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Research Paper

Unveiling topographic impacts on soil texture in mountainous forest landscape of Kashmir

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ABSTRACT

This study explores the interactions among soil texture, aspect, and topographic elevation in temperate Himalayan region. The major findings underscore substantial variations in soil texture across the studied locations. Soils at an altitude of 2200-2500 meters exhibits a pronounced prevalence of clay loam texture and soils at an altitude of 1800-2200 meters showcases a loam texture on the Northern aspect. While soils located at an altitude of 2200-2500 and 1800-2200 meters are sandy loam and sandy clay loam in texture respectively. The bulk density is rather constant throughout the study area, averaging 1.27 g/cc. The significance of customized soil management strategies in mountainous areas is highlighted by this research, which advances our understanding of the dynamic link between topography and soil characteristics. The results highlight the significance of taking into account the spatial distribution of soil qualities in varied landscapes and offer insightful information for sustainable land use planning and agricultural practices.

Key words: Aspect, elevation, forest soils, Himalayan region, soil texture

The vitality of our terrestrial ecosystems is generally attributed to the soil, which is essential to maintaining life on Earth. It is a dynamic and sophisticated system that promotes plant development, serves as the backbone of agriculture, and serves as a water filter for our cities (Shah *et al.*, 2022). The complex web of life that exists beneath the surface of the Earth depends on the physical and chemical characteristics of the soil, with soil texture being one of the most important characteristics (Bashir *et al.*, 2021). Water retention, nutrient availability, and overall soil health are influenced by soil texture, which is defined by the proportions of sand, silt, and clay particles in the soil (Guo *et al.*, 2022). For sustainable land management, agriculture, and environmental conservation, it is crucial to comprehend the factors that influence soil texture.

Altitude and aspect are two significant topographic variables that affect soil properties (Farooq *et al.,* 2022). The vertical elevation above sea level, or altitude, provides differences in temperature, precipitation, and pressure that can have a big impact on how soil develops. A slope's aspect, or the compass direction it faces, affects how much solar radiation it receives and creates microclimatic variations on slopes and ridges. Altitude and aspect's combined impacts have the potential to produce a varied mosaic of soil textures in various locations. The purpose of this study work is to fill a knowledge vacuum about the influence of altitude and aspect on soil texture, despite their significance.In mountainous areas, where steep slopes and different elevations contribute to microscale environmental heterogeneity, the interplay between altitude and aspect can be particularly strong (Bangroo *et al.,* 2021). In addition to being important environmentally, mountain habitats are also essential for agriculture and human settlement. Planning land uses, managing resources, and reducing the effects of climate change all depend on knowing how topographic characteristics and soil texture interact in these regions (Lal, 2012). This study aims to clarify the complex link between topographic aspect, altitude, and soil texture. We aim to clarify the patterns and processes regulating soil texture differences temperate forest mountains of Kashmir Himalayas.

MATERIALS AND METHODS

Study Area: The research was carried out in the Mawer Range, nestled in the heart of the Langate Forest Division, situated within the Kupwara District of the Jammu and Kashmir valley, India. This pristine location is positioned geographically between latitudes 34°17' and 34°22' North and longitudes 73°19' to 74°59' east, as illustrated in Figure 1. The Mawer Range, distinguished by its lacustrine origins, boasts a robust natural drainage system that ultimately converges into the Mawar River. The mean annual rainfall of the region is 1052.6 mm, mean annual minimum temperature and mean annual maximum temperature is 19.9 and 6.3 °C respectively.

The topography of the study area is characterized by a diverse range of slopes, spanning from moderate inclinations of 15-30% to steeper gradients of 30-50%. The Mawer landscape is predominantly adorned with coniferous species and the presence of broad-leaved species is limited, primarily confined to select areas, especially within the upper reaches of moist depressions and watercourses.

Conspicuously, the Mawer division is primarily dominated by three key conifer species: Deodar (*Cedrus deodara*), Kail (*Pinus wallichiana*), and Fir (*Abies pindrow*). In certain instances, the Fir zone harbors rare occurrences of spruce (*Picea smithiana*) and yew (*Taxus buccata*). Deodar and Kail thrive in lower elevations, gracing the landscape in both mixed and pure stands. Kail, renowned for its adaptability, occasionally extends its presence to the warmer and more exposed regions of the Fir zone. In specific locales, the Fir zone interlaces with the Deodar-Kail belt, facilitated by the presence of water torrents and moisture-rich depressions.

Significantly, the Deodar Forest, encompassing altitudes ranging from 1650 to 2625 meters, constitutes the most substantial forested expanse within the division, covering approximately 44% of the total area. Kail, on the other hand, constitutes roughly 19% of the stocked forest area, and its altitudinal range spans from 1700 to 2300 meters. In some instances, Kail can ascend to elevations as high as 2900 meters within the Fir zone, particularly in exposed and warmer aspects of the landscape. The lofty altitudes, ranging from 2100 to 3500 meters, are predominantly inhabited by the Fir species, which encompasses nearly 37% of the entire stocked forest area, exemplifying its prevalence in the division's higher reaches.

Soil sampling and analysis: Four soil samples were systematically collected from the respective forest compartments within eight forest beats located in the Mawer range from the Northern and Southern aspect and mid to high altitude regions. A total of thirty-two samples were gathered with meticulous consideration to ensure equal distribution across both altitude and aspect categories. The altitudinal range covered in soil sampling effort extended from 1814 to 2263 meters above sea level (masl). The specific sites chosen for sample collection are shown in Fig. 1.

The collected soil samples were pre-processed and sieved through 2mm sieve. The particle size distribution was determined by international pipette method (Blacke and Hartge, 1986) and bulk density by core method (Klute and Dirksen 1986).

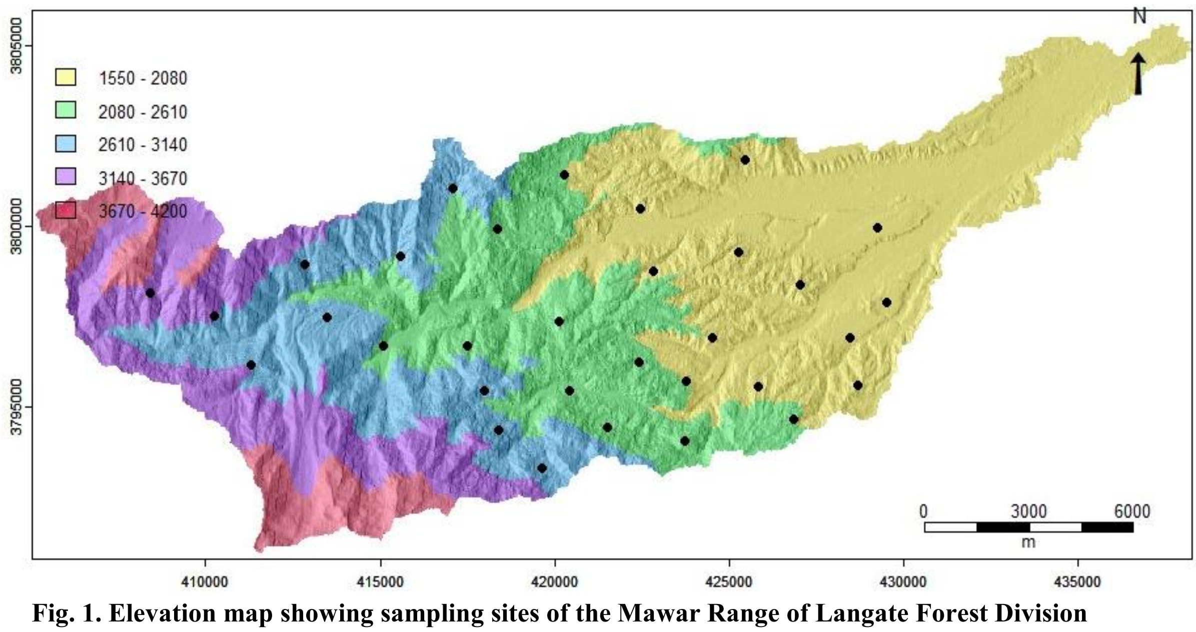

Fig. 1. Elevation map showing sampling sites of the Mawar Range of Langate Forest Division

RESULTS AND DISCUSSION

Topographic Influences on Soil Texture: The soil composition of mountainous landscapes is a complex interplay of topographical factors, each contributing to the intricate mosaic of particle distribution. In the verdant expanse of Kashmir's mountainous forest landscape, the study delves into the profound impact of topography on soil texture, unraveling the nuances through: spatial distribution and altitudinal gradients, and microtopographic variations impacting on soil texture heterogeneity.

Spatial Distribution and Altitudinal Gradients: The Particle Size Distribution (PSD) analysis, detailed in Table 1, offers a comprehensive insight into the variations of sand, silt, and clay across different altitude zones and aspects. In the altitude zone of 1800-2200 masl on the northern aspect, the sand content ranged from 21.34 to 32.45 percent, with a mean value of 27.79 percent. In contrast, the 2200-2500 masl altitude zone of the northern aspect exhibited a broader range, from 28.5 to 42.2 percent, with a mean value of 39.45. Silt content demonstrated distinct patterns in both northern and southern aspects across varying altitude zones, underscoring the profound influence of topography on silt distribution.

In the southern aspect's 2200-2500 masl and 1800-2200 masl altitude zones, clay content ranged from 16.5 to 28.3 percent and 19.21 to 28.7 percent, respectively. Conversely, the northern aspect exhibited a wider range, from 14.6 to 39.8 percent and 18.4 to 28.3 percent, indicating a significant microtopographic impact. The highest clay content was consistently observed in the soils of the northern aspect, particularly in moderately sloping areas.

The study discerns the impact of altitude and aspect on silt distribution, emphasizing the role of vegetation, temperature and precipitation gradients in PSD dynamics. Cooler temperatures at higher altitudes can impede soil formation processes, leading to the accumulation of coarser particles (Li *et al.*, 2021; Bogunovic *et al.*, 2017; Yang *et al.*, 2021). Consequently, soils at higher altitudes tend to display a relatively higher proportion of sand and silt compared to finer clay particles (Wicki *et al.*, 2023).

Microtopographic variations impacting on soil texture heterogeneity: The microtopographic variations further elucidate the intricate relationship between altitude, aspect, and soil texture. The precipitation pattern, influenced by orographic precipitation at higher altitudes, contributes to leaching in soils. Differences in insolation period and intensity change with aspect, thereby forming a range of microclimates in multifaceted landscapes (Holland and Steyn, 1975; Lou *et al.*, 2021). Higher altitudes receive more precipitation, potentially removing finer particles like clay and leaving coarser particles behind (Adebiyi *et al.*, 2023).

Moreover, the study observes a fascinating texture gradient between north-facing and south-facing soils. North-facing soils exhibit a finer texture, while plains and near-level lands showcase finer soils than those on sloping lands. Altitude plays a pivotal role in shaping these variations, influencing sunlight exposure and temperature gradients on slopes. South-facing slopes, receiving more direct sunlight, can be warmer and drier compared to north-facing slopes, impacting evaporation rates and potentially altering soil texture. In contrast, north-facing slopes retain more moisture, resulting in distinct texture characteristics (Cantlon, 1953; Kutiel and Lavee, 1999). Several studies conclude that the variation between two contrasting aspects is the result of the differences in solar radiation received, e.g. in Australia (Kirkpatrick *et al.,* 1988), in east Africa (Vetaas, 1992), the Himalaya (Ghimire *et al.,* 2010), and even within the same elevation (Shank and Noorie, 1950).

Table 1: Soil particle distribution of surface samples of mawar range of Langate forest division

S. No.	Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cc)	Texture	Aspect	Altitude (masl)
1	39.45±3.88	29.01±3.65	31.45±0.81	1.27±0.02	Clay Loam	Northern Aspect	2200-2500
2	27.79±3.15	47.34±2.76	22.76±2.48	1.26±0.02	Loam	Northern Aspect	1800-2200
3	53.62±3.82	27.05±3.63	19.33±1.58	1.27±0.02	Sandy Loam	Southern Aspect	2200-2500
4	55.67±6.37	18.51±5.45	25.82±1.84	1.27±0.02	Sandy Clay Loam	Southern Aspect	1800-2200

Bulk density dynamics in relation to altitude and aspect: The bulk density ranged from 1.18 to 1.32 g/cc and 1.19 to 1.35 g/cc in the 1800-2200 masl and 2200-2500 masl altitude zones of northern aspect with a mean value of 1.26 and 1.23 g/cc, respectively. In the southern aspect, bulk density ranged from 1.19 to 1.34 g/cc and 1.21 to 1.33 g/cc with a mean-values of 1.21 and 1.27 g/cc, respectively.

The analysis of bulk density in the northern and southern aspects across different altitude zones provides further insights. Despite the focus on altitude and aspect, no substantial differences in bulk density were observed. It's crucial to note that soil bulk density can be influenced by various factors, including organic matter content, soil structure, compaction, and land management practices. In this specific study, the constant land use underscores the need for further research and a broader dataset to comprehensively understand the relationship between soil bulk density, altitude, and aspect in diverse mountainous landscapes.

CONCLUSION

This study elucidates the impact of topographic factors on soil texture in Kashmir's mountainous terrain. The diverse altitudes (1800-2500 meters) and aspects (Northern and Southern) examined revealed distinct soil texture patterns. Altitude played a pivotal role in shaping soil characteristics, with each site showcasing a unique combination of sand, silt, and clay percentages. Surprisingly, soil bulk density exhibited remarkable consistency across all sites, suggesting a lesser influence of altitude and aspect in this regard. These findings underscore the importance of tailoring soil management strategies to the specific topographic conditions of mountainous landscapes. While this study contributes valuable insights, further research considering additional factors and a broader dataset is warranted to enhance our understanding of the nuanced relationships between topography and soil properties.

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