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RESEARCH ARTICLE

Floristic diversity of threatened medicinal plants at two major reservoirs associated regions in Lahaul Valley, Western Himalayas, India

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ABSTRACT

Agriculture is the leading sector in Ethiopia and its economy The present study emphasizes the quantitative estimation of plant species diversity and ecosystems at Lahaul-Spiti two lake reservoirs, Deepak tall (DT) and Suraj Tall (ST). These are the finest visiting spots during summer in Keylong (Himachal Pradesh), India. Despite huge anthropogenic pressure and environmental disturbance, the reservoir-associated regions still harbor numerous angiosperm species including various kinds of grasses and medicinal herbs. Two-year surveys were conducted in six-landscape elements at an altitude of 3752 m and 4890 m. Plant diversity assessment was based on their numbers in each Landscape elements (LSEs) using a $2m^2$ quadrant followed by random sampling methods for herbs, shrubs, and grasses. Within the total, 32 specimens belonging to 17 families (most dominated by Asteraceae), 29 plants show medicinal importance. The east landscape of ST was observed with maximum species richness (Shannon wiener H =1.07), followed by the Northeast (H =1.05) dominated by *Saxifraga mucronulata* royle (35), *Tussilago farfara* (l), and *T. farfara* (26). The maximum species richness value was for *Impatiens glandulifera* (26 plants/m^2) while *Gentianella moorcroftiana* (43 plants/m^2) and categorized as vulnerable species. Highest population of the endangered plant was recorded in ST where *Allardia tomentosa* (9 plants/m^2), *Nepeta longibracteata* (7 plants/m^2), *Pleurospermum candollei* (6 plants/m^2), and *S. mucronulata* (35 plants/m^2) comparatively to DT enriched with five vulnerable species (*G. moorcroftiana*, *Chamerion latifolium*, *Ranunculus hirtellus* and *Rheum emodii*). Considering the floristic diversity value, effective attention towards conserving valuable plant bio-resources is suggested.

Keywords: Endangered species, Floristic diversity, Landscape elements, Medicinal herbs, Western Himalayas.

INTRODUCTION

The Himalayan reservoirs harbor a unique diversity of flora and fauna (Dhar et al., 2002). The different sizes and shapes of these ecosystems turn out significant drivers in the overall water cycle of the basins. Suraj tall (ST) and Deepak tall (DT) reservoirs draw diminutive attention so far in terms of management and conservation, however, they are becoming suitable models for assessing conceivable concerns of diversity loss under climate change (Dhar et al., 2000; Dhar, 2002; Kala et al., 2006). The inhabitant communities of adjoining areas in these reservoirs use these endangered plants in different forms i.e., fuel, food (wild edible), disease aliment, religion, and other aspects. The requirements for moist surface, prolonged winter, dry summers, and continuous short-term weather fluctuation in these barren regions limits the vegetation pattern of specific plants in these reservoirs (Dhar et al., 2000).

The rapid anthropogenic activities and climate changes are the two main factors that unbalance the habitat of any pioneer species with relatively very narrow regeneration niches. The Deepak Tall and Suraj Tall in Himachal Pradesh is an unexplored ecological reservoir region that is rich in numerous diversified ecological landscape elements and favors an array of angiosperms. Most of these plants are herbs and have properties for diseases and ailments. During the summer season, a diverse range of plant species appears in both reservoirs associated regions from mid-May to October. An increase in transportation, tourism, and grazing pressure threatened the biodiversity of these regions. Floristic diversity associated with both sites diminishing at an alarming rate owing to over-exploration and habitat loss from native habitats which may cause the extinction of many valuable species. These reservoirs are located near the highest mountain passes (Baralacha pass 4,890 m) known for their beauty in the Himalayan region. Regionally, herbal vegetation of high altitudes in reservoirs regulates avalanche movements of wind at near-surface levels and protects these places. The mass balance at the bottom is often hampered by the aloofness of these two reservoirs due to numerous obstacles like the treacherously jagged terrain, continuous landslides, and hostile weather conditions that challenge the adaptive strategies of plants.

The continuous visits of tourist vehicles as a major pass for Leh-Ladakh during dry summer has resulted in oouze out of pollutants (Cole, 1999; Cole and Sinclair, 2002). There are many physically extensive impacts sowing to knock over the fragile native vegetation. A different form of non-biodegradable material harms the soil properties as a result of low productivity thrown down by the people. These plant species are facing the rapid and unpredictable risk of extinction due to their specific germination and reproduction requirements. The two different regions in lakes are predominated by herbaceous and small grasses. To evaluate the regions (50-200 m) areas were examined for representing the valuable diversity. No doubt plant diversity in these cold-arid regions faces huge anthropogenic activities and increasing pollutant pressure causes habitat degradation already reported from Rohtang pass (Tourism center in summer season), Lahaul-Spiti (Kuniyal et al., 2003). The average number of visitors was more than 12,000 per day which increased 20 times from 1995 and is considered as one of the most visited spots of Himachal Pradesh.

These high-altitude reservoirs of Lahaul valley come under the district Lahaul-Spiti. While studying the floristic diversity of the wetland, we observed that several species are collected and used by the local people for different medicinal purposes. Ecologist faces the challenges of assessing the sensitivity of biological diversity to changes in the environment. The vegetation components of reservoir ecosystems vary diversity greatly in their habitat (Blangy and Mehta, 2006; Kumar et al., 2021). None of the literature has thrown light on quantitative plant status and ecological diversity growing in various landscape elements as no attempt of reservoirs associated region still so far in this regard. The assessment, maintenance, and inventorization of plant diversity would promote strategies for biodiversity conservation. Ecological studies on the plant's abundance and their distribution status in their native habitat along with their governing factors and population dynamics for the framework of conservation plans for these specific regions (Dhār, 2002; Uniyal et al., 2002). The population status and micro-habitat preference for economic plants specifically aromatic and medicinal plants virtually not been reported from the Himalayan regions so far. Large-scale exploitation of threatened herb species, namely *Allardia tomentosa*, *Nepeta longibracteata*, and *Pleurospermum candollei* reported from Lahaul valley may lead to extinction, until much-needed conservation measures for the preservation of diversity at ex-situ habitat (Aswal and Mehrotra, 1994, Uniyal et al., 2002). The literature scrutinization insinuates that despite unique floristic diversity at these reservoir slopes in the alpine landscape of Lahaul, none of the specific research documentation has been done. More than 10 endemics and threatened species are growing in this locality creating a unique biome (Adhikari et al., 2003). However, it is necessary to monitor the plant resources and create a piece of baseline information on distribution status and their abundance. There is an urgent need for pro-poor conservation strategies for these different landscape elements around the reservoirs. The present study draws the attention of researchers to the floristic inventory in these ecological regions, the document of valuable ethnomedicinal and fodder plants, and uses their potential in future research.

MATERIAL AND METHODS

Survey site

Suraj tall and Deepak tall two major water reservoirs (locally known as Tall) are located in the Lahaul region of Lahaul-Spiti district and resides entirely away from the village Jispa boundaries lies in subdivision Keylong, Himachal Pradesh.

Deepak tall (32°45′11′′ N 77°15′ 20′′ E) is situated at 3752 m on way to Suraj tall. It is located about 21 km from Jispa whereas ST has located 49 km from Jispa, these two water reservoirs are associated with the Darcha pass for the water source. DT the two types of soils that occurs within reservoirs are characterized by both very poor drainage and high drainage and different sides. The soil type in the adjoining trans regions, characteristics of broad depression, terrains, and convex the poor drainage side is enriched with *Mentha longifolia, Epilobium latifolium, and Impatiens balsamina*. The regions are devoid of trees but consistent good patches of short rich grasses met with wildflowers diversity. The *Genetianella moorocroftiana* grows in great luxuriance with *Anaphalis busua* and *Elymus repens*. Some of the *Euphrasia himalaica* plants occur in extensive beds that appear creamish white color recognizable from a reasonable distance of about 50 km.

Suraj Tall (32°45′02.09′′ N 77°24′52.79′′ E) is situated at 4890 meters and is one of the highest lakes in India, and the 21st-highest in the world originating from Baralacha pass. Suraj tall lake is the source of the Bhagariver which joins the Chandra river downstream at Tandi to form the Chandra-Bhaga river (also known as Chenab) in Himachal Pradesh.

Approximately 4 km in size ST is the largest lake as compared to DT depth are similar, ST holds the maximum size in length. Water moves downstream through small channels, furrows, and down the Bhaga river which later on joined the Chandra river formed as Chandar-Bagha (India) and Chenab (Pakistan). The place is uninhabited because of the severe climatic conditions including scanty snowfall throughout the year. Rainfall precipitation is rare in the region. The average total snowfall recorded in 2017-2018 is reported to be 12 m (39.4 ft.) –15 m (49.2 ft.) with temperatures of highest max. 13 °C (55.4 °F), mean max. 0.5 °C (32.9 °F), mean minimum minus 11.7 °C (53.1 °F), and the lowest minimum of minus 27 °C (80.6 °F). The ground in the zone is covered with scree and boulders whereas the quadrant data are intensively laborious and provide only a discontinuous and patchy coverage of study sites, they do provide detailed species lists. The climate is temperate in overall conditions of severe winters and dry summers, more preferably restricted with these two seasons. The precipitation rate, humidity, and annual rainfall are highly varied and unpredictable. The native population of plants is influenced by continuous anthropogenic pressure and natural destructions. The stony steep slopes have poor soil binding so the regions around these water reservoirs have remained under the pressure of continuous landslides, road construction, sheeps grazing by domestic cattle due to the shifting of livestock by Gaddis and Lahoulis from Kullu to Lahaul-Spiti and vice versa.

Survey method

A total of six visits have been made to explore the region in regular intervals from 2016-2018 from May to September. The field visits were arranged in such a manner to gain maximum floristic diversity during the flowering season. According to Mishra 1968, the number of quadrats was concluded with the species curve method. The data were collected from each of 12 randomly distributed quadrats that cover most of the diversity. Different quadrats are used at landscape elements of both reservoirs at the same places but with different time intervals and climate patterns.

Data analysis

Species richness was estimated as the number of species recorded in the sampling site in each Landscape element (LSE). The presence and absence of species in sampling LSE were calculated whereas numerical richness was calculated as the number of species. Species evenness (E) was computed by the Shannon diversity index using the following equation

$$E = H' / \ln S$$

H' is the value of Shannon's diversity whereas lnS is the total species number.

Shannon diversity index (*H'*) is calculated as:

$H' = -\sum pi \ln pi$

where *pi* is the number of individuals of the *ith* species and ln*pi* is the number of individuals of all the species. The Shannon index increases as both the evenness and the richness of the species increase

Evenness for species was estimated using Shannon-wiener index and calculated as:

Evenness = H'/ lns

H is taken as Shannon wiener index value whereas lns is the number of total species.

Menhinick's index, Dmn (Whittaker, 1977), is calculated using:

Dmn=S/N

where N is the total number of individuals in the sample and S is the species number.

The PAST 3.14 (Paleontological Statistics Software Package for Education and data analysis) was used for the analysis of data. Collection sites were surveyed with Apaches, Lahoulis, Bhotia, and Gaddis tribes whereas identification and information regarding the medicinal uses of plants were collected via discussion and interviews. Moreover, data on medicinal uses and their threatened status were incorporated from earlier reports for comprehensive information.

RESULTS

Species diversity analysis of landscape elements

Overall, both reservoirs were categorized with six different ecological directional slopes such as East, North, South, Northeast, Northwest, and South West harbors maximum diversity. These slopes were varied in soil habitats including barren, rocky, and moist grass poisture ranging at altitude gradient of 3752 to 4890 m. A total of 32 sample species belonging to 17 families mainly dominated by Asteraceae followed by Apiaceae, Balsaminaceae, Caryophyllaceae, Chenopodiaceae, Crassulaceae Cyperaceae, Ephedraceae, Fabaceae, Gentianaceae, Lamiaceae, and others. The collection in these slopes includes 29 herb species viz; *Astragalus munroi, A. tomentosa, Allardia glabra, Anaphalis triplinervi, Ajania tibetica, Bistorta affinis, Chenopodium foliosum, Clematis bunchaniana, Chamerion latifolium, Cotoneaster macrophyllus, Elymus officinalis, G. moorcroftiana, Hamelia patens, I. glandulifera, Seline vulgare, Leontopodium ochroleucum*, *M. longifolia, Thymus serphyllum, Hylotelephium ewersii, P. candollei, Phlomis bracteosa, Rheum emodii, Nepeta longibracteata, Taraxacum officinale, Tussilago farfara, Saxifraga mucronulata, S. jacquemontiana, Sassaurea gosspiphora, Ranunculus hirtellus,* and *Viola biflora* **(Table 1), (Figure 1).**

Besides, grass species, *E. repens,* and sedge species *Carex nivalis* were predominant while only one gymnosperm species *Ephedra gerardiana* was observed at these sites (Chandrasekhar and Srivastava, 2009). Both the reservoirs in Lahaul valley harbor rich floristic diversity at different landscape elements. Most of the plant species recorded were unique and endemic to these regions viz: *N. longibracteata, A. munroi,* and *S. gosspiphora* found only in these regions. (Table 1). The threatened medicinal plant species diversity and richness spotted in the existing regions are higher than those in other high-altitude regions that were protected by boulders like the Kinnaur district in Himachal Pradesh, India. Among these, *Euphrasia officinalis, I. glandulifera, G. moorcroftiana, B. affinis, C. macrophyllus, S. Vulgare, M. longifolia, C. foliosum, A. triplinervis* were common. Two slopes in both sites for *B. affinis* (major medicinal plant for amchis) were distributed on the East and south-facing sides. These steep slopes were devoid of moist conditions and favor the micro-habitats of *B. vivipara*. Its distribution was limited to specific sites in DT and ST. The East facing slope of DT carries maximum plant species dominated by *G. moorcroftiana* followed by *I. grandulifera, E. repens,* and *B. affinis*. **(Table 2) (Figure 2)**.

S. gosspiphora (Braham Kamal) and *N. longibracteata* were grown on the Southwest facing slope of Suraj Tall. Its distribution was restricted to Suraj Tall only, while 2 herb species were present on LSEs of the east-facing slope (Table 3) (Figure 2). The value of the Simpson index of Dominance and Shannon wiener index for Suraj Tall on the east-facing slope were comparably low (D = 0.47 and H = 0.66) with East and northeast facing slope for other herb species at D = 0.66, H = 1.09 and D = 0.63 and H = 1.05 respectively at Deepak Tall (Table 4). Evenness estimated on the Southwest facing slope was 0.97 similar to north-facing slopes.

R. emodi (Chukri), *P. bracteosa,* and *E. repens* were observed on the south-facing slopes in Deepak Tall. The value of the Simpson index of Dominance and Shannon wiener index on southwest-facing slope were comparably higher (D = 0.51 and H = 0.87) with all slope except North (D = 0.55 and H = 0.86) for others herb species D = 0.66, H = 1.09 and D = 0.63 and 1.05 respectively. Evenness estimated on the Southwest facing slope was 0.97 similar to north-facing slopes (Table 3) (Figure 1).

A unique Northwest facing slope was found only on Deepak tall. The abundance and dense population of *A. munroi* and *M. longifolia* were recorded at the restricted site of Deepak Tall. Regular grazing and squashing by tourists were not confined to this LSE site. The distribution of both species was higher than those on the Northeast-facing slope (*H. ewersii* and *T. serphyllum*) at Deepak tall. Species diversity on Northwest-facing slope (D = 0.46 and H = 0.66) as compared to North east-facing slope (D = 0.44 and H = 0.64) (Table 3) (Table 4). A low level of anthropogenic activities might be maintained a balanced ecological habitat at the Northwest-facing slope might be the reason for high species diversity compared to those on the Northeast-facing slope. However, plant species at the Northwest-facing slope were exposed much towards the sunlight and may perhaps be much warmer as compared to the North east-facing slope, which might be persuading the plant numbers. It was observed that the low population status of *H. ewersii* and *T. serphyllum* (Threatened species) at the Northeast-facing slope were due to disturbance at the micro and macro level. Evenness value for Northwest facing slope (0.96) was higher than Northeast facing slope (0.94) whereas Menhinick richness of Northwest facing slope (0.60) was lower than Northeast facing slope (0.82) (Table 3) (Figure 2). Two LSEs of *E. repens* (a fodder and wheat wild relative locally known as 'Kasam') were found in dry and stony slopes toward the East and Southwest facing slopes of Suraj Tall and Deepak Tall, respectively.

The value of Shannon-weiners (H=1.09) and Simpson diversity index (D = 0.66) for East facing slope of Suraj Tall is higher than Deepak Tall (H = 0.52 and D = 0.34) (Table 4) (Figure 2). Evenness value is more (0.99) observed at Suraj Tall suggesting much abundance and individual distribution of various species (*T. farfara, B. affinis*, and *E. repens*) at the East-facing slope compared to other grasses occupied Southwest facing slope of Deepak Tall. A wide distribution of *E. repens, P. bracteosa*, and *R.* emodi (Chutki) was observed on moderate and moist slopes across South facing slopes with an evenness value of 0.84. In term of species, the East facing LSEs of Deepak Tall was less diverse than other LSEs except for the evenness value at North east-facing slope (0.79) than 0.84 at Est facing slope. The similarity index between the species at both sites was only 0.11% i.e., shows a 0.89% dissimilarity index.

The maximum diversity of medicinal herb species monitored at Suraj Tall lies under endangered categories whereas, the least number of threatened plants were observed at Deepak Tall. However, dispersal of these plant species was probably specific-habitat and favored with the microenvironment.

The rate of alteration in species numbers and their compositions studied among landscape elements gave clues regarding the variation in a microhabitat that affects the abundance of the species at different slopes. The northeast-facing slopes might be favorable for more species richness and diversity in both reservoir-associated regions. The herbaceous diversity is dominated by *B. affinis*, grasses by *E. repens* in ST while *Impatiens* and *M. longifolia* are two herbaceous species whereas *E. himalayensis* is the dominant grass in Deepak tall. Most of the species were climate indicator species so their abundance and flowering responses to the regional climate show visible indications of climate change. (Higaa et al*.,* 2003). The heavy snowfall full-fill the vernalization requirements and accomplishes the germination by breaking their seed dormancy. The vegetation homogeneity of *S. gossipiphora, S. mucronulata, A. glabra, A. tibetica, A. munroi, P. candollei,* and *L. ochroleucum* takes place in the reservoir region due to the continued dominance of these resistant and vigorous species.

The shrubs and trees are present in negotiable numbers except for *Rosa webbiana* and *C. macrophyllus*. The uniqueness of these two reservoirs is that the altitudinal difference is less than 200m but the diversity of the similarity in floristic diversity is less than 10%. The relatively high slopes, and distance from the highway in ST maintained humidity and moisture to micro-level on the surface is one of the major factors that help to harbor the different herb species as compared to DT surrounded by the snowcapped mountain district of Lahaul and Spiti.

Ecological richness of species and nestedness

Species diversity and distribution are identified at six slopes in Deepak tall: North, East, Northeast, Northwest, South, and Southwest. While Suraj Tall is categorized as five slopes: North, East, Northeast, South, and Southwest. (**Table 7**). Ecological factors were known for species richness and their distribution. For example, most of the North facing in both the location slopes facing least disturbance could be favorable for the high density of *C. microphyllus*.

On the other side, species diversity was showed habitat-specific distribution and found in distinct restricted habitats and which is validated by various workers in the literature (Uniyal et al., 2002, Uniyal et al., 2006) In the existing study, the inhabitants of *N. longibracteata* and *A. munroi* was found only on the north-facing slope through high density and was noticed in the Suraj tall and Deepak Tall respectively. Various ecological disruption and anthropogenic factors were found responsible for the distribution of endemic diversity of these plant species. Higher estimates of species diversity in *M. longifolium, I. glandulifera,* and *E. repens* on a North-facing slope may be accredited to the sensible biological micro-habitat with a minimum level of ecological pressure as compared to East-facing slopes in both reservoirs. For example, in the case of the slope was reasonably higher on a Southeast-facing slope and East-facing slope which could certainly be unenthusiastic for higher species richness and diversity of *S. mucronulata, T. farfara,* and *I. glandulifera*. However, the north-facing slope was unmasked to sun flakes and could be much exposed as compared to other slopes in both locations which may be complaisant to assist the abundance of several plant species. It was visualized that *B. affinis* and *E. himalyensis* on the Southwest-facing slope were at a 4-6 m distance from the roadside and tend to be subjected to many disturbances. Both plant species are economically important for the local population. The deleterious continuous exposure to biotic stresses could be responsible for low species diversity and population status. The shrubs and trees are present in negotiable numbers except for *R. webbiana* and *C. macrophyllus*. The uniqueness of these two reservoirs is that the altitudinal difference is less than 200m but the diversity of the similarity in floristic diversity is less than 10%. The relatively high slopes, and distance from the highway in ST maintained humidity and moisture to micro-level on the surface is one of the major factors that help to harbor the different herb species as compared to DT. The flora of lakes consists of an assemblage of herb species that dominate in these phytogeographical regions. The distance from the mainland identifies island size as the two main factors that favor the richness of certain species. However, several studies in relevant areas indicate that there was a negotiable impact on ecological subgroups and total species richness related to distance from the mainland in the present study. Also, a few endemic species such as *N. longibracteata, S. gossyphora,* and *A. munroi* were recorded on these reservoirs occurring in the district (Uniyal et al*.,* 2002). From a viewpoint of biodiversity conservation, threatening anthropogenic activities and climate change harm the species diversity in these sites. The stony steep slopes have poor soil binding so the regions around these water reservoirs have remained under the pressure of continuous landslides and road construction due to the shifting of livestock from Kullu to Lahaul-Spiti and vice versa (Ved et al*.,* 2003; Uniyal et al*.,* 2006). These kinds of human activities have a serious impact on the micro as well as macro environment supporting the floristic diversity in these natural landscapes.

Distribution status of threatened medicinal plant

Status of threatened medicinal plants: Total number of 16 medicinal plants belonging to IUCN categorized as threatened was recorded from both sites. These species were dispensed in the distribution range of 3252 to 4890 m (**Table 3**). The species densities of *S. gosspiphora, R. emodi,* and *E. geardiana* are categorized under vulnerable categories while five species from Suraj tall including *A. tomentosa, S. mucronulata, Saxifraga jacquemontiana, Ajania tibetica,* and *N. longibracteata* (endangered) were enlisted in table 5. The distribution of *S. jacquemontiana* on North east-facing slope was highest (35 plants /m^2) while the lowest population was recorded similarly in *A. tibetica* and *P. candollei* (6 plants /m^2) located on northeast and southeast facing slopes respectively **(Table 1).** The density on North facing slope of *N. longibracteata* (7 plants /m^2) than that of *A. tomentosa* (9 plants /m^2) on Northeast facing slopes (Fig2) (Table 1). In Deepak tall, the population of *G. moorcroftiana* was highest (43 plants /m^2) whereas lowest in *E. gerardiana* (1 plants /m^2) abundance on East facing slope and north facing slope respectively (Sharma et al*.* 2018). The population of *C. latifolium* (2 plants/m^2) is facing on East slope whereas *R. emodii* (6 plants/m^2) is abundant on the South-facing slope (Samant and Shreekar, 2003; Sood et al*.,* 2021). The *H. ewarsii* density calculated on the Northwest facing slope was 7 plants/m^2, 4 individuals/m^2 of *Ranunculus hirtellus* were recorded from east-facing slopes. **(Table 1.) (Figure 1.).** The lowest population among all plant specimens was recorded as *E. gerardiana* (1plants/m^2). All sampling units were herbaceous except *E. gerardiana*, which is a prostrate shrub. The highest population distribution of threatened medicinal plants was recorded on the northeast-facing slopes and east-facing slopes. Moreover, the distribution of these plant densities was microclimatic and habitat-specific.

Shannon diversity index

H values of East slope in ST and DT were 0.66 and 0.34 respectively whereas Shannon wiener of ST site was (1.09) much higher than DT (0.52). The highest evenness was recorded in the East slope in ST and south slope similar to DT as 0.99. The lowest evenness was confined to 0.79 (DT) and 0.95 in ST. The Menhinick richness will be least (0.5) in the Northeast all slopes element **(Table 6).**

Species composition rate among Northwest in DT shows minimum disturbance favored the abundance of *A. munroi* and *M. longifolia* (Table 5). The Shannon diversity was calculated as 0.66 while the Simpson index was 0.46. (Table 6). Comparatively, in the Northwest slope of DT, the North slope of ST also hold the abundance of *M. longifolia*. The shimpson diversity index was recorded as 0.47, Shannon weiver and Menhinck richness in ST was 0.66 and 0.71 respectively (Table 6). Only three species such as *E. repens* (wheat wild relative), *C. macrophyllus,* and *B. affinis* were found commonly in both locations. Both sites were situated at an altitude difference of just 1280m but attain a unique floral diversity of economically important plants.

DISCUSSION

The reservoir-associated regions in the cold-arid Himalaya harbor unique floristic diversity in different landscape elements. Plant species recorded from these sites were found to show their narrower range of distribution and habitat specificity. Among these only *E. repens* and *B. affinis* were common in both locations. Moreover, species richness similarity turns over around landscape elements was low, though total species diversity and richness recorded in the present study are much higher comparatively in other high altitudes floristic diversity assessment in the area like Chota Bhangal and Rohtang in Himachal Pradesh, India (Uniyal et al., 2006; Singh et al., 2008).

The threatened and endangered medicinal plant flora were found in different habitats showed the species-environment relation and their distribution reported in various research reports (Dhar, 2000; Dhar et al., 2000; Kala, 2000; Uniyal et al., 2002). In these documents, the abundance of *S. gossyphora* and *N. longibracteata* was only restricted on a southwest-facing slope with high density and was recorded in the habitats that were facing the continuous challenges of habitat disturbance. Various anthropogenic and ecological factors were responsible for the distribution and abundance of plant species such as, in the case of *A. tomentosa* altitude and slope were higher in the Northeast but faced much habitat disturbance comparatively in all sites at Suraj Tall **(Figure 3).** Higher estimates of *P. bracteosa* and *R. emodi* on a southwest slope may be attributed to microhabitat ecological balance facing narrower anthropogenic activity. Moreover, *G. moorocroftiana* in the east-facing slope of Deepak tall was subjected to high disturbance but still gain higher species diversity **(Figure 4).**

Many ecologically important species other than threatened species found in localized areas were *S. mucronulata, T. farfara and I. glandulifera, A. munroi, P. candollei, L. ochroleucum, E. officinalis, I. glandulifera, G. moorcroftiana, B. affinis, C. macrophyllus, S. vulgare, M. longifolia, Chenopodium foliosum, A. triplinervis* and *B. affinis* **(Figure 5**). The present paper highlights the abundance of important crop relatives, medicinal plants, and ecologically important species and they are practically used in amchis medicinal systems. Besides this, it was also observed that the frequent grazing pressure, trampling, waste material accumulation, and tourism activities for habitat destruction were alarming threats to plant diversity in these reservoir-associated regions. If these activities continue to large extent, they will be responsible for the extinction of major threatened species categorized in the IUCN list. For efficient and proper management of plant diversity in these reservoir-associated regions, the following facts concluded from the present research:

1. Demarcation of the Gaddis route and their places of grazing to prevent habitat degradation for this floristic diversity and their disturbance in these regions.
2. Focus on quantitative ecological assessment of medicinal plants, species diversity especially population status of threatened species in native habitat.
3. Monitoring the plant availability help to detect the effect of climate change in a short interval of time. Longevities, life forms, and their sensitivity to the environment project them good candidates for monitoring long-term climate effects (Higaa et al., 2013).
4. Strengthen the strategies for ecological restoration and guidelines given by the ecotourism society (TIES, 2006). Also needs to be created of general awareness regarding conservation measures among local people, tourists, amchis, and ecologists about monitoring these plant resources for future use.
5. The study helps to evaluate the key components of chemical compounds released by plants from their origin in two major rivers Chandra-Bhaga (India) and Chenab (Pakistan).

Table 1. Overall floristic composition at two water reservoirs

1. Suraj tall (Lahaul, at an altitude of c. 3,800 m)

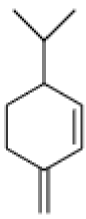
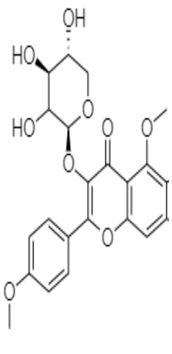
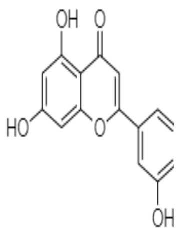
Plant species	Family	Group	Life-form	Conservation status	Density (plants/m²)
Ajania tibetica ((*Hook.f. & Thomson*) *Tzvelev*)	Asteraceae	Dicotyledon	Herb	Endangered	6
Allardia glabra (*Decne.*)	Asteraceae	Dicotyledon	Herb	-	4
A. tomentosa ((*Decne.*) *Regel.*)	Asteraceae	Dicotyledon	Herb	Endangered	9
Bistorta affinis (*D. Don*)	Polygonaceae	Dicotyledon	Herb	Common	14
Carex nivalis	Cyperaceae	Monocots	Herb	Least common	11
Leontopodium ochroleucum ((*Pers.*) *R.br. Ex Cass.*)	Asteraceae	Dicotyledon	Herb	Least concern	5
Nepeta longibracteata Benth.	Lamiaceae	Dicotyledon	Herb	Endangered	7
Pleurospermum candollei (*Benth. Ex C.B.Clarke*)	Apiaceae	Dicotyledon	Herb	Endangered	6
Sassaurea gosspiphora	Asteraceae	Dicotyledon	Herb	Vulnerable	10
Saxifraga jacquemontiana Decne.	Saxifragaceae	Dicotyledon	Herb	Endangered	11
S. mucronulata Royle	Saxifragaceae	Dicotyledon	Herb	Endangered	35
Silene vulgaris (*Moench*) *Garcke*	Caryophyllaceae	Dicotyledon	Herb	Common	4
Tussilago farfara L.	Asteraceae	Dicotyledon	Herb	Least common	26

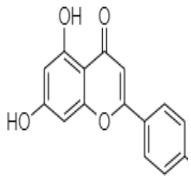
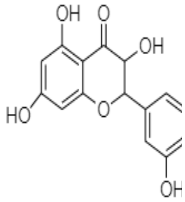
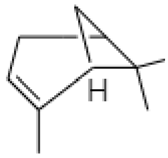
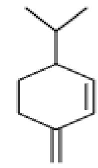
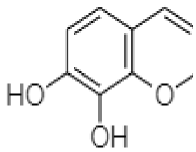
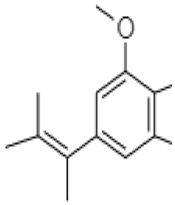
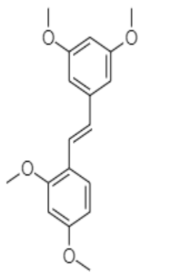
2. Deepak tall (Lahaul, at an altitude of c. 3,800 m)

Plant species	Family	Group	Life-form	Conservation status	Density (plants/m²)
Impatiens glandulifera Royle	Balsaminaceae	Dicotyledon	Herb	-	26
Euphrasia officinalis L.	Orobanchaceae	Dicotyledon	Herb	-	9
Astragalus munroibunge	Fabaceae	Dicotyledon	Herb	DD	4
Gentianella moorcroftiana (*Wall. Ex G. Don*)	*Gentianaceae*	Dicotyledon	Herb	Vulnerable	43
Bistorta affinis (*D. Don*)	Polygonaceae	Monocot	Herb	Common	17
Elymus repens L.	Poaceae	Dicotyledon	Grass	Common	17
Cotoneaster macrophyllus Rehder & E. H.	Rosaceae	Dicotyledon	Shrub	Common	5
Seline vulgare ((*Moench*) *Garcke*)	Caryophyllaceae	Dicotyledon	Herb	Common	3
Mentha longifolia L.	Lamiaceae	Dicotyledon	Herb	Common	18
Thymus serphyllum L.	Lamiaceae	Dicotyledon	Herb	Least concern	6
Clematis bunchaniana	Ranunculaceae	Dicotyledon	Herb	Common	2

Chamerion latifolium ((L.) *Sweet)*	Onagraceae	Dicotyledon	Herb	Vulnureable	2
Hylotelephium ewersii ((*Ledeb.*) *H. Ohba*)	Crassulaceae	Dicotyledon	Herb	Vulnureable	7
Chenopodium foliosum((*Moench*) *Asch.*)	Chenopodiaceae	Dicotyledon	Herb	Common	2
Rheum emodi D.Don	Polygonaceae	Dicotyledon	Herb	VU	6
Phlomisbracteosa Royle ex Benth.	Lamiaceae	Dicotyledon	Herb	Not assessed	2
Ranunculus hirtellus Royle	Ranunculaceae	Dicotyledon	Herb	Vulnureable	4
Taraxacum officinale Wigg.	Asteraceae	Dicotyledon	Herb	Common	3
Anaphalistriplinervis(*Sims*) *C.B. Clarke*	Asteraceae	Gymnosperm	Herb	Common	11
Ephedra gerardiana	Ephedraceae	Dicotyledon	Shrub	VU	1
Viola biflora	Violaceae	Dicotyledon	Herb	Least common	3

Table 2. Diversity, Chemical compounds, part used, Indigenous uses of wild plants of Suraj tall, Lahaul-Spiti.

Plant species	Family	Valuable compound	Part used	Local use	Altitude range for species (m)	References
Allardia tomentosa	Asteraceae	 β-phellandrene	Whole plant	Headache and rheumatism	3200-4850	Abbas et al. (2021)
Bistorta affinis	Polygonaceae	 Viviparum (a &b)	Flower, Leaves	Anti-inflammatory and tonsillitis and fever	3000-4700	Sultana et al. (2019)
Leontopodium ochroleucum	Asteraceae	 Luteolin	Flower	Hypertension and inflammatory disorders	3000- 5000	Cho et al. (2020)

Silene vulgaris	Caryophyllaceae	 Apigenin,  Quercetin	Stem	Demulcent	2750-3950	Yildirim et al. (2016)
Allardia glabra	Asteraceae	 α-pinene,  β-phellandrene	Aerial parts	Spasmodic and anti-inflamatory	3310-4700	Khan et al. (2018)
Saxifraga mucronulata	Saxifragaceae	 Daphnetin	Whole plant	Renal pain, backache and dyspepsia	3350-5150	Gao et al. (2015)
Pleurospermum candollei (*Dc.*) *Benth. Ex Clarke*	Apiaceae	 Isomyristicin	Fruit and whole plant	Renal pain, antibacterial, antimalaria, cures stomachache, renal pain, dyspepsia, dyspepsia, stomachache, flatulence and backache	3500-4650	Ali et al. (2021)
Carex nivalis Boott	Cyperaceae	 Tetrastilbenes	Roots, shoot	Wounds	3000-4700	Kala (2006)

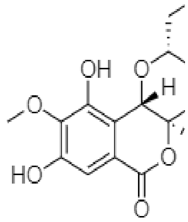
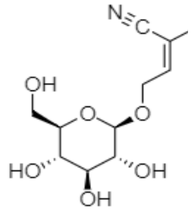
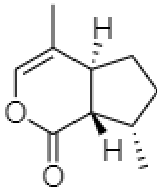
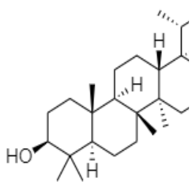
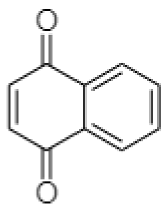
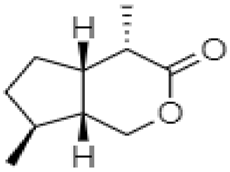
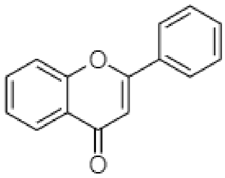
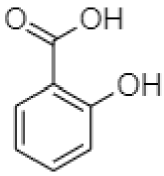
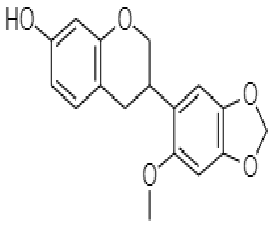
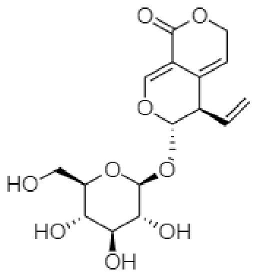
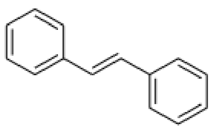
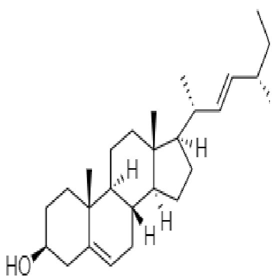
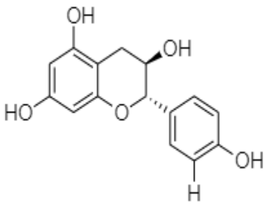
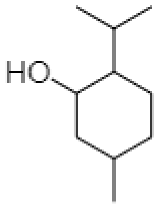
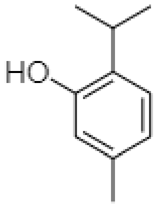
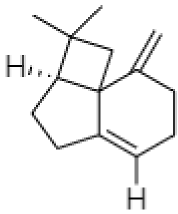
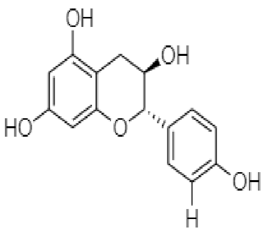
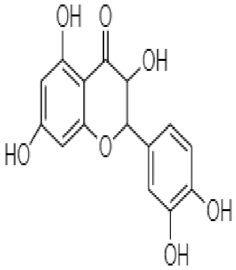
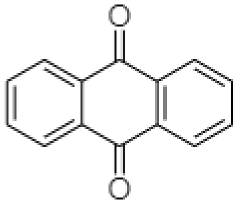
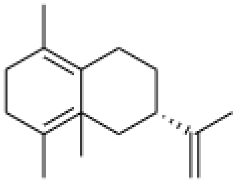
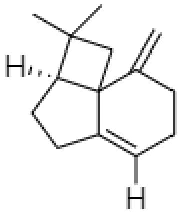
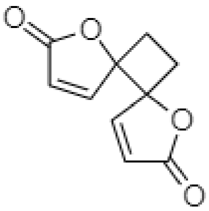
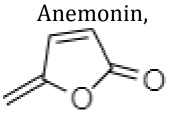
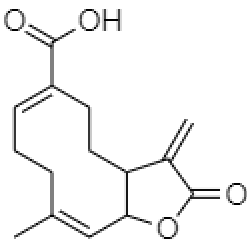
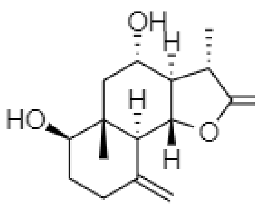
Saxifraga jacquemontiana	Saxifragaceae	 Bergenin	Leaf	Wounds	3350-5000	Gao et al. (2015)
Sassaurea gossypiphora	Asteraceae	 Sarmentosine	Flower bud	Boils	3500-5200	Kala (2006)
Nepeta longibracteata Benth.	Lamiaceae	 Nepetalactone	Shoot	Liver complaints and indigestion	3500-5000	Sharma et al. (2021)
Tussilago farfara	Asteraceae	 Pyrrolizidine  Taraxasterol	Whole plant	Fever and dyspesia	3350-4750	Chen et al. (2021)

Table 3. Diversity, chemical compound, part used, indigenous uses of wild plants of Deepak tall (Lahaul-Spiti). [Source: Kumar et al., 2011, Kala, 2000, Kala, 2005, Samant and Joshi, 2004, Samant and Pant, 2006, Sharma et al., 2018, Sharma and Samant, 2014.]

Plant species	Family	Valuable compound	Part used frequently	Local use	Species distribution range (m)	Referen-ces
Impatiens glandulifera Royle	Balsaminaceae	 Naphthoquinones	Leaf, seed	Cooling, tonic and dye	2500–3510	Abbas et al. (2021)

Euphrasia officinalis Wettst.	Orobanchaceae	 Iridoids,  Flavonoids  Phenolic acids	Aerial part	Conjunctivitis	2760–3510	Khan et al. (2018)
Astragalus munroi	Fabaceae	 Astraciceran	Flower, root	Aesthetic, skin diseases, and cough	3350-5000	Kala (2006)
Gentianella moorcroftiana (*Wall. Ex. G. Don*) *Airy Shaw*	Gentianaceae	 Gentiopicroside	Aerial part, leaf, flower	Febrifuge, blood purifier, fever, cough, rheumatism, and gastric	3450–3900	Kala (2006)
Bistorta affinis Greene	Polygonaceae	 Stilbenes	Roots, seeds	Cold, diarrhoea, flatulence, and dysentery	2700–4000	Sultana et al. (2019)
Elymus repens	Poaceae	-	Seeds	Antioxidant	2750-3500	Khan et al. (2018)
Cotoneaster macrophyllus	Rosaceae	 Stigmasterol	Fruits	Diarrhoea	3150-3900	Sharma et al. (2011)

Seline vulgare	Caryophyllace-ae	 Catechins	Flower and leaf	Dysentery and spasmodic	2650-3800	Yildirim et al. (2016)
Mentha longifolia (*L.*) *Huds.*	Lamiaceae	 Menthol	Leaf and flowers	Antiseptic, carminative,	1200–3650	Sharma et al. (2011)
Thymus serphyllum	Lamiaceae	 Thymol	Flowers,leaves, and seed	Diarrhoea	2850-4500	Kala (2006)
Clematis orientalis L. Var. Acutifoliahk. F. Th.	Ranunculaceae	Clemontanoside	Flower, leaf	Anti-microbial and anti-oxidants	3000-4350	Sharma et al. (2011)
Chamerion latifolium	Onagraceae	 Caryophyllenes	Aerial part	Anti-microbial	3150-4300	Abbas et al. (2021)
Hylotelephium ewersii	Crassulaceae.	 Catechins	Leaves and flower	Spasmodic	3000-4850	Abbas et al. (2021)
Chenopodium botrys L.	Chenopodiaceae	 Quercetin	Leaf, flower	Indigestion, antiphlogistic, astringent and diuretic properties	2350-3600	Kala (2006)

Rheum emodi Wall. Ex Meissn.	Polygonaceae	 Anthraquinone	Whole plants	Eye diseases, piles, skin disorders, abdominal pain, asthma, and bronchitis	3015 – 3910	Sharma et al. (2011)
Phlomis bracteosa Royle Ex Benth.	Lamiaceae	 Germacrene,  β-caryophyllene		Anti-ulcerogenic, cures eye diseases, anti-allergic and anticancer	3250-4500	Abbas et al. (2021)
Ranunculus hirtellus	Ranunculaceae	 Anemonin,  Protoanemonin	Flower,roots	Arthritis and asthma	2650-3800	Kala (2006)
Taraxacum officinale	Asteraceae	 Taraxinic acid,  Eudesmanolides,	Whole plants	Cuts, headache, fever, kidney, chronic digestive disease, Jaundice, loss of appetite, food poisoning, antibiotic, tonic and blood purifier	2710–3800	Sharma et al. (2011)

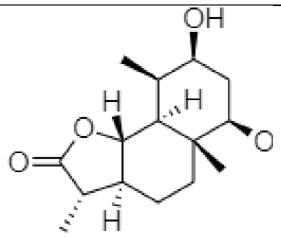
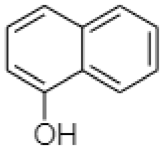
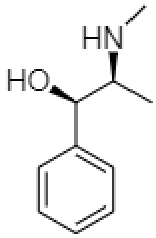
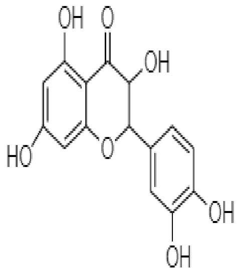
		 Tetrahydroridentin b				
Anaphalis triplinervi (*Sims.*) *Cl. Var. Intermedia* (*Dc.*) *Airy Shaw*	Asteraceae	 Naphatol	Leaf, shoot	Wounds and skin diseases	2700-3950	Sharma et al. (2011)
Ephedra gerardiana	Ephedraceae	 Ephedrine	Berry, twigs	Respiratory	3100-4800	Abbas et al. (2021)
Viola biflora	Violaceae	 Quercetin	Shoot as well aswhole plant	Fever, anti-spasmodic, diaphoretic, emollient, and cold	1800–3000	Khan et al. (2018)

Table 4. Distribution of plant species in different slopes of Deepak-tall and Suraj Tall of Lahaul-spiti.

Landscape elements	Suraj Tall	Deepak tall
North	*Cotoneaster microphyllus* *Pleurospermumcandollei* - - -	- - *Impatiens glandulifera* *Mentha longifolia* *Cotoneaster macrophyllus*
East	- - *Alladia tomentosa* *Saxifraga mucronulata Tussilago farfara*	*Gentianella moorcroftiana* *Euphrasia species* - - -
Northeast	- *Alladia tomentosa* *Saxifraga mucronulata* -	*Hylotelephium ewersii,* - - *Thymus serphyllum*
South	*Tussilago farfara* *Saxifraga jacquemontiana* - *Cerex nivalis*	- - *Anaphalis triplinervi,* -
Northwest	- - -	*Bistorta affinis* *Astragalus munroi* *Mentha longifolia*

Southwest	- *Sassaureagossyphora* - *Nepeta longibracteata* -	*Phlomis bracteosa,* - *Rheum emodi* - *Elymus repens*

Note: Northwest slope of Suraj tall has no diversity.

Table 5. Diversity indices for plant species in different slopes of Deepak Tall and Suraj tall.

Landscape elements	Simpson diversity		Shannon wiener		Evenness		Menhinick richness	
	ST	DT	ST	DT	ST	DT	ST	DT
North	0.47	0.55	0.66	0.86	0.97	0.79	0.71	0.49
East	0.66	0.34	1.09	0.52	0.99	0.84	0.57	0.33
Northeast	0.63	0.44	1.05	0.64	0.95	0.94	0.5	0.82
South	0.46	0.49	0.65	0.68	0.96	0.99	0.53	0.41
Northwest	-	0.46	-	0.66	-	0.96	-	0.60
Southwest	0.47	0.51	0.67	0.87	0.97	0.80	0.55	0.73

Note: Similarity index between the diversity of two reservoir-associated regions only 0.11% i:e shows 0.89% dissimilarity index.

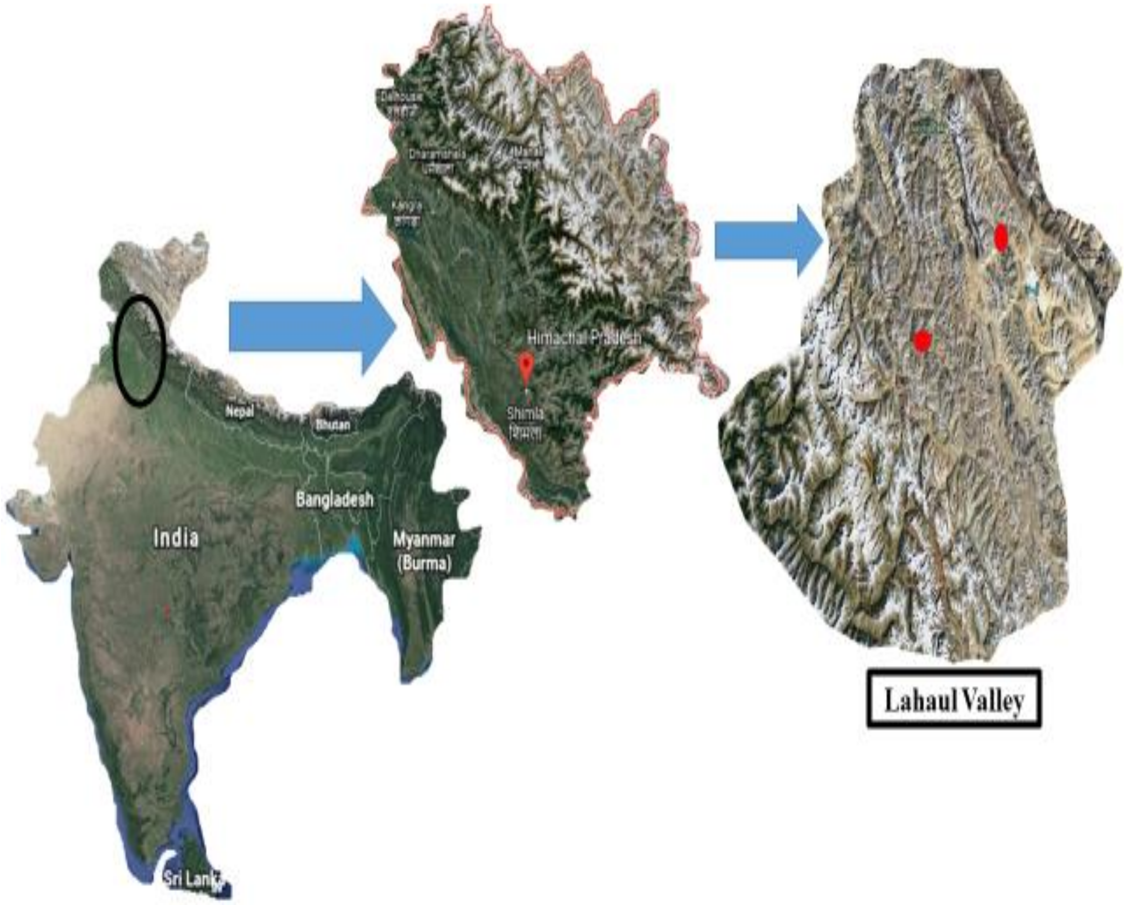


Figure 1. Map of the study site at the Keylong region associated with reservoirs (Deepak Tall and Suraj Tall) in the Western Himalayas, India.

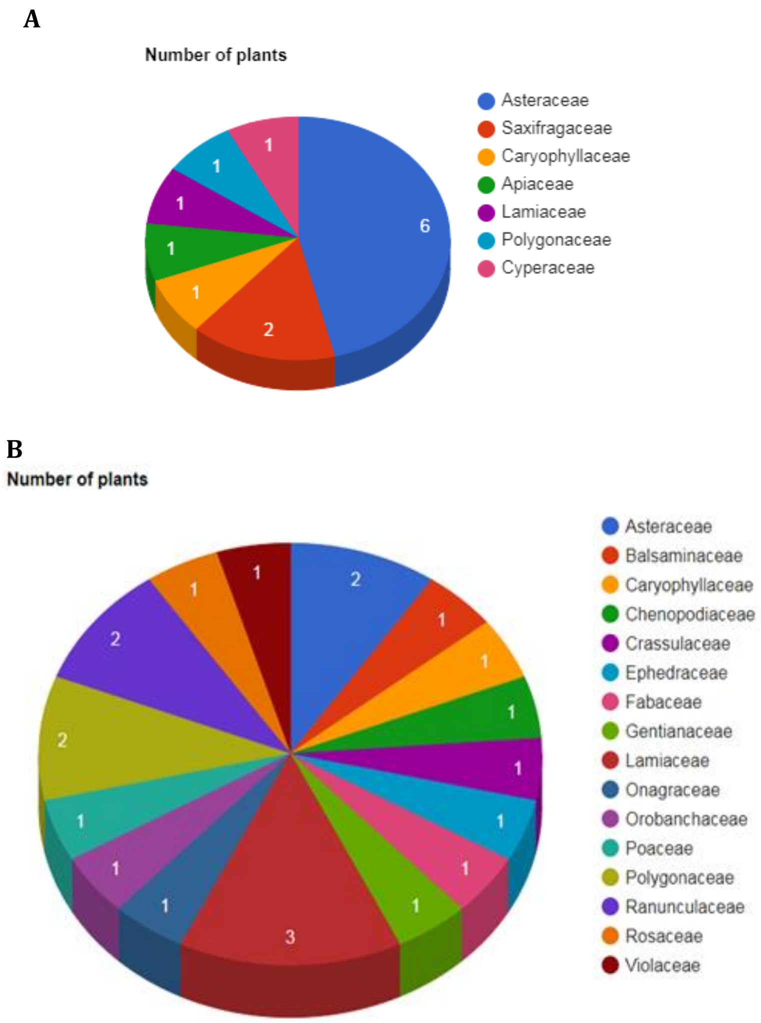


Figure 2. Distribution of plant species belonging to different families. 2A. Suraj Tall 2B. Deepak tall.

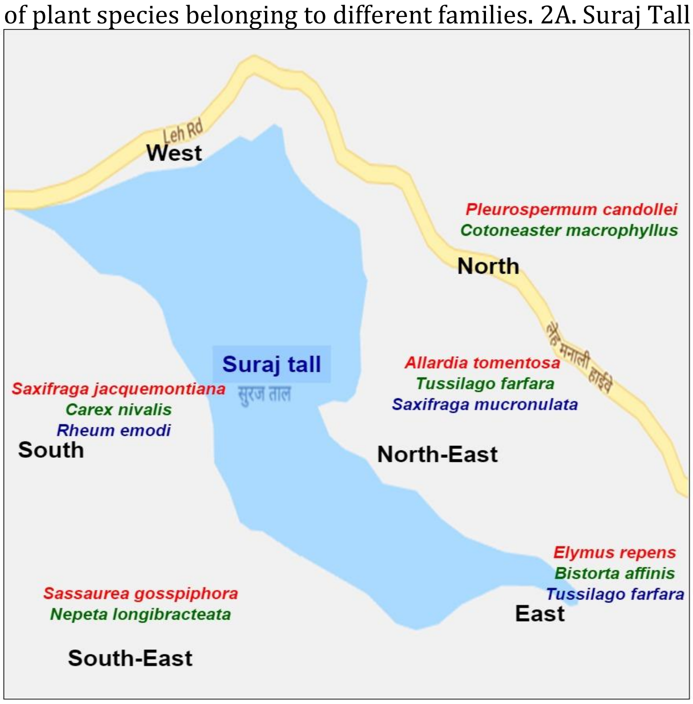


Figure 3. Distribution of plant species on different slopes of Suraj Tall.

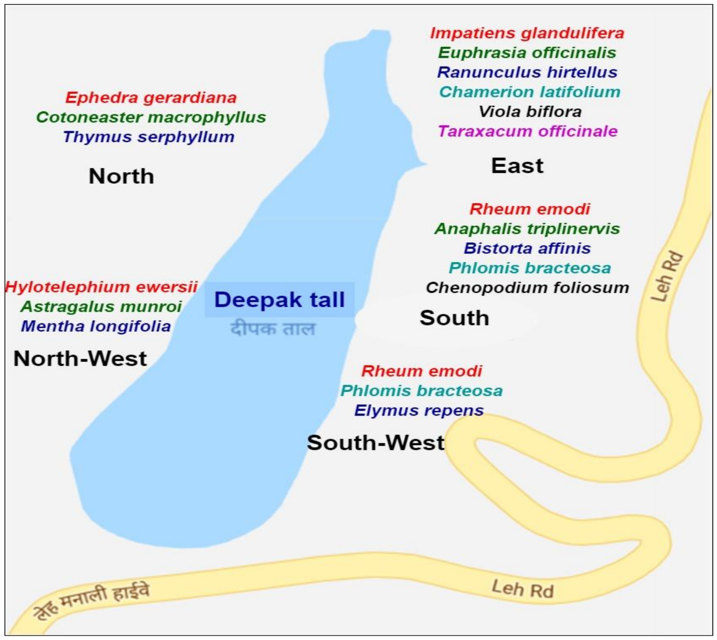


Figure 4. Distribution of plant species on different slopes of Deepak Tall.

Figure 5. Diversity of Medicinal plants present in reservoir associated regions of Deepak tall and Suraj tall. A. *Hamelia patens* B. *Allardia tomentosa,* C. *Allardia glabra,* D. *Euphrasia officinalis,*E. *Carex nivalis,* F. *Rheum emodi,* G. *Saxifraga mucronulata*, H. *Hylotelephium ewarsii,* I. Deepak Tall, J. Suraj Tall, K. *Leontopodium ochroleucum,* L. *Clematis bunchaniana,* M. *Nepeta longibracteata,* N. *Sassaurea gossypiphora,*O. *Saxifraga jacquemontiana,* P. *Astragalus munroi,* Q. *Ajania tibetica*and, R. *Bistorta affinis.*

CONCLUSION

There is no attempt till recorded to assess the floristic diversity in these ecological zones in western Himalayan regions (Samant et al., 1998). The environmental conditions present in such reservoirs limit the presence of shrubs, conifers/gymnosperms, or other tree species. The most exceptional results from a survey are that almost similar climate conditions but the humidity, altitude gradients and soil type is little variable in DT as compared to ST. The term conservation for future biodiversity in reservoirs of these mountain regions provide a warning for climate change, these results are continuous changes that floristic composition rapidly reduced in these areas. The trees and shrubs are completely absent in these regions. However, there may be at least transient fluctuation in flowering very rapidly and changes because these plants are adapted to microenvironment conditions. The species continuously come through filters of habitat fragmentation, isolation, invasion pressure, and climate change which increases day by day. Despite current status and reports on climate change, these high-altitude plants face survival challenges. Considering the increase in global carbon rise and increasing anthropogenic activities the declining rate of these plants recorded in recent times. The quantitative measurement of these floristic diversity-rich regions was important as well as the inventorization of assessment and conservation measures. Ecological studies of slopes wise provide detailed literature and throw light on micro-habitat priorities, associated species, and survival strategies for these specific areas. Ecological studies of wild habitats are vital and valuable for conserving biodiversity in these ecological landscapes of reservoirs. No literature efforts have been confirmed still so far regarding floristic diversity adjoining these reservoirs.

DISCLOSURE STATEMENT

No any potential conflict of interest was reported by Authors

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