Online: ISSN 2771-5868
Print: ISSN 2771-585X

Original Research Article

Diversity, Distribution and Conservation Status of *Quercus* Species in the Kailash Sacred Landscape Part of Indian Himalaya

Poonam Mehta[1], Balwant Kumar*[2] and Kapil Bisht[1]

[1]Centre for Biodiversity Conservation and Management, G B Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora – 263 643, Uttarakhand, India

[2]Biodiversity Research Laboratory, Department of Botany, S. S. J. University, Almora – 263 601, Uttarakhand, India

*Corresponding author: drbalwantkumararya@gmail.com

Received: August 24, 2021; revised: December 01, 2021; accepted: December 10, 2021

https://doi.org/10.17605/OSF.IO/P3ZMA

Abstract: Sacred natural forests are the best examples of conserving biodiversity in Indian Himalayan region with their beliefs related to customs reflect relationship in between nature and human beings. In India, presence of about 13,270 sacred sites has been recorded, out of which 476 sacred sites are reported from the present study area. In the present investigation a total of 22 oak (*Quercus* spp.) dominated forests along the altitudinal range (1100 - 2800 m asl) were studied to know the status of their regeneration dynamics, species richness, similarity and conservation strategies, and phyto-sociological analysis. For vegetation assessment, a sample stand of 50m×50m size was randomly plotted in each targeted site. In each stand, 10 quadrats of 10m×10m size for trees, 20 quadrats of 5m×5m for shrubs (2 sub-quadrats in each 10m×10m) and, 100 quadrats of 1m×1m for herbs and seedlings (10 sub-quadrats in each 10m×10m) were laid respectively. All the phytosociological parameters density, IVI, basal area, different diversity indices etc. were quantitatively analyzed following standard methodologies. For summarizing the compositional variations among studied sacred forests, Principal Component Analysis (PCA) was performed by using PAST software. The study revealed that *Q. leucotrichophora* was recorded in maximum 18 sites, followed by *Q. glauca* (7), *Q. lanuginosa* (6), *Q. floribunda* and *Q. semecarpifolia* (5 each). The oaks contributed about 39% and 41.59% for density and IVI respectively of the total tree layer of the studied sites. Good regeneration was recorded in seven sites and fair in only one site i.e. Alaimal reserve forest at 1100m altitude while 14 sites showed poor regeneration. Only few patches of oaks are sustained and which are devoted to local deities as sacred forests. To protect the oaks from high consumption pressure specific conservation implications are needed and to achieve that such studies need to be conducted so that the actual position of oaks in the region can be determined and further proper steps can be taken for their conservation.

Key words: Conservation status, Diversity, Kailash Sacred Landscape, *Quercus* species

Introduction

The diverse physiographic and climatic variability of western Himalaya provide suitable habitats for rich vegetation type, ranging from tropical moist deciduous to temperate and sub-alpine forests, grasslands, alpine scrub and meadows (Champion and Seth, 1968). The temperate region in western Himalaya is dominated by broad leaved forests among them oaks (*Quercus* spp.) constitute a major dominance. Among various broad leaved tree species five species of evergreen oaks viz. *Quercus glauca* Thunb. (Phalyant), *Q. floribunda* Rehder (Moru), *Q. lanuginosa* J. E. Sm. (Rianj), *Q.*

leucotrichophora A. Camus (Banj) and *Q. semecarpifolia* Sm. (Kharsu) make major forest vegetation in Indian West Himalaya. Western Himalaya in the IHR is known for its rugged topography and steep vertical gradient and relatively higher snow cover than the eastern Himalayan region. It includes three states of India namely, Jammu & Kashmir, Himachal Pradesh and Uttarakhand, and is known for diversity of its forests. Oak forest represents climax vegetation between 1000m-3500m altitude in the region and plays a vital role in conservation of soil, water, native flora and fauna, thereby, providing numerous ecosystem services to mankind (Upreti, *et al.*, 1985; Singh and Singh, 1992). The Himalayan region (IHR) is mostly inhabited by the agro-pastoral communities which live in close association with oaks and clear the oak forests for agriculture and habitation. Besides this, these mountain communities depend on oaks for several purposes on which their daily life sustains. During recent decades increased human population has led to more demand of fuel wood and fodder which has increased pressure on oak forests in the hilly regions of Indian West Himalaya (Singh, et al. 2016). The poor regeneration in oak forests is attributed to reduction in acorn production due to heavy lopping and proliferation of alien invasive species (Singh and Singh, 1992; Thandani and Ashton, 1995). Selective removal of oaks through cutting and burning and changes in soil properties in many parts of western Himalaya have led to invasion of Chir pine (*Pinus roxburghii*) (Saxena and Singh, 1982; Tewari, 1982; Singh, *et al.*, 1984). All the above mentioned factors are the main cause of depletion of oaks in the region.

Uttarakhand is home to rare species of plants and animals, many of which are protected by sanctuaries and reserves. Evergreen oaks, Rhododendrons, and conifers predominate in the hills. *Shorea robusta*, *Dalbergia sissoo*, *Mallotus philippensis*, *Acacia catechu*, *Bauhinia racemosa* and *Bauhinia variegata* are some of the major trees of the region. Uttarakhand (Deobhumi: the Land of Gods) in the lap of the Himalaya is a hub of spiritual sacredness in India. Besides the presence of Char-Dham and the sacred tract of Mt. Kailash, Uttarakhand is a hub of several ancient temples and monuments which are considered sacred and are source of spirituality for the mankind. Besides this Uttarakhand is also a hub of sacred natural sites (SNS) which are managed by the communities residing nearby areas. The sacred forests are generally dominated either by *Quercus leucotrichophora*, *Q. semecarpifolia*, *Cupressus torulosa*, *Cedrus deodara*, *Betula utilis* and *Rhododendron campanulatum*, or at higher altitudes by *Juniperus communis*, *J. indica*, which in turn are considered as sacred species (Negi, 2010).

Knowing the exact status and extent of oaks is essential for further conservation planning. Satellite remote sensing technology has been proven as an effective tool for assessment and monitoring the extent, distribution and status of forests from regional to global scale (Kushwaha, 1990; Rathore, *et al.*, 1997; Lilles and Kiefer, 2000) and this tool can be aided with the field studies which can provide the actual ground conditions of oaks with their several ecological attributes *viz.* diversity, frequency, density, abundance, basal area, crown cover, circumference at breast height, regeneration patterns, soil properties and climatic factors etc. It is a tool for monitoring vegetation status, especially in forests, because the hilly or swampy terrain is inaccessible (Chellamani, *et al.*, 2014). Previous attempts on mapping of vegetation types in the Himalayan region have yielded limited information on this aspect of Banj oak/*Q. leucotrichophora* forests (Tiwari and

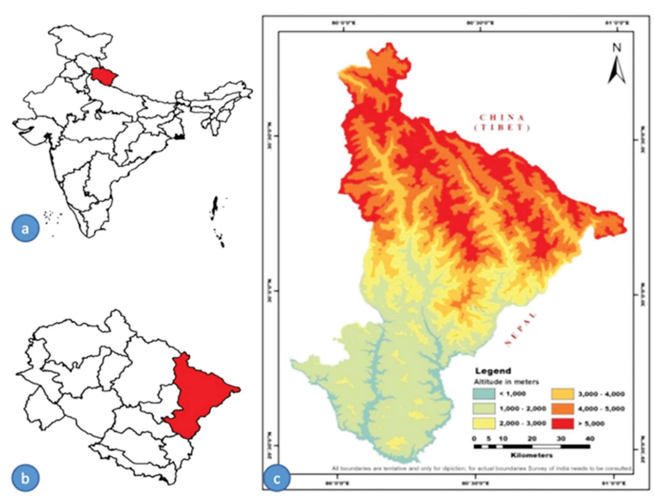

Fig. 1. Map of the study area (a) India (b) Uttarakhand (c) Study area map (Pithoragarh district)

Singh, 1984 & 1987; Pant and Kharkwal, 1995). So far, there has not been any quantitative study on the spatial distribution and phyto-sociology particularly of oak forests at a landscape level covering different elevation zones, management regimes (reserve, community forests and private forests) and disturbance levels (dense, open and degraded forests). Present study deals with the floristic diversity of oak dominated forests with forest composition, forest health, similarity, sacredness, and their conservation measures.

Materials and methods

Study area

Pithoragarh is eastern most Himalayan district in the state of Uttarakhand and is globally recognized as Kailash Sacred Landscape (KSL) part of India. Present study was conducted in Pithoragarh district, along an elevation gradient of 1100m-2800m (Fig. 1. 29^{0}26´ 35´´ - 30^{0}35´ 15´´ N and 80^{0}01´ 24´´ - 81^{0}02´ 38´´ E). It is abode of high mountains, snow capped peaks, passes, valleys, alpine meadows, forests, waterfalls, perennial rivers, glaciers and springs. The geographical area of the district is 7,110 km^{2}. The district shares its northern and eastern boundaries with Tibet and Nepal respectively. The Mahakali river originating from Lipulekh flows southward and forms the eastern border with Nepal. The Hindu pilgrimage route for Mount Kailash and Manasarovara Lake passes through Pithoragarh via Lipulekh Pass in the Greater Himalaya. The vast altitudinal range <500 to >7000 m asl provides different habitats, ecosystems and forest types representing tropical to subalpine-alpine vegetation. These forest types provide favorable habitats for different biodiversity elements. Among the various forest types, oaks attain an important place in the forests of this landscape.

Selection of study sites

In Uttarakhand total 194 oak dominated sacred sites were identified through secondary sources and field survey. Out of which, 68 sites are located in KSL Pithoragarh district (Fig. 2a) of theses 22 sites having varied altitudinal range and comprising all the 5 oak species were selected for the present study (Fig. 2b & Table 1) and some representative photographs of study sites of oak dominated forests (Fig 8).

Vegetation sampling and analysis

For vegetation assessment, a sample stand of 50m×50m size was randomly plotted in each targeted site. In each stand, 10 quadrats of 10m×10m size for trees, 20 quadrats of 5m×5m for shrubs (2 sub-quadrats in each 10m×10m) and, 100 quadrats of 1m×1m for herbs and seedlings (10 sub-quadrats in each

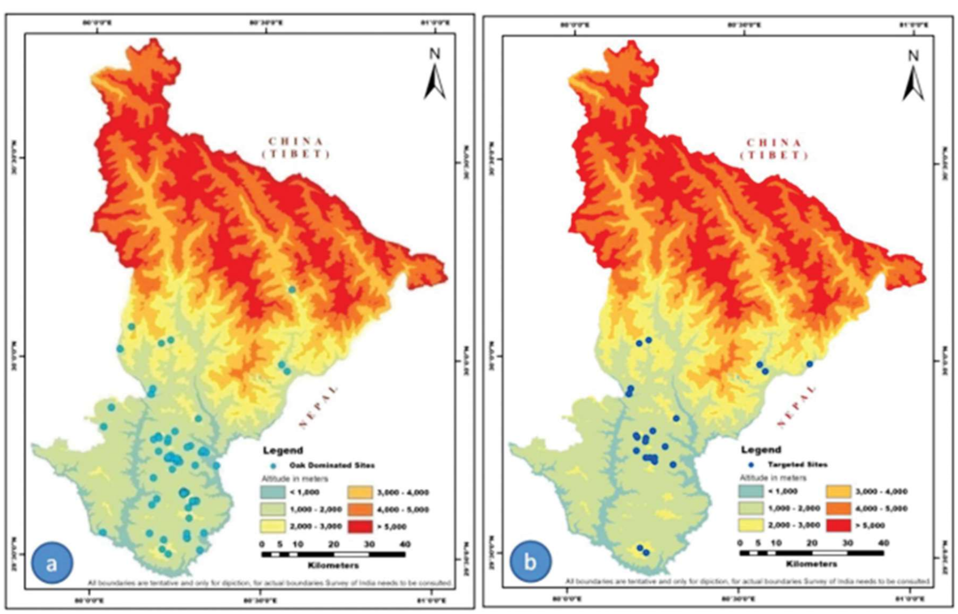

Fig. 2. (a) Oak dominated sites (b) Targeted oak dominated sites of the study area

Table 1. Different phytosociological attributes of the study area.

Site	Site name	Altitude (m)	Forest management	Forest area	Dominant tree species	Aspect	Slope (degree)	Canopy cover(%)	Regener-ation status	Average tree density (ind/ ha)	Basal area (m^2/ ha)	H'
S1	Jaikot	2392	Panchayat forest	2 ha	*Quercus leucotrichophora*	N, NE	45	60	Poor	470	2123.63	1.55
S2	Syangse Gabla	2715	Reserve forest	4 ha	*Q. semecarpifolia*	S, SE	30	70	Good	1030	2021.70	1.71
S3	Narayan Ashram	2697	Panchayat forest	6000 m^2	*Q. semecarpifolia*	S	40	50	Poor	480	1339.96	0.84
S4	Thal Ke Dhar	2422	Reserve forest	> 50 ha	*Q. leucotrichophora, Q. floribunda*	E	35	50	Good	1400	1958.97	2.35
S5	Ghandhura	2458	Reserve forest	> 50 ha	*Q. leucotrichophora*	NE	50	70	Good	1310	1975.57	2.17
S6	Balaknath	1668	Panchayat forest	2 ha	*Q. leucotrichophora*	E	20	40	Poor	1500	1744.50	2.11
S7	Latenath	1722	Panchayat forest	3 ha	*Q. leucotrichophora*	SE	30	80	Poor	1140	1968.20	1.97
S8	Malainath	2009	Panchayat forest	1 ha	*Q. leucotrichophora*	SW	35	60	Poor	1170	1867.30	1.82
S9	Aankot	1732	Panchayat forest	3 ha	*Q. leucotrichophora*	E	25	40	Poor	1260	6951.24	2.07
S10	Dhanlekh	1752	Civil forest	2 ha	*Q. leucotrichophora*	S, W	40	40	Poor	1110	1734.90	3.19
S11	Mirthi	1613	Panchayat forest	> 20 ha	*Q. glauca*	S	35	40	Poor	1080	18367.2	3.46
S12	Jal Devi	1838	Reserve forest	2 ha	*Q. leucotrichophora*	E	30	60	Good	1430	2200.01	3.29
S13	Malainath swami	2005	Reserve forest	2 ha	*Q. leucotrichophora*	N	40	60	Good	1010	2041.07	3.37
S14	Deochula	2308	Reserve forest	> 50 ha	*Q. leucotrichophora, Q. lanuginosa*	N, NE	35	50	Good	1240	4052.23	3.28
S15	Panchmod	1889	Panchayat forest	1 ha	*Q. leucotrichophora*	E	15	40	Fair	950	2040.59	3.57
S16	Alaimal	1110	Reserve forest	1 ha	*Q. leucotrichophora*	E	15	20	Poor	770	1396.02	3.17
S17	Chhurmul Devta	1664	Panchayat forest	1 ha	*Q. leucotrichophora*	N, S	25	20	Poor	530	1840.87	3.4
S18	Thamrikund	2734	Panchayat forest	> 50 ha	*Q. floribunda*	E,W,N,S	25	55	Poor	670	2660.82	3.37
S19	Kalamuni	2732	Panchayat forest	2 ha	*Q. floribunda, Q. semecapifolia*	NE	35	40	Poor	750	1357.53	3.51
S20	Lalghati	1788	Panchayat forest	2 ha	*Q. glauca*	W	65	40	Poor	870	1544.63	3.62
S21	Nachni	1811	Panchayat forest	2 ha	*Q. glauca*	S	60	40	Poor	840	1557.16	3.61
S22	Lateshwar	2729	Panchayat forest	4-5 ha	*Q. floribunda*	S	20	50	Good	760	1798.63	3.35

$T \times \bar{S}$ *with*

N= North, NE= North East, S= South, SE= South East, SW= South West, E= East, H' = Shannon Weiner Index

10m×10m) were laid respectively. The plant having circumference at breast height (cbh) i.e. 1.37m above the ground more than 30cm were considered as trees; those having cbh lower than 30cm but not less than 10cm were considered as saplings and plants having cbh below 10cm were considered as seedlings (Knight, 1963).

Quantitative analysis

The quadrate vegetation data were pooled for species richness, density, diversity and frequency. The Importance Value Index (IVI) for the trees was calculated by using method of McIntosh (1950). Relative values were determined following Phillips (1959). Species richness was determined as the total number of species recorded in sampling plots in each site. The regeneration status of tree species was determined on the basis of population size of seedlings, saplings and trees as per Shankar (2001). Good regeneration, i.e., if particular species is present in number of seedlings > saplings > trees; fair regeneration, i.e., if species present in number of seedlings > saplings d" trees; poor regeneration, i.e., if a species survives only in sapling stage, but not as seedling; if a species is present only in adult form it is considered as not regenerating. A species is considered as new if the species has no tree representatives, but only saplings and/or seedlings. Alpha diversity (H2) was estimated as the Shannon-Weiner index (Shannon and Weaver, 1949) for the establishment of alternative estimates of species diversity in studied sites.

Multiple- site similarity

All similarity indices represent variations over three parameters: species composition in each of two sites and the species shared between the two sites (Novotny and Weiblen, 2005). The widely used Sorensen Similarity Index (Magurran, 2004) measures similarity in species composition for two sites, A and B, by the equation

$$Cs = \frac{2ab}{a+b},$$

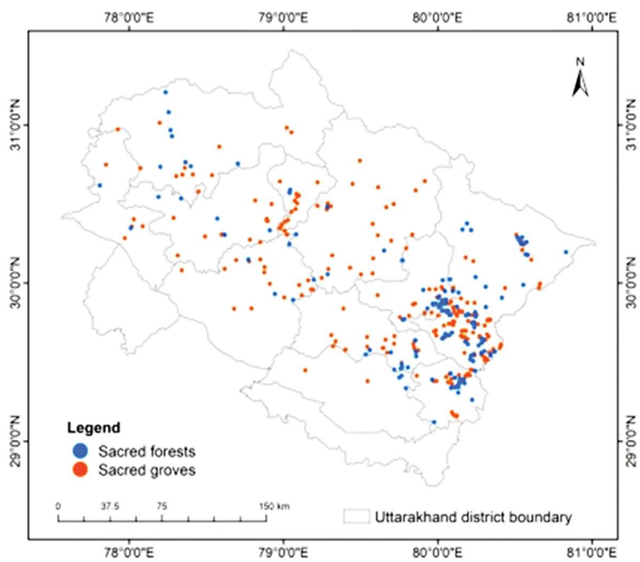

Fig. 3. Sacred Forest and sacred groves of Uttarakhand.

where *a* is the number of species found in site A; *b* is the number of species in site B and *ab* is the number of species shared by the two sites.

Multiple-site similarity versus β- diversity

β diversity is essentially a measure of how much similar the sites are in terms of the variety of species found in them. A high similarity indicates that there are few species differences between sites, yielding low β-diversity values. One of the most straightforward measures of β-diversity is Whittaker's (1972) measure, $\beta w = S_T / \bar{S}\ within$, where S_T is the total number of species; and $\bar{S}\ within$ is the average species richness for the T sites. The link between Sorensen's similarity measure for two sites and β-diversity measures is well known (Koleff, *et al.*, 2003). The relation between our multiple-site similarity and Whittaker's β_W is simply

$$C_S^T = \frac{T - \beta w}{T - 1}$$

If all sites, contain the same species, both C_S^T and β_W will be equal to 1. If no sites share species, $C_S^T = 0$ and $\beta_W = T$, indicating that the total number of species S_T is just the product.

$$T \times \bar{S}\ within = \sum_i \alpha i$$

Statistical analysis

For summarizing the compositional variations among studied sacred forests, Principal Component Analysis (PCA) was performed by using PAST software (Hammer, *et al.*, 2001). The degree of variance explained by PCA axis 1, axis 2 and axis 3, which were considered as Principal Components. For the said determination, different environmental (altitude, forest area and slope) and quantitative parameters (canopy cover, IVI, number of species, number of families, number of genera, number of herbs, number of shrubs, number of trees, number of seedlings, number of saplings, basal area, Shannon-Weiner diversity, concentration of dominance, Simpson diversity index and number of associated taboos) were used. For knowing the relationship between explanatory variables (altitude, forest area and slope) and response variables [score of PC1, PC2 and PC3, and above mentioned quantitative parameters], Pearson's correlation coefficient was determined by using SPSS software (16.0 versions). Polynomial regression analysis was performed to compare the number of species and Shannon-Weiner diversity with altitude, forest area and slope by using PAST software.

Results

Floristic diversity: The 22 study sites revealed presence of 72 plant species including 22 tree species (17 angiosperms and 5 gymnosperms); 27 shrub species, 23 herb species represented by 33 families and 59 genera. Among families, Rosaceae (14 species), Asteraceae (6 species) and Fabaceae and Fagaceae (5 species each) were most species rich. Thymelaceae and Pinaceae were represented by 3 species each; Adoxaceae, Asparagaceae, Berberidaceae, Ericaceae, Hypericaceae, Lamiaceae, Orchidaceae, Primulaceae, Ranunculaceae were represented by 2 species each; remaining 18 species were monospecific. Out of the study sites *Q. leucotrichophora* was found in maximum 18 sites, followed by *Q. glauca* (7), *Q. lanuginosa* (6) *Q. floribunda* and *Q. semecarpifolia* (5 each) (Table 1).

Forest composition

The average tree density of all the sites was 990 ind/ha and average tree density of *Quercus* spp. was 386 ind/ha. The

Table 2. Density and IVI covered by *Quercus* dominated species of studied forests.

Sites	Species	D (ind/ha)	IVI (%)	Sites	Species	D (ind/ha)	IVI (%)
S 1	*Quercus leucotrichophora*	420.00	32.41	S 14	*Q. leucotrichophora*	280.00	15.96
S 2	*Q. semecarpifolia*	470.00	34.33		*Q. glauca*	60.00	4.84
S 3	*Q. semecarpifolia*	320.00	63.61		*Q. lanuginosa*	70.00	18.31
S 4	*Q. leucotrichophora*	300.00	18.28	S 15	*Q. leucotrichophora*	270.00	20.36
	Q. floribunda	100.00	8.26		*Q. glauca*	50.00	5.67
	Q. lanuginose	90.00	7.94		*Q. lanuginosa*	10.00	7.68
	Q. semecarpifolia	100.00	8.15	S 16	*Q. leucotrichophora*	250.00	25.95
S 5	*Q. leucotrichophora*	370.00	24.29	S 17	*Q. leucotrichophora*	210.00	28.28
	Q. floribunda	90.00	7.12		*Q. glauca*	140.00	20.54
	Q. lanuginose	150.00	10.26	S 18	*Q. floribunda*	250.00	45.49
S 6	*Q. leucotrichophora*	360.00	21.23		*Q. semecarpifolia*	180.00	55.68
S 7	*Q. leucotrichophora*	310.00	23.00	S 19	*Q. floribunda*	280.00	69.09
S 8	*Q. leucotrichophora*	350.00	25.51		*Q.semecarpifolia*	50.00	55.79
S 9	*Q. leucotrichophora*	240.00	12.55	S 20	*Q. leucotrichophora*	200.00	22.44
S 10	*Q. leucotrichophora*	280.00	20.35		*Q. glauca*	210.00	26.37
S 11	*Q. leucotrichophora*	210.00	13.21	S 21	*Q. leucotrichophora*	180.00	19.26
	Q. glauca	280.00	19.46		*Q. glauca*	190.00	24.46
	Q. lanuginose	60.00	4.99	S 22	*Q. leucotrichophora*	190.00	18.63
S 12	*Q. leucotrichophora*	360.00	18.78		*Q. floribunda*	170.00	22.36
	Q. glauca	40.00	4.09				
S 13	*Q. leucotrichophora*	280.00	20.35				
	Q. lanuginose	90.00	10.28				

density of *Quercus* spp. contributed about 39% of the total tree density. Among the 22 sites, regeneration was good and fair in 7 and 1 sites respectively, while 14 sites showed poor regeneration (Table 1). As far as 5 species of *Quercus* are concerned, *Q. leucotrichophora* showed maximum average tree density 230 ind/ha followed by *Q. glauca* (44 ind/ha), *Q. floribunda* (40 ind/ha), *Q. semecarpifolia* (29 ind/ha) and *Q. lanuginosa* (21 ind/ha). Average IVI of *Quercus* spp. with respect to the total IVI of all sites was 41.59% (Table 2).

Status of oak dominance in sacred forests

As per available sources, the sacred sites exist in 19 out of 28 states in India, and India ranks 4th with 13270 sacred sites across the globe (Malhotra *et al.* 1998) (Fig. 3.) According to Negi, (2014); Joshi, *et al.* (2016) and Upadhyay, *et al.*, (2018) a total of 476 sacred sites have been solely reported from Uttarakhand, out of which, 318 are sacred groves and 158 are sacred forests (Fig. 4). Oaks are present in 194 sacred sites in which *Q. leucotrichophora* is dominantly found in maximum sites (138), followed by *Q. semecarpifolia* (20), *Q. glauca* (18) and *Q. floribunda* (14) and *Q. lanuginosa* (4). Pithoragarh have found maximum number of sacred sites (193) followed by Chamoli (54) and Champawat (48).

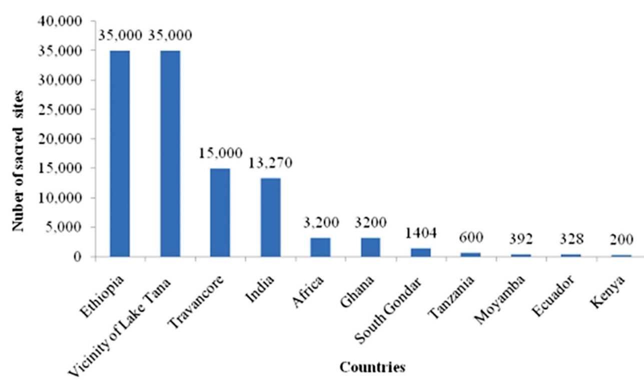

Fig. 4. Worldwide number of sacred sites as per available literature

Sorenson's similarity coefficient

Similarity measures are the most intuitive and common measures for comparing two or more sites, or samples; *w.r.t.* their species overlap. The species occurring in S6 and S7 exhibit maximum similarity of 93% followed by 91% between those

Table 3. Sorenson's similarity coefficient (in %) among the different altitudinal range based on the vegetation

	S1	S 2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S 13	S14	S15	S 16	S17	S18	S19	S20	S21	S22
S1	100	36	37	44	42	21	22	38	45	35	48	29	41	33	52	30	23	24	14	34	41	47
S2		100	10	23	21	21	22	17	18	25	12	13	25	18	18	17	15	17	12	15	17	42
S3			100	42	37	07	07	13	29	19	17	47	50	44	38	27	11	43	38	12	29	30
S4				100	88	37	39	55	56	38	41	62	67	67	56	61	31	42	41	32	41	58
S5					100	35	36	41	46	36	55	55	91	90	71	38	49	63	44	24	46	51
S6						100	93	82	55	67	37	47	56	40	48	46	27	23	22	33	42	39
S7							100	79	56	63	46	48	57	41	44	44	33	33	27	34	44	32
S8								100	81	80	45	55	60	49	59	46	29	31	24	30	53	28
S9									100	72	47	39	46	38	44	42	30	24	29	31	33	39
S10										100	36	45	48	47	36	34	62	33	39	43	46	47
S11											100	39	55	43	67	31	29	14	19	30	47	41
S12												100	55	43	67	31	29	14	19	30	47	41
S13													100	67	72	24	29	37	39	29	29	39
S14														100	58	24	38	45	40	26	26	28
S15															100	26	35	32	30	22	22	83
S16																100	30	30	33	44	44	38
S17																	100	50	54	51	51	30
S18																		100	61	47	47	35
S19																			100	63	63	26
S20																				100	46	37
S21																					100	42
S22																						100

occurring S5 and S13 and least similarity 57.6% between S3 and S6, and S3 and S7 (Table 3). The high similarity in between sites (S6 and S7) shows a very low β diversity (1) while sites S3 and S6, and S3 and S7 showing highest β diversity having a large number of unique species in both the forests.

Relationship among different parameters in studied oak dominated sites

Principal Component Analysis (PCA) exhibited that the vegetation along with different parameters varied from site to site; indicating distinct vegetation assemblages at different sites. Through the PCA ordination plot it was observed that no one sites were adjacent to each other on the basis of studied parameters (Fig.5). In the PCA ordination plot, PCA axis 1 explained 35.61% of the variation in composition of vegetation in studied sites and PCA axis 2 explained 19.27% variation, while PCA axis 3 explained 12.41%. All the three axes explained 67.29% variation in the vegetation composition of studied sites. All the 18 variables were required for the completion of 100% of the PCA ordination plot.

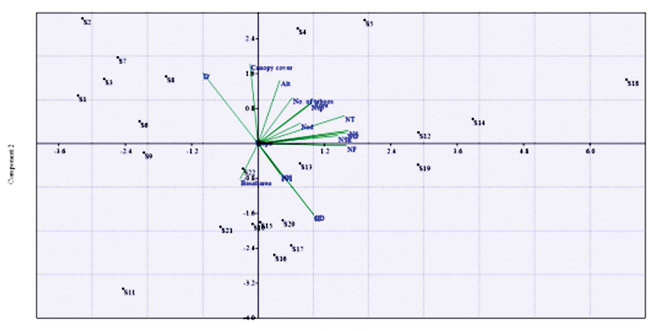

Fig. 5. Principal Component Analysis (PCA) between different response and explanatory variables

For knowing the relationship between different parameters, Pearson's Correlation Coefficient was performed and it was analyzed that PCA axis 1 was significantly related to 11 variables and highly related with number of species, number of genera and number of families; indicating that these are the main factors differentiating vegetation composition of the studied sites (Table 4). Similarly, canopy cover was significantly related to PCA axis 2 indicating differences in the studied sites (Table 4). Axis scores of PCA axis 3 were significantly related with

Table 4. Pearson's Correlation Coefficient of studied forests.

	PC1	PC2	PC3	Alt	Area	Slope	CC	IVI	NS	NF	NG	NH	NSh	NT	Nsd	Nsp	Basal	H	CD	D	T
PC1	1.000																				
PC2	.000	1.000																			
PC3	.000	.000	1.000																		
Alt	.230	.626**	-.357	1.000																	
Area	.578**	.417	.331	.383	1.000																
Slope	-.038	.044	.184	.118	.080	1.000															
CC	-.084	.786**	.092	.478*	.232	.203	1.000														
IVI	.241	-.312	.011	-.263	.119	.099	-.282	1.000													
NS	.956**	.128	-.180	.315	.575**	-.089	-.024	.147	1.000												
NF	.934**	-.020	-.124	.165	.408	-.125	-.148	.175	.917**	1.000											
NG	.934**	.108	-.251	.303	.486*	-.104	-.036	.130	.988**	.918**	1.000										
NH	.235	-.299	.774**	-.481*	.271	-.007	-.208	-.069	.119	.152	.078	1.000									
NSh	.839**	.076	-.459*	.366	.430*	-.182	-.071	.137	.933**	.854**	.927**	-.095	1.000								
NT	.912**	.275	-.099	.386	.573**	.028	.103	.180	.931**	.850**	.932**	.021	.786**	1.000							
Nsd	.447*	.201	.683**	.036	.422	.053	.052	.121	.278	.356	.224	.420	-.006	.441*	1.000						
Nsp	.556**	.390	.667**	.247	.632**	.159	.328	-.054	.429*	.423*	.371	.470*	.144	.561**	.859**	1.000					
BA	-.191	-.352	.257	-.233	.159	-.047	-.124	.070	-.212	-.207	-.265	.299	-.186	-.328	-.242	-.131	1.000				
H	.589**	-.703**	.119	-.278	.054	-.003	-.477*	.241	.435*	.551**	.423*	.462*	.402	.271	.186	.131	.144	1.000			
CD	.585**	-.697**	-.035	-.148	.008	.079	-.455*	.315	.422	.495*	.425*	.221	.385	.343	.107	.101	.089	.857**	1.000		
D	-.585**	.697**	.035	.148	-.008	-.079	.455*	-.315	-.422	-.495*	-.425*	-.221	-.385	-.343	-.107	-.101	-.089	-.857**	-1.000**	1.000	
T	.362	.453*	.174	-.029	.415	-.188	.472*	.179	.364	.334	.314	.093	.306	.355	.233	.364	-.215	-.077	-.123	.123	1.000

** Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed)

number of herbs, number of seedling and saplings indicating importance of the herbaceous vegetation (Table 4).

Canopy cover and number of herb species were significantly related with altitude in which canopy cover was positively related and number of herbs was negatively related. In case of the forest area, it influences the number of species, number of genera, number of tree species and number of seedlings. Slope of the studied sites didn't influence any vegetation parameter. In case of the quantitative parameters some were related with each other and others were not related.

Second degree polynomial fits to the data suggests that plants varies along the altitude and data points along the altitude indicates that there were more plant species in S18 (Fig. 5). During this study it was also analyzed the impact of altitude with number of species and alpha diversity and found, which was non-significant [r^2=0.113, p=0.310; r^2=0.077, p=0.463 ($y=8.758E{-}08x^2-0.0008645x+4.165$)]. The relationship between forest area and species richness was non-linear and significant (r^2=0.451, p=0.003). This result supports the hypothesis given by Neigel (2003) about the relationship between area and biodiversity that larger areas harbor more species compared to smaller area. But in case of the alpha diversity, it didn't affect by the area (r^2=0.029, p=0.749, $y=0.001126x^2 + 0.06019x + 2.602$). In case of the slope, it didn't affect the number of species and alpha diversity [r^2=0.009, p=0.916; r^2=0.161, p=0.186 ($y=0.001565x^2 - 0.1206x + 4.805$)]. Fig. 6 & 7.

Discussion

Among the five species of oaks, *Q. leucotrichophora* forest has the maximum extent and it covers 1284.60 km^2 (5.24 % of total forest cover of the state). About 774.93 km^2 of this forest lies within reserved forest while the remaining 509.66 km^2 lies in unclassified and village forest (Singh *et al.* 2016). Oaks are present in more than 40% of the total sacred natural sites in Uttarakhand. But still these oak forests are facing various natural as well as anthropogenic pressures viz. clearing the oak forests for agriculture land and human settlements,

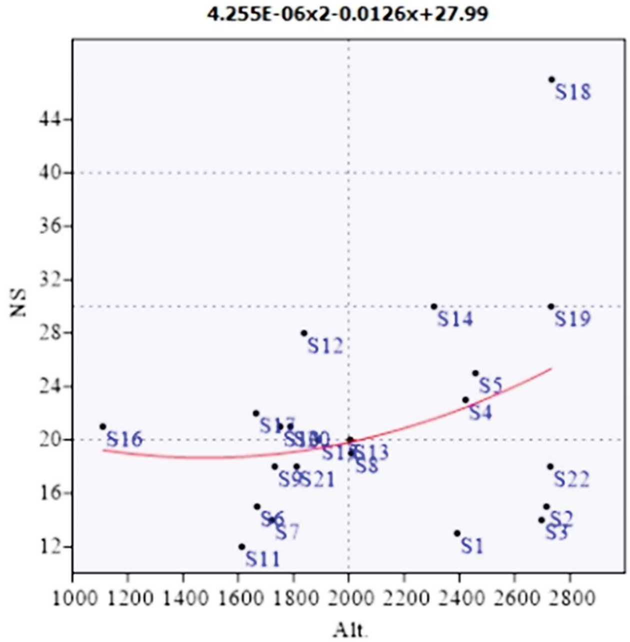

Fig. 6. Relationship between number of species and altitude (m asl).

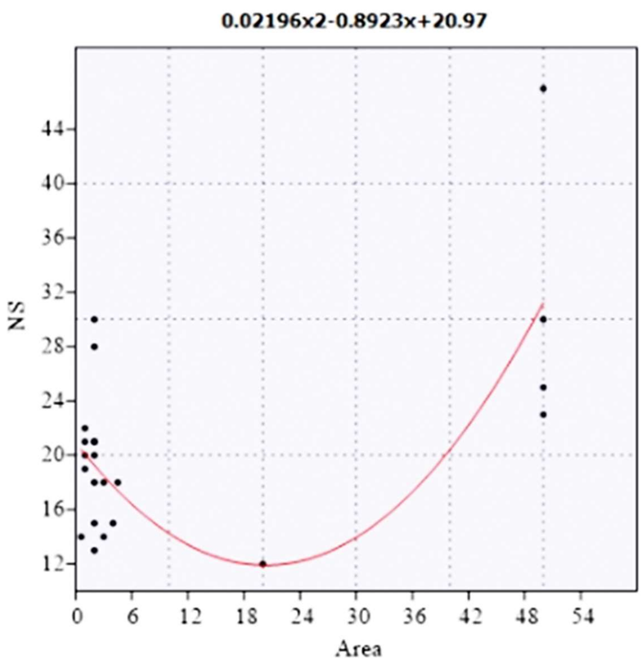

Fig. 7. Relationship between number of species and area (ha).

grazing, lopping, invasion of alien invasive species, forest fire, developmental projects etc. (Tewari, 1982; Singh, *et al.*, 1984; Singh and Singh, 1992; Thandani and Ashton, 1995).

Due to the modernization, the indigenous knowledge among the locals and religiousness is shrinking rapidly, which is a major cause of depletion of biodiversity. Sacred forest is a social institution which conserves the biodiversity through the traditional methods and peoples' participation in a regional level. In a regional level sacred forest is a best practice to conserve the local biodiversity for upcoming future. It is a cost effective management practice to conserve the biodiversity by involvement of local people. So we have to move towards old era for the conservation of biodiversity. Sacred forests need special attention and it is a high time to protect these forests not only for higher plant diversity but also to conserve other groups of organisms (Joshi, *et al.*, 2016).

Fig. 8. Oak dominated forests of Kumaun Himalaya (A) Nearby Ankot (B) Thal Ke Dhar (C) Jhuma dhuri (D) Jaikot

For shaping the diversity and distribution pattern of any living organism in macro as well as micro level, ecological factors (biotic as well as abiotic factors) play a key role. A biotic and abiotic factor affects the living organisms directly or indirectly. Distribution of plants along with different ecological factors such as altitude, forest area and slope in the studied forests is not uniform and during this study it was confirmed by the given statistical analysis. With the help of PCA ordination plot, it was observed that no one site adjacent to each other means plot shows the distinct vegetation assemblage in different sites. Distribution of the vegetation was not related with altitude and slope but the forest area shows the positive impact on number of species. Rules governed by the inhabitants positively affected the canopy cover, means for the conservation of biodiversity in a regional level, it has to regularize the rules by using traditional methods and local people's participation because inhabitants of the rural areas believe in their local deity.

Conclusions

In a nut shell it can be stated that sacred forests are likely to contribute significantly to biodiversity conservation in local and regional level. The awareness among local inhabitants needs to be generated as the young generation has gone far from the land and beliefs. In the present study it was observed that most of the taboos regulated for a site are not strictly followed. There should be a proper mechanism for monitoring of the rules and regulations of a particular site. The taboos regulated for a particular site should be strictly followed and respected. In the Himalayan region the biodiversity is very rich and gets changed within a few miles. Every region either big or small consist vast biodiversity including some unique, rare and ethnic land races of plants, animals, crops etc. Sacred sites can act as a gene pool of these unique and rare biodiversity elements and contribute towards their conservation for sustainable future.

Acknowledgement

Thanks to the Director, GBP-NIHE and Head of Department, Botany, S.S.J. University, Almora for providing laboratory facilities.

References

Champion HG and Seth JD. 1968. A Revised Survey of the Forest Types of India. Manager of Publications, Govt. of India, New Delhi.

Chellamani P, Singh CP, Panigrahy S. 2014. Assessment of the health status of Indian mangrove ecosystems using multi temporal remote sensing data. Tropical Ecology. 55: 245-253.

Curtis JT and McIntosh RP. 1950. The interactions of certain analytic and synthetic phytosociological characters. Ecology. 31:434-455.

Hammer O, Harper DAT and Ryanm DP. 2001. PAST: Paleontological statistics software packages for education and data analysis. Palaeontol Electron 4:9

Kushwaha SPS. 1990. Forest-type mapping and change detection from satellite imagery. ISPRS J. Photogramm. Remote Sensing. 45:175-181.

Joshi Y, Upadhyay S and Shukla S. 2016. Sacred Groves: treasure house for macrolichen diversity in Kumaun Himalaya. Proc Natl Acad Sci India Sect B Biol Sci. 88: 935-948.

Knight DH. 1975. A phytosociological analysis of species rich tropical forest on Barroclorada Island. Panama. Ecol Monogr. 45: 259-284.

Koleff P, Gaston KJ and Lennon JJ. 2003. Measuring beta diversity for presence–absence data. J Anim Ecol. 72: 367-382.

Lilles TM and Kiefer RW. 2000. Remote Sensing and Image Interpretation. 4th edn. John Willey and Sons, New York.

Magurran A. 2004. Measuring biological diversity. Oxford, UK: Blackwell Publishing.

Malhotra KC. 1998. Anthropological dimensions of sacred groves in India: an overview. In Ramakrishnan PS, Saxena KG, Chandrasekara UM. (eds) Conserving the sacred for biodiversity management. Oxford and IBH, New Delhi.

Negi CS. 2010. Traditional knowledge and biodiversity conservation: a preliminary study of the sacred natural sites in Uttarakhand, Central Himalaya. J Biodiver. 1: 43-62.

Negi CS. 2014. The Sacred Uttarakhand: Ethno-biological study surrounding sacred natural sites in Uttarakhand. Bishen Singh Mahendra Pal Singh, Dehradun.

Neigel JE. 2003. Species-area relationships and marine conservation. Ecol Appl. 13: S138-S145.

Novotny V and Weiblen GD. 2005. From communities to continents: beta diversity of herbivorous insects. Ann Zool Fennici. 42: 463-475.

Pant DN and Kharkwal SC. 1995. Monitoring landuse change and its impact on environment of central Himalaya using remote sensing and GIS techniques. Journal of Hill Research. 8: 1-8.

Phillips EA. 1959. Methods of vegetation study. Henry Holt & Co., Claremont, CA, USA.

Rathore SKS, Singh SP and Singh JS. 1997. Changes in forest cover in a central Himalayan catchments: inadequacy of assessment based on forest area alone. J Environ Manage. 49: 265-276.

Saxena AK and Singh JS. 1982. A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. Vegetatio. 50: 3-22.

Shankar U. 2001. A case of high tree diversity in a Sal (Shorea robusta)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. Curr Sci. 81: 776-786.

Shannon CE and Weaver W. 1949. The Mathematical Theory of Communication. Urbana, University of Illinois Press.

Simpson EH. 1949. Measurement of diversity. Nature. 163: 688.

Singh G, Padallia H, and Rai ID. 2016. Spatial extent and conservation status of Banj oak (*Quercus leucotrichophora* A. Camus) forests in Uttarakhand, Western Himalaya. Trop Ecol. 57: 255-262.

Singh JS, Rawat YS and Chaturvedi OP. 1984. Replacement of oak forest with pine in the Himalaya affects the nitrogen cycle. Nature. 311: 54-56.

Singh JS and Singh SP. 1992. Forest of Himalaya. Gyanodaya Prakashan, Nainital.

Tewari JC. 1982. Vegetation Analysis along Altitudinal Gradients around Nainital. PhD Dissertation. Kumaun University, Nainital.

Thandani R and Ashton PMS. 1995. Regeneration of Banj oak (*Quercus leucotrichophora* A. Camus) in the Central Himalaya. Forest Ecol Managem. 78: 17-224.

Tiwari AK and Singh JS. 1984. Mapping forest biomass in India through aerial photographs and non-destructive field sampling. Appl Geogr. 4: 151-165.

Tiwari AK and Singh JS. 1987. Analysis of forest land-use and vegetation in a part of central Himalaya using aerial photographs. Environ Conser. 14: 233-244.

Upadhyay S, Joshi Y and Bisht K. 2018. Macrolichen diversity associated with a regenerating sacred grove; a case study from Futsil sacred grove, Gangolihat, Pithoragarh, Uttarakhand, India. International Journal of Ecology and Environmental Sciences. 44: 199-205.

Upreti N, Tewari JC and Singh SP. 1985. The oak forests of the Kumaun Himalaya (India): composition, diversity and regeneration. Mt Res Dev. 5: 163-174.

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon. 21: 213-251.