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STRUCTURE OF CENTRAL HIMALAYAN FORESTS UNDER DIFFERENT MANAGEMENT REGIMES: AN EMPIRICAL STUDY

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Abstract

The conservation, management and sustainable resource utilisation of forests are crucial issues keeping in view the growth in population. Among the conservation approaches, three are commonly known in the Indian Central Himalaya. They are: (1) Traditional Conserved Forests (TCF), (2) Government Conserved Forests (GCF), and (3) Community Conserved Forests (CCF). The important indicators were identified for the assessment of these forests. Based on a comparative study, CCF was found diverse and rich in comparison to other forest types of the region.

Introduction

Forested landscapes are important ecological, economic, and social/ cultural resources that provide the basis for the sustainability of any region and contribute significantly to the quality of life of the local people . The extent of forest land within the landscape, in general, has a positive effect on the quality of the landscape (Brabyn, 2005). Sustainable management and utility of forest resources requires accurate information about their extent and spatial distribution (Lu et al., 2004). To understand the quality and structure of forests, data pertaining to forest species, density and average stand diameter are important.to assess. Human and forest ecosystem interaction and resource conservation, management and development in such natural reservoirs are of major concern all over the world (Liu, 2001). Understanding the human influences on forested landscape needs additional attention in developing countries in view of complex interaction between human and forest ecosystems. Furthermore, in the mountainous region the topography and environmental

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heterogeneity needs further emphasis as unsustainable forest resource management and overexploitation of the resources accelerates erosion, which partly contributes to devastating floods in the plains (Ives and Messerli 1989; Saxena et al. 2001).

The Himalayas in India account for more than 50 percent of its forest cover and comprise 40 percent of the species endemic to the Indian subcontinent. Various approaches exist in the Himalayan region for the conservation and management of forest resources. Among them three viz., sacred groves Traditional Conserved Forests (TCF), Government Conserved Forests (GCF) and Community Conserved Forests (CCF) have been selected for detail study. Here the hypothesis is introduced - How do forest structures differ from each other under the three conservation approaches and which conservation approach yields more fruitful results. To evaluate the hypothesis, important indicators (quantified information that help to summarise the complex information) such as species richness, diversity, frequency, density, total basal cover and importance value index (sum of relative values of frequency, density, and dominance) were chosen for the present study to understand pattern and vegetation dynamics across three different conservation regimes in the mountains of the Indian Himalayas.

Study area and climate

The study sites for this research are located in Pithoragarh, Chamoli and Tehri administrative districts of Uttarakhand State (Central Himalayas) of India. The forests types located in these administrative districts come under the Himalayan moist temperate forests category as per Champion and Seth's (1967) classification. The forests—TCF (Thalkedar of Pithoragarh district), GCF (Urgam of Chamoli district) and CCF (Jardhar of Tehri district)—were studied in detail (Table 1). These forests represent the whole mid-high elevational landscape of the Central Himalayas.

Table 1: Some characteristics of studied Forests

Parameters	Forests types		
	TCF Traditional Conserved Forest	GCF Government Conserved Forest	CCF Community Conserved Forest
Approximate area (ha)	1300	800	850
Altitude	1600-2450	1800-2300	1500-1935
Slope	30-40	35-45	25-35
Forest types	Mixed	Mixed	Mixed
Category of the forest	Moist Temperate	Moist Temperate	Moist Temperate
Ground vegetation	Dense	Comparatively sparse	Moderately Dense
Management regimes	Traditional socio-cultural	Government control	Community rules

Description of the study sites, forests and conservation theories

- **Traditional Conserved Forest (TCF):** The TCF or sacred forests, are guarded by the common village folk who safeguard them of green through their own set of rules, in the form of taboos, religious sanctions and belief systems. The sacred forest of Thalkedar is one such example (Negi 2005). The sacred forests are undisturbed ecosystems that are dedicated to the local deity and therefore not exploited for the sake of a livelihood. The Hariyali (Sinha and Maikhuri 1998; Ramakrishnan, et al,1998) and Kartik Swami landscapes of Central Himalayas, Konthoujam Lairembi, Mahabali, Laggol Thongak Lairembi and Heingang Marjing of north-east India (Khumbongmayum et al. 2006) and Oorani and Olagapuram in south India are examples of sacred groves where local people intertwine their socio-cultural and religious practices for the conservation and management of resources (Ramanujam and Kadamban 2001). Undoubtedly, the concept of sacred groves has saved the biodiversity to a great extent for many generations. But, due to a variety of factors, most of the world's sacred groves have disappeared and only a few still exist today (Ramakrishnan et al, 1998). Unfortunately, minimal efforts are being made for their better conservation. Empirical studies indicate that change in socio-cultural and religious beliefs, and migrants with different cultural value systems and beliefs adversely affect such traditional reservoirs (Saikia 2006).

- **Government Conserve Forest (GCF):** The forest department of a government ministry is the responsible and accountable for managing GCF through policies that include the Wildlife Protection Act 1972, Forest Conservation Act 1980, and Forest Policy 1988. Due to changes over time, the rights of communities have been taken away by the government, alienating them from management practices (Guha 1998 p. 95 cited in Bandhopadhyay et al. 2005; Wakeel et al. 2005). These forests are controlled by the forest department and the villagers are excluded from their management. Sometimes the government may also delegate the management to a panchayat (village council), non governmental organisations and adjacent residential communities but the forest department retains full ownership, command and direction of the forests. Hence it is not legally necessary to inform the people or stakeholders regarding management decisions taken by the forest department (IUCN 2002).

- **Community Conserved Forests (CCF):** The CCF have recently drawn the attention of conservationists, researchers and environmentalists. These forests are conserved through community efforts, and rules and regulations are setup to use the resources. All villagers, involved in the management of community forests, are responsible for the conservation of the resources from CCFs. This is a socio-ecological setup, that helps to maintain the forest resources while also using the forest produce needed for sustainable livelihood in rural areas (Kothari et al. 1998). The Jardhar forest in Tehri district is an example of the community-based conservation in the mountains of the Indian Himalayas. The external factors are not the big concern and locals are more responsible for the conservation of their forests. The theory behind community-based conservation is that "in a given case it is not necessary that community development objectives are consistent with the objectives setup for conservation" therefore, community-based conservation supports conservation theory in a positive way (Berkes 2004).

Methodology

The forests were visited and analysed for structure using established methods (Cottam and Curtis 1956; Ralhan et al. 1982; Saxena and Singh 1982, Nayak et al. 2000). The preliminary studies on TCF (Negi and Nautiyal 2005) and CCF (Semwal et al., 1999) were helpful to take this integrated approach for studying the different forests having different management regimes in the mountains of the Indian Himalayas. However, for this study the framework of methodology was revised and considered the entire forest in one forest stand (Figure 1).

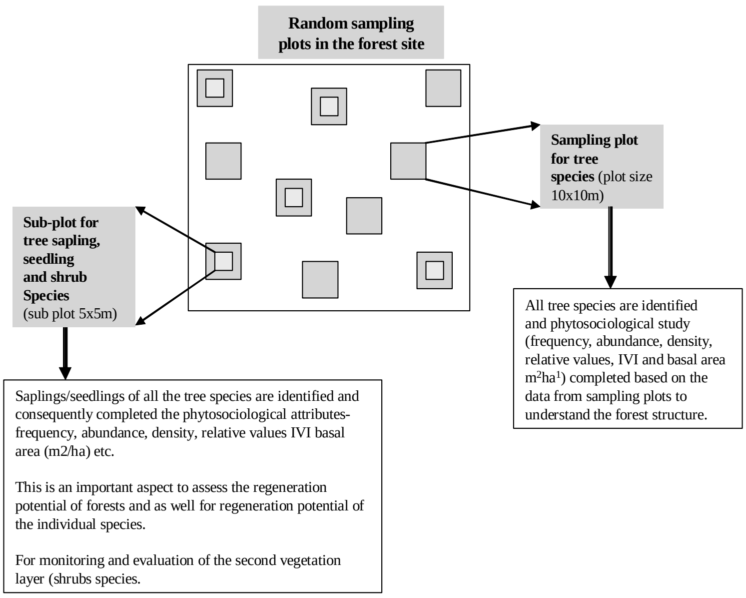

Figure 1: Framework to collect the ground data on forest structure and regeneration pattern

Geographical information was recorded through Global Positioning System (GPS) and sample plots were laid down randomly in all the forest types in the region. Density was calculated using the following formula.

$$d = \frac{xn}{n}$$

d= Density, xn = Total number of individual of a species in all quadrats

N=total number of quadrats studied

The basal cover was calculated using the following formula

Basal cover of a single tree, $BC = \pi * r^2$

$r = radius, \pi = 3.14$

Basal cover (m^2/ha) for each vegetation class (seedling, sapling and tree) obtained by adding value of all species together and presented as follows

$$BC = \sum_{i=1}^{n} BCSe, \sum_{j=i}^{n} BCSa, \sum_{k=1}^{n} BCTr$$

where BC = basal cover; n=number of species, Se=seedling; Sa=sapling Tr=tree;

To evaluate the ecological state of the investigated forest, the results were compared with those from other researchers for other forests located in the region. Relative frequency, relative density and relative dominance were calculated and summed to represent the importance value index (IVI) for each species in the forests (Nayak et al., 2000). The sum of relative frequency, relative density and relative dominance represented IVI and denotes the structural role for the various species in the forest. Similarity index (community coefficient) of woody species among three forests was calculated following the formula given by Jaccard (1912) as cited in Khumbongmayum et al. (2006).

$$Cj = j/(a + b - j)$$

where '*J*' is the number of species common to both stands, '*a*' is the number of species in stand A and '*b*' is the number of species in stand B.

The diversity was determined by using the Shannon and Wiener (1963) index:

$$\bar{H} = -\sum \frac{ni}{N} \log_2 (\frac{ni}{N})$$

and beta diversity ($\bar{\beta}$) among all the studied forests was calculated following the method given by Whittaker (1975).

$$\beta = \sum \frac{Sc}{s}$$

where Sc is the total number of the species among all the forests and s = number of species in per forest/stand. Concentration of dominance following Simpson (1949)

$$C = \sum (\frac{ni}{N})^2$$

where *ni* is the IVI of the species *i* and *N* is the IVI of the community. Meanwhile the Simpson reciprocal index was calculated for the assessment of the diversity of each studied forest in Central Himalayas.
Simpson's Reciprocal Index = 1 / D

where $D = \frac{\sum n(n-1)}{N(N-1)}$

N = Total number of species, *n*= number of species in one community

The concentration of dominance increases with a decrease of diversity. However, the Simpson reciprocal index an increases with increase in diversity.

During field visits the local people, mainly knowledgeable elders, were also asked to provide information pertaining to plant use for a variety of purposes in their socio-ecological setup.

Results and Discussion

The tree and shrub species recorded in the studied forests of the Indian Himalayas is depicted in Tables 2a and 2b. Briefly, the use value of the each species is also described in the tables. The maximum species (19 of tree and 25 of shrubs) was recorded in CCF, followed by (15 species of tree/tree seedlings, and 22 species of shrubs) in TCF and least (11 tree species and 21 shrub species) in GCF. The seedlings of all the mature trees were found in GCF and CCF. However, in TCF seedlings of three tree new species, viz., *Cornus oblonga*, *Cupressus torulosa* and *Lindera pulcherrima* was recorded as no mature trees of these species was found in study plots. The maximum number of species reported here are native to the Himalayas (Tables 2a and 2b).

Table 2a: Tree species of studied forests in Himalayas of India

Tree species	Vernacular Name	TCF	GCF	CCF	Uses	Nativity
Cedrus deodara (Roxb. Ex Lambert) D. Don	Devdar		+		F, T, M	H
Cinnamomum tamala Nees	Dalchini	-	-	+	F, Fd, M, T	EA
Coculus laurifolius DC	Tilphara	-	-	+	F, M, Mis	H,EA
Cornus capitata Wall	Bhamora	+	-	+	F, Fd	EH
Cornus macrophylla Wall	Khagsa	-	-	+	F, Ed, M	C,J,H
Cornus oblonga Wall	Kasmol	+	-		F, Fd, Ed	H,P,C
Cupressus torulosa D.Don	Surai	+	-		F, T, Mis	WC, H
Englehardtia sp	Mahuwa	-	-	+	F, Fd, M, Ed	
Fucus sp	Chadula	-	-	+	F, T, Ed	
Lindera pulcherrima	Cheir	+	-		T, F	EA
Litsea sp	Maliya	-	-	+	Fd, F, T, Ed	
Lyonia ovalifolia Wall (Drude)	Aynar	+	+	+	F,T,Fd,Ed,M	C,J,H
Machilus duthiei King ex Hook.f.	Kaul	-	-	+	Mis	EA
Morus serrata Roxb.	Satut			+	Ed, F, T	EA

Continued....

Tree species	Vernacular Name	TCF	GCF	CCF	Uses	Nativity
Myrica esculenta Buch-Ham. Ex. D.Don	Kafal	-	+	+	Ed, M, F, T	EA
Persea duthiei Hook.f.	Gardar	+	-	-	T, F	EA
Pinus roxburghii Sarg.	Kulain	+	+	+	T, F, M,Ed, Rl, Mis	EA
Prunus cerasoides D.Don	Paiyan	-	+	+	F, Ed. Rl, T, Mis	EA
Pyrus pashia Buch-Ham	Mehal	+	+	+	Ed, T, Fd, F, Mis	EH
Quercus floribunda Lindl.ex.A.Camus	Tilonj / moru	+	+	-	Fd, F, T, Ed, M	EA
Quercus lanuginosa (Lam.) Thuill.	Rianj	+	-	-	Fd, F, T, Ed, M	H
Quercus leucotrichophora A. Camus	Banj	+	+	+	Fd, F, T, Ed, M	H
Rhododendron arboreum Smith	Burans	+	+	+	Ed, F, M, Rl, Mis	H,EA
Rhus sp	Akhoriya	-	-	+	F, Mis	
Symplocos chinensis	Lodh	+	-	-	F, M	H, EA
Symplocos cretaegoides Buch-Ham	Lodh	-	-	+	F, M	H,EA
Viburnum cotinifolium D.Don	Guana	+	+	+	Ed, M, Fd, F, Mis	H
Viburnum mullaha D.Don	Baith bamora	+	-	+	Ed. M, Fd, F, Mis	H,EA
Total		15	11	19		

+ present in study plots, - absent in study plots, Abbreviations: F, Fuel; Fd, Fodder; M, Medicinal value; T, Timber, Ed, Edible; Rl, Religious; Mis, Miscellaneous; H, Himalaya; EA, East Asia; EH, Eastern Himalaya; WC, West China; C, China; J, Japan

A total of 68 species for primary and secondary vegetation layers was reported from all the studied forests. All the species were being used for a variety of purposes. The largest proportion of the species was reported as being used for medicinal purposes (30, 24, 22 for CCF, GCF and TCF respectively) followed by edible, fuel, fodder, timber, wood, and ornamental purpose. Several studies from the Himalayas reported the dependency of the local people on forest resources for a variety of purposes and the ethnobotany of the region is helpful to understand the human–plant interaction from the viewpoint of sustainable utilisation and conservation of the resources ((Maikhuri et al. 1998; Silori and Badola, 2000; Kala 2003).

Table 2b: Shrub species encountered through the studied forest of Central Himalaya

Shrub species	Vernacular Name	TCF	GCF	CCF	Uses	Nativity
Asparagus adscendens Roxb	Bhutroon	-	-	+	M, Ed, Or, Mis	H,EA,CH
Berberis aristata DC.	Kingora	+	+	+	M, F, Fd, Ed, D, Fn	H,EA
Berberis chitria Lindl.	Totar	-	-	+	M, F, Fd, Ed, Fn	H,EA
Coriaria nepalensis Wallich.	Makola	+	+	+	Ed, Md, Mis,	H,EA
Cotoneaster bacillaris Wall, ex.Lindl.	Ruins	+	+	+	Me, D, Mis	WH,EA
Cornus sp	Gaunta	-	-	+	W, Mis	
Daphne cannabina Wall.	Baruwa	+	+	-	M, W, Mis	H
Desmodium elagans DC	Chamlai	-	+	+	W, M, Fr, Mis	H,EA
Daphne papyracea Decne, Willich. Ex. Steud.	-	-	-	+	W, M, Fr, Mis	H,EA
Elaeagnus umbellata Thunb	Gyanli	+	+	-	M, W, Mis	H, EA
Euphorbia royleana Boiss	Sullu	-	+	+	Fn, Rl, P	B
Goldfussia dalhousiana Wall	Jaundela	+	-	-	Mis	H
Hypericum cernuum Roxb.ex D.Don	Silkya	+	-	-	M, Mis	
Hippophae rhamnoides L.	Ames	-	+	-	Ed, M, F, Mis	E, EA
Indigofera gerardiana Wall	Sakina	-	+	+	Ed, M, Fd, F	H,EA
Jasminum humile L.	Pilichameli	+	-	-	Ed, M, W, Ar	H,C
Lonicera sp	Garhruins	-	-	+	M, Mis	
Lonicera quinquilocularis Hardw	Bhatkukra	+	-	+	Ed, F	H
Leucas sp	-	-	+	+	Mis	
Mahonia nepaulensis DC.	Kaniya	+	+	-	Ed, M, Ar, D	EA

Continued....

Shrub species	Vernacular Name	TCF	GCF	CCF	Uses	Nativity
Myrsine africana L.	Ghani/ Jhingariya	+	+	+	M, Ed, W, Ar	H, NA, EA
Murraya sp	Marchyliya	-	+	+	Ed, M, Mis	
Princepia utilis Royle	Bhenkal	-	+	+	Ed, M, F, Fn	H, EA
Pyracantha crenulata D.Don	Ghingaru	+	+	+	W, Ed, F, Fd, M	H,C
Rhus parviflora Roxb.	Tungla	-	-	+	M, F, Fn, Fd	
Rhus cotinus L.	Jaltungla	-	-	+	M, Ed, F, Fd, Fn	E,WA
Rubus niveus Thunb.	Gowriphal	+	+	-	Ed, M, Fn, F	H,EA
Rubus ellipticus Sm.	Hisalu	+	+	+	Ed, D, M, Fn	H,EA
Rubus biflorus Buch.-Ham	Kala Hisalu	+	+	-	Ed, D, Mis	H,EA
Rubus lasiocarpus Sm	Kalihinsar	-	-	+	Ed, D	EA
Rosa brunonii Lindl	Kunjha	-	-	+	Ed, Fn, F, D	H
Sarcococca hookeriana Baill.	Sukat sing	+	-	-	W, Mis	H
Sarcococca sp	Sukat sing	-	+	+	W, Mis	EA,H
Smilax vaginata Decne.	Kukardura	+	-	-	Mis	H
Spiraea canescens D.Don.	Kath-ruins	+	-	-	W, Fn	EA
Senecio rufinervis DC.	Fusar-patya	+	-	-	F, Mis	E,WA
Symplocos ramosissima Wall	Lodra	+	-	-	Mis	H
Woodfordia fruticosa Kutz	Dhaula	-	-	+	F, Ed, D	H,EA
Wikstroemia canescens Wall	Chambai	+	-	-	F, Fr, Mis	EA, J
Zanthoxylum alatum Roxb.	Timru	+	+	+	Ed, W, Fn, M,	H, EA
Total		22	21	25		

+ present in study plots, - absent in study plots; Abbreviations: F, Fuel; Fd, Fodder; M, Medicinal value; T, Timber, Ed, Edible; Rl, Religious; D, Dye; W, Wood; Fr, Fibre; Or, Ornamental, Fn, Fencing; P, Poisonous; Ar, Aromatic; Mis, Miscellaneous; H, Himalaya; EA, East Asia; EH, Eastern Himalaya; WC, West China; C, China; J, Japan; E, Europe; NA, North Africa; B, Bhutan

The similarity index (community coefficient) of tree and shrub species is presented in Table 3. The similarity index illustrates significant differences in species composition between forests (Komo et al. 2002). The highest similarity index value (0.61) was recorded between TCF and GCF followed by GCF and CCF. Low (0.24) similarity noticed between TCF and CCF. The analysis of the similarity indices (Table 3) showed that the species composition differed between GCF and CCF of the region with comparatively few common species. However, the TCF and GCF seemed to be more similar than the other combination and, relatively more common species were recorded in these forests.

Table 3: Similarity index (community coefficient) of species in studied forests

Forests	TCF	GCF	CCF
TCF	1	0.61	0.24
GCF		1	0.45
CCF			1

Tree/ tree sapling

Data on density, basal cover (BC)/ m^2 and importance value index (IVI) for tree, tree seedlings and shrubs are shown in Tables 4a, 4b and 4c respectively. The top story vegetation in TCF forest was dominated by *Quercus leucotrichohora* (550 individual per ha) followed by *Q. floribunda, Rhododendron arboreum, Viburnum cotinifolium* (237, 227 and 150 individual per ha respectively). Least individual (20/ha) of *Q. lanuginosa* and *P. pashia* was recorded from this forest stand (Table 4a). The total basal cover (m^2/ha) at tree layer for TCF was recorded (28.32 m^2/ha) for *Q. leucotrichophora* followed by *R. arboretum* (10.478 m^2/ha), *Q. floribunda* (7.311 m^2/ha), *L. ovalifolia* (5.82 m^2/ha), *Q. lanuginosa* (4.945 m^2/ha) and least basal cover was recorded for *V. mullah* (0.1439 m^2/ha). CCF was found dominated by *C. capitata* (380 individual per ha) followed by *Quercus leucotricophora* (340 individual per ha), *Rhododendron* *arboreum* (280 individual per ha), *Myrica esculenta* (135 individual per ha). Minimum number of individuals in this forest was recorded for *M. duthiei* (22 individual per ha). The basal cover (m^2/ha) at tree layer for CCF was recorded highest for *Q. leucotrichophora* (17.28), followed by *Rhododendron arboretum* (5.41), *C capitata* (2.66) and least basal cover was recorded for *Rhus* species (0.026). Regarding density, GCF was dominated by *Rhododendron arboreum* (489 individual per ha) followed by *Q. leucotrichophora* (299) *Q. floribunda* (280), *Myrica esculanta* (205) and *P. roxburghii* (105). Minimum number of individuals (22) in this forest was for *C. deodara* (Table 4a). Basal cover (m^2/ha) at tree layer was recorded highest for *Q. floribunda* (7.35) followed by *R. arboretum* (5.98), *Q. leucotrichophora* (5.65) and least for *C. deodara* (0.0151). In mixed oak forests the density value for different species of *Quercus* ranged between 30 and 850 individual per ha with basal cover of 3.5 to 54.8 m^2/ha (Ralhan et al. 1985). The density value for *Myrica esculenta* was reported between 18 and 348 and for *Rhododendron arboretum* between 128 and 333 individual per ha in different forest types of the Central Himalayas (Ralhan et al. 1985; Saxena and Singh 1984; Maikhuri et al. 2000; Rawal et al. 2003). The density value for other species such as *C. oblonga*, *L. ovalifolia*, *P. pashia*, *V. cotinifolium*, *C. deodara*, *C. torulosa* has been reported in a range between 3 and 393 individual per ha in different forest stands of Central Himalayas (Saxena and Singh 1984; Ralhan et al. 1985; Rawat and Singh 1988).

Table 4a: Tree species of different forests for Central Himalaya

Tree species	TCF			GCF			CCF		
	D	BC/m²	IVI	D	BC/m²	IVI	D	BC/m²	IVI
Cedrus deodara				22	0.0154	4.4505			
Cinnamomum tamala							23	0.04	3.5357
Coculus laurifolius							30	0.079	4.7264
Cornus capitata	40	0.6155	9.7113				380	2.66	37.0155
Cornus macrophylla							35	0.67	7.5310
Cornus oblonga									
Cupressus torulosa									
Englehardtia sp							69	0.204	6.5359
Fucus sp							30	0.077	3.1393
Lindera pulcherrima									
Litsaea sp							116	0.176	13.0730
Lyonia ovalifolia	113	5.82	24.8001	30	0.1202	8.7549	130	0.611	12.5779
Machilus duthiei.							22	0.088	4.2785
Morus serrata Roxb.									
Myrica esculenta				205	3.45	34.1049	135	2.51	21.3418
Persea duthiei	65	2.51	12.2821						
Pinus roxburghii	120	1.86	18.1794	105	1.52	16.5654	80	2.08	14.48
Prunus cerasoides				42	2.114	19.6691	132	1.472	14.3226
Pyrus pashia	20	0.531	3.8279	45	2.245	18.9703	65	0.235	9.2714
Quercus floribunda	237	7.311	39.2799	280	7.35	56.2695			
Quercus lanuginosa	20	4.945	12.4634						
Quercus leucotrichophora	550	28.32	91.3632	299	5.65	50.8170	340	17.28	78.3530
Rhododendron arboreum	227	10.478	39.9148	489	5.98	66.3858	280	5.41	40.1193
Rhus sp							39	0.026	3.6056
Symplocos chinensis	50	0.8585	7.0175						
Symplocos cretaegoides							60	0.217	8.1380
Viburnum cotinifolium				75	3.25	24.0121			
	150	1.447	26.9344				70	0.103	8.9808
Viburnum mullaha	103	0.1439	14.2254				67	0.238	8.9732

D= density, BC = basal cover; IVI= Importance Value Index

Table 4b: Tree seedling of different forests for Central Himalaya

Tree seedling	TCF			GCF			CCF		
	D	BC/m²	IVI	D	BC/m²	IVI	D	BC/m²	IVI
Cedrus deodara				205	0.0135	23.1585			
Cinnamomum tamala							50	0.038	10.7331
Coculus laurifolius							57	0.0064	6.2373
Cornus capitata	360	0.0667	25.7448				75	0.0115	8.6760
Cornus macrophylla							100	0.0296	13.3998
Cornus oblonga	225	0.048	19.2012						
Cupressus torulosa	5	0.0019	1.7536						
Englehardtia sp							65	0.0088	8.1784
Fucus sp							44	0.0924	14.4583
Lindera pulcherrima	324	0.038	21.5739						
Litsaea sp							124	0.0084	11.1781
Lyonia ovalifolia	287	0.071	26.1636	215	0.0321	26.0025	146	0.0532	16.4381
Machilus duthiei							66	0.0085	6.6548
Morus serrata.									
Myrica esculenta				208	0.0548	30.1234	246	0.285	46.2789
Persea duthiei	311	0.0652	25.5727						
Pinus roxburghii	151	0.09	19.9405	250	0.0101	24.2590	67	0.0348	11.2642
Prunus cerasoides				387	0.0478	34.0271	151	0.0268	12.8246
Pyrus pashia	184	0.0155	14.5362	115	0.0032	11.78	66	0.0087	8.2250
Quercus floribunda	525	0.1246	41.8876	232	0.089	40.3546			
Quercus lanuginosa	80	0.0085	6.6988						
Quercus leucotrichophora	704	0.0713	35.1993	247	0.074	41.6771	814	0.235	66.9836
Rhododendron arboreum	247	0.0887	27.3876	287	0.054	38.3851	250	0.075	22.2178
Rhus sp							44	0.020	7.4548
Symplocos chinensis	80	0.0353	11.7997						
Symplocos cretaegoides							38	0.0027	5.6763
Viburnum cotinifolium	167	0.031	14.0436	204	0.039	30.2421	96	0.012	10.7929
Viburnum mullaha	48	0.01	8.4961				154	0.0148	12.3273

Table 4c: Shrub species encountered through the studied forest of Central Himalaya

Shrub species	TCF			GCF			CCF		
	D	BC/m^2	IVI	D	BC/m^2	IVI	D	BC/m^2	IVI
Asparagus adscendens							278	0.078	13.5089
Berberis aristata	450	0.05538	22.5104	190	0.08	16.6650	175	0.12	12.9800
Berberis chitria							124	0.13	10.8381
Coriaria nepalensis	53	0.336	18.1164	120	0.12	14.0203	411	0.076	16.6320
Cotoneaster bacillaris	26	0.034	4.2769	175	0.005	12.8106	216	0.021	8.4186
Cornus sp							136	0.032	7.0257
Daphane cannabina	1120	0.213	44.2265	154	0.85	54.4596			
Desmodium elagnans				385	0.0354	20.3244	246	0.076	14.0777
Daphane paparacea							316	0.012	9.4358
Elaeagnus umbellata	296	0.57	38.2433	180	0.187	18.8271			
Euphorbia royleana							421	0.15	19.4445
Goldfussia dalhousiana	216	0.027	8.3484						
Hypericum cernuum	26	0.0084	2.3866						
Hippophae rhamnoides				152	0.092	17.6244			
Indigofera gerardiana		254	0.0976	22.3870		236	0.187	16.8262	
Jasminum humile	226	0.012	11.3615						
Lonicera sp							147	0.076	9.8487
Lonicera quinquelocularis	350	0.289	28.1183				55	0.392	19.5384
Leucas sp				142	0.00134	9.2684	93	0.087	8.1056
Mahonia nepaulensis	230	0.186	20.4130	128	0.09	12.4136			
Myrsine africana	110	0.102	8.4018	71	0.089	10.2688	65	0.078	8.7853
Murraya sp				105	0.0034	5.3176	123	0.076	7.7836
Princepia utilis				81	0.0937	10.8355	162	0.143	10.8292
Pyracantha crenulata	236	0.0131	13.8909	134	0.0146	13.0945	236	0.10	14.4761
Rhus parviflora							318	0.12	13.91

Continued.....

Shrub species	TCF			GCF			CCF		
	D	BC/m²	IVI	D	BC/m²	IVI	D	BC/m²	IVI
Rhus cotinus							365	0.087	15.0325
Rubus niveus	140	0.004	8.8164	143	0.098	15.3598			
Rubus ellipticus	190	0.045	9.3618	151	0.0032	12.5020	269	0.045	11.1738
Rubus biflorus	20	0.0032	1.5828	198	0.0875	19.4703			
Rubus lasiocarpus							284	0.043	11.3610
Rosa brunonii							165	0.065	8.9028
Sarcococca hookeriana	37	0.0047	2.1211						
Sarcococca sp				180	0.0045	8.3983	251	0.076	10.4906
Smilax vaginata	376	0.0025	14.8936						
Spiraea canescens	129	0.0015	3.1412						
Senecio rufinervis	38	0.0039	3.0161						
Symplocos ramosissima	138	0.3874	22.3465						
Woodfordia fruticosa							187	0.098	9.8371
Wikstroemia canescens	284	0.01113	11.4197						
Zanthoxylum alatum	23	0.027	3.0056	111	0.012	5.9519	290	0.065	10.7388

The sum of all relative values (relative frequency + relative density + relative dominance) shows the dominance of the species in the forests. In natural forests, dominance can be shared by a number of species or one single species can be found dominant. In TCF and CCF the IVI for *Quercus leucotrichophora* was found to be 91.36 and 78.35 respectively, a dominant species in both the forest sites. In CCF the co-dominance is shared by many species—such as *R. arboretum* (40.11) and *C. capitata* (37.01). In TCF the co-dominance is shared by *R. arboreum* (39.9148) and *Q. floribunda* (39.2799).

Among the forests studied the GCF was comparatively species poor. In GCF the *Rhododendron arboretum* was found most dominant having high IVI value (66.3858) followed by *Quercus floribunda* (56.2695), *Q. leucotrichophora* (50.8170), *M. esculenta* (34.1049). The least IVI value was recorded for *C. deodara* (4.4505). It seems that the pressure for lopping *Quercus* species is high as this multipurpose species is always in demand for fodder and good quality fuel in the region (Bhandari et al. 1997). In all three forest studied of the Central Himalayas, the tree density was maximum in CCF (2103) followed by TCF (1695) and least density of standing tree species (1592) was recorded from the GCF (Figure 2). The basal cover (m^2 ha^1) for trees stratum for all the studied forests ranged from 31 to 65. The maximum was recorded for TCF (64.8399 m^2 ha^1) followed by CCF (34.176 m^2 ha^1) and the least was for GCF (31.6934 m^2/ha^1). Total basal area and density of tree layer was reported in the range of 27–191.5 m^2/ha and 350 to 2070 plants per ha, respectively, for various broad-leaved, traditionally conserved (sacred grove) and protected (Nanda Devi Biosphere Reserve) forests of the Central Himalayas (Bhandari and Tiwari 1997; Maikhuri et al. 2000; Saxena and Singh 1982; Sinha and Maikhuri 1998). Within the present study the values for individual per ha are slightly higher than those previously reported because here tree saplings and tree species were grouped together.

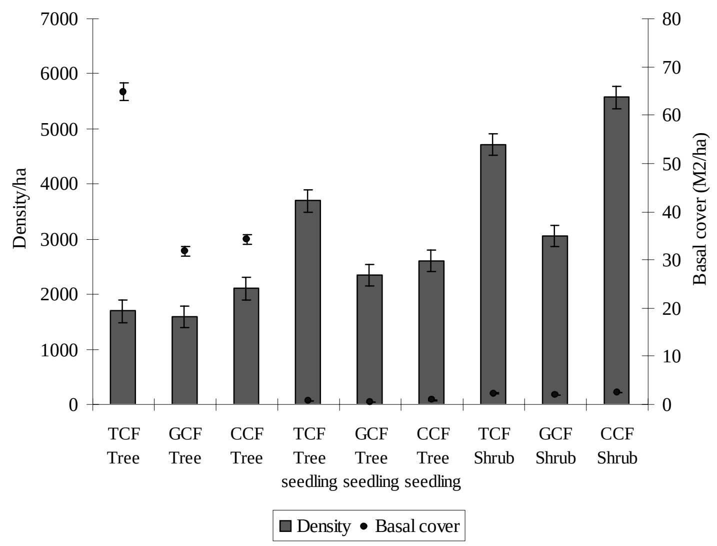

Figure 2: Density and basal cover of different vegetation strata in the study region

High basal cover and low density in TCF in comparison to CCF suggests that few species have attained maturity in this forest. Higher values of density and lower values of basal cover suggest that the CCF is younger and newly conserved. High tree density suggests that the diversity and luxuriance of this community forest may be maintained in a healthy state if the extent of biotic pressure is maintained at an optimum limit. Low density and basal cover (m^2/ha) of GCF indicates that the pressure on such forests in the Himalayas is comparatively higher than that of TCF and CCF. Studies have reported that strict protection of natural ecosystems and overexploitation lead to changes in vegetation dynamics (structure, species composition and diversity) of the area, (Vega-Garcia and Chuvieco 2006; Nautiyal and Kaechele 2007) besides influencing the productivity and quality of forest resources (Bhandari 2003).

Based on our empirical study the results show that the TCF of the Central Himalayas was once dominated completely by *Q. leucotricophora*, which is a late successional and climax species. Rules based on religious/ traditional beliefs kept such forests unmolested. Therefore, few successional species attained the status of the climax species in the forest. In GCF, the analysis indicated (moderate density, low diversity and less basal cover) that pressure on this kind of forest in the Central Himalayas is high in comparison with other forests (CCF and TCF). The high pressure to fulfill the demands of the people, coupled with other factors—such as not considering people's efforts in management of such forests—are the reasons for poor management of such forests (Maikhuri et al. 2000). In developing countries the governments' accession of a large tract in diverse and rich landscape to achieve the biodiversity conservation goal (Colchester 1997) accelerates conflicts between people and conservation policies and leads to further exploitation of the resources, rather than the sustainable utilisation (Nautiyal and Kaechele, 2007).

Tree seedlings

The number (density) of seedlings of any species can be considered as the regeneration potential of that species in the forest. High tree seedling density (individual/ha) was recorded maximum for TCF, followed by CCF and least for GCF. From the density values (Table 4b), the results showed that the regeneration of *Q. leucotrichophora* is low (247 individual per ha) in GCF in comparison to CCF (814 individual/ha) and TCF (704 individual per ha). The density of Quercus spp was high (1309 individual per ha) in TCF, but also the presence of many other species at seedling strata was found in TCF. The presence of *Pinus roxburghii* is an indication of high pressure on *Quercus* spp., in such kinds of unscathed ecosystems and the new arrival of three species was noticed in this grove (Table 4b). Anthropogenic pressure was found to be responsible for co-dominance of *Pinus roxburghii* in Quercus (oak) dominated forest, which is emphasised as a keystone species in the moist temperate region of the Himalayas (Bhandari 2003). This is because the regeneration potential of *Pinus roxburghii* is higher than that of Quercus species (Bhandari et al. 1997). In the GCF, high regeneration potential was recorded for *Prunus cerasoides*, followed by *Myrica esculenta*, *Rhododendron arboreum*, *Lyonia ovalifolia* (Table 4b). But, comparatively, the regeneration potential of *Pinus roxburghii* was very high in GCF (250 individual per ha). The Quercus (oak) a multipurpose species and having better fodder and fuel quality, was coming under threat in the central Himalayan forests due to high human pressure (Saxena et al. 1978; Tiwari and Singh 1982; Bankoti et al. 1986). However, few pockets, when disturbed by various anthropogenic factors (i.e., lopping, cutting burning etc.) changed the microclimatic conditions and this provides appropriate conditions for the chir-pine *(P. roxburghii)* - an early successional, low nutrient demander, light demanding and shade intolerant species- to invade, thereby posing a serious threat to the ecological balance of this region (Saxena et al. 1978; Tiwari and Singh 1982; Singh et al. 1984; Bankoti et al. 1986). Density (individual per ha) at seedling strata was found maximum for

TCF (3698 individual per ha) followed by CCF (2609 individual per ha) and least regeneration (2350 individual per ha) of tree species was recorded in the GCF (Figure 2). The regeneration potential of tree species in forests depends on the population structure, influenced by the production and germination of seeds, establishment of seedling and saplings in the forests (Rao 1988). In terms of regeneration potential, the TCF and CCF showed good regeneration potential. In general, both the anthropogenic factors (Khan and Tripathi 1989) and natural phenomenon (Welden et al. 1991) affect the regeneration of species in a forest's ecosystem. Complete absence or low density of seedlings of tree species in a forest indicates poor regeneration, while good occurrence of seedlings is an indicator of successful regeneration of the species at primary vegetation layer (Khumbongmayum et al., 2006; Saxena and Singh 1984).

Shrubs

Among the studied forests of the Central Himalayas, CCF showed good species richness of the second vegetation layer (shrub), followed by TCF and GCF. In CCF, density at shrub layer was highest for *E. royleana* (having 421 individual/ha) followed by *C. nepalensis* (411 individual/ha) and *R. cotinus* (365 individual/ha). However, the IVI was maximum for *L. quinquelocularis* (19.5384) subsequently for *E. royleana* (19.4445) and *C. nepalensis* (16.6320). The density of *D. cannabina* was highest in TCF (1120 individual/ha) and this species was also dominant in TCF (IVI 44.2265). *Berberis aristata* was second in density (450 individual/ha) in TCF, followed by *S. vaginata* (376 individual/ha), *L. quinquelocularis* (350) and *E. umbellata* (296). The co-dominance at shrub layer in TCF was shared by *E. umbellata* (IVI 38.2433), *L. quinquelocularis* (IVI 28.1183), *B. aristata* (IVI 22.5104) and *S. ramosissima* (IVI 22.3465). In GCF the density was highest for *D. elagnans* (385 individual/ha) followed by *I. gerardiana* (254 individual/ha), *R. biflorus* (198 individual/ha) and least individual (71) of M. africana was recorded at shrub layer in GCF. The *D. cannabina* was dominant (IVI 54.4596) in this forest stand at shrub layer.

The density (ha) and basal cover (m^2 /ha) at shrub layer was recorded maximum for CCF (5569 individual/ ha and basal cover 2.433 m^2 /ha), followed by TCF (4714 individual/ ha and basal cover 2.3362 m^2 /ha) and least (3054 individual/ ha and basal cover 1.9642 m^2 /ha) was reported for GCF (Figure 2). The shrub density of TCF and GCF was comparable to other broad leaved forests of the Central Himalayas (Bhandari and Tiwari 1997; Bhandari et al. 1997). Among the forests studied, comparatively high density of shrubs was found in CCF. The high basal area and large canopy cover of the primary vegetation layer in TCF do not allow much regeneration and growth of secondary vegetation beneath the tree cover as in CCF. In CCF, high species richness in shrub layer may be due to the relatively less developed canopy in these young forests where sufficient sunlight reaching the ground results in high regeneration of shrub species. However, it is assumed that high anthropogenic pressure is responsible for the lowest density and diversity of secondary vegetation layers in GCF (Figure 2).

The distribution pattern indicated that forest species are distributed contagiously (clumped) in TCF (1.08) and GCF (1.20) followed by random distribution in CCF (2.69). The distribution pattern of trees did not correspond with the distribution pattern of shrubs. Similar findings have been reported for the Central Himalayan forests by different workers (Bhandari and Tiwari 1997; Saxena and Singh 1982). Clumped (contagious) distribution in natural vegetation was reported by Kershaw (1973), Singh and Yadava (1974), and Singh and Singh (1991). Odum (1971) described that in natural conditions, contagious (clumped) distribution was the most common type of distribution that is caused by small but significant variations in the environmental conditions. The preponderance of random distribution in tree and seedling layers, as compared to shrub layers, reflects the dimension of biotic interferences in the forest.

Diversity of the studied forests in the Central Himalayas

Diversity parameters are summarized in Table 5. Diversity is a combination of two factors, the number of species present, referred to as species richness and the distribution of individuals among the species, referred to as evenness or equitability. Single species populations are defined as having a diversity of zero, regardless of the index used. Species diversity therefore, refers to the variations that exist among the different forms. Among the studied forests the Shannon–Wiener index was recorded highest for CCF followed by TCF and least for GCF. Previous studies report that the moderate amount of disturbance in forest ecosystems promotes species diversity (Singh et al. 1997; Thadani and Ashton 1995). However, overexploitation and strict protection also change vegetation dynamics, but in natural conditions it always gives negative implications (Nautiyal and Kaechele 2007) as homogenisation generally has a negative impact on the landscape (Vega-Garcia and Chuvieco 2006).

Table 5: Species diversity ($\bar{H}$) for different vegetation layer and Beta Diversity (β) for all the studied forests of Central Himalaya

Parameters		TCF	CCF	GCF
Shannon-Wiener Index ($\bar{H}$)				
	Tree layer	2.46	2.72	2.21
	Tree seedling layer	2.839	3.24	2.32
	Shrub layer	2.651	3..01	2.02
Beta Diversity (β)				
	Tree layer	1.82	2.21	1.79
	Tree seedling layer	1.20	1.38	1.03
	Shrub layer	1.25	1.33	1.05
Concentration of dominance (cd)				
	Tree layer	0.1518	0.1155	0.1474
	Tree seedling layer	0.1003	0.090	0.1067
	Shrub layer	0.0770	0.0441	0.0615
Simpson reciprocal index	For whole forest	2.92	3.06	2.78

The value of beta diversity was recorded highest for CCF with 2.21 tree, 1.38 seedling and 1.33 shrub layer. These values for CCF were found to be comparable with the other broad leaved forests of the region (Bhandari et al. 1997; Ralhan et al. 1982) however, lower for TCF and GCF. The concentration of dominance (cd) showed low values for tree, tree seedling and shrub layers for CCF, followed by GCF and TCF. This value decreases with increasing diversity. A higher concentration of dominance shows the lower species diversity in the forest. It simply means that CCF is species rich at the top vegetation layer and second layer (shrub). The concentration of dominance and diversity are indirectly proportional to each other (Singh and Singh 1991). The Simpson reciprocal index was used to evaluate the diversity of all three studied forest of the Central Himalayas and found that CCF forest is highly diverse and rich (3.06) in comparison to TCF (2.92) and GCF (2.78). The comparative study done here was to evaluate the hypothesis that how every conservation approach differ from each other in regard to diversity and structure of the forests. It was found that the conservation in CCF to be more positive and the analysis done here would be helpful in assessing the potential value of the effective and fruitful conservation program/regimes in the mountains of the Indian Himalayan region.

Conclusion

In general, the quality of all the forests studied is comparable with other good forests of the region. The current study supported the community conservation approach that positive human influences have positive external effects on the structure of the forest conserved through community efforts. The CCF was species-rich having high density and diversity of species. However, the TCF was also species-rich but not as significant as the CCF. The high basal cover of TCF indicates that this forest is preserved to last many generations. Data based on empirical studies shows that GCF is comparatively poor when comparing the indicators taken in this study for evaluation of forest quality. The field study concludes that the theory and practical applications for CCF gives positive results and support

The empirical study could explain, generally, the present status of the forests, but not the developmental phases under the different conservation regimes. The scientific question arises regarding the nature of the developmental phases of the forests under different conservation regimes? What is the path dependence of the current situation of these forests? The present situation is result of long-term management or natural phenomenon in varied topographic or environmental conditions? To answer these questions there is a need to understand the developmental pattern of the forests using a spatio-temporal framework. In this context, remote sensing analysis with visual observations, would be a helpful tool to provide accurate information on the spatial extent of vegetation cover in multi-temporal dimensions.

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