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A Review on Beta Diversity Patterns of Mountain Regions in India

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Abstract: *Species turnover, or beta (β) diversity, fluctuates with environmental and elevational gradients. Ecologists have always been captivated by the Mountain ecosystems due to their abundant floristic diversity. The beta diversity of these mountain regions is influenced by multiple ways. Consequently, by comprehending these drivers of beta diversity, research needs will be identified, important insights into the variables influencing the structure of plant communities across different environments will be gained, and conservation efforts in mountainous areas can be more effectively implemented. Nevertheless, no other research has offered detailed information on the several factors influencing the plant variety in these alpine habitats. We examined different trends and reasons for β-diversity in the alpine area at vertical gradients that give rise to different plant community forms and structures. This review paper covered many elements that contribute to species turnover on various vertical gradients and provided in-depth information. This review article carefully examines the body of scientific material that has been published, concentrating on key factors such as topographical characteristics, climatic gradients, and human influences. The goal of this critical synthesis of these variables is to clarify the intricate ecological processes regulating beta diversity in these particular settings. This study will address several factors influencing the plant variety in the mountain ranges and contribute to our understanding of the relevance of species turnover in plant communities.*

Keywords: *Beta diversity, Mountain regions, topographical features, climatic gradients, scientific literature, plant communities*

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1. Introduction

Mountainous ecosystems have always fascinated ecologists due to their rich floristic diversity. Nearly 24% of the Earth's land surface is occupied by mountains, which directly support over 12% of the world's population that lives in these regions [1]. Furthermore, one-fifth of humans obtain ecosystem services from mountains, including fresh water, food, air purification, bioresources, and spiritual renewal [2][3]. Mountain ecosystems also have an extremely high level of biological diversity, which results from the compression of different micro eco-climatic zones along topographical gradients, and different vegetation types narrow down to very small distances [4][5]. However, because of the harsh natural conditions and severe threats due to human-induced pressures and climate change, mountain ecosystems are among the most fragile [6].

The Himalayas are one of the world's most diverse and expansive mountain ecosystems and one of the most critical biodiversity hotspots [2]. The Himalayan Mountain range represents the highest elevational gradient and is bestowed with exceptionally rich and distinctive biodiversity [7]. The spatial variation in species diversity and its underlying mechanisms are a fundamental but still unsolved mystery in ecology [8] and mountainous regions such as the Himalayas are ideal for such studies. Forest ecosystems' most significant ecological features are species richness and composition, which display fluctuations in response to environmental conditions [5][9]. Plant species composition, structure, and distribution patterns within a community in mountainous regions are determined by a combination of variables, including vegetation type aspects and elevation [5][9].

Elevation is among the most significant factors having a robust impact on the vegetation structure in mountain ecosystems such as the Himalayas [9][10]. Elevation is a complex collection of related meteorological variables strongly linked to various other environmental properties such as soil profile, nutrients, and moisture. Furthermore, within a given altitude, co-factors such as topography, aspect, slope, and edaphic parameters impact forest composition [11]. As a result, changes in altitude result in the formation of distinct microclimatic conditions, which promote

diversity in species composition [12]. Plants have long served as a significant object for studying the elevational richness pattern and its underlying mechanism, owing to their distribution and ease of surveying [12]. Numerous workers have predicted and demonstrated the uphill migration of plant species in response to changing climatic circumstances; hence, investigating species richness and composition patterns is a global concern [13][14]. In the Himalayan Mountains ecosystems, climatic zones may change rapidly, which is reflected by prominent changes in vegetation structure even at small distances [15]. Although many studies along the Himalayan altitudinal gradients have been conducted to understand large-scale biogeographical patterns better and what drives them, a clear pattern has yet to emerge, as most of these studies attempted to document the pattern of species and composition at lower or higher elevational zones.

Kashmir Himalaya is located in the extreme northwest of the IHR with varied geography and a considerable area under forests, meadows, and glaciers [16]. Owing to its wide habitat heterogeneity, it is regarded as one of the ecologically complex and biologically diverse ranges within the Himalayan Biodiversity Hotspot [17]. Despite representing only 0.4% of the total geographic area of India, the region encompasses 12% of the total angiosperms of India signifying its rich floristic diversity [16]. Like other parts of the Himalayan region, the biodiversity of Kashmir Himalaya is also undergoing severe alterations owing to various drivers of biodiversity loss. Over the decades, many plant species have become threatened due to habitat loss, habitat fragmentation, deforestation, the introduction of invasive species, overexploitation, overgrazing, land-use change, colossal tourist influx, and building of roads, coupled with political disturbances [18].

The interplay of cultural practices and traditional agriculture adds a layer of complexity to its biodiversity, setting the stage for studying beta diversity and plant species richness along the vertical gradient. Therefore, it is crucial to discuss various factors that can influence alpha diversity and beta diversity patterns at different vertical ranges of the mountain. In this review article, we presented varied affecting the beta diversity of the Himalayan region of Jammu and Kashmir, India. For this, we discussed multiple studies till now conducted in the area by considering various parameters.

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2. Beta diversity in the Mountain regions

The plant diversity is irregularly distributed throughout space and typically follows a latitudinal gradient, with diversity rising from the poles toward the equator. Significant regional differences in species richness have been observed between different habitats, e.g., between an open grassland and a forested area [19]. Three degrees of species diversity have been developed as a result of these observed spatial patterns: alpha, beta, and gamma diversity [20]. For small-scale or local species variety within a community, the term "Alpha (α) Diversity" (local-level species variation) is used; this often corresponds to the size of an individual ecosystem. The term "alpha diversity" is typically used when discussing variety in a particular domain. Comparably, species diversity between two communities or ecosystems is described by Beta Diversity (β), which takes the stage and details diversity between ecosystems. Functioning on a larger scale, this idea seeks to compare the diversity of species in two different entities, which are frequently separated by observable geographic features like rivers or mountain ranges. In contrast, gamma diversity, or diversity across biomes, takes a broad view and looks at species variety within a biome on a large scale. This analysis covers large areas, such as the whole littoral zone of a shoreline or a full mountain slope. Gamma diversity sheds light on the total species richness in various ecosystems within a more expansive, integrated setting.

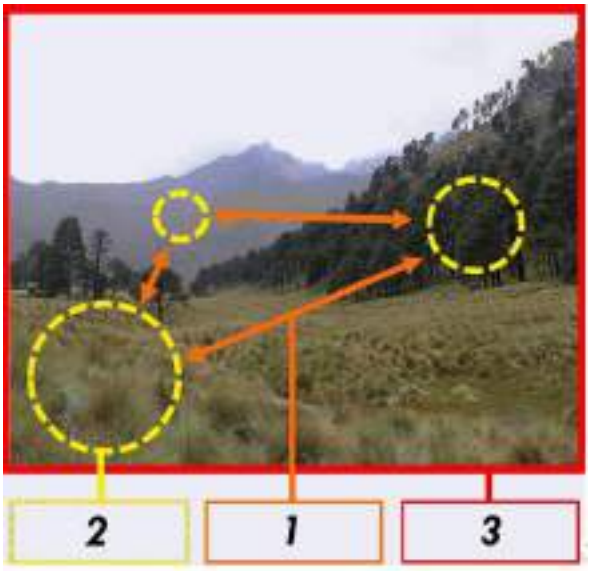

Fig. 1.: The photograph of the mountain region representing various levels of diversity, including alpha (2), beta (1), and gamma diversity (3).

1.1 Studies conducted to explore the Beta diversity of Mountain regions in India

In India, a study was conducted in the Himalayan region (Kashmir, Uttarakhand, and Sikkim) to explore lichen diversity in the Indian Himalayan Arc at three different places covering a wide range of elevations. The study has found 245 lichen species in total, with

only 11 species common to all three locations. Despite differences in species, the dominant lichen types were similar. Most lichen groups showed a pattern of more diversity at middle elevations, although some had the opposite pattern. The diversity between locations (β-diversity) varied along the elevation gradient, with turnover being more important than nestedness. Overall, this study mainly emphasizes that lichen species richness and diversity change with elevation, suggesting the need to consider elevation when planning conservation efforts in Himalayan region [21].

Another study was conducted in the Dhauladhar Mountains range of the Indian Himalayan region to understand how plant communities vary with the altitudinal variation [22]. For this, they set up 21 spots at different heights and studied the plants in each spot. The researchers have found that plants grow at different heights (from 2000 to 4000 meters). The study found that the variety of plants followed a specific pattern as you go up or down the mountain. Some areas in the middle of the mountain had a mix of different plants, while the ones at the top and bottom were more distinct. This was because the middle areas provided a special environment that suited certain plants. However, human activities have disturbed the areas at lower altitudes, making the plant life more similar there. The study suggests that it's crucial to protect these middle areas, even though we shouldn't forget about preserving the unique plant communities at the top and bottom of the mountain.

Likewise, some studies were also carried out in the Western Ghats, a mountain range in India aimed to understand how different factors influence the variety of tree species [23]. The study explored the impact of various climatic factors and terrain on the characteristics of the tree species. The results highlighted that the Western Ghats stretch along the western coast of India, covering a long distance from about 8° N to almost 21° N latitude. This study looked at data from 60 small plots in three areas: the southern part of the Western Ghats, the Nilgiri Hills, and the central Western Ghats. In this study, researchers used Sorensen's index to compare how similar the plant species were in different plots. This study looked at how the similarity changed with the distance between plots. They also studied how differences in climate, like rainfall and seasonality, affected plant diversity. The results showed that plant diversity varied the most along the north-south

axis and in areas with different rainfall levels. Differences in seasonality between sites were strongly linked to plant diversity along the north-south gradient and in the southern part of the Western Ghats. Overall, the study suggests that climate, especially seasonality, is likely the main reason why plant diversity differs in the Western Ghats rainforests.

In another study conducted at the Mehao Wildlife Sanctuary in Arunachal Pradesh, India, researchers examined the diversity and distribution of lichens across 10 different sites [24]. They found a total of 177 lichen species, belonging to 71 genera and 35 families, within the Sanctuary's varied landscape, ranging from 400 to 2700 meters in altitude. The Sanctuary showcased a wide range of lichen types, including those that grow on trees (133 species), on both rocks and bark (25 species), on rocks (17 species), and the ground (2 species). Crustose lichens were most common among those growing on trees, while fruticose lichens dominated those on rocks and the ground. Each site had its own unique set of lichen species, with 77 species found at only one site. The study identified altitude and humidity as important factors influencing lichen diversity, with the mid-altitude range of 1400 to 1600 meters exhibiting the highest diversity. Overall, the research revealed a peak in lichen diversity at mid-altitude levels, suggesting a significant relationship between altitude and lichen distribution within the Sanctuary.

In the Eastern Himalayan region, researchers have explored how satellite imagery, plant data, and geographic mapping tools can be combined to study biodiversity [25]. By dividing the area into six zones based on different vegetation types and altitudes, the study examined how disturbances like human activity affect the richness of plant species. The findings revealed that areas with higher levels of human disturbance, such as settlements and roads, tend to have a lower diversity of economically important, medicinal, and endemic plant species as altitude increases. Conversely, habitats with lower disturbance levels, more complex terrain, and greater species richness and endemism exhibit higher biological richness. Overall, while disturbance decreases with altitude, biological richness follows a hump-shaped pattern. This study highlighted the utility of integrating remote sensing and GIS techniques for understanding biodiversity distribution in the Eastern Himalayas, particularly in Arunachal Pradesh.

2. Conclusion

In conclusion, the review sheds light on the divergent patterns of beta diversity observed across the Indian Himalayan regions. Through an extensive examination of existing literature, it becomes evident that various factors such as topography, climate, and anthropogenic influences play crucial roles in shaping these divergences. The diverse landscapes of the Indian Himalayas present unique ecological challenges and opportunities, influencing the distribution and composition of plant and animal species across different altitudinal gradients. By synthesizing the findings from multiple studies, this review underscores the importance of comprehensive conservation strategies that account for the complex interplay of ecological factors driving beta diversity variations. Moving forward, further research efforts are needed to deepen our understanding of these dynamics and to inform effective conservation and management practices in this ecologically rich and fragile region.

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