**DISTRIBUTION OF MEDICINAL AND AROMATIC PLANTS (MAPS) ALONG ELEVATION GRADIENTS IN MYAGDI CENTRAL HIMALAYA, NEPAL**

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**Abstract**

Altitude is a critical factor influencing vegetation composition, ecosystem properties, and soil nutrient availability. This study, conducted in the Central Himalaya's Myagdi area in Nepal, explores the distribution of medicinal and aromatic plants (MAPs) across an altitudinal range from 1800 m to 3800 m above sea level. A total of 50 species were identified, predominantly herbs (40), followed by shrubs (7), climbers (2), and ferns (1). The researchers employed square plots (n=69 of 25 m2) sampled at 100-meter intervals along the altitudinal gradient. Various factors such as slope aspect, disturbance levels, and habitat characteristics were recorded at each plot. Soil samples were collected using standard methods, and soil variables including pH, soil organic carbon (SOC), total nitrogen, potassium, and phosphorus were investigated. The findings indicated a decline in plant species abundance with increasing elevation, as determined by a linear model. The Kruskal-Wallis test revealed a significant correlation (p < 0.05) between habitat characteristics and slope aspect. However, there was no significant correlation (p > 0.05) between disturbance levels and MAP abundance. Soil pH exhibited a decreasing trend with elevation (4.5 to 6.5), while SOC increased with higher elevations, suggesting a positive relationship. Although species richness did not significantly correlate with SOC, total nitrogen showed a positive relationship with elevation. Available potassium exhibited a significant positive relationship with elevation, as did the correlation between plant abundance and potassium. Conversely, available phosphorus displayed a significant negative relationship with elevation, while a positive relationship was observed between plant number and phosphorus.

The study underscores the intricate relationships between soil parameters, MAPs, and environmental factors along altitude gradients. Further research in different Himalayan regions will enhance our understanding of these interactions, contributing to broader insights into the impacts of altitude on vegetation and ecosystems.

**Key words:** *Altitudinal Gradient, Aspect, Disturbance, Habitat*, *Medicinal and Aromatic plant species, Soil parameters*

1. **Introduction**

Aromatic plants are within the category of medicinal plants, and together they are referred to as Medicinal and Aromatic Plants (MAPs). These are plants that offer therapeutic benefits or aid in maintaining good health. Medicinal plants are devices that have certain characteristics that have been proved to offer medicinal benefits (Taylor, 1996), also called herbal drugs. In traditional and modern medical systems throughout the world, they are used to treat diseases. Raw, processed, or semi-processed versions of medicinal plants are used, usually combined with other plants or chemicals (Bhattarai & Ghimire, 2006). Globally, around 28,000 plant species are used for medicinal purposes (Willis, 2017) and approximately 3,000 species of them are in local, regional, and global systems (World Bank, 2018).

The world is home to a large variety of aromatic and medicinal plants, including those from south and southeast Asia, America, Europe, Africa, and Australia. More than 7,500 species, or 50% of the native plant species in India(Shankar & Majumdar, 1997) are employed in traditional medicine. Around 6,000 species with therapeutic qualities are used in China (Pei-Gen, 1991). In the context of Nepal, the catalog has reported 1,792 (Rokaya et al., 2010), however according to Baral & Kurmi, (2006) in Nepal, there are 2,331 beneficial medicinal and aromatic plants in Nepal, describing their significance in easing human suffering due to their long-standing use for traditional medicines, home cures, and subsistence.

The abundance of medicinal plant species in Nepal increases between 1000 and 2500 m above sea level (Bhattarai & Ghimire, 2006; Rokaya et al., 2012) and then declines as elevation increases (Pyakurel & Oli, 2013). This indicates the outstanding contribution of the mid-hills and lower mountain physiography to the diversity of medicinal plants (Kutal et al., 2021).

According to (Havlicek & Mitchell, 2014), soils are complex systems where interactions between mineral particles and soil organisms result in a diversity and complexity of species. In a specific climate regime, the capacity for rangeland production can be determined by the soil composition (Holland & Steyn, 1975). Additionally, research (Toure et al., 2015) indicate that soil characteristics may have a significant influence in regulating the spatial patterns of vegetation. According to some researchers, height and climate factors like temperature and rainfall influence species diversity. Co-factors like topography, aspect, slope inclination, and soil type also influence the vegetation composition within a given height (Holland & Steyn, 1975).

The influence of soil physicochemical parameters on plant species diversity can be reflected by an elevation gradient (Han et al., 2022). Only a few research on the influence of environmental conditions on grassland diversity and biomass production in the Himalayan Range have been conducted (Bhandari & Zhang, 2019). However, studies on the distribution of MAPs and analyzing the relationship with environmental factors were lacking in the study area. This study aims to analyze the distribution of medicinal plants in the central Himalaya of Myagdi, Nepal, focusing on the impact of elevation gradient, soil nutrients, and disturbance activities on species richness and abundance. The research aims to help in conservation decisions and management of medicinal plants, addressing the limited studies on this relationship.

1. **Materials and Methods**

***2.1 Study Area***

The study was conducted in the Myagdi Area of Central Himalaya Region in Raghuganga Rural Municipality, Gandaki Province of Nepal. Myagdi district is bounded by 83°08' to 83°53' longitudes and 28°20' to 28°47' latitudes, Myagdi District extends from altitude of 792m to 8,167m. Figure 1 shows the study area in the given below. It is named after the name of Myagdi River which flows from Dhaulagiri Himalayas West-North to South-East. The Department of Hydrology and Meteorology recorded June as the highest average temperature (31.403°C), with similar readings in May, July, and August. July and November saw maximum and minimum rainfall.

According to Gewali & Awale, (2008) In Nepal's subtropical zone (between 1,000 and 2000 metres), 54% of the MAPS are available and the dominant plants in the drier areas, woods of *Pinus roxburghii* can be found. Subtropical forests in more humid areas are dominated by *Schima wallichii,* *Castanopsis indica*, and *Castanopsis tribuloides*. In Temperate Zone (2000-3000m) 36% available of MAPS and *Rhododendron arboreum,* *Rhododendron barbatum*, *Lyonia* spp., *Pieris formosa*; *Tsuga dumosa* forest with such deciduous species as *Acer* and *Magnolia*; deciduous mixed broadleaved forest of *Acer campbellii*, *Acer pectinatum*, *Sorbus cuspidata*, and *Magnolia campbellii*; mixed broadleaved forest of *Rhododendron arboreum*, *Acer campbellii*, *Symplocos ramosissima* and Lauraceae species. The region also boasts a variety of significant plant species, including *Abies pindrow*, *Betula utilis*, *Buxus rugulosa*, *Benthamidia capitata,* *Corylus ferox*, *Deutzia staminea*, *Euonymus tingens*, *Abies spectabilis, Acanthopanax cissifolius, Coriaria terminalis, Fraxinus macrantha, Dodecadenia grandiflora, Eurya cerasifolia, Hydrangea heteromala, Ilex dipyrena, Ligrestum* spp*., Litsea elongata, Juglans regia, Michelia doltsopa, Myrsine capitallata, Neolitsea umbrosa, Philadelphus tomentosus, Osmanthus fragrans, Prunus cornuta, Rhododendron campanulatum,* and *Vibernum continifoliums.* In Sub alpine zone (3,000-4,000m) 54% of the MAPS available However, *Abies spectabilis, Betula utilis, and Rhododendron* spp*.* are responsible for most of the forests in the subalpine zones*.* The subalpine region is home to a wide variety of beneficial plant species*,* including those from the *genus Aconitum, Allium, Bergenia, Ephedra, Betula, Paris, Neopicrorhiza, Swertia, and Taxus. Sorbus cuspidata, Euonymus tingens, Ribis glaciale, Acer pectinatum, Salix spp., Lyonia spp., Prunus rufa, Acer candatum, Acanthopanax cessifloia, Sorbus microphylla, Berberis spp., and Juniperus spp*. are other significant plant species present in the subalpine zone.

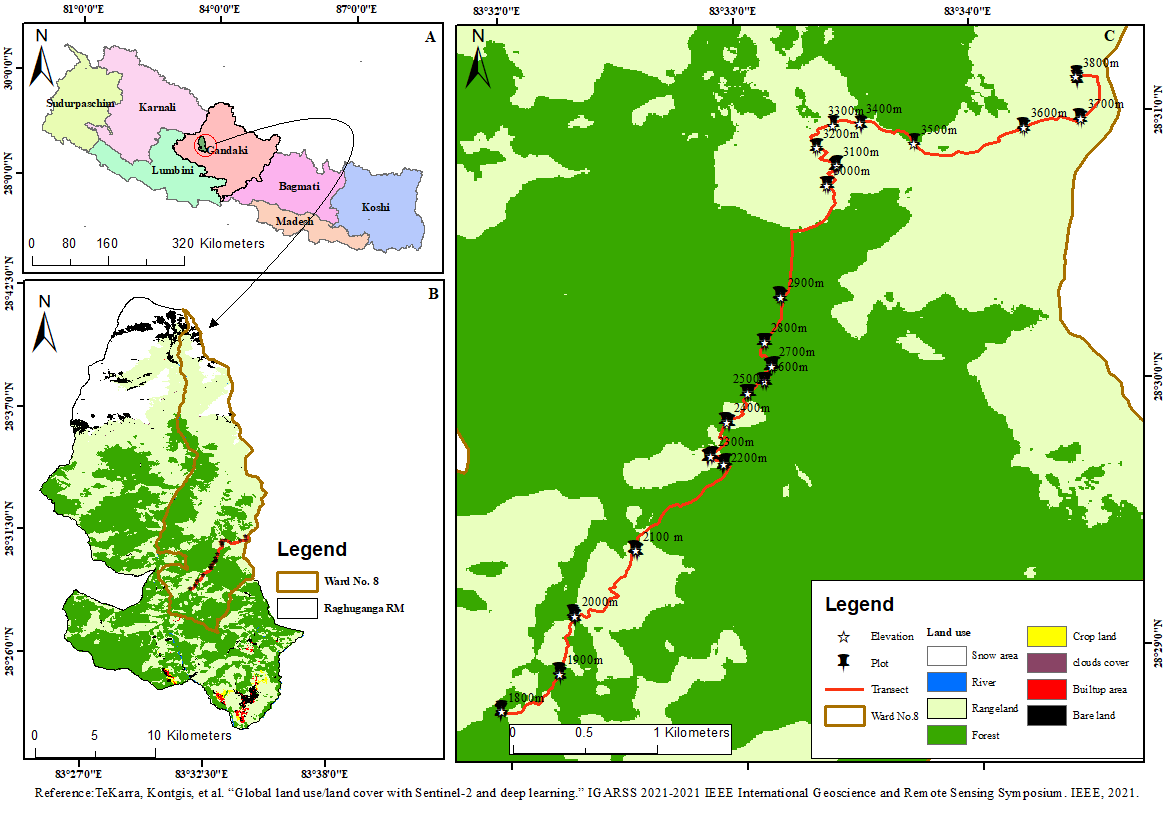


Figure 1: Study Area, A) Nepal's provinces, B) Representation of Raghuganga Rural Municipality's ward, and C) Transect with sampling plots.

***2.2 Sampling methods***

The altitudinal gradients start from 1800 m along foot trail to 3800 m. Garmin GPS Survey Instrument and GPS Essential android application (with an accuracy of ±10 m) was used regularly to fix the altitudinal position along transect. Each plot was sampled exhaustively (2-3 hrs by 3 persons) and the plot area was kept constant thus controlling both effort and area in our measure (Lomolino, 2001). Each sample site (Figure 2 and figure 3) consisting of 4 plots were selected in every 100-meter elevation starting from 1800 m to 3800 m. A quadrat of size (5\*5 m) was laid in a plot. All the MAPs were enumerated thoroughly and written in a checklist. From sample plots aspect, habitat and disturbance signs were also collected.

A diagram of a foot trail

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Figure 2: Transect Research Design for Sampling.

A map of a road

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Figure 3: The map shows the Transect with Sampling Plots.

A systematic survey was implemented in the 5m\*5m quadrats along the transect line from 1800 m to 3800 m. The soil samples were taken from each quadrat, combined, and the resulting composite soil sample was used for analysis. A few environmental factors were also noted, including the quadrat's latitude and longitude, height, and Aspect. In each quadrat, soil samples were taken from the topsoil layer (0–15 cm) (Kewlani et al., 2021), which had been cleared of any leaf litter. Table 1 shows the detailed methodology for the analysis of soil sample.

Table 1: Soil Sample Analysis Methodology

|  |  |  |
| --- | --- | --- |
| **S.N.** | **Soil Parameters** | **Methods** |
| 1 | pH | probe method (Fernández & Hoeft, 2009) |
| 2 | soil organic carbon (SOC) | Walkley and Black method (Walkley & Black, 1934) |
| 3 | Total Nitrogen | Kjeldhal method (Baker & Thompson, 1992) |
| 4 | Available Phosphorus (ppm) | Bray's method (Bray & Kurtz, 1945) |
| 5 | Available Potassium (ppm) | Flame-Photometer method (Pratt, 1965) |

1. **Results**

***3.1 Distribution with Altitudinal Range***

The medicinal and aromatic plants were distributed in various locations with varying elevations, ranging from 1800 meters to 3800 meters in the Himalayan region. There were 19 of these plants (Aaiselu, Aakashe lahara (Aakase Beli), Amali, Bannko, Bhatwasee, Bilaune, Charchari, Chariamlo, Chiple, Chutro, Dhimsi Ghans, Furkejhar, Ghodtapre, Gujargano (Batulepate), Halhale, Niuro, Nigale Saag, Pyauli, Sukulejhar, Titepati) between 1800 and 2300 meters in elevation. At higher elevations, between 3200 and 3800 meters, there were seven species (Bishjara, Raktmaal, Nirmasi, Jatamasi, Paanchaunle, and Padamchal). There were fewer MAPs in the region, between 2300 and 3200 meters.

***3.2 Plants Diversity with their Lifeforms***

The result presented in Table 2 provides important information about the lifeforms of plant species in a transect. There were 493 distinct plant species in total. This suggests the local plant community is abundant and diverse. The elevation transect was characterized by a diverse plant community with a strong contribution of herbaceous (80%) species, followed by shrubs (14%), climbers (4%), and ferns (2%).

Table 2: Plant Diversity Across Different Lifeforms

|  |  |  |  |
| --- | --- | --- | --- |
| **S.N.** | **Lifeform** | **Total Species** | **Percentage** |
| 1 | Herb | 40 | 80 |
| 2 | Shrub | 7 | 14 |
| 3 | Climber | 2 | 4 |
| 4 | Fern | 1 | 2 |
|  | **Total** | **50** | **100** |

***3.3 Medicinal and Aromatic Plants Abundance along the Altitudinal Gradient***

The below figure 4 indicates that, with a count of 68 species, the largest species abundance was found at an altitude of 2000 meter above sea level (m a.s.l.). In contrast, 3 plants species were found at the elevation of 3300 meter above sea level, which has the lowest species abundance. Notably, plant species were missing at elevations of 2400 m, 2500 m, and 2600 m a.s.l. plots. The number of plant species present consistently declines as elevation rises. This pattern suggests that the plant communities at higher elevations are less varied.

Figure 4: The relationship between plant abundance and elevation (x-axis=m a.s.l.). The fitted line is based on a linear regression using a linear model.

***3.4 Variation of Plant Number with Habitat Level***

Table 3 indicate that plant abundance varies among several habitat types, with grassland having the maximum number of plants (316), followed by forests (81), cropland (51), rocky areas (21), shrubland (15) and barren ground (9).

Table 3: Habitat-Level Variation in Plant Numbers

|  |  |  |
| --- | --- | --- |
| **S.N.** | **Habitat** | **Total Plants in number** |
| 1 | Grassland | 316 |
| 2 | Forest Area | 81 |
| 3 | Cropland | 51 |
| 4 | Rocky Area | 21 |
| 5 | Shrubland | 15 |
| 6 | Bare Land | 9 |

Figure 5 illustrates that the average highest number of plants was found in the cropland and the average lowest no of plants was found in the shrubland between the different habitat categories. The Kruskal-Wallis test result shows that there is a significant difference in the number of plants among various habitat categories, With five degrees of freedom, the test statistic, chi-squared, has a value of 25.733 and p-value of < 0.01.

A graph of different sizes and colors

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Figure 5: Habitat level variation in Plant Numbers

***3.5 Variation of Plant Number with Aspect***

The medicinal and aromatic plant abundance was seen to be highly influenced by aspect and were typically higher on the southern aspect i.e., 257 (Table 4). The aspect of a slope, i.e., its orientation to the sun, can play a role in controlling several environmental factors and contribute to differences in plant abundance.

Table 4: Aspect level variation in plant numbers

|  |  |  |
| --- | --- | --- |
| **S.N.** | **Aspect** | **Total Plants in number** |
| 1 | South | 257 |
| 2 | West | 146 |
| 3 | Southwest | 44 |
| 4 | East | 37 |
| 5 | Northeast | 9 |

Figure 6 results, the total number of plants varies significantly depending on the aspect of the terrain. With 4 degrees of freedom and a chi-squared statistic of 29.629, the Kruskal-Walli’s test obtained an incredibly small p-value of <0.05. This highly significant finding implies that the terrain's aspect has strong control on plant species composition and abundance.

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Figure 6 Aspect Level variation in Plant Numbers

***3.6 Variation of Plant Number with Disturbance***

From Table 5, comparison of the two disturbance levels present i.e. 307 and absent i.e 186 the medicinal and aromatic plants number was higher in disturbed area than relatively undisturbed area.

Table 5: Disturbance wise level variation in plant numbers

|  |  |  |  |
| --- | --- | --- | --- |
| **S.N.** | **Disturbance** | **Total Plants in number** | **Percentage (%)** |
| 1 | Present | 307 | 62 |
| 2 | Absent | 186 | 38 |

The average number of plants in low disturbance areas found 5 plots per quadrat compared to 9 plots in disturbed sites (figure 7). However, the difference was not statistically significant (U=1.73, df=1, p=0.1876).

A diagram of a number of objects

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Figure 7: Disturbance wise Level variation in Plant Numbers

***3.7 Correlation matrix between Altitude and other variables***

Figure 8 explains how altitude is related to various soil parameters, and the coefficients and significance levels help to quantify the strength and direction of these relationships. It demonstrates that altitude influences soil properties, either positively or adversely. Specifically, variables such as the total number of plants and organic carbon indicate a highly significant negative relationship with altitude, as they have very low p-values. This implies that both the total number of plants and organic carbon tend to decrease as altitude increases Similarly, variables like pH, available phosphorous, and available potassium indicate a statistically significant negative relationship between the altitude, as they have a low p-value (0.005), but the variable total nitrogen was found to have a highly significant positive relationship with altitude which indicate higher altitude is associated with a higher level of total nitrogen in the soil.

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Figure 8: Correlation matrix between Altitude and other variables

1. **Discussion**

The Nepal Himalayas regions provide very important habitats with a very high diversity of medicinal plant species (Ghimire 2016). Total 50 species of MAPs were recorded in the study area. High altitude MAP species are the key natural resources of the Himalayas which have long been extracted for both trade and local health care systems (Olsen and Larsen 2003). Herbaceous vegetation in alpine and subalpine meadows typically begins to sprout in early May, reaches its peak coverage in mid-August, and ceases to grow by the end of September (Bhandari & Zhang, 2019). The studied species along with other high-altitude medicinal plant species are critically vulnerable to trade in the commercial market, for which an alternative protection mechanism is required.

The aspect-wise distribution of soil characteristics and species richness were clearly influenced by soil temperature. We may claim that altitude is the most important factor influencing distribution of MAPs. However, aspect influences species richness by generating a dry or damp environment and affecting the rate of decomposition of leaf litter (Gewali & Awale, 2008).

Our study demonstrates that among the various levels of habitat, including bare land, crop land, forest area, grassland, rocky area, and shrubland, the Grassland had the highest number of MAPs (316), followed by forest area (81), crop land, rocky area, shrubland, and bare land, in that order. The development of clonal dispersion organs is influenced by environmental factors (Sachs & Novoplansky, 1997). Our samples mostly came from the grassland sites, this could be possible cause of higher abundance.

In the Himalaya region, species distribution patterns regarding altitude, aspect, and habitat types were the focus of the current study. Our result showed that the southern aspect has a higher number of medicinal and aromatic plants distribution. According to Panthi et al. (2007) The south face has a higher species richness and altitudinal range than the other faces. In general, the north slope aspect of Nepali hills is moister than the south, resulting in greater species richness in the north slope aspect of Manang valley than in the south. Plant growth may be slower in the south facing slope aspect than in the north aspect due to higher solar radiation and less moisture. It is also supported by Måren et al. (2015) because water affects the type, structure, and density of plant communities**.**

The ecologists and environmentalists have been focusing on studying how different plant species coexist and interact with each other and with their surroundings (Bhatt et al., 2021). They are particularly interested in understanding these interactions as the pressures from both natural factors and human activities have been increasing over time. In comparison to locations with human involvement from cropping activities, trampling, and over-exploitation leading to habitat degradation, our study found that the sites with disturbance present (i.e., 307) had much higher plant species distribution rather than absent (i.e. 186) of disturbance. This pattern implies that human actions, particularly grazing, tramping etc., may have a limited positive impact on medicinal plant species**.**

The distribution of species was strongly influenced by elevation, and its impacts might be spread by a network of processes including the mineral and organic composition of the soil (Laughlin & Abella, 2007). In our study area, all soils were acidic, ranging from 4.5 to 6.5, the trendline shows that the pH of soil decreasing with the increasing of elevation, it means negative relationship between pH with elevation. The soil pH characteristics showed up as not important predictors i.e., not significant for the distribution of medicinal and aromatic plants using the Generalized linear model (GLM). Soil pH and overall plant diversity were inversely associated (Marshall, 2014).

The species richness has no significant (P>0.05) relationship with soil organic carbon similar result was found in Bryophytes species richness and soil organic carbon had no statistically significant relationship (p =0.4423) (Neupane, 2023). The same result was found in our study. The amount of soil organic carbon can alter as moves up or down the altitudinal gradient due to several variables, including temperature, precipitation, vegetation type, and soil characteristics.

The trendline shows that the Total nitrogen is slightly i.e., 0.0001 % increasing with the increasing of elevation, it means positive relationship between total nitrogen with elevation. Result shows that no significant (P>0.05) relationship between plants number with Total nitrogen similar result was found in Bryophytes species richness and total nitrogen had no statistically significant relationship (p =0.4308) (Neupane, 2023). It may be the higher microbial activity and decomposition rates at lower altitudes, which promote greater nutrient recycling and organic matter breakdown, the availability of nitrogen in the soil may rise.

The Available potassium is slightly i.e., 0.0028 ppm increasing with the increasing of elevation, it means positive relationship between available potassium with elevation. In our result shows that significant (P<0.05) relationship with potassium same as in Neupane, (2023) showed a similar relationship, however the relationship between mosses and potassium was statistically significant with a p-value of 0.0497. So, the available Potassium (K) is a necessary nutrient for plants species for processes including enzyme activation, photosynthesis, and water uptake. The parent rock type and weathering processes can have an impact on the availability of potassium, which may not follow a predictable pattern over the altitudinal gradient.

The Available Phosphorus is slightly i.e., 0.0043 ppm decreasing with the increasing of elevation same as trends along the elevation was observed on Himalayan mountains summit (Hamid et al., 2021), it means negative relationship between available phosphorus with elevation. In our result shows that significant (P<0.05) relationship with phosphorus.

1. **Concussion**

This study explores the distribution of medicinal and aromatic plant species in the Myagdi, Central Himalayan region. It investigates the impact of habitat types, aspect, and disturbance levels on species abundance and richness along the altitudinal gradient. The research found a declining trend in species richness and abundance along the gradient, particularly in areas above 1800 to 2200 meters. The study also found a decrease in soil pH with increasing elevation, a positive relationship between soil organic carbon and species richness, and a negative relationship between plant abundance and phosphorus. The findings highlight the importance of preserving mountain grassland habitats to maintain plant species diversity.

**Author’s contribution**

Mohanilal Acharya (MA) contributed to Conceptualization, Data curation, Formal analysis, Investigation, Methodology, validation, writing-original draft and writing review and editing.

Madan Acharya (1MA) contributed to Data curation, Investigation, Methodology, validation, writing-original draft.

Prakash Chandra Aryal (PCA) contributed to Conceptualization, Formal analysis, Methodology, supervision, writing-original draft.

and Dinesh Raj Bhuju (DRB) contributed to Conceptualization, Formal analysis, Methodology, supervision, writing-original draft.

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**Conflict of Interest statement**

The authors declare that they have no conflict of interests.

**Data Availability statement**

All the data used in this study are used in the manuscript.

**Keyword**

*Altitudinal Gradient, Aspect, Disturbance, Habitat*, *Medicinal and Aromatic plant species, Soil parameters*

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