp.* (S), *Eupatorium adenophorum* (H), *Ageratum conzoides* (H), *Reinwardtia tetragyna* (H), *Oplismenus burmannii* (H), *Thalypteris parasitica* (H), *Bidens pilosa* (H), *Emilia sonchifolia* (H), *Adiuntum incisum* (H), *Oxalis Corniculata* (H), *Cynodon dactylon* (H), *Dioscorea deltoides* (H), *Solanum nigrum* (H)

Species ranking along with landscape position

\The *Shorea robusta* has emerged as leading plant species having the highest IVI values in all aspects and landscape positions. *Lantana camara* was another leading species with the presence in both landscape positions in the eastern aspect and hill base of the western aspect. *Sida rhombifolia* was one of the leading 5 species but it is restricted within the eastern aspect. Similarly, *Jasminum abyssinicum* was only found in both landscape positions of western aspect (Table 2).

Table 2: Ranking of species at different landscape positions and aspects

	Hill Base	Hill Top
	Eastern Aspect	
Ranking of species (IVI)	1. *Shorea robusta* (70.63)	1. *Shorea robusta* (78.99)
	2. *Lantana camara* (54.37)	2. *Lantana camara* (54.84)
	3. *Desmodium pulchellum* (16.96)	3. *Oxalis corniculata* (19.31)
	4. *Sida rhombifolia* (15.61)	4. *Sida rhombifolia* (10.40)
	5. *Ageratum conzoides* (15.36)	5. *Urena lobata* (10.04)
	Western Aspect	
	1. *Shorea robusta* (62.55)	1. *Shorea robusta* (82.52)
	2. *Lantana camara* (26. 73)	2. *Carissa spinarum* (33.29)
	3. *Eupatorium adenophorum* (22.40)	3. *Jasminum abyssinicum* (21.91)
	4. *Jasminum abyssinicum* (18.67)	4. *Cynodon dactylon* (19.18)
	5. *Ageratum conzoides* (17.96)	5. *Reinwardtia tetragyna* (16.37)

Species density along with landscape position: Tree density was found highest (9 trees/100m^2) at the hilltop of western aspect whereas it was lowest (4.6 trees/100m^2) at hill base of eastern aspect. The highest shrub density (15.4 shrubs/100m^2) was recorded at the hilltop of the western aspect while its value was lowest (7.8 shrubs/100m^2) at the hilltop of the eastern aspect. Herb density was highest (38.3 herbs/100m^2) at hill base of western aspect and lowest (19.8 herbs/100m^2) at the hilltop of the eastern aspect. Tree density was recorded higher in hilltops to hill base and herb density was recorded higher in hill base than hilltop. Tree density was found higher in the eastern aspect than the western aspect whereas herb density was recorded higher in the western aspect than the eastern aspect. A mixed trend was found in the density values of shrubs (Table 3).

Table 3: Species density at different landscape positions and aspects

	Hill Base	Hill Top
Eastern Aspect		
Total number of Species	25	26
Density (100 Sqm for the tree/shrub and 1 sqm for herb)	5.6 trees 14.8 shrubs 30.2 herbs	7.2 trees 7.8 shrubs 19.8 herbs
Western Aspect		
Total number of Species	28	25
Density (100 Sqm for the tree/shrub and 1 sqm for herb)	4.6 trees 13.0 shrubs 38.3 herbs	9.0 trees 15.4 shrubs 25.4 herbs

Physical properties of soil along with landscape position

The water holding capacity was more or less similar in both landscape positions of the eastern aspect whereas it decreased from hill base (34.23) to hilltop in the western aspect. Bulk density was found higher in the western aspect than the eastern aspect but its values were found increasing from hill base to hilltop in the eastern aspect and decreasing in the western aspect. The highest value (8.46%) of moisture % was recorded in the hill base of the western aspect and it was found higher at hill base than hilltop in both aspects (Fig. 2).

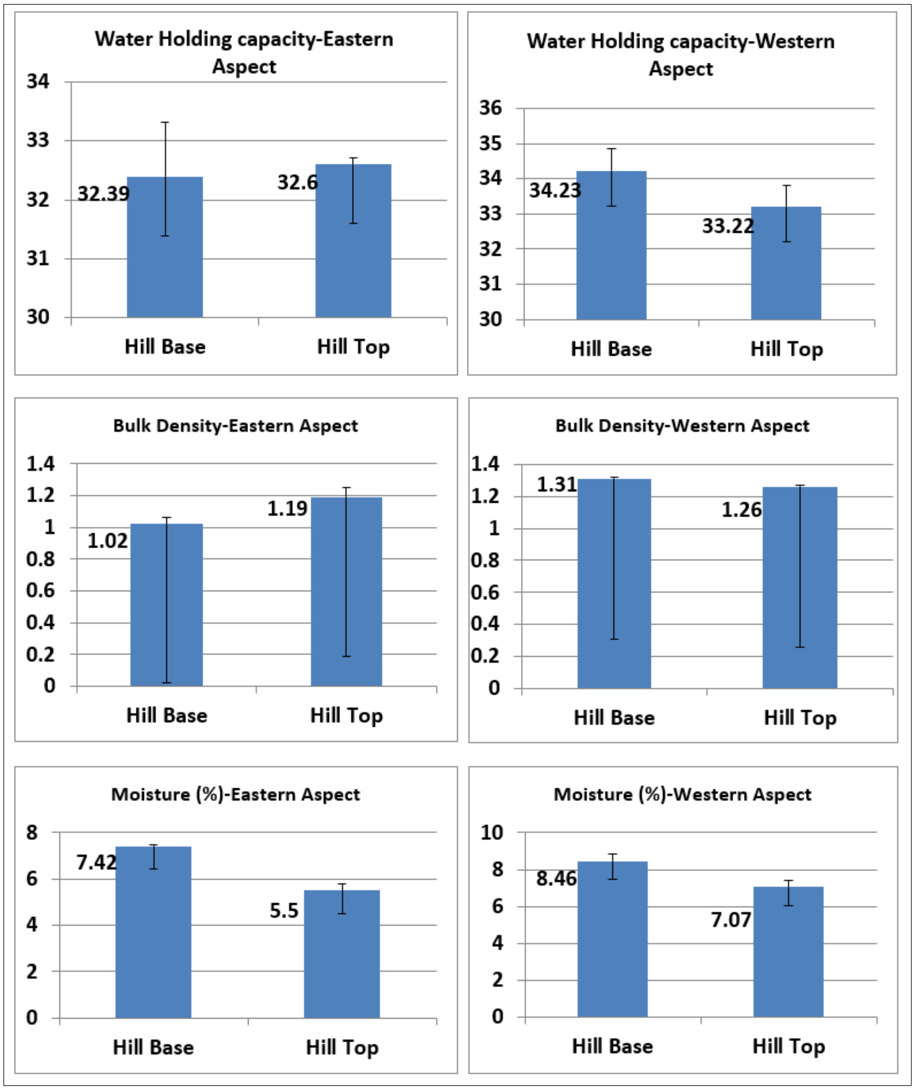

Fig 2: Landscape position impact on physical properties of soil

Chemical properties of soil along with landscape position

The highest pH value (6.99) was recorded at hill base of western aspect and lowest (6.4) at hill base of eastern aspect. The pH values are more or less similar in both aspects. Organic carbon was recorded highest (0.6) at the hilltop of the eastern aspect and lowest at hill base of western aspect. Total Nitrogen was recorded highest (0.4 g/kg) at the hilltop of the western aspect. The phosphorous content in soil was found highest (0.07) at the hill base of the eastern aspect. Eastern aspect has higher phosphorous that the western aspect. As far as the available potassium is concerned, its values were recorded higher in western aspects than eastern aspects in both landscape positions (Fig. 3).

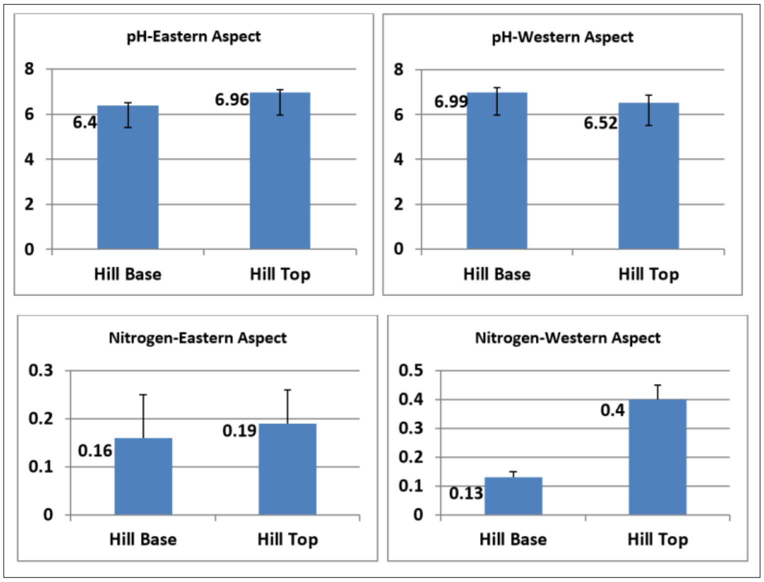

Fig 3: Landscape position impact on chemical properties of soil (Nitrogen- g/kg)

Discussion

Sal (*Shorea robusta*) has shown its dominance in all aspects and landscape positions and the species has effectively attained dominance over other species. This pattern of dominance of sal species showed that the studied forest is in its pure form. Such kind of results has been previously reported by Abhishek Raj (2018) [16] during a study on Sal dominated tropical dry deciduous forest in Chhattisgarh. Another dominant species *Lantana camara* was recorded as the top five plant species in all landscape positions and aspects except hilltop of western aspect. It showed that *Lantana camara* can survive in a wide range of topographic conditions. The *Lantana camara* lost its rank and get out of the top 5 dominant plant species at hilltop position of western aspects because it is unable to compete with a high density of trees (9.0 trees/100m^2) due to its lack of tolerance for shade (Cronk and Fuller, 1995) [1]. *Sida rhombifolia*, one of the top five plant species in the eastern aspect, losing its position in the western aspect and it is because it grows best under high luminosity and is tolerant of temperature variation (FAO, 1983) [2].

The tree density has recorded highest in western aspect than an eastern aspect that conforms to the study of Desta (2004) [3] who reported 23% more stems per hectare in the west aspect than the east aspect. The tree density was found higher in hilltops in both aspects shows a moderate type of disturbance in the forest in which people are extracting tree biomass from easily access areas (the hill base). Some other workers like Bargali *et al.*, (2013) [4] also reported that the tree density increased from hill base to hilltop in the moderately disturbed forest area. Herb density was found higher in the western aspect than the eastern aspect in both landscape positions. It might be due to higher moisture percent that is recorded in western aspects (present study).

The higher percentage of moisture content in soil was recorded at hill base that is a simple observation as hill base receives more water due to gravitational force. Western aspect holds higher moisture than eastern aspect because eastern aspects are warmer than western aspect and having a high evaporation rate. Soil pH values were 6.4 to 6.99 which is higher than previous studies as Singh and Singh (1989) [17] reported soil pH range between 4.5 and 5.5 Sal forest. These higher values of pH indicate poor regeneration of the species as sal trees favor good regeneration at low pH value (Puri, 1950) [18]. Nitrogen plays a significant role in controlling the rate of carbon fixation and organic matter accumulation. In the present study total nitrogen was recorded lower than previously reported values of Sharma *et al.*, (2017) [5]. It was interesting to see that Nitrogen accumulation in soil was higher at hilltops than hill base. Nitrogen stock increased with tree density as its values were found higher at hilltops where tree density is at its peak. It shows higher tree density induces nitrogen accumulation on the forest floor. Sanford *et al.*, (1982) [19] was also found a significantly positive correlation of total nitrogen with tree density.

Conclusion

The present study concluded that aspects and landscape positions influence soil and vegetation characters in *Shorea robusta* forest significantly. Lower areas (hill base) of sal forests are subject to mild disturbance due to tree biomass extraction in lower areas. The western aspect was found moister than the eastern aspect and it is more conducive for the development of the herbaceous community. The study indicated a higher pH value that is hazardous for the regeneration of the sal forest. Hilltop is the best-suited place for tree species development where tree density showing a positive correlation with nitrogen content in the soil. The study recommends a minimum tree resource extraction at the hill base of sal forest and in-depth studies on soil-plant interaction in the sal forest zone.

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