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Soil Impacts on the Natural Vegetation of the Tropical and Sub Alpine Region of Central Himalayas

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Abstract

In the Central Himalayas' tropical and sub-alpine regions, a study was conducted to analyze the impact of soil on natural vegetation. The study took place in the Dolakha and Sindhupalchowk districts and involved ecological sampling in six different forest types at various elevations. The random sampling method with circular plots of different radius viz. 10m, 2.5m & 1m to sample trees, shrubs, and herbs were utilized respectively.

The study examined various soil properties, including texture, pH, water holding capacity, sticky point, water rising and percolation. The analysis revealed that the Mixed Broadleaf Forest soil had the highest water holding capacity (86.97%), while the Sal Forest in Sukute had the lowest. In terms of soil pH, the Rhododendron-dominated Forest had the least acidic soil with a pH of 6.45, whereas the Pine Forest and *Taxus wallichiana*-dominated forest had more acidic soil with a pH of 5.6. The study also found that the sticky point of the Mixed Broadleaf Forest soil was 47.46%, indicating it was much drier, while the Sal Forest in Sukute soil was very wet with a sticky point of 22.73%. The results of this study suggest that vegetation patterns are influenced by a combination of topographic, edaphic factors and change in climatic conditions.

Keywords**:** *Soil texture, soil pH, water holding capacity, sticky point, water rising & percolation*

1. Introduction

Vegetation has been a significant focus of ecological study to explore the correlation and interaction between the vegetation types and their natural environment to understand their relationships and offer informed decision making for conservation and management of natural resources (Addicott *et al*. 2021, Schwienfurth 1992).

The altitude of Nepal starts from the height of 60m to 8848.86m above sea level. Nepal has 35 forest types, 75 vegetation units and 118 ecosystems (Dobremez, 1976; Dobremez, 1972) which demonstrates an altitudinal distribution of flora of central Nepal. Nepal is divided into six bio-climatic zones or belts with 11 sub-zones. The presence of variation in vegetation is due to different environmental factors. The structure of plant community is diverse along the locations because of variation of altitude, orientation of slope, nature of soil and disturbance found there (Vetaas, 1997). Different types of vegetation are also found due to rainfall patterns and natural disturbance like forest fire, soil erosion, landslides and climate change.

The number of species of flowering plants is estimated to be in the range of 250,000 to 400,000 (Thorne 2002, Scotland and Wortley 2003). The top 10 largest genera of flowering plants in world are *Carex* (Cyperaceae), followed by *Astragalus* (Fabaceae), *Dendrobium* (Orchidacea), *Rhododendron* (Ericaceae), *Desmodium* (Fabaceae), *Saxifraga* (Saxifragaceae), *Primula* (Primulaceae), *Salix* (Salicaceae), *Cyperus* (Cyperaceae), and *Aconitum* (Ranunculaceae). The flora with largest families in Nepal are Orchidaceae, Poaceae, Asteraceae, Fabaceae, and Cyperaceae followed by Lamiaceae, Ranunculaceae, Rosaceae, Apiaceae, Gentianaceae, Primulaceae and Rubiaceae.

Soil is an important natural resource for the growth and development of lithophytes which produce different materials to support the livelihood of human (Corstanje *et. al*, 2006). The structure of plant community, richness, diversity is determined by the properties of soil (Ram *et. al.*, 2015). The properties of soil include both physical and chemical characteristics. Physical characters are soil texture, structure, density, porosity, color etc. Chemical properties of soil include pH, nitrogen level, phosphorous, potassium (Ram *et. al.*, 2015) found in soil. Soil texture determines the water retention capacity, leaching, erosion, nutrient storage capacity etc. so, soil texture study is important criteria for agriculture and forest development (Gajda *et. al.*, 2001). Soil texture influences the water retention capabilities of soils of different locations, as soil with high clay percentage or organic matter content tends to have high soil water holding capacity, Senjobi and Ogunkunle (2011).

Soil pH is an acidic or alkaline measurement of soil. A pH of soil affects the mineral nutrient availability to plants (FAO, 2006; Baxter, 2007). The presence of bacteria, decomposing materials like leaves, grasses and addition of lime has direct relation in maintaining the soil pH. Soil pH is controlled by several factors such as clay and organic matter content (Dahal, *et al.*, 2018). The stickiness of soil is determined by its texture, which is influenced by the type and proportion of different mineral particles that make up the soil, pH level and the amount of moisture present in the soil. Clay soil generally shows high sticky point due to large surface area which allow it to hold onto water and other nutrients. Clay soil with plenty of organic material mixed in rarely becomes sticky and compacted, Prescott and Poole (1934). Soil properties depend on various environmental factors like slope, aspect, climate, landscape, microclimate, topography and vegetation (Tsui *et. al.*, 2004). This study reforms the dynamics of eco evolution where the soil drives the evolution of new traits in vegetation and sometimes even the formation of new plant species through the course of resilience in soil properties due to the change in climate.

2. Sites, Data and Methodology

2.1 Study sites

The Dolakha district, with Charikot as its headquarters, covers an area of 2,191 $km^{2.}$ It is a district with a strong religious affiliation, popularly known among most Nepalese for the temple of Dolakha Bhimeshwor. The study area ranges from an elevation of 671m to 3492m from sea level. The first study area was Sindhupalchowk, Sunkoshi riverside slopy hill at an altitude of 671 m asl with coordinates 27.36 °N and 85.324 °E. The second study area was on the way to Kalinchowk. Two plots were plotted at different altitudes i.e., first plot at 2589m asl. with coordinates 27.69 °N, 86.01 °E and the second plot was plotted at 2860m asl. with coordinates 27.713 °N and 86.015 °E.

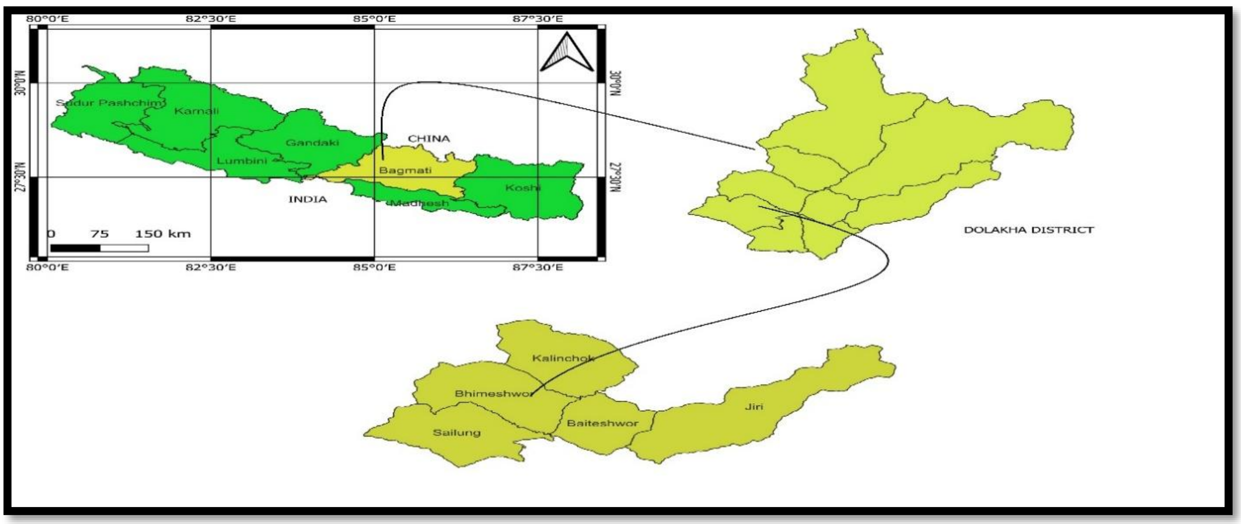

Fig. 1. Map of Nepal with Dolakha district and study sites.

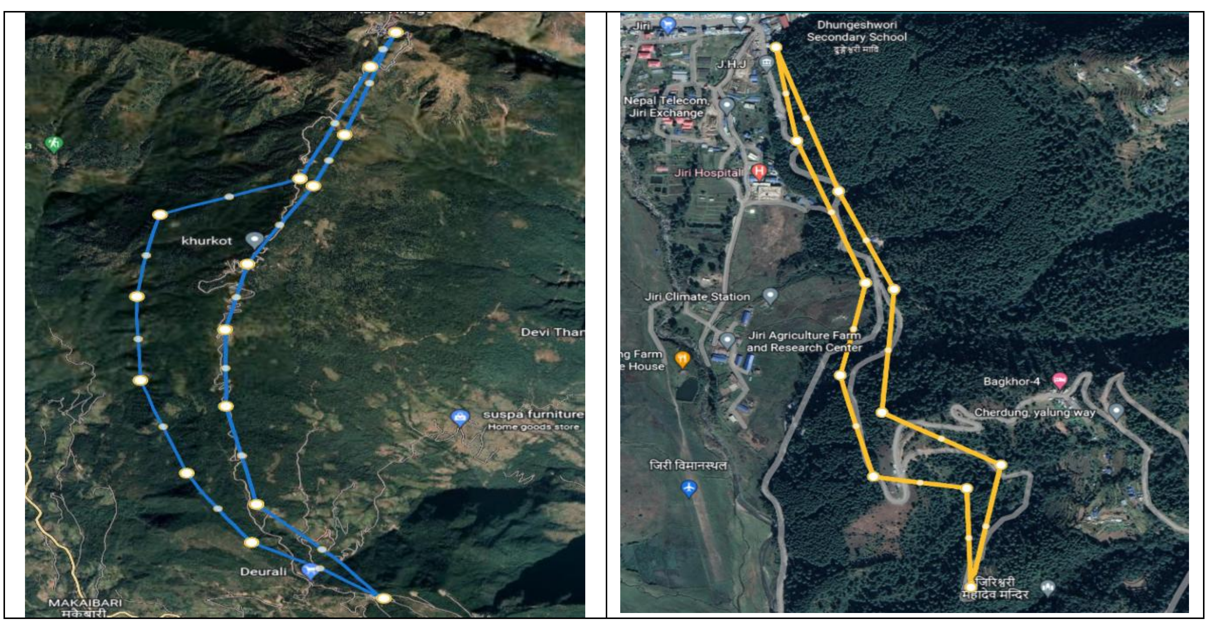

Fig. 2. Way from Deurali to Kuri, Kalinchowk (Blue) Way from Jiri to Jireshwor Temple (Yellow).

Similarly, the fourth plot was plotted around Kuri village of Kalinchowk at an altitude of 3384m asl. 27.74 °N and 86.029 °E coordinates. Following that area, the next sampling plot was plotted at an altitude of 3492m asl of coordinates 27.73 °N and 86.02 °E. Another sampling was done in the Sal Forest at an altitude of 929m asl and coordinates 27.62 °N and 86.07 °E. The final sampling plot was plotted at Jiri at an altitude of 1991m asl and coordinates 27.623 °N and 86.233 °E. (Figure 1&2).

2.2 Methodology

Ecological sampling was carried out during the month of July 2023. The random sampling method was used for vegetation sampling. The circular plot samples of 10 m radius were taken at different altitudes for the analysis of vegetations within the study area (Sundryal and Sharma, 1996). For shrubs, one circular plot of 2.5 m radius was plotted in different transects of the main plot. Similarly, for sampling of herbs, three circular plots within main plot having radius 1m were plotted at different areas. In each circular plot, the number of individuals of each species in different lifeform were counted and diameter at breast height (DBH, measured at 137 cm above the ground) of each tree was measured. Individuals of tree species were divided into three growth stages: trees (DBH>10 cm), saplings (DBH<10 cm) and seedling (height < 5cm) (Figure 3).

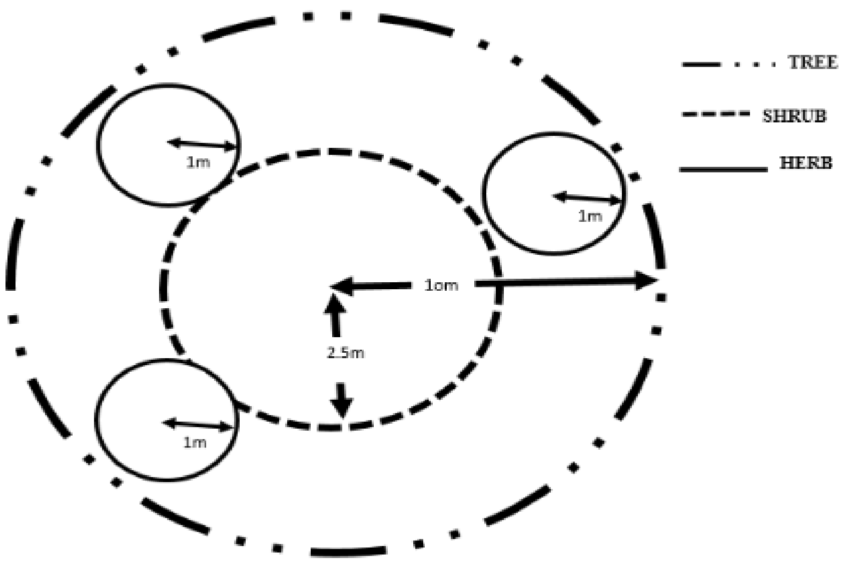

Fig. 3. Sampling plot design

Soil texture

Soil texture refers to the portion of sand, silt and clay sized particles that make up the mineral fractions of the soil. The most common method of determination of soil texture is by sieving. Sieving is a long-established but still widely used soil analysis technique. In sieving, the known weight of sample material passes through finer sieves. The amount collected on each sieve is weighed to determine the percentage weight in each size fraction. Texture of soil were identified using the ternary graph which is represented below (figure 4).

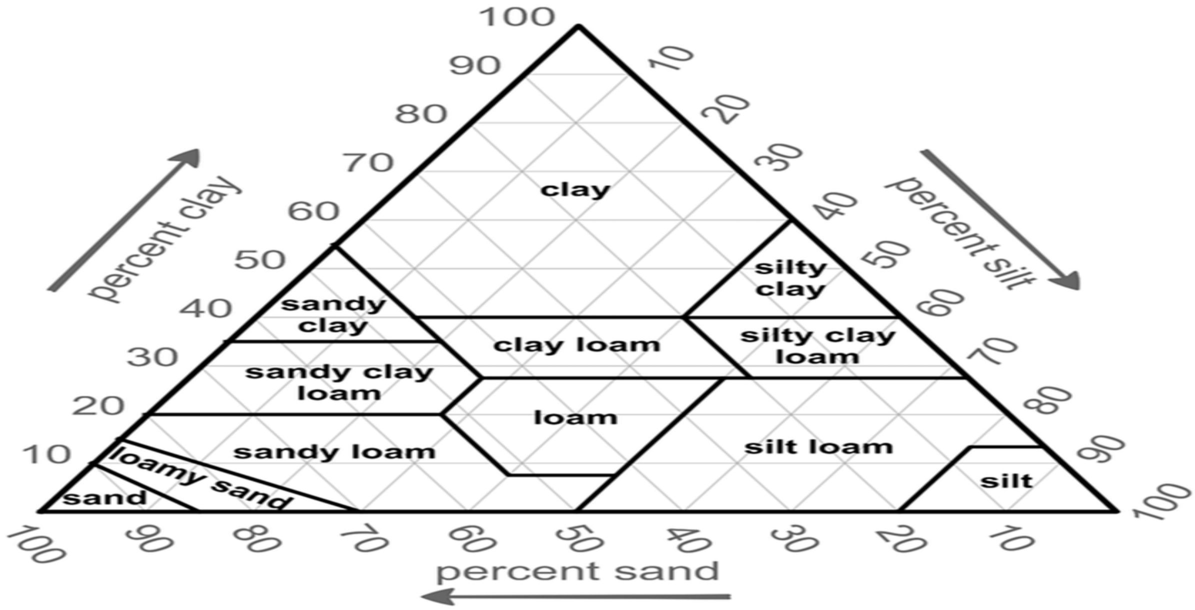

Fig. 4. Ternary graph for identification of different soil types.

Soil pH

The soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. Soil pH is defined as the negative logarithm of the hydrogen ion concentration. For determination of soil pH, the soil samples weighed about 20gm and double volume of distilled water (soil: distilled water=1:2) was added and stirred for few minutes. The pH meter was labelled 9.2 with the buffer solution and then deionized with distilled water. The deionized pH meter was dipped into the soil sample and was rested for certain minutes for constant reading in the pH meter. Similar procedures were repeated for all the soil samples, and the pH meter reading was noted.

Water holding capacity

Water holding capacity of soil is the ability of soil of a certain soil texture to physically hold water against the force of gravity. It is calculated as the difference between the weight of moist soil on filter paper and the weight of moist filter paper in percentile of dry soil. Mathematically,

$$WHC = \frac{\text{wt. of wet soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100$$

Sticky point

The sticky point of soil refers to the maximum amount of moisture content in the soil at which the soil shows adhesive nature toward the corresponding surface. It is calculated as the difference between the weight of dry soil and moisture containing soil in percentile. Mathematically,

$$\text{Sticky point} = \frac{\text{wt. of moist soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100$$

Water rising and percolation

Water rising or capillary action of water in the soil is the maximum height attained by water movement in the soil sample per unit time Similarly, water percolation is the downward movement of water through the surfaces deep into the layers of soil in unit interval of time. Water rising and percolation were calculated by observing the distance travelled by water (upward and downward) per 2 minutes of time interval. The initial and final points were noted, and the difference was plotted against the time interval in the graph.

3. Results

3.1 Lifeform

The vegetation analysis with circular plotting was done in six different forest types at various elevation ranges. The tropical region showed the dominance of *Shorea robusta* at an altitude of 671m and 929m at Sukute, Sindhupalchowk district and Jiri, Dolakha district respectively. A total of nine trees, 17 shrubs and 31 herbs were enumerated from two different *S. robusta* forests of Sukute and Jiri. Similarly, *Taxus wallichiana* dominated forest was observed in an elevated area at an altitude of 2,860 m in the temperate region where a total of seven trees species were recorded whereas 13 shrubs species along with 23 species of herbs were also enumerated from the sampling area. Two samplings were done at temperate region at an altitude of 2589m and 2860m of Dolakha district which are Mixed broadleaf forest and *Taxus wallichiana* dominated forest. The Mixed broadleaf forest observed in the sampling area showed six species of trees, 15 shrubs species and 31 herbs species.

Two circular samplings were done at sub-alpine region of Dolakha district which showed dominance of different trees species at different altitude ranges. At an altitude of 3384m, *Abies spectabilis* and *Rhododendron* sp. Were mixed whereas at an altitude of 3492m, the vegetation was purely dominated by *Rhododendron* species. In the *Abies-Rhododendron* mixed forest, two tree species, two shrub species and 11 herbs species were enumerated. Similar samplings taken in the *Rhododendron* species dominated forest represented two tree species, single shrub species and 9 herbs. In the samplings of sub-tropical region at an altitude of 1991m of Dolakha district showed the Pine Forest type where *Pinus wallichiana* was relevantly abundant with three tree species, 17 shrubs species and 28 herbs species.

Fig. 5. A: *Sedum lineare* B: *Jacobaea vulgaris* C: Sampling plot D: Collection of soil from the study plot.

3.2 Soil analysis

Table 1: Table representing computed data of soil analysis.

Soil Analysis	Sal Forest (Sukute)	Sal Forest (Jiri)	Pine Forest	Mixed Broad leaf Forest	*Taxus wallichiana* Dominated Forest	Abies Rhododendron Forest	Rhododendron Dominated Forest
Water Holding Capacity (%)	44.88	54.53	59.33	86.97	69.86	72.04	56.22
Soil pH	6	5.8	5.6	5.7	5.6	6.03	6.45
Sticky point (%)	22.73	32.7	39.73	47.46	42.06	42.23	38.86
Soil Texture	Loamy Sand	Loamy Sand	Loamy Sand	Sandy Loam	Sandy Loam	Clay Loam	Clay Loam
Water Rising (unit/2min)	0.13	0.16	0.16	0.16	0.13	0.2	0.2
Water Percolation (unit/2min)	0.26	0.23	0.16	0.2	0.2	0.33	0.4

Water holding

The soil samples collected from the plot area of different forest types showed that the water holding capacity of Mixed broadleaf forest at an altitude of 2589m was maximum with WHC % 86.97% while minimum water holding capacity was found in the Sal Forest of Sukute at an altitude of 671m. Thus, the soil properties showed that mixed broadleaf forests were much more moisture than other comparative forest types.

Soil textures

During the soil analysis, the different textures of different forest types with composition as coarse sand, fine sand, silt and clay. The composition of soil analysis showed maximum percentage of coarse sand in mixed broadleaf forest at an altitude of 2589 m and minimum was reported at Rhododendron dominated forest at altitude of 3492 m. Similarly, the percentage of fine sand was maximum in the Sal Forest at an altitude of 671 m and minimum in the Rhododendron dominated forest at an altitude of 2589 m. Likewise, silt percentage was found maximum in the Rhododendron dominated forest at an altitude of 2589 m while minimum was found in the Sal Forest of Jiri at an altitude of 926m. In context of clay sand, the maximum percentage was found in the Rhododendron dominated forest at an altitude of 2589 m while minimum was found in the Sal Forest of Sukute at an altitude of 671 m.

Soil pH

The soil analysis done for the determination of soil acidity and alkalinity showed that the soil of Rhododendron dominated forest was less acidic with pH value 6.45 while the soil of Pine Forest and *Taxus wallichiana* dominated forest were highly acidic with pH value 5.6.

Sticky point

Soil analysis done for the determination of sticky point of different forest types was done with weighting of 100gm of dry soil sample and adding required amount of water to reach its sticky nature. Thus, the observation showed that the sticky point of soil sample of mixed broadleaf forest was much drier as it absorbed more amount of water to reach its sticky point, i.e., 47.46 %. Similarly, the soil sample of Sal Forest of Sukute area was very wet, and its sticky point was found to be 22.73%.

Water rising

The determination of water rising of different soil samples against time interval showed that the soil sample of Mixed broadleaf forest was much more porous, and the water rising was vigorously high while the soil sample of *Taxus wallichiana* dominated forest was less porous and contained less amount of humus composition as the water rising was comparatively steady. The constant water rising of different forests was observed at around 30 minutes of time interval.

Water percolation

The treatment of different soil samples against time interval for the determination of water percolation resulted that the soil sample of *Taxus wallichiana* dominated forest was less composted with external components as it showed rapid percolation rate while the rate of water percolation was minimum for the soil sample of Pine Forest. Similar comparative constant reading was observed at about 26-28 minutes of observation.

4. Discussion

The Subalpine region consisted of two study areas: one at an altitude of 3384 m and the other at 3492 m asl. These study areas consisted of mainly two tree species. The *Abies-Rhododendron* Mixed Forest at an altitude of 3384m had only two species *Abies* and *Rhododendron*. Altogether two species of trees, two species of shrubs and 11 species of herbs were enumerated. Sujakhu, et al., 2013 observed four species of tree from *Abies* forest in Samagaun are with altitudinal variation of (3500-4000m) altitude which were *Betula utilis, Abies spectabilis, Larix himalaica* and *Rhododendron campanulatum*. Among which *Betula utilis* was found to be ecologically more important in the mixed *Abies* forest. The species which were most abundant in shrub and herb layer were *Berberis* and *Anaphalis* respectively.

Another study site was dominated by *Rhododendron* Forest associated along with other species of plants like *Berberis, Adiantum, Cyperus* etc. The tree diversity was comparatively low as only two species of trees were recorded. In contrast with our record, eight other species of trees were recorded in the lower subalpine zone of Langtang National Park which shows similar altitudinal range with our study site (Pandey *et.al*.,2016).

Our study area consists of seven different sites. Out of which, three sites consisted soil of loamy sand texture, two sites consisted soil of sandy loam texture and remaining two sites consisted soil of sandy clay loam and clay loam texture. The first site was Sal Forest which consisted of 27.13% coarse sand, 50.63% fine sand, 19.34% slit and 2.86% of clay with texture of loamy sand. Another site of Sal Forest, however, consisted of 34.3% of coarse sand, 44.57% fine sand, 18.22% slit and 2.88% of clay. Sand amounts were higher as compared to other soil this is because our site was affected by landslides. The soil texture of this site was found to be loamy sand.

In contrast, Gautam and Mandal (2013) observed soil from different Sal Forest of Bhabar belt of Sunsari district to be of loam texture. The succeeding study site was selected in Pine Forest which consisted of 33.91% coarse sand, 42.96% fine sand, 19.53% slit and 3.57% clay with loamy sand texture however Mandal et al., (2018) observed soil of Pine Forest from Shikharpur VDC of Baitadi district (2100 m asl) to be of slit texture. The mixed broad leaf consisted of soil with 39.09% coarse sand, 26.68% fine sand, 18.40% slit and 15.8% clay. The *Taxus* forest consisted of 37.67% coarse sand, 22.66% fine sand, 20.51% slit and 19.12% clay. *Abies* forest consisted of 23.67 % coarse sand, 25.71% fine sand, 24.09% slit and 26.49% of clay. The final site of *Rhododendron* Forest consisted of 20.86 % coarse sand, 19.18% fine sand, 24.51% and 35.41% clay which helps in water retention during longer dry periods in these regions for proper growth of plants.

The values of WHC in six different forest types were different ranging from 44.88%-86.97%. The maximum value of WHC was 86.97%in the soil of mixed broad leaf forest followed by *Abies-Rhododendron* Forest i.e.,72.04%. The minimum values of WHC were 44.88% and 54.53% both in the soil of Sal Forest contrast to the report of (Bhatnagar 1965; Bhatta, 2016) from the soil of Sal regeneration areas. Similarly, the WHC of pine forest of our study site was higher i.e.,59.33%than the pine forest in Garhwal Himalayas (Sah.*et.al*.,1994; Bhandari 2003). Saha *et.al*., (2018) reported the maximum range of WHC was 67.70% in the soil of mixed forest of temperate zone which was lower to the value of WHC from our study site. Furthermore, the differences in the WHC of different forest type soil are altered by the key component of the soil like soil texture, organic matter (Nayak *et.al*.,2014). Due to less clay content in the soil of Sal Forest the WHC was minimum as compared to that of mixed broad forest.

During soil analysis, soil samples of seven different sites were treated for pH test. The highest pH value was recorded from *Rhododendron* dominated forest (6.45) followed by *Abies-Rhododendron* Forest (6.03) and Sal Forest (6) that showed the soil was moderately basic. Acharya and Shrestha (2012) collected soil samples from southeastern and southwestern slopes of mixed *Shorea robusta* forest in Parroha community forest of Rupandehi District where the soil was acidic with pH ranges from 4.2-6.2. Gautam and Mandal (2013) analyzed soil pH from different Sal Forest of Bhabar belt of Sunsari district where the soil pH was 5.6 in the upper layer and 6.6 in deep layer. This observational result aligned with the study of Acharya and Shrestha

(2012) and Gautam and Mandal (2013). Similarly, the least soil pH value was recorded from Pine and *Taxus Wallichiana* dominated forest (5.6) which was moderately acidic.

Soil water rising and water percolation capacity of seven different types of forest from the tropical region to sub alpine region were analyzed. Among the studied forests, the average water rising capacity was found to be highest of mixed broad leaf forest of temperate region which was of sandy loam (0.656 cm/min) and lowest was found to be of loamy sand (0.29 cm/min) of Sal Forest of Sukute which lies at tropical zone (altitude of 671m) respectively. Similarly, the average water percolation was found to be highest of clay loam (0.89 cm/min) of *Rhododendron* dominated forest of sub alpine region (altitude of 3492m) and lowest was found to be of loamy sand (0.39 cm/min) of Pine Forest of Jiri (altitude of 1991m) of sub- tropical region respectively. The data showed that the rate of movement of water on the soil in upward direction for water rising and water percolation capacity was found comparatively more and gradually the rate decreases as time increases.

4. Conclusions

The study was done for the soil analysis of six different forests of Sindhupalchowk and Dolakha districts. Random sampling was done by making circular plots of size 10 m radius for tree species, 2.5 m radius for shrubs/ saplings and 1 m radius for herbs and seedlings respectively. Altogether 100 plant species of different families were enumerated from different locations of the sampling sites.

The soil analysis of different forests was done based on examining their textures, pH, sticky point, water holding capacity, water rising and percolation. Among soil samples collected from seven different forests, *Rhododendron* dominated forest had the least acidity with pH value of 6.45 whereas *Taxus* dominated forest and Pine Forest had more acidic soil with pH 5.6. During soil texture analysis, the soil samples of Sal Forest of both sites, i.e., Sukute and Jiri and Pine Forest were found to be Loamy sand whereas *Taxus wallichiana* dominated forest and Mixed Broadleaf Forest were found to have Sandy loam type of soil. In contrast, *Abies-Rhododendron* mixed forest had Sandy clay loam and *Rhododendron* dominated forest had clay loam type of soil.

Thus, the overall outcome of this study suggests that vegetation pattern depends upon different topographic and edaphic factors. The result may differ in accordance with different sampling designs respectively to different geographical variations. More work can be done to link vegetation patterns and soil qualities according to the altitudinal gradient.

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Conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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