Structure and Composition of Vegetation along an altitudinal gradient in Outer Seraj Region of Kullu District of Himachal Pradesh, India

**ABSTRACT**

Phytosociological characteristics of tree species along an altitudinal gradient in Anni block of Outer Seraj area of Kullu district was documented and analyzed during the period 2022 and 2024. The vegetation composition of plant species in three elevation ranges has been determined using a variety of phytosociological and diversity indices. A total of 101 species (33 trees, 28 shrub species and 40 herb species)belonging to 90 genera and 46 families were recorded in the study area and dominant families were Rosaceae (12 spp.), Fabaceae (11 spp.), Pinaceae and Asteraceae (5 spp. each), Sapindaceae, Lamiaceae and Solanaceae (4 spp. each), Polygonaceae and Urticaceae (3 spp. each). Significant variations in species composition and phytosociological traits were observed among the three elevation zones. As per studied diversity indices, the medium altitudinal zone (Zone II) showed the highest species diversity and richness for shrubs, whereas the lower altitudinal zone (Zone I) showed the highest species richness for trees and shrubs. The value of Shannon diversity index was recorded between 0.70 to 2.80 for trees, 0.66 to 1.90 for shrubs and 0.52 to 1.65 for herbs. The concentration of dominance values recorded for the study site was 0.13-0.65 for trees, 0.17-0.54 for shrubs and 0.21-0.99 for herbs. Species richness ranged from 1.65 to 5.71 for herbs, 1.63 to 7.68 for shrubs and 3.42 to 11.39 for trees. Most of the recorded species exhibited contagious distribution across all zones except one species *(Thymus linearis)* that exhibited random distribution. This study provides crucial baseline information on phytosociological diversity of plant species in Outer Seraj area of Kullu district and conservation of biodiversity in the Outer Seraj region.

**Keywords:** Phytosociological characteristics, Outer Seraj, vegetation composition, altitudinal zone, diversity indices, conservation

**1. INTRODUCTION**

The study of species composition and the complex sociocultural relationships between species in communities are both included in vegetation ecology (Mueller-Dombois & Ellenberg, 1974). Phytosociology is a quantitative field that focuses on how plant communities work and deepens our understanding of the complex interactions between plants and their surroundings (Braun & Blanquet, 1932). Assessing the condition of natural resources and creating efficient management and conservation plans require an understanding of the floristic composition, species diversity, and community structure of a given area (Lata et al., 2024). The primary goal of the quantitative research, called phytosociology, is to describe vegetation, clarify or predict its patterns, and classify it into useful categories (Ilorkar & Khatri, 2003). Phytosociology, often called the Braun-Blanquet approach, is a vegetation science that effectively examines and categorizes plant communities. The data recording in phytosociology aims to detail all plant taxa, noting their presence in vertical strata and quantifying their cover-abundance within a specific plot representing a vegetation stand (Dengler et al., 2008). These studies are essential for understanding how different plant species are interconnected with each other and with their environment and the processes that modify these communities (Concenço et al., 2017).

The vegetation in the Himalayan forests covers a wide spectrum, transitioning from tropical dry deciduous forests in the foothills to moist temperate forests approaching the timberline. Altitudinal variations are crucial in determining species distribution and patterns of species richness at any given site (Gupta et al., 2018). Diversity of species is crucial to the biodiversity of forests as trees provide habitats and resources for other associated species. They have a major impact on the environmental and structural complexity of forests (Bhat et al., 2020). The variety of tree species found in forests varies and is greatly impacted by biogeography, habitat, and disturbances (Sharma & Kant, 2014)**.** The shrub layer is essential to forest ecosystems as they provide food and habitat for various organisms and also aids in environmental restoration (Moreno-Fernández et al., 2021). In forest ecosystems, herbaceous plants are crucial because they preserve soil and water, control local microclimates, and provide resources for wildlife (Hart and Chen, 2008). Therefore, knowledge of woody vegetation's diversity and distribution is essential to comprehending forest ecology restoration. Altitudinal variation-based phytosociological analysis has been studied by a number of researchers (Gupta et al., 2018; Rana & Gairola, 2009; Meena et al., 2020; Kumari et al., 2023; Verma & Kapoor, 2014; Rana & Gairola, 2009).

The diverse climate of the Outer Seraj region contributes to its enormous ecological importance and abundance of valuable species (Singh et al., 1999). Although little is known about the floristic composition of the Outer Seraj location, it has great ecological value. In order to fully investigate the floristic composition characteristics in the Outer Seraj region of the Kullu district in Himachal Pradesh, a phytosociological study was carried out.

**2. MATERIALS AND METHODS**

**2.1 Study site**

The study was conducted in the Anni block of Outer Seraj area of Kullu district, India. Outer Seraj region of the Kullu district of Himachal Pradesh is surrounded by tall mountains and deep gorges that support a wide range of forest plants. It is located between latitudes 31°39'32"N to 31°20'40"N and longitudes 77°41'22"E to 77°23'12"E. The overall area of the Outer Seraj is 715 km². The tract is located in Shrikhand Mahadev and is hilly and undulating, with elevations ranging from 738 to 5227 meters. The lowest point is located in the Nither Range, close to Behna hamlet, where the Satluj river meets the Behna Khad.

**2.2 Methods**

In order to conduct floristic surveys, the study area was divided using the Global Positioning System into three altitudinal zones: Zone I (800–1600 m), Zone II (1601-2400 m), and Zone III (2401-3200 m) **(Table 1).** The phytosociological analysis of vegetation was conducted between the years 2022 to 2024 across the selected study sites. The vegetation features along various altitudinal gradients were evaluated using random sampling. Quadrats of the proper size, as established by the species-area curve approach, were used for sampling at each location (Mishra, 1968). The running mean approach was used to calculate the number of quadrats required for sufficient sampling (Kershaw, 1973). In each aspect/site/habitat, 60 plot of 50x50 m was marked. Within this plot for trees, 10 quadrates (10x10m) were randomly placed for tree sampling, 20 quadrates (5x5 m) for shrubs, and 20 quadrates (1x1m) for herbs. Every individual's circumference at breast height (CBH) was measured in each quadrat at a height of 1.37 meters above the ground.

**Table 1** **Details of the study sites to conduct floristic studies**

|  |  |  |
| --- | --- | --- |
| **Block** | **Zone** | **Name of the Study sites** |
| Anni | Zone 1 (800-1600m) | Behna (I), Nimla (II), Jamedi (III), Nigan (IV), Shamesha (V), Panjvi (VI), Showad (VII), Shamshar (VIII), Runa (IX) and Tihni (X) |
| Zone II (1601-2400m) | Kammand (I), Kungash (II), Namhong (III), Deori (IV), Batala (V), Karana (VI), Dalash (VII), Gugra (VIII), Rewari (IX) and Amarbaag (X) |
| Zone III (2401-3200m) | Khanag (I), Jalori Pass (II), Karshala (III), Karad (IV), Buchair (V), Deem (VI), Sroa (VII), Kothi (VIII), Khani (IX) and Lajheri (X) |

Standard ecological methods were used to analyze the data, which included density, frequency, abundance, total basal area, and Importance Value Index (IVI) (Curtis & McIntosh, 1950; Singh & Singh, 1992; Dhar et al., 1997; Samant et al*.,* 2002; Joshi & Samant, 2004; Samant & Joshi, 2005). In order to analyze the data, Microsoft Excel Office 2019 was used.

The abundance-to-frequency ratio (A/F) values were used to determine the distribution pattern of plant diversity. Species exhibits contiguous (>0.050), random (0.025 to 0.050), and regular (<0.025) distributions according to the A/F values (Curtis & Cottam, 1953). The following Diversity Indices were used to calculate the plant diversity:

**2.2.1 Species richness, Species diversity and Concentration of dominance:** The overall number of species in a given community, place, or habitat is known as species richness. The concentration of dominance by Simpson's Index (Simpson, 1949) and the Shannon and Wiener Information Statistics (H') (Shannon & Weiner, 1963) were used to quantify species diversity.Shannon-Wiener diversity Index (H) was calculated by following formula (Shannon & Wiener, 1963).

Where, ni = Importance value of species i and N = total importance value of all species.

The equation used to calculate Concentration of dominance (Simpson’s index) was

D=

Where D = Simpson (1949) Index of dominance, ni = total number of individuals of particular species, and N = total number of individuals of all species.

The Richness Index was measured as per Margalef, (1958).

R = S-1/ln N

Where, S = Total number of species, N = Total number of individuals of all the species

**3. Results and Discussion**

The vegetation of Anni block of Outer Seraj area exhibited notable variations across different altitudes. A total of 102 species (32 trees, 31 shrub species and 39 herb species)belonging to 89 genera and 63 families were recorded in the study area **(Figure 1).** The dominant families were Fabaceae and Rosaceae (11 spp. each), Pinaceae and Asteraceae (5 spp. each), Sapindaceae and Lamiaceae (4 spp. each), and Polygonaceae and Urticaceae (3 spp. each) **(Figure 2)**. The phytosociological attribute values and composition of the species varied significantly among the three elevation zones: Zone I (800–1600m), Zone II (1601-2400m), and Zone III (2401-3200m). The phytosociological status of plant species of Anni block is described as follows:

**Figure 1** **Contribution of wild plant species according to their habit in Anni block of Outer Seraj area**

**Figure 2** **Dominant families with the number of species found in Anni block of Outer Seraj area**

**Tree species distribution**

A total of 33 tree species belonging to 29 genera and 15 families were recorded in the study area. Photographs of some tree species recorded during field surveys are given in **Plate 1.** The dominant families were Fabaceae (6 spp.), Pinaceae (5 spp.), Fagaceae and Sapindaceae (3 spp. each), Myrtaceae, Moraceae, Malvaceae, Rosaceae and Meliaceae (2 spp. each) **(Figure 3).** *Quercus* (3 spp.) was the dominant genera, followed by *Pinus* and *Eucalyptus* (2 spp. each)**.**

At Zone-I, *Quercus leucotrichophora* (IVI=158.34) at study site IX was the dominant species followed by *Grewia optiva* (IVI=126.08) at site IV and *Dalbergia sissoo* (IVI=117.02) at site II. Maximum value of frequency (%) was observed for *Quercus leucotrichophora* (38.46) at study site X followed by *Grewia optiva* (35.29) at site IV and *Dalbergia sissoo* (33.32) at site II. Maximum density was recorded for *Quercus leucotrichophora* (49.09) at site X followed by *Dalbergia sissoo* (39.66) at site II *and Grewia optiva* (36.84) at site IV. Abundance was found to be highest for *Quercus leucotrichophora* (70.79)at site Xfollowed by *Grewia optiva* (57.81) at site IX and *Dalbergia sissoo* (44.04) at site II. The distribution pattern of species showed contiguous distribution **(Table 2).**

At Zone-II, the highest importance value was recorded for *Cedrus deodara* (IVI = 244.76) at site III followed by *Abies pindrow* (IVI = 98.91) at site I and *Picea smithiana* (IVI = 67.87) at site II. Maximum value of frequency (%) was observed for *Cedrus deodara* (47.37) at study site IX followed by *Abies pindrow* (31.25) at site VII and *Picea smithiana* (29.41) at site II. Maximum density was recorded for *Cedrus deodara* (90.16) at site III followed by *Abies pindrow* (32.65) at site VI and *Picea smithiana* (20.00) at site II. Abundance was found to be highest for *Cedrus deodara* (94.60)at site IIIfollowed by *Abies pindrow* (50.06) at site I and *Picea smithiana* (20.14) at site IX. All the recorded species were distributed contiguously **(Table 3).**

At Zone-III, the highest importance value was recorded for *Quercus semecarpifolia* (IVI = 239.42) at site VII followed by *Cedrus deodara* (IVI = 203.96) at site II and *Abies pindrow* (IVI = 122.23) at site III. Maximum value of frequency (%) was observed for *Quercus semecarpifolia* (67.31) at study site IX followed by *Cedrus deodara* (50.00) at site II and *Abies pindrow* (43.75) at site III. Maximum density was recorded for *Cedrus deodara* (87.93) at site VII followed by *Cedrus deodara* (73.47) at site VI and *Picea smithiana* (32.08) at site IV. Abundance was found to be highest for *Quercus semecarpifolia* (88.99)at site VIIfollowed by *Cedrus deodara* (80.62) at site II and *Abies pindrow* (58.14) at site III. All the recorded species were distributed contiguously **(Table 4).**

**Table 2 Phytosociological attributes of Trees at Zone-I**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Toona ciliata* M.Roem. | Meliaceae | 4.76 | 8.51 | 1.68 | 0.35 | 14.95 |
| *Pyrus pashia*Buch.-Ham. ex D.Don | Rosaceae | 14.29 | 12.77 | 18.92 | 1.32 | 45.98 |
| *Sapindus mukorossi* Gaertn. | Sapindaceae | 14.29 | 8.51 | 21.08 | 1.48 | 43.88 |
| *Ficus palmata* Forssk. | Moraceae | 4.76 | 8.51 | 1.65 | 0.35 | 14.92 |
| *Grewia optiva*J.R.Drumm. ex Burret | Malvaceae | 19.04 | 27.66 | 31.58 | 1.66 | 78.28 |
| *Bombax ceiba* L. | Malvaceae | 14.29 | 14.89 | 10.78 | 0.75 | 39.96 |
| *Leucaena leucocephala* (Lamk.) de Wit | Fabaceae | 4.76 | 2.13 | 2.05 | 0.43 | 8.94 |
| *Morus alba* L. | Moraceae | 14.29 | 12.76 | 8.93 | 0.62 | 35.98 |
| *Eucalyptus globulus* Labill. | Myrtaceae | 4.76 | 2.13 | 1.97 | 0.41 | 8.86 |
| *Dalbergia sissoo*Roxb. ex DC. | Fabaceae | 4.76 | 2.13 | 1.35 | 0.28 | 8.24 |
| II | *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 33.32 | 39.66 | 44.04 | 1.32 | 117.02 |
| *Leucaena leucocephala* (Lamk.) de Wit | Fabaceae | 16.67 | 15.52 | 14.45 | 0.87 | 46.64 |
| *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 5.56 | 6.90 | 1.50 | 0.27 | 13.96 |
| *Morus alba* L. | Moraceae | 22.22 | 17.24 | 26.19 | 1.18 | 65.65 |
| *Albizia chinensis* (Osbeck) Merr. | Fabaceae | 16.67 | 17.24 | 12.57 | 0.75 | 46.48 |
| *Bauhinia variegata* L. | Fabaceae | 5.56 | 3.45 | 1.25 | 0.22 | 10.26 |
| III | *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 13.04 | 13.79 | 12.18 | 0.93 | 39.01 |
| *Ficus palmata* Forssk. | Moraceae | 21.74 | 31.03 | 28.35 | 1.30 | 81.12 |
| *Bauhinia variegata* L. | Fabaceae | 17.39 | 20.69 | 19.03 | 1.09 | 57.11 |
| *Morus alba* L. | Moraceae | 17.39 | 15.52 | 12.08 | 0.69 | 44.99 |
| *Toona ciliata* M.Roem. | Meliaceae | 21.74 | 12.07 | 26.06 | 1.199 | 59.87 |
| *Robinia pseudoacacia* Linn | Fabaceae | 4.35 | 5.17 | 1.34 | 0.31 | 10.86 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 4.35 | 1.72 | 0.96 | 0.22 | 7.03 |
| IV | *Sapindus mukorossi* Gaertn. | Sapindaceae | 23.53 | 28.07 | 26.73 | 1.12 | 78.33 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 35.29 | 36.84 | 53.95 | 1.53 | 126.08 |
| *Toona ciliata* M.Roem. | Meliaceae | 11.76 | 5.26 | 3.78 | 0.32 | 20.80 |
| *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 11.76 | 17.54 | 6.61 | 0.56 | 35.91 |
| *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 11.76 | 7.02 | 6.82 | 0.58 | 25.60 |
| *Leucaena leucocephala* (Lamk.) de Wit | Fabaceae | 5.88 | 5.26 | 2.11 | 0.36 | 13.25 |
| V | *Melia azedarach* L. | Meliaceae | 10.52 | 16.33 | 10.53 | 1.00 | 37.38 |
| *Pyrus pashia*Buch.-Ham. ex D.Don | Rosaceae | 15.79 | 8.16 | 15.79 | 1.00 | 39.74 |
| *Bombax ceiba* L. | Malvaceae | 10.52 | 14.29 | 10.53 | 1.00 | 35.34 |
| *Ficus palmata* Forssk. | Moraceae | 10.52 | 6.12 | 10.53 | 1.00 | 27.17 |
| *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 15.79 | 16.33 | 15.79 | 1.00 | 47.91 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 15.80 | 18.36 | 15.79 | 1.00 | 49.94 |
| *Leucaena leucocephala* (Lamk.) de Wit | Fabacaee | 10.52 | 10.20 | 10.53 | 1.00 | 31.25 |
| *Sapindus mukorossi* Gaertn. | Saindaceae | 5.26 | 4.09 | 5.26 | 1.00 | 14.61 |
| *Toona ciliata* M.Roem. | Meliacaee | 5.26 | 6.12 | 5.26 | 1.00 | 16.64 |
| VI | *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 16.67 | 21.67 | 9.50 | 0.57 | 47.84 |
| *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 4.17 | 3.33 | 0.79 | 0.19 | 8.29 |
| *Morus alba* L. | Moraceae | 8.33 | 5.00 | 5.04 | 0.61 | 18.37 |
| *Leucaena leucocephala* (Lamk.) de Wit | Fabaceae | 16.67 | 23.33 | 14.44 | 0.87 | 54.44 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 29.17 | 28.33 | 37.46 | 1.28 | 94.96 |
| *Toona ciliata* M.Roem. | Meliaceae | 25.00 | 18.33 | 32.77 | 1.31 | 76.10 |
| VII | *Eucalyptus umbellata* Domin | Myrtaceae | 12.5 | 11.11 | 9.11 | 0.73 | 32.72 |
| *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 12.5 | 11.11 | 15.84 | 1.27 | 39.45 |
| *Ficus palmata* Forssk. | Moraceae | 6.25 | 7.41 | 2.46 | 0.39 | 16.12 |
| *Bombax ceiba* L. | Malvaceae | 6.25 | 3.70 | 6.60 | 1.06 | 16.55 |
| *Melia azedarach* L. | Meliaceae | 12.5 | 18.52 | 15.46 | 1.24 | 46.48 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 18.75 | 9.26 | 21.48 | 1.15 | 49.49 |
| *Bauhinia variegata* L. | Fabaceae | 12.50 | 11.11 | 11.89 | 0.95 | 35.50 |
| *Toona ciliata* M.Roem. | Meliaceae | 6.25 | 11.11 | 2.97 | 0.48 | 20.33 |
| *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 12.50 | 16.67 | 14.19 | 1.14 | 43.36 |
| VIII | *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 5.56 | 11.37 | 3.24 | 0.58 | 20.17 |
| *Jacaranda mimosifolia* D.Don | Bignoniaceae | 16.68 | 13.64 | 22.14 | 1.33 | 52.46 |
| *Pinus roxburghii* Sarg. | Pinaceae | 11.12 | 6.82 | 14.32 | 1.29 | 32.26 |
| *Melia azedarach* L. | Meliaceae | 5.56 | 4.54 | 2.26 | 0.41 | 12.36 |
| *Bauhinia variegata* L. | Fabaceae | 22.24 | 20.45 | 35.86 | 1.61 | 78.55 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 5.56 | 6.82 | 2.83 | 0.51 | 15.21 |
| *Morus alba* L. | Moraceae | 5.56 | 2.27 | 3.07 | 0.55 | 10.9 |
| *Celtis australi s* L. | Cannabaceae | 5.56 | 9.09 | 2.97 | 0.53 | 17.62 |
| *Acacia catechu* (L.f.) Willd. | Fabaceae | 5.56 | 9.09 | 3.51 | 0.63 | 18.16 |
| *Dalbergia sissoo*  Roxb. ex DC. | Fabaceae | 5.56 | 4.54 | 3.98 | 0.72 | 14.08 |
| *Toona ciliata* M.Roem. | Meliaceae | 5.56 | 6.82 | 2.41 | 0.43 | 14.79 |
| *Eucalyptus umbellata* Domin | Myrtaceae | 5.56 | 4.54 | 3.40 | 0.61 | 13.5 |
| IX | *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 15.79 | 19.3 | 11.04 | 0.70 | 46.13 |
| *Grewia optiva* J.R.Drumm. ex Burret | Malvaceae | 26.32 | 19.3 | 57.81 | 2.20 | 103.43 |
| *Bauhinia variegata* L. | Fabaceae | 5.26 | 7.02 | 1.96 | 0.37 | 14.24 |
| *Pyrus pashia* Buch.-Ham. ex D.Don | Rosaceae | 5.26 | 3.51 | 1.96 | 0.37 | 10.73 |
| *Morus alba* L. | Moraceae | 5.26 | 7.02 | 2.56 | 0.49 | 14.84 |
| *Toona ciliata* M.Roem. | Meliaceae | 5.26 | 7.02 | 2.11 | 0.40 | 14.39 |
| *Acacia catechu* (L.f.) Willd. | Fabaceae | 10.52 | 19.3 | 9.35 | 0.89 | 39.17 |
| *Melia azedarach* L. | Meliaceae | 5.26 | 5.26 | 1.66 | 0.32 | 12.18 |
| *Jacaranda mimosifolia* D.Don | Bignoniaceae | 10.52 | 7.02 | 8.12 | 0.77 | 25.66 |
| *Populus ciliata* Wall. ex Royle | Salicaceae | 5.26 | 3.52 | 1.56 | 0.30 | 10.34 |
| *Bombax ceiba* L. | Malvaceae | 5.26 | 1.76 | 1.87 | 0.36 | 8.89 |
| X | *Dalbergia sissoo* Roxb. ex DC. | Fabaceae | 15.38 | 18.18 | 7.56 | 0.49 | 41.12 |
| *Celtis australis* L. | Cannabaceae | 15.38 | 14.55 | 10.54 | 0.69 | 40.47 |
| *Quercus leucotrichophora* A. Camus | Fagaceae | 38.46 | 49.09 | 70.79 | 1.84 | 158.34 |
| *Robinia pseudoacacia* Linn | Fabaceae | 7.69 | 1.82 | 2.70 | 0.35 | 12.21 |
| *Bauhinia variegata* L. | Fabaceae | 7.69 | 7.27 | 2.61 | 0.34 | 17.57 |
| *Pinus roxburghii* Sarg. | Pinaceae | 7.69 | 7.27 | 1.77 | 0.23 | 16.73 |
| *Morus alba* L. | Moraceae | 7.69 | 1.82 | 4.03 | 0.52 | 13.54 |

**Table 3 Phytosociological attributes of Trees at Zone-II**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 26.92 | 33.93 | 29.30 | 1.09 | 90.15 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 11.54 | 10.71 | 4.96 | 0.43 | 27.21 |
| *Abies pindrow* Zucc. | Pinaceae | 26.92 | 21.43 | 50.06 | 1.86 | 98.41 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 3.85 | 1.78 | 1.29 | 0.34 | 6.92 |
| *Prunus cornuta* (Wall. ex Royle) Steud. | Rosaceae | 7.69 | 8.93 | 3.40 | 0.44 | 20.02 |
| *Ulmus wallichiana* Planch. | Ulmaceae | 7.69 | 5.36 | 1.80 | 0.23 | 14.85 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 15.39 | 17.86 | 9.20 | 0.60 | 42.45 |
| II | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 41.18 | 56.36 | 64.12 | 1.56 | 161.66 |
| *Picea smithiana*(Wall.) Boiss. | Pinaceae | 29.41 | 20.00 | 18.46 | 0.63 | 67.87 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 11.76 | 10.91 | 5.52 | 0.47 | 28.19 |
| *Abies pindrow* Zucc. | Pinaceae | 17.65 | 12.73 | 11.90 | 0.67 | 42.28 |
| III | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 60 | 90.16 | 94.60 | 1.58 | 244.76 |
| *Abies pindrow* Zucc. | Pinaceae | 13.33 | 3.28 | 0.91 | 0.07 | 17.52 |
| *Aesculus indica* (Wall. ex Cambess.) Hook. | Sapindaceae | 6.67 | 1.64 | 0.64 | 0.10 | 8.95 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 13.33 | 3.28 | 3.01 | 0.23 | 19.62 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 6.67 | 1.64 | 0.84 | 0.13 | 9.15 |
| IV | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 60 | 86.54 | 83.0 | 1.38 | 229.54 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 13.33 | 3.85 | 0.92 | 0.10 | 18.10 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 20 | 5.77 | 10.43 | 0.52 | 36.20 |
| *Abies pindrow* Zucc. | Pinaceae | 6.67 | 3.85 | 5.66 | 0.85 | 16.18 |
| V | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 50.0 | 77.97 | 79.02 | 1.58 | 206.99 |
| *Aesculus indica* (Wall. ex Cambess.) Hook. | Sapindaceae | 18.75 | 6.78 | 4.63 | 0.25 | 30.16 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 25 | 11.86 | 11.48 | 0.46 | 48.34 |
| *Abies pindrow* Zucc. | Pinaceae | 6.25 | 3.39 | 4.87 | 0.78 | 14.51 |
| VI | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 40 | 46.94 | 46.55 | 1.16 | 133.49 |
| *Abies pindrow* Zucc. | Pinaceae | 30 | 32.65 | 32.75 | 1.09 | 95.40 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 20 | 14.29 | 18.72 | 0.94 | 53.01 |
| *Ulmus wallichiana* Planch. | Ulmaceae | 5 | 4.08 | 0.94 | 0.19 | 10.02 |
| *Juglans regia*  L. | Juglandaceae | 5 | 2.04 | 1.03 | 0.21 | 8.07 |
| VII | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 43.75 | 65.45 | 67.66 | 1.55 | 176.86 |
| *Abies pindrow* Zucc. | Pinaceae | 31.25 | 14.55 | 23.23 | 0.74 | 69.03 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 6.25 | 9.09 | 1.69 | 0.27 | 17.03 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 18.75 | 10.91 | 7.42 | 0.40 | 37.08 |
| VIII | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 38.10 | 43.08 | 66.52 | 1.75 | 147.7 |
| *Pinus wallichiana*(Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 23.81 | 16.92 | 26.45 | 1.11 | 67.18 |
| *Populus ciliata*Wall. ex Royle | Salicaceae | 19.05 | 18.46 | 2.43 | 0.13 | 39.94 |
| *Quercus leucotrichophora* A. Camus | Fagaceae | 4.76 | 6.15 | 0.98 | 0.21 | 11.89 |
| *Picea smithiana*(Wall.) Boiss. | Pinaceae | 9.52 | 9.23 | 2.29 | 0.24 | 21.04 |
| *Abies pindrow* Zucc. | Pinaceae | 4.76 | 6.15 | 1.34 | 0.28 | 12.25 |
| IX | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 47.37 | 66.67 | 80.44 | 1.70 | 194.48 |
| *Aesculus indica* (Wall. ex Cambess.) Hook. | Sapindaceae | 15.79 | 7.41 | 4.25 | 0.27 | 27.45 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 10.53 | 11.11 | 8.71 | 0.83 | 30.35 |
| *Picea smithiana*(Wall.) Boiss. | Pinaceae | 15.79 | 11.11 | 5.35 | 0.34 | 32.25 |
| *Abies pindrow* Zucc. | Pinaceae | 5.26 | 1.85 | 0.81 | 0.15 | 7.92 |
| *Quercus floribunda* Lindl. ex A.Camus | Fagaceae | 5.26 | 1.85 | 0.44 | 0.08 | 7.55 |
| X | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 46.67 | 60.34 | 70.65 | 1.51 | 177.66 |
| *Pinus wallichiana* (Wall. ex. D.Don) A.B.Jacks. | Pinaceae | 20.00 | 12.07 | 5.88 | 0.29 | 37.95 |
| *Picea smithiana*(Wall.) Boiss. | Pinaceae | 20.00 | 18.97 | 20.14 | 1.01 | 59.11 |
| *Abies pindrow* Zucc. | Pinaceae | 13.33 | 8.62 | 3.33 | 0.25 | 25.28 |

**Table 4 Phytosociological attributes of Trees at Zone-III**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 31.58 | 49.06 | 38.35 | 1.21 | 118.99 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 26.32 | 20.75 | 25.73 | 0.98 | 72.80 |
| *Picea smithiana*(Wall.) Boiss. | Pinaceae | 26.32 | 18.87 | 32.67 | 1.24 | 77.86 |
| *Abies pindrow* Zucc. | Pinaceae | 10.53 | 9.43 | 2.38 | 0.23 | 22.34 |
| *Prunus cornuta* (Wall. ex Royle) Steud. | Rosaceae | 5.26 | 1.89 | 0.86 | 0.16 | 8.01 |
| II | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 50.00 | 73.34 | 80.62 | 1.61 | 203.96 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 15.00 | 8.89 | 8.78 | 0.59 | 32.67 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 10.00 | 4.44 | 2.93 | 0.29 | 17.37 |
| *Abies pindrow* Zucc. | Pinaceae | 15.00 | 6.67 | 6.12 | 0.41 | 27.79 |
| *Prunus cornuta* (Wall. ex Royle) Steud. | Rosaceae | 5.00 | 4.44 | 0.95 | 0.19 | 10.39 |
| *Taxus wallichiana* Zucc. | Taxaceae | 5.00 | 2.22 | 0.60 | 0.12 | 7.82 |
| III | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 18.75 | 25.42 | 16.40 | 0.87 | 60.57 |
| *Quercus semecarpifolia* Sm. | Fagaceae | 25 | 35.59 | 18.83 | 0.75 | 79.42 |
| *Quercus floribunda* Lindl. ex A.Camus | Fagaceae | 12.50 | 18.64 | 6.62 | 0.53 | 37.76 |
| *Abies pindrow* Zucc. | Pinaceae | 43.75 | 20.34 | 58.14 | 1.33 | 122.23 |
| IV | *Picea smithiana* (Wall.) Boiss. | Pinaceae | 22.22 | 32.08 | 21.53 | 0.97 | 75.83 |
| *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 27.78 | 24.53 | 23.60 | 0.85 | 75.91 |
| *Abies pindrow* Zucc. | Pinaceae | 33.33 | 16.98 | 41.56 | 1.25 | 91.87 |
| *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 16.67 | 26.42 | 13.32 | 0.80 | 56.41 |
| V | *Picea smithiana* (Wall.) Boiss. | Pinaceae | 22.22 | 30 | 20.92 | 0.94 | 73.14 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 33.33 | 28 | 53.02 | 1.59 | 114.35 |
| *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 27.78 | 34 | 19.82 | 0.71 | 81.6 |
| *Taxus wallichiana* Zucc. | Taxaceae | 11.11 | 4.00 | 5.49 | 0.49 | 20.6 |
| *Abies pindrow* Zucc. | Pinaceae | 5.56 | 4 | 0.75 | 0.13 | 10.31 |
| VI | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 45.45 | 73.47 | 63.36 | 1.39 | 182.28 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 13.64 | 6.12 | 5.43 | 0.40 | 25.19 |
| *Abies pindrow* Zucc. | Pinaceae | 31.82 | 14.29 | 29.90 | 0.94 | 76.01 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 4.55 | 4.08 | 0.61 | 0.13 | 9.24 |
| *Taxus wallichiana* Zucc. | Taxaceae | 4.55 | 2.04 | 0.70 | 0.15 | 7.29 |
| VII | *Quercus semecarpifolia* Sm. | Fagaceae | 62.50 | 87.93 | 88.99 | 1.42 | 239.42 |
| *Abies pindrow* Zucc. | Pinaceae | 18.75 | 6.90 | 7.81 | 0.42 | 33.46 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 12.50 | 3.45 | 2.00 | 0.16 | 17.95 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 6.25 | 1.72 | 1.20 | 0.192 | 9.17 |
| VIII | *Quercus semecarpifolia* Sm. | Fagaceae | 30.43 | 46.07 | 50 | 1.6 | 126.5 |
| *Prunus cornuta* (Wall. ex Royle) Steud. | Rosaceae | 4.35 | 2.25 | 0.46 | 0.11 | 7.06 |
| *Abies pindrow* Zucc. | Pinaceae | 17.39 | 8.99 | 11.54 | 0.66 | 37.92 |
| *Taxus wallichiana* Zucc. | Taxaceae | 26.09 | 15.73 | 22.13 | 0.85 | 63.95 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 13.04 | 11.24 | 10.47 | 0.80 | 34.75 |
| *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 8.70 | 15.73 | 5.39 | 0.62 | 29.82 |
| IX | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 7.69 | 5 | 0.65 | 0.08 | 13.34 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 5.77 | 15 | 9.47 | 1.64 | 30.24 |
| *Quercus semecarpifolia* Sm. | Fagaceae | 67.31 | 45 | 79.70 | 1.18 | 192.01 |
| *Taxus wallichiana* Zucc. | Taxaceae | 5.77 | 10 | 2.81 | 0.49 | 18.58 |
| *Abies pindrow* Zucc. | Pinaceae | 5.77 | 10 | 4.38 | 0.76 | 20.15 |
| *Acer caesium* Wall. ex Brandis | Sapindaceae | 3.85 | 5 | 0.80 | 0.21 | 9.65 |
| *Quercus floribunda* Lindl. ex A.Camus | Fagaceae | 1.92 | 5 | 0.89 | 0.46 | 7.81 |
| *Prunus cornuta* (Wall. ex Royle) Steud. | Rosaceae | 1.92 | 5 | 1.30 | 0.68 | 8.22 |
| X | *Cedrus deodara* (Roxb. ex D.Don) G.Don | Pinaceae | 5.0 | 8.0 | 0.67 | 0.13 | 13.67 |
| *Picea smithiana* (Wall.) Boiss. | Pinaceae | 30.0 | 14.0 | 32.73 | 1.09 | 76.73 |
| *Quercus semecarpifolia* Sm. | Fagaceae | 40.0 | 60.0 | 35.86 | 0.90 | 135.86 |
| *Quercus floribunda* Lindl. ex A.Camus | Fagaceae | 10.0 | 6.0 | 3.17 | 0.32 | 19.17 |
| *Abies pindrow* Zucc. | Pinaceae | 10.0 | 8.0 | 5.92 | 0.59 | 23.92 |
| *Taxus wallichiana* Zucc. | Taxaceae | 5.0 | 4.0 | 1.65 | 0.33 | 10.65 |

**Table 5** **Diversity indices of tree species**

|  |  |  |  |
| --- | --- | --- | --- |
| Study Site | Shanon’s index (H) | Simpson index (CD) | Species richness (R) Margadex |
| Zone-I | | | |
| I | 2.05 | 0.15 | 9.40 |
| II | 1.54 | 0.25 | 5.43 |
| III | 1.75 | 0.19 | 6.43 |
| IV | 1.50 | 0.27 | 5.43 |
| V | 2.10 | 0.13 | 8.41 |
| VI | 1.58 | 0.23 | 5.44 |
| VII | 2.13 | 0.13 | 8.42 |
| VIII | 2.25 | 0.13 | 11.39 |
| IX | 2.04 | 0.18 | 10.43 |
| X | 1.48 | 0.33 | 6.43 |
| Zone-II | | | |
| I | 1.63 | 0.24 | 6.43 |
| II | 1.17 | 0.37 | 3.43 |
| III | 0.72 | 0.68 | 4.44 |
| IV | 0.79 | 0.61 | 3.42 |
| V | 0.93 | 0.51 | 3.44 |
| VI | 1.24 | 0.33 | 4.41 |
| VII | 1.07 | 0.42 | 3.43 |
| VIII | 1.40 | 0.32 | 5.45 |
| IX | 1.16 | 0.45 | 6.42 |
| X | 1.10 | 0.41 | 3.43 |
| Zone-III | | | |
| I | 1.35 | 0.29 | 4.42 |
| II | 1.10 | 0.49 | 5.40 |
| III | 1.30 | 0.29 | 3.44 |
| IV | 1.37 | 0.26 | 3.42 |
| V | 1.37 | 0.28 | 4.41 |
| VI | 1.06 | 0.44 | 4.41 |
| VII | 0.70 | 0.65 | 3.43 |
| VIII | 1.5 | 0.27 | 5.41 |
| IX | 133 | 0.35 | 7.42 |
| X | 1.10 | 0.49 | 5.41 |

**Figure 3 Dominant families with the number of tree species found in Anni block of Outer Seraj area**

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**Plate 1 A.** *Pinus wallichiana,* **B**. *Albizzia chinensis*, **C.** *Abies pindrow*, **D.** *Jacaranda mimosifolia,* **E.** *Aesculus indica***, F.** *Pinus wallichiana*, **G.** *Pyrus pashia,* **H.** *Ficus palmata*

**Shrub species distribution**

A total of 28 shrub species belonging to 23 genera and 17 families were recorded in the study area. Photographs of some shrub species recorded during field surveys are given in **Plate 2.** The dominant families were Rosaceae (7 spp.), Fabaceae (3 spp.), Berberidaceae, Rutaceae, and Thymelaeaceae (2 spp. each) **(Figure 4).** *Rosa* (3 spp.) was the dominant genera, followed by *Rubus, Indigofera* and *Berberis* (2 spp. each)**.**

At Zone-I, *Debregeasia saeneb* (IVI=191.15) at sudy site IX was the dominant species followed by *Prinsepia utilis* (IVI=174.80) at site VIII and *Rosa brunonii* (IVI=155.38) at site VI. Maximum value of frequency (%) was observed for *Debregeasia saeneb* (60.87) at study site IX followed by *Prinsepia utilis* (47.22) at site VIII and *Rosa brunonii* (42.42) at site VI. Maximum density was recorded for *Debregeasia saeneb* (63.73) at site IX followed by *Prinsepia utiis* (57.60) at site VIII and *Rosa brunonii* (54.15) at site VI. Abundance was found to be highest for *Prinsepia utilis* (69.98)at site VIIIfollowed by *Debregeasia saeneb* (66.55) at site IX and *Rosa brunonii* (58.81) at site VI. The distribution pattern of species showed contiguous distribution **(Table 6).**

At Zone-II, *Rosa brunonii* (IVI=138.84) at sudy site IV was the dominant species followed by *Prinsepia utilis* (IVI=105.40) at siteVII and *Desmodium elegans* (IVI=103.90) at site VI. Maximum value of frequency (%) was observed for *Rosa macrophylla* (42.11) at study site IV followed by *Berberis lycium* (31.58) at site V and *Prinsepia utilis* (30.19) at site VII. Maximum density was recorded for *Rosa macrophylla* (54.62) at site IV followed by *Daphne papyracea* (40.94) at site X and *Prinsepia utilis* (34.47) at site VI. Abundance was found to be highest for *Desmodium elegans* (45.08)at site VIfollowed by *Debregeasia saeneb* (42.11) at site IV and *Indigofera heterantha* (58.81) at site VI. The distribution pattern of species showed contiguous distribution **(Table 7).**

At Zone-III, *Myrsine africana* (IVI=194.98) at sudy site VIII was the dominant species followed by *Berberis aristata* (IVI=131.97) at siteVI and *Desmodium elegans* (IVI=130.09) at site II. Maximum value of frequency (%) was observed for *Coriaria nepalensis* (56.00) at study site III followed by *Rosa sericea* (50.00) at site VII and *Prinsepia utilis* (45.45) at site I. Maximum density was recorded for *Coriaria nepalensis* (59.93) at site III followed by *Berberis aristata* (49.56) at site VI and *Desmodium elegans* (46.15) at site II. Abundance was found to be highest for *Coriaria nepalensis* (73.52*)* at site IIIfollowed by *Myrsine africana* (71.23) at site VIII and *Rosa sericea* (54.77) at site V. All the recorded species were distributed contagiously **(Table 8).**

**Table 6 Phytosociological attributes of Shrubs at Zone-I**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Debregeasia saeneb* (Forssk.) Hepper & J.R.I.Wood | Urticaceae | 32.73 | 34.81 | 37.19 | 1.14 | 104.73 |
| *Berberis lycium* Royle | Berberidaceae | 20.0 | 18.95 | 16.33 | 0.82 | 55.28 |
| *Prinsepia utilis* Royle | Rosaceae | 25.45 | 25.16 | 27.89 | 1.10 | 78.50 |
| *Woodfordia fruticosa*(L.) Kurz | Lythraceae | 21.82 | 21.08 | 18.52 | 0.85 | 61.42 |
| II | *Justicia adhatoda* L. | Acanthaceae | 31.03 | 32.89 | 37.64 | 1.21 | 101.56 |
| *Ricinus communis* L. | Euphorbiaceae | 24.14 | 22.32 | 17.53 | 0.73 | 63.99 |
| *Rubus ellipticus* Sm. | Rosaceae | 22.41 | 24.05 | 22.15 | 0.10 | 68.61 |
| *Carissa spinarum* L. | Apocynaceae | 22.41 | 20.74 | 22.68 | 1.01 | 65.83 |
| III | *Berberis lycium* Royle | Berberidaceae | 30.43 | 26.57 | 19.23 | 0.63 | 76.23 |
| *Cotinus coggygria* Scop. | Anacardiaceae | 21.74 | 26.37 | 22.09 | 1.02 | 70.20 |
| *Prinsepia utilis* Royle | Rosaceae | 15.22 | 14.73 | 20.70 | 1.36 | 50.65 |
| *Ricinus communis* L. | Euphorbiaceae | 23.91 | 23.89 | 28.69 | 1.20 | 76.49 |
| *Justicia adhatoda* L. | Acanthaceae | 8.7 | 8.44 | 9.29 | 1.07 | 26.43 |
| IV | *Rubus ellipticus* Sm. | Rosaceae | 39.02 | 41.91 | 45.29 | 1.16 | 126.22 |
| *Coriaria nepalensis* Wall. | Coriariaceae | 17.07 | 13.32 | 12.87 | 0.75 | 43.26 |
| *Cotinus coggygriya* Scop. | Anacardiaceae | 17.07 | 20.23 | 17.84 | 1.05 | 55.14 |
| *Berberis lycium* Royle | Berberidaceae | 9.76 | 9.40 | 7.52 | 0.77 | 26.68 |
| *Prinsepia utilis* Royle | Rosaceae | 7.32 | 6.92 | 8.85 | 1.21 | 23.09 |
| *Woodfordia fruticosa* (L.) Kurz | Lythracaee | 9.76 | 8.22 | 7.63 | 0.78 | 25.61 |
| V | *Prinsepia utilis* Royle | Rosaceae | 33.33 | 41.54 | 35.68 | 1.07 | 110.55 |
| *Berberis lycium* Royle | Berberidaceae | 15.56 | 11.55 | 14.25 | 0.92 | 41.36 |
| *Ricinus communis* L. | Euphorbiaceae | 17.78 | 18.29 | 14.25 | 0.80 | 50.32 |
| *Cotinus coggygria* Scop. | Anacardiaceae | 33.33 | 28.61 | 35.82 | 1.07 | 97.76 |
| VI | *Rosa brunonii* Lindl. | Rosaceae | 42.42 | 54.15 | 58.81 | 1.39 | 155.38 |
| *Rubus ellipticus* L. | Rosaceae | 27.27 | 23.15 | 18.95 | 0.69 | 69.37 |
| *Berberis lycium* Royle | Berberidaceae | 30.30 | 22.70 | 22.24 | 0.73 | 75.24 |
| VII | *Berberis lycium* Royle | Berberidaceae | 41.02 | 44.25 | 40.75 | 0.99 | 126.02 |
| *Rubus ellipticus* Sm. | Rosaceae | 17.95 | 21.52 | 17.69 | 0.99 | 57.16 |
| *Zanthoxylum armatum* DC. | Rutaceae | 20.51 | 16.91 | 15.85 | 0.77 | 53.27 |
| *Carissa spinarum* L. | Apocynaceae | 20.51 | 17.32 | 25.71 | 1.25 | 63.54 |
| VIII | *Prinsepia utilis* Royle | Rosaceae | 47.22 | 57.60 | 69.98 | 1.48 | 174.8 |
| *Murraya koenigii* (L.) Spreng. | Rutaceae | 8.33 | 5.38 | 4.38 | 0.53 | 18.09 |
| *Indigofera heterantha* Wall. ex Brandis | Fabaceae | 19.44 | 16.55 | 14.47 | 0.74 | 50.46 |
| *Dodonaea viscosa* Jacq. | Sapindaceae | 25.0 | 20.46 | 11.18 | 0.45 | 56.64 |
| IX | *Dabregesia saeneb* (Forssk.) Hepper & J.R.I.Wood | Urticaceae | 60.87 | 63.73 | 66.55 | 1.09 | 191.15 |
| *Prinsepia utilis* Royle | Rosaceae | 39.13 | 36.27 | 33.45 | 0.85 | 108.85 |
| X | *Murraya koenigii* (L.) Spreng. | Rutaceae | 33.33 | 40.48 | 47.26 | 1.42 | 121.07 |
| *Carissa spiarum* L. | Apocynaceae | 19.61 | 16.05 | 10.68 | 0.54 | 46.34 |
| *Rubus ellipticus* Sm. | Rosaceae | 15.69 | 15.11 | 14.75 | 0.94 | 45.55 |
| *Cotinus coggygria* Scop. | Anacardiaceae | 21.57 | 21.64 | 22.22 | 1.03 | 65.43 |
| *Berberis lycium* Royle | Berberidaceae | 9.80 | 6.73 | 5.09 | 0.52 | 21.62 |

**Table 7 Phytosociological attributes of Shrubs at Zone-II**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 17.30 | 29.90 | 28.62 | 1.65 | 75.82 |
| *Rubus niveus* Thunb. | Rosaceae | 28.85 | 30.09 | 29.42 | 1.02 | 88.36 |
| *Sarcococca saligna*Mull.Arg. | Buxaceae | 25 | 19.07 | 16.20 | 0.65 | 60.27 |
| *Indigofera gerardiana* Wall. ex Baker | Fabaceae | 21.15 | 12.76 | 16.08 | 0.76 | 49.99 |
| *Coriaria nepalensis* Wall. | Coriariaceae | 7.69 | 8.18 | 9.68 | 1.26 | 25.55 |
| II | *Zanthoxylum armatum* DC. | Rutaceae | 12.31 | 7.36 | 7.50 | 0.61 | 27.17 |
| *Dodonaea viscosa* Jacq. | Sapindaceae | 13.85 | 16.15 | 16.29 | 1.18 | 46.29 |
| *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 13.85 | 17.26 | 14.0 | 1.01 | 45.11 |
| *Indigofera heterantha* Wall. ex Brandis | Fabaceae | 23.08 | 30.09 | 36.96 | 1.60 | 90.13 |
| *Debregeasia saeneb*(Forssk.) Hepper & J.R.I.Wood | Urticaceae | 12.31 | 9.74 | 6.22 | 0.51 | 28.27 |
| *Cotoneaster microphyllus* Wall. ex Lindl. | Rosaceae | 7.69 | 5.15 | 4.30 | 0.56 | 17.14 |
| *Prinsepia utilis* Royle | Rosaceae | 4.62 | 3.33 | 1.28 | 0.28 | 9.23 |
| *Berberis lycium* Royle | Berberidaceae | 12.31 | 10.93 | 13.45 | 1.09 | 36.69 |
| III | *Desmodium elegans* DC. | Fabaceae | 26.92 | 32.06 | 32.11 | 1.19 | 91.09 |
| *Prinsepia utilis* Royle | Rosaceae | 17.31 | 15.22 | 19.27 | 1.11 | 51.80 |
| *Berberis lycium* Royle | Berberidaceae | 25.0 | 24.08 | 19.69 | 0.79 | 68.77 |
| *Indigofera gerardiana* Wall. ex Baker | Fabaceae | 17.31 | 17.66 | 18.35 | 1.06 | 53.32 |
| *Rosa macrophylla* Lindl. | Rosaceae | 13.46 | 10.98 | 10.58 | 0.79 | 35.02 |
| IV | *Rosa macrophylla* Lindl. | Rosaceae | 42.11 | 54.62 | 42.11 | 1.00 | 138.84 |
| *Zanthoxylum armatum* DC. | Rutaceae | 5.26 | 3.76 | 5.26 | 1.00 | 14.28 |
| *Desmodium elegans* DC. | Fabaceae | 21.06 | 12.02 | 21.06 | 1.00 | 54.14 |
| *Berberis lycium* Royle | Berberidaceae | 31.58 | 29.60 | 31.58 | 1.00 | 92.76 |
| V | *Berberis lycium* Royle | Berberidaceae | 22.45 | 22.71 | 26.99 | 1.20 | 72.15 |
| *Prinsepia utilis* Royle | Rosaceae | 26.53 | 27.62 | 21.20 | 0.80 | 75.35 |
| *Daphne papyracea*Wall. ex G.Don | Thymelaeaceae | 26.53 | 27.43 | 22.30 | 0.84 | 76.26 |
| *Rubus ellipticus* Sm. | Rosaceae | 14.29 | 15.59 | 24.67 | 1.73 | 54.55 |
| *Zanthoxylum armatum* DC. | Rutaceae | 10.20 | 6.64 | 4.84 | 0.47 | 21.68 |
| VI | *Desmodium elegans* DC. | Fabaceae | 27.50 | 31.32 | 45.08 | 1.64 | 103.90 |
| *Prinsepia utilis* Royle | Rosaceae | 40 | 34.47 | 16.92 | 0.42 | 91.39 |
| *Rosa macrophylla* Lindl. | Rosaceae | 32.50 | 34.21 | 38.0 | 1.17 | 104.71 |
| VII | *Prinsepia utilis* Royle | Rosaceae | 30.19 | 30.92 | 44.29 | 1.47 | 105.40 |
| *Zanthoxylum armatum* DC. | Rutaceae | 28.30 | 32.69 | 25.34 | 0.90 | 86.33 |
| *Sarcococca saligna*Mull.Arg. | Buxaceae | 28.30 | 25.19 | 23.54 | 0.83 | 77.03 |
| *Desmodium elegans* DC. | Fabaceae | 13.21 | 11.20 | 6.83 | 0.52 | 31.24 |
| VIII | *Desmodium elegans* DC. | Fabaceae | 28.30 | 29.57 | 27.74 | 0.98 | 85.61 |
| *Cotoneaster microphyllus* Wall. ex Lindl. | Rosaceae | 26.42 | 29.04 | 27.36 | 1.04 | 82.82 |
| *Prinsepia utilis* Royle | Rosaceae | 24.53 | 22.95 | 21.47 | 0.88 | 68.95 |
| *Rubus ellipticus* Sm. | Rosaceae | 11.32 | 11.56 | 16.78 | 1.48 | 39.66 |
| *Wilkestromea canescens* Meisn. | Thymelaeaceae | 9.43 | 6.88 | 6.65 | 0.71 | 22.96 |
| IX | *Zanthoxylum armatum* DC. | Rutaceae | 21.92 | 22.43 | 23.72 | 1.08 | 68.07 |
| *Carissa spinarum* L. | Apocynaceae | 16.44 | 17.33 | 9.90 | 0.60 | 43.67 |
| *Sarcococca saligna*Mull.Arg. | Buxaceae | 13.70 | 15.11 | 13.28 | 0.97 | 42.09 |
| *Cotoneaster microphyllus* Wall. ex Lindl. | Rosaceae | 16.44 | 19.61 | 29.71 | 1.81 | 65.76 |
| *Indigofera heterantha* Wall. ex Brandis | Fabaceae | 12.33 | 13.43 | 18.06 | 1.46 | 43.82 |
| *Berberis aristata* DC. | Berberidaceae | 2.74 | 1.54 | 0.44 | 0.16 | 4.72 |
| *Desmodium elegans* DC. | Fabaceae | 16.44 | 10.54 | 4.90 | 0.30 | 31.88 |
| X | *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 25 | 40.94 | 29.83 | 1.19 | 95.77 |
| *Zanthoxylum armatum* DC. | Rutaceae | 25 | 18.50 | 22.90 | 0.92 | 66.40 |
| *Cotoneaster microphylla* Wall. ex Lindl. | Rosaceae | 25 | 20.51 | 29.60 | 1.18 | 75.11 |
| *Prinsepia utilis* Royle | Rosaceae | 25 | 20.06 | 17.67 | 0.71 | 62.73 |

**Table 8 Phytosociological attributes of Shrubs at Zone-III**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | RF | RD | RDO | A/F | IVI |
| I | *Prinsepia utilis* Royle | Rosaceae | 45.45 | 45.31 | 38.29 | 0.84 | 129.05 |
| *Rosa sericea* Lindl. | Rosaceae | 33.33 | 37.13 | 53.94 | 1.62 | 124.40 |
| *Coriaria nepalensis* Wall. | Coriariaceae | 21.21 | 17.56 | 7.77 | 0.37 | 46.54 |
| II | *Desmodium elegans* DC. | Fabaceae | 39.47 | 46.15 | 44.47 | 1.13 | 130.09 |
| *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 28.95 | 27.57 | 29.37 | 1.01 | 85.89 |
| *Rhododendron campanulatum* D.Don | Ericaceae | 31.58 | 26.28 | 26.16 | 0.83 | 84.02 |
| III | *Coriaria nepalensis* Wall. | Coriariaceae | 56 | 59.93 | 73.52 | 1.31 | 189.45 |
| *Desmodium elegans* DC. | Fabaceae | 44 | 40.07 | 26.48 | 0.60 | 110.55 |
| IV | *Rosa sericea* Lindl. | Rosaceae | 33.33 | 30.10 | 35.69 | 1.07 | 99.12 |
| *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 33.33 | 38.74 | 38.76 | 1.16 | 110.83 |
| *Berberis lycium* Royle | Berberidaceae | 33.33 | 31.17 | 25.55 | 0.77 | 90.05 |
| V | *Rosa sericea* Lindl. | Rosaceae | 35.55 | 47.65 | 54.77 | 1.54 | 137.97 |
| *Myrisine africana* L. | Primulaceae | 22.22 | 18.58 | 15.44 | 0.69 | 56.24 |
| *Desmodium elegans* DC. | Fabaceae | 22.22 | 21.20 | 19.99 | 0.90 | 63.41 |
| *Rubus niveus* Thunb. | Rosaceae | 20.0 | 12.57 | 9.80 | 0.49 | 42.37 |
| VI | *Berberis aristata* DC. | Berberidaceae | 42.42 | 49.56 | 39.99 | 0.94 | 131.97 |
| *Prinsepia utilis* Royle | Rosaceae | 33.33 | 33.04 | 46.75 | 1.40 | 113.12 |
| *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 24.24 | 17.40 | 13.26 | 0.55 | 54.90 |
| VII | *Rosa sericea* Lindl. | Rosaceae | 50.00 | 50.11 | 40.21 | 0.80 | 140.32 |
| *Berberis aristata* DC. | Berberidaceae | 28.95 | 32.94 | 46.54 | 1.61 | 108.43 |
| *Coriaria nepalensis* Wall. | Coriariaceae | 21.05 | 16.95 | 13.25 | 0.63 | 51.25 |
| VIII | *Myrsine africana* L. | Primulaceae | 52.94 | 60.81 | 71.23 | 1.35 | 194.98 |
| *Rhododendron campanulatum* D.Don | Ericaceae | 11.76 | 4.61 | 2.14 | 0.18 | 18.51 |
| *Rubus niveus* Thunb. | Rosaceae | 35.29 | 34.58 | 26.63 | 0.75 | 96.50 |
| IX | *Rosa macrophylla* Lindl. | Rosaceae | 26.09 | 28.48 | 20.99 | 0.80 | 75.56 |
| *Daphne papyracea* Wall. ex G.Don | Thymelaeaceae | 21.74 | 22.61 | 23.18 | 1.07 | 67.53 |
| *Berberis aristata* DC. | Berberidaceae | 23.91 | 27.25 | 37.71 | 1.58 | 88.87 |
| *Lonicera angustifolia*Wall. ex DC. | Caprifoliaceae | 28.26 | 21.67 | 18.11 | 0.64 | 68.04 |
| X | *Berberis aristata* DC. | Berberidaceae | 37.50 | 43.65 | 36.12 | 0.96 | 117.27 |
| *Prinsepia utilis* Royle | Rosaceae | 34.38 | 28.85 | 28.50 | 0.83 | 91.73 |
| *Coriaria nepalensis* Wall. | Coriariaceae | 28.12 | 27.50 | 35.38 | 1.26 | 91.00 |

**Table 9** **Diversity indices of Shrub layer**

|  |  |  |  |
| --- | --- | --- | --- |
| Study Site | Shanon’s index (H) | Simpson index (CD) | Species richness (R) Margalef index |
| Zone-I | | | |
| I | 1.36 | 0.26 | 3.67 |
| II | 1.37 | 0.26 | 3.68 |
| III | 1.55 | 0.22 | 4.67 |
| IV | 1.58 | 0.25 | 5.65 |
| V | 1.31 | 0.29 | 3.65 |
| VI | 1.03 | 0.38 | 2.65 |
| VII | 1.32 | 0.29 | 3.65 |
| VIII | 1.10 | 0.41 | 3.65 |
| IX | 0.66 | 0.54 | 1.63 |
| X | 1.46 | 0.26 | 4.66 |
| Zone-II | | | |
| I | 1.54 | 0.23 | 4.69 |
| II | 1.90 | 0.17 | 7.68 |
| III | 1.56 | 0.22 | 4.68 |
| IV | 1.12 | 0.37 | 3.70 |
| V | 1.54 | 0.22 | 4.67 |
| VI | 1.10 | 0.33 | 2.65 |
| VII | 1.31 | 0.28 | 3.67 |
| VIII | 1.52 | 0.23 | 4.67 |
| IX | 1.81 | 0.17 | 6.68 |
| X | 1.37 | 0.26 | 3.68 |
| Zone-III | | | |
| I | 1.02 | 0.38 | 2.67 |
| II | 1.08 | 0.35 | 2.67 |
| III | 0.66 | 0.53 | 1.66 |
| IV | 1.10 | 0.34 | 2.67 |
| V | 1.28 | 0.31 | 3.68 |
| VI | 1.04 | 0.37 | 2.67 |
| VII | 1.03 | 0.38 | 2.66 |
| VIII | 0.83 | 0.49 | 2.61 |
| IX | 1.38 | 0.25 | 3.67 |
| X | 1.09 | 0.34 | 2.66 |

**Figure 4** **Dominant families with the number of shrub species found in Anni block of Outer Seraj area**



**Plate 2 I.** *Rosa brunonii,* **J**. *Rubus ellipticus,* **K.** *Rosa sericea,* **L.** *Justicia adhatoda,* **M.** *Debregeasia saeneb,* **N.** *Lonicera angustifolia*, **O.** *Indigofera heterantha,* **P.** *Woodfordia fruticosa*

**Herb species distribution**

A total of 40 herb species belonging to 38 genera and 22 families were recorded in the study area. Photographs of some herb species recorded during field surveys are given in **Plate 3.** The dominant families were Asteraceae (5 spp.), Lamiaceae and Solanaceae, (4 spp. each), and Polygonaceae (3 spp.) Urticaceae, Rosacea and, Amaranthaceae (2 spp. each)**(Figure 5).**

At Zone-I, *Cannabis sativa* (IVI=133.23) at sudy site IX was the dominant species followed by *Hypericum perforatum* (IVI=117.07) at site IV and *Centella asiatica* (IVI=109.26) at site II. Maximum value of frequency (%) was observed for *Cannabis sativa* (43.24) at study site IX followed by *Centella asiatica* (39.02) at site II and *Trifolium repens* (37.50) at site IV. Maximum density was recorded for *Cannabis sativa* (42.34) at site IX followed by *Hypericum perforatum* (41.05) at site IX and *Asparagus officinalis* (37.07) at site VI. Abundance was found to be highest for *Cannabis sativa* (47.65)at site IXfollowed by *Hypericum perforatum* (41.02) at site IV and *Trifolium repens* (40.38) at site IX. The distribution pattern of species showed contiguous distribution **(Table 10).**

At Zone-II, *Boenninghausenia albiflora* (IVI=199.71) at sudy site II was the dominant species followed by *Circium wallichii* (IVI=166.71) at site VI and *Ajuga bracteosa* (IVI=166.71) at site VI. Maximum value of frequency (%) was observed for *Boenninghausenia albiflora* (55.55) at study site II followed by *Chrysopogon fulvus* (48.39) at site I and *Circium wallichii* and *Ajuga bacteosa* (45.16 each) at site VI. Maximum density was recorded for *Boenninghausenia albiflora* (68.87.) at site II followed by *Chrysopogon fulvus* (58.95) at site I and *Ajuga bracteosa* and *Circium wallichii* (50.39 each) at site VI and *Prinsepia utilis* (34.47) at site VI. Abundance was found to be highest for *Boenninghausenia albiflora* (75.29)at site IIfollowed by *Circium wallichii* (61.75) at site II and *Chrysopogon fulvus* (57.8) at site I. The distribution pattern of species showed contiguous distribution **(Table 11).**

At Zone-III, *Galium aparine* (IVI=229.86) at sudy site I was the dominant species followed by *Achyranthes aspera* (IVI=228.06) at site II and *Galium aparine* (IVI=202.71) at site V. Maximum value of frequency (%) was observed for *Thymus linearis* (77.88) at study site VIII followed by *Girardiana diversifolia* (70) at site X and *Galium aparine* (68.42) at site I. Maximum density was recorded for *Girardiana diversifolia* (79.99) at site X followed by *Thymus linearis* (77.97) at site VIII and *Galium aparine* (75.67) at site IX. Abundance was found to be highest for *Achyranthes aspera* (99.42*)* at site VIfollowed by *Potentilla astrosanguinea* (97.29) at site X and *Galium aparine* (89.19) at site V. Most of the recorded species were distributed contagiously. Only one species i.e., *Thymus linearis* (0.01) showed random distribution **(Table 12).**

**Table 10 Phytosociological attributes of Herbs at Zone-I**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | Relative frequency | Relative density | Relative dominance | R/F | IVI |
| I | *Ageratum conyzoides* L. | Asteraceaeae | 23.26 | 30.63 | 28.31 | 1.22 | 82.2 |
|  | *Galinsoga parviflora* Cav. | Solanaceae | 27.91 | 25.74 | 24.14 | 0.86 | 77.79 |
|  | *Cannabis sativa* L. | Cannabaceae | 11.63 | 10.17 | 7.38 | 0.63 | 29.18 |
|  | *Urtica dioica* L. | Urticaceae | 23.26 | 23.57 | 30.06 | 1.29 | 76.89 |
|  | *Asparagus filicinus*Buch.-Ham. ex D.Don | Asparagaceae | 13.96 | 9.89 | 10.11 | 0.72 | 33.96 |
| II | *Centella asiatica*(L.) Urb. | Apiaceae | 39.02 | 36 | 34.24 | 0.88 | 109.26 |
|  | Bidens pilosa L. | Asteraceae | 24.4 | 28.78 | 24.99 | 1.02 | 78.17 |
|  | *Girardiana diversifolia* (Link) Friis | Urticaceae | 21.95 | 19.43 | 21.38 | 0.97 | 62.76 |
|  | *Galinsoga parviflora* Cav. | Solanaceae | 14.63 | 15.79 | 19.39 | 1.33 | 49.81 |
| III | *Datura stramonium* L. | Solanaceae | 28.07 | 27.44 | 32.75 | 1.17 | 88.26 |
|  | *Anaphalis busua* (Buch.-Ham.) DC. | Asteraceae | 22.81 | 24.45 | 25.14 | 1.1 | 72.4 |
|  | *Chrysopogon fulvus* (Spreng.) Chiov. | Poaceae | 14.04 | 11.23 | 15.37 | 1.09 | 40.64 |
|  | *Mentha longifolia* (L.)Huds. | Lamiaceae | 8.77 | 6.42 | 8.09 | 0.92 | 23.28 |
|  | *Galinsoga parviflora* Cav. | Solanaceae | 22.81 | 23.67 | 16.81 | 0.74 | 63.29 |
|  | Bidens pilosa L. | Asteraceae | 3.5 | 6.79 | 1.84 | 0.53 | 12.13 |
| IV | *Trifolium repens* L. | Fabaceae | 37.5 | 34.24 | 40.38 | 1.08 | 112.12 |
|  | *Hypericum purforatum* L. | Hypericaceae | 35 | 41.05 | 41.02 | 1.17 | 117.07 |
|  | *Solanum nigrum* L. | Solanaceae | 22.5 | 20.76 | 17.29 | 0.77 | 60.55 |
|  | *Atropa acuminata* Royle ex Lindl. | Solanaceae | 5 | 3.95 | 1.31 | 0.26 | 10.26 |
| V | *Solanum nigrum* L. | Solanaceae | 31.7 | 32.62 | 37.11 | 1.17 | 101.43 |
|  | *Asparagus filicinus*Buch.-Ham. ex D.Don | Asparagaceae | 26.83 | 26.86 | 24.56 | 0.92 | 78.25 |
|  | *Ageratum conyzoides*L. | Asteraceae | 31.7 | 33.3 | 31.58 | 0.1 | 96.58 |
|  | *Trifolium repens* L. | Fabaceae | 9.76 | 7.22 | 6.75 | 0.69 | 23.73 |
| VI | *Asparagus filicinus*Buch.-Ham. ex D.Don | Asparagaceae | 28.89 | 37.07 | 37.72 | 1.31 | 103.68 |
|  | *Ageratum conyzoides* L. | Asteraceae | 26.67 | 21.94 | 20.04 | 0.75 | 68.65 |
|  | *Urtica dioica* L. | Urticaceae | 17.78 | 13.1 | 17.59 | 0.99 | 48.47 |
|  | *Galinsoga parviflora* Cav. | Solanaceae | 8.89 | 10.03 | 9.1 | 1.02 | 28.02 |
|  | *Argemone maxicana* L. | Papaveraceae | 17.77 | 17.86 | 15.55 | 0.88 | 51.18 |
| VII | *Asparagus filicinus*Buch.-Ham. ex D.Don | Asparagaceae | 31.58 | 31.48 | 37.63 | 1.19 | 100.69 |
|  | *Ageratum conyzoides* L. | Asteraceae | 31.58 | 34.34 | 35.62 | 1.13 | 101.54 |
|  | *Urtica dioica* L. | Urticaceae | 21.05 | 17.68 | 18.03 | 0.86 | 56.76 |
|  | *Saccharum spontaneum* L. | Poaceae | 10.53 | 10.1 | 8.2 | 0.78 | 28.83 |
|  | *Argemone maxicana* L. | Papaveraceae | 5.26 | 6.4 | 0.52 | 0.1 | 12.18 |
| VIII | *Acorus calamus* L. | Acoraceae | 26.85 | 28.59 | 26.64 | 0.99 | 82.08 |
|  | *Datura stramonium* L. | Solanaceae | 18.6 | 17.51 | 18.75 | 1.01 | 54.86 |
|  | *Nicotiana tabacum*L. | Solanaceae | 24.79 | 27.23 | 33.82 | 1.36 | 85.84 |
|  | *Plantago major* L. | Plantaginaceae | 14.88 | 13.64 | 6.24 | 0.42 | 34.76 |
|  | *Centella asiatica* (L.) Urb. | Apiaceae | 14.88 | 13.02 | 14.55 | 0.98 | 42.45 |
| IX | *Cannabis sativa* L. | Cannabaceae | 43.24 | 42.34 | 47.65 | 1.1 | 133.23 |
|  | Bidens pilosa L | Asteraceae | 32.43 | 35.34 | 33.8 | 1.04 | 101.57 |
|  | *Solanum nigrum* L. | Solanaceae | 24.32 | 22.32 | 18.55 | 0.76 | 65.21 |
| X | *Circium wallichii* DC. | Asteraceae | 30.95 | 32.59 | 27.03 | 0.873 | 90.57 |
|  | Bidens pilosa L | Asteraceae | 21.43 | 19.64 | 17.58 | 0.82 | 58.65 |
|  | *Trifolium repens* L. | Fabaceae | 23.81 | 22.95 | 21.58 | 0.91 | 68.34 |
|  | *Galinsoga parviflora* Cav. | Solanaceae | 11.9 | 11.09 | 20.9 | 1.76 | 43.89 |
|  | *Ajuga bracteosa* Wall. ex Benth. | Lamiaceae | 11.9 | 13.73 | 12.91 | 1.08 | 38.54 |

**Table 11** Phytosociological attributes of Herbs at Zone-II

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | Relative frequency | Relative density | Relative dominance | A/F | IVI |
| I | *Chrysopogon fulvus* (Spreng.) Chiov. | Poaceae | 48.39 | 58.95 | 57.88 | 1.20 | 165.22 |
| *Galinsoga parviflora* Cav. | Solanaceae | 29.03 | 30 | 31.7 | 1.09 | 90.73 |
| *Circium wallichii* DC. | Asteraceae | 22.58 | 11.05 | 10.42 | 0.46 | 44.05 |
| II | *Boenninghausenia albiflora*(Hook.) Meisn. | Rutaceae | 55.55 | 68.87 | 75.29 | 1.36 | 199.71 |
| *Chenopodium album* L. | Amaranthaceae | 37.04 | 26.33 | 23.28 | 0.63 | 86.65 |
| *Potentilla indica* (Andrews) Th.Wolf | Rosaceae | 7.41 | 4.8 | 1.43 | 0.193 | 13.64 |
| III | *Anaphalis busua* (Buch.-Ham.) DC. | Asteraceae | 38.1 | 42.98 | 50.15 | 1.32 | 131.23 |
| *Datura stramonium* L. | Solanaceae | 26.19 | 23.92 | 18.22 | 0.70 | 68.33 |
| *Potentilla indica* (Andrews) Th.Wolf | Rosaceae | 21.43 | 22.57 | 24.67 | 1.15 | 68.67 |
| *Urtica dioica* L. | Urticaceae | 14.29 | 10.53 | 6.96 | 0.49 | 31.78 |
| IV | *Potentilla indica* (Andrews) Th.Wolf | Rosaceae | 27.45 | 28.96 | 2.02 | 0.07 | 58.43 |
| *Trifolium pretense* L. | Fabaceae | 25.49 | 28.54 | 3.29 | 0.13 | 57.32 |
| *Ajuga bracteosa* Wall. ex Benth. | Lamiaceae | 17.65 | 11.32 | 92.5 | 5.24 | 121.47 |
| *Galinsoga parviflora* Cav. | Solanaceae | 11.76 | 13.34 | 1.35 | 0.11 | 26.45 |
| *Circium wallichii* DC. | Asteraceae | 17.65 | 17.84 | 0.84 | 0.05 | 36.33 |
| V | *Rumex hastatus* D.Don | Polygonaceae | 37.5 | 39.3 | 43.56 | 1.16 | 120.36 |
| *Chenopodium album* L. | Amaranthaceae | 37.5 | 35.58 | 30.55 | 0.81 | 103.63 |
| *Potentilla indica* (Andrews) Th.Wolf | Rosaceae | 25 | 25.12 | 25.89 | 1.04 | 76.01 |
| VI | *Ajuga bracteosa* Wall. ex Benth. | Lamiaceae | 45.16 | 50.39 | 46.32 | 1.03 | 166.71 |
| *Persicaria capitata*(Buch.-Ham. ex D.Don) H.Gross | Polygonaceae | 25.81 | 20.27 | 21.89 | 0.85 | 82.16 |
| *Thalictrum foliolosum* DC. | Ranunculaceae | 29.03 | 29.34 | 31.79 | 1.10 | 106.13 |
| *Circium wallichii* DC. | Asteraceae | 45.16 | 50.39 | 46.32 | 1.03 | 166.71 |
| VII | *Ageratum conyzoides*L. | Asteraceae | 28.95 | 30 | 22.05 | 0.76 | 81 |
| *Urtica dioica* L. | Urticaceae | 23.68 | 29.58 | 36.88 | 1.56 | 90.14 |
| *Rumex hastatus* D.Don | Polygonaceae | 18.42 | 25.17 | 28.41 | 1.54 | 72 |
| *Anaphalis busua* (Buch.-Ham.) DC. | Asteraceae | 28.95 | 15.25 | 12.66 | 0.44 | 56.86 |
| VIII | *Rheum australe* D.Don | Polygonaceae | 28.95 | 32.55 | 37.28 | 1.29 | 98.78 |
| *Rumex hastatus* D.Don | Polygonaceae | 28.95 | 28.27 | 18.59 | 0.64 | 75.81 |
| *Chrysopogon fulvus* (Spreng.) Chiov. | Poaceae | 23.68 | 20.8 | 30.28 | 1.28 | 74.76 |
| *Ageratum conyzoides*L. | Asteraceae | 18.42 | 18.38 | 13.85 | 0.75 | 50.65 |
| IX | *Circium wallichii* DC. | Asteraceae | 39.39 | 44.35 | 44.94 | 1.14 | 128.68 |
| *Urtica dioica* L. | Urticaceae | 30.3 | 30.73 | 33.63 | 1.11 | 94.66 |
| *Anaphalis busua* (Buch.-Ham.) DC. | Asteraceae | 30.3 | 24.92 | 21.42 | 0.71 | 76.64 |
| X | *Anaphalis busua* (Buch.-Ham.) DC. | Asteraceae | 35.14 | 31.79 | 24.02 | 0.68 | 90.95 |
| *Salvia moorcroftiana* Wall. ex Benth. | Lamiaceae | 24.32 | 23.14 | 14.23 | 0.59 | 61.69 |
| *Circium wallichii* DC. | Asteraceae | 40.54 | 45.07 | 61.75 | 1.52 | 147.36 |

**Table 12** Phytosociological attributes of Herbs at Zone-III

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Species | Family | Relative frequency | Relative density | Relative dominance | A/F | IVI |
| I | *Galium aparine* L. | Rubiaceae | 68.42 | 75.67 | 89.19 | 1.30 | 229.86 |
| *Artemisia roxburghiana* Besser | Asteraceae | 31.58 | 24.33 | 10.81 | 0.34 | 65.14 |
| II | *Achyranthes aspera* L. | Amaranthaceae | 73.68 | 73.2 | 81.18 | 1.10 | 228.06 |
| *Galium aparine* L. | Rubiaceae | 26.32 | 26.8 | 18.82 | 0.72 | 71.94 |
| III | *Thymus linearis* Benth. | Lamiaceae | 56.25 | 62.21 | 64.74 | 1.15 | 183.2 |
| *Bergenia ciliata*(Haw.) Sternb. | Saxifragaceae | 43.75 | 37.79 | 35.26 | 0.81 | 116.8 |
| IV | *Galium aparine* L. | Rubiaceae | 61.9 | 59.89 | 61.46 | 0.99 | 183.25 |
| *Thymus linearis* Benth. | Lamiaceae | 38.1 | 40.11 | 38.54 | 1.01 | 116.75 |
| V | *Galium aparine* L. | Rubiaceae | 54.17 | 65.01 | 83.53 | 1.54 | 202.71 |
| *Achyranthes aspera* L. | Amaranthaceae | 25 | 22.86 | 9.39 | 0.38 | 57.25 |
| *Geranium wallichianum* D.Don | Geraniaceae | 20.83 | 12.13 | 7.05 | 0.34 | 40.01 |
| VI | *Galium aparine* L. | Rubiaceae | 57.89 | 63.48 | 0.58 | 0.01 | 121.95 |
| *Achyranthes aspera* L. | Amaranthaceae | 42.11 | 36.52 | 99.42 | 2.36 | 178.05 |
| VII | *Galium aparine* L. | Rubiaceae | 47.62 | 50.78 | 39.57 | 0.83 | 137.97 |
| *Podophyllum hexandrum* Royle | Berbeiadaceae | 33.33 | 32.71 | 30.8 | 0.92 | 96.84 |
| *Potentilla astrosanguinea* G.Lodd. ex D.Don | Rosaceae | 19.05 | 16.51 | 29.63 | 1.56 | 65.19 |
| VIII | *Thymus linearis* Benth. | Lamiaceae | 77.78 | 77.97 | 75.41 | 0.97 | 231.16 |
| *Potentilla astrosanguinea* G.Lodd. ex D.Don | Rosaceae | 22.22 | 22.03 | 24.59 | 1.11 | 68.84 |
| IX | *Rheum australe*  D.Don | Polygonaceae | 40.74 | 45.01 | 45.31 | 1.11 | 131.06 |
| *Geranium wallichianum*D.Don | Geraniaceae | 29.63 | 29.75 | 27.26 | 0.92 | 86.64 |
| *Girardinia diversifolia*(Link) Friis | Urticaceae | 29.63 | 25.24 | 27.43 | 0.93 | 82.3 |
| X | *Girardinia diversifolia*(Link) Friis | Urticaceae | 70 | 79.99 | 2.71 | 0.04 | 152.7 |
| *Potentilla astrosanguinea* G.Lodd. ex D.Don | Rosaceae | 30 | 20.01 | 97.29 | 3.24 | 147.3 |

**Table 13** Diversity indices of herb species distribution

|  |  |  |  |
| --- | --- | --- | --- |
| Study Site | Shanon’s index (H) | Simpson index (CD) | Species richness (R) Margalef index |
| Zone-I | | | |
| I | 1.52 | 0.23 | 4.69 |
| II | 1.35 | 0.27 | 3.69 |
| III | 1.65 | 0.21 | 5.71 |
| IV | 1.19 | 0.33 | 3.70 |
| V | 1.29 | 0.29 | 3.69 |
| VI | 1.52 | 0.24 | 5.69 |
| VII | 1.29 | 0.30 | 4.69 |
| VIII | 1.54 | 0.23 | 4.70 |
| IX | 1.06 | 0.36 | 2.69 |
| X | 1.56 | 0.22 | 4.70 |
| Zone-II | | | |
| I | 0.99 | 0.99 | 2.68 |
| II | 0.76 | 0.53 | 2.67 |
| III | 1.27 | 0.31 | 3.69 |
| IV | 1.47 | 026 | 4.70 |
| V | 1.08 | 0.34 | 2.68 |
| VI | 1.06 | 0.36 | 2.68 |
| VII | 1.37 | 0.26 | 3.69 |
| VIII | 1.37 | 0.26 | 3.69 |
| IX | 1.08 | 0.35 | 2.69 |
| X- | 1.04 | 0.3 | 2.68 |
| Zone-III | | | |
| I | 0.53 | 0.65 | 1.67 |
| II | 0.55 | 0.64 | 1.66 |
| III | 0.67 | 0.52 | 1.66 |
| IV | 0.67 | 0.52 | 1.67 |
| V | 0.85 | 0.51 | 2.67 |
| VI | 0.68 | 0.52 | 1.66 |
| VII | 1.05 | 0.36 | 2.66 |
| VIII | 0.52 | 0.67 | 1.67 |
| IX | 1.07 | 0.35 | 2.67 |
| X | 0.69 | 0.50 | 1.65 |

**Figure 5 Dominant families with the number of herb species found in Anni block of Outer Seraj area**

****

**T**

**S**

**V**

**U**

W

X

**Plate 3 Q.** *Trifolium pratense*, **R**. *Persicaria capitata,* **S.** *Salvia moorcroftiana****,* T.** *Cotoneaster microphyllus,* **U.** *Thymus linearis***, V.** *Geranium wallichianum***, W.** *Potentilla indica,* **X.** *Podophyllum hexandrum*

**Diversity Indices**

Species richness in the tree layer was highest in Zone I at study site VIII (11.39**) (Table 5)**, for shrubs at study site II of Zone-II (7.68) **(Table 9)** andfor herbsat study site III of Zone-I (5.71) **(Table 13).** The concentration of dominance values ranged from 0.13-0.65 for trees **(Table 5)**, 0.17-0.54 for shrubs **(Table 9)** and 0.21-0.99 for herbs **(Table 13).** The Simpson's Diversity Index (H) showed a reverse relationship with CD across all layers, indicating contrasting patterns of diversity.

Altitude has a significant impact on habitat microclimates, which makes it a crucial element in determining tree distribution (Rawal & Pangtey, 1994). *Quercus leucotrichophora* was the dominating species in the 800-1600 m altitude range in the current study, whereas *Cedrus deodara* was the predominant species in the 1601-2400 m elevation range. In the 2401-3200m range, *Quercus semecarpifolia* showed dominance. Among shrub, *Debregeasia saeneb* showed maximum dominancein lower elevation range (800-1600m). *Rosa brunonii* was predominantly found in middle elevation range (1601-2400m). In higher elevation range (2401-3200m) *Myrsine africana* showed maximum dominance. Among herb communities, *Cannabis sativa* in the 800-1600 m altitude range, *Boenninghausenia albiflora* at middle elevation range (1601-2400) and *Galium aparine* athigher elevation zone(2401-3200)have shown dominance over other recorded species.

Few studies have been conducted on the woody species' vegetation structure in the Himalayan region. A number of variables influence the distribution of woody species in a given area, including geography, edaphic conditions, and uncontrolled human activity (Sharma & Kant, 2014). Across three altitudinal zones, the current study found variations in species composition, diversity, and structure. Diversity indices showed that species richness and diversity were highest in the lower altitudinal zone (Zone I) for tree vegetation. The Simpson's Diversity Index (H) revealed a reverse relationship with CD across all layers, other studies found similar findings (Bhat et al., 2020; Meena et al., 2020; Mastan & Reddy, 2023; Sharma et al., 2017). According to diversity indicators, the medium altitude zone (Zone II) has the highest species diversity and richness values for shrub vegetation (Joshi, 2012).

The value of the Shannon diversity index ranged from 0.70 to 2.80 for trees **(Table 5)**, 0.66 to 1.90 for shrubs **(Table 9)** and 0.52-1.65 for herbs **(Table 13)** which is in line with previous studies (Sharma & Kant, 2014; Meena et al., 2020; Verma & Kapoor, 2014; Sharma et al., 2017). The concentration of dominance values for the study site was 0.13-0.65 for trees **(Table 5)**, 0.17-0.54 for shrubs **(Table 9)** and 0.21-0.99 for herbs **(Table 13)** which aligns with previous reports (Whittaker, 1965; Sharma & Kant, 2014; Meena et al., 2020; Verma & Kapoor, 2014; Sharma et al., 2017; Geelani et al., 2018; Sahu et al., 2012). The species richness in the studied forests spanned from 3.42-11.39 for trees **(Table 5)**, 1.63-7.68 for shrubs **(Table 9)** and 1.65-5.71 for herbs **(Table 13)** which aligns with the reported results reported for the Himalayan region (Pande, 2001; Kunwar & Sharma, 2004: Sharma et al., 2014: Shah et al.,2009).

The study found a dominating contagious distribution pattern among tree, shrub and herb species based on the ecological framework proposed by Odum (1971); similar findings have been reported in other studies conducted in the Himalayan region (Hill, 1973; Karshaw, 1973; Kumar & Bhatt, 2006; Kumari et al., 2023; Lata et al., 2024; Verma & Kapoor, 2014; Gupta et al., 2018; Meena et al., 2020). This study investigated on the complex interrelationships among altitude, species distribution, and ecological processes in the locations under study, offering important new information for management and conservation plans.

**4. CONCLUSION**

The phytosociological analysis of plant species has yielded important information about the distribution, variety, and composition of species along the altitudinal gradient. The findings revealed that the community of tree species is dominated by a few key species: *Quercus leucotrichophora, Grewia optiva* & *Dalbergia sissoo* in zone I, *Cedrus deodara, Abies pindrow* and *Picea smithiana* in Zone II, *Quercus semecarpifolia, Cedrus deodara* and *Abies pindrow* in zone III. Among shrub communities, *Debregeasia saeneb, Prinsepia utilis* and *Rosa brunonii* in zone I, *Rosa brunonii, Prinsepia utilis* and *Desmodium elegans* in Zone II, *Myrsine africana, Berberis aristata* and *Desmodium elegans* in zone III have shown dominance over other recorded species. Among herb communities, *Cannabis sativa, Hypericum perforatum* and *Centella asiatica* at Zone-I; *Boenninghausenia albiflora*, *Circium wallichii* and *Ajuga bracteosa* at Zone II; *Galium aparine, Achyranthes aspera* and *Chrysopogon fulvus* at Zone-III have shown dominance over other recorded species. By contributing to the overall biodiversity, structure, and function of the forest or woodland area, these species are ecologically significant due to their density and frequency. Overall, the current study offers a thorough understanding of plant communities that might direct future research in related habitats, conservation strategies and forest management.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

The authors declare that neither the writing nor the editing of this work involved the use of generative AI tools such as text-to-image generators or large language models (ChatGPT, COPILOT, etc.).

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