Original Research Article

Study on Arboreal Floristic Diversity, Phytosociology and Conservation Strategy of Endangered Species in Chandi Beat of Majathal Wildlife Sanctuary, Himachal Pradesh, Western Himalaya

Abstract

Himachal Pradesh, a land of snow abode mountains is significant for its natural wealth and unique habitat, flora and fauna. Majathal Wildlife Sanctuary, the site of the present study was located in Solan and Shimla districts (Wildlife Division, Shimla) of Himachal Pradesh spread over an area of 37.71 sq km. Phytosociological studies for arboreal flora were conducted in the Chandi beat, Majathal wildlife sanctuary. Altitude of this beat varied from 625m to 1960m amsl. Total number of plant species recorded in the study area was 155, belonging to 46 families and 97 genera. The dominant families included Fabaceae, Moraceae, Asteraceae, Malvaceae, Lamiaceae and Rosaceae. *Pinus roxburghii* recorded the highest value of IVI and is most dominant tree species of forest followed by *Quercus leucotrichophora.* Results revealed that, range of Concentration of dominance (C) 0.04-0.06, Index of Diversity (H) 2.55-3.58, Richness index (R) 3.47-7.78 and Evenness Index (E) 0.84-0.93 was for trees and range of Concentration of dominance (C) 0.03-0.04, Index of Diversity (H) 3.37-3.86, Richness index (R) 6.22-6.12 and Evenness Index (E) 0.91-0.93 for shrubs at different elevation in Chandi beat. There were three woody plant species found as threatened category plant according to CAMP, 2013 i.e., *Pleurolobus gangeticus*, *Oroxylum indicum* and *Zanthoxylum armatum* which require conservation efforts suggested except *Zanthoxylum armatum* which has shown good population in nature. The study will provide baseline information of biodiversity status of woody vegetation of sanctuary and encourage the conservation efforts.

Keywords: Floristic, Threatened, Biodiversity, Density, Frequency, conservation

Comment [IA1]: The abstract should also contain the purpose of the work, techniques and methodology.

Introduction

India is one of the 17 mega-diverse countries of the world with a huge variation in the climate, altitude, rainfall pattern, and vegetation. It covers an area of 32,87,263 km^2, out of which nearly 8,09,537 km^2 (24.62%) geographical area of India is forest and tree cover, and 1,73,629.52 km^2

Comment [IA2]: Citation style for this journal is number in bracket [ ]. Introduction should also contain a clear defined problem and proposed solution.

(5.28 %) is included under a protected area network (Indian State Forest Report, 2023). A network of 998 PAs has been established in India, comprising 106 National Parks (1.36%), 567 Wildlife Sanctuaries (3.73 %), 105 Conservation Reserves (0.16%), and 220 Community Reserves (0.04%) (ENVIS, 2023). A wildlife sanctuary is an area of major ecological, floral, faunal, or natural significance, which is notified by State Governments and protected by the Forest Department under the provisions of the Wildlife (Protection) Act, 1972.

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The Himalayas is one of the youngest mountain ecosystems on this planet Earth with magnificent beauty uniqueness and endemism in life forms (Kala, 2006). With a wider range of climates and habitat types, this gigantic system of mountain chains supports highly diverse flora and fauna (Singh, 2006). Himachal Pradesh, a north Indian state, is located in western part of the Himalayan range. Vast geographical spread (55,673 km2) and remarkable altitudinal variation (350-7,000 m amsl) have blessed this state with rich biodiversity. Himachal Pradesh is having 37033 km^2 (66.52 percent of the total geographical area) total forest area out of which 1898 km^2 area comes under the Reserve forest, 33130 km^2 area protected forest and 2005 km^2 area under un-classed forest (State of Forest Report, 2021). Conservation of biodiversity is one of the most important concerns, and the state ranks third in the country in terms of the percentage of total area under protected area coverage. There are 5 National Parks and 28 Wildlife Sanctuaries and 3 conservation reserves that occupy about 8391.4231 km^2 area 15.07 percent of the state's geographical area (ENVIS, 2023).

Species cannot be studied under isolation, being at the basic level of the ecological hierarchy, they play very important roles in the concerned community, ecosystem, and finally the biosphere. Biotic community refers to an assemblage of populations occurring in a prescribed area or physical habitat. It is a well-organized unit that possesses its own characteristic features in addition to its individual components and functions through coupled metabolic transformations (Odum, 1971). Owing to its high importance in explaining and predicting the vegetation structure of a community, phytosociology has been considered a basic biological science with applied importance in plant resource management (Lebrun, 1977). Phytosociological studies allow ecologists to analyze the diversity, richness, and abundance of

plants in an ecosystem. They help in depicting the rate of succession and climate change and play an important role in monitoring rare or endangered plants (Brown *et al.*, 2013).

Knowledge of the biodiversity of an area is of paramount importance for sustainable utilization, management, and conservation of natural resources. Such a measure of plant species diversity in an area is referred to as floristic composition and diversity (Dansereau, 1960). It is one of the major distinguishing characteristics of a community reflecting its gene pool, genetic worth, variability, and adaptation potential (Chapin *et al.*, 2000). Floristic composition enables scientists to understand differences among various ecosystems (Chytry *et al.*, 2011), and provides them with a tangible tool for the management of different ecological patterns and processes. Such information has its own importance in the management, utilization, and conservation of plant resources for the fruitful future of mankind. With this information, the present study objective was refined to carry out the field survey for baseline information on arboreal plant diversity and conservation strategies for threatened plants.

Materials and Methods

Study area

Majathal Wildlife Sanctuary, the site of the present study, was located in Solan and Shimla district (Wildlife Division, Shimla) of Himachal Pradesh spread over an area of 37.71 sq km. It is located within the Geo-coordinates North 31˚18'4" N and 76˚58'21"E, East 31˚16'12"N and 77˚02'25"E, South 31˚15'03"N and 77˚02'17"E and West 31˚18'07" North and 77˚56'26"E which falls on Survey of India toposheet No. 53A/15 and 53E/3 on scale 1: 50000. The Sanctuary was established in the year 1962, later re-notified as a wildlife sanctuary. It experiences variation with respect to altitude (600 to 1972 m amsl). The sanctuary has four beats namely as Chandi beat, Matrech beat, Harsang Bhaji, and Kangari beat. The average annual precipitation is 1,525 mm and temperature ranges between 1 ºC to 35ºC. Monsoon fog also persists for small duration, and high-elevation areas usually experience high-velocity winds (Anonymous, 2023). There are two major forest types in this sanctuary viz; Himalayan Subtropical Pine Forests and Ban Oak Forests. The present study was done in the Chandi beat i.e 769 ha area of the sanctuary.

Methodology:

Comment [IA5]: A method to determine endangered species should be provided.

The sites to carry out the studies were finalized after carrying out a thorough survey of the sanctuary and procurement of the relevant maps, information, etc. of the study sites. For the assessment of floristic diversity and phytosociology, the area of the different sites was further subdivided into three altitudes. While carrying out the phytosociological study stratified random sampling was carried out and quadrates of size 10mx10m and 3mx3m were laid out randomly for enumerating trees and shrubs + tree saplings, respectively. Plants will be identified with the help of standard Floras (Kanjilal, 1928; Chowdhery and Wadhwa, 1984; Dhaliwal and Sharma, 1999). Quantitative analyses of vegetation, such as density, frequency, dominance, and basal area of trees and shrubs were investigated (Singh, 1969 and Curtis and McIntosh, 1950). The Importance Value Index (IVI) was computed for various species by adding the relative values of frequency, density, and basal area following Misra (1968). Based on IVI values, dominant, co-dominant, and main associated species were identified.

The abundance-to-frequency ratio (A/F) of different species was determined for eliciting the distribution pattern of the floral elements. This ratio indicates regular (<0.025), random (0.025 to 0.050) and contiguous (>0.050) distribution (Curtis and Cottam, 1956). The plant species diversity was calculated by following formulas:

- **Shannon-Wiener Diversity Index (H):**

The plant species diversity will be calculated following Shannon-Wiener diversity Index (H) (Shannon-Wiener, 1963).

$$H = -\sum_{i=1}^{S} (Ni/N) \ln (Ni/N)$$

Where Ni = Number of individuals of species i and N= Total number of individuals of all the species.

- **Simpson's Index:**

Dominance Index (C) will be measured by Simpson's Index (Simpson, 1949).

$$C = \sum_{i=1}^{S} (Ni/N)^2$$

Where Ni = total number of individuals of particular species and N = total number of individuals of all species.

- **Richness Index:**

Richness Index will be estimated as per Margalef (1958) *i .e*. R = S-1/ln N

- **Evenness Index:**

Evenness Index will be calculated as per Hill (1973) *i. e*. E = H/ ln S

Where S= Total number of species, N= Total number of individuals of all the species, H = Index of Diversity.

Results and Discussion

Phytosociological studies for shrub and trees were conducted in the Chandi beat, Majathal wildlife sanctuary. Range of altitude varied from 625m to 1960m. Total number of plant species recorded in the study area was 155, belonging to 46 families and 97 genera (Plate-1). The dominant families included Fabaceae, Moraceae, Asteraceae, Malvaceae, Lamiaceae, Urticaceae and Rosaceae (Fig.-2). At an elevation of 625-1000 m, the total number of tree species was 48 (Table 1). *Pinus roxburghii* was dominant species having maximum value for density ha^{-1} (90) followed by *Lannea coromandelica* (64), *Bauhinia variegata* (64) and lowest value (4) was observed for *Litsea glutinosa.* Maximum frequency % was observed for *Bauhinia variegata* (28.00) followed by *Lanea coromandelica* (26.00), and minimum value (4.00) was observed for *Litsea glutinosa, Albizia lebbeck, Bridelia verrucosa, Dalbergia sissoo, Leuceana leucocephala, Machillus odoratissima and Terminalia bellirica.* Abundance was found to be highest for *Cassia fistula* and *Pinus roxburghii* (4.50) followed by (3.50) *Senegalia catechu* and minimum value (1.00) was observed for *Litsea glutinosa, Grewia tiliifolia, Kydia calycina, Melia azedarach, Albizia procera, Erythrina suberosa* and *Falconeria insignis. Pinus roxburghii* (37.19) recorded the highest value of IVI followed by *Lanea coromandelica* (22.12), and least dominant was *Litsea glutinosa* (1.82). Contiguous distribution pattern was observed trees species. The concentration of dominance (C), diversity index (H), richness index (R) and evenness index (E) for trees was 0.04, 3.58, 7.62 and 0.93, respectively (Table7). Similar type of flora species has been recorded in the Pine forests of Himachal Pradesh at lower altitudes (Kunhikannan et al., 1994, Verma et al., 2005, Joshi et al., 2000,)

The total number of 63 shrub species was recorded at an elevation of 625-1000m (Table 2). *Woodfordia fruticosa* was dominant species having highest value for density ha^{-1} (2592.59) followed by *Rubus ellipticus* (1092.59) *Bergera koenigii* (1037.04) and and lowest value (37.04) was observed for *Trema politoria, Pistacia chinensis, Mallotus philippensis, Ficus auriculata,* and *Falconeria insignis.* Maximum frequency % was observed for *Woodfordia fruticosa* (38.33) followed by *Rubus ellipticus* (35.00), *Bergera koenigii* (30.00) and minimum value (3.33) was

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observed *Ziziphus oxyphylla, Ziziphus jujube, Vitex negundo, Toona ciliata, Sterculia villosa, Solanum viarum, Solanum indicum, Rhamnus virgate, Opuntia tuna* and *Pistacia chinensis.* In terms of abundance, *Woodfordia fruticosa* was dominant species having maximum value (6.09) followed by *Isodon rugosus* (5.60), *Leptodermis lanceolata* (5.33), and minimum value (1.00) was observed for *Falconeria insignis, Ficus auriculata, Mallotus philippensis, Pistacia chinensis, Toona ciliata.* On the basis of IVI, *Woodfordia fruticosa* recorded the highest value (30.54) followed *Rubus ellipticus* (17.12), *Bergera koenigii* (16.10) and least dominant was *Solanum virginianum* (1.00). Contiguous distribution pattern was observed for shrubs at Chandi beat. The concentration of dominance , diversity index, richness index and evenness index for shrub was 0.04, 3.71, 8.99 and 0.90 respectively (Table 7). Other supporting evidences which also shown similar type of results for biodiversity and phytosocial studies (Verma et al., 2009, Uniyal et al., 2010, Thakur et al., 2016 and Khushwah and Kumar, 2000)

At an elevation varying from 1000m-1500m, the total number of tree species recorded was 37 (Table 3). *Pinus roxburghii* was dominant species having maximum highest value for density ha^{-1} (110) followed by *Punica granatum* (56) and *Bauhinia variegata* (50), and lowest value (4) was observed for *Albizia lebbeck, Albizia julibrissin, Syzygium cuminii and Grewia tiliifolia.* Maximum frequency % was recorded for *Punica granatum* (40.00) followed by *Pinus roxburghii* and *Pyrus pashia* (36.00) and minimum value (2.00) was recorded for *Albizia lebbeck, Albizia procera,* and *Syzygium cumini. Bauhinia variegata* (3.57) recorded the highest value of abundance followed by *Pinus roxburghii* (3.06) and minimum value (1.00) was observed for *Grewia tiliifolia.* On the basis of IVI *Pinus roxburghii* (48.40) showed highest value followed by *Punica granatum* (27.38) and least dominant was *Grewia tiliifolia* (2.21). Contiguous distribution pattern was observed for trees. The concentration of dominance, diversity index , richness index and evenness index for trees was 0.06, 3.18, 6.25 and 0.89 respectively (Table 7).

In between elevation of 1000m-1500m, among 50 species of shrubs including saplings (Table 4) were recorded. *Rubus ellipticus* was the dominant species having maximum value for density ha^{-1} (1592.59) followed by *Myrsine africana* (1277.78), *Woodfordia fruticosa* (1055.55), and lowest value (37.04) was observed for *Ficus auriculata.* The highest value for frequency % was

recorded for *Rubus ellipticus* (51.67) followed by *Woodfordia fruticosa* (35.00), *Myrsine africana* (26.67), and minimum value (3.33) was recorded for *Cyathula tomentosa, Falconeria insignis, Ficus auriculata, Salvia strobilifera, Toona ciliate, Ziziphus oxyphylla.* In term of abundance, maximum abundance was recorded for *Chromolaena odorata* (6.25) followed by *Leptodermis lanceolata* (6.00), *Senna occidentalis* (6.00) and minimum value (1.00) was recorded for *Ficus auriculata, Opuntia tuna, Pinus roxburghii* and *Pistacia chinensis.* On the basis of IVI, *Rubus ellipticus* (23.83) recorded the highest value followed by *Myrsine africana* (18.54), *Berberis lycium* (16.23) and least dominant was *Ziziphus oxyphylla* (1.20). Contiguous distribution pattern was observed for shrubs. The concentration of dominance , diversity index , richness index and evenness index for shrub was 0.04, 3.59, 7.17 and 0.92 respectively (Table 7).

At an elevation of 1500m-1960m the total number of tree species recorded was 21 (Table 5). *Pinus roxburghii* was dominant species recorded having maximum value for density ha^{-1} (112) followed by *Quercus leucotrichophora* (94) and *Cedrus deodara* (82), and lowest value (4) was recorded for *Butea monosperma* and *Rhododendron arboreum.* Maximum frequency % was recorded for *Pinus roxburghii* (40.00) followed by *Quercus leucotrichophora* (32.00) and minimum value (4.00) was observed *Ficus auriculata*, and *Rhododendron arboreum.* Abundance was found to be highest for *Quercus leucotrichophora* (2.94) followed by *Pinus roxburghii* (2.80), and lowest value (1.00) was observed for *Salix tetrasperma* and *Butea monosperma. Pinus roxburghii* (54.36) recorded the highest value for IVI followed by *Quercus leucotrichophora* (48.58), *Cedrus deodara* (35.41), and lowest was *Ficus auriculata* (1.85). Contiguous distribution pattern was observed for trees. The concentration of dominance, diversity index , richness index and evenness index for shrub was 0.10, 2.59, 3.50 and 0.85 respectively (Table 7). Many studies has also given similar results of species association, structure, composition and phytosocial analysis (Singh, 1998, Singh and Rawat, 2000, Verma et al., 2005, Subramani, 2006, Sharma Samant, 2013,

Amongst 41 shrubs recorded at an elevation of 1500-1960, *Myrsine Africana* was the dominant species having maximum value for density ha^{-1} (1388.89) followed by *Rubus ellipticus* (740.74), *Rosa moschata* (611.11) and minimum value (37.04) was observed for *Bauhinia variegata,*

Solanum viarum, *Pistacia chinensis* (Table 6). The highest frequency % was recorded for *Myrsine africana* (51.67) followed by *Rubus ellipticus* (35.00), *Berberis lycium* (23.33), and lowest value (3.33) was observed *Bauhinia variegata*, *Himalrandia tetrasperma*, *Pinus roxburghii*, *Pistacia chinensis*, *Pyrus pashia*, *Salvia strobilifera*, *Solanum viarum*, and *Toona ciliata.* In terms of abundance, *Isodon rugosus* was the dominant species having maximum value (5.60) followed by *Rosa moschata* (4.71) *Sarcococca saligna* (4.67), and minimum value (1.00) was recorded for *Bauhinia variegata*, *Pistacia chinensis*, *Prunus cerasoides*, *Solanum viarum* On the basis of IVI, *Myrsine africana* (45.62) recorded the highest value followed by *Rubus ellipticus* (17.14), *Woodfordia fruticosa* (14.38) and least dominant was *Solanum viarum* (1.25). Contiguous distribution pattern was observed for shrubs. The concentration of dominance , diversity index , richness index and evenness index for shrub was 0.04, 3.37, 6.22 and 0.91 respectively (Table 7).There are many studies which show the similar type of results and association of plant species in different locations of Chir Pine and Ban forest types (Prakash and Uniyal, 1999, Meenakshi, 2002, Negi and Nautiyal, 2005, Rattan and Singh, 2009, Rohit and Sharma, 2010, Man et al., 2012, Sharma and Samant, 2013 and Verma and Kapoor, 2017)

Threatened plants:

Comment [IA7]: data from this current study should be shown particularly on the number of individual that still present in this sanctuary.

There were three woody plant species found as threatened category plant according to CAMP, 2013 report (Goraya *et al*. 2013) i.e., *Pleurolobus gangeticus*, *Oroxylum indicum* and *Zanthoxylum armatum* (Table 8).

Threatened plants conservation strategies

As the results has shown in the study area, three threatened plants species has been found but the population status of *Zanthoxylum armatum* was quite good due to the best suitable habitat conditions in the locality but the population size of other species was not very satisfactory as it requires conservation measures to improve its populations in the natural vicinity. *Desmodium giganticum* has shown less population in the wild which requires nursery raising and protection against forest fire as it has been observed very common incidence in the study area. *Oroxylum indicum* plant's pods are collected for cap decoration in the traditional outfits, root collection for medicinal uses that can be a reason for less population in the wild. Its nursery-raising and plantation programs should be encouraged by the local forest department. Supporting studies

which also give strategies for the conservation of different plants (Man et al., 2012, Meenakshi, 2002, Negi et al., 2011, Sharma and Samant, 2013, Verma and Kapoor, 2017)

Conclusions

Comment [IA8]: Onclusion should briefly state the major findings of the study.

India as a one of the large countries of world which holds a great wealth of nature in terms of diverse flora and fauna. In present study we tried to generate a baseline data for the woody flora wealth of Majathal wildlife sanctuary. This type of study will help in the conservation aspects and knowing the real wealth of nature for the better utilization and conservation for mankind and glorious future of biodiversity conservation, which is a need of an hour as climate is changing and deteriorating or bio-resources. Nursery-raising and plantation programs should be encouraged by the local forest department.

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Comment [IA10]: References should be listed in the order they appear in the text.

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Table and figures

Table- 1: Phytosociological attributes of tree species in Chandi beat at 625-1000m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI
1	*Ailanthus excelsa* Roxb.	14.00	8.00	1.75	0.22	4.72
2	*Albizia chinensis* (Osbeck) Merr.	12.00	6.00	2.00	0.33	5.00
3	*Albizia lebbeck* (L.) Benth.	8.00	4.00	2.00	0.50	3.23
4	Albizia procera (Roxb.) Benth.	8.00	8.00	1.00	0.13	3.73
5	*Bauhinia variegata* L.	64.00	28.00	2.29	0.08	19.85
6	*Bombax ceiba* L.	16.00	8.00	2.00	0.25	6.44
7	*Bridelia montana* (Roxb.) Willd.	6.00	4.00	1.50	0.38	2.20
8	*Broussonetia papyrifera* (L.) L'Hér. ex Vent	12.00	10.00	1.20	0.12	4.97
9	*Butea monosperma* (Lam.) Kuntze	12.00	6.00	2.00	0.33	3.98
10	*Cassia fistula* L.	36.00	8.00	4.50	0.56	8.73
11	*Celtis australis* L.	14.00	8.00	1.75	0.22	5.25

12	*Cordia dichotoma* G.Forst.	14.00	6.00	2.33	0.39	4.74
13	*Dalbergia sissoo* Roxb. ex DC.	32.00	14.00	2.29	0.16	10.93
14	*Engelhardia colebrookeana* Lindl.	16.00	6.00	2.67	0.44	5.23
15	*Erythrina suberosa* Roxb.	8.00	8.00	1.00	0.13	4.09
16	*Falconeria insignis* Royle	8.00	8.00	1.00	0.13	3.97
17	*Ficus auriculata* Lour.	18.00	12.00	1.50	0.13	7.48
18	*Ficus palmata* Forssk.	8.00	6.00	1.33	0.22	3.58
19	*Ficus racemosa* L.	8.00	6.00	1.33	0.22	3.33
20	*Flacourtia indica* (Burm.f.) Merr.	12.00	8.00	1.50	0.19	3.96
21	*Grewia optiva* J.R.Drumm. ex Burret	10.00	8.00	1.25	0.16	4.38
22	*Grewia tiliifolia* Vahl	6.00	6.00	1.00	0.17	2.85
23	*Hymenodictyon orixense* (Roxb.) Mabb	12.00	12.00	1.00	0.08	4.86
24	*Kydia calycina* Roxb.	6.00	6.00	1.00	0.17	3.04
25	*Lannea coromandelica* (Houtt.) Merr.	64.00	26.00	2.46	0.09	22.09
26	*Leucaena leucocephala* (Lam.) de Wit	12.00	4.00	3.00	0.75	3.92
27	*Litsea glutinosa* (Lour.) C.B.Rob.	4.00	4.00	1.00	0.25	1.82
28	*Machilus odoratissima* Nees	8.00	4.00	2.00	0.50	2.71
29	*Mallotus philippensis* (Lam.) Müll.Arg.	12.00	6.00	2.00	0.33	3.80
30	*Melia azedarach* L.	6.00	6.00	1.00	0.17	2.69
31	*Moringa oleifera* Lam.	12.00	6.00	2.00	0.33	4.51
32	*Oroxylum indicum* (L.) Kurz	8.00	6.00	1.33	0.22	3.14
33	*Ougeinia oojeinensis* (Roxb.) Hochr.	20.00	12.00	1.67	0.14	6.85
34	*Phoenix sylvestris* (L.) Roxb.	20.00	8.00	2.50	0.31	6.60
35	*Phyllanthus emblica* L.	12.00	6.00	2.00	0.33	3.68
36	*Pinus roxburghii* Sarg.	90.00	20.00	4.50	0.23	37.12
37	*Pistacia chinensis* subsp. integerrima	18.00	8.00	2.25	0.28	7.67
38	*Punica granatum* L.	30.00	10.00	3.00	0.30	8.11
39	*Pyrus pashia* Buch.-Ham. ex D.Don	26.00	10.00	2.60	0.26	9.00
40	*Salix tetrasperma* Roxb.	12.00	10.00	1.20	0.12	4.72
41	*Senegalia catechu (L.f.) P.J.H.Hurter &*	28.00	8.00	3.50	0.44	7.58
42	*Sterculia villosa* Roxb. ex Sm.	16.00	8.00	2.00	0.25	5.31
43	*Syzygium cumini* (L.) Skeels	8.00	6.00	1.33	0.22	3.78
44	*Terminalia bellirica* (Gaertn.) Roxb.	6.00	4.00	1.50	0.38	2.53
45	*Toona ciliata* M.Roem.	20.00	8.00	2.50	0.31	7.94
46	Trema politoria (Planch.) Blume	18.00	8.00	2.25	0.28	5.06
47	*Ziziphus jujuba* Mill.	12.00	6.00	2.00	0.33	4.04
48	*Ziziphus oxyphylla* Edgew.	16.00	6.00	2.67	0.44	4.34

Table- 2 : Phytosociological attributes of shrub species in Chandi beat at 625-1000m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI

1	*Abutilon indicum* (L.) Sweet	222.22	5.00	4.00	0.80	2.92
2	*Asparagus adscendens Roxb.*	407.41	10.00	3.67	0.37	5.12
3	*Barleria cristata* L.	444.44	13.33	3.00	0.23	6.81
4	*Bauhinia variegata* L.*	74.07	3.33	2.00	0.60	2.05
5	*Berberis asiatica* Roxb. ex DC.	407.41	8.33	4.40	0.53	5.44
6	*Berberis lycium* Royle	537.04	16.67	2.90	0.17	8.38
7	*Bergera koenigii* L.	1037.04	30.00	3.11	0.10	16.10
8	*Boehmeria virgata* var. macrostachya	185.19	3.33	5.00	1.50	2.85
9	*Bridelia stipularis* (L.) Blume	222.22	6.67	3.00	0.45	3.45
10	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.*	92.59	6.67	1.25	0.19	4.29
11	*Buddleja asiatica* Lour.	370.37	8.33	4.00	0.48	5.33
12	*Callicarpa macrophylla* Vahl	370.37	11.67	2.86	0.24	6.03
13	*Capparis spinosa* L.	185.19	6.67	2.50	0.38	3.61
14	*Carissa spinarum* L.	370.37	6.67	5.00	0.75	5.18
15	*Cassia fistula* L.*	74.07	3.33	2.00	0.60	2.56
16	*Chromolaena odorata* (L.) R.M.King &	481.48	8.33	5.20	0.62	6.41
17	*Colebrookea oppositifolia* Sm.	370.37	6.67	5.00	0.75	5.34
18	*Cotinus coggygria Scop.*	444.44	20.00	2.00	0.10	7.73
19	*Debregeasia longifolia* (Burm.f.) Wedd.	240.74	5.00	4.33	0.87	3.89
20	*Dodonaea viscosa* Jacq.	518.52	16.67	2.80	0.17	8.10
21	*Euphorbia royleana Boiss.*	203.70	5.00	3.67	0.73	6.21
22	*Falconeria insignis* Royle*	37.04	3.33	1.00	0.30	1.70
23	*Ficus auriculata* Lour.*	37.04	3.33	1.00	0.30	1.05
24	*Flacourtia indica* (Burm.f.) Merr.*	111.11	3.33	3.00	0.90	2.20
25	Flemingia macrophylla (Willd.) Kuntze ex	148.15	6.67	2.00	0.30	2.75
26	*Hypericum oblongifolium* Choisy	388.89	15.00	2.33	0.16	6.34
27	*Indigofera cassioides* Rottler ex DC.	148.15	5.00	2.67	0.53	2.41
28	*Indigofera tinctoria* L.	185.19	5.00	3.33	0.67	2.51
29	Isodon rugosus (Wall. ex Benth.) Codd	518.52	8.33	5.60	0.67	6.66
30	*Jasminum mesnyi* Hance	111.11	5.00	2.00	0.40	2.09
31	*Justicia adhatoda L.*	481.48	20.00	2.17	0.11	8.16
32	*Leptodermis lanceolata* Wall.	296.30	5.00	5.33	1.07	3.85
33	*Mallotus philippensis* (Lam.) Müll.Arg.*	37.04	3.33	1.00	0.30	2.01
34	*Mimosa rubicaulis subsp. himalayana*	185.19	8.33	2.00	0.24	3.25
35	*Myrsine africana* L.	370.37	8.33	4.00	0.48	4.61
36	*Opuntia tuna* (L.) Mill.	92.59	3.33	2.50	0.75	2.69
37	*Ototropis multiflora* (DC.) H.Ohashi &	259.26	10.00	2.33	0.23	4.14
38	*Phanera vahlii* (Wight & Arn.) Benth.	185.19	6.67	2.50	0.38	5.29
39	*Phoenix loureiroi* Kunth	166.67	5.00	3.00	0.60	4.88
40	*Phoenix sylvestris* (L.) Roxb.*	148.15	5.00	2.67	0.53	3.21
41	*Pinus roxburghii* Sarg.*	92.59	5.00	1.67	0.33	3.47
42	*Pistacia chinensis* subsp. integerrima	37.04	3.33	1.00	0.30	1.36
43	*Pleurolobus gangeticus (L.) J.St.-Hil. ex*	111.11	5.00	2.00	0.40	1.63

44	*Pouzolzia rugulosa* (Wedd.) Acharya &	277.78	8.33	3.00	0.36	4.40
45	*Punica granatum* L.*	222.22	6.67	3.00	0.45	4.45
46	*Pyrus pashia* Buch.-Ham. ex D.Don*	166.67	5.00	3.00	0.60	2.53
47	Rhamnus virgata Roxb.	111.11	3.33	3.00	0.90	3.42
48	*Rosa moschata* Herrm.	222.22	5.00	4.00	0.80	3.00
49	*Rubus ellipticus* Sm.	1092.59	35.00	2.81	0.08	17.12
50	*Senna occidentalis* (L.) Link	444.44	10.00	4.00	0.40	6.66
51	*Sohmaea laxiflora (DC.) H.Ohashi &*	185.19	5.00	3.33	0.67	2.54
52	*Solanum indicum L.*	166.67	3.33	4.50	1.35	2.24
53	*Solanum viarum* Dunal	111.11	3.33	3.00	0.90	1.66
54	*Solanum virginianum L.*	74.07	1.67	4.00	2.40	1.00
55	*Sterculia villosa* Roxb. ex Sm.*	55.56	3.33	1.50	0.45	1.46
56	*Toona ciliata* M.Roem.*	37.04	3.33	1.00	0.30	1.60
57	*Trema politoria* (Planch.) Blume*	185.19	5.00	3.33	0.67	2.66
58	*Vitex negundo* L.	148.15	3.33	4.00	1.20	2.11
59	*Woodfordia fruticosa* (L.) Kurz	2592.59	38.33	6.09	0.16	30.54
60	*Xanthium strumarium L.*	111.11	3.33	3.00	0.90	1.75
61	*Zanthoxylum armatum DC.*	574.07	20.00	2.58	0.13	11.76
62	*Ziziphus jujuba* Mill.*	74.07	3.33	2.00	0.60	3.35
63	*Ziziphus oxyphylla Edgew.**	111.11	3.33	3.00	0.90	1.69

* Saplings of trees

Table- 3: Phytosociological attributes of tree species in Chandi beat at 1000-1500m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI
1	*Ailanthus excelsa* Roxb.	12.00	4.00	3.00	0.75	4.85
2	*Albizia chinensis* (Osbeck) Merr.	10.00	8.00	1.25	0.16	5.36
3	*Albizia julibrissin* Durazz.	6.00	4.00	1.50	0.38	2.83
4	*Albizia lebbeck* (L.) Benth.	4.00	2.00	2.00	1.00	2.19
5	Albizia procera (Roxb.) Benth.	6.00	2.00	3.00	1.50	2.38
6	*Bauhinia variegata* L.	50.00	14.00	3.57	0.26	17.58
7	*Bombax ceiba* L.	16.00	12.00	1.33	0.11	8.35
8	*Broussonetia papyrifera* (L.) L'Hér. ex Vent	14.00	12.00	1.17	0.10	8.89
9	*Butea monosperma* (Lam.) Kuntze	10.00	4.00	2.50	0.63	4.18
10	*Celtis australis* L.	6.00	4.00	1.50	0.38	2.96
11	*Engelhardia colebrookeana* Lindl.	12.00	8.00	1.50	0.19	7.37
12	*Erythrina suberosa* Roxb.	8.00	4.00	2.00	0.50	3.50
13	*Falconeria insignis* Royle	14.00	8.00	1.75	0.22	5.59

14	*Ficus auriculata* Lour.	8.00	4.00	2.00	0.50	3.45
15	*Ficus palmata* Forssk.	14.00	12.00	1.17	0.10	6.98
16	*Ficus racemosa* L.	12.00	8.00	1.50	0.19	4.97
17	*Flacourtia indica* (Burm.f.) Merr.	12.00	4.00	3.00	0.75	3.81
18	*Grewia optiva* J.R.Drumm. ex Burret	10.00	4.00	2.50	0.63	4.56
19	*Grewia tiliifolia* Vahl	4.00	4.00	1.00	0.25	2.05
20	*Hymenodictyon orixense* (Roxb.) Mabb	6.00	4.00	1.50	0.38	2.44
21	*Kydia calycina* Roxb.	8.00	4.00	2.00	0.50	3.76
22	*Lannea coromandelica* (Houtt.) Merr.	28.00	16.00	1.75	0.11	12.32
23	*Leucaena leucocephala* (Lam.) de Wit	12.00	4.00	3.00	0.75	3.46
24	*Machilus odoratissima* Nees	8.00	4.00	2.00	0.50	3.51
25	*Ougeinia oojeinensis* (Roxb.) Hochr.	16.00	8.00	2.00	0.25	6.69
26	*Phyllanthus emblica* L.	12.00	8.00	1.50	0.19	5.64
27	*Pinus roxburghii* Sarg.	158.00	56.00	2.82	0.05	64.62
28	*Pistacia chinensis* subsp. integerrima	10.00	6.00	1.67	0.28	4.23
29	*Prunus cerasoides* Buch.-Ham. ex D.Don	16.00	6.00	2.67	0.44	6.11
30	*Punica granatum* L.	56.00	40.00	1.40	0.04	25.27
31	*Pyrus pashia* Buch.-Ham. ex D.Don	42.00	16.00	2.63	0.16	14.93
32	*Quercus leucotrichophora* A.Camus	38.00	16.00	2.38	0.15	22.43
33	*Syzygium cumini* (L.) Skeels	4.00	2.00	2.00	1.00	2.12
34	*Toona ciliata* M.Roem.	12.00	8.00	1.50	0.19	7.78
35	*Trema politoria* (Planch.) Blume	8.00	4.00	2.00	0.50	2.72
36	Ziziphus jujuba Mill.	6.00	4.00	1.50	0.38	3.24
37	*Ziziphus oxyphylla* Edgew.	20.00	10.00	2.00	0.20	6.91

Table- 4 : Phytosociological attributes of shrub species in Chandi beat at 1000-1500m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI
1	*Asparagus adscendens Roxb.*	407.41	15.00	2.44	0.16	5.95
2	*Barleria cristata* L.	222.22	6.67	3.00	0.45	3.27
3	*Berberis asiatica* Roxb. ex DC.	388.89	10.00	3.50	0.35	7.67
4	*Berberis lycium* Royle	907.41	25.00	3.27	0.13	16.23
5	*Bergera koenigii L.*	703.70	16.67	3.80	0.23	9.56
6	*Boehmeria nivea* (L.) Gaudich.	148.15	6.67	2.00	0.30	2.38
7	*Buddleja asiatica* Lour.	370.37	13.33	2.50	0.19	7.30
8	*Chromolaena odorata* (L.) R.M.King & H.Rob.	462.96	6.67	6.25	0.94	7.09
9	*Colebrookea oppositifolia* Sm.	444.44	10.00	4.00	0.40	6.25
10	*Cotinus coggygria Scop.*	370.37	18.33	1.82	0.10	6.93
11	*Cyathula capitata* Moq.	148.15	5.00	2.67	0.53	2.38
12	*Cyathula tomentosa* (Schult.) Moq.	129.63	3.33	3.50	1.05	2.10
13	*Daphne papyracea Wall. ex G.Don*	537.04	18.33	2.64	0.14	12.18

14	*Debregeasia longifolia* (Burm.f.) Wedd.	111.11	5.00	2.00	0.40	2.02
15	*Deutzia staminea* R.Br. ex Wall.	370.37	10.00	3.33	0.33	5.19
16	*Duhaldea cappa (Buch.-Ham. ex D.Don) Pruski & Anderb.*	296.30	6.67	4.00	0.60	5.58
17	*Falconeria insignis* Royle*	74.07	3.33	2.00	0.60	2.90
18	*Ficus auriculata* Lour.*	37.04	3.33	1.00	0.30	1.82
19	*Flacourtia indica* (Burm.f.) Merr.*	74.07	5.00	1.33	0.27	5.32
20	*Himalrandia tetrasperma (Wall. ex Roxb.)*	166.67	10.00	1.50	0.15	3.16
21	*Hypericum oblongifolium* Choisy	351.85	8.33	3.80	0.46	4.83
22	*Indigofera tinctoria* L.	296.30	8.33	3.20	0.38	3.68
23	*Isodon rugosus* (Wall. ex Benth.) Codd	574.07	16.67	3.10	0.19	7.39
24	*Justicia adhatoda L.*	481.48	13.33	3.25	0.24	7.29
25	*Lantana camara L.*	314.81	13.33	2.13	0.16	4.76
26	*Leptodermis lanceolata* Wall.	555.56	8.33	6.00	0.72	6.67
27	*Mimosa rubicaulis subsp. himalayana (Gamble) H.Ohashi*	277.78	10.00	2.50	0.25	5.99
28	*Myrsine africana* L.	1277.78	26.67	4.31	0.16	18.54
29	*Opuntia tuna* (L.) Mill.	111.11	10.00	1.00	0.10	11.22
30	*Pinus roxburghii* Sarg.*	55.56	5.00	1.00	0.20	2.73
31	*Pistacia chinensis* subsp. integerrima (J.L.Stewart) Rech.f.*	55.56	5.00	1.00	0.20	1.31
32	*Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi*	259.26	6.67	3.50	0.53	5.01
33	*Pouzolzia rugulosa* (Wedd.) Acharya & Kravtsova	129.63	8.33	1.40	0.17	2.80
34	*Prunus cerasoides* Buch.-Ham. ex D.Don*	148.15	10.00	1.33	0.13	3.52
35	*Punica granatum* L.*	222.22	10.00	2.00	0.20	3.78
36	*Pyrus pashia* Buch.-Ham. ex D.Don*	259.26	16.67	1.40	0.08	7.60
37	*Rhamnus virgata* Roxb.	111.11	5.00	2.00	0.40	1.72
38	*Ricinus communis L.*	148.15	8.33	1.60	0.19	3.90
39	*Rosa moschata* Herrm.	351.85	13.33	2.38	0.18	5.69
40	*Rubus ellipticus* Sm.	1592.59	51.67	2.77	0.05	23.83
41	*Rubus niveus* Thunb.	222.22	8.33	2.40	0.29	3.27
42	*Salvia strobilifera (Benth.) J.G.González*	92.59	3.33	2.50	0.75	1.46
43	*Sarcococca saligna* (D.Don) Müll.Arg.	574.07	10.00	5.17	0.52	7.15
44	*Senna occidentalis* (L.) Link	333.33	5.00	6.00	1.20	5.80
45	*Solanum viarum* Dunal	185.19	6.67	2.50	0.38	2.71
46	*Toona ciliata* M.Roem.*	55.56	3.33	1.50	0.45	2.64
47	*Vitex negundo* L.	259.26	10.00	2.33	0.23	6.17
48	*Woodfordia fruticosa* (L.) Kurz	1055.55	35.00	2.71	0.08	14.72
49	*Zanthoxylum armatum DC.*	444.44	13.33	3.00	0.23	7.30
50	*Ziziphus oxyphylla Edgew.**	74.07	3.33	2.00	0.60	1.20

* Saplings of trees

Table-5 : Phytosociological attributes of tree species in Chandi beat at 1500-1960m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI
1	*Ailanthus excelsa* Roxb.	36.00	14.00	2.57	0.18	19.74
2	*Albizia chinensis* (Osbeck) Merr.	12.00	8.00	1.50	0.19	7.28
3	*Bauhinia variegata* L.	52.00	18.00	2.89	0.16	21.24
4	*Butea monosperma* (Lam.) Kuntze	4.00	4.00	1.00	0.25	3.11
5	*Cedrus deodara* (Roxb. ex D.Don) G.Don	82.00	14.00	5.86	0.42	35.41
6	*Celtis australis* L.	12.00	8.00	1.50	0.19	8.35
7	*Cornus capitata* Wall.	14.00	8.00	1.75	0.22	7.25
8	*Ficus auriculata* Lour.	4.00	2.00	2.00	1.00	1.85
9	*Ficus palmata* Forssk.	12.00	8.00	1.50	0.19	6.64
10	*Grewia optiva* J.R.Drumm. ex Burret	16.00	10.00	1.60	0.16	8.25
11	*Ougeinia oojeinensis* (Roxb.) Hochr.	6.00	4.00	1.50	0.38	3.24
12	*Pinus roxburghii* Sarg.	112.00	40.00	2.80	0.07	54.36
13	*Pistacia chinensis* subsp. integerrima	10.00	4.00	2.50	0.63	4.83
14	*Prunus cerasoides* Buch.-Ham. ex D.Don	16.00	10.00	1.60	0.16	9.33
15	*Punica granatum* L.	32.00	14.00	2.29	0.16	14.42
16	*Pyrus pashia* Buch.-Ham. ex D.Don	30.00	12.00	2.50	0.21	13.38
17	*Quercus leucotrichophora* A.Camus	94.00	32.00	2.94	0.09	48.58
18	*Rhododendron arboreum* Sm.	4.00	2.00	2.00	1.00	3.03
19	*Robinia pseudoacacia* L.	32.00	16.00	2.00	0.13	13.07
20	*Salix tetrasperma* Roxb.	10.00	10.00	1.00	0.10	7.59
21	*Toona ciliata* M.Roem.	12.00	8.00	1.50	0.19	9.07

Table- 6 : Phytosociological attributes of shrub species in Chandi beat at 1500-1960m elevation

Sr. No.	Name of Species	Density ha^{-1}	Frequency (%)	Abundance	A/F	IVI
1	*Asparagus adscendens* Roxb.	407.41	10.00	3.67	0.37	8.03
2	*Bauhinia variegata* L.*	37.04	3.33	1.00	0.30	1.26
3	*Berberis asiatica* Roxb. ex DC.	92.59	5.00	1.67	0.33	2.40
4	*Berberis lycium* Royle	592.59	23.33	2.29	0.10	12.84
5	*Bergera koenigii* L.	296.30	6.67	4.00	0.60	5.18
6	*Boehmeria nivea* (L.) Gaudich.	92.59	5.00	1.67	0.33	2.49
7	*Boehmeria virgata* var. macrostachya (Wight)	185.19	8.33	2.00	0.24	4.74
8	*Cedrus deodara* (Roxb. ex D.Don) G.Don*	111.11	8.33	1.20	0.14	7.58
9	Chromolaena odorata (L.) R.M.King & H.Rob.	203.70	5.00	3.67	0.73	3.49

10	*Colebrookea oppositifolia* Sm.	277.78	8.33	3.00	0.36	5.70
11	*Cotinus coggygria* Scop.	222.22	8.33	2.40	0.29	4.64
12	*Daphne papyracea* Wall. ex G.Don	537.04	13.33	3.63	0.27	15.96
13	Debregeasia longifolia (Burm.f.) Wedd.	185.19	5.00	3.33	0.67	10.57
14	*Deutzia staminea* R.Br. ex Wall.	296.30	8.33	3.20	0.38	5.73
15	*Ficus auriculata* Lour.*	74.07	5.00	1.33	0.27	4.98
16	*Ficus palmata* Forssk.*	111.11	8.33	1.20	0.14	8.19
17	*Himalrandia tetrasperma* (Wall. ex Roxb.)	111.11	3.33	3.00	0.90	2.49
18	*Hypericum oblongifolium* Choisy	462.96	18.33	2.27	0.12	11.32
19	*Indigofera cassioides* Rottler ex DC.	296.30	10.00	2.67	0.27	5.80
20	Isodon rugosus (Wall. ex Benth.) Codd	518.52	8.33	5.60	0.67	7.81
21	*Justicia adhatoda* L.	185.19	10.00	1.67	0.17	4.60
22	*Leptodermis lanceolata* Wall.	351.85	11.67	2.71	0.23	6.88
23	*Myrsine africana* L.	1388.89	51.67	2.42	0.05	45.62
24	*Pinus roxburghii* Sarg.*	74.07	3.33	2.00	0.60	5.81
25	*Pistacia chinensis* subsp. integerrima	37.04	3.33	1.00	0.30	2.57
26	*Pleurolobus gangeticus* (L.) J.St.-Hil. ex	111.11	5.00	2.00	0.40	2.76
27	*Pouzolzia rugulosa* (Wedd.) Acharya &	166.67	6.67	2.25	0.34	3.60
28	*Prunus cerasoides* Buch.-Ham. ex D.Don	74.07	6.67	1.00	0.15	5.09
29	*Punica granatum* L.	185.19	5.00	3.33	0.67	6.80
30	*Pyrus pashia* Buch.-Ham. ex D.Don	166.67	6.67	2.25	0.34	7.72
31	*Quercus leucotrichophora* A.Camus	55.56	3.33	1.50	0.45	3.78
32	*Rosa moschata* Herrm.	611.11	11.67	4.71	0.40	9.74
33	*Rubus ellipticus* Sm.	740.74	35.00	1.90	0.05	17.14
34	*Rubus niveus* Thunb.	314.81	6.67	4.25	0.64	5.29
35	*Salvia strobilifera* (Benth.) J.G.González	74.07	3.33	2.00	0.60	1.84
36	*Sarcococca saligna* (D.Don) Müll.Arg.	518.52	10.00	4.67	0.47	8.36
37	*Solanum viarum* Dunal	37.04	3.33	1.00	0.30	1.25
38	*Toona ciliata* M.Roem.*	55.56	3.33	1.50	0.45	4.26
39	*Vitex negundo* L.	259.26	6.67	3.50	0.53	4.60
40	*Woodfordia fruticosa* (L.) Kurz	388.89	8.33	4.20	0.50	6.72
41	*Zanthoxylum armatum* DC.	574.07	23.33	2.21	0.09	14.38

* Saplings of trees

Table 7: Concentration of dominance (C), Index of Diversity (H), Richness index (R) and Richness index (R) for trees and shrubs at different elevation in Chandi beat

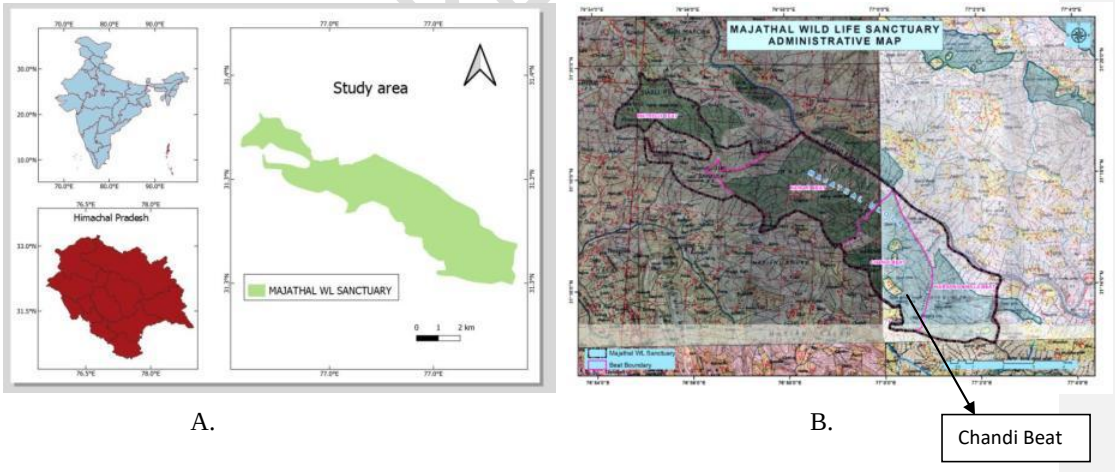
Altitude	Plant Category	Concentration of dominance (C)	Index of Diversity (H)	Richness Index (R)	Evenness Index (E)
625-1000m	Tree	0.04	3.58	7.78	0.93
	Shrub	0.03	3.86	9.12	0.93

1000-1500m	Tree	0.06	3.20	6.25	0.89
	Shrub	0.03	3.62	7.19	0.93
1500-1960m	Tree	0.11	2.55	3.47	0.84
	Shrub	0.04	3.37	6.22	0.91

Table 8: List of threatened plants found in Chandi beat

S. No.	Name of species	Habit	Threat status (As per Shimla CAMP, 2003)	Threat status (As per Kullu CAMP, 2010)	Threat status (As per IUCN, 2023)
1	*Pleurolobus gangeticus* (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	Shrub	-	NE	LC
2	*Oroxylum indicum (L.) Kurz*	Tree	-	NE	EN
3	*Zanthoxylum armatum* DC.	Shrub	EN	EN	LC

NE- Near Endangered, LC- Least concern, EN- Endangered



A. B.

Figure: 1.: A and B Map of Majathal Wildlife Sanctuary, Himachal Pradesh (source- Anonymous, 2023)

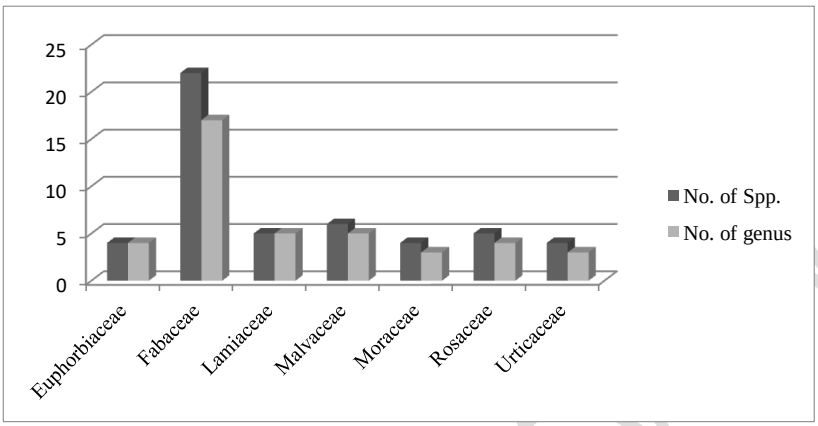


Figure-2: Dominant families and number of genus and species found in Majathal Wildlife Sanctuary

		
Woodfordia fruticosa (L.) Kurz	*Ficus auriculata* Lour.	*Senna occidentalis* (L.) Link
		
Indigofera cassioides Rottler ex DC.	*Moringa oleifera* Lam.	*Ougeinia oojeinensis* (Roxb.) Hochr.

		
Bauhinia variegata L.	*Euphorbia royleana Boiss.*	*Zanthoxylum armatum* DC.
		
Bergera koenigii L.	*Punica granatum* L.	*Berberis lycium* Royle

Plate-1: Arboreal flora found in Majathal Wildlife Sanctuary, Solan