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Research Paper

Vegetation structure, floristic composition and species diversity of woody plant communities in sub-tropical *Kandi* Siwaliks of Jammu, J & K, India

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Abstract

The study was conducted on sub-tropical forest of districts Jammu and Samba of Jammu province of Jammu and Kashmir state, India with the objective of determining floristic composition, species diversity and structure of woody vegetation in drier *Kandi* Siwaliks. The forests of *Kandi* belt represent typical subtropical vegetation with distinct vertical zonation of three forest types *i.e.*, Northern dry mixed deciduous forests (5B/C2), Himalayan subtropical scrub (9/C1/DSI) and Himalayan subtropical Pine forest (9/C1a) in an altitudinal range of 300 m asl to 990 m asl. The community analysis was performed using stratified random sampling involving 0.01 % of the total area for each community. Accordingly, 750 quadrats of 400 m^2 and 100 m^2 were laid for trees and shrubs respectively after attaining their species area curve. Various phytosociological parameters and diversity indices have been used to reveal the community structure, species richness, diversity and evenness for the phanerophytes in different forest types. A total of 112 species comprising 65 trees and 47 shrubs belonging to 92 genera and 48 families were recorded from the forest. The vegetation analysis revealed the dominance of *Mallotus philippensis* (SIV %, 6.4), *Acacia modesta* (10.44 %) and *Pinus roxburghii* (24.27%) as over storey elements in northern dry mixed deciduous forests, Himalayan subtropical scrub and Himalayan subtropical Pine forest respectively. The northern dry mixed deciduous forests occupying 27.3 % of the study area revealed maximum species richness and diversity as indicated by the higher values obtained for Shannon-Wienner's index and Simpson's index of dominance. Most of the forest landscapes are influenced by human disturbances and thus necessitates the need for immediate conservation action plan to ensure sustainable utilization and better management of forest.

Keywords: *Community Analysis; Subtropical Vegetation; Phanerophytes; Deciduous Forests; Species Area Curve; Phytosociological Parameters; Human Disturbances.*

1. Introduction

Forest composition, community structure and diversity patterns are important ecological attributes significantly correlated with prevailing environmental as well as anthropogenic variables [1], [3]. The diversity of tree species is fundamental to total forest biodiversity, because trees provide resources and habitats for almost all other forest species [4], [5]. The tropical and sub-tropical forests harbor maximum diversity of plant species on earth. Covering only 7 % of earth's land surface these forests have more than half of world's species [6]. Of the 86% of the tropical forests in India, 54% are classified as dry deciduous and 37% as moist deciduous [7], [8]. The disappearance of these forests at an estimated rate of 1-2 % per year comes at a time when our knowledge of their structure, composition, dynamics, diversity and taxonomy has not fully unraveled [9]. Kharakwal et al. [10] opines that accelerated species loss could lead to collapse of the ecosystem. Further, these forests are the most disturbed and least protected ecosystems of the world [11] and are disappearing at alarming rates owing to deforestation and unscientific extraction of forest produce [12], [13]. The species diversity, floristic composition and vegetation structure are important to judge the state of natural forests in the region and to suggest conservation strategies thereof. Generally tree species diversity in a forest varies

greatly from place to place mainly due to variation in biogeography, habitat and disturbance [14]. The local communities residing in and around *Kandi* belt are dependent upon the forests for an array of ecosystem services and values. The variations in community attributes are directly correlated with the intensity of variable like geographical location, productivity, evolutionary competition and human forest interactions [34]. In *Kandi* belt, the destruction and fragmentation increases the vulnerability of forest patches especially those at the interfaces thus influencing the composition of vegetation especially the understory significantly. Moreover, the fragile terrain, rocky slopes and geological dips further contribute to varying degrees of natural fragmentation [30], [42].

There have been some important contributions on vegetation analysis, phytosociology and community structure in certain Himalayan forest types [15], [28]. The forest diversity patterns and governing environmental as well as anthropogenic variables in the Himalayan sub-tropical region have been studied in the past by phytosociologists [1], [29], [36]. Similar studies have been carried out in different regions of Jammu province [30], [37], [46]. The present study aims to provide the baseline information on important ecological factors which influence the distribution of vegetation along different ecological and environmental gradients. The ecological attributes, their linkages, stand disturbance regime have been detailed out and viable strategies have been suggested for efficacious management of these vulnerable ecosystems.

2. Materials and methods

2.1. Vegetation sampling and data analysis

The entire area under study was demarcated using toposheets and satellite imageries and reconnaissance survey was undertaken to define vegetation type and community association. Traverses along roads, drainage, hills and ridges were made and three forest types were identified on the basis of Champion and Seth classification [47]. Physiographic factors *i.e.*, altitude, slope steepness and direction were measured by GPS (Garmin, Rino-130). A total of seven hundred fifty sample points were laid separately for northern dry mixed deciduous (370), Himalayan sub-tropical scrub (280) and Himalayan sub-tropical pine forest (100) respectively for quantitative sampling. Stratified random sampling was adopted for analyzing vegetation composition of woody species. A sample intensity of 0.01 per cent of the total area was adopted covering all vegetation types.

The analysis was carried out by laying the quadrats of 20 m^2 each for trees (gbh > 30 cm) and a nested plot of 10 m × 10 m for shrubs/saplings (gbh > 17 cm and < 30 cm) in the centre. In case of multi stemmed trees, girth was measured separately. Basal area per hectare was calculated using the formula $gi^2/4p$, where gi is the girth of trees at breast height. A single summary statistic or Importance values was calculated by summing the relative values for species according to Ganesh et al. [48]. The equations used is Species Importance Value (SIV%) = relative frequency + relative density + relative dominance.

2.2. Species richness and diversity

Total species richness was simply taken as a count of number of species present in the respective forest type. Species richness (number of species per unit area) was calculated as Margalef's Index [49] using formula Da = S-1/ln (N) and Menhinik's index of richness [50] was calculated as Richness Db= $S/\sqrt{N}$, where, S = number of species and N = Total number of individuals (of all species in case of Menhinik's index). The diversity (H′) was determined by using Shannon-Weiner information index [51] as $H' = -\sum ni/n \log 2\ ni/n$; where ni was the SIV value of a species and n was the sum total SIV values of all species in that forest type. Simpson's diversity index [52] was calculated as Ds = 1-Cd, Where Cd = Simpson's concentration of dominance = $(\sum ni/n)^2$. Indices used to calculate 'r' species evenness included Peilou's Index [53] as $E_1 = H'/\ln (s)$ and Sheldon's Index [54] $E_2 = eH'/s$, where H′ is Shannon-Wiener's Index and 's' is the number of species. The intensity of disturbance was calculated based on number of cut stumps divided by total number of stems of al tree species including cut stumps in each fragment [19].

2.3. Study area

The present study is focused on low-level hill country outside Pir-Panjal and between Jhelum and Ravi constituting Jammu hills, Jammu and Kashmir State, India. The region extends northwards of Pathankote-Jammu national highway covering the southern areas of Kathua, Samba and Jammu districts respectively with an approximate geographical coverage of 3350 sq km with predominance of typical sub-tropical vegetation ranging from 300 m asl to 990 m asl (Fig.-1) The *Kandi* belt, in local terminology it includes small dry hillocks and gentle slopes made up of boulder mass. Beset with gorges and ravines, the major part of this zone is under forests and offers but limited facility to agriculture. This undulating tract, criss-crossed through a number of shallow seasonal streams locally known as *'Khads'* with stony beds, active only during rains. The soils are shallow and infested with gravel and stones. The Jammu Siwaliks has a markedly periodic climate, characterized by dry and increasingly hot season from March to June, a warm humid monsoon season from July to September and a dry and cold weather from October to December. The normal annual

rainfall of Jammu is 1113 mm, 72% of it is received during monsoon months with average number of rainy days per year being 54. June is recorded as hottest month with average maximum 47^0C with January being the coldest month with average 6.8^0C. The foggy winters and scorching summers bear a marked climatic perturbation.

3. Results and discussion

3.1. Vegetation structure and composition

The forests of *Kandi* Siwaliks were divided into three types in accordance with the classification made in revised survey of forest types of India by Champion and Seth [47].

3.1.1. Northern dry mixed deciduous forest (5B/C2)

Occupying an area of 804.46 km^2 accounting to 27.3% of total geographical area, this forest type is restricted to Jammu foothills of low to moderate elevations (Fig.-1). The area was found richest during monsoon and post-monsoon period with great diversity among epiphytic and herbaceous flora. Among arboreal elements *Mallotus philippensis* was found gregarious in certain depressions along seasonal streams mainly associated with *Cassia fistula* especially in the western range. Other associated species included *Grewia optiva, Dalbergia sissoo, Toona ciliata, Flacourtia indica, Ficus palmata, Lannea coromandalica, Crataeva adansonii, Mangifera indica, Melia azedarach, Syzigium cumini, Aegle marmelos, Bombax ceiba, Albizia lebbeck, Phyllanthus emblica, Ougenia oogeinensis, Bauhinia variegata, Mitragyna parviflora.*
Among shrubs, *Dodonaea viscosa* formed the conspicuous shrub occurring almost in pure formations and covering large areas of ground in certain places. Isolated thickets of *Carissa opaca* and patches of *Justicia adhatoda* were other components interspersed in *Dodonaea* scrub. *Woodfordia fruticosa, Coolebrookia oppositifolia, Capparis sepiaria, Abutilon indicum, Nerium indicum, Punica granatum* were seen strikingly abundant and frequently associating. The forest interfaces were heavily infested with dense patches of *Lantana camara*.

3.1.2. Himalayan subtropical scrub (9/C1/DSI)

296.80 km^2, amounting to 10.1% of the total geographic area under study, recorded the dominance of scrubby vegetation. Restricted to dry hillocks and gentle slopes of low elevation, the fairly dense vegetation cover comprised an admixture of shrubs and rather small sized deciduous trees, mostly of thorny type (Fig.-1). *Acacia modesta*, which occupied the top and gentle slopes of the hillocks, was the most dominant species, followed by *Zizyphus mauritiana* and *Flacourtia indica*. Large patches of *Acacia catechu* plantations were found along the southern and southeastern slopes. *Aegle marmelos, Grewia optiva, Crataeva adansonii, Wrightia tomentosa. Mallotus philippensis, Cassia fistula* were only of sporadic occurrence. *Bauhinia variegata - Ougenia oogeinensis* was the second largest association of this forest. Other usual trees included *Lannea coromandelica, Phyllanthus emblica, Premna barbata, Ehretia laevis, Casseria tomentosa, Dalbergia sissoo* and *Albezia lebbeck*.
The dense understory of this forest type comprised of *Lantana camara, Carissa opaca, Mimosa rubicaulis, Zizyphus oxyphylla, Randia tetrasperma, Capparis sepiaria* and *Justicia adhatoda*. *Lantana camara* the most common weed of the area had fully acclimated to the climatic conditions of the region. *Dodonaea viscosa, Woodfordia fruticosa, Colebrookia oppositifolia* and *Punica granatum* were found restricted in few patches in association with broadleaved deciduous over storey.

3.1.3. Himalayan subtropical pine forest (9/C1a)

This forest type occupied an area of 99.85 km^2, thus forming 3.4% of the total area under study. It comprised of 25-30 m high pure crop of *Pinus roxburghii* in all the higher ridges and on the steeper rocky slopes at an altitude of 900 m asl, with broad-leaved species and shrubs towards moderate and lower elevations (Fig.-1). The associations included *Acacia catechu, Dalbergia sissoo, Mallotus philippensis, Cassia fistula, Syzigium cumini, Phyllanthus emblica, Ficus palmata, Ficus benghalensis, Lannea coromandelica* and *Butea monosperma*. The undergrowth chiefly comprised of contiguous patches of *Dodonaea viscosa* and isolated patches of *Carissa opaca, Woodfordia fruticosa and Nyctanthes arbro-tristis, Wendlandia heynii, Colebrookia oppositifolia, Justicia adhotoda* and *Rubus ellipticus*. *Euphorbia royleana* inhabited southern and southwestern rocky slopes.

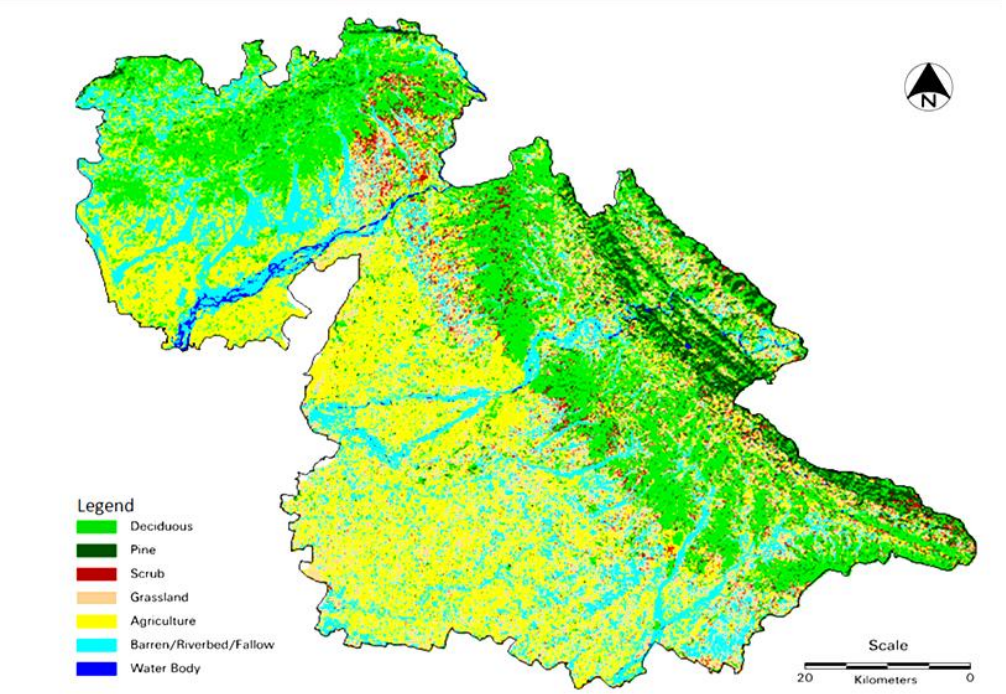

Fig. 1: Land use / Land Cover map of the study area

3.2. Floristic structure species richness and diversity

A total of 112 specimens of woody plants (65 Trees and 47 shrubs) in 92 genera and 48 families have been recorded from the study area. These included 4259 individuals from subtropical dry deciduous forest, 4065 in Himalayan subtropical scrub and 1994 in Himalayan subtropical Pine forest. The number of trees per hectare varied from 288, 363 and 498 in subtropical dry deciduous forest, Himalayan subtropical scrub and Himalayan Chirpine dominated forests respectively. Whereas, the under storey exhibited more density than the trees with number of shrubs recorded per hectare arrived to be 376 and 595 in case of subtropical dry deciduous forest and Himalayan subtropical scrub respectively. The least value *i.e.*, 163 shrubs ha^{-1} was recorded in the case of Himalayan subtropical pine forest. The total basal area of trees was found to be 14.32 m^2/ha in subtropical dry deciduous forest, 15.03 m^2/ha in Himalayan subtropical scrub and 37.75 m^2/ha in Himalayan Chirpine dominated forest.

The canopy trees included the only gymnosperm *i.e., Pinus roxburghii* besides its broadleaved associates *viz., Acacia modesta, Lannea coromandelica, Dalbergia sissoo* and *Albezia lebbeck,* while the middle storey comprised of *Cassia fistula, Zizyphus mauritiana, Flacourtia indica, Grewia optiva, Mallotus philippensis*. The understory in almost all forest types was dominated by dense patches of cosmopolitan weed *Lantana camara* followed by *Carissa opaca, Justicia adhatoda, Zizyphus oxyphylla, Woodfordia fruticosa, Colebrookia oppositifolia, Capparis sepiaria* and *Punica granatum.*

Among the angiosperm families, Euphorbiaceae topped the list with 9 genera and 9 species followed by Mimosaceae (4/9), Moraceae (2/8), Rubiaceae (5/6) and Verbenaceae (5/6) respectively. As many as 22 families showed monotypic representation in the area as represented by a single genus and single species. Maximum species richness *i.e* 91 (56 trees and 35 shrubs) was recorded for subtropical dry deciduous forest followed by 68 (44 trees and 24 shrubs) in Himalayan subtropical scrub and 59 (40 trees and 19 shrubs) in Himalayan subtropical pine forest respectively (Table -1). Further, the species diversity was also found maximum in subtropical dry deciduous forest with highest values recorded for Margalef's Index (16.46 for trees / 10.27 for shrubs), Menhinick's Index (1.21 for trees / 0.77 for shrubs), Simpson's Index (0.96 for trees / 0.89 for shrubs) and Shannon-Wiener's Index (3.38 for trees / 2.68 for shrubs) followed by Himalayan subtropical scrub [Margalef's Index (13.19 for trees / 6.86 for shrubs), Menhinick's Index (1.04 for trees / 0.51 for shrubs), Simpson's Index (0.94 for trees / 0.90 for shrubs) and Shannon-Wiener's Index (3.07 for trees / 2.52 for shrubs)] and Himalayan subtropical Pine forest [Margalef's Index (13.47 for trees / 5.84 for shrubs), Menhinick's Index (1.42 for trees / 0.55 for shrubs), Simpson's Index (0.82 for trees / 0.88 for shrubs) and Shannon-Wiener's Index (2.48 for trees / 2.52 for shrubs)] respectively (Table -1)

Table 1: Community Characteristics of Different Forest Ecosystems

Parameter	Forest Types					
	Subtropical dry deciduous forest		Himalayan subtropical scrub		Himalayan subtropical Pine forest	
	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs
Number of families	30	16	21	17	22	14
Number of genera	49	29	37	23	38	16
Species richness	56	35	44	24	40	19
Total number of individuals	2196	2063	1826	2239	784	1210
Stand density (individuals ha^{-1})	288	376	363	595	498	163
Disturbance index (%)	5.11	2.19	7.74	1.98	4.45	2.76
Margalef's Index (Da)	16.46	10.27	13.19	6.86	13.47	5.84
Menhinick's Index (Db)	1.21	0.77	1.04	0.51	1.42	0.55
Simpson's Index (Ds)	0.96	0.89	0.94	0.90	0.82	0.88
Shannon-Wiener's Index (H)	3.38	2.68	3.07	2.52	2.48	2.52
Pielou's Index (E_1)	0.84	0.75	0.81	0.79	0.67	0.84
Sheldon's Index (E_2)	0.52	0.41	0.48	0.51	0.29	0.62

The Peilou's evenness Index varied from 0.67 to 0.84 with maximum values recorded as 0.84 for trees and shrubs each in subtropical dry deciduous forest and Himalayan subtropical pine forest respectively. The Sheldon's evenness index ranged from 0.29 to 0.62 with highest value (0.62) noticed in case of shrubs of Himalayan subtropical Pine forest and 0.52 for trees in subtropical dry deciduous Forest. The disturbance index values revealed that Himalayan subtropical scrub with values 7.74 % for trees / 1.98% for shrubs is moderately disturbed followed by subtropical dry deciduous forest (5.11 % for trees / 2.19 % for shrubs) and Himalayan subtropical pine forest (4.45 % for trees and 2.76% for shrubs) (Table -1).

3.3. Vegetation analysis

Vegetation analysis shows that highest Species Importance Value (Value, percentage) amongst the trees and shrubs in different forest communities has been recorded for *Mallotus philippensis* (19.21, 6.4%) and *Carissa opaca* (44.15, 14.71%) in subtropical dry deciduous forest; *Acacia modesta* (31.32, 10.44%) and *Carissa opaca* (42.48, 14.16%) in Himalayan subtropical scrub, and, *Pinus roxburghii* (72.81, 24.27%) and *Dodonoea viscosa* (48.61, 16.20%) in Himalayan subtropical pine forest. The other prominent tree species included *Dalbergia sissoo* (17.76, 5.92%), *Cassia fistula* (15.35, 5.11%), *Bombax ceiba* (12.07, 4.02%), *Mangifera indica* (11.42, 3.80%), *Lannea coromandelica* (11.23, 3.74%) in subtropical dry deciduous forest; *Acacia catechu* (21.27, 7.09%), *Zizyphus mauritiana* (19.07, 6.35%), *Flacourtia indica* (16.35, 5.45%), *Dalbergia sissoo* (14.34, 4.78%), *Acacia nilotica* (12.82, 4.27%), *Butea monosperma* (11.76, 3.92%) in Himalayan subtropical dry scrub. Besides *Pinus roxburghii*, the other co-dominants in Himalayan Subtropical pine forest included *Phoenix sylvistris* (15.03, 5.01%), *Mallotus philippensis* (13.01, 4.33%), *Lannea coromandelica* (12.37, 4.12%), *Ficus benghalensis* (12.25, 4.08%), *Bombax cieba* (9.93, 3.31%) etc. The highest density values amongst trees were recorded for *Pinus roxburghii* (319) in Himalayan subtropical Pine forest followed by *Acacia modesta* (84.64) in Himalayan subtropical scrub and *Mallotus philippensis* (48.37) in Subtropical dry deciduous forest. (Table-2.1).

Among the shrubs, the dominant co-associates included *Dodonoea viscosa* (35.19, 11.73%), *Lantana camara* (28.28, 9.42%), *Woodfordia fruticosa* (18.53, 6.17%), *Capparis sepiaria* (14.71, 4.90%) in subtropical dry deciduous forest. *Lantana camara* (35.59, 11.86%), *Dodonoea viscosa* (29.06, 9.68%), *Justicia adhatoda* (21.35, 7.11%), *Woodfordia fruticosa* (16.60, 5.53%) were the other co-dominants in Himalayan subtropical scrub. The understory of Himalayan subtropical Pine forest, other than the gregarious thickets of *Dodonoea viscosa* included *Carissa opaca* (36.86, 12.28%), *Woodfordia fruticosa* (28.41, 9.47%), *Colebrookea oppositifolia* (23.14, 7.71%), *Justicia adhatoda* (19.02, 6.34%), *Zizyphus oxyphylla* (17.39, 5.79%) etc. Among the shrubs, the highest density was found in case of *Dodonoea viscosa* (294) in Himalayan subtropical Pine forest followed by *Carissa opaca* (167.50 and 112.16) in Himalayan subtropical scrub and Subtropical dry deciduous forest respectively (Table-2).

3.4. Discussion

Our understanding of various aspects of woody species distribution in this part of Himalayas is far from adequate. The edaphic conditions, topography, weather and seasonal pattern coupled with unregulated man-made disturbances have greatly influenced the pattern and distribution of woody species in *Kandi* Siwaliks. Present study revealed the changing patterns of vegetation composition, diversity and structure in different forest communities. Northern dry mixed deciduous forests occupying 27.3% of the study area exhibited maximum species richness and diversity. Several factors as less elevation, moist habitat, resource availability, disturbance levels, moderate fragmentation together with stochastic factors like random climatic variability, fluctuations to resources and dispersal limitation may influence the vegetation composition [3], [9], [33], [34], [55] and [56]. The species richness values (40-56 for trees and 19-35 for shrubs) are in accordance to the results of several related phytosociological investigations [31], [34], [57] and [58]. The recorded diversity values (H′) of 2.48 to 3.38 lie more or less within the reported range of 0.91 to 3.0 for Himalayas

[59], [61]. Ram et al. [62] reported shrub density between 2.6 to 3.8 for different forest types in Kumaon Himalayas. The values of the present study are in consonance to the values reported for different forest by many workers [10], [17], [28], [58], [63] and [70]. The concentration of dominance (Simpson's index) in the present study sites are within the reported range (0.10- 1) for tropical dry forests by other workers [28], [68], [69], [71] and [72]. The Peilou's evenness Index varied from 0.67 to 0.84 whereas the Sheldon's evenness index ranged from 0.29 to 0.62. Similar results have been obtained in the studies conducted in other parts of Himalayas [28], [73] and [74].

Table 2.1: Species Importance Value Index of tree species in different forest types of *Kandi* Siwaliks

S. No.	Species	Northern dry mixed deciduous forest			Himalayan subtropical dry scrub			Himalayan subtropical Pine forest		
		Density (Trees Ha^{-1})	Basal Area (m^2)	SIV (%)	Density (Trees Ha^{-1})	Basal Area (m^2)	SIV (%)	Density (Trees Ha^{-1})	Basal Area (m^2)	SIV (%)
1.	*Acacia catechu*	11.35	2.19	4.83	67.50	2.86	21.37	24.00	1.83	6.87
2.	*Acacia farnesiana*	-	-	-	4.64	2.19	2.62	-	-	-
3.	*Acacia modesta*	11.89	3.90	6.29	84.64	4.47	31.32	18.00	3.36	7.45
4.	*Acacia nilotica* ssp. *Indica*	8.64	3.11	4.54	38.92	3.62	12.82	9.00	2.86	4.55
5.	*Aegle marmelos*	4.05	3.36	3.14	1.07	3.11	2.19	4.00	1.61	2.47
6.	*Albizia lebbeck*	10.54	4.47	5.19	13.92	4.78	7.08	5.00	3.90	4.47
7.	*Bauhinia variegata*	8.64	2.86	3.74	4.64	2.77	3.14	2.00	2.63	2.64
8.	*Bombax ceiba*	26.21	7.18	12.07	17.50	6.52	9.28	23.00	5.19	9.93
9.	*Butea monosperma*	10.00	2.63	4.47	34.64	3.38	11.76	2.00	2.25	2.10
10.	*Casearia tomentosa*	4.59	1.61	2.21	5.00	1.85	2.46	5.00	1.61	2.59
11.	*Cassia fistula*	40.54	3.36	15.35	23.92	2.49	9.76	15.00	3.03	5.56
12.	*Cordia dichotoma*	5.67	6.62	5.25	3.57	4.18	3.38	3.00	3.11	3.11
13.	*Crataeva adansonii*	8.64	2.19	3.89	1.07	2.01	1.53	5.00	1.83	3.31
14.	*Dalbergia sissoo*	37.83	6.81	17.76	36.42	5.48	14.34	15.00	4.47	7.85
15.	*Diospyrus cordifolia*	2.43	2.63	1.98	-	-	-	-	-	-
16.	*Ehretia laevis*	1.08	2.19	1.49	-	-	-	-	-	-
17.	*Elaeodendron roxburghii*	1.89	1.83	1.58	-	-	-	-	-	-
18.	*Euphorbia royleana*	-	-	-	-	-	-	25.00	3.36	8.90
19.	*Ficus cunia*	2.43	0.86	1.28	1.78	1.79	1.60	4.00	0.86	1.67
20.	*Ficus palmata*	21.35	2.93	8.56	16.78	2.19	6.66	19.00	2.63	7.92
21.	*Ficus racemosa*	5.13	4.04	3.46	2.14	3.62	2.65	2.00	4.04	3.66
22.	*Ficus auriculata*	4.59	5.19	4.12	6.07	4.18	4.30	3.00	2.19	2.47
23.	*Ficus benghalensis*	6.75	13.40	8.95	8.21	13.97	10.48	4.00	15.60	12.25
24.	*Ficus hispida*	3.51	0.98	1.71	3.92	1.61	2.16	-	-	-
25.	*Ficus religiosa*	2.97	8.36	5.24	3.21	6.81	5.08	-	-	-
26.	*Flacourtia indica*	23.24	3.76	9.25	41.78	3.98	16.35	24.00	3.76	7.65
27.	*Flueggea virosa*	6.21	2.25	3.32	-	-	-	-	-	-
28.	*Gmelina arborea*	4.59	3.65	3.18	1.07	2.47	1.80	-	-	-
29.	*Grewia optiva*	22.43	3.49	8.59	12.14	3.26	4.94	19.00	2.93	7.56
30.	*Helicteres isora*	2.43	0.98	1.40	-	-	-	-	-	-
31.	*Hiptage benghalensis*	1.62	1.74	1.37	-	-	-	-	-	-
32.	*Holarrhena antidysenterica*	1.35	0.88	0.91	-	-	-	-	-	-
33.	*Lannea coromandelica*	24.86	4.47	11.23	31.78	6.44	13.24	31.00	5.19	12.37
34.	*Leea edgeworthii*	3.24	0.69	1.34	-	-	-	-	-	-
35.	*Mallotus philippensis*	48.37	3.03	19.21	21.42	2.49	8.16	39.00	3.03	13.01
36.	*Mangifera indica*	21.35	8.94	11.42	20.00	7.37	11.04	4.00	6.81	6.39
37.	*Melia azedarach*	9.72	3.70	5.42	5.71	2.79	3.32	7.00	2.70	3.33
38.	*Moringa oleifera*	5.94	2.70	3.15	4.64	1.59	2.09	-	-	-
39.	*Morus alba*	2.16	3.16	2.20	-	-	-	-	-	-
40.	*Oroxylum indicum*	6.75	2.03	2.97	1.78	1.66	1.52	3.00	0.98	1.62
41.	*Ougeinia oogeinensis*	4.86	2.60	2.72	2.85	1.16	1.55	4.00	1.83	2.34
42.	*Phanera vahlii*	-	-	-	-	-	-	15.00	1.61	5.85
43.	*Phoenix sylvestris*	1.62	5.09	2.90	3.92	3.98	3.58	43.00	5.19	15.03
44.	*Phyllanthes emblica*	10.27	2.91	4.79	6.78	3.41	4.20	3.00	2.30	2.54
45.	*Pinus roxburghii*	38.01	7.18	14.07	20.71	5.19	9.57	319.00	7.18	72.81
46.	*Pistacea integeriima*	6.21	5.19	4.73	3.92	5.21	3.55	3.00	3.90	3.94
47.	*Premna latifolia*	3.51	2.47	2.23	-	-	-	-	-	-
48.	*Pyrus pashia*	6.21	2.74	3.56	2.14	2.25	1.92	9.00	2.75	4.18
49.	*Sapium sebiferum*	2.43	1.83	1.60	-	-	-	-	-	-
50.	*Syzygium cumini*	17.02	6.92	8.79	9.64	5.57	6.12	15.00	4.47	7.57
51.	*Terminalia bellirica*	11.08	9.02	7.64	2.85	7.76	5.50	1.00	9.02	6.70
52.	*Terminalia chebula*	8.37	6.82	5.20	-	-	-	-	-	-
53.	*Toona ciliata*	10.54	5.82	6.36	7.50	5.03	5.29	-	-	-
54.	*Trema politoria*	2.43	1.83	1.47	-	-	-	-	-	-
55.	*Wendlandia heynei*	23.51	2.30	7.94	12.85	2.36	5.73	29.00	1.83	9.19
56.	*Wrightia tomentosa*	3.78	2.84	2.58	1.78	1.48	1.41	1.00	1.68	1.57
57.	*Xylosma longifolium*	0.81	1.68	1.06	5.35	1.14	2.28	3.00	2.19	2.75
58.	*Zanthoxylum alatum*	0.54	1.47	0.92	2.14	1.89	1.79	2.00	2.19	2.34
59.	*Zizyphus mauritiana*	19.72	5.19	9.36	49.64	6.20	19.07	23.00	5.09	9.86

Table 2.2: Species Importance Value Index of shrub / sapling species in different forest types of *Kandi* Siwaliks

S. No.	Species	Northern dry mixed deciduous forest			Himalayan subtropical dry scrub			Himalayan subtropical Pine forest		
		Density (Shrubs / 100 m^2)	Basal Area (m^2)	SIV (%)	Density (Shrubs / 100 m^2)	Basal Area (m^2)	SIV (%)	Density (Shrubs / 100 m^2)	Basal Area (m^2)	SIV (%)
1.	*Abutilon indicum*	9.45	0.41	7.46	26.07	0.265	10.90	-	-	-
2.	*Abutilon ramosum*	2.97	0.23	3.19	4.64	0.191	2.68	-	-	-
3.	*Agave sisalana*	2.16	0.56	6.13	10.35	0.591	7.68	-	-	-
4.	*Antidesma diandrum*	2.70	0.63	7.09	-	-	-	-	-	-
5.	*Asparagus adscendens*	4.59	0.18	3.41	15.35	0.137	6.02	28.00	0.23	8.41
6.	*Buddleja asiatica*	19.72	0.42	10.27	12.85	0.430	7.76	49.00	0.42	13.08
7.	*Calotropis procera*	11.08	0.06	5.54	28.92	0.134	8.77	-	-	-
8.	*Capparis sepiaria*	35.40	0.23	14.71	45.00	0.257	15.64	29.00	0.18	6.52
9.	*Carissa opaca*	112.16	0.58	44.15	167.50	0.704	42.48	179.00	0.58	36.86
10.	*Colebrookea oppositifolia*	19.18	0.25	9.76	31.78	0.477	14.13	93.00	0.48	23.14
11.	*Deeringia amaranthoides*	4.05	0.13	2.43	-	-	-	-	-	-
12.	*Dodonoea viscosa*	92.70	0.48	35.19	101.07	0.474	29.06	294.00	0.60	48.61
13.	*Euphorbia royleana*	6.21	0.76	9.32	12.50	0.669	10.11	34.00	0.76	14.70
14.	*Glochidion velutinum*	1.35	0.13	1.75	-	-	-	-	-	-
15.	*Gymnosporia royleana*	2.16	0.23	2.83	4.64	0.257	4.03	-	-	-
16.	*Indigofera cassioides*	1.35	0.13	1.28	-	-	-	-	-	-
17.	*Indigofera tinctoria*	1.89	0.09	1.84	-	-	-	-	-	-
18.	*Ipomea caricia*	-	-	-	17.50	0.092	5.16	-	-	-
19.	*Jasminum auriculatum*	0.54	0.26	2.73	-	-	-	-	-	-
20.	*Justicia adhatoda*	37.56	0.19	13.75	78.21	0.236	21.35	93.00	0.21	19.02
21.	*Lantana camara* var. *aculeate*	79.72	0.39	28.28	114.64	0.527	35.59	53.00	0.26	12.53
22.	*Mimosa rubicaulis*	8.91	0.23	5.69	20.00	0.449	8.65	37.00	0.51	13.73
23.	*Murraya koenigii*	26.75	0.23	9.18	-	-	-	-	-	-
24.	*Myrsine africana*	0.54	0.09	1.14	-	-	-	-	-	-
25.	*Neruim indicum*	-	-	-	11.42	0.302	5.90	-	-	-
26.	*Nyctanthes arbortristis*	8.37	0.13	3.59	-	-	-	11.00	0.16	4.28
27.	*Pogostemon benghalense*	1.08	0.07	1.14	-	-	-	-	-	-
28.	*Punica granatum*	7.83	0.51	7.27	10.35	0.635	9.01	29.00	0.48	10.53
29.	*Randia tetrasperma*	10.00	0.76	10.19	10.71	0.646	8.96	9.00	0.62	9.51
30.	*Rhamnus triquetra*	0.81	0.19	2.11	-	-	-	5.00	0.21	3.59
31.	*Rubus ellipticus*	17.56	0.23	8.13	8.21	0.580	7.40	63.00	0.23	13.79
32.	*Spermadictyon suaveolens*	4.59	0.31	4.20	3.92	0.161	2.39	5.00	0.31	5.04
33.	*Vitex negundo*	6.21	0.63	7.69	7.509	0.580	7.41	19.00	0.56	10.57
34.	*Vitis latifolia*	2.43	0.14	2.47	-	-	-	-	-	-
35.	*Woodfordia fruticosa*	32.70	0.37	18.53	31.78	0.704	16.60	109.00	0.58	28.41
36.	*Zizyphus oxyphylla*	4.59	0.23	4.31	24.64	0.548	12.58	71.00	0.42	17.39

Fragmentation of natural forest due to anthropogenic pressure is a common phenomenon. Disproportionate growth in human and livestock population over the last few decades in this region is posing significant threat to these ecosystems. The present study confirms moderate degree of disturbance in Himalayan subtropical scrub followed by Himalayan Chirpine and subtropical dry deciduous forest. Similar results have been obtained during the studies in similar ecosystems [33], [42] and [73]. The distribution of Chirpine is very narrow and the patches are more or less exposed to southern which being dry expose these stands to intense and frequent forest fires which is in conformity to other similar investigations [30], [42] and [75].

The tree density recorded as 288, 363 and 498 per hectare in subtropical dry deciduous forest, Himalayan subtropical scrub and Himalayan Chirpine dominated forest respectively is comparatively less than the recorded standards for sub-tropical forests in other Himalayan regions like 534 -620 Ha^{-1} in lesser Himalayas [76]; 1158 Ha^{-1} in Himachal Pradesh [77], [78]; 530-940 Ha^{-1} in Kumaon Himalayas [31], [79]; 790-1059 Ha^{-1} in Gharwal Himalayas [32], [80] and 341-462 Ha^{-1} in Nepal broadleaved forests [81] and 344 Ha^{-1} in Bagh district of Kashmir, Pakistan [34]. The under storey, however exhibits more density and abundance near the forest interfaces thus reflecting pronounced edge effect.

4. Conclusions

Forest destruction and fragmentation often leads to reduction of species richness, diversity and significantly affect ecosystem health and resilience. The forests in *Kandi* Siwaliks over the years have witnessed reduction of forested areas, isolation of smaller patches, habitat loss and rise in disturbance level. Large fragments which were less disturbed, subtropical dry deciduous forest in this case harboured more species and healthy over and understory as compared to

subtropical scrub and Chirpine forest. Therefore to conserve plant diversity around the forest-village/town interfaces a protective buffer of edge species around newly created fragmented forest patches is required to protect the core species.

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