TEMPORAL CHANGES IN TREE SPECIES COMPOSITION IN SHIMLA FOREST CIRCLE, HIMACHAL PRADESH

Status Report

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Himachal Pradesh Council for Science, Technology & Environment
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Introduction

The Himalayas cover a vast expanse of 595,000 square kilometres with 2,400 km of parallel mountain ranges encompassing parts of India, Pakistan, Afghanistan, China, Bhutan, Nepal, and Tibet. Situated between 72^0- 91^0 E Longitudes and 27^0-36^0 N Latitudes, the Himalayas separate the alluvial plans of Indian subcontinent on the south from the Plateau of Tibet to the north; and connects the mountains of near East and Central Asia with those in the East Asia. Further, the Himalayan landscape is characterised with a unique geographic and ecological profile, and is home to an array of rivers such as Yangtze Ganga, Brahmaputra, Ganga, Indus, Yarlung, Yangtze, Yellow, Mekong, and Nujiang, which serve as a critical water source for Asian countries.

The Himalayan ecological diversity is altitude dependent where climatic and topographic effects on ecosystems and biota become more pronounced with increasing gradient. Further, there exist stark differences between the eastern and the western Himalayas in altitude, precipitation, and vegetation patterns. The eastern Himalayas are four-times wetter than the western Himalayas with a higher snowline, and a rich biodiversity. Meanwhile, the western Himalayan ranges are farther apart from the plains with precipitous landscape and a colder-drier climate. The altitude gradient and climatic conditions play a decisive role in determining the vegetative pattern in the bio-diverse rich ecology of the Himalayas. At the mountain foothills, there are tropical and sub-tropical broadleaf forests; whereas temperate broadleaf mixed forests with a dominant canopy of oak and maple at the middle; and coniferous, sub-alpine, and alpine vegetation at the higher altitudes adorned with pine, hemlock,

spruce, and fir conifers. Areas under inaccessible landscapes are characterised with alpine grasslands, high-altitude meadows, scrubland, which is followed by snowline.

The Indian Himalayan Region

The Indian Himalayan Region (IHR) is home to over 72 million people living in over 10 states covering 95 districts in a total geographic area of 5 lacs square km. With its foot-hills in Shivalik at the south, the vast Himalayan region expands to the Tibetan Plateau on the north, thus, serving as a natural northern boundary for India. The region covers three bio-geographic zones – the trans Himalaya (cold deserts of Ladakh and Kargil in Jammu & Kashmir, Lahaul & Spiti in Himachal Pradesh), the Himalaya (north-west parts of Jammu & Kashmir and Himachal Pradesh and Uttarakhand on west), and Eastern & North-east India (Sikkim, Arunachal Pradesh, and Darjeeling district of West Bengal, Manipur, Meghalaya, Mizoram, Nagaland, Tripura). According to the State of Forest Report, (FSI, 2011), around 42 per cent of the total IHR area is covered under forests (one-third of the total forest area in India) offering invaluable ecological security and resources to the country. Around 22 per cent of India's total geographical area was found to be under forest cover, of which 2.99 per cent was under Very Dense Forest, 9.38 per cent under Moderately Dense Forest, and 9.18 per cent under Open Forest Area. In the Himalayan region, the extent of forest cover varies significantly across the Himalayan states. In terms of percentage of total geographic area under administrative boundary, in North-west region, Jammu & Kashmir, Himachal Pradesh, and Uttarakhand have 10.46%, 27.12%, and 45.43% of total area under forest cover, respectively; in Eastern region, Sikkim and Arunachal Pradesh had 47.14% and 79.96% respectively; and in North-Eastern region, states of Manipur, Meghalaya, Mizoram, Nagaland,

Tripura had 77.69%, 76.45%, 86.27%, 75.33%, and 73.68% of their respective geographic area under forest cover (FSI, 2017).

Forests of Himachal Pradesh

Himachal Pradesh is a mountainous state in the northernmost part of India, situated in the western Himalayas between latitude 30º 22' 40" N to 33 º 12' 40" N and longitude 75 º 45' 55" E to 79 º 04' 20" E. The State's geographic landscape is divided into three distinct regions – Shivalik up to 1500m altitude; Mid-Himalayans between 1500-3000m and above 3000m stands the Himadris. Two-thirds of Himachal Pradesh's area (55,673 square km) comes under recorded forest area, however, only 27.12 per cent of this area is accounted under forest and tree cover. One-third of the state's geographic area remains permanently under snow glaciers and inaccessible cold deserts, thus is permanently beyond the tree line. Administratively, the forests are classified as Reserved (5.12 per cent), Protected (89.45 per cent), and Un-classed forest (2.39 per cent), within which certain areas are categorised for specific wildlife, flora, and natural ecosystem protection (HPFD, 2012).

As per Champion and Seth (1968) classifications, Himachal Pradesh Forests are classified under 8 types:

Table 1: Forest Classifications for Himachal Pradesh

Forest Type	Altitude	Mean Annual Temperature / Rainfall	Dominant Forests
Tropical Dry Deciduous Forests	>1000 m above mean sea level	24-27°C 750-1300 mm/annum	*Shorea robusta* and other associates such as *Acacia catechu, Aegle marmelos, Feronia limonia, Anogeissus latifolia, Buchanania lanzan, Woodfordia fruitcosa, Indigofera pulchella, Eulaliopsis binata*
Tropical Moist Deciduous forests	>1000 m above mean sea level	21-26°C 1000-2000mm/annum	*Olea cuspidata, Acacia modesta* and other associates such as *Pyrus pashia, Coriaria nepalensis, Rhus continus, Indigofera gerardiana, Prinsepia utilis*
Subtropical Pine Forests	1000-1800m above mean sea level	15-22°C 1000-3000mm/annum	*Pinus roxburghii* and other associates such as *Terminalia chebula, Mallotus philippensis, Pyrus pashia, Syzygium cumini, Albizzia chinensis, Emblica sp., Acacia catechu, Murraya spp., Rosa moschata*
Himalayan Moist Temperate Forests	1500-3300m above mean sea level	13-16°C 1500-3300mm/annum	Chief Oaks - *Quercus leucotrichophora, Q. dilatata* Other associates such as *Rhododendron, Acer, Aesculus, Cedrus deodara*
Himalayan Dry Temperate Forests	>1,700m above mean sea level	6-17°C 80-800 mm/ annum	Conifers - *Cedrus deodara, Pinus gerardiana, Junipers, Abies, Pinus wallichiana* Broad-leaved – *Acer, Quercus*
Sub-Alpine Forests	2,900-3,500m above mean sea level	2-6°C 10-55mm/annum	Conifers – *Abies pindrow, Pinus wallichiana* Deciduous trees – *Betula utilis, Querus semecarpifola, Rhododendron*
Moist Alpine Scrub	>3,350 m above mean sea level	-	*Betula utilis, Berberis, Salix, Rosa, Aconitum, Lonicera*
Dry Alpine Scrub	>6,000 m above mean sea level	-	*Juniperus, Artemisia, Lonicera, Salix, Myricaria*

Source: (Champion & Seth, 1968)

The forest types are also stratified as per the altitude driven four agro-ecological zones in Himachal Pradesh.

Table 2: Agro-Ecological profile – Himachal Pradesh

	Zone I	Zone II	Zone III	Zone IV
Ecology	Sub Montane & Low Hill Sub-tropical	Mid Hills Sub-humid	High Hills Temperate Wet	High Hill Temperate Dry
Geographic Area (%)	18.43	8.37	16.54	56.61
Altitude (m)	240-1,000	1,001-1,500	1,501-3250	Above 2501
Mean Annual Temp	15 °C - 23°C	14°C - 22°C	9.1°C – 20.6°C	9°C - 20°C
Rainfall (mm)	1,100	1,500	1,000	>1,500
Dominant Forest	Tropical mixed deciduous and thorn scrub	Sub-tropical pine forest	Himalayan Moist Temperate forest	Sub-alpine
Native Species	*Acacia catechu, Emblica officinalis, Dalbergia sissoo, Terminalia chebula, Cassia fistula, Anogeissus latifolia, Zizyphus jujuba* Shrubs - *Euphorbia royleana, Adhatoda vasica, Vitex negundo, Woodfordia fruticosa*	*Pinus roxburghii* and its sub-types *Quercus incana, Lannea sp., Lyonia ovalifolia, Rhododendron arboretum, Indigofera sp., Myrsine sp., Rubus sp.* Himalayan Scrub – *Diospyros melanoxylon, Emblica officinalis, Carissa sp., Dodonea viscose, Acacia catechu, Anogeissus sp Lannea sp., Cassia fistula* Dry evergreen bush- *Olea cuspidata, Punica granatum*	Conifers - *Pinus wallichiana, Cedrus deodara, Picea smithiana, Abies pindrow* Broad-leaved – *Quercus incana, Q. semecarpifolia, Q. dilata* *Aesculus indica, Acer caesium, Prunus padus, Populus cilata*	Grass – *Agropyron longeristatum, A.semicostatum, Bracypodium sylvaticum, Bromus asper* Mesophytic Herbs – *Primula, Anemone, Fritillaria, Iris, Gentiana spp.* Other Herbs – *Sedum crassipes, Primula minutissima, Saxifraga imbricate, Potentilla fruticosa* Dwarf shrub – *Juniperus wallichiana, J. communis, Caragana sp.*
Districts	Kangra, Una, Hamirpur, Bilaspur, Solan, and Parts of Chamba, Sirmaur	Parts of Chamba, Kangra, Mandi, Shimla, Sirmaur, Kullu, Kinnaur, Hamirpur, Bilaspur	Shimla, Chamba, Kangra, Mandi, Kullu, Solan, Sirmaur, Kinnaur, Lahaul & Spiti	Kangra, Lahaul & Spiti, Kinnaur, and Parts of Chamba, Mandi, Kullu, Sirmaur, Shimla

Source: Agro-Ecological Zonation of Himachal Pradesh – Agricultural System Information Development at micro-level, Centre of Geo-informatics, CSK Himachal Pradesh Agriculture University, Palampur (Bhagat et al., 2006)

Himachal Pradesh is blessed with a rich biodiversity adorned with diverse natural ecosystems comprising 8 forest types, 38 sub-types, which are home to 3,295 plant species of the 45,000 found in India. 95 per cent of these species are endemic to the state and only 5 per cent known as exotic species have been introduced in the last 150 years. The state's forest ecosystem offers critical ecological, environmental, economic, and social support to the populace serving as a primary source of food, fuel, fodder, timber, and other non-timber forest produce for both urban and rural population. However, these forest resources are currently experiencing greater stress with increasing pressure from burgeoning population, and rising impact of anthropogenic activities. In the western Himalayas, in particular, striking vegetative changes are observed where in various plant species are migrating to higher altitudes owing to warming trends (Padma, 2014), while other remain in danger of extinction. Additionally, the Hindu-Kush-Himalayan region is witnessing early trends of greening while habitat loss of around 30 per cent is expected for Snow Leopards owing to continuous forest losses (Panday & Ghimire, 2012) (Forrest et al., 2012).

To that effect, this temporal study was designed to get a preliminary insight into the current status of vegetation viz. species composition in the four forest divisions - Shimla Forest Division, Theog Forest Division, Chopal Forest Division, and Rohru Forest Division under the Shimla Forest Circle. The assessment techniques are designed with scalable modalities that can be adapted to other forest circles in the State.

The next section outlines the details on study area and the adopted methodology with information on data sources and applied techniques of assessments. Following which, the section on Results and

Findings discusses the outcomes for Shimla, Chopal, Rohru, and Theog Forest divisions separately. The report concludes with a categorised and consolidated snapshot of species composition in the Shimla Forest Circle with information on tree community level variation with respect to altitudinal gradients.

STUDY AREA AND METHODS

District Shimla – A Background

District Shimla lies between 76°59' 22" to 78°18'40" East longitude and 30° 45'48" to 30° 43'0" North latitude, bordering Mandi and Kullu in the north, Kinnaur in the east, Sirmour in the west, Solan in the south-west, and Uttarakhand in the south-east. With an average elevation of 2206m above mean sea level, and an area of 5131 sq. km, the district is divided into eight development blocks viz. Shimla (Urban), Shimla (Rural), Theog, Rampur, Rohru, Chopal, Dodra-Kwar, and Kumarsain.

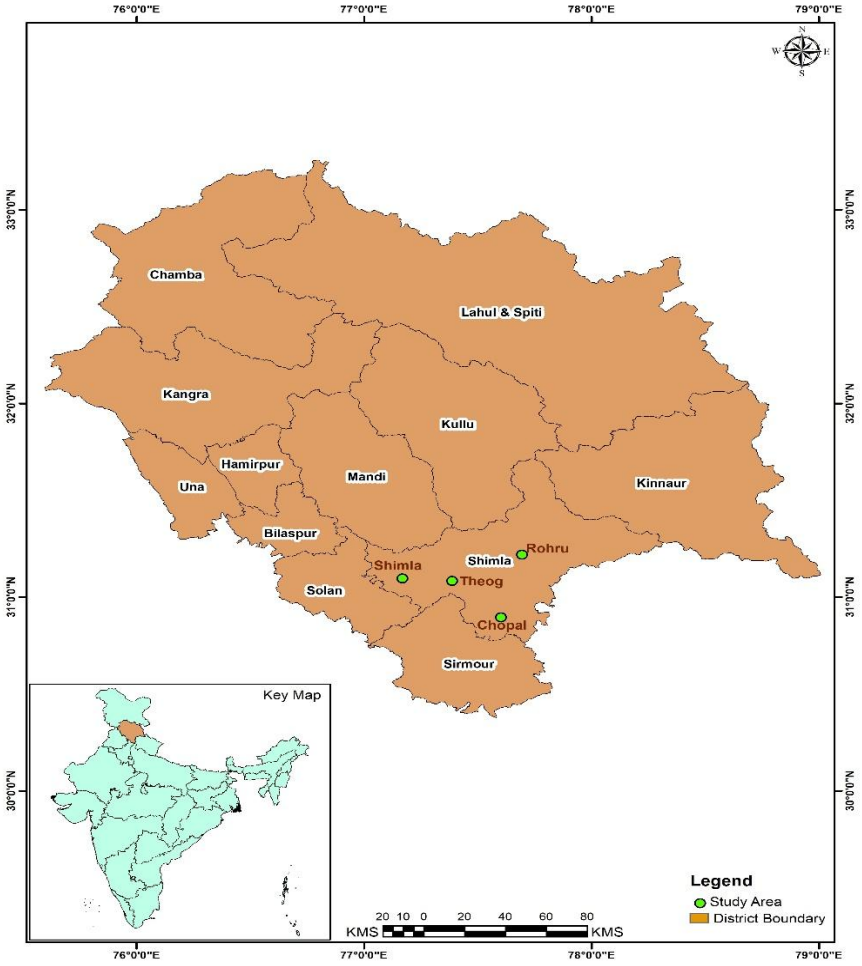

Figure 1: Forest Divisions of District Shimla, Himachal Pradesh
Source: HPSCCC, 2018

CLIMATE

The district experiences cool winters and moderately warm summers with annual temperature range of 4°C to 31°C, average temperature of 17°C (winters - 1°C to 10°C; summers - 19°C to 28°C), and mean precipitation of 1577mm. District Shimla gets four broad seasons – winters from mid-November to mid-March; spring from mid-March to mid-May; summers till mid-July; and monsoons extending up to mid-September. Autumn in District Shimla are relatively small, ranging from mid-September to mid of November, which follows an early setting of harsh winters. During peak winters, the upper reaches receive snow and sleet falls; while lower regions experience frequent rains.

FOREST

Table 3 below gives a snapshot of forest profile for Shimla Forest Circle with specific details on ecological zones, land use, forest administrative setup and ecosystem for the three forest divisions.

Table 3: Profile – Shimla Forest Circle

Forest Profile – Shimla Forest Circle				
Agro-Ecological Sub region	Western Himalayas, Warm Sub-humid			
Agro Climatic Zone (NARP)*	High Hill Temperate Wet Zone			
Land Use	**Geographical Area (sq. km):** 5131	**Legal Forest Area (sq. km):** 3418	**% of Forest Area** 66.6	**% of HP Forest Area:** 9.2
Forest Areas	**Reserved (sq km):** 53.4 (including 2 of wildlife)	**Demarcated Protected (sq km):**1149	**Un-demarcated Protected (sq km):** 2161	
Forest Cover	**Very Dense (sq.km):** 736	**Moderately Dense (sq. km):** 1039	**Open Forest (sq. km):** 624	
Key Biodiversity Areas	Daranghati Wildlife Sanctuary		171.5 sq. km	
	Shimla Water Catchment		10 sq. km	
	Talra Wildlife Sanctuary		46.48 sq. km	
Forest Divisions and ranges	***Forest Circle***	***Forest Division***	***Forest Range***	
	Shimla	Shimla	Mashobra Koti Bhajji Tara Devi Dhami	
		Theog	Theog Balson Kotkhai	
		Chopal	Chopal Kanda Nerwa Sarain	
		Rohru	Rohru Tikker Khashdhar Jubbal Bashala Sarswati Nagar	
Major Forest Ecosystems	Division – Shimla, Chopal, Rohru, Theog Forest Division *Tropical Dry Deciduous Forest* *Sub-Tropical Pine Forest* *Himalayan Moist Temperate Forest*			

Source: Himachal Forest Statistics, HPFD, (2013), *Forest Survey of India* (FSI, 2017)

Aims &Objectives: To study the status of forest tree species by

1. Identifying the tree communities (pure and mixed) based on the relative density of tree species.

2. Analysing the variations in species compositions along different altitudinal gradients as well as diameter classes.

Methods

To ascertain the temporal changes in different tree species composition in the three forest division of Shimla, Chopal, Rohru, and Theog under the Shimla Forest Circle, two-tier assessment was conducted, covering: *1) tree community based variation; and 2) altitude gradient driven variation.*

For each of the four forest divisions, enumerated data was collected, and analysed for their respective forest ranges.

- ***Shimla Forest Division*** – There are five forest ranges in this division *viz.* Mashobra, Koti, Bhajji, Tara Devi, and Dhami. The last ranges i.e. Tara Devi and Dhami were not considered as their respective working plans couldn't be procured. The total area of these forest ranges is 10,297ha out of which 1793.2ha was assessed in this study.
- ***Chopal Forest Division*** – There are four forest ranges in this division *viz.* Chopal, Kanda, Nerwa, and Sarain. Total forest area under this division is 13602ha out of which 6876.3ha was assessed in this study.
- ***Rohru Forest Division*** – There are six forest ranges in this division *viz.* Rohru, Tikker, Khashdhar, Jubbal, Bashala, and

Sarswati Nagar. Total forest area under these ranges is 25194ha, of which 9429.74ha was assessed in this study.

- ***Theog Forest Division*** – There are three forest ranges in this division *viz.* Theog, Balson, and Kotkhai. Total forest area under these ranges is 31,722.4ha, of which 1660.9ha was assessed in this study. We have taken less then 10% area assessed because of data shortage.

DATA SOURCES AND TECHNIQUES

Working plans from the Himachal Pradesh Forest Department and Compartment History files were consulted and the species composition change during the successive working plans was analysed for four forest divisions i.e. Shimla, Chopal, Rohru, and Theog. The time period for each division is different as per enumerated information available through these working plans.

Shimla Forest Division: 1981-1996

Chopal Forest Division: 1965-2003

Rohru Forest Division: 1969-1994

Theog Forest Division: 1981-1996

Working plan is a written scheme of management that aims to ensure continuity of policy action, and controlled treatment of a forest. Within a working plan, Forest Division is the basic unit. This document is utilized to evaluate status of forests and the biodiversity resources within a particular division.

Respective files were collected from the library of Himachal Pradesh Forest Department, and offices of the four forest divisions and their respective ranges.

Based on the information from the Working Plans for the Shimla Forest Circle and information from the Compartment History files, tree communities were identified. Table 4 gives information on the identified species for Shimla, Chopal, Rohru, and Theog forest divisions.

Table 4: Division-wise Detail on Tree Community and respective Altitude Gradient, Forest Compartment, and Area Assessed, Shimla Forest Circle

Forest Division	Tree community	Min. altitude (m)	Max. altitude (m)	Forest Compart.	Area assessed (ha)
Shimla Division	*Cedrus deodara*	1710	2300	16	627.2
	Pinus roxburghii	1200	1945	6	327.8
	Pinus wallichiana	1785	2342	7	280.8
	Quercus leucotrichophora	1490	1980	5	268.8
	Cedrus deodara-Quercus floribunda mixed	1830	2440	1	38.4
	Cedrus deodara-Quercus leucotrichophora mixed	1980	2310	1	98.8
	Pinus roxburghii-Cedrus deodara mixed	1750	3130	1	36.4
	Pinus roxburghii-Broad-leaved mixed	1680	1900	1	12.6
	Pinus wallichiana-Quercus floribunda mixed	1890	2316	1	102.4
Total				**39**	**1793.2**
Chopal Division	*Cedrus deodara*	1785	2580	69	2373.41
	Pinus wallichiana	1680	2910	11	375.46
	Quercus floribunda	2150	2520	1	60.7
	Picea smithiana	2160	2850	10	478.2
	Abies pindrow	2400	2880	5	353.68
	Broad-leaved	2150	2550	4	269.51
	Quercus semecarpifolia	2650	3580	2	225.81
	Cedrus deodara-Pinus wallichiana mixed	1920	2380	4	118.15
	Cedrus deodara-Quercus floribunda	2070	2370	1	59.08

	mixed				
	Cedrus deodara-Quercus semecarpifolia mixed	2160	2850	2	127.87
	Cedrus deodara- Abies pindrow mixed	2070	2760	3	122.21
	Cedrus deodara- Broad-leaved mixed	2070	2650	2	152.96
	Cedrus deodara- Picea smithiana mixed	2150	2700	1	23.47
	Pinus wallichiana-Cedrus deodara mixed	2220	2700	2	100.77
	Abies pindrow-Cedrus deodara mixed	1950	2670	3	142.04
	Abies pindrow-Picea smithiana mixed	2250	2757	3	101.97
	Broad-leaved- *Taxus baccata* mixed	1980	2850	1	32.37
	Picea smithiana-Abies pindrow	2160	2880	5	291.34
	Picea smithiana-Broad-leaved	2070	2400	1	37.23
	Picea smithiana Cedrus deodara	2160	2695	1	73.65
	Picea smithiana-Taxus baccata mixed	2460	3470	2	193.43
	Picea smithiana-Quercus semecarpifolia mixed	2460	3490	2	207.22
	Pinus wallichiana-Broad-leaved mixed	2070	2400	1	56.65
	Pinus wallichiana-Quercus leucotrichophora mixed	1950	2280	2	73.64
	Broad-leaved- *Pinus wallichiana* mixed	1890	2200	1	75.27
	Broad-leaved- *Abies pindrow* mixed	2040	2490	1	50.18
	Taxus baccata- Abies pindrow mixed	2220	2760	1	54.63
	Quercus semecarpifolia-Taxus baccata mixed	2280	3360	4	491.68
	Quercus semecarpifolia-Picea smithiana mixed	2490	3450	1	153.73
Total				**146**	**6876.31**
Rohru Division	*Cedrus deodara*	2034	2819	19	1365.82
	Pinus wallichiana	2187	2712	45	4551.71
	Abies pindrow	2700	2945	9	1150.54
	Pinus roxburghii	1600	1974	6	399.02
	Broad-leaved	1650	2100	3	335.08
	Quercus	1700	1890	2	121

	leucotrichophora				
	Picea smithiana	2310	2690	1	66.37
	Abies pindrow-Broad-leaved mixed	2670	2900	1	117.36
	Pinus smithiana-Cedrus deodara mixed	2380	2415	4	346.01
	Abies pindrow-Picea smithiana mixed	2330	2440	3	309.17
	Cedrus deodara-Pinus wallichiana mixed	2010	2890	1	84.58
	Pinus wallichiana-Cedrus deodara mixed	2100	2800	1	212.4
	Broad-leaved-*Pinus wallichiana* mixed	2300	2760	1	82.55
	Picea smithiana-Abies pindrow mixed	2160	2700	2	288.13
	Total			**98**	**9429.74**
Theog Division	*Cedrus deodara*	1680	2670	15	517.7
	Pinus wallichiana	1580	2680	10	501
	Abies pindrow	2500	3010	1	75
	Broad-leaved	2210	2590	1	25
	Pinus wallichiana-Broad-leaved mixed	1800	2570	2	120.6
	Cedrus deodara-Pinus wallichiana mixed	1740	1830	1	16.6
	Cedrus deodara-Picea smithiana mixed	1980	2820	2	158.6
	Quercus floribunda-Broad-leaved mixed	2000	2680	2	87
	Pinus wallichiana-Picea smithiana mixed	2060	2620	1	67.6
	Abies pindrow-Quercus floribunda mixed	2130	2600	1	91.8
	Total			**36**	**1660.9**

For the assessment purpose, the forests were categorized according to the delineated communities i.e. if for a single species the relative density is more than 50 per cent, then the tree community was identified as ***single species dominant community***. For cases where more than one species collectively accounted for 50 per cent of the relative density, the tree community was referred as ***mixed community***. Forests were further classified into different altitude

gradients of 1,500-2,000m; 2,000-2,500m; 2,500-3,000m. For Shimla division, altitude ranges of 1000-1500m, 1500-2000m, and 2000-2500m were considered, as per the information from the working plans. Species composition was assessed for changes in the tree density, where *individuals per hectare* were calculated and the percentage change was determined for the two time period. The area under the assessed forest compartments for respective divisions was taken to be more than 10 per cent of the total forest area.

The next section elaborates the employed assessment techniques for *1) tree community based variation; and 2) altitude gradient driven variation*

ASSESSMENT TECHNIQUES

Tree Community-based Variations

Each forest division constitutes different tree communities where dominant species is identified based on its relative density *(more than 50 per cent categorised as dominant community; and a collective majority as mixed community*). For each of the identified pure species in each forest division i.e. Shimla, Chopal, Rohru, and Theog, variations in density were determined for the two time periods i.e. 1981-82 and 1996-97, 1965-66 and 2003-04, 1969-70 and 1994-95, and 1981-82 and 1996-97, respectively.

Altitude Gradient driven Variations

Three altitudes were selected for comprehensive representation of all tree species in the Shimla, Chopal, Rohru, and Theog Forest Divisions – 1,500-2000m, 2,000-2,500m and 2,500-3,000m. In the Working Plan documents, different values of altitudinal ranges were observed for certain species that were normalized by using the average values for

respective range. Further, the forest in a given altitude range was categorised according to species and their total number in both years was calculated. The density (individuals per hectare) was calculated for all species for respective altitudes that represented concentration of individual species in one hectare. This altitudinal based study was aimed to indicate species status, their density, and movement along altitudinal gradients.

Key Terminologies

Stand: An aggregation of trees occupying a specific area sufficiently uniform in composition (species), age arrangement, and condition to be distinguishable from the forest on adjoining areas.

Tree community: Group or association of populations of two or more different tree species that occupy the same geographical area at a particular time period

Forest compartment: A section of forest with homogeneous growth conditions and tree species

RESULTS & FINDINGS

This section presents the findings from the assessment of the tree community composition for four forest divisions i.e. Shimla Forest Division, Chopal Forest Division, Rohru Forest Division, and Theog Forest Division for their respective species.

Shimla Forest Division

Based on the assessment of Working Plans from the Himachal Pradesh Forest Department and Compartment History files from Mashobra, Koti, and Bhajji forest ranges, 4 pure tree communities - *Cedrus deodara (CD), Pinus roxburghii (PR), Pinus wallichiana (PW), Quercus leucotrichophora (QL);* and 5 mixed tree communities - *Cedrus deodara-Quercus floribunda, Cedrus deodara-Quercus leucotrichophora, Pinus roxburghii-Cedrus deodara, Pinus roxburghii-*Broad-leaved, and *Pinus wallichiana-Quercus floribunda* were identified between 1981 and 1996.

As highlighted earlier in

Table 4 these tree communities were assessed from 39 forest compartments spread over a total area of 1793.2ha.

The Tree Community based Variations

The following section discusses the tree community based variations in density for the species identified.

1. ***Cedrus deodara community***

   Data was collected from 16 forest compartments covering an area of 627.2ha, at altitude range of 1710-2300m above mean sea level. As

illustrated in Figure 2, in its dominant tree community, density of *Cedrus deodara* decreased from 338.7 ind./ha to 316.2 ind./ ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – density of all species recorded a decline except for *Pinus roxburghii,* where density increased from 1.3 ind./ha to 4.2 ind./ha. Amongst the declining species, maximum decline was seen for *Quercus floribunda* where density dropped by 87 per cent between the two time periods. Meanwhile, for Broad-leaved, *Quercus leucotrichophora, Cedrus deodara, Pinus wallichiana,* and *Picea smithiana* density declined by 43 per cent, 24 per cent, 7 per cent, 22 per cent, and 13 per cent, respectively between the two-years.

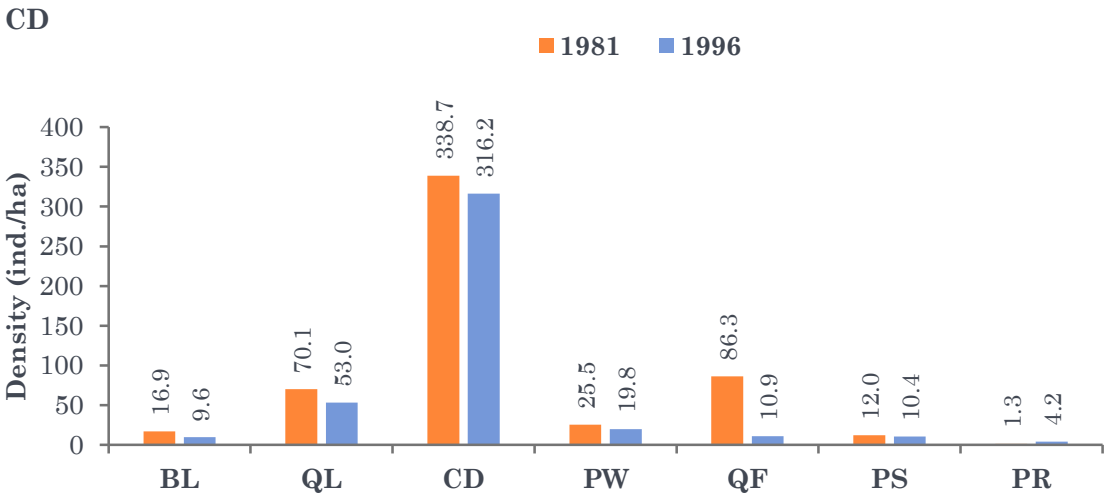

Figure 2: Density Variations in Species Composition in *Cedrus deodara* community, Shimla Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

2. *Pinus wallichiana community*

Data was collected from 7 forest compartments covering an area of 280.8ha, at altitude range of 1785-2342m above mean sea level, for pure *Pinus wallichiana* stands. As illustrated in Figure 3, in its

dominant tree community, density of *Pinus wallichiana* decreased from 268.6 ind./ha to 207.6 ind./ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – density of all species recorded a decline except for *Pinus roxburghii,* where density increased from 0.5 ind./ha to 0.6 ind./ha. Amongst the declining species, maximum decline was seen for *Quercus leucotrichophora* where density reduced by 67 per cent. Meanwhile, for Broad-leaved, *Cedrus deodara, Pinus wallichiana, Quercus floribunda,* and *Picea smithiana* density declined by 47 per cent, 19 per cent, 23 per cent, 19 per cent, and 21 per cent, respectively between the two-years.

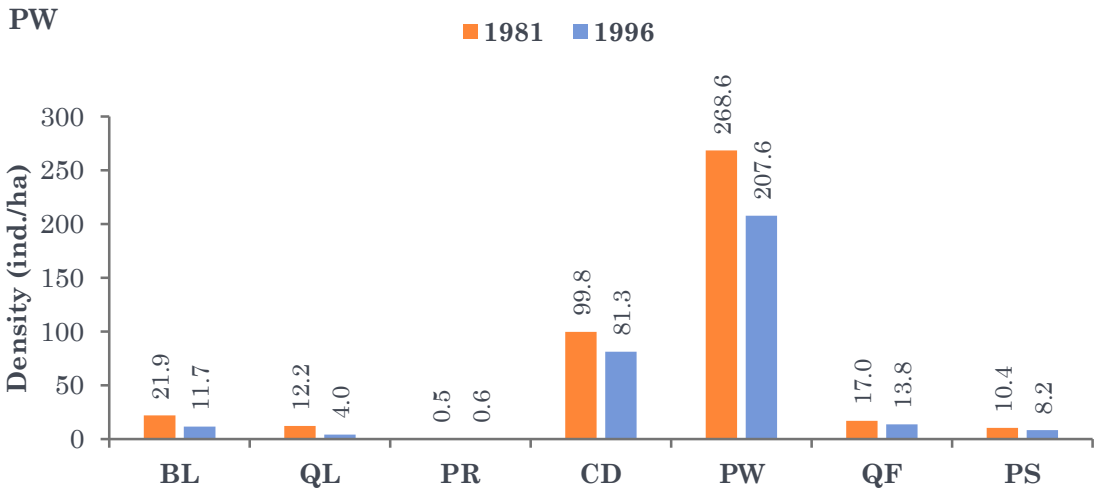

Figure 3: Density Variations in Species Composition in *Pinus wallichiana* community, Shimla Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

3. *Pinus roxburghii community*

Data was collected from 6 forest compartments covering an area of 327.8 ha, at altitude range of 1200-1945m above mean sea level, for pure *Pinus roxburghii* stands. As illustrated in Figure 4, in its

dominant tree community, density of *Pinus roxburghii* increased by nominal 3 per cent, moving from 187.8 ind./ha to 193.5 ind./ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – from 1981 to 1996, density of all species increased except for *Cedrus deodara* that witnessed a decline of nominal 1 per cent. Density of Broad-leaved, *Quercus leucotrichophora*, *Pinus wallichiana,* and *Quercus floribunda* increased by 5 per cent, 3 per cent, 2 per cent, and 29 per cent, respectively during the study period.

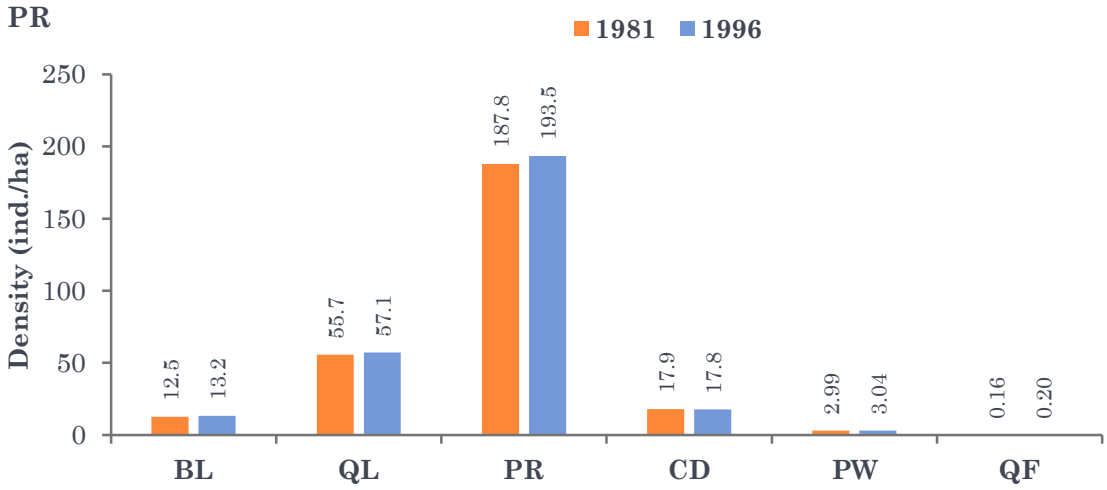

Figure 4: Density Variations in Species Composition in *Pinus roxburghii* community, Shimla Forest Division, 1981-1996
Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved; **PR**= *Pinus roxburghii;* **QL**= *Quercus leucotrichophora;* **QF**= *Quercus floribunda*
Source: HPSCCC, 2018

4. *Quercus leucotrichophora community*

Data was collected from 5 forest compartments covering an area of 268.8ha, at altitude range of 1490-1980m above mean sea level, for pure *Quercus leucotrichophora* stands. As illustrated in Figure 5, in its dominant tree community, density of *Quercus leucotrichophora* increased by 65 per cent from 1981 to 1996. In these forest compartments, representation (density) of other species between

1981 and 1996 is as follows – for *Cedrus deodara* and *Quercus floribunda* density surged by 22 per cent and 65 per cent, respectively. Meanwhile, tree density for Broad-leaved declined by 27 per cent, of *Pinus roxburghii* reduced by 26 per cent, of *Pinus wallichiana* declined by 40 per cent, and maximum decrease of 72 per cent was seen for *Picea smithiana* between 1981 and 1996.

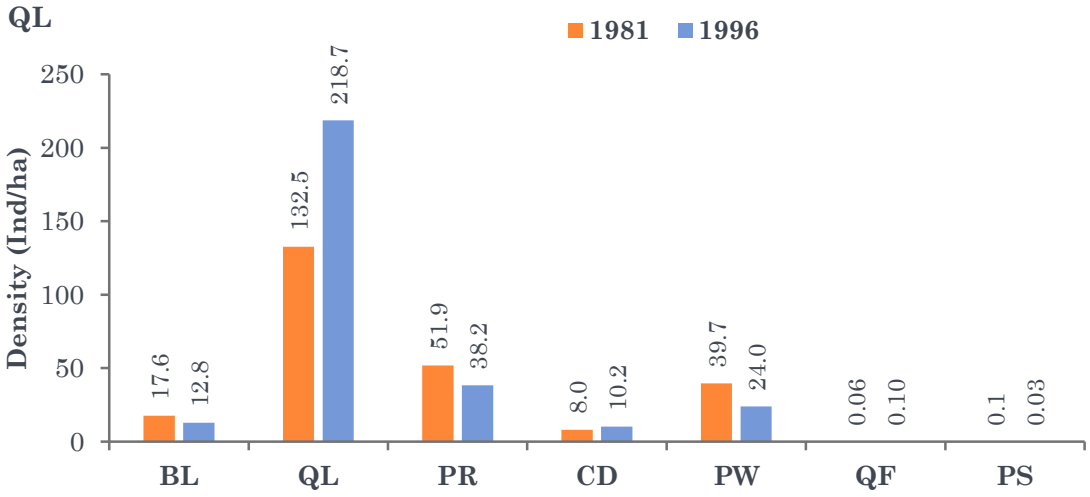

Figure 5: Density Variations in Species Composition in *Quercus leucotrichophora* community, Shimla Forest Division, 1981-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

5. *Cedrus deodara-Quercus floribunda* mixed community

Data was collected from 1 forest compartment covering an area of 38.4ha, at altitude range of 1830-2440m above mean sea level, for *Cedrus deodara-Quercus floribunda* mixed community. As per the enumerated data, tree density of *Cedrus deodara* declined from 303.8 ind./ha to 290.5 ind./ha; while for *Quercus floribunda* it remained unchanged at 152 ind./ha. Only *Pinus wallichiana* recorded a decline in density from 105.4 ind./ha to 100.4 ind./ha; for the other species i.e. Broad-leaved, *Quercus leucotrichophora, Pinus*

roxburghii, Quercus floribunda, and *Picea smithiana* individuals per hectare remained unchanged between 1981 and 1996, as exhibited in Figure 6.

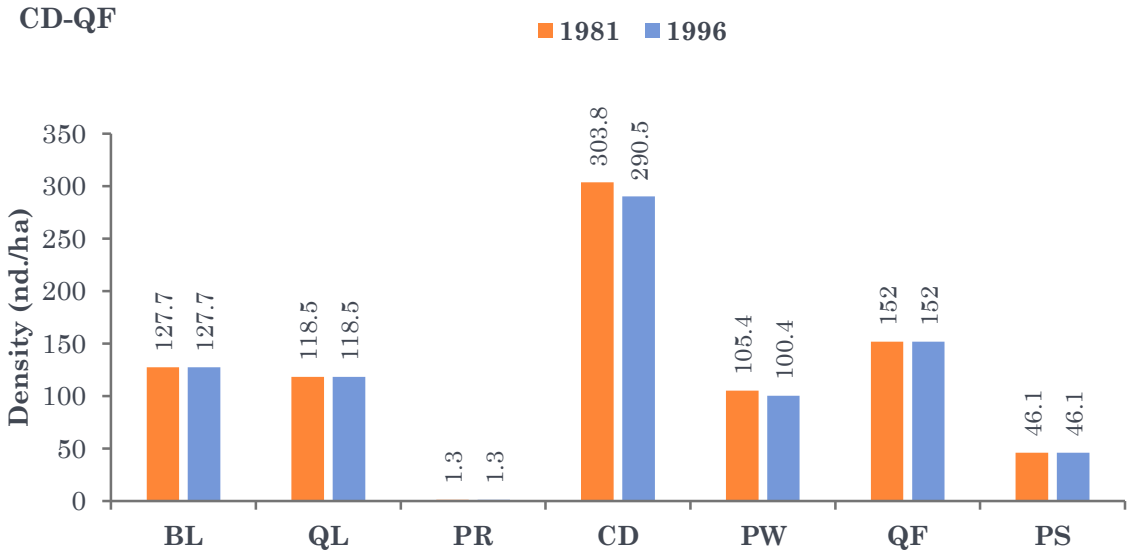

Figure 6: Density Variations in Species Composition in *Cedrus deodara-Quercus floribunda* mixed community, Shimla Forest Division, 1981-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

6. *Cedrus deodara-Quercus leucotrichophora* mixed community

Data was collected from 1 forest compartment covering an area of 98.8ha, at altitude range of 1980-2310m above mean sea level, for *Cedrus deodara-Quercus leucotrichophora* mixed community. The tree density of *Cedrus deodara* decreased by 28 per cent moving from 268.4 ind./ha to 193.5 ind./ha; while for *Quercus leucotrichophora,* tree density marginally increased by 0.1 per cent between 1981 and 1996. In these forest compartments, representation (density) of other species between 1981 and 1996 is as follows – density of *Pinus wallichiana* and *Picea smithiana* declined by 8 per cent and 4 per cent, respectively. Meanwhile,

density of Broad-leaved, *Pinus roxburghii,* and *Quercus floribunda* remained unchanged, as exhibited in Figure 7.

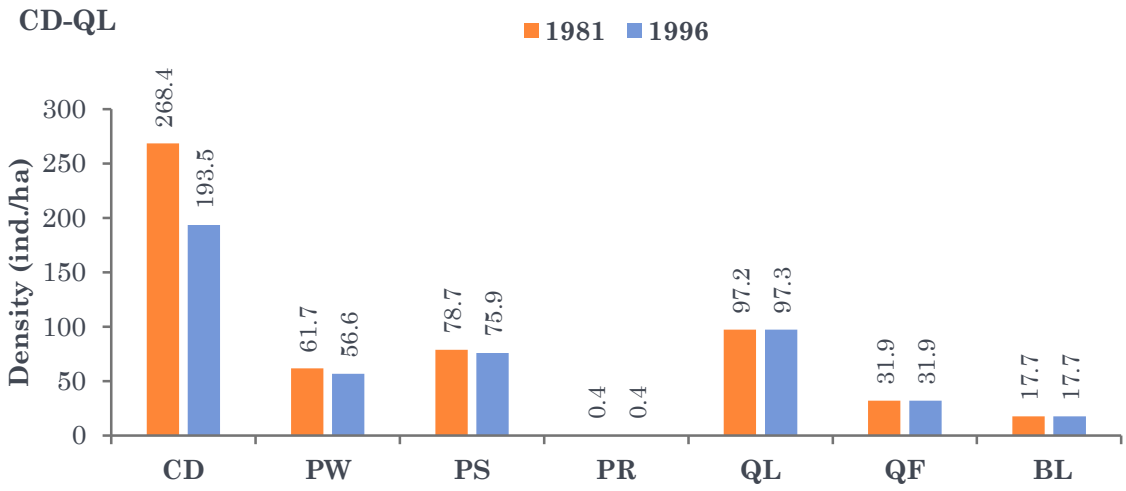

Figure 7: Density Variations in Species Composition in *Cedrus deodara-Quercus leucotrichophora* mixed community, Shimla Forest Division, 1981-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

7. *Pinus roxburghii-Cedrus deodara* mixed community

Data was collected from 1 forest compartment covering an area of 36.4ha, at altitude range of 1750-3130m above mean sea level, for *Pinus roxburghii-Cedrus deodara* mixed community. Limited variations were registered in densities for all species. The tree density of *Pinus roxburghii* reduced by just 0.3 per cent while that of *Cedrus deodara* decreased by 7 per cent between 1981 and 1996. In these forest compartments, representation (density) of other species between 1981 and 1996 is as follows – density of *Pinus wallichiana* recorded a nominal decline of just 1 per cent, while those of other species i.e. *Picea smithiana,* Broad-leaved, and *Quercus leucotrichophora* remained unchanged between 1981 and 1996, as exhibited in Figure 8.

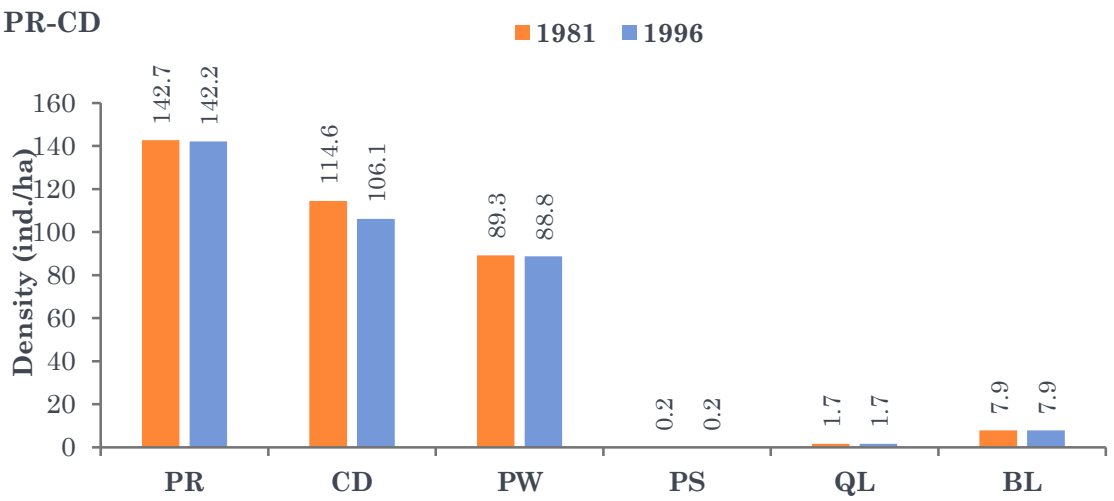

Figure 8: Density Variations in Species Composition in *Pinus roxburghii-Cedrus deodara* mixed community, Shimla Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora*

Source: HPSCCC, 2018

8. *Pinus roxburghii*-Broad-leaved mixed community

Data was collected from 1 forest compartment covering an area of 12.6ha, at altitude range of 1680-1900m above mean sea level, for *Pinus roxburghii*-Broad-leaved mixed community. Remarked positive variations were registered in densities for all the composite species. The tree density of *Pinus roxburghii* surged by 325 per cent while that of Broad-leaved escalated by 245 per cent between 1981 and 1996. In these forest compartments, representation (density) of other species between 1981 and 1996 is as follows – density of *Pinus wallichiana* recorded an increase of 539 per cent, *Cedrus deodara* by 600 per cent, and *Quercus leucotrichophora* by 304 per cent, as per enumerated data.

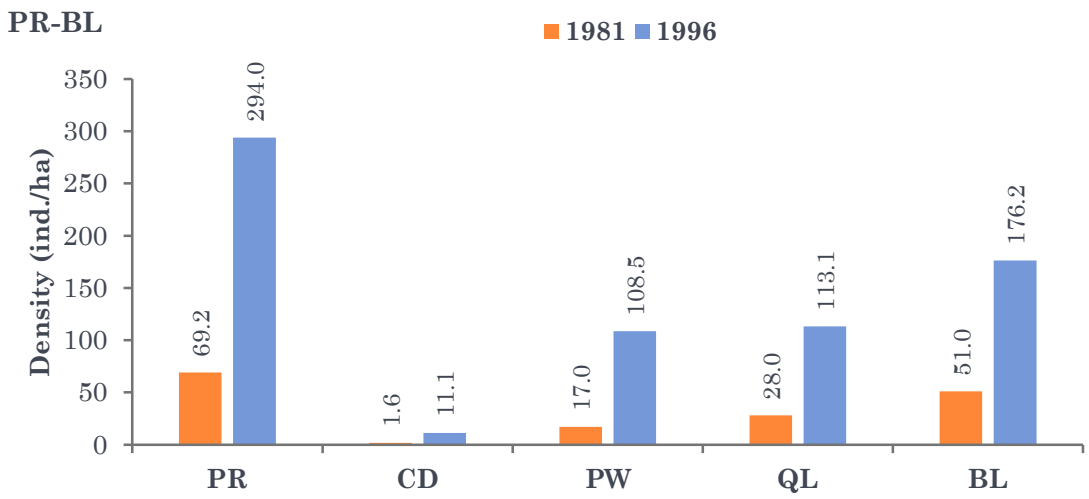

Figure 9: Density Variations in Species Composition in *Pinus roxburghii*-Broad-leaved mixed community, Shimla Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved; **PR**= *Pinus roxburghii;* **QL**= *Quercus leucotrichophora*

Source: HPSCCC, 2018

9. *Pinus wallichiana-Quercus floribunda* mixed community

Data was collected from 1 forest compartment covering an area of 102.4ha, at altitude range of 1890-2316m above mean sea level, for *Pinus wallichiana-Quercus floribunda* mixed community. The tree density of *Pinus wallichiana* decreased by only 2 per cent moving from 103.5 ind./ha to 101.9 ind./ha; while for *Quercus floribunda,* tree density remained unchanged at 86.4 ind./ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – density of *Pinus roxburghii, Cedrus deodara* and *Picea smithiana* declined. Meanwhile, density of Broad-leaved, *Quercus leucotrichophora,* and *Quercus floribunda* remained unchanged, as exhibited in Figure 10.

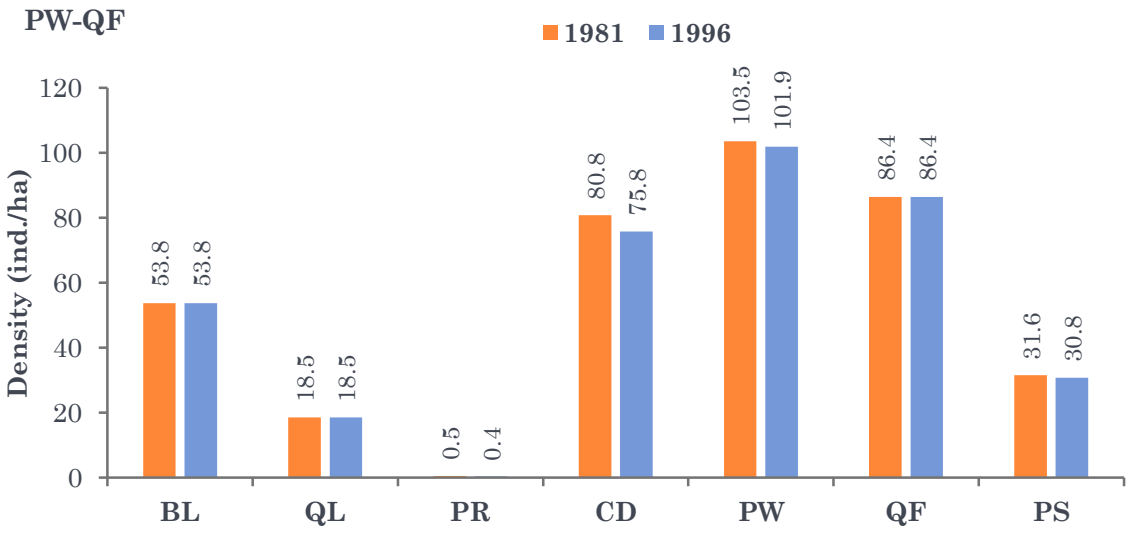

Figure 10: Density Variations in Species Composition in *Pinus wallichiana-Quercus floribunda* mixed community, Shimla Forest Division, 1981-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study, the forests compartments of Shimla Forest Division were divided into 3 altitudinal ranges i.e. 1000-1500m, 1500-2000m, and 2000-2500m, as per information from enumerated data. The forests in a particular altitudinal range were categorized species wise, and then their total number was calculated for both years i.e. 1981 and 1996. The density (individuals per hectare) was then calculated for all species at respective altitudes representing individuals in one hectare.

1. 1000-1500m

There are 3 forest compartments at this altitude gradient with a total area of 77.2ha falling under Mashobra, Koti, and Bhajji forest ranges. At 1000-1500m altitude range, *Pinus roxburghii* had the highest concentration but its density decreased by 37 per cent between 1981 and 1996. Density of *Cedrus deodara* and Broad-

leaved also declined at this altitude, however, maximum reduction was seen for *Picea smithiana,* whose individuals per hectare plummeted by 72 per cent. Meanwhile, *Quercus leucotrichophora* recorded a 228 per cent surge in density.

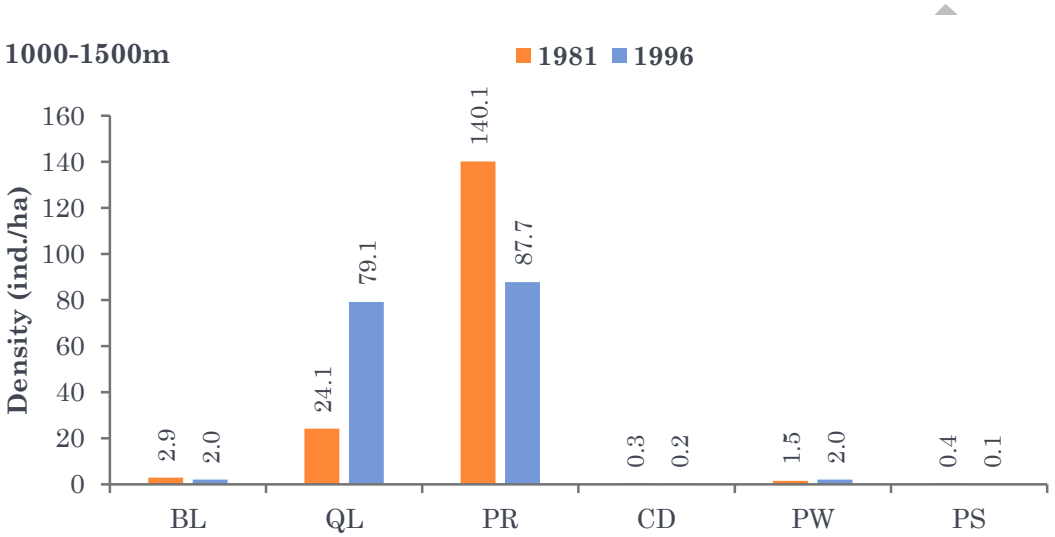

Figure 11: Density Variations in Species Composition at 1000-1500m Altitude, Shimla Forest Division, 1981-1996
Source: HPSCCC, 2018

2. 1500-2000m

There are 15 forest compartments at this altitude gradient with a total area of 474.2ha falling under Mashobra, Koti, and Bhajji forest ranges. At 1500-2000m altitude, majority of species witnessed an increase in density, with maximum surge reported for density of *Quercus floribunda* and *Picea smithiana* by 65 per cent each. Density of *Quercus leucotrichophora, Pinus roxburghii, Cedrus deodara,* and Broad-leaved surged by 57 per cent, 43 per cent, 10 per cent, and 7 per cent, respectively. Only *Pinus wallichiana* reported a decline of 18 per cent in its density at 1500-2000m altitude range between 1981 and 1996.

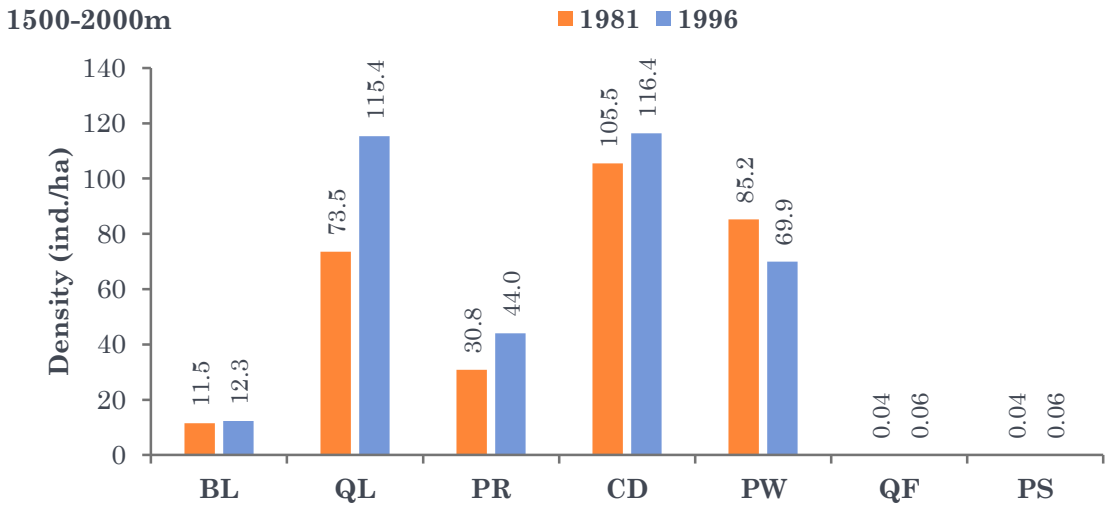

Figure 12: Density Variations in Species Composition at 1500-2000m Altitude, Shimla Forest Division, 1981-1996
Source: HPSCCC, 2018

3. 2000-2500m

There are 8 forest compartments at this altitude gradient with a total area of 489.6ha falling under Mashobra, Koti, and Bhajji forest ranges. At 2000-2500m altitude range, all species recorded a decline in their individuals per hectare between 1981 and 1996. Density of *Quercus floribunda* plummeted by 71 per cent, followed by Broad-leaved (22 per cent), *Pinus roxburghii* (15 per cent), *Pinus wallichiana* (13 per cent), and *Quercus leucotrichophora* (1 per cent). At the study's highest altitude range, *Cedrus deodara* assumed highest concentration, however its density fell from 220.1 ind./ha to 200.6 ind./ha, exhibiting a decline of 9 per cent between 1981 and 1996, as exhibited in Figure 13.

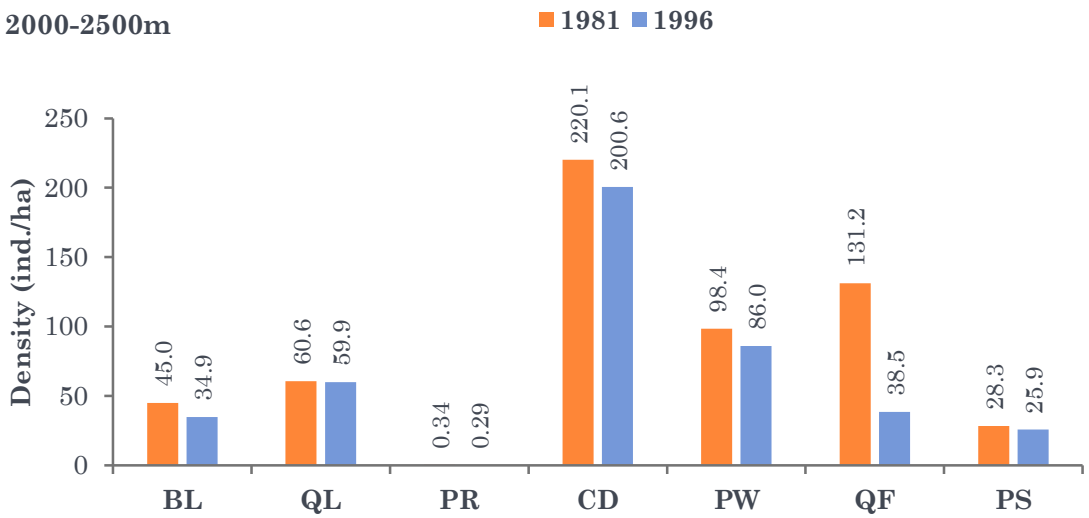

Figure 13: Density Variations in Species Composition at 2000-2500m Altitude, Shimla Forest Division, 1981-1996
Source: HPSCCC, 2018

Table 5 below gives information on suitable altitude ranges for identified tree species juxtaposed with observation made for the Shimla Forest Division under Shimla Forest Circle.

Table 5: Suitable Altitude Range for Different Tree Species in Shimla Forest Division

Species	Suitable Altitude	Observed Changes		
		1000-1500m	1500-2000m	2000-2500m
Cedrus deodara	1800 – 3000m	Decreased	Increased	Decreased
Pinus wallichiana	1800 – 3000m	Increased	Decreased	Decreased
Pinus roxburghii	1000 – 2000m	Decreased	Increased	Decreased
Quercus leucotrichophora	1500 – 2400m	Increased	Increased	Decreased
Picea smithiana	2100 – 3600m	Decreased	Increased	Decreased
Quercus floribunda	2000 – 2500m	Not Present	Increased	Decreased
Broad leaved (temperate)	2000 – 3300m	Decreased	Increased	Decreased

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Shimla Forest Division, its density was observed to increase only at the mid-altitude range of 1500-2000m, though only by 10 per cent. At higher altitude it assumed highest relative composition amongst other

species but its density decreased by 9 per cent. While, its suitable range is 1800-3000m, few individuals (27 ind. in 1981 and 16 ind. in 1996) were found to grow in Mashobra forest range at an altitude of 1450m. However, here too its density registered a decline.

Pinus wallichiana is found between 1800m and 3000m altitude above sea level, and in the Shimla Forest Division, its density decreased at mid to higher altitude ranges – 18 per cent at 1500-2000m and 13 per cent at 2000-2500m; while it exhibited an increase of 34 per cent at 1000-1500m altitude range between 1981 and 1996.

Pinus roxburghii grows at 1000-2000m altitude range, and in the Shimla Forest Division, its density registered 37 cent decline at 1000-1500m, and increased by 43 per cent at 1500-2000m. While, its suitable range is 1000-2000m, few individuals (168 ind. in 1981 and 142 ind. in 1996) were found to grow in Mashobra and Koti forest ranges between 2045m and 2250m. However, here too its density registered a decline between 1981 and 1996.

Quercus leucotrichophora grows at 1500-2400m altitude range, and in this forest division, at 1000-1500m and 1500-2000m, its density surged by 228 per cent and 54 per cent, respectively. Meanwhile at 2000-2500m, a decline of nominal 1 per cent was registered between 1981 and 1994.

Picea smithiana thrives at 2100-3600m altitude, and in the Shimla Forest Division, its density decreased by 8 per cent at 2000-2500m altitude range. While, its suitable range is 2100-3600m, few individuals (39 ind. in 1981 and 29 ind. in 1996) were found to grow in Mashobra and Bhajji forest ranges between 1490m and 1945m. However, here too its density registered a decline between 1981 and 1996.

Quercus floribunda thrives at 2000-2500m, and in Shimla Forest Division, its density increased by 65 per cent at 1500-2000m; while it plummeted by 71 per cent at 2000-2500m altitude range. The species was not found at lower altitude between 1981 and 1996.

Broad-leaved species in temperate forests thrive at 2000-3000m altitude range, and in Shimla Forest Division its density showed 7 per cent increase at 1500-2000m, and 22 per cent decline at 2000-2500m. While, its suitable range is 2000-3000m, few individuals (225 ind. in 1981 and 158 ind. in 1996) were found to grow in Mashobra forest range at 1490m altitude. However, here too its density registered a decline of 30 per cent between 1981 and 1996.

Chopal Forest Division

For Chopal Forest Division, enumerated information in the Working Plans from Himachal Pradesh Forest Department and Compartment History files was taken for 1965 and 2003. As per the assessment, 7 pure tree communities - *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP), Picea smithiana (PS),* Broad-leaved (BL), *Quercus semecarpifolia (QS),* and *Quercus floribunda (QF),* and 22 mixed tree communities – *Cedrus deodara-Pinus wallichiana, Cedrus deodara-Quercus floribunda, Cedrus deodara-Quercus semecarpifolia, Cedrus deodara-Abies pindrow, Cedrus deodara*-Broad-leaved, *Cedrus deodara-Picea smithiana, Pinus wallichiana-Cedrus deodara, Abies pindrow-Cedrus deodara, Abies pindrow-Picea smithiana,* Broad-leaved-*Taxus baccata, Picea smithiana-Abies pindrow, Picea smithiana*-Broad-leaved, *Picea smithiana-Cedrus deodara, Picea smithiana-Taxus baccata, Picea smithiana-Quercus semecarpifolia, Pinus wallichiana*-Broad-leaved, *Pinus wallichiana-Quercus leucotrichophora,* Broad-leaved-*Pinus wallichiana,* Broad-leaved-*Abies pindrow, Taxus baccata-Abies pindrow, Quercus semecarpifolia-Taxus baccata, Quercus semecarpifolia-Picea smithiana* were identified.

As highlighted earlier in

Table 4 these tree communities were assessed from 146 forest compartments spread over a total area of 6876.3ha.

The Tree Community based Variations

The following section discusses *the tree community based variations in density* for the identified species.

1. *Cedrus deodara* community

Data was collected from 69 forest compartments covering an area of 2373.41ha, at altitude range of 1785-2580m above mean sea level. As illustrated in Figure 14, in its dominant tree community, density of *Cedrus deodara* increased by 7 per cent, moving from 218.9 ind./ha to 234 ind./ha. In these forest compartments, representation (density) of other species is as follows – density of *Pinus roxburghii, Abies pindrow,* Broad-leaved, and *Quercus floribunda* registered extreme positive variations in respective densities i.e. 1350 per cent, 206 per cent, 18 per cent, and 94 per cent between 1965 and 2003. Density of *Quercus leucotrichophora* and *Pinus wallichiana* too reported an increase of 15 per cent and 8 per cent, respectively. Meanwhile, density of *Taxus baccata, Quercus semecarpifolia,* and *Picea smithiana* all declined by significant 81 per cent, 61 per cent, and 11 per cent, respectively.

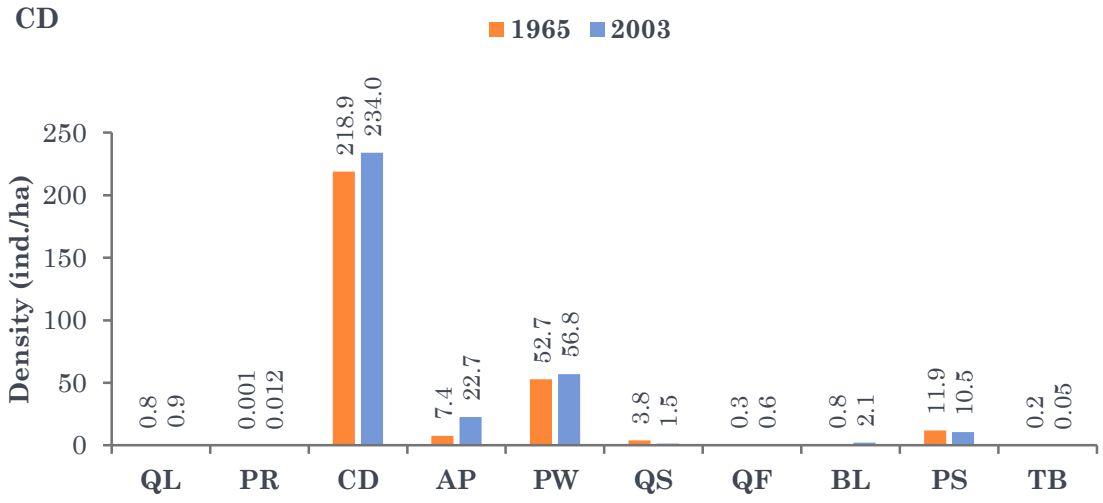

Figure 14: Density Variations in Species Composition in *Cedrus deodara* community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **QF=** *Quercus floribunda;* **BL=** Broad-leaved; **QS**= *Quercus semecarpifolia;* **TB**=*Taxus baccata;* **QL=** *Quercus leucotrichophora;* **PR=** *Pinus roxburghii;* **AP=** *Abies pindrow*

Source: HPSCCC, 2018

2. *Pinus wallichiana* community

Data was collected from 11 forest compartments covering an area of 375.46ha, at altitude range of 1680-2910m above mean sea level. As illustrated in Figure 15, in its dominant tree community, density of *Pinus wallichiana* declined significantly from 106.5 ind./ha to 55.9 ind./ha between 1965 and 2003. In these forest compartments, representation (density) of other species is as follows – all species i.e. *Picea smithiana, Cedrus deodara,* and *Abies pindrow* registered a noticeable decline in density by 95 per cent, 75 per cent, 61 per cent, and 48 per cent, respectively between 1965 and 2003. Density of *Pinus roxburghii* and *Quercus leucotrichophora* increased from 0.02 ind./ha to 0.05 ind./ha, and 7.7 ind./ha to 8.3 ind./ha, respectively from 1965 to 2003.

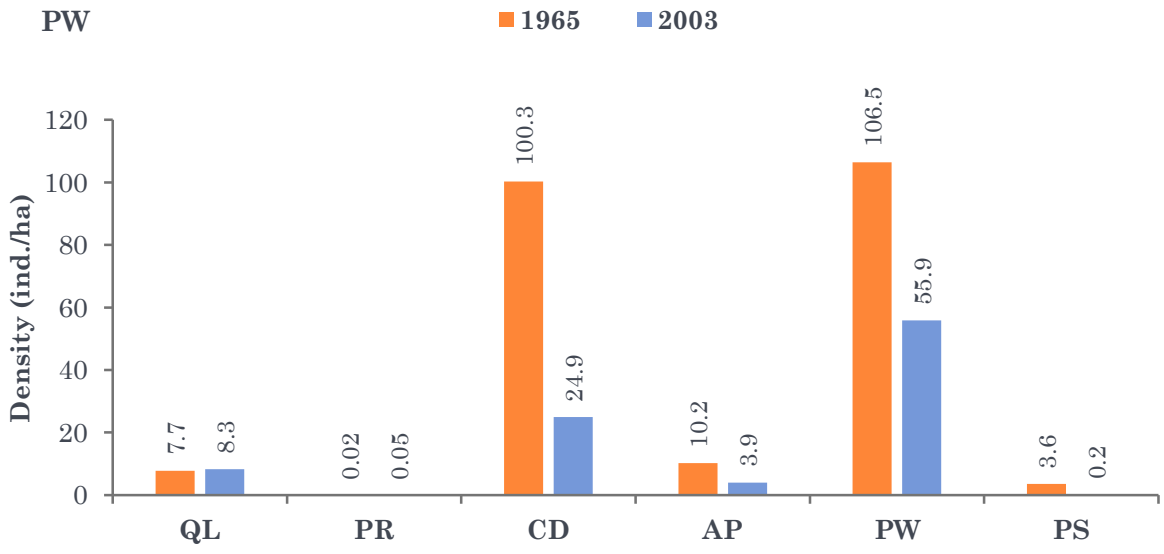

Figure 15: Density Variations in Species Composition in *Pinus wallichiana* community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **QL**= *Quercus leucotrichophora;* **PR**= *Pinus roxburghii;* **AP**= *Abies pindrow*

Source: HPSCCC, 2018

3. *Picea smithiana* community

Data was collected from 10 forest compartments covering an area of 478.2ha, at altitude range of 2160-2850m above mean sea level. As illustrated in Figure 16, in its dominant tree community, density of *Picea smithiana* increased by 93 per cent moving from 62.2 ind./ha in 1965 to 119.8 ind./ha in 2003. In these forest compartments, representation (density) of other species is as follows– density of *Quercus floribunda* jumped by over 1000 per cent, increasing from only 0.5 ind./ha to 6.1 ind./ha; while for *Taxus baccata* density increased by nominal 3 per cent. Densities of the remaining species exhibited a decline - *Cedrus deodara* decreased from 33.3 ind./ha to 24.4 ind./ha; *Abies pindrow* declined from 63.2 ind./ha to 53.7 ind./ha, and *Pinus wallichiana* decreased from 16.7 ind./ha to 15.7 ind./ha between 1965 and 2003.

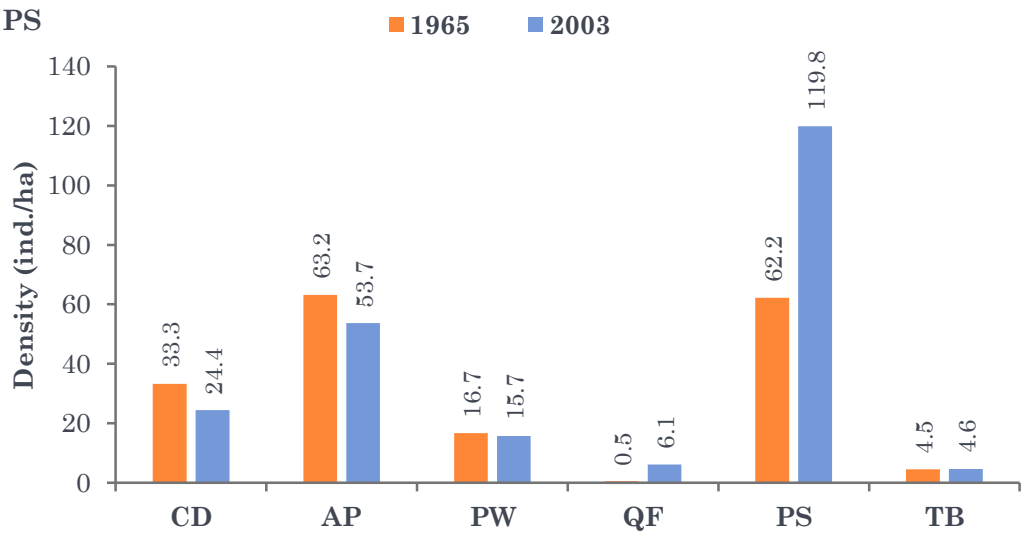

Figure 16: Density Variations in Species Composition in *Picea smithiana* community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **QF=** *Quercus floribunda*; **TB=***Taxus baccata;* **AP=***Abies pindrow*
Source: HPSCCC, 2018

4. *Abies pindrow* community

Data was collected from 5 forest compartments covering an area of 353.68ha, at altitude range of 2400-2880m above mean sea level. As illustrated in Figure 17, in its dominant tree community, density of *Abies pindrow* increased from 118.4 ind./ha to 136.7 ind./ha between 1965 and 2003. In these forest compartments, representation (density) of other species is as follows – density of *Quercus floribunda* increased by 453 per cent moving from 0.4 ind./ha to 2.3 ind./ha; and density of Broad-leaved increased from 0.8 ind./ha to 1.6 ind./ha. Meanwhile, for all the remaining species, significant decline in density was registered. Density of *Cedrus deodara* declined from 26.7 ind./ha to 11.9 ind./ha; density of *Pinus wallichiana* declined from 1.0 ind./ha to 0.9 ind./ha; for *Quercus semecarpifolia* declined from 2.6 ind./ha 2.0 ind./ha, density of *Taxus baccata* reduced from 13.0 ind./ha to 9.2 ind./ha, and for *Picea smithiana,* maximum decline of 84 per cent was registered, where its density reduced from 109.6 ind./ha to only 17.7 ind./ha between 1965 and 2003.

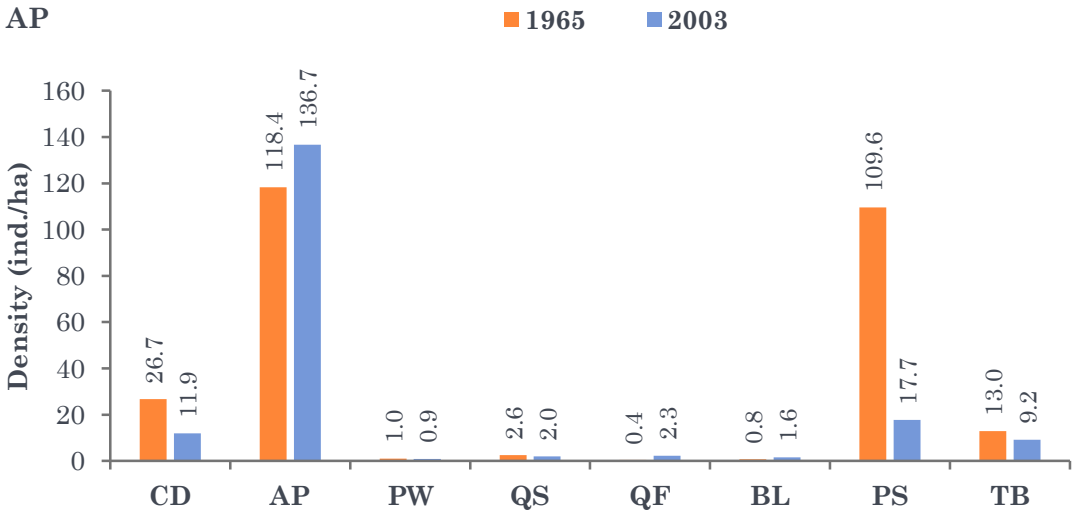

Figure 17: Density Variations in Species Composition in *Abies pindrow* community, Chopal Forest Division, 1965-2003
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **TB**=*Taxus baccata;* **AP**=*Abies pindrow;* **QS**=*Quercus semecarpifolia;* **QF**= *Quercus floribunda*
Source: HPSCCC, 2018

5. *Quercus floribunda* community

Data was collected from 1 forest compartment covering an area of 60.7ha, at altitude range of 2150-2520m above mean sea level. As illustrated in Figure 18, in its dominant tree community, density of *Quercus floribunda* decreased from 80.7 ind./ha in 1965 to only 68.2 ind./ha in 2003. In this one forest compartment, representation (density) of other species is as follows – density of *Quercus semecarpifolia* decreased from 32.5 ind./ha to 18.1 ind./ha. Meanwhile, Broad-leaved exhibited an increase of 844 per cent in its density between 1965 and 2003.

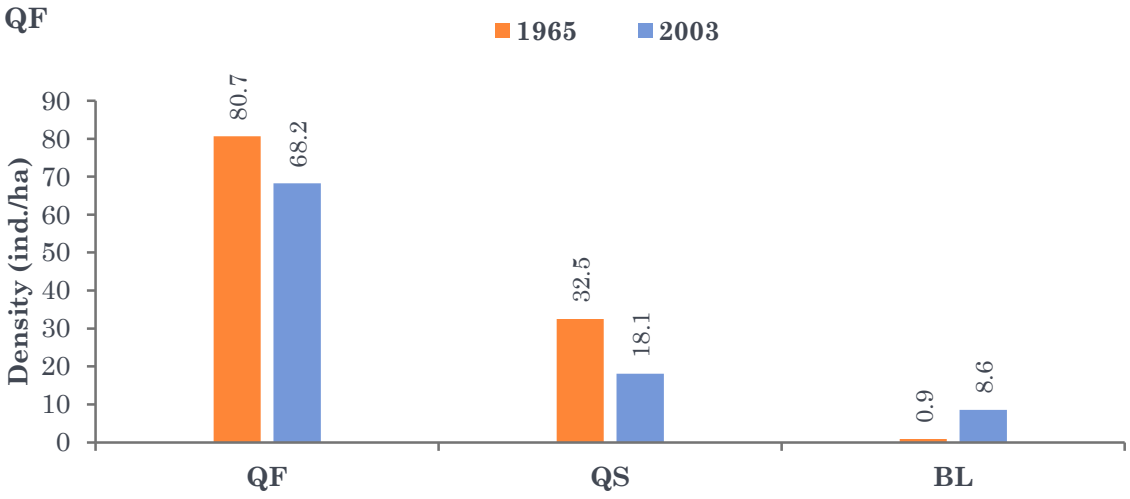

Figure 18: Density Variations in Species Composition in *Quercus floribunda* community, Chopal Forest Division, 1965-2003
Abbreviations: QF= *Quercus floribunda*; **QS**=*Quercus semecarpifolia*; **BL**= Broad-leaved
Source: HPSCCC, 2018

6. Broad-leaved community

Data was collected from 4 forest compartments covering an area of 269.51ha, at altitude range of 2150-2550m above mean sea level. As

illustrated in Figure 19, in its dominant tree community, density of Broad-leaved increased from 24.5 ind./ha in 1965 to 60.0 ind./ha in 2003. In these forest compartments, representation (density) of other species is as follows – density of *Quercus leucotrichophora, Cedrus deodara, Quercus floribunda,* and *Abies pindrow* increased between 1965 and 2003. Particularly for *Abies pindrow,* where density increased from only 0.1 ind./ha to 5.4 ind./ha. Meanwhile, individuals per hectare reduced for *Pinus wallichiana, Picea smithiana,* and *Taxus baccata.*

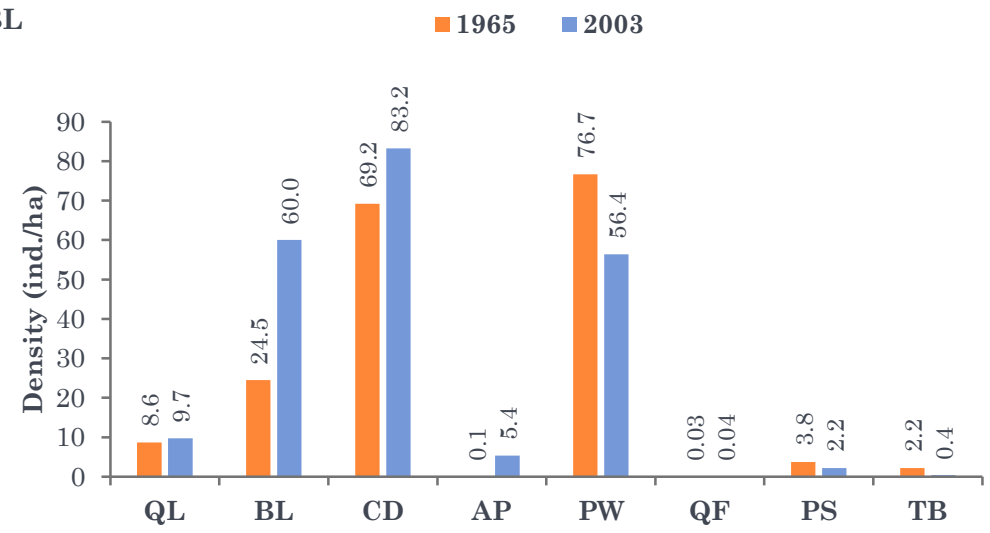

Figure 19: Density Variations in Species Composition in Broad-leaved community, Chopal Forest Division, 1965-2003
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **TB**=*Taxus baccata;* **AP**=*Abies pindrow;* **QL**= *Quercus leucotrichophora;* **QF**= *Quercus floribunda*
Source: HPSCCC, 2018

7. *Quercus semecarpifolia* community

Data was collected from 2 forest compartments covering an area of 225.81ha, at altitude range of 2650-3580m above mean sea level. As illustrated in Figure 20, in its dominant tree community, density of *Quercus semecarpifolia* increased from 177.1 ind./ha in 1965 to 255.5 ind./ha in 2003. In these forest compartments, representation (density) of

other species is as follows – density of Broad-leaved increased from 7.2 ind./ha to 13.1 ind./ha; density of *Picea smithiana* increased from 25.2 ind./ha to 44.9 ind./ha; for *Taxus baccata,* density increased from 84.6 ind./ha to 114.5 ind./ha; and the density of *Pinus wallichiana* too increased from 0.03 ind./ha to 2.5 ind./ha. Meanwhile, *Cedrus deodara* and *Abies pindrow* recorded reduced density from 3.8 ind./ha to 0.9 ind./ha, and 49.5 ind./ha to 15.1 ind./ha, respectively between 1965 and 2003.

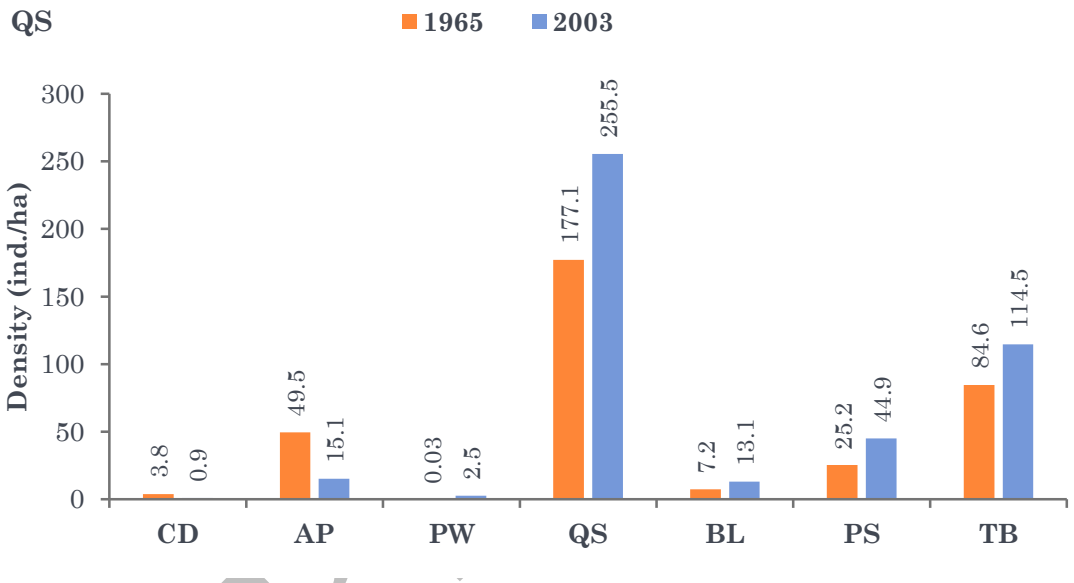

Figure 20: Density Variations in Species Composition in *Quercus semecarpifolia* community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **TB**=*Taxus baccata;* **AP**=*Abies pindrow;* **QL**= *Quercus leucotrichophora;* **QF**= *Quercus floribunda*

Source: HPSCCC, 2018

8. *Cedrus deodara-Pinus wallichiana* community

Data was collected from 4 forest compartments covering an area of 118.15ha, at altitude range of 1920-2380m above mean sea level, for *Cedrus deodara-Pinus wallichiana* mixed community. All species recorded extreme variations in their respective tree densities. *Cedrus deodara* experienced 116 per cent increase in density, while for *Pinus wallichiana* density surged by 141 per cent between 1965 and 2003.

In this mixed community, density of other species i.e. Broad-leaved, *Abies pindrow, Pinus roxburghii,* and *Quercus leucotrichophora* increased by 821 per cent, 195 per cent, 50 per cent, and 36 per cent, respectively. Only for *Picea smithiana,* a density decline of 40 per cent was seen during the study period, as illustrated in Figure 21.

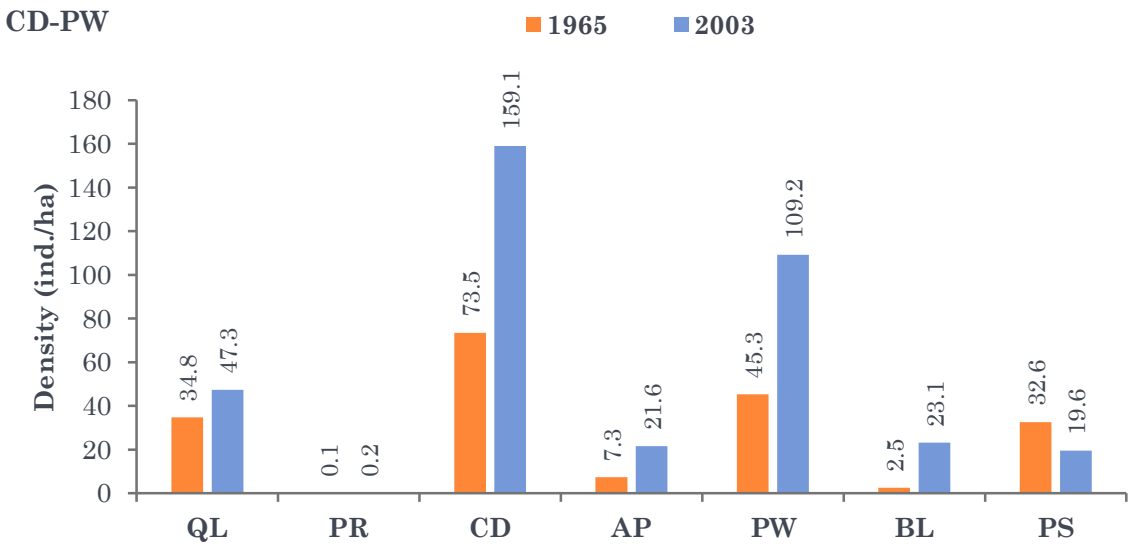

Figure 21: Density Variations in Species Composition in *Cedrus deodara-Pinus wallichiana* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **PR**= *Pinus roxburghii*

Source: HPSCCC, 2018

9. *Cedrus deodara-Quercus floribunda* community

Data was collected from 1 forest compartment covering an area of 59.08ha, at altitude range of 2070-2370m above mean sea level, for *Cedrus deodara-Quercus floribunda* mixed community. All species recorded significant variations in their respective tree densities. *Cedrus deodara* experienced 28 per cent increase in density, while for *Quercus floribunda* density surged by 20 per cent between 1965 and 2003. In this mixed community, density of other species i.e. Broad-leaved, *Picea smithiana, Quercus leucotrichophora, Abies pindrow,* and *Pinus wallichiana* increased by 211 per cent, 93 per cent, 66 per

cent, 49 per cent, and 41 per cent, respectively. Only for *Taxus baccata,* a density decline of 45 per was seen during the study period, as illustrated in Figure 22.

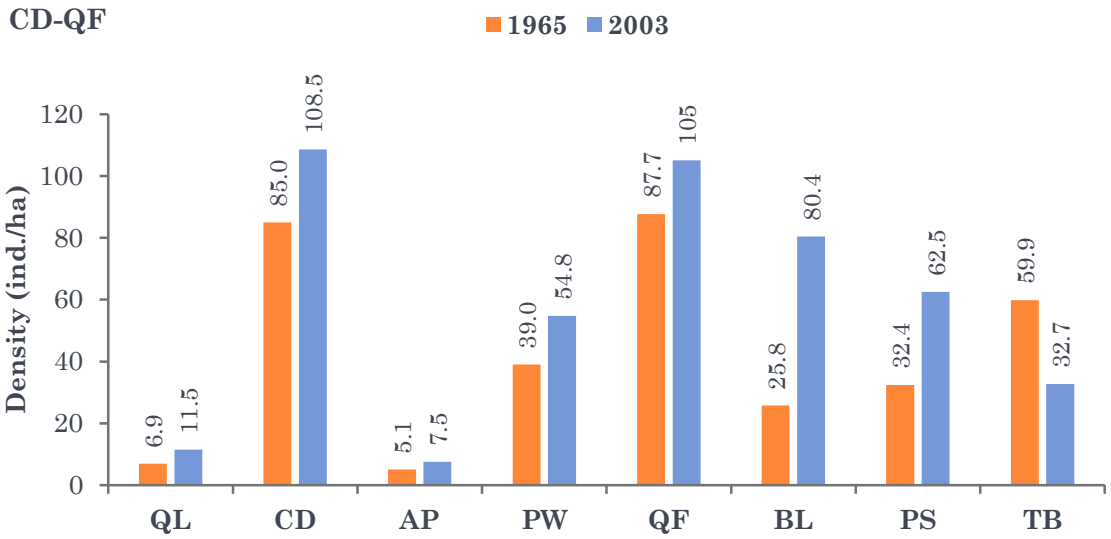

Figure 22: Density Variations in Species Composition in *Cedrus deodara-Quercus floribunda* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **TB**=*Taxus baccata;* **QF**= *Quercus floribunda*

Source: HPSCCC, 2018

10. *Cedrus deodara-Quercus semecarpifolia* community

Data was collected from 2 forest compartments covering an area of 127.87ha, at altitude range of 2160-2850m above mean sea level, for *Cedrus deodara-Quercus semecarpifolia* mixed community. The tree density of *Cedrus deodara* marginally decreased from 163 ind./ha in to 160.8 ind./ha; and for *Quercus semecarpifolia* the density increased from 53.4 ind./ha to 73.6 ind./ha from 1969 to 2003. In this mixed community, density of Broad-leaved remained unchanged; of *Quercus leucotrichophora* surged by 643 per cent, of *Taxus baccata* jumped by 431 per cent, and of *Abies pindrow,* the density surged by 182 per cent. Only *Pinus wallichiana, Quercus*

floribunda, and *Picea smithiana* witnessed a decline in density during the study time period, as illustrated in Figure 23.

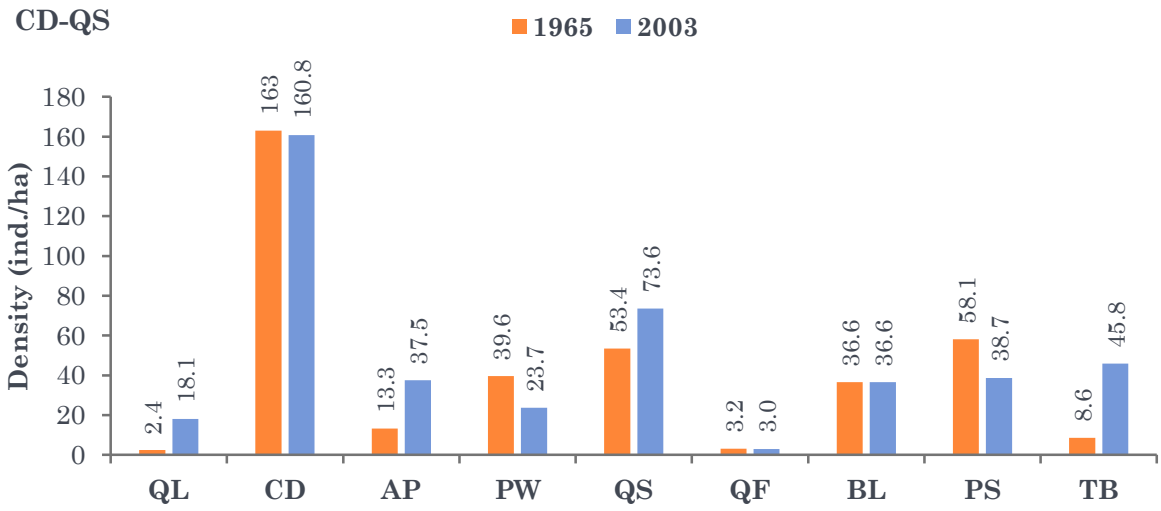

Figure 23: Density Variations in Species Composition in *Cedrus deodara-Quercus semecarpifolia* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **TB**=*Taxus baccata;* **QF**= *Quercus floribunda;* **QS**= *Quercus semecarpifolia*

Source: HPSCCC, 2018

11. *Cedrus deodara-Abies pindrow* community

Data was collected from 3 forest compartments covering an area of 122.21ha, at altitude range of 2070-2760m above mean sea level, for *Cedrus deodara-Abies pindrow* mixed community. The tree density of *Cedrus deodara* increased from 172.4 ind./ha to 209.2 ind./ha, exhibiting a 20 per cent increase; while for *Abies pindrow,* density increased by 460 per cent between 1965 and 2003. In this mixed community, density of all other species also increased in the following order - *Quercus leucotrichophora* by 187 per cent, Broad-leaved by 158 per cent, *Taxus baccata* by 66 per cent, *Quercus semecarpifolia* by 53 per cent, *Pinus wallichiana* by 40 per cent,

Quercus floribunda by 32 per cent, and *Picea smithiana* by 10 per cent from 1965 to 2003.

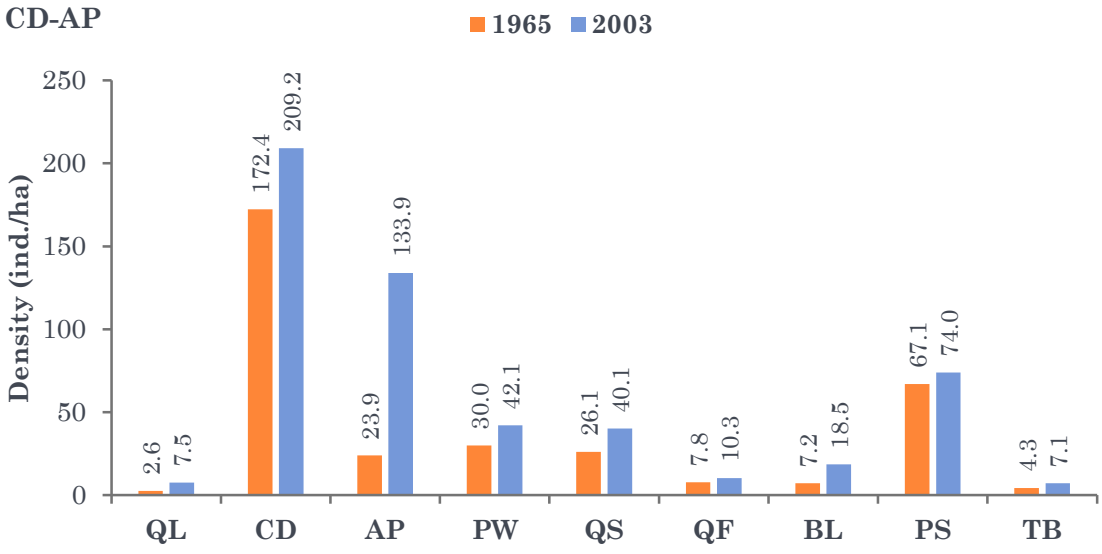

Figure 24: Density Variations in Species Composition in *Cedrus deodara-Abies pindrow* mixed community, Chopal Forest Division, 1965-2003
Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **TB**=*Taxus baccata;* **QF**= *Quercus floribunda;* **QS**= *Quercus semecarpifolia*
Source: HPSCCC, 2018

12. *Cedrus deodara*-Broad-leaved community

Data was collected from 2 forest compartments covering an area of 152.96ha, at altitude range of 2070-2650m above mean sea level, for *Cedrus deodara*-Broad-leaved mixed community. Density of *Cedrus deodara* marginally increased from 83.2 ind./ha to 83.6 ind./ha; while for Broad-leaved species, a dramatic increase from only 0.5 ind./ha to 71.2 ind./ha was registered between 1965 and 2003. *Quercus leucotrichophora, Pinus roxburghii, Abies pindrow,* and *Quercus floribunda* reported increased density; while those of *Picea smithiana* and *Pinus wallichiana* declined from 1965 to 2003.

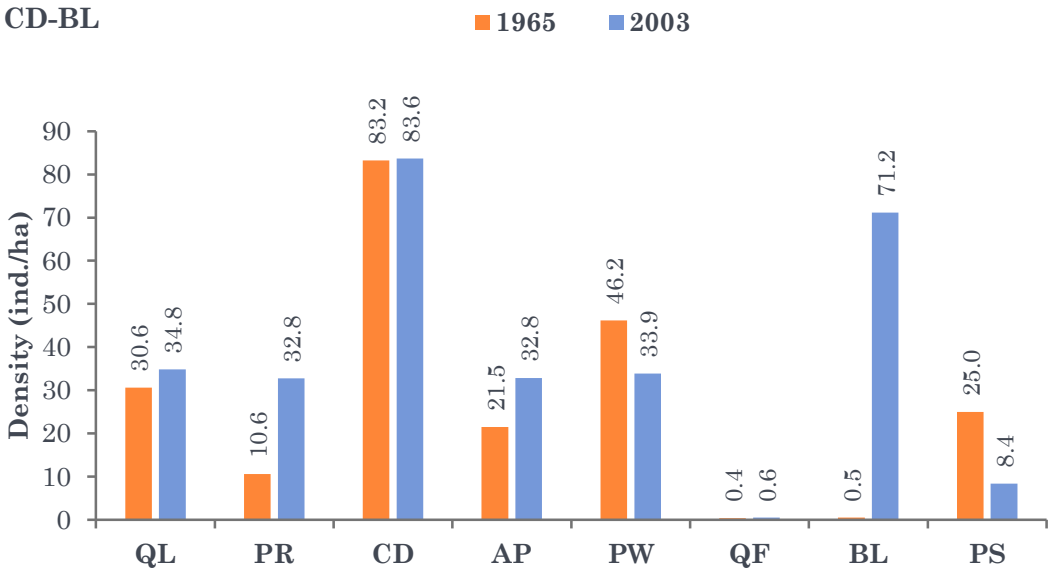

Figure 25: Density Variations in Species Composition in *Cedrus deodara*-Broad-leaved mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **QF**= *Quercus floribunda;* **PR**= *Pinus roxburghii*

Source: HPSCCC, 2018

13. *Cedrus deodara-Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 23.47ha, at altitude range of 2150-2700m above mean sea level, for *Cedrus deodara-Picea smithiana* mixed community. Except for *Abies pindrow*, density of other species exhibited an increase. Density of *Cedrus deodara* increased from 190.7 ind./ha to 267.6 ind./ha; of *Picea smithiana,* density increased from 113.4 ind./ha to 203.5 ind./ha; and for *Pinus wallichiana,* density increased from 140.9 ind./ha to 180.5 ind./ha between 1965 and 2003.

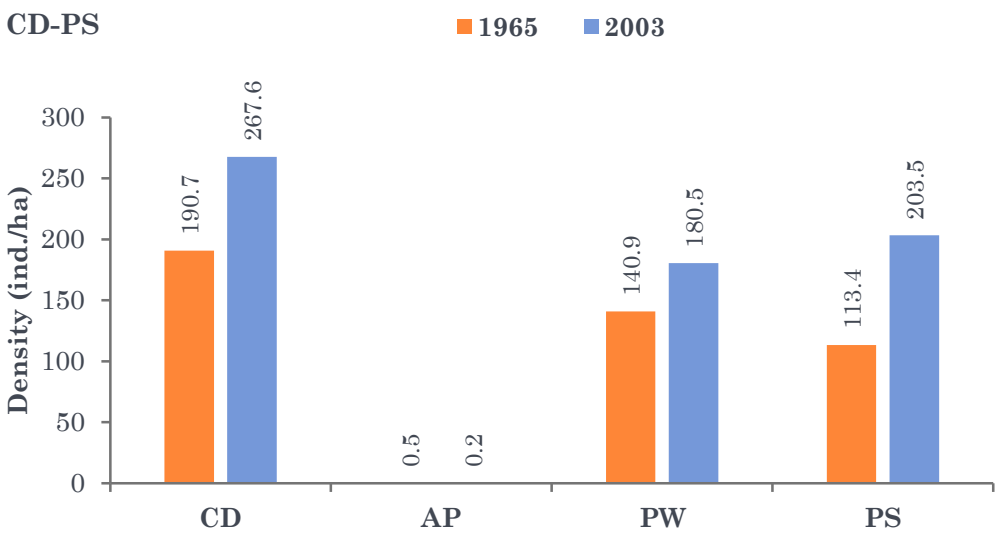

Figure 26: Density Variations in Species Composition in *Cedrus deodara-Picea smithiana* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD= *Cedrus deodara;* **PW=***Pinus wallichiana;* **PS=***Picea smithiana;* **BL=** Broad-leaved; **AP=***Abies pindrow;* **TB=***Taxus baccata;* **QS=***Quercus semecarpifolia*

Source: HPSCCC, 2018

14. *Pinus wallichiana-Cedrus deodara* community

Data was collected from 2 forest compartments covering an area of 100.77ha, at altitude range of 2220-2700m above mean sea level, for *Pinus wallichiana-Cedrus deodara* mixed community. All species reported extreme and significant variations in their respective tree densities. *Pinus wallichiana* experienced 190 per cent increase in density, while for *Cedrus deodara* density surged by 81 per cent between 1965 and 2003. In this mixed community, density of other species i.e. *Quercus leucotrichophora* (382 per cent), *Pinus roxburghii* (342 per cent), *Abies pindrow* (280 per cent), *Quercus semecarpifolia* (241 per cent), Broad-leaved (231 per cent), and *Picea smithiana* (34 per cent) all recorded exorbitant density increase during 1965 and 2003, as exhibited in Figure 27.

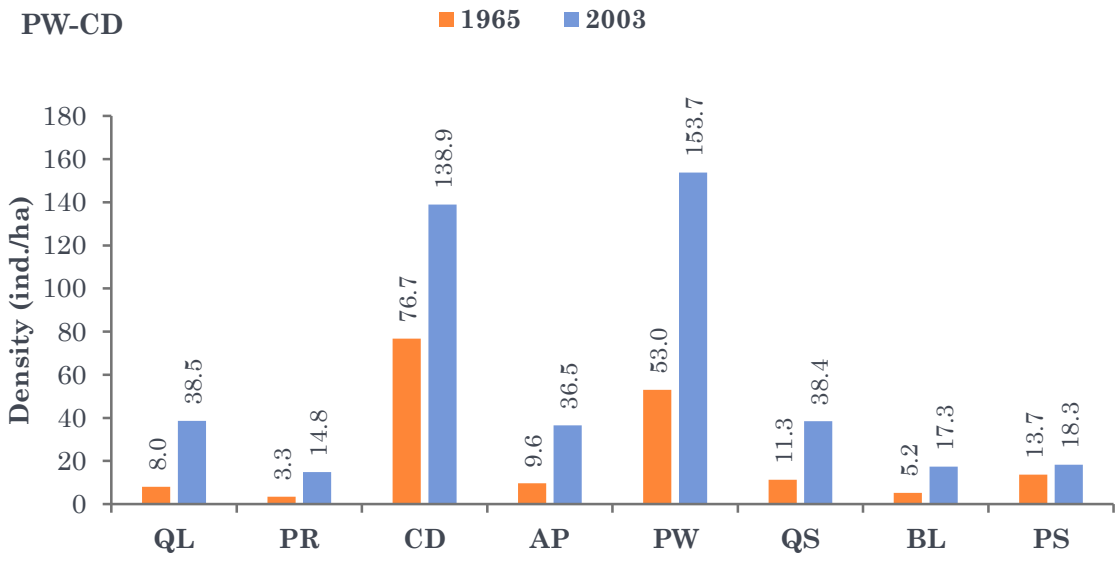

Figure 27: Density Variations in Species Composition in *Pinus wallichiana-Cedrus deodara* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*; **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **PR**= *Pinus roxburghii;* **QS**= *Quercus semecarpifolia*

Source: HPSCCC, 2018

15. *Abies pindrow-Cedrus deodara* community

Data was collected from 3 forest compartments covering an area of 142.04ha, at altitude range of 1950-2670m above mean sea level, for *Abies pindrow-Cedrus deodara* mixed community. The tree density of *Abies pindrow* increased significantly from 64.5 ind./ha in year 1965 to 112.3 ind./ha in year 2003; and for *Cedrus deodara,* the density increased only by 8 per cent, from 61.3 ind./ha to 66.3 ind./ha. In this mixed community, maximum increase was seen in the density of *Quercus floribunda,* increasing from 7.3 ind./ha to 30.7 ind./ha, followed by variations in Broad-leaved species, *Taxus baccata,* and *Picea smithiana.* The remaining species in these forest compartments experienced significant reduction in their respective densities i.e. *Quercus leucotrichophora* (75 per cent), *Quercus semecarpifolia* (66 per cent), and *Pinus wallichiana* (23 per cent) between 1965 and 2013, as exhibited in Figure 28.

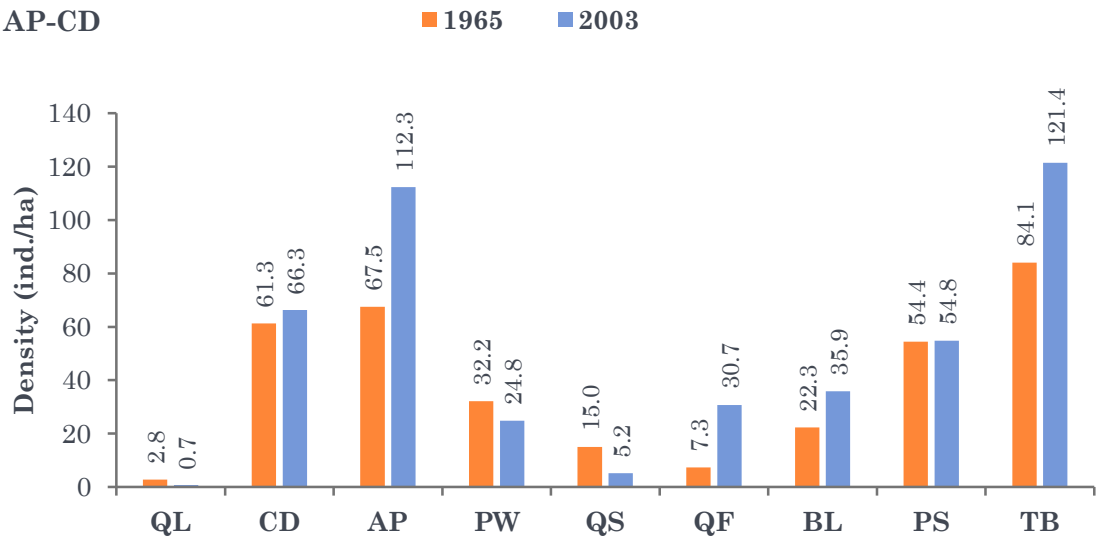

Figure 28: Density Variations in Species Composition in *Abies pindrow-Cedrus deodara* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*; **PS**=*Picea smithiana*; **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **AP**= *Abies pindrow;* **QF**= *Quercus floribunda;* **QS**= *Quercus semecarpifolia;* **TB**= *Taxus baccata*

Source: HPSCCC, 2018

16. Broad-leaved-*Taxus baccata* community

Data was collected from 1 forest compartment covering an area of 32.7ha, at altitude range of 1980-2850m above mean sea level, for Broad-leaved-*Taxus baccata* mixed community. All species reported extreme and significant variations in their respective tree densities. Broad-leaved experienced 81 per cent increase in density, while for *Taxus baccata* density surged by 818 per cent between 1965 and 2003. In this mixed community, density of other species i.e. *Abies pindrow* (563 per cent), *Cedrus deodara* (378 per cent), *Quercus floribunda* (225 per cent), *Picea smithiana* (115 per cent), and *Pinus wallichiana* (79 per cent all recorded exorbitant density increases during 1965 and 2003.

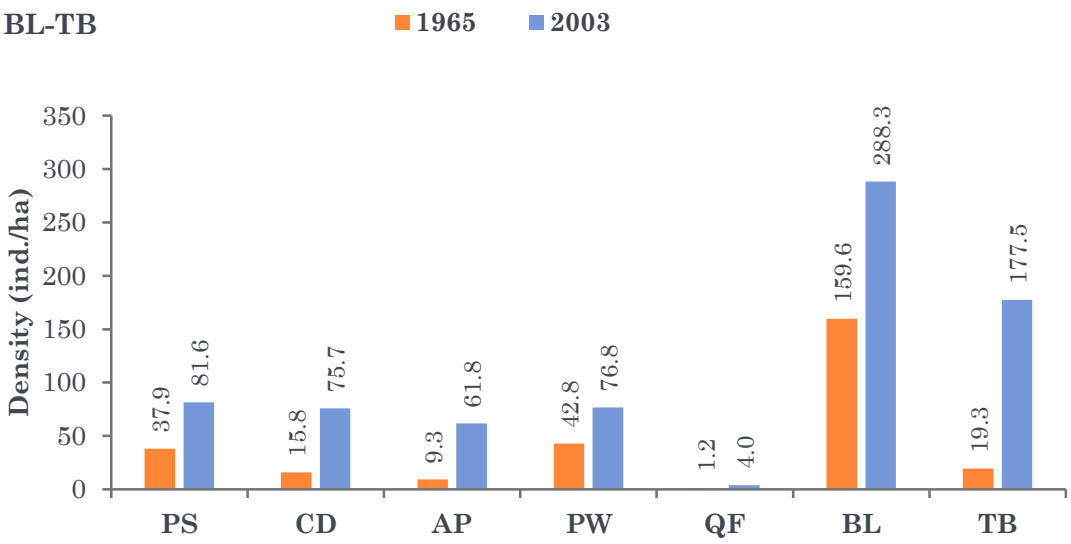

Figure 29: Density Variations in Species Composition in Broad-leaved-*Taxus baccata* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **PS=***Picea smithiana;* **TB=** *Taxus baccata;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

17.*Picea smithiana-Taxus baccata* community

Data was collected from 2 forest compartments covering an area of 193.43ha, at altitude range of 2460-3490m above mean sea level, for *Picea smithiana-Taxus baccata* mixed community. The tree density of *Picea smithiana* increased from 39.9 ind./ha in 1965 to 111.1 ind./ha in 2003; and for *Taxus baccata,* the density appreciated from 67.3 ind./ha to 87.5 ind./ha. In this mixed community, density of Broad-leaved, *Cedrus deodara,* and *Quercus floribunda* inclined; for *Abies pindrow* and *Quercus semecarpifolia,* density noticeably declined between 1965 and 2003, as illustrated in Figure 30.

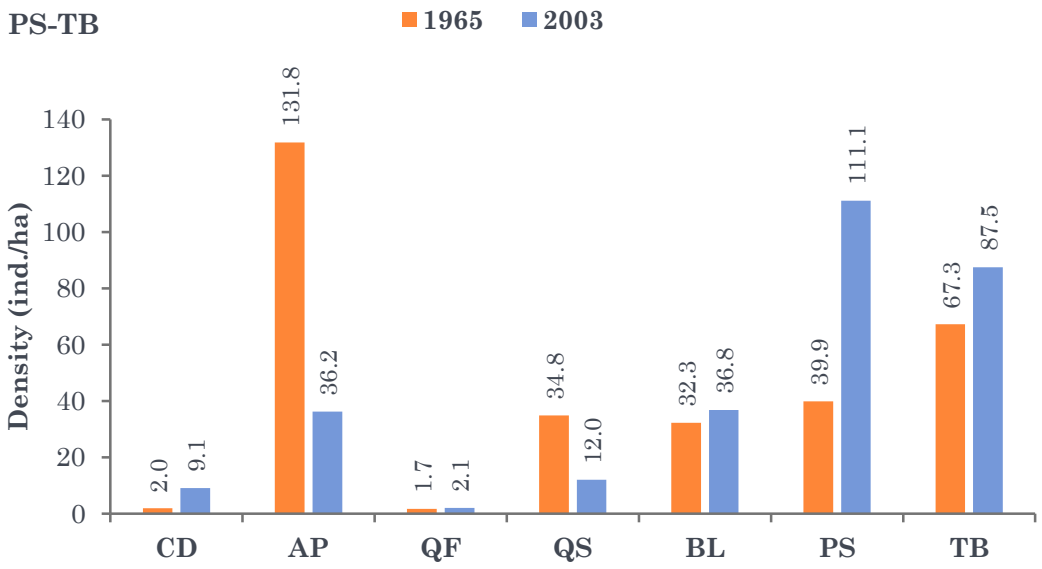

Figure 30: Density Variations in Species Composition in *Picea smithiana-Taxus baccata* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

18. *Picea smithiana-Cedrus deodara* community

Data was collected from 1 forest compartment covering an area of 73.65 ha, at altitude range of 2160-2695m above mean sea level, for *Picea smithiana-Cedrus deodara* mixed community. The tree density of *Picea smithiana* augmented from 40.0 ind./ha to 49.7 ind./ha; and for *Cedrus deodara,* the density increased from 20.1 ind./ha to 30.5 ind./ha. In this mixed community, density of Broad-leaved and *Picea smithiana* inclined; and for *Abies pindrow, Pinus wallichiana, Quercus floribunda,* and *Taxus baccata* declined between 1965 and 2003, as illustrated in Figure 31.

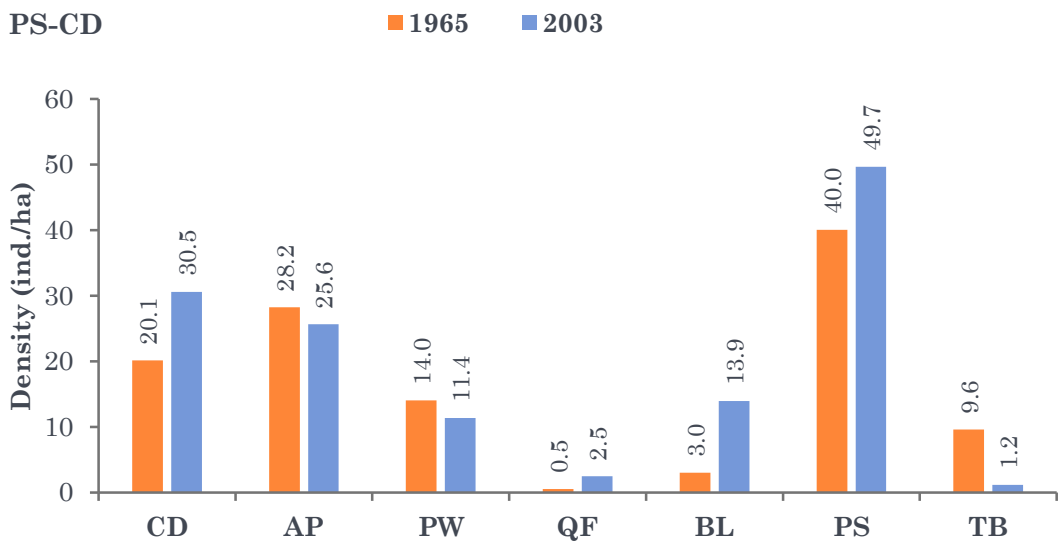

Figure 31: Density Variations in Species Composition in *Picea smithiana-Cedrus deodara* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

19. *Picea smithiana*-Broad-leaved community

Data was collected from 1 forest compartment covering an area of 37.23ha, at altitude range of 2200-2600m above mean sea level, for *Picea smithiana*-Broad-leaved mixed community. The tree density of *Picea smithiana* rose from 120 ind./ha to 243.3 ind./ha; and Broad-leaved registered a steep jump from only 34.1 ind./ha to 195.3 ind./ha between 1965 and 2003. In this mixed community, density of *Cedrus deodara, Abies pindrow,* and *Quercus floribunda* increased; and for *Pinus wallichiana* declined during the study period, as illustrated in Figure 32.

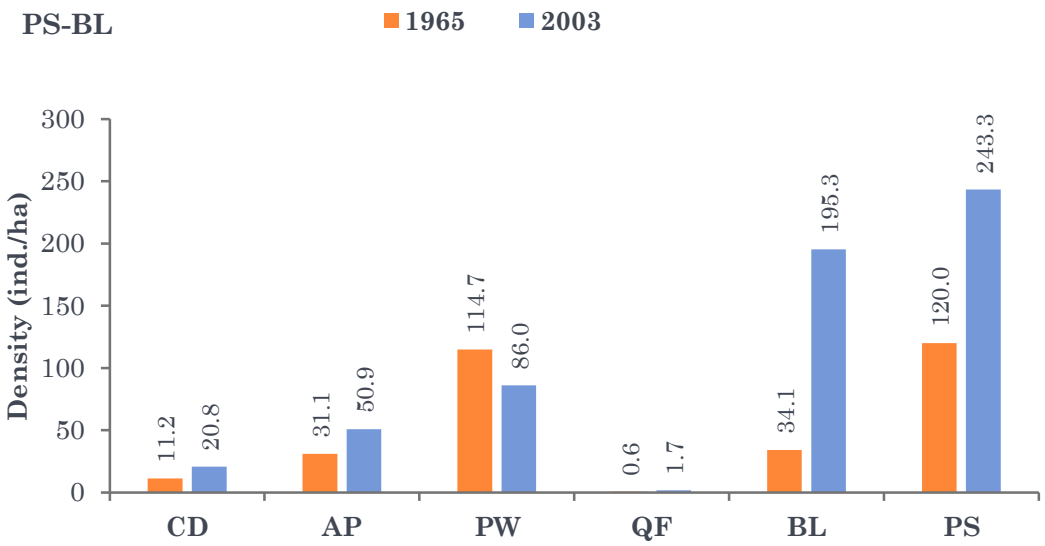

Figure 32: Density Variations in Species Composition in *Picea smithiana*-Broad-leaved mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **PS=***Picea smithiana;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

20. *Picea smithiana-Quercus semecarpifolia* community

Data was collected from 2 forest compartment covering an area of 207.22ha, at altitude range of 2460-3490m above mean sea level, for *Picea smithiana-Quercus semecarpifolia* mixed community. The tree density of *Picea smithiana* soared from just 25.8 ind./ha to 129.1 ind./ha; and for *Quercus semecarpifolia,* it registered an incline from 102.1 ind./ha to 118.3 ind./ha between 1965 and 2003. In this mixed community, density for all species increased expect for *Abies pindrow*. Amongst the increasing species, *Quercus floribunda* exhibited maximum increase, moving from just 0.04 ind./ha to 5.1 ind./ha between 1965 and 2003, as illustrated in Figure 33.

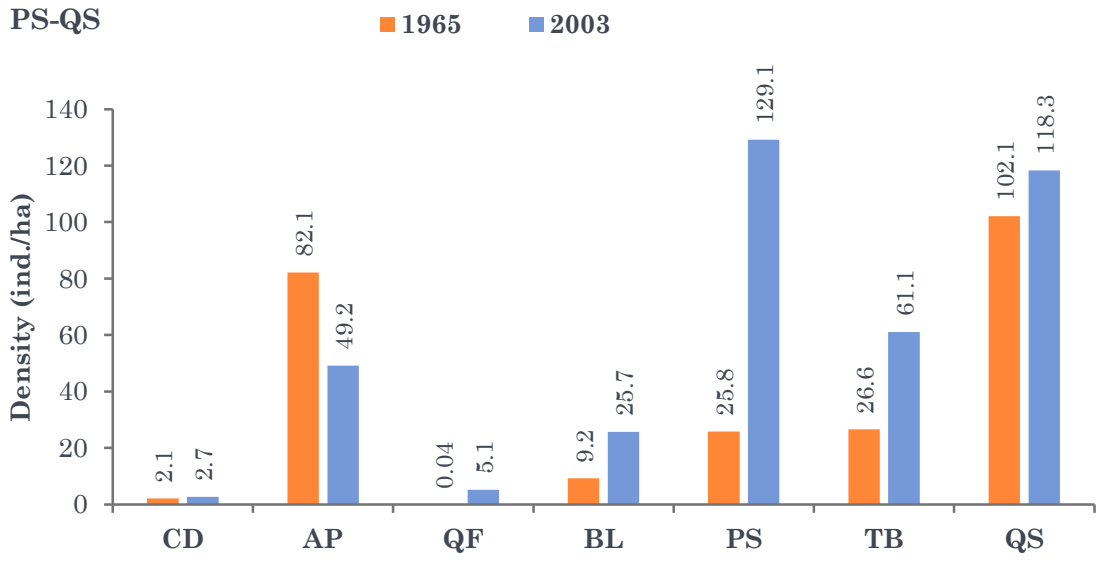

Figure 33: Density Variations in Species Composition in *Picea smithiana-Quercus semecarpifolia* mixed community, Chopal Forest Division, 1965-2003
Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

21. *Picea smithiana-Abies pindrow* community

Data was collected from 5 forest compartments covering an area of 291.34ha, at altitude range of 2160-2880m above mean sea level, for *Picea smithiana-Abies pindrow* mixed community. The tree density of *Picea smithiana* increased from 52.1 ind./ha to 98.4 ind./ha; and of *Abies pindrow* declined from 100.9 ind./ha to just 68.8 ind./ha between 1965 and 2013. In this mixed community, density of *Pinus wallichiana,* Broad-leaved, *Quercus floribunda, Taxus baccata* increased; while for *Cedrus deodara* and *Quercus semecarpifolia* declined between 1965 and 2003, as illustrated in Figure 34.

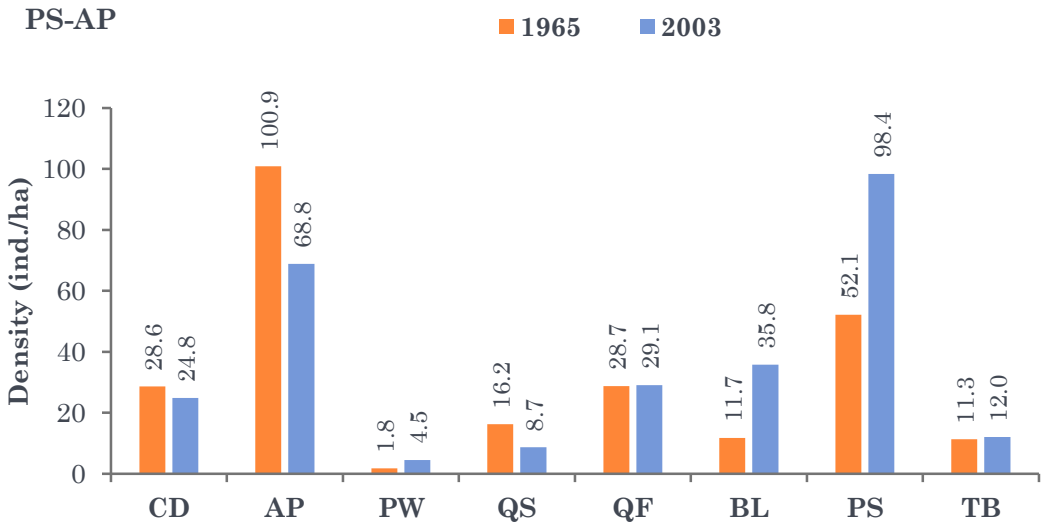

Figure 34: Density Variations in Species Composition in *Picea smithiana-Abies pindrow* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

22. *Pinus wallichiana*-Broad-leaved community

Data was collected from 1 forest compartment covering an area of 56.65ha, at altitude range of 2070-2400m above mean sea level, for *Pinus wallichiana*-Broad-leaved mixed community. The tree density of *Pinus wallichiana* increased from 122.7 ind./ha to 210.5 ind./ha; and of Broad-leaved significantly increased from only 15.7 ind./ha to 158.2 ind./ha between 1965 and 2013. In this mixed community, density of *Cedrus deodara* and *Quercus floribunda* both increased during the study time period, as exhibited in Figure 35.

Figure 35: Density Variations in Species Composition in *Pinus wallichiana*-Broad-leaved mixed community, Chopal Forest Division, 1965-2003
Abbreviations: CD= *Cedrus deodara;* **BL=** Broad-leaved; **QF=** *Quercus floribunda;* **PW=***Pinus wallichiana*
Source: HPSCCC, 2018

23.*Pinus wallichiana-Quercus leucotrichophora* community

Data was collected from 2 forest compartments covering an area of 73.64ha, at altitude range of 1950-2280m above mean sea level, for *Pinus wallichiana-Quercus leucotrichophora* mixed community. The tree density of *Pinus wallichiana* increased from 76.7 ind./ha to 247 ind./ha; and of *Quercus leucotrichophora* significantly increased from only 56.8 ind./ha to 124.6 ind./ha between 1965 and 2013. In this mixed community, density of all remaining species increased, however, the density of *Cedrus deodara* increased dramatically from only 6.5 ind./ha to 150.1 ind./ha; and of *Abies pindrow* from only 0.04 ind./ha to 2.3 ind./ha.

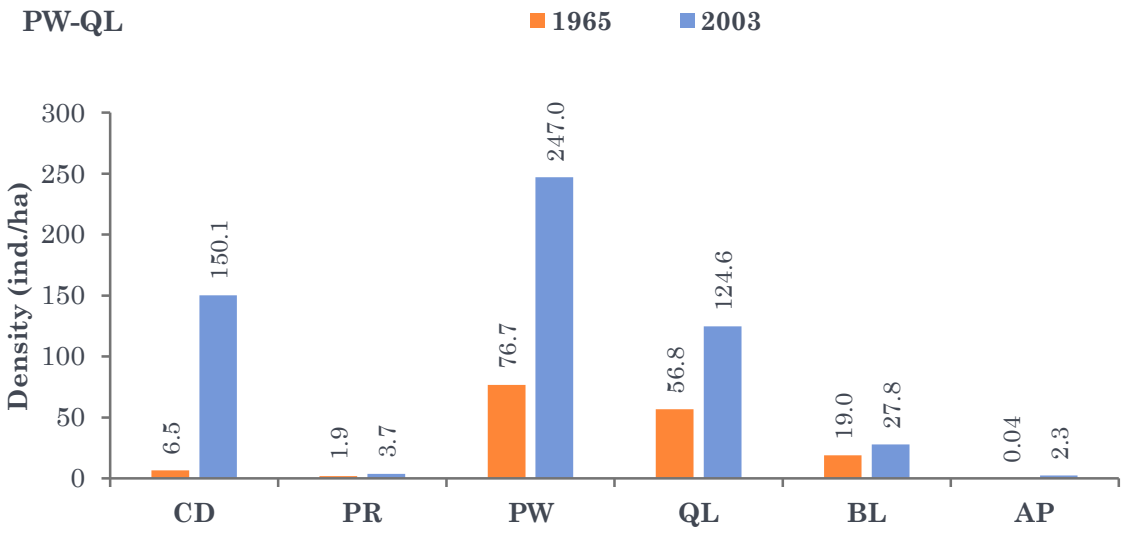

Figure 36: Density Variations in Species Composition in *Pinus wallichiana-Quercus leucotrichophora* mixed community, Chopal Forest Division, 1965-2003
Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **QF=** *Quercus floribunda;* **QL=** *Quercus leucotrichophora*
Source: HPSCCC, 2018

24. Broad-leaved-*Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 75.27ha, at altitude range of 1890-2200m above mean sea level, for Broad-leaved-*Pinus wallichiana* mixed community. The tree density of Broad-leaved rocketed from only 4.5 ind./ha to 280.0 ind./ha, and for *Pinus wallichiana,* the density increased from 119.8 ind./ha to 196.6 ind./ha between 1965 and 2013. In this mixed community, density of all species i.e. *Pinus roxburghii, Cedrus deodara,* and *Quercus floribunda* all registered significant increases from 1965 to 2003, as illustrated in Figure 37.

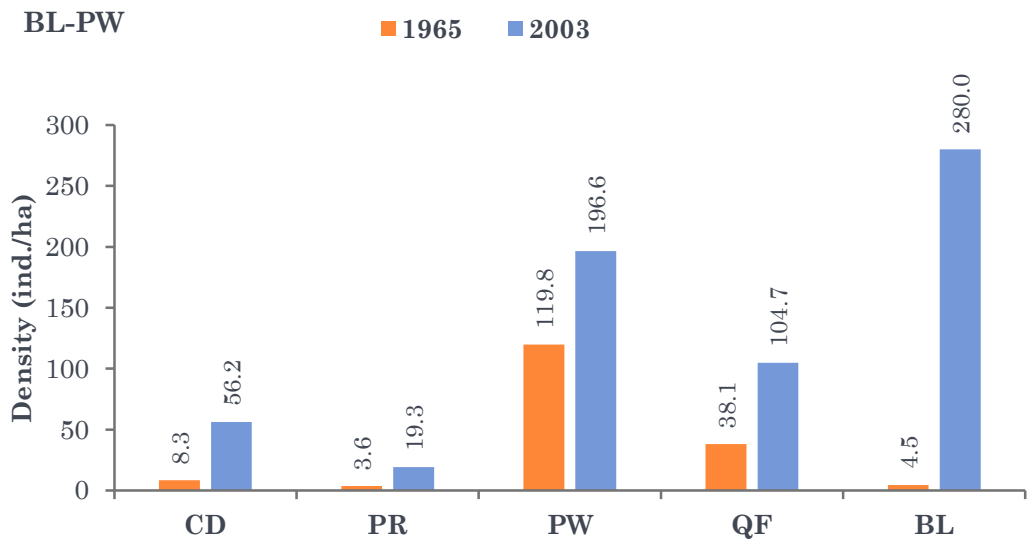

Figure 37: Density Variations in Species Composition in Broad-leaved-*Pinus wallichiana* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD= *Cedrus deodara;* **BL=** Broad-leaved; **QF=** *Quercus floribunda;* **PW=***Pinus wallichiana;* **PR=** *Pinus roxburghii*

Source: HPSCCC, 2018

25.*Abies pindrow-Picea smithiana* community

Data was collected from 3 forest compartments covering an area of 101.97ha, at altitude range of 2250-2757m above mean sea level, for *Abies pindrow-Picea smithiana* mixed community. The tree density of *Abies pindrow* decreased from 102.1 ind./ha to 98.7 ind./ha; and of *Picea smithiana* increased from 54.7 ind./ha to 85.3 ind./ha between 1965 and 2013. In this mixed community, while the density of *Cedrus deodara* and *Taxus baccata* declined; those of *Pinus wallichiana, Quercus semecarpifolia, Quercus floribunda,* and Broad-leaved registered a noticeable increase between 1965 and 2003, as illustrated in Figure 38.

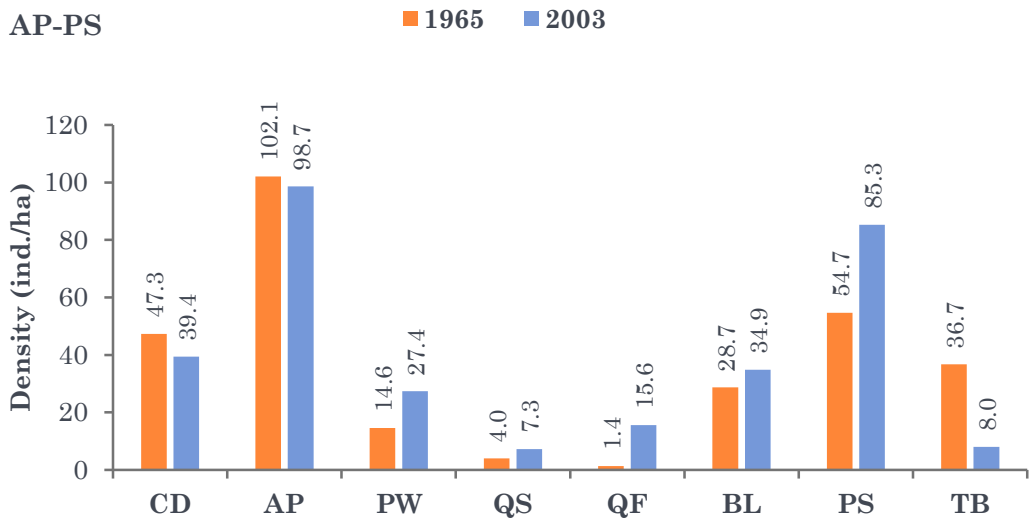

Figure 38: Density Variations in Species Composition in *Abies pindrow-Picea smithiana* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

26. *Taxus baccata-Abies pindrow* community

Data was collected from 1 forest compartment covering an area of 54.63ha, at altitude range of 2220-2760m above mean sea level, for *Taxus baccata-Abies pindrow* mixed community. The tree density of *Taxus baccata* rose from 30.8 ind./ha in 1965 to 123.9 ind./ha in 2003; and for *Abies pindrow,* the density appreciated from 50.4 ind./ha to 106.9 ind./ha. In this mixed community, density of Broad-leaved, *Quercus floribunda, Quercus semecarpifolia, Cedrus deodara,* and *Picea smithiana* all registered an increase; while for *Quercus leucotrichophora* declined, and for *Pinus wallichiana* remained unchanged between 1965 and 2003, as illustrated in Figure 39.

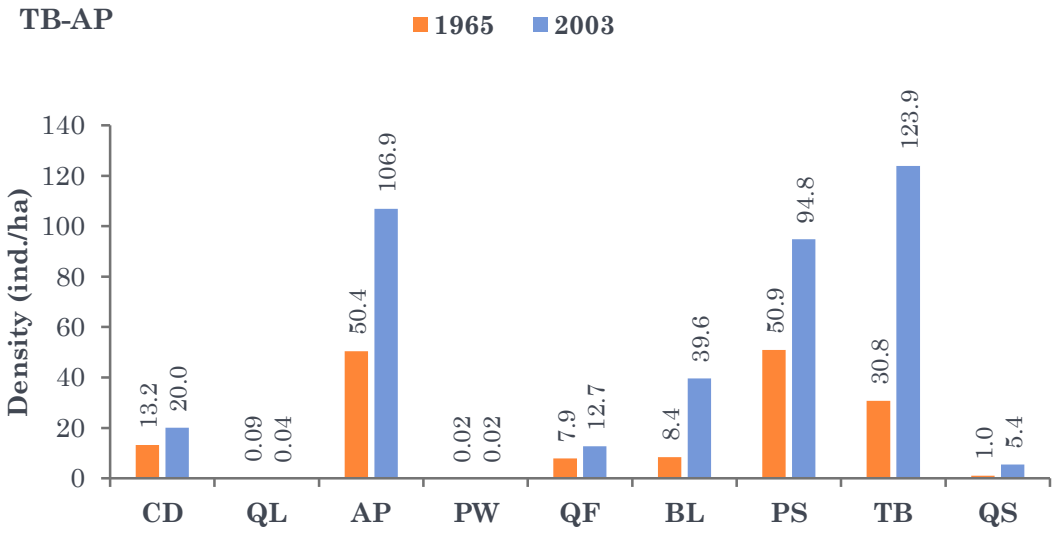

Figure 39: Density Variations in Species Composition in *Taxus baccata-Abies pindrow* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda;* **QL=** *Quercus leucotrichophora;* **PW=***Pinus wallichiana*

Source: HPSCCC, 2018

27. Broad-leaved-*Abies pindrow* community

Data was collected from 1 forest compartment covering an area of 50.18ha, at altitude range of 2040-2490m above mean sea level, for Broad-leaved-*Abies pindrow* mixed community. The tree density of Broad-leaved rose from only 0.9 ind./ha to 40.4 ind./ha, and for *Abies pindrow,* the density decreased from 35.4 ind./ha to 32.1 ind./ha between 1965 and 2013. In this mixed community, density of *Quercus floribunda, Quercus semecarpifolia,* and *Cedrus deodara* increased; while for *Quercus leucotrichophora, Pinus wallichiana,* and *Taxus baccata* surged between 1965 and 2003, as illustrated in Figure 40.

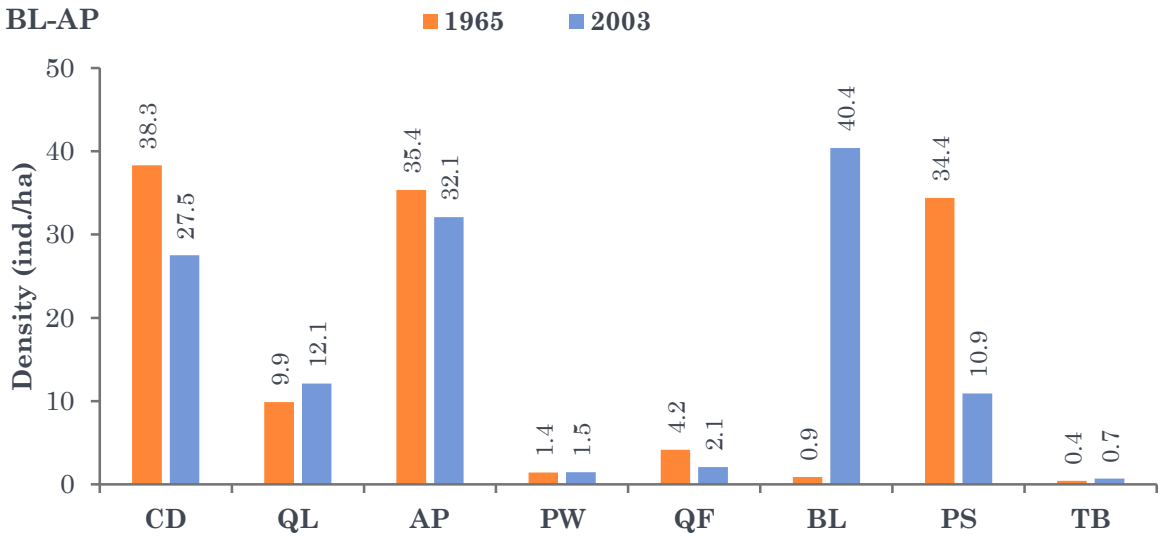

Figure 40: Density Variations in Species Composition in Broad-leaved-*Abies pindrow* mixed community, Chopal Forest Division, 1965-2003

Abbreviations: CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **QF=** *Quercus floribunda;* **QL=** *Quercus leucotrichophora;* **PW=***Pinus wallichiana*

Source: HPSCCC, 2018

28. *Quercus semecarpifolia-Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 153.73ha, at altitude range of 2490-3450m above mean sea level, for *Quercus semecarpifolia-Picea smithiana* mixed community. The tree density of *Quercus semecarpifolia* soared from 88.6 ind./ha to 155.4 ind./ha; and for *Picea smithiana* it registered an incline from just 27.9 ind./ha to 137 ind./ha between 1965 and 2003. In this mixed community, density for all species increased expect for *Abies pindrow*. Amongst the increasing species, *Pinus wallichiana* exhibited maximum increase, moving from just 0.3 ind./ha to 1.8 ind./ha between 1965 and 2003, as illustrated in Figure 41.

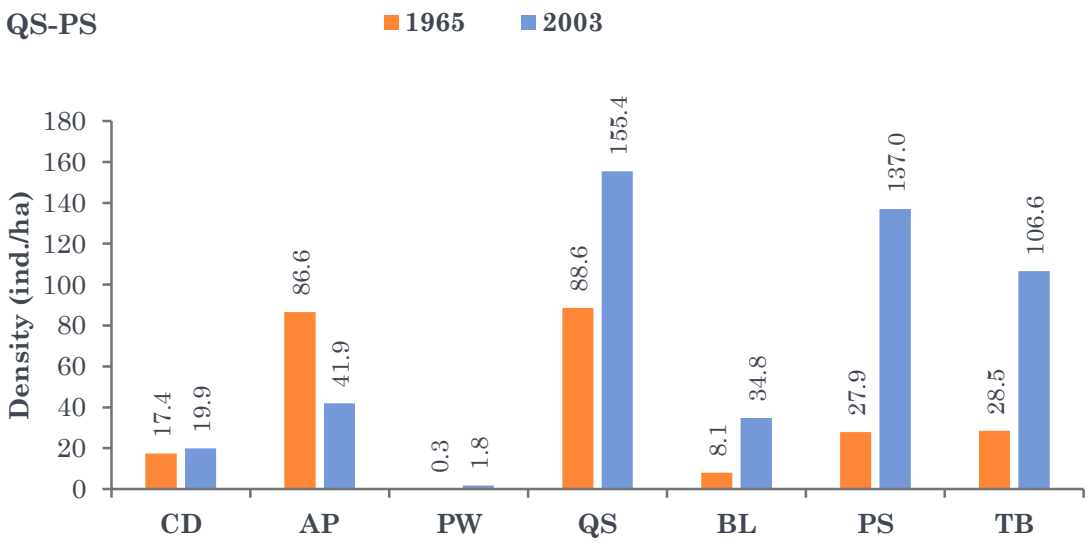

Figure 41: Density Variations in Species Composition in *Quercus semecarpifolia-Picea smithiana* mixed community, Chopal Forest Division, 1965-2003
Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **PW=***Pinus wallichiana*
Source: HPSCCC, 2018

29. *Quercus semecarpifolia-Taxus baccata* community

Data was collected from 4 forest compartments covering an area of 491.68ha, at altitude range of 2280-3360m above mean sea level, for *Quercus semecarpifolia-Taxus baccata* mixed community. The tree density of *Quercus semecarpifolia* increased from 137.7 ind./ha to 145.1 ind./ha; and for *Taxus baccata*, it registered an incline from just 95.2 ind./ha to 108.3 ind./ha between 1965 and 2003. In this mixed community, density of *Cedrus deodara, Picea smithiana, Abies pindrow,* and Broad-leaved declined; and for *Pinus wallichiana* and *Quercus floribunda* increased between 1965 and 2003, as illustrated in Figure 42.

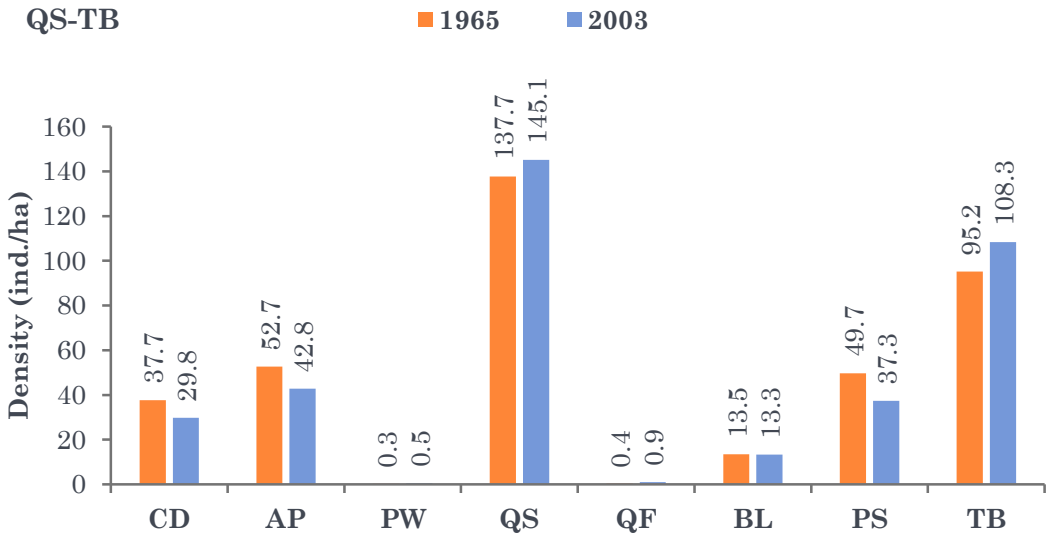

Figure 42: Density Variations in Species Composition in *Quercus semecarpifolia-Taxus baccata* mixed community, Chopal Forest Division, 1965-2003
Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved; **QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana;* **PW=***Pinus wallichiana;* **QF=** *Quercus floribunda*
Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study the forests compartments of Chopal Forest Division were divided into 3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500m and above. The forests in particular altitudinal range were categorized species wise, and then their total number was calculated for both of years i.e. 1965 and 2003. The density (individuals per hectare) was then calculated for all species at respective altitudes representing individuals in one hectare.

1. 1500-2000m

There are 6 forest compartments at this altitude gradient with a total area of 130.29ha falling under Chopal, Kanda, Nerwa, and

Sarain forest ranges. At 1500-2000m altitude, *Cedrus deodara* assumed highest concentration in both the years; however it underwent negative temporal change in density, moving from 311.5 ind./ha in 1965 to 287.2 ind./ha in 2003. Meanwhile, the remaining species registered positive density variations. Density of *Pinus wallichiana* increased from 46.3 ind./ha to 51.3 ind./ha; of *Quercus leucotrichophora,* density increased from 0.1 ind./ha to 0.2 ind./ha; and maximum increase was reported for *Pinus roxburghii,* whose density rocketed from only trace 0.02 ind./ha to 0.22 ind./ha between 1965 and 2003 at 1500-2000m altitude.

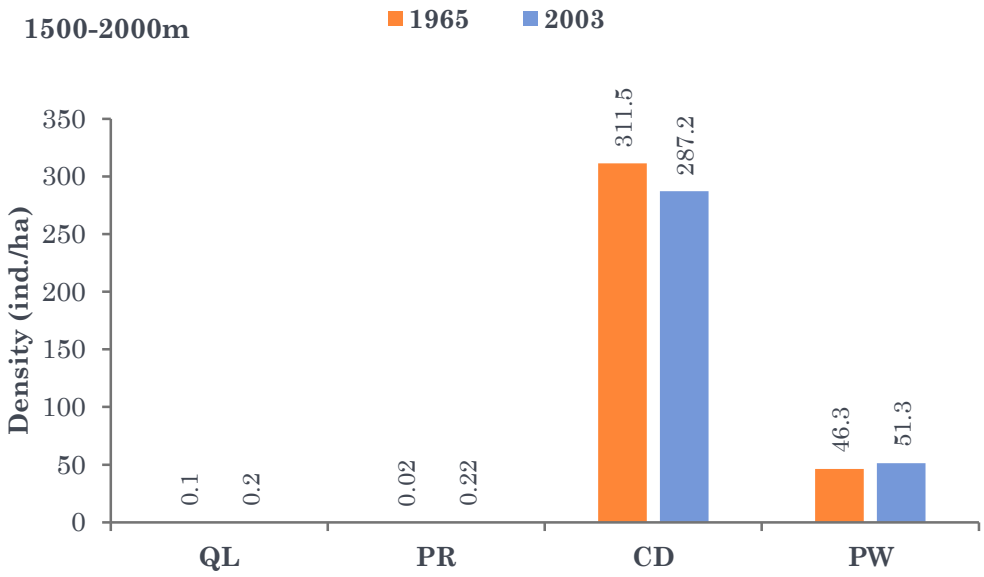

Figure 43: Density Variations in Species Composition at 1500-2000m Altitude, Chopal Forest Division, 1965-2003
Source: HPSCCC, 2018

2. 2000-2500m

There are 53 forest compartments at this altitude gradient with a total area of 2117.92ha falling under Chopal, Kanda, Nerwa, and Sarain forest ranges. At 2000-2500m altitude, extent and scale of positive variations outweighed reductions in densities between 1965

and 2003. Amongst the declining densities, *Quercus floribunda* and *Pinus wallichiana* registered reduction of 10 per cent and 6 per cent, respectively. For other species, individuals per hectare of *Quercus leucotrichophora* surged by 161 per cent followed by Broad-leaved with 142 per cent density increase, *Abies pindrow* with 92 per cent, *Taxus baccata* with 63 per cent, *Picea smithiana* with 18 per cent, and *Quercus semecarpifolia* and *Cedrus deodara* with nominal increments of 6 per cent and 0.1 per cent, respectively.

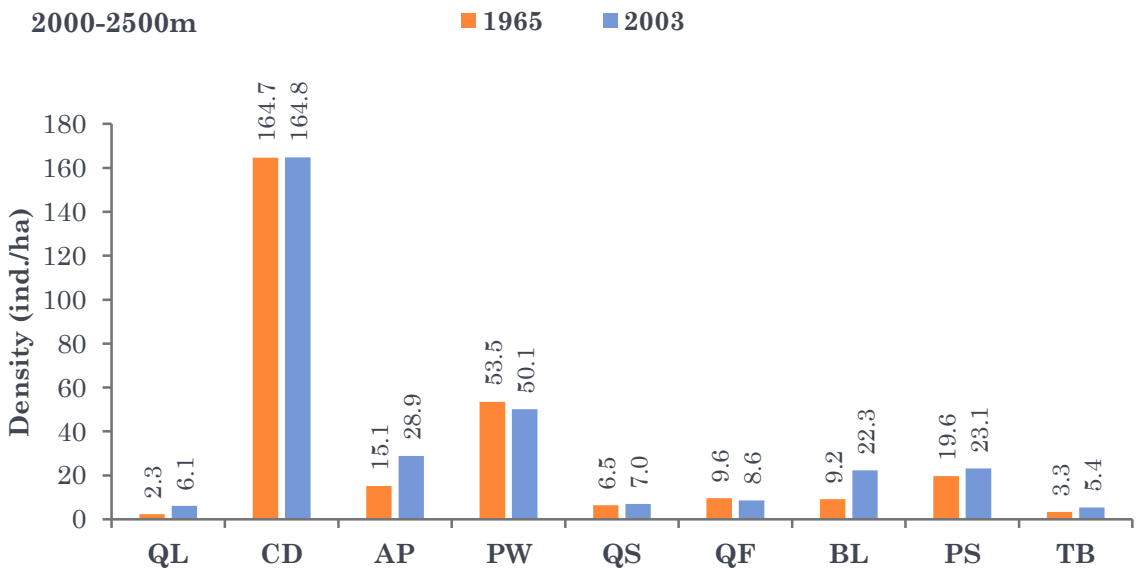

Figure 44: Density Variations in Species Composition at 2000-2500m Altitude, Chopal Forest Division, 1965-2003
Source: HPSCCC, 2018

3. 2500m and above

There are 29 forest compartments at this altitude gradient with a total area of 2134.91ha that fall under Chopal, Kanda, Nerwa, and Sarain forest ranges. At the study's highest altitude range, only *Abies pindrow* registered a reduction in density, moving from 71.9 ind./ha to 57.9 ind./ha between 1965 and 2003. All of the remaining species registered an increase in density with Broad-leaved

increasing by 78 per cent, *Taxus baccata* by 39 per cent, *Picea smithiana* by 31 per cent, *Pinus wallichiana* by 20 per cent, *Quercus semecarpifolia* by 17 per cent, and *Cedrus deodara* by 14 per cent. Density of *Quercus leucotrichophora* remained unchanged between 1965 and 2003 at altitude 2500m and above.

Figure 45: Density Variations in Species Composition at 2500-3000m Altitude, Chopal Forest Division, 1965-2003
Source: HPSCCC, 2018

Table 6 below gives information on suitable altitude ranges for identified tree species juxtaposed with observation made for the Chopal Forest Division under Shimla Forest Circle.

Table 6: Suitable Altitude Range for Different Tree Species in Chopal Division

Species	Suitable Altitude	Observed Changes		
		1500-2000m	2000-2500m	2500-3000m
Cedrus deodara	1800 – 3000m	Decreased	Increased	Increased
Pinus wallichiana	1800 – 3000m	Increased	Decreased	Increased
Abies pindrow	2000 – 3300m	Not Present	Increased	Decreased
Picea smithiana	2100 – 3600m	Not Present	Increased	Increased
Pinus roxburghii	1000 – 2000m	Increased	Not Present	Not Present
Quercus leucotrichophora	1500 – 2400m	Increased	Increased	Unchanged
Quercus floribunda	2000 – 2500m	Not Present	Decreased	Not Present

Quercus semecarpifolia	1830 – 3050m	Not Present	Increased	Increased
Taxus baccata	2100 – 3200m	Not Present	Increased	Increased
Broad-leaved (temperate)	2000 – 3000m	Not Present	Increased	Increased

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Chopal Forest Division, its density was observed to decrease at lower altitudes of 1500-2000m, registering a decline of 8 per cent. At 2000m and above, marginal increase in density was witnessed i.e. just 0.1 per cent at 2000-2500m, and 14 per cent at 2500m and higher.

Pinus wallichiana is found between 1800m and 3000m altitude above sea level, and in the Chopal Forest Division, its density was observed to be in higher concentration at 1500-2000m (by 11 per cent), and by 20 per cent at 2500m and above. At mid-altitude range, it witnessed a decline of 6 per cent.

Abies pindrow grows at 2000-3300m altitude, and in this forest Division, the species registered an increase of 92 per cent at 2000-2500m and a decline of 19 per cent at 2500m and higher. The species was not found at lower altitudes in Chopal Forest Division.

Picea smithiana thrives at 2100-3600m altitude, and in the Chopal Forest Division, its density increased at 2000-2500m, and 2500m and above by 18 per cent, and 31 per cent, respectively. The species was not found at lower altitudes in Chopal Forest Division.

Broad-leaved species in temperate forests thrive at 2000-3000m altitude range, and in Chopal Forest Division its density rocketed by

142 per cent at 2000-2500m, and 78 per cent at 2500m and above. The species was not found at lower altitudes in Chopal Forest Division between 1965 and 2003.

Quercus semecarpifolia is found at 1830-3050m, and in this forest division, it registered an increase of 7 per cent at 2000-2500m, and 17 per cent at 2500m and higher. This species too was not observed at the lower altitude range of 1500-2000m.

Quercus floribunda thrives at 2000-2500m, and in Chopal Forest Division, its density declined by 10 per at 2000-2500m. The species was not observed in other two altitude ranges, as per the enumerated data.

Quercus leucotrichophora thrives at 1500-2400m altitude range, and in this forest division, the species registered comprehensive increase of 69 per cent and 161 per cent at 1500-2000m, and 2000-2500m, respectively. At 2500m and higher altitudes, its density remained unchanged between 1965 and 2003.

Pinus roxburghii grows at lower altitude range of 1000-2000m, and in the Chopal Forest Division, its density jumped by over thousand percent (from 0.02 ind./ha to 0.22 ind./ha) between 1500 and 2000m altitude range.

Rohru Forest Division

For Rohru Forest Division, enumerated information in the Working Plans from Himachal Pradesh Forest Department and Compartment History files from 6 forest ranges (Rohru, Tikker, Khashdhar, Jubbal, Bashala, and Sarswati Nagar) was taken for 1969 and 1994. As per the assessment, 7 pure tree - *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP), Quercus leucotrichophora (QL), Picea smithiana (PS), Pinus roxburghii (PR),* and Broad-leaved, and 7 mixed tree communities – *Abies pindrow*-Broad-leaved, *Picea smithiana-Cedrus deodara, Abies pindrow-Picea smithiana, Pinus wallichiana-Cedrus deodara, Pinus wallichiana- Cedrus deodara,* Broad-leaved-*Pinus wallichiana,* and *Picea smithiana- Abies pindrow* were identified.

As highlighted in

Table 4 earlier, these tree communities were assessed from 98 forest compartments spread over a total area of 9429.74 ha.

The Tree Community based Variations

The following section discusses *the tree community based variations in density* for the identified species.

1. ***Cedrus deodara community***

   Data was collected from 19 forest compartments covering an area of 1365.82ha, at altitude range of 2034-2819m above mean sea level. As illustrated in Figure 46, in its dominant tree community, density of *Cedrus deodara* increased from 98.5 ind./ha to 107.6 ind./ha. In these forest compartments, representation (density) of other species

is as follows – density of *Pinus wallichiana* plummeted from 81.5 ind./ha in 1969 to 33.7 ind./ha in 1994, density of *Picea smithiana,* Broad-leaved, and *Abies pindrow* also declined from 15.8 ind./ha to 9.7 ind./ha, 4.0 ind./ha to 3.5 ind./ha, and 1.2 ind./ha to 0.5 ind./ha, respectively. Tree density of *Quercus leucotrichophora* and *Quercus floribunda* increased from 0 ind./ha to 0.3 ind./ha, and 0.1 ind./ha to 0.4 ind./ha, respectively between 1969 and 1994.

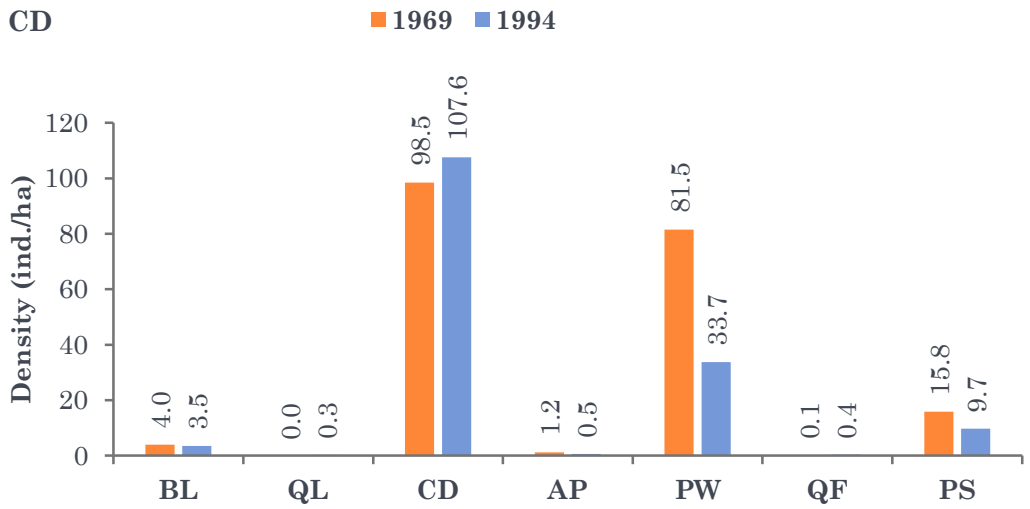

Figure 46: Density Variations in Species Composition in *Cedrus deodara* community, Rohru Forest Division, 1969-1994
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **PR=** *Pinus roxburghii;* **QF**= *Quercus floribunda;* **QL**= *Quercus leucotrichophora*
Source: HPSCCC, 2018

2. *Pinus wallichiana* community

Data was collected from 45 forest compartments covering an area of 4551.71ha, at altitude range of 2187-2712m above mean sea level. As illustrated in Figure 47, in its dominant tree community, density of *Pinus wallichiana* increased from 106.9 ind./ha to 131.1 ind./ha between 1969 and 1994. In these forest compartments, representation (density) of other species is as follows – tree density of *Abies pindrow* plummeted from 10.8 ind./ha in 1969 to only 0.6

ind./ha in 1994; density of Broad-leaved, *Pinus roxburghii, Quercus floribunda,* and *Picea smithiana* too declined from 4.1 ind./ha to 2.7 ind./ha, 0.7 ind./ha to 0.2 ind./ha, 2.2 ind./ha to 1.8 ind./ha, and 21.3 ind./ha to 15.7 ind./ha, respectively. Meanwhile, tree density of *Cedrus deodara* increased from 22.4 ind./ha to 33.7 ind./ha from 1969 to 1994.

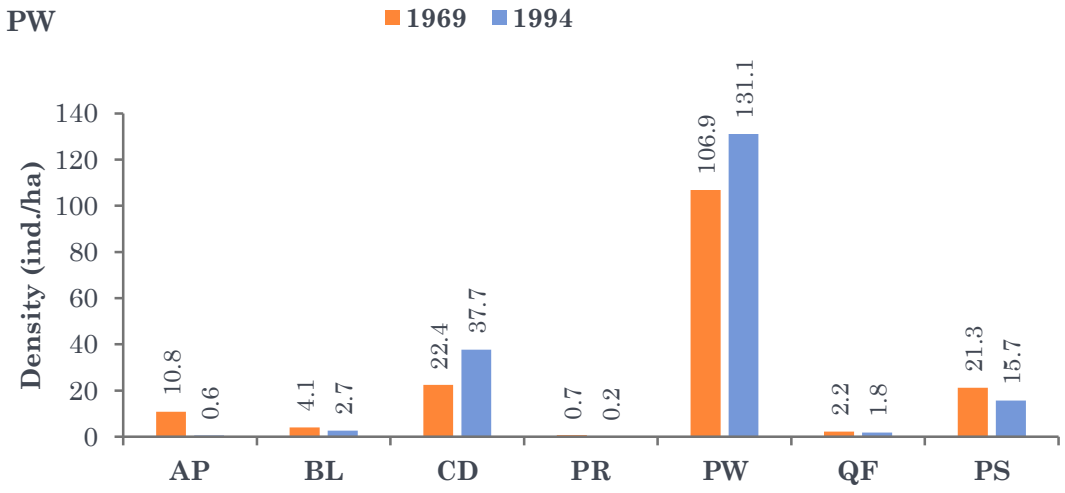

Figure 47: Density Variations in Species Composition in *Pinus wallichiana* community, Rohru Forest Division, 1969-1994
Abbreviations: CD=*Cedrus deodara*, **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies Pindrow;* **PR=** *Pinus roxburghii;* **QF**= *Quercus floribunda*
Source: HPSCCC, 2018

3. *Abies pindrow* community

Data was collected from 9 forest compartments covering an area of 1150.54ha, at altitude range of 2700-2945m above mean sea level. As illustrated in Figure 48, in its dominant tree community, density of *Abies pindrow* decreased from 189 ind./ha in 1969 to 83.2 ind./ha in 1994. In these forest compartments, representation (density) of other species is as follows – tree density of *Picea smithiana* and *Cedrus deodara* too declined from 42.1 ind./ha to 29.9 ind./ha, and 7.3 ind./ha to 5.0 ind./ha, respectively. Meanwhile, density of *Pinus wallichiana* increased from 16.5 ind./ha to 16.8 ind./ha between 1969 and 1994.

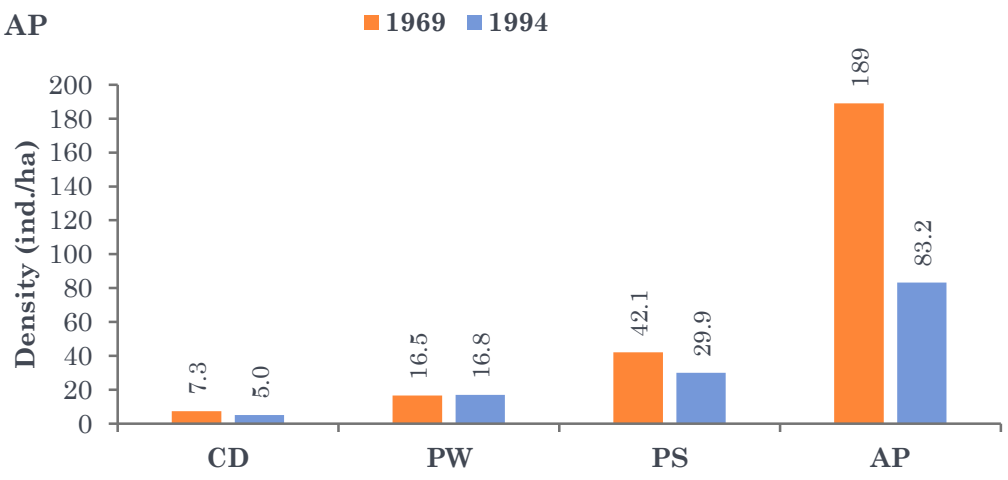

Figure 48: Density Variations in Species Composition in *Abies pindrow* community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **AP=** *Abies pindrow*

Source: HPSCCC, 2018

4. *Pinus roxburghii* community

Data was collected from 6 forest compartments covering an area of 399.02ha, at altitude range of 1600-1974m above mean sea level. As illustrated in Figure 49, in its dominant tree community, density of *Pinus roxburghii* declined from 105.5 ind./ha to 74.4 ind./ha between 1969 and 1994. In these forest compartments representations (density) of other species are as follows – tree density of *Cedrus deodara* decreased from 0.8 ind./ha to 0.4 ind./ha; tree density of *Pinus wallichiana* plummeted from 3.0 ind./ha to 0.8 ind./ha; and density of Broad-leaved increased to 1.7 ind./ha.

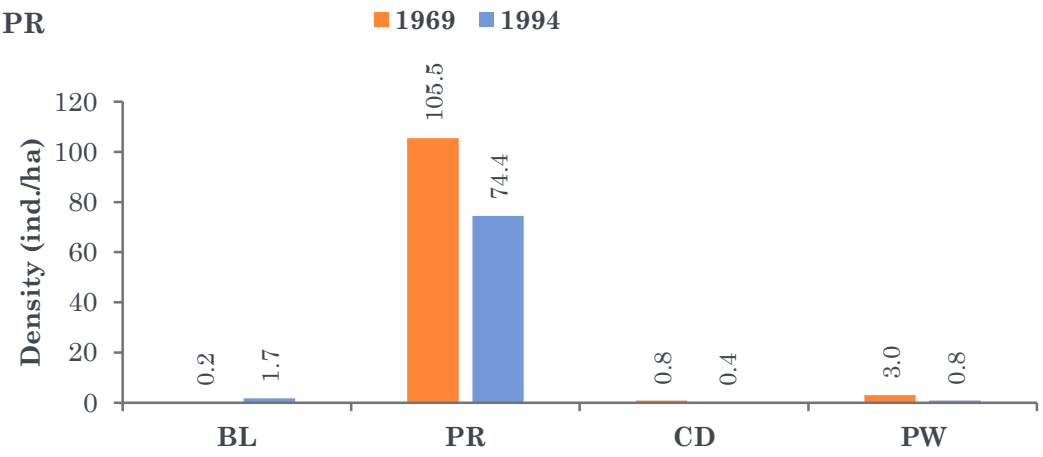

Figure 49: Density Variations in Species Composition in *Pinus roxburghii* community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved, **PR=** *Pinus roxburghii*

Source: HPSCCC, 2018

5. Broad-leaved community

Data was collected from 3 forest compartments covering an area of 335.08ha, at altitude range of 1650-2100m above mean sea level. As illustrated in Figure 50, in its dominant tree community, density of Broad-leaved increased from 51.4 ind./ha to 82.1 ind./ha between 1969 and 1994. In these forest compartments, representation (density) of other species is as follows – tree density of *Pinus roxburghii* plummeted from 27.5 ind./ha to 9.3 ind./ha; while for *Quercus leucotrichophora, Quercus floribunda, Abies pindrow*, and *Picea smithiana* the tree density declined from 12.3 ind./ha to 11.1 ind./ha, 36.7 ind./ha to 20.4 ind./ha, 30.1 ind./ha to 16.2 ind./ha, and 10 ind./ha to 8.1 ind./ha, respectively. Meanwhile, density of *Cedrus deodara* and *Pinus wallichiana* increased from 2.2 ind./ha and 0.8 ind./ha to 2.3 ind./ha and 1.1 ind./ha, respectively between 1996 and 1994.

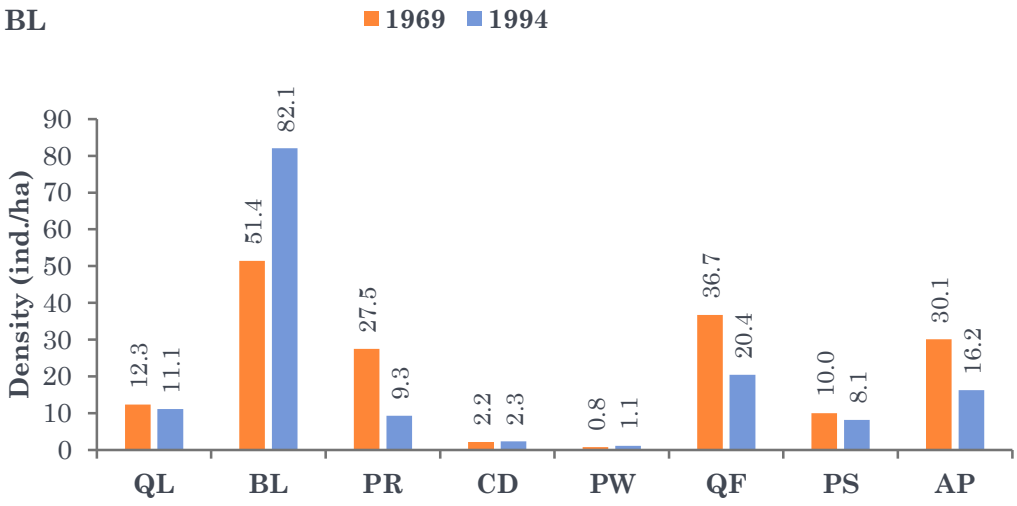

Figure 50: Density Variations in Species Composition in Broad-leaved community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **PR=** *Pinus roxburghii;* **QL**= *Quercus leucotrichophora;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

6. *Quercus leucotrichophora* community

Data was collected from 2 forest compartments covering an area of 121ha, at altitude range of 1700-1890m above mean sea level. As illustrated in Figure 51, in its dominant tree community, density of *Quercus leucotrichophora* noticeably increased from 34.1 ind./ha to 74.3 ind./ha between 1969 and 1994. In these forest compartments, representation (density) of other species is as follows – tree density of all species significantly declined. Density of *Pinus roxburghii* plummeted from 81.6 ind./ha to 30.7 ind./ha; while for Broad-leaved, *Quercus floribunda, Cedrus deodara* and *Pinus wallichiana,* the tree density declined from 51.6 ind./ha to 33.1 ind./ha, 3.1 ind./ha to 2.5 ind./ha, 1.5 ind./ha to 1.2 ind./ha, and 3.1 ind./ha to 2.5ind./ha, respectively between 1996 and 1994.

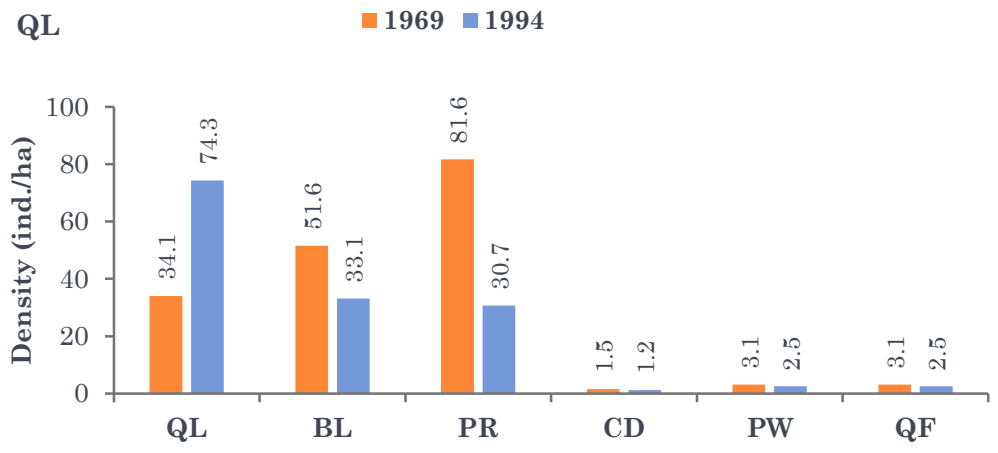

Figure 51: Density Variations in Species Composition in *Quercus leucotrichophora* community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved; **PR=** *Pinus roxburghii;* **QL**= *Quercus leucotrichophora;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

7. *Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 66.37ha, at altitude range of 2310-2690m above mean sea level. As illustrated in Figure 52, in its dominant tree community, density of *Picea smithiana* declined from 138.5 ind./ha to 81.3 ind./ha between 1969 and 1994. In these forest compartments, representation (density) of other species is as follows – tree density of *Pinus wallichiana* and *Abies pindrow* plummeted from 119.4 ind./ha to just 46.2 ind./ha and 28.8 ind./ha to only 4.3 ind./ha, respectively; while for *Cedrus deodara,* the tree density declined from 8.4 ind./ha to 7.1 ind./ha. Meanwhile, density of Broad-leaved increased from 6.2 ind./ha to 10.8 ind./ha between 1996 and 1994.

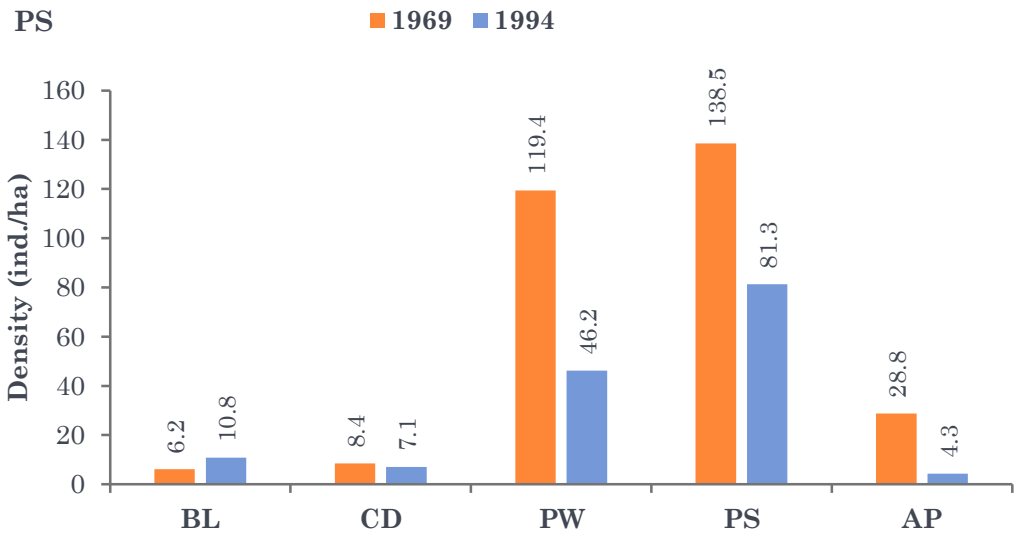

Figure 52: Density Variations in Species Composition in *Picea smithiana* community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved; **PS**=*Picea smithiana;* **AP=** *Abies pindrow*

Source: HPSCCC, 2018

8. *Abies pindrow*-Broad-leaved community

Data was collected from 1 forest compartment covering an area of 117.36ha, at altitude range of 2670-2900m above mean sea level, for *Abies pindrow*-Broad-leaved mixed community. The tree density of *Abies pindrow* decreased from 138.0 ind./ha in year 1969 to 123.9 ind./ha in year 1994; and for Broad-leaved the density increased from 55.1 ind./ha to 76.6 ind./ha. In this mixed community, density of all other species i.e. *Cedrus deodara, Pinus wallichiana,* and *Picea smithiana* declined between 1969 and 1994, as illustrated in Figure 53.

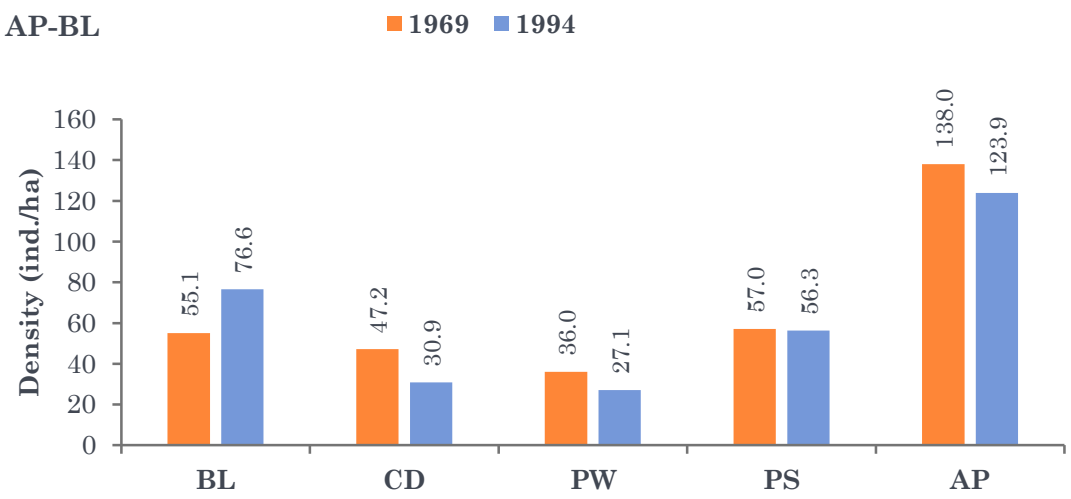

Figure 53: Density Variations in Species Composition in *Abies pindrow*-Broad-leaved mixed community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **BL**= Broad-leaved

Source: HPSCCC, 2018

9. *Picea smithiana-Cedrus deodara* community

Data was collected from 4 forest compartments covering an area of 346.01ha, at altitude range of 2380-2415m above mean sea level, for *Picea smithiana-Cedrus deodara* mixed community. The tree density of *Picea smithiana* increased from 85.8 ind./ha in year 1969 to 95.9 ind./ha in year 1994; and for *Cedrus deodara,* the density increased from 11.4 ind./ha to 11.5 ind./ha. In this mixed community, density of *Pinus wallichiana* and *Abies pindrow* registered a noticeable decline from 76.2 ind./ha to 62.3 ind./ha, and 48.2 ind./ha to 21.5 ind./ha, respectively; and that of Broad-leaved marginally increased from 5.7 ind./ha to 5.8 ind./ha between 1969 and 1994, as illustrated in Figure 54.

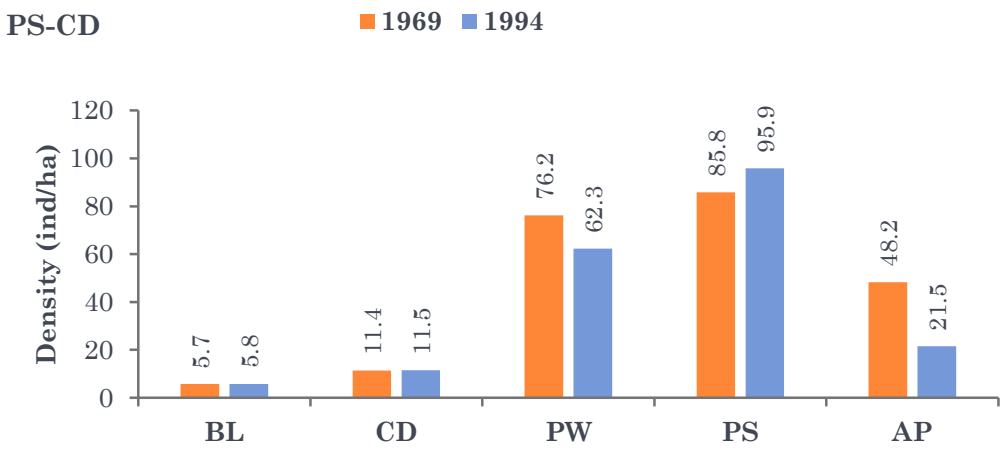

Figure 54: Density Variations in Species Composition in *Picea-smithiana-Cedrus deodara* mixed community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **BL**= Broad-leaved

Source: HPSCCC, 2018

10. *Abies pindrow-Picea smithiana* community

Data was collected from 3 forest compartments covering an area of 309.17ha, at altitude range of 2330-2440m above mean sea level, for *Abies pindrow-Picea smithiana* mixed community. The tree density of *Abies pindrow* declined from 52.8 ind./ha in year 1969 to 41 ind./ha in year 1994; and for *Picea smithiana,* the density increased from 31.0 ind./ha to 34.6 ind./ha. In this mixed community, density of *Cedrus deodara* registered a noticeable decline from 22.3 ind./ha to 11.2 ind./ha; Broad-leaved and *Pinus wallichiana* decreased from 8.1 ind./ha to 5.7 ind./ha, and 28 ind./ha to 15.3 ind./ha, respectively between 1969 and 1994, as illustrated in Figure 55. Meanwhile, tree density of *Picea smithiana* and *Quercus semecarpifolia* registered an incline.

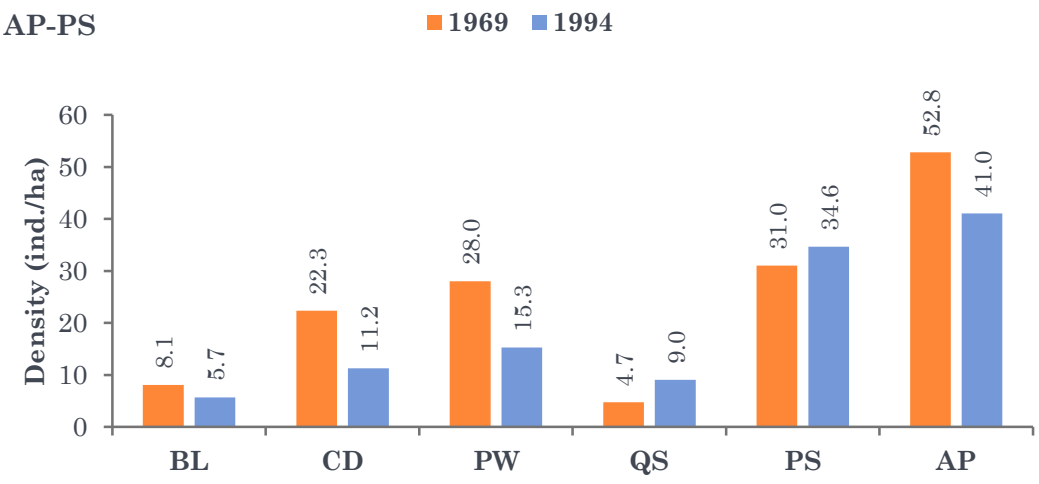

Figure 55: Density Variations in Species Composition in *Abies pindrow-Picea smithiana* mixed community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **BL**= Broad-leaved; **QS**= *Quercus semecarpifolia*

Source: HPSCCC, 2018

11. *Cedrus deodara- Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 84.58ha, at altitude range of 2010-2890m above mean sea level, for *Cedrus deodara-Pinus wallichiana* mixed community. The tree density of *Cedrus deodara* marginally decreased from 111.1 ind./ha to 109.8 ind./ha between 1969 and 1994; and for *Pinus wallichiana,* the density plummeted from 156.4 ind./ha to 108 ind./ha. In this mixed community, density of *Abies pindrow* registered a considerable decline from 7.4 ind./ha to 4.5 ind./ha; and that of *Quercus floribunda* decreased from 1.4 ind./ha to 1.1 ind./ha. Menwhile, tree density of Broad-leaved and *Picea smithiana* registered an increase between 1969 and 1994, as illustrated in Figure 56.

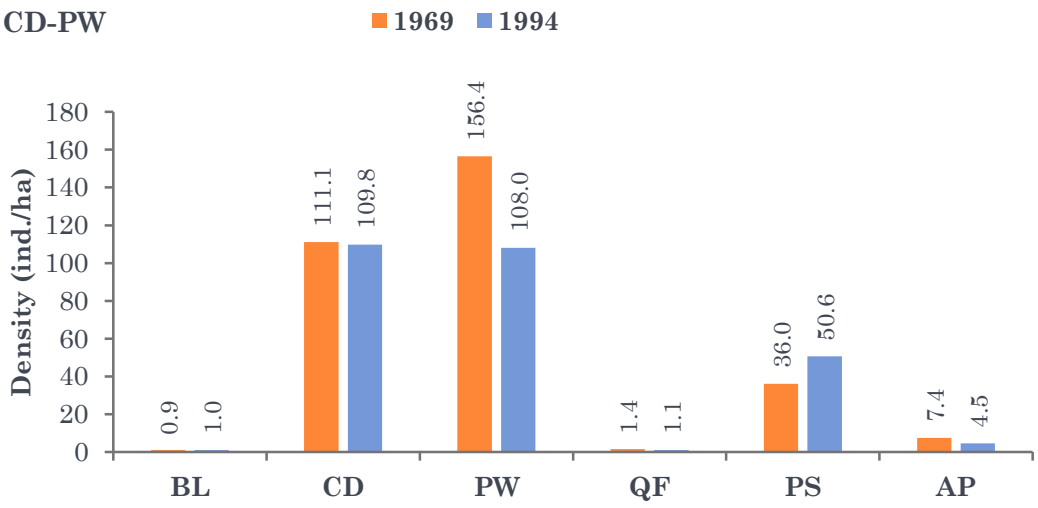

Figure 56: Density Variations in Species Composition in *Cedrus deodara-Pinus wallichiana* mixed community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **BL**= Broad-leaved; **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

12. *Pinus wallichiana-Cedrus deodara* community

Data was collected from 1 forest compartment covering an area of 212.4ha, at altitude range of 2100-2800m above mean sea level, for *Pinus wallichiana-Cedrus deodara* mixed community. The tree density of *Pinus wallichiana* decreased from 58.5 ind./ha to 52.5 ind./ha between 1969 and 1994; and for *Cedrus deodara,* the density increased from 45.4 ind./ha to 50.7 ind./ha. In this mixed community, density of *Abies pindrow* registered a considerable increase from just 7.2 ind./ha to 16.6 ind./ha; and that of *Picea smithiana* increased from 32.0 ind./ha to 46.2 ind./ha between 1948 and 1996, as illustrated in Figure 57.

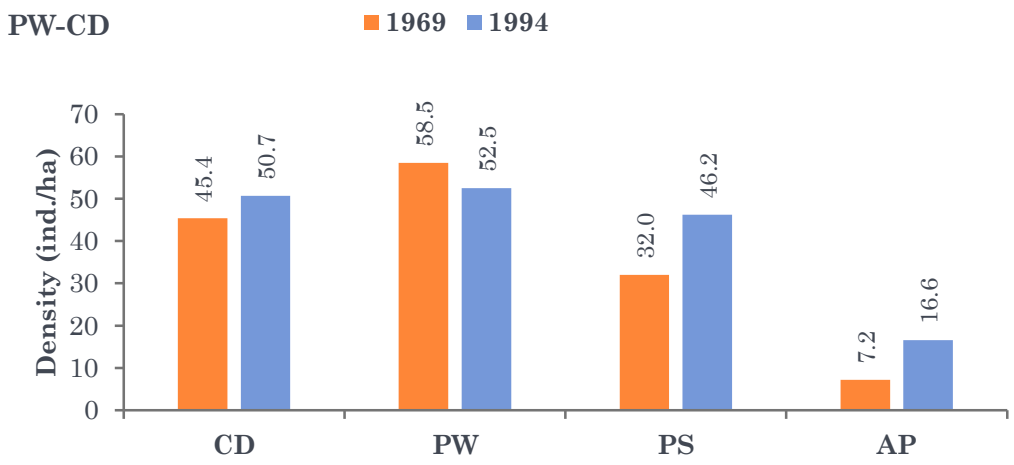

Figure 57: Density Variations in Species Composition in *Pinus wallichiana-Cedrus deodara* mixed community, Rohru Forest Division, 1969-1994
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

13. Broad-leaved - *Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 82.55ha, at altitude range of 2300-2760m above mean sea level, for Broad-leaved- *Pinus wallichiana* mixed community. The tree density of Broad-leaved increased from 63.3 ind./ha in 1969 to 65.5 ind./ha in 1994; and for *Pinus wallichiana*, the density declined from 150.4 ind./ha to 135.1 ind./ha. In this mixed community, density of *Abies pindrow, Cedrus deodara,* and *Picea smithiana* all registered a noticeable increase between 1969 and 1994, as illustrated in Figure 58.

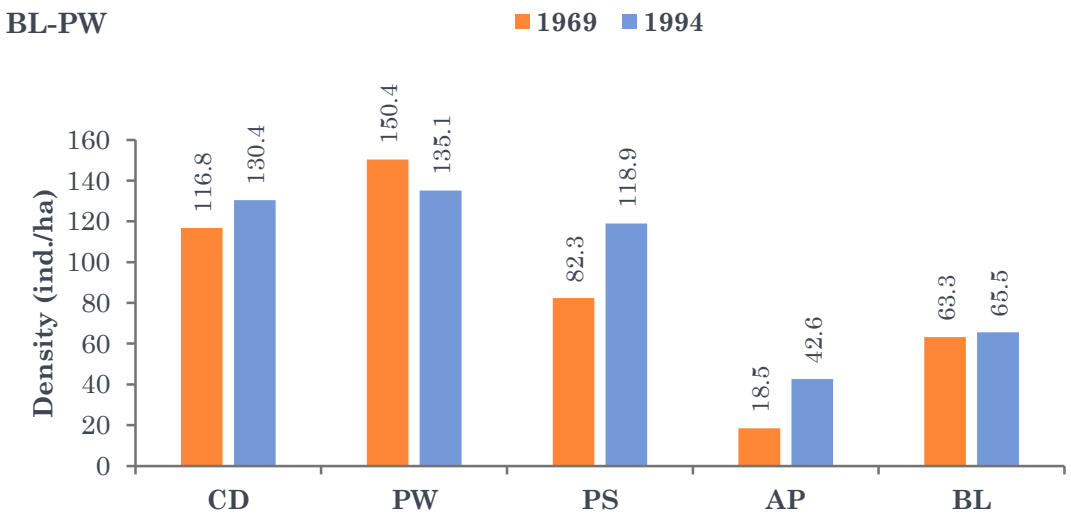

Figure 58: Density Variations in Species Composition in Broad-leaved-*Pinus wallichiana* mixed community, Rohru Forest Division, 1969-1994

Abbreviations: CD=*Cedrus deodara*; **BL**=Broad-leaved; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*

Source: HPSCCC, 2018

14. *Picea smithiana- Abies pindrow* community

Data was collected from 2 forest compartments covering an area of 288.13ha, at altitude range of 2160-2700m above mean sea level, for *Picea smithiana-Abies pindrow* mixed community. The tree density of *Picea smithiana* decreased from 50.2 ind./ha in 1969 to 37.4 ind./ha in 1994; and for *Abies pindrow* too, the density declined from 53.3 ind./ha to 29.4 ind./ha. In this mixed community, density of other species i.e. *Pinus wallichiana, Cedrus deodara,* and *Quercus floribunda* decreased between 1969 and 1994, as illustrated in Figure 59. Meanwhile, the Broad-leaved community registered a sharp increase from only 1.5 ind./ha to 13.5 ind./ha.

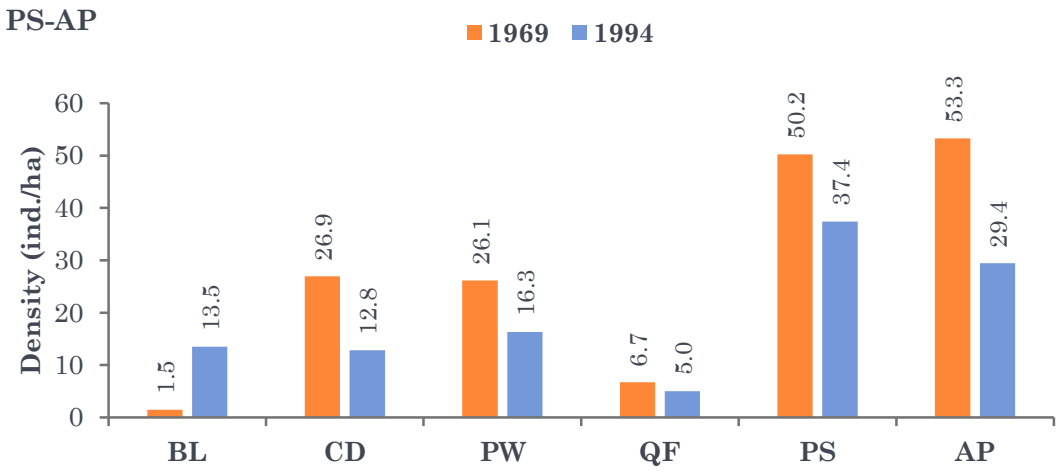

Figure 59: Density Variations in Species Composition in *Cedrus deodara-Picea smithiana* mixed community, Rohru Forest Division, 1948-1996

Abbreviations: **CD**=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP**= *Abies pindrow;* **BL**=Broad-leaved; **QF**= *Quercus floribunda*

Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study the forests compartments of Rohru Forest Division were divided in 3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500-3000m. The forests in particular altitudinal range were categorized species wise, and then their total numbers were calculated for both of years i.e. 1969 and 1994. The density (individuals per hectare) is calculated for all species at respective altitudes, representing individuals in one hectare.

1. **1500-2000m**

   There are 6 forest compartments at this altitude gradient with a total area of 346.01ha falling under Rohru, Tikker, Khashdhar, Jubbal, Bashala, and Sarswati Nagar forest ranges. At 1500-2000m altitude, only *Quercus leucotrichophora* registered an increase in density (11.9 ind./ha to 26 ind./ha); while the tree density of all other species declined during the study period. Density of *Pinus*

roxburghii and *Quercus floribunda* dropped from 87.2 ind./ha to 46.2 ind./ha, and 5.4 ind./ha to 0.2 ind./ha, respectively; and those of Broad-leaved, *Cedrus deodara,* and *Pinus wallichiana* reduced from 18.3 ind./ha, 1.5 ind./ha, and 4.6 ind./ha to 13.4 ind./ha, 0.9 ind./ha, and 1.9 ind./ha, respectively between 1969 and 1994 at 1500-2000m altitude, as exhibited in Figure 60.

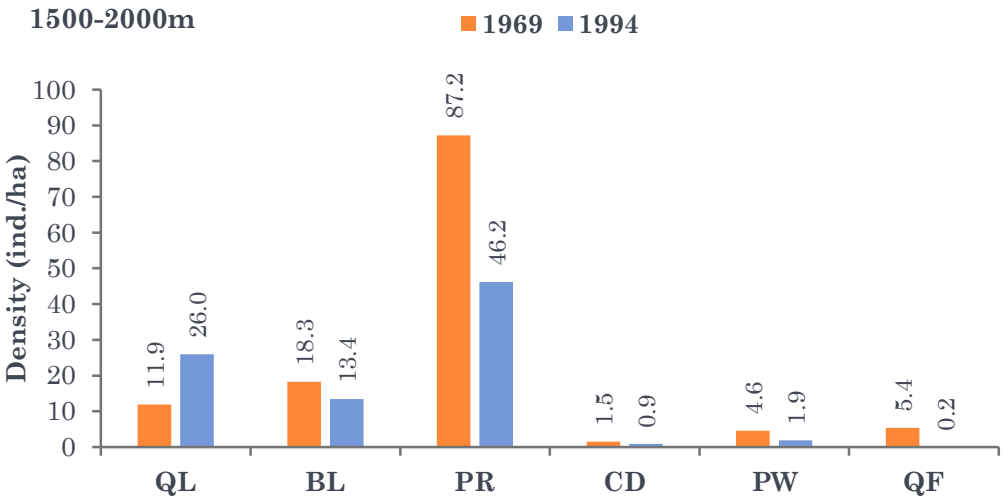

Figure 60: Density Variations in Species Composition at 1500-2000m Altitude, Rohru Forest Division, 1969-1994
Source: HPSCCC, 2018

2. 2000-2500m

There are 27 forest compartments at this altitude gradient with a total area of 2311.45ha falling under forest ranges Rohru, Tikker, Khashdhar, Jubbal, Bashala, and Sarswati Nagar. At 2000-2500m altitude, mixed outcomes for density variations were recorded. While, individuals per hectare of *Quercus leucotrichophora,* Broad-leaved, and *Abies pindrow* showed a decline of 35 per cent, 24 per cent, and 11 per cent respectively; the density of *Quercus floribunda, Cedrus deodara, Pinus wallichiana*, and *Picea smithiana* registered a sharp

increase of 95 per cent, 77 per cent, 46 per cent, and 27 per cent, respectively between 1969 and 1994 at 2000-2500m altitude range. See Figure 61.

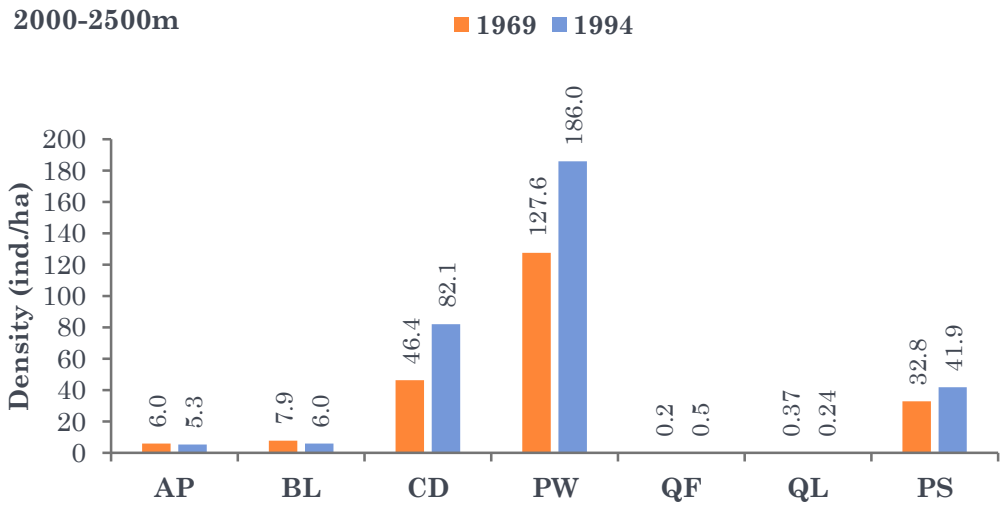

Figure 61: Density Variations in Species Composition at 2000-2500m Altitude, Rohru Forest Division, 1969-1994
Source: HPSCCC, 2018

3. 2500-3000m

There are 13 forest compartments at this altitude gradient with a total area of 1217.73ha falling under Rohru, Tikker, Khashdhar, Jubbal, Bashala, and Sarswati Nagar forest ranges. At the study's highest altitude range, *Abies pindrow* assumed maximum relative concentration; however, its density witnessed a decline of 43 per cent between 1969 and 1994. Density of *Pinus wallichiana* and *Picea smithiana* too recorded a decline of 1 per cent and 27 per cent, respectively. Meanwhile, individuals per hectare for *Cedrus deodara, Quercus floribunda,* and Broad-leaved increased at 2500-3000m altitude, as exhibited in Figure 62.

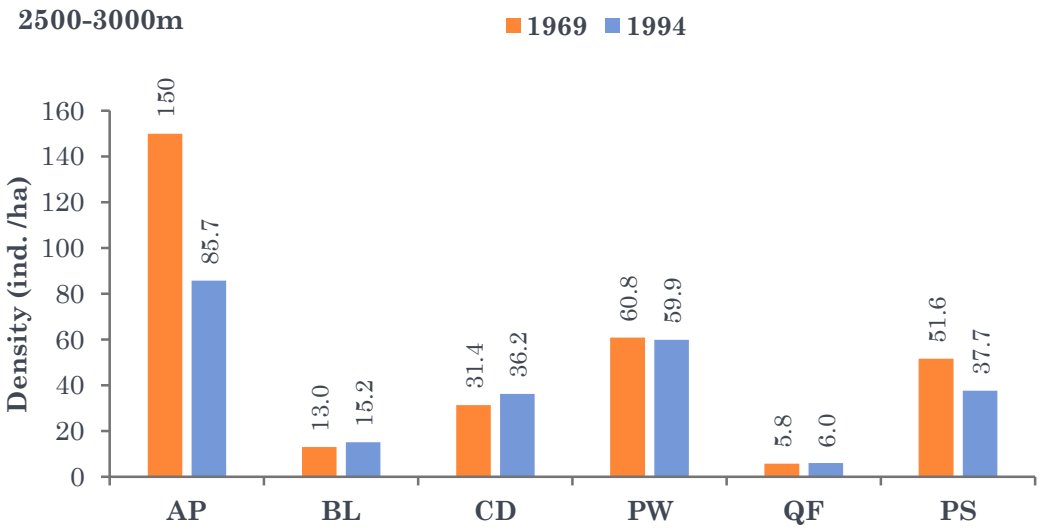

Figure 62: Density Variations in Species Composition at 2500-3000m Altitude, Rohru Forest Division, 1969-1996
Source: HPSCCC, 2018

Table 7 below gives information on suitable altitude ranges for identified tree species juxtaposed with observation made for the Rohru Forest Division under Shimla Forest Circle.

Table 7: Suitable Altitude Range for Different Tree Species in Rohru Forest Division

Species	Suitable Altitude	Observed Changes		
		1500-2000m	2000-2500m	2500-3000m
Cedrus deodara	1800 – 3000m	Decreased	Increased	Increased
Pinus wallichiana	1800 – 3000m	Decreased	Increased	Decreased
Abies pindrow	2000 – 3300m	Not Present	Decreased	Decreased
Picea smithiana	2100 – 3600m	Not Present	Increased	Decreased
Pinus roxburghii	1000 – 2000m	Decreased	Not Present	Not Present
Broad-leaved (temperate)	2000 – 3000m	Deceased	Decreased	Increased
Quercus leucotrichophora	1500 – 2400m	Increased	Decreased	Not Present
Quercus floribunda	2000 – 2500m	Decreased	Increased	Increased

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Rohru Forest Division, its density was observed to increase at mid to high altitude ranges i.e. 2000m and above. Specifically, at 2000-2500m altitude range where its density increased by 77 per cent between 1969

and 1994. At lower altitude range of 1500-2000m, its density declined by 42 per cent.

Pinus wallichiana is found between 1800m and 3000m altitude above mean sea level, and in Rohru Forest Division its density increased at mid to higher altidtude ranges – 46 per cent at 2000-2500m and 1 per cent at 2500-3000m; while it exhibited a sharp fall of 60 per cent at 1500-2000m altitude range, between 1969 and 1994.

Abies pindrow grows at 2000-3300m altitude, and in this forest division, the species registered a decline of 11 per cent at 2000-2500m; and 43 per cent at 2500-3000m between 1969 and 1994. The species was not found at lower altitude of 1500-2000m.

Picea smithiana thrives at 2100-3600m altitude, and in the Rohru Forest Division, its density plummeted at 2000-2500m and jumped at 2500-3000m by 27 per cent each, between 1969 and 1994. The species was not found at lower altitude of 1500-2000m.

Pinus roxburghii grows at 1000-2000m altitude range, and in the Rohru Forest Division, its density registered a 47 cent decline at 1500-2000m between 1949 and 1996. The species was not found at altitude over 2000m above mean sea level.

Broad-leaved species in temperate forests thrive at 2000-3000m altitude range and in Rohru Forest Division its density showed a 27 per cent decline at 1500-2000m, a 24 per cent decline at 2000-2500m; and a 17 per cent increase at 2500-3000m altitudes, between 1969 and 1994.

Quercus leucotrichophora grows at 1500-2400m altitude range, and in this forest division, at 1500-2000m, its density surged by 118 per cent; while at 2000-2500m a decline of 35 per cent was registered between 1969 and 1994. The species was not found at higher altitude range.

Quercus floribunda thrives at 2000-2500m, and in Rohru Forest Division, its density increased by 95 per cent and 4 per cent at 2000-2500m and 2500-3000m, respectively. Meanwhile, at 1500-2000m, the species witnessed a drastic decline of 97 per cent in its individuals per hectare between 1969 and 1994.

Theog Forest Division

For the Theog Forest Division, enumerated information in the Working Plans from Himachal Pradesh Forest Department and Compartment History files from 3 forest ranges (Theog, Balson, and Kotkhai) was taken for 1981 and 1996. As per the assessment, 4 pure tree communities - *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP),* and Broad-leaved, and 6 mixed tree communities – *Pinus wallichiana-* Broad-leaved, *Cedrus deodara-Pinus wallichiana, Quercus floribunda-* Broad-leaved, *Pinus wallichiana-Picea smithiana,* and *Abies pindrow- Quercus floribunda* were identified.

As highlighted in

Table 4 earlier these tree communities were assessed from 36 forest compartments spread over a total area of 1660.9ha.

The Tree Community based Variations

The following section discusses *the tree community based variations in density* for the identified species.

1. ***Cedrus deodara community***

   Data was collected from 15 forest compartments covering an area of 517.7ha, at altitude range of 1680-2670m above mean sea level. As illustrated in Figure 63, in its dominant tree community, density of *Cedrus deodara* decreased from 332.7 ind./ha to 286.2 ind./ha. In these forest compartments, representation (density) of other species is as follows – density of Broad-leaved, *Pinus roxburghii, Pinus wallichiana, Picea smithiana,* and *Taxus baccata* all recorded a declining trend; while the density of *Abies pindrow, Quercus*

leucotrichophora, and *Quercus floribunda* increased between 1981 and 1996, as exhibited in Figure 63.

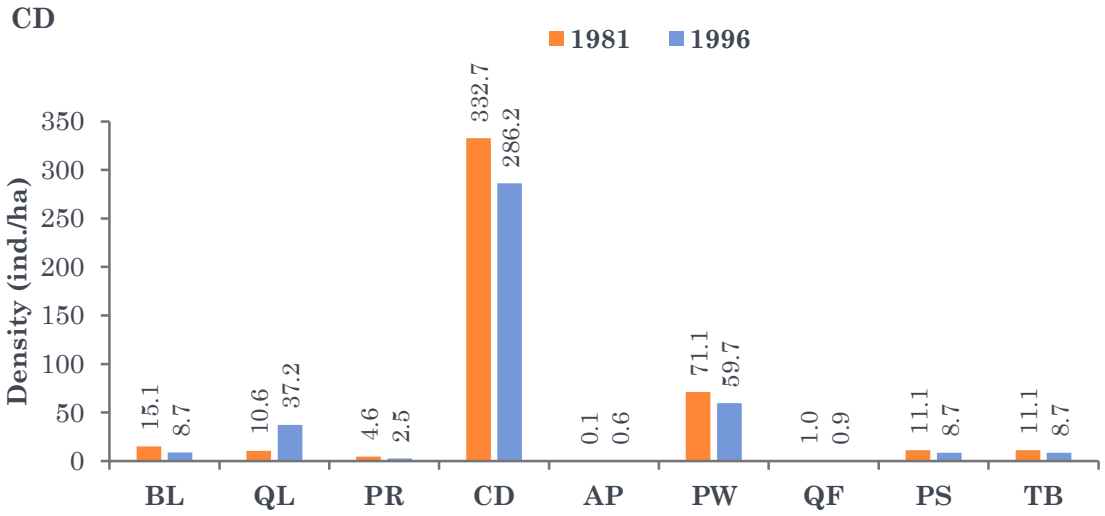

Figure 63: Density Variations in Species Composition in *Cedrus deodara* community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda;* **TB=***Taxus baccata*

Source: HPSCCC, 2018

2. *Pinus wallichiana* community

Data was collected from 10 forest compartments covering an area of 501ha, at altitude range of 1580-2680m above mean sea level. As illustrated in Figure 64, in its dominant tree community, density of *Pinus wallichiana* declined from 168.8 ind./ha to 167.3 ind./ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – tree density of Broad-leaved and *Quercus leucotrichophora* declined from 9.4 ind./ha to 7.1 ind./ha, and 1.6 ind./ha to 1.5 ind./ha, respectively; density of *Abies pindrow* and *Picea smithiana* remained static at 0.01 ind./ha and 2.3 ind./ha, respectively. Meanwhile, tree density of *Pinus roxburghii, Cedrus deodar, Quercus floribunda,* and *Taxus baccata* all recorded an increasing trend between 1981 and 1996.

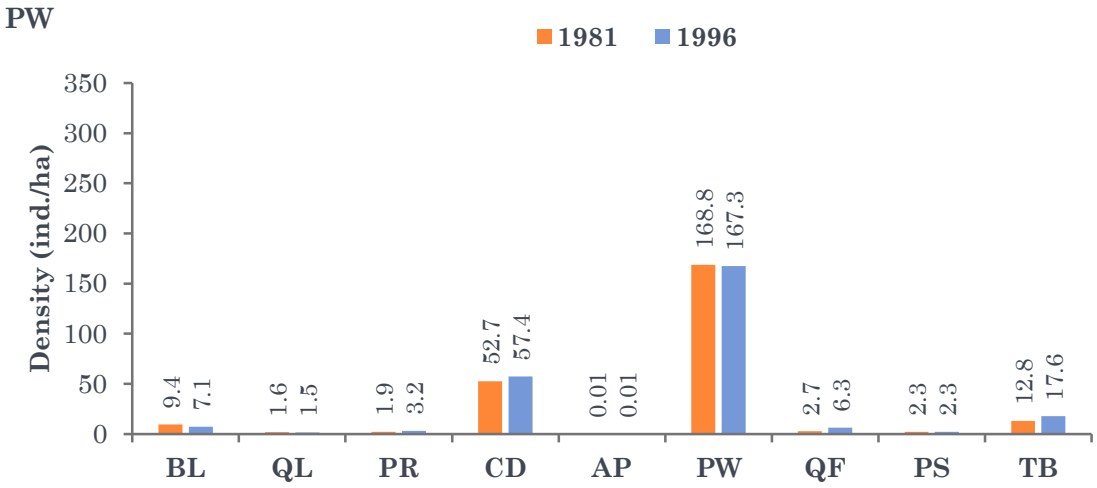

Figure 64: Density Variations in Species Composition in *Pinus wallichiana* community, Theog Forest Division, 1948-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora;* **QF=** *Quercus floribunda;* **TB**=*Taxus baccata*
Source: HPSCCC, 2018

3. *Abies pindrow* community

Data was collected from 1 forest compartment covering an area of 75ha, at altitude range of 2500-3010m above mean sea level. As illustrated in Figure 65, in its dominant tree community, density of *Abies pindrow* declined from 182.2 ind./ha to 123.6 ind./ha between 1981 and 1996. In these forest compartments representations (density) of other species are as follows – tree density of *Quercus semecarpifolia, Quercus floribunda,* and *Picea smithiana* remained the same at 11.9 ind./ha, 0.04 ind./ha, and 37.8 ind./ha, respectively. Meanwhile, density of Broad-leaved recorded a comprehensive increase from 11.1 ind./ha to 38.6 ind./ha; and *Pinus wallichiana* reported a marginal decline from 6.7 ind./ha to 6.5 ind./ha, during the study period.

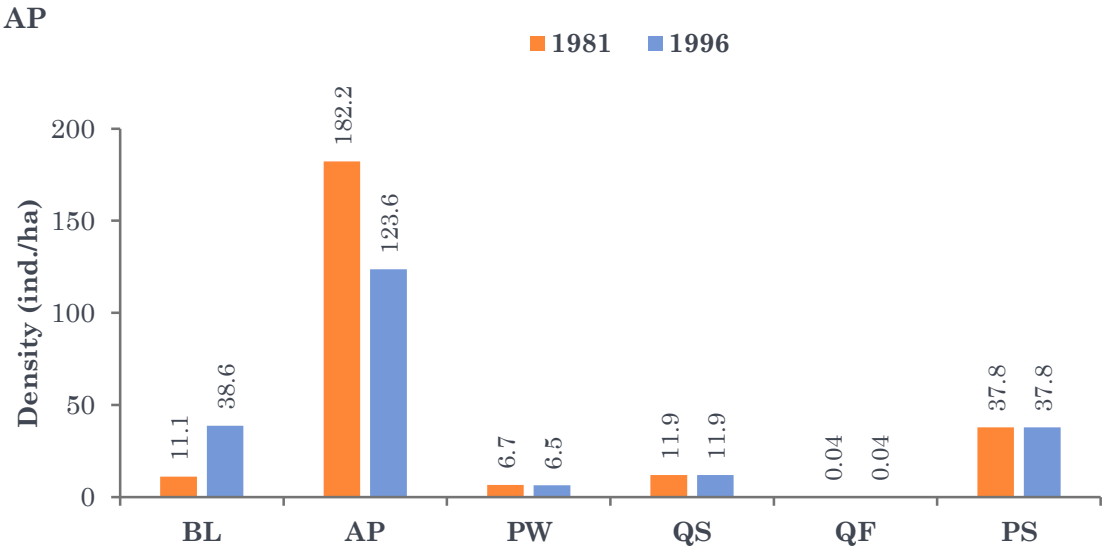

Figure 65: Density Variations in Species Composition in *Abies pindrow* community, Theog Forest Division, 1981-1996

Abbreviations: **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **QS**= *Quercus semecarpifolia;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

4. Broad-leaved community

Data was collected from 1 forest compartment covering an area of 25ha, at altitude range of 2210-2590m above mean sea level. As illustrated in Figure 66, in its dominant tree community, density of Broad-leaved decreased from 106.8 ind./ha to 104.5 ind./ha between 1981 and 1996. In these forest compartments, representation (density) of other species is as follows – tree density of *Picea smithiana, Abies pindrow,* and *Quercus floribunda* remained unchanged at 24.6 ind./ha, 8.8 ind./ha, and 26.8 ind./ha, respectively. Meanwhile, *Cedrus deodara* and *Pinus wallichiana* recorded a marginal decline from 4.52 ind./ha to 4.48 ind./ha, and 37.2 ind./ha to 37.1 ind./ha, respectively between 1981 and 1996.

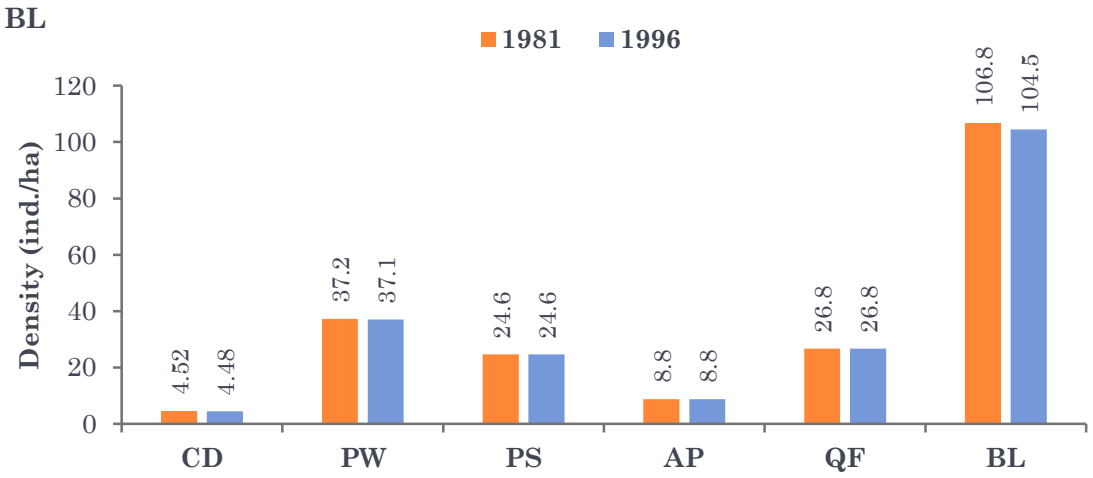

Figure 66: Density Variations in Species Composition in Broad-leaved community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **QF=** *Quercus floribunda*

Source: HPSCCC, 2018

5. *Pinus wallichiana*-Broad-leaved community

Data was collected from 2 forest compartments covering an area of 120.6ha, at altitude range of 1800-2570m above mean sea level, for *Pinus wallichiana*-Broad-leaved mixed community. The tree density of *Pinus wallichiana* increased from 62.5 ind./ha in year 1981 to 69.2 ind./ha in year 1996; and for Broad-leaved the density plummeted from 129.3 ind./ha to 59.2 ind./ha between 1981 and 1996. In this mixed community, density of *Cedrus deodara* and *Quercus floribunda* significantly declined; for *Abies pindrow* and *Picea smithiana* increased; and for *Quercus leucotrichophora* and *Taxus baccata* remained unchanged, as illustrated in Figure 67.

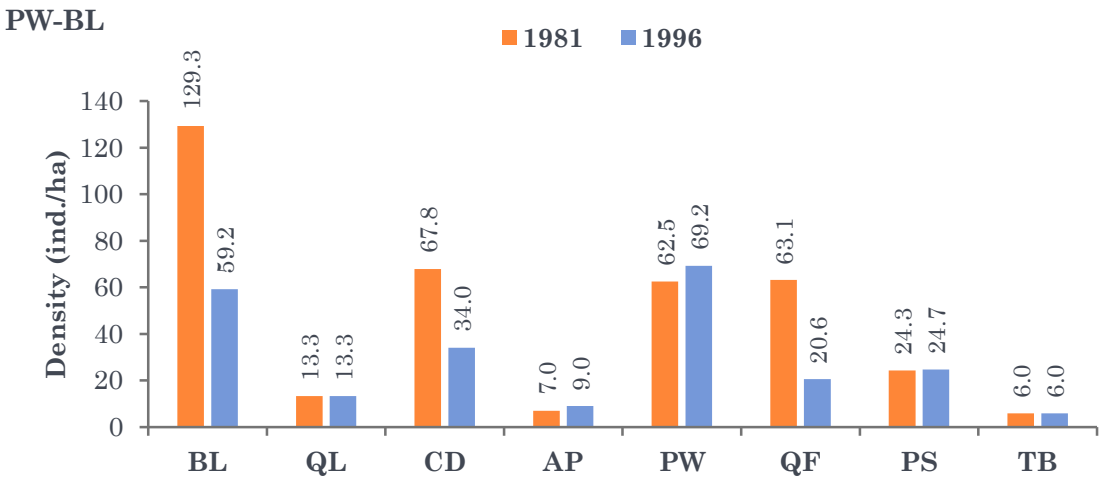

Figure 67: Density Variations in Species Composition in *Pinus wallichiana*-Broad-leaved mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **QL**= *Quercus leucotrichophora;* **QF=** *Quercus floribunda;* **TB**=*Taxus baccata*

6. *Cedrus deodara- Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 16.6ha, at altitude range of 1740-1830m above mean sea level, for *Cedrus deodara-Pinus wallichiana* mixed community. The tree density of both *Cedrus deodara* and *Pinus wallichiana* declined marginally from 121.1 ind./ha to 119.3 ind./ha, and 162.7 ind./ha to 162.4 ind./ha, respectively between 1981 and 1996. In this mixed community, density of other species i.e. *Picea smithiana, Quercus leucotrichophora,* and *Pinus roxburghii* remained unchanged during the study period, as illustrated in Figure 68.

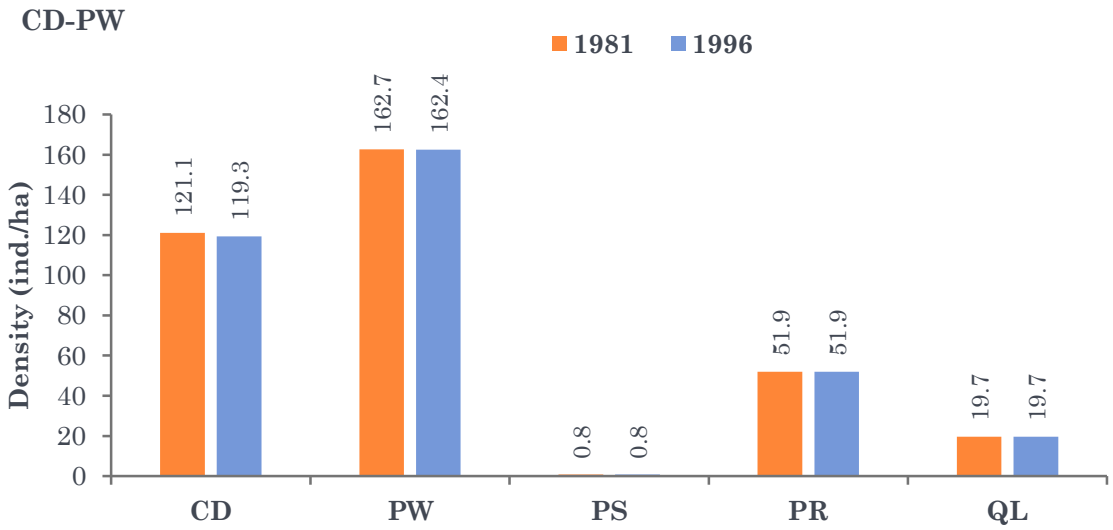

Figure 68: Density Variations in Species Composition in *Cedrus deodara-Pinus wallichiana* mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **PR=** *Pinus roxburghii;* **QL=** *Quercus leucotrichophora*

Source: HPSCCC, 2018

7. *Cedrus deodara-Picea smithiana* community

Data was collected from 2 forest compartments covering an area of 158.6ha, at altitude range of 1980-2820m above mean sea level, for *Cedrus deodara-Picea smithiana* mixed community. The tree density of both *Cedrus deodara* and *Picea smithiana* recorded a sharp increase of 175 per cent and 101 per cent, respectively between 1981 and 1996. In this mixed community, density of all species increased except for *Quercus floribunda* that registered a decline of 29 per cent. Meanwhile, amongst the remaining species, maximum increase was seen for *Abies pindrow,* whose density increased by 178 per cent between 1981 and 1996, as exhibited in Figure 69.

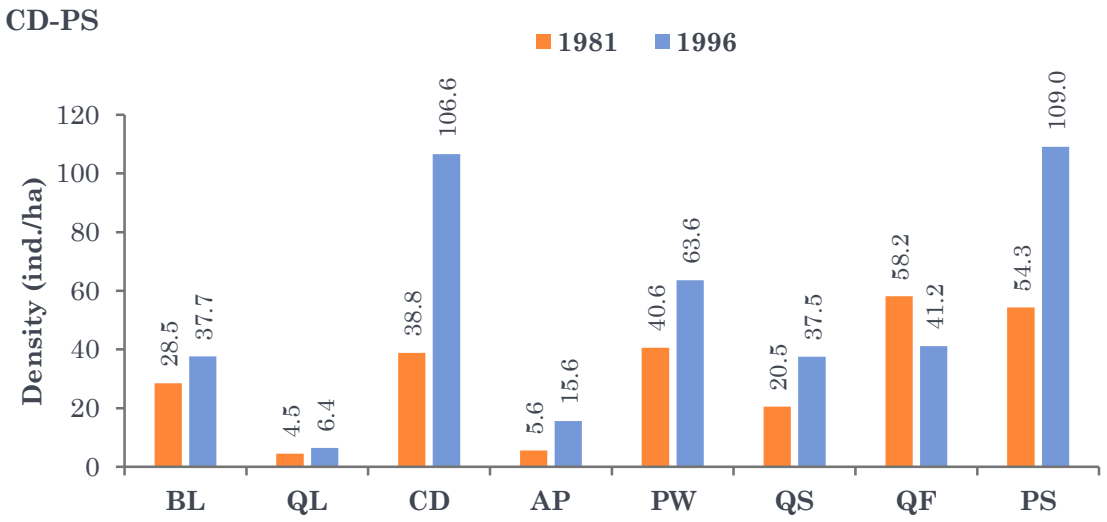

Figure 69: Density Variations in Species Composition in *Cedrus deodara-Picea smithiana* mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **QL**= *Quercus leucotrichophora;* **QF=** *Quercus floribunda;* **BL=** Broad-leaved; **QS=** *Quercus semecarpifolia*

Source: HPSCCC, 2018

8. *Quercus floribunda*-Broad-leaved community

Data was collected from 2 forest compartments covering an area of 103.19ha, at altitude range of 2000-2680m above mean sea level, for *Quercus floribunda*-Broad-leaved mixed community. The tree density of *Quercus floribunda* decreased from 133.4 ind./ha to 128.7 ind./ha; while for Broad-leaved, the density increased from 131.7 ind./ha to 172.9 ind./ha between 1981 and 1996. In this mixed community, density of *Abies pindrow, Cedrus deodara, Picea smithiana,* and *Pinus wallichiana* all registered an increase, while that of *Quercus leucotrichophora,* density remained unchanged between 1981 and 1996, as illustrated in Figure 70.

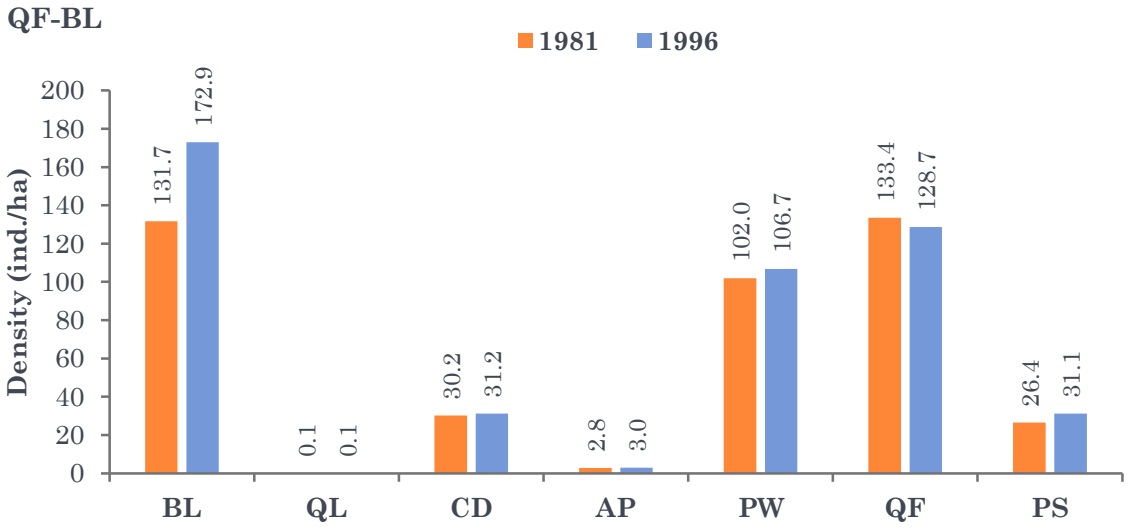

Figure 70: Density Variations in Species Composition in *Quercus floribunda*-Broad-leaved mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow;* **QL**= *Quercus leucotrichophora;* **QF=** *Quercus floribunda;* **BL=** Broad-leaved

Source: HPSCCC, 2018

9. *Pinus wallichiana-Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 67.6ha, at altitude range of 2060-2620m above mean sea level, for *Pinus wallichiana-Picea smithiana* mixed community. The tree density of *Pinus wallichiana* declined by 19 per cent; and for *Picea smithiana*, by 36 per cent between 1981 and 1996. In this mixed community, extreme positive and negative density variations were recorded for all of the remaining species. Density of *Quercus floribunda* increased by steep 533 per cent; of *Taxus baccata* by 151 per cent; and of *Cedrus deodara* by 79 per cent. Meanwhile, *Quercus semecarpifolia* recorded an extreme decline in density of 98 per cent, and Broad-leaved by 53 per cent.

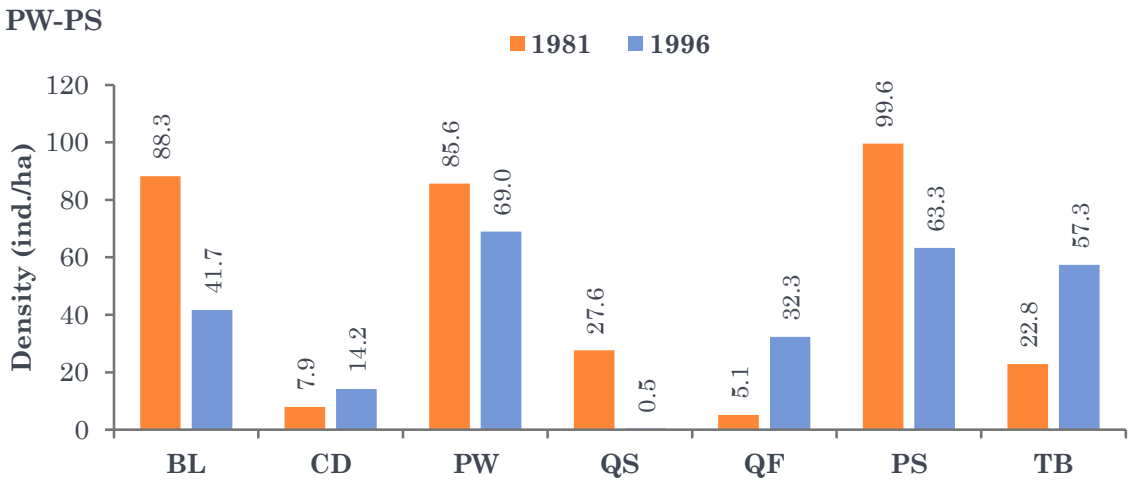

Figure 71: Density Variations in Species Composition in *Pinus wallichiana-Picea smithiana* mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **QF=** *Quercus floribunda;* **BL=** Broad-leaved; **QS=** *Quercus semecarpifolia;* **TB**=*Taxus baccata*

Source: HPSCCC, 2018

10. *Abies pindrow-Quercus floribunda* community

Data was collected from 1 forest compartment covering an area of 91.8ha, at altitude range of 2130-2600m above mean sea level, for *Abies pindrow-Quercus floribunda* mixed community. The tree density of *Abies pindrow* registered a nominal increase of 1 per cent; while the density of *Quercus floribunda* remained unchanged at 64.4 id./ha between 1981 and 1996. In this mixed community, density of other species i.e. *Cedrus deodara* and *Pinus wallichiana* both decreased; while that of Broad-leaved recorded an increase of 65 per cent. Tree density of *Picea smithiana* and *Quercus semecarpifolia* remained unchanged between 1981 and 1996, as illustrated in Figure 72.

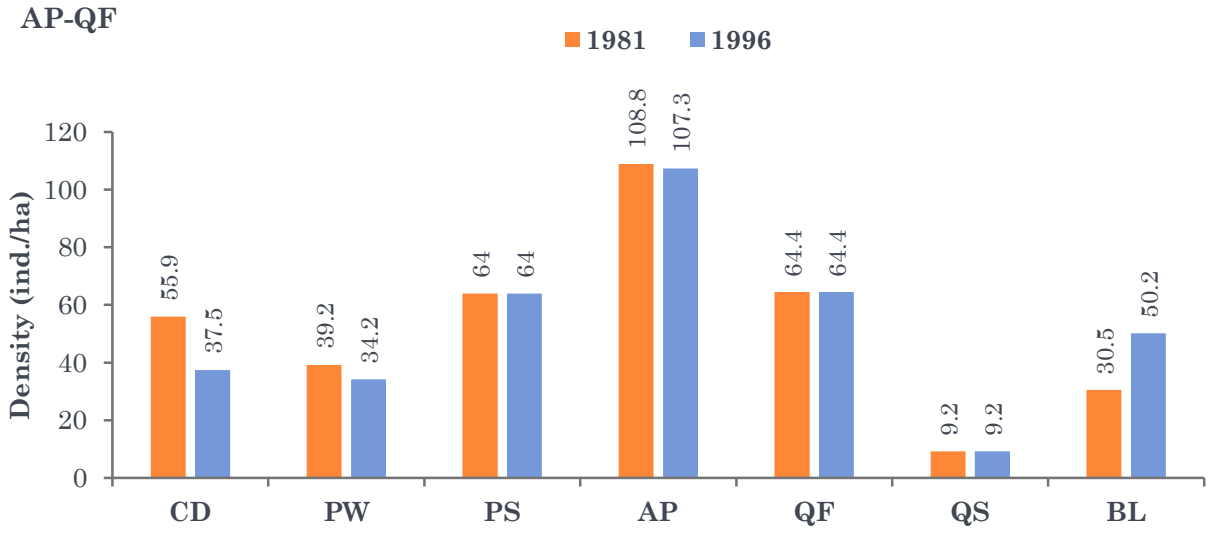

Figure 72: Density Variations in Species Composition in *Abies pindrow-Quercus floribunda* mixed community, Theog Forest Division, 1981-1996

Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **QF=** *Quercus floribunda;* **BL=** Broad-leaved; **QS=** *Quercus semecarpifolia;* **AP=** *Abies pindrow*

Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study the forests compartments of Theog Forest Division were divided in 3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500-3000m. The forests in particular altitudinal range were categorized species wise, and then their total numbers were calculated for both of years i.e. 1981 and 1996. The density (individuals per hectare) is calculated for all species at respective altitudes, representing individuals in one hectare.

1. 1500-2000m

There are 4 forest compartments at this altitude gradient with a total area of 81.2ha falling under Theog, Balson, and Kotkhai forest ranges. At 1500-2000m altitude, while the density of Broad-leaved,

Pinus wallichiana, Pinus roxburghii, and *Cedrus deodara* increased by 67 per cent, 37 per cent, 24 per cent, and 6 per cent, respectively between 1981 and 1996; those of *Taxus baccata* and *Quercus leucotrichophora* remained unchanged at 1500-2000m, as illustrated in Figure 73.

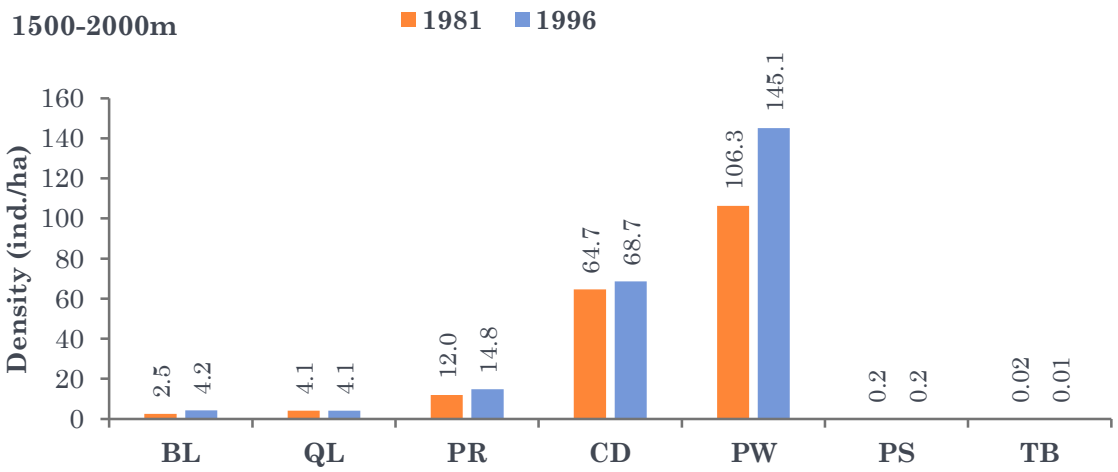

Figure 73: Density Variations in Species Composition at 1500-2000m Altitude, Theog Forest Division, 1981-1996
Source: HPSCCC, 2018

2. 2000-2500m

There are 15 forest compartments at this altitude gradient with a total area of 524.8ha falling under forest ranges of Theog, Balson, and Kotkhai forest ranges. At 2000-2500m altitude, density of all species declined, except for *Abies pindrow, Quercus floribunda,* and *Taxus baccata* whose density remained unchanged during the study period. Decline in density for other species is as follows – *Pinus roxburghii* and *Picea smithiana* by 22 per cent each, Broad-leaved by 20 per cent, *Pinus wallichiana* by 9 per cent, and *Cedrus deodara* by 8 per cent between 1981 and 1996 at 2000-2500m altitude range. See Figure 74.

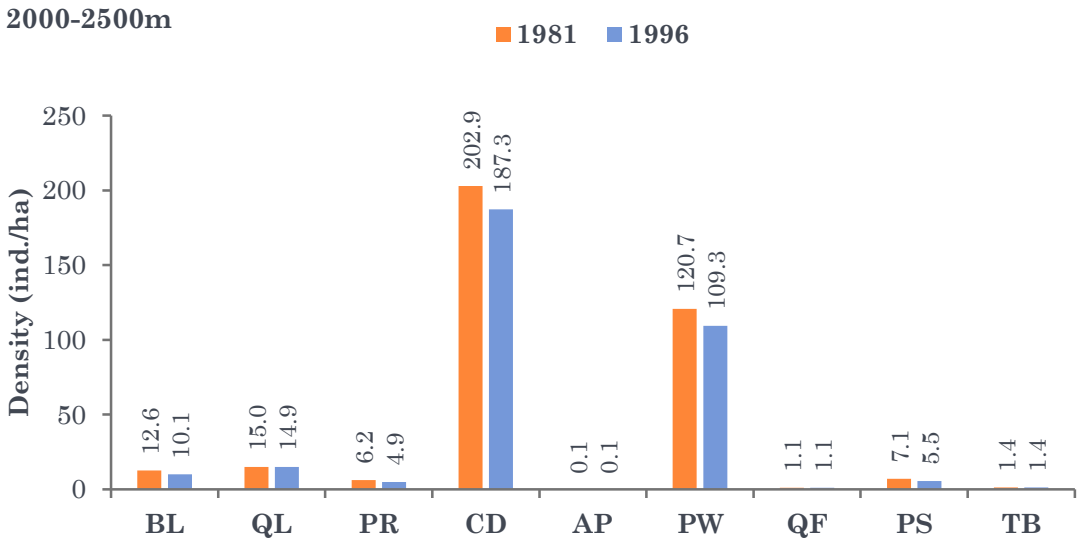

Figure 74: Density Variations in Species Composition at 2000-2500m Altitude, Theog Forest Division, 1981-1996
Source: HPSCCC, 2018

3. 2500-3000m

There are 17 forest compartments at this altitude gradient with a total area of 1126.1ha falling under Theog, Balson, and Kotkhai forest ranges. At the study's highest altitude range, *Cedrus deodara* assumed highest concentration; however, its desnity declined by 8 per cent between 1981 and 1996. Density of Broad-leaved, *Abies pindrow*, and *Quercus floribunda* too registered a decline of 12 per cent, 8 per cent, and 12 per cent, respectively. Meanwhile, for *Quercus leucotrichophora, Quercus semecarpifolia, Picea smithiana,* and *Taxus baccata* recorded an increase in density at 2500-3000m altitude range, as exhibited in Figure 75.

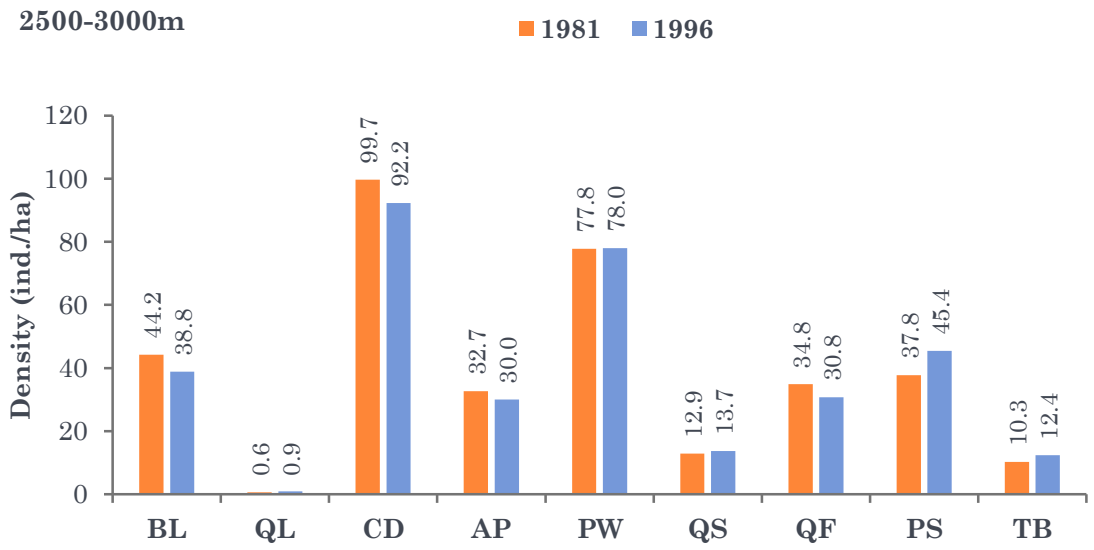

Figure 75: Density Variations in Species Composition at 2500-3000m Altitude, Theog Forest Division, 1986-2013
Source: HPSCCC, 2018

Table 8 below gives information on suitable altitude ranges for identified tree species juxtaposed with observation made for the Theog Forest Division under Shimla Forest Circle.

Table 8: Suitable Altitude Range for Different Tree Species in Theog Forest Division

Species	Suitable Altitude	Observed Changes		
		1500-2000m	2000-2500m	2500-3000m
Cedrus deodara	1800 – 3000m	Increased	Decreased	Decreased
Pinus wallichiana	1800 – 3000m	Increased	Decreased	Increased
Abies pindrow	2000 – 3300m	Not Present	Unchanged	Decreased
Picea smithiana	2100 – 3600m	Unchanged	Decreased	Increased
Quercus floribunda	2000 – 2500m	Not Present	Unchanged	Decreased
Broad-leaved (temperate)	2000 – 3000m	Increased	Decreased	Decreased

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Theog Forest Division, its density was observed to increase at lower altitude range (6 per cent) and decreased at mid to high altitude (2000-3000m) ranges by 8 per cent each between 1981 and 1996.

Pinus wallichiana is found between 1800m and 3000m altitude above mean sea level, and in Theog Forest Division, its density increased by 37 per cent at 1500-2000m, and by a marginal 0.3 per cent at 2500m and above. At mid-altitudes of 2000-2500m, its density declined by 9 per cent.

Abies pindrow grows at 2000-3300m altitude, and in this forest Division, the species registered decline of 8 per cent at 2500-3000m; and remained unchanged at 2000-2500m between 1981 and 1996. The species was not found at lower altitude of 1500-2000m.

Picea smithiana thrives at 2100-3600m altitude, and in the Theog Forest Division, its density remained unchanged at 1500-2000m, decreased by 22 per cent at 2000-2500m, and increased by 20 per cent at 2500-3000m.

Quercus floribunda grows at 2000-2500m altitude range, and in the Theog Forest Division, its density remained unchanged at 2000-2500m, and declined by 12 per cent at 2500m and above altitude range between 1981 and 1996. The species was not found at lower altitude of 1500-2000m.

Broad-leaved species in temperate forests thrives at 2000-3000m altitude range, and in the Theog Forest Division its density showed a sharp increase of 67 per cent at 1500-2000m, and a decline of 20 per cent and 12 per cent at 2000-2500m and 2500-3000m, respectively between 1981 and 1986.

CONCLUSION

The temporal study was commissioned with a view to get a preliminary insight in to the current status of vegetation viz. species composition in the four forest divisions - Shimla Forest Division, Chopal Forest Division, Rohru Forest Division, and Theog Forest Division under the Shimla Forest Circle. To ascertain the temporal changes in different tree species composition in the four forest divisions, two types of variations were analysed: *1) tree community based variation;* and *2) altitude gradient driven variation.*

Shimla Forest Division

Four pure communities of *Cedrus deodara (CD), Pinus roxburghii (PR), Pinus wallichiana (PW), Quercus leucotrichophora (QL)*; and 5 mixed tree communities - *Cedrus deodara-Quercus floribunda, Cedrus deodara-Quercus leucotrichophora, Pinus roxburghii-Cedrus deodara, Pinus roxburghii*-Broad-leaved, and *Pinus wallichiana-Quercus floribunda* were identified in the Mashobra, Koti, and Bajji forest ranges between 1981 and 1996. In this division altitude ranges were defined as 1000-1500m, 1500-2000m, and 2000-2500m, as per the information from enumerated data.

***Cedrus deodara* community** registered a decline in density in its dominant community (338.7 ind./ha to 316.2 ind./ha), driven by decrease of 9 per cent at 2000-2500m altitude. Its density was observed to increase only at the mid-altitude range of 1500-2000m, however only by 10 per cent. While, its suitable range is 1800-3000m, few individuals (27 ind. in 1981 and 16 ind. in 1996) were found to grow in Mashobra forest range at an altitude of 1450m. However, here too its density registered a 41 per cent decline between 1981 and 1996.

***Pinus wallichiana* community** too recorded reduced density in its dominant community (268.6 ind./ha to 207.6 ind./ha). Its density decreased at mid to higher altitude ranges – 18 per cent at 1500-2000m and 13 per cent at 2000-2500m; while it exhibited an increase of 34 per cent at 1000-1500m between 1981 and 1996.

***Pinus roxburghii* community** showed increased density in its dominant community (187.8 ind./ha to 193.5 ind./ha) between 1981 and 1996. Its density registered a 37 cent decline at 1000-1500m, and an increase of 43 per cent at 1500-2000m. While, its suitable range is 1000-2000m, few individuals (168 ind. in 1981 and 142 ind. in 1996) were found to grow in Mashobra and Koti forest ranges between 2045m and 2250m. However, here its density registered a decline of 15 per cent between 1981 and 1996.

***Quercus leucotrichophora* community** experienced a 65 per cent increase in individuals per hectare from 1986 to 1991, driven by a surge in density by 228 per cent and 54 per cent at 1000-1500m and 1500-2000m, respectively. Meanwhile at 2000-2500m, a decline of nominal 1 per cent was registered between 1981 and 1994.

Chopal Forest Division

Seven pure tree communities of *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP), Picea smithiana (PS),* Broad-leaved (BL), *Quercus semecarpifolia (QS),* and *Quercus floribunda (QF),* and 22 mixed tree communities – *Cedrus deodara-Pinus wallichiana, Cedrus deodara-Quercus floribunda, Cedrus deodara-Quercus semecarpifolia, Cedrus deodara-Abies pindrow, Cedrus deodara*-Broad-leaved, *Cedrus deodara-Picea smithiana, Pinus wallichiana-Cedrus deodara, Abies pindrow-Cedrus deodara, Abies pindrow-Picea smithiana,* Broad-leaved-*Taxus baccata, Picea smithiana-Abies pindrow, Picea*

smithiana-Broad-leaved, *Picea smithiana-Cedrus deodara, Picea smithiana-Taxus baccata, Picea smithiana-Quercus semecarpifolia, Pinus wallichiana*-Broad-leaved, *Pinus wallichiana-Quercus leucotrichophora,* Broad-leaved-*Pinus wallichiana,* Broad-leaved-*Abies pindrow, Taxus baccata-Abies pindrow, Quercus semecarpifolia-Taxus baccata, Quercus semecarpifolia-Picea smithiana* were identified in the Chopal, Kanda, Nerwa, and Sarain forest ranges between 1965 and 2003.

***Cedrus deodara* community** registered increased density in its dominant community (218.9 ind./ha to 234 ind./ha) driven by positive changes of just 0.1 per cent at 2000-2500m, and 14 per cent at 2500m and higher altitudes. At lower of 1500-2000m, its density declined by 8 per cent.

***Pinus wallichiana* community** registered reduced density in its dominant community (106.5 ind./ha to 55.9 ind./ha) driven by reduction at 2000-2500m altitude range. Nevertheless, increments at the other two altitude ranges were witnessed during the study time period.

***Abies pindrow* Community** registered increased density in its dominant community (118.4 ind./ha to 136.7 ind./ha. The species registered an increase of 92 per cent at 2000-2500m and a decline of 19 per cent at 2500m and higher. It was not found at lower altitudes in Chopal Forest Division.

***Picea smithiana* community** registered increased density in its dominant community (62.2 ind./ha to 119.8 ind./ha) categorically at 2000-2500m, and 2500m and above altitude ranges with respective increases of 18 per cent and 31 per cent between 1965 and 2003. The species was not found at lower altitudes in the Chopal Forest Division.

Broad-leaved community registered increased density in its dominant community (24.5 ind./ha to 60 ind./ha), driven by significant surge of 142 per cent at 2000-2500m, and 78 per cent at 2500m and above, between 1965 and 2003. The species was not found at lower altitudes in Chopal Forest Division.

***Quercus semecarpifolia* community** registered increased density in its dominant community (177.1 ind./ha to 255.5 ind./ha), driven by surge of 7 per cent at 2000-2500m, and 78 per cent at 2500m and above between 1965 and 2003. This species too was not observed at the lower altitude range of 1500-2000m.

***Quercus floribunda* community** registered reduced density in its dominant community (80.7 ind./ha to 68.2 ind./ha) driven by reduction of 10 per at 2000-2500m. The species was not observed in the other two altitude ranges, as per the enumerated data from working plans.

Rohru Forest Division

Seven pure tree communities of *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP), Quercus leucotrichophora (QL), Picea smithiana (PS), Pinus roxburghii (PR),* and Broad-leaved, and 7 mixed tree communities – *Abies pindrow*-Broad-leaved, *Picea smithiana-Cedrus deodara, Abies pindrow-Picea smithiana, Pinus wallichiana-Cedrus deodara, Pinus wallichiana-Cedrus deodara,* Broad-leaved-*Pinus wallichiana,* and *Picea smithiana- Abies pindrow* were identified in the Rohru, Tikker, Khashdhar, Jubbal, Bashala, and Sarswati Nagar forest ranges under the Rohru Forest Division between 1969 and 1994.

***Cedrus deodara* community** registered increased density in its dominant community (98.5 ind./ha to 107.6 ind./ha) driven by increments at 2000-3000m altitude ranges, especially at 2000-2500m where its density increased by 77 per cent between 1969 and 1994. At lower altitude range of 1500-2000m, its density declined by 42 per cent.

***Pinus wallichiana* community** registered increased density in its dominant community (106.9 ind./ha to 131.1 ind./ha) driven by increments of 46 per cent at 2000-2500m and 1 per cent at 2500-3000m between 1969 and 1994. Meanwhile it exhibited a sharp fall of 60 per cent at 1500-2000m altitude range.

***Abies pindrow* community** registered a sharp decline in density in its dominant community (189.0 ind./ha to 83.2 ind./ha), the species registered a decline of 11 per cent at 2000-2500m; and 43 per cent decrease at 2500-3000m between 1969 and 1994. The species was not found at lower altitude of 1500-2000m.

***Picea smithiana* community** recorded a decline in density in its dominant community (138.5 ind./ha to 81.3 ind./ha) where its density plummeted at 2000-2500m and jumped at 2500-3000m both by 27 per cent between 1969 and 1994. The species was not found at lower altitude of 1500-2000m.

***Pinus roxburghii* community** too reported a decline in density in its dominant community (105.5 ind./ha to 74.4 ind./ha) driven by 47 cent decline at 1500-2000m between 1949 and 1996. The species was not found at altitude over 2000m above mean sea level.

Broad-leaved community registered increased density in its dominant community (51.4 ind./ha to 82.1 ind./ha), where 17 per cent

increase was seen at 2500-3000m, and declines at other two altitude ranges between 1969 and 1994.

***Quercus leucotrichophora* community** experienced a noticeable increase in its dominant community (34.1 ind./ha to 74.3 ind./ha), anchored by a surge of 118 per cent at 1500-2000m. Its density declined by 35 per cent at 2000-2500m between 1969 and 1994. The species was not found at higher altitude range.

Theog Forest Division

Four pure tree communities of *Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP),* and Broad-leaved, and 6 mixed tree communities – *Pinus wallichiana*- Broad-leaved, *Cedrus deodara-Pinus wallichiana, Quercus floribunda*-Broad-leaved, *Pinus wallichiana-Picea smithiana,* and *Abies pindrow-Quercus floribunda* were identified in the Theog, Balson, and Kotkhai forest ranges under the Theog Forest Division between 1948 and 1996.

***Cedrus deodara* community** registered decreased density in its dominant community (332.7 ind./ha to 286.2 ind./ha) where at mid to high altitude (2000-3000m) ranges, its density declined by 8 per cent between 1981 and 1996. At 1500-2000m, its individuals per hectare increased by 6 per cent.

***Pinus wallichiana* community** too registered marginally reduced density in its dominant community (168.8 ind./ha to 167.3 ind./ha). At mid-altitudes of 2000-2500m, its density declined by 9 per cent; while at 1500-2000m, its density increased by 37 per cent and by a marginal 0.3 per cent at 2500m and above altitudes between 1981 and 1996.

***Abies pindrow* community** registered a considerable decline in density in its dominant community (182.2 ind./ha to 123.6 ind./ha), driven by a decline of 8 per cent at 2500-3000m. Its density remained unchanged at 2000-2500m and the species was not found at lower altitude of 1500-2000m between 1981 and 1996.

Broad-leaved community registered reduced density in its dominant community (106.8 ind./ha to 104.5 ind./ha), driven by a decline of 20 per cent and 12 per cent at 2000-2500m and 2500-3000m altitudes between 1981 and 1986. Nevertheless, at 1500-2000m, the species registered a sharp increase of 67 per cent.

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