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

Status Report

STATE CENTRE ON CLIMATE CHANGE,
Himachal Pradesh Council for Science, Technology & Environment
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Introduction

The Himalayas cover a vast expanse of 595,000 square kilometres with 2,400km 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 conditionsplay 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) 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 (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 – Shivaliks upto 1500m altitude; Mid-Himalayans between 1,500-3000m, and above 3000m exisits 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).

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 three forest divisions - Kullu Forest Division, Seraj Forest Division, and Parvati Forest Division under the Kullu Forest Circle. The assessment techniques are designed with scalable modalities that can be adapted to other forest circles in the State.

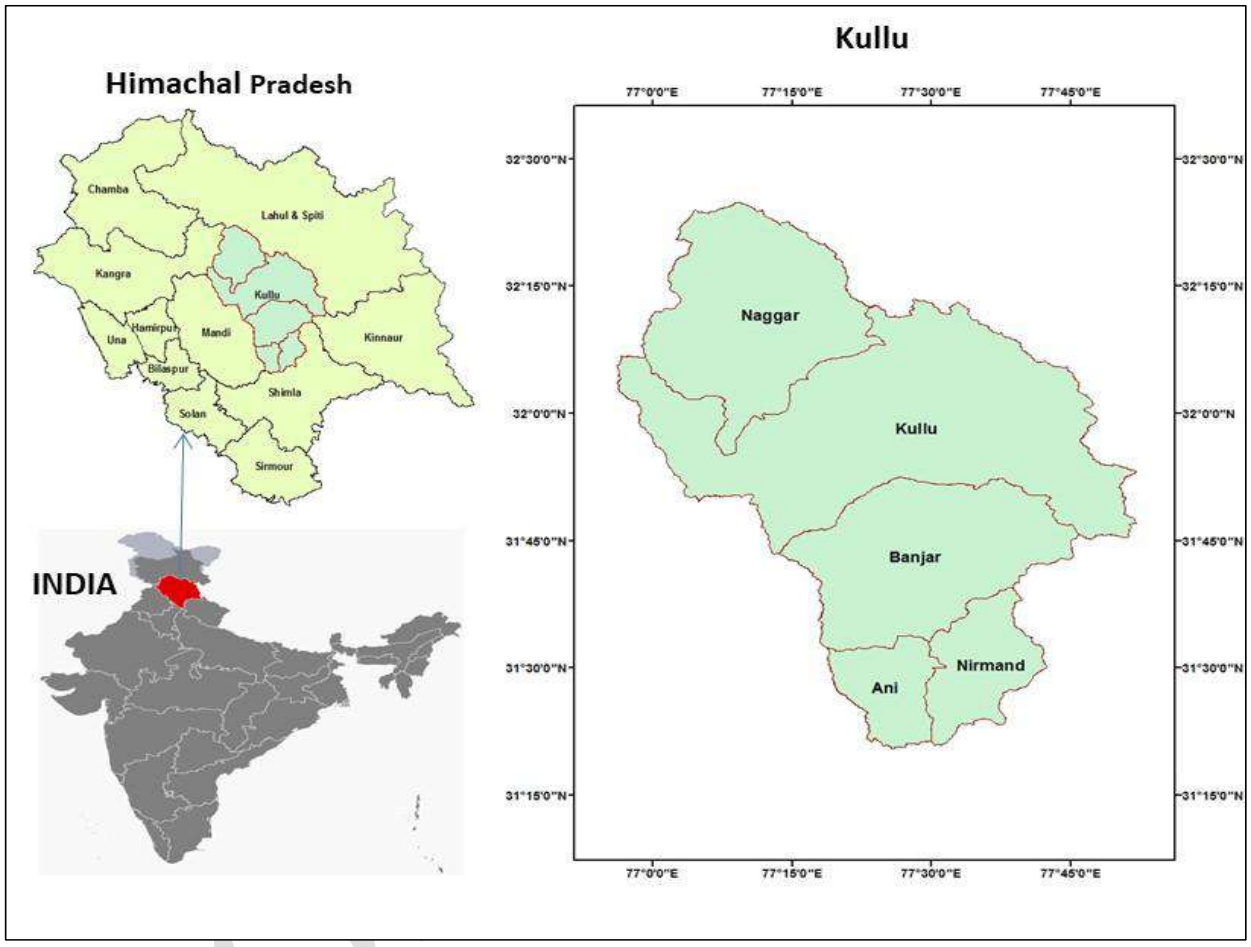
The next section outlines the details on study area and the adopted methodology with information on data sources and applied techniques of assessments. Following which, the section on Results and Findings discusses the outcomes for Kullu, Seraj, and Paravti Forest divisions separately. The report concludes with a categorised and consolidated snapshot of species composition in the Kullu Forest Circle with information on tree community level variation with respect to altitudinal gradients and diameter classes.

STUDY AREA AND METHODS

District Kullu – A Background

Nestled in the Pir Panjal range of the western Himalayas, District Kullu lies between 76° 56' 30" to 77° 52' 20" East longitude and 31° 20' 25" to 32° 25' 0" North latitude, bordering Lahaul & Spiti on north-east, Kinnaur on the east, Shimla on south-east, Mandi on south-west, and Kangra on the west. Spread across an area of 5503 sq. km, Kullu is the fifth largest district in the State, divided into five development blocks (Kullu, Naggar, Banjar, Anni, and Nirmand) that's is fed by rivers the Beas and the Satluj.

Figure 1: Map of District Kullu
Source: HPSCCC, 2018



CLIMATE

The district has a cold-dry weather with maximum temperature varying from 15.1°C in January to 37.2°C in July, and minimum temperature ranging from 19.4°C in July to -1.5°C in January. Kullu experiences mild summers and harsh winters where upper regions receive snow and sleet falls. Rainfall is well distributed from January to September (confined to lower heights), with maximum downpour in

the month of July. Exposure to natural events such as flash floods, cloudburst, and droughts are common and frequent compared to the other districts in the state. As per the findings from climate change hazards and risks assessment conducted by the Indian Himalayas Climate Adaptation Programme, during 1950-2014, District Kullu experienced over 40 per cent of the recorded flood events in the State (IHCAP, 2015).

FOREST

Table 3 below gives a snapshot of forest profile for Kullu Forest Circle with specific details on ecological zones, land use, forest administrative setup, and ecosystem for the three forest divisions. Figure 2 exhibits the graphical representation of the three forest divisions.

Table 1: Profile – Kullu Forest Circle

Forest Profile –Kullu Forest Circle				
Land Use	**Geographical Area (sq. km):** 5503	**Legal Forest Area (sq. km):** 4952	**% of Forest Area** 89.9	**% of HP Forest Area:** 13.4
Forest Areas	**Reserved (sq km):** 60 (including 80 of wildlife)	**Demarcated Protected (sq km):**3,209	**Un-demarcated Protected (sq km):**1,582	
Forest Cover	**Very Dense (sq.km):** 582	**Moderately Dense (sq. km):** 843	**Open Forest (sq. km):** 562	
Key Biodiversity Areas	Great Himalayan National Park		754 sq. km	
	Kais Wildlife Sanctuary		14.19 sq. km	
	Kanawar Wildlife Sanctuary		54.0 sq. km	
	Manali Wildlife Sanctuary		31.80 sq. km	
	Tirthan Wildlife Sanctuary		61.12 sq.km	
Forest Divisions and ranges	***Forest Circle***	***Forest Division***	***Forest Range***	
	Kullu	Kullu	Kullu Manali Bhutti Patlikhul Naggar	
		Seraj	Banjar Sainj Tirthan	

		Parvati	Parvati Jari Hurla Kasol
Major Forest Ecosystems	Division – Anni, Kullu Wildlife Division *Tropical Dry Deciduous Forest* Division – Kullu, Parvati, Seraj, Anni *Sub-tropical Pine Forest* *Himalayan Moist Temperate Forest* *Himalayan Dry Temperate Forest* *Sub-Alpine Forest* *Moist Alpine Scrub* *Dry Alpine Scrub*		

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

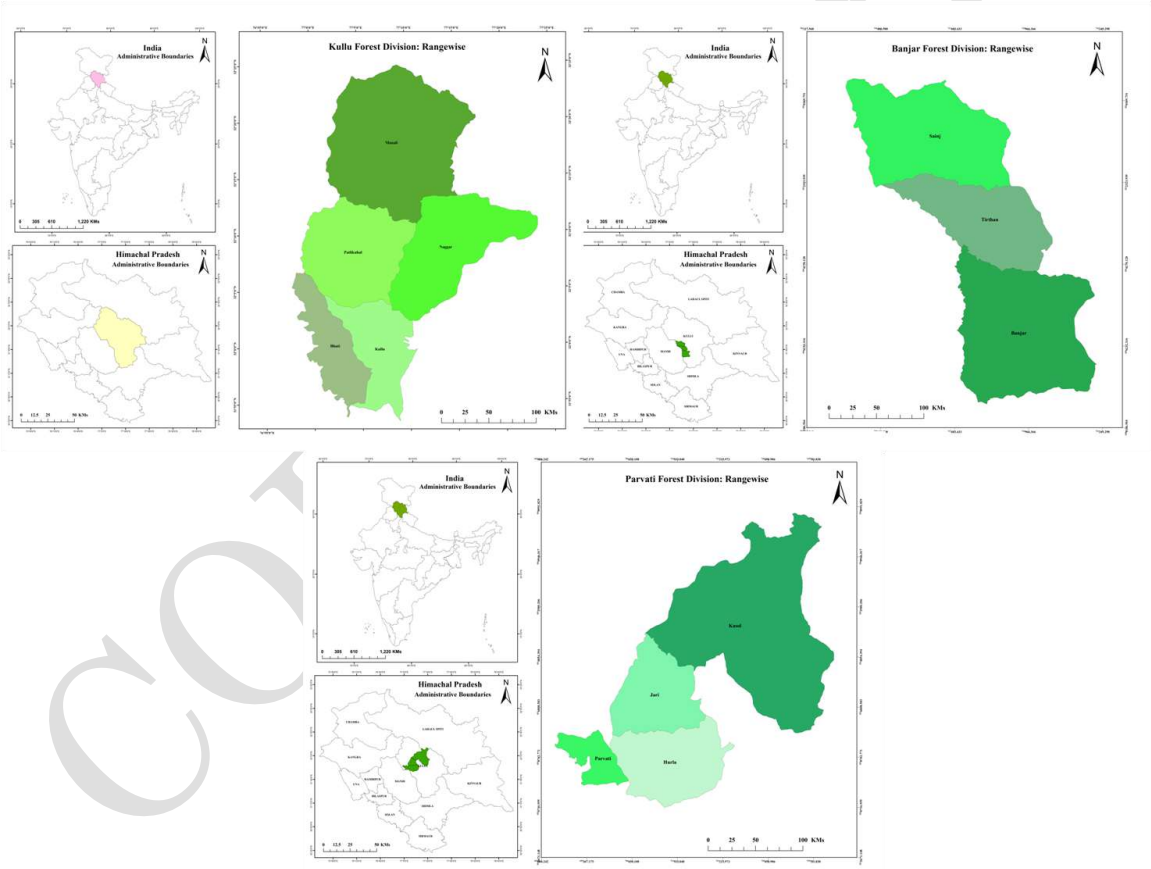


Figure 2: Maps for Kullu, Banjar/Seraj, and Parvati Forest Divisions, Kullu Forest Circle

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 divisions of Kullu, Parvati, and Seraj under the Kullu Forest Circle, three-tier assessment was conducted, covering: *1) tree community based variation; 2) altitude gradient driven variation; and 3) diameter class wise variations in tree composition.*

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

- ***Kullu Forest Division*** – There are five forest ranges in this division *viz.*, Kullu, Manali, Bhutti, Patlikuhl, and Naggar. The total area of these forest rangesis 40,069.31 ha out of which 6972.59 ha was assessed in this study.
- ***Banjar/Seraj Forest Division*** – There arethree forest ranges in this division *viz.* Banjar, Sainj, and Tirthan. Total forest area under this division is 104,820.24 ha out of which 2891.12 ha was assessed in this study which is less than minimum sample size (i.e., 2.75) to be taken of the total forest area. The reason is quite obvious which is based on the data availability from the respective working plans/Compartment History Files.
- ***Parvati Forest Division*** – There are four forest ranges in this division *viz.*Parvati, Hurla, Jari, and Kasol. Total forest area under these ranges is 9199.98ha, of which 4343.66 ha was

assessed in this study. The total number of tree communities considered for the study is quite less. This anomaly can be explained by the fact that the data availability was in such a manner/way that the comparable data for the two years was quite less.

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 three forest divisions i.e. Kullu, Banjar/Seraj, Parvati. The time period for each division is different as per enumerated information available through these working plans.

Kullu Forest Division: 1949-1994

Seraj Forest Division: 1986-2013

Parvati Forest Division:1948-1996

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 three forest divisions and their respectiveranges.

Based on the information from the Working Plans for the Kullu Forest Circle and information from the Compartment History files, tree communities were identified. Table 4 gives information on the identified species for Kullu, Parvati, and Seraj forest divisions.

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.Species composition was assessed forchanges 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.

There were more number of compartments in the respective forest divisions that were analysed in pure forest communities with respect to those of mixed forest communities. This is due to the fact that in case of mixed forest communities, the combinations of two species (i.e., Conifer-Conifer and Conifer-Broad leaved) were rare, so that only few compartments were observed under such combinations and can be clearly seen in this report.

The next section elaborates the employed assessment techniques for *1) tree community based variation; 2) altitude gradient driven variation; and 3) diameter class wise variations in tree composition.*

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. Kullu, Parvati, and Banjar/Seraj, variations in density were determined for the two time periods i.e. 1949-50 and 1994-95, 1986-87 and 2013-14, and 1948-49 and 1996-97, respectively.

Altitude Gradient driven Variations

Three altitudes were selected for comprehensive representation of all tree species in the Kullu, Parvati, and Banjar/Seraj Forest Division – 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.

Diameter Class-wise Variations with Altitude Gradient

On the basis of above mentioned altitudinal gradients, the data of different forest compartments were analysed and studied for their density variations in different classes of 10-20cm, 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, 90-100cm, >100cm. This assessment was conducted individual species for at the three altitude levels. Diameter class wise distribution is analysed to represent the population structure of forests and ascertain the nature of species undergoing varation in different tree communities and altitude 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 three forest divisions i.e. Kullu Forest Divisions, Banjar/Seraj Forest Division, and Parvati Forest Division for their respective species.

Kullu Forest Division

Based on the assessment of Working Plans from the Himachal Pradesh Forest Department and Compartment History files from Kullu, Manali, Bhutti, Patlikuhl, and Naggar forest ranges, 6 pure tree communities i.e. where for a single species the relative density was more than 50 per cent, which are - *Cedrus deodara (CD), Pinus wallichiana (PW),Abies pindrow (AP), Picea smithiana (PS), Quercus semecarpifolia (QS),* Broad-leaved *(BL);* and2 mixed tree communities - *Cedrus deodara- Picea smithiana*and *Pinus wallichiana- Cedrus deodara*were identified.Additionally, two minority tree species were also identified in the above mentioned dominant and mixed tree communities, which are:*Taxus baccata and Quercus floribunda.*

As highlighted earlier in **Error! Reference source not found.**these tree communities were assessed from 129 forest compartments spread over a total area of 6972.59 ha.

The Tree Community based Variations

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

1. ***Cedrus deodara community***

   Data was collected from 27 forest compartments covering an area of 870.67 ha, at altitude range of 1500-2500m above mean sea level. As illustrated inFigure 3, in its dominant tree community, density of*Cedrus deodara*increased from 101.0Ind/ha to 132.2Ind/ha. In these forest compartments, representation (density) of other species is as follows – density of*Pinus wallichiana*declined from 28.2Ind/ha in 1949 to 26.9Ind/ha in 1994, density of Broad-leaved too declined from 0.6 Ind/ha to 0.5 Ind/ha; while the density of*Picea smithiana*increased from 14.2 Ind/ha in 1949 to 15.3Ind/ha in 1994, and density of *Abies pindrow*remained static at 1.5 Ind/ha between the two-years.

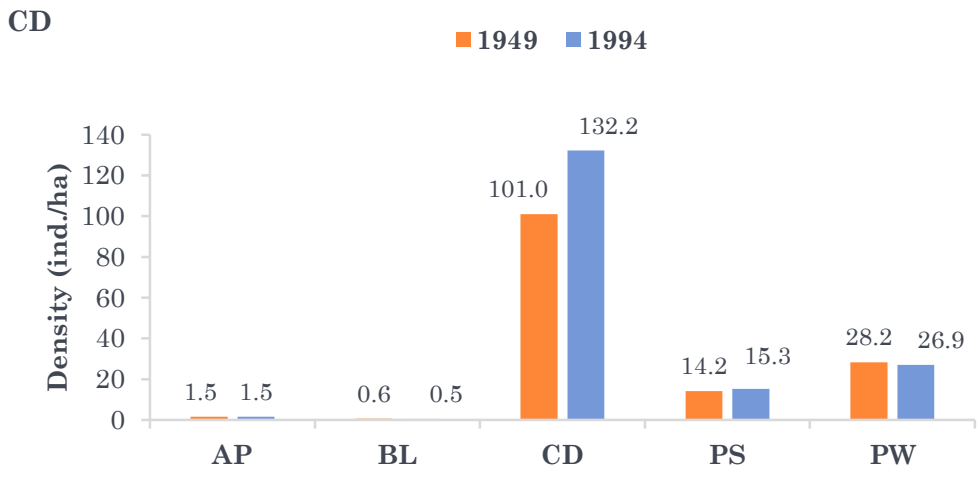


Figure 3: Density Variations in Species Composition in*Cedrus deodara* community, Kullu Forest Division, 1949-1994

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

Source: HPSCCC, 2018

2. *Pinus wallichiana community*

Data was collected from 12 forest compartments covering an area of 527.27 ha, at altitude range of 1500-2500m above mean sea level,for pure *Pinus wallichiana*stands. As illustrated in Figure 4, in its dominant tree community, density of *Pinus wallichiana* increased from 40.1 Ind/ha to 59.7Ind/ha. In these forest compartments, representation (density) of other species is as follows – density of *Cedrus deodara* increased from 13.6Ind/ha in 1949 to 18.2Ind/ha in 1994; density of both *Abies pindrow* and *Quercus semecarpifolia*increased from 0.3Ind/ha in 1949 to 0.4Ind/ha in 1994;density ofBroad-leaved species increased from 0.01Ind/ha to 0.2Ind/ha; and for *Picea smithiana* density declined from 8.1Ind/ha in 1949 to 4.8Ind/ha in 1994.

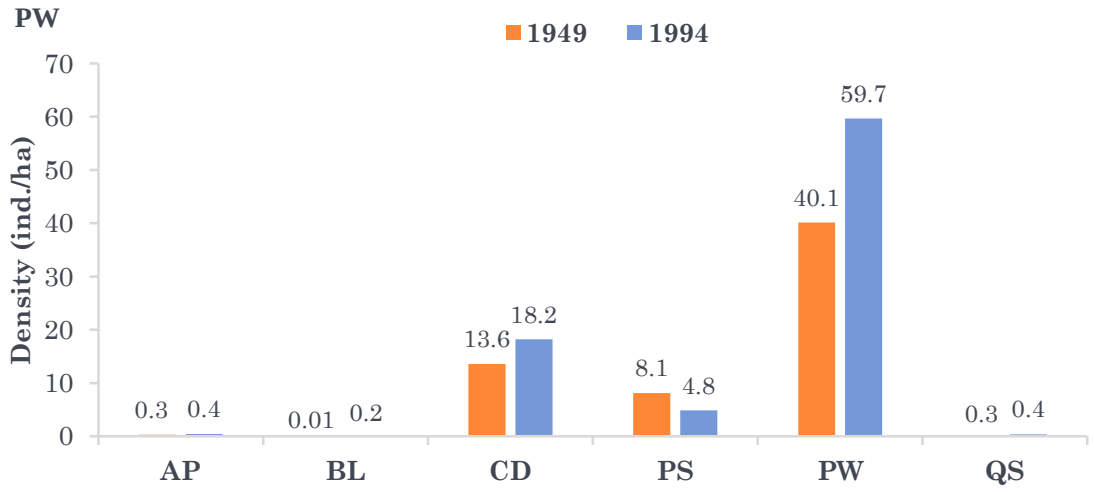


Figure 4: Density Variations in Species Composition in *Pinus wallichiana*community, Kullu Forest Division, 1949-1994

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

Source: HPSCCC, 2018

3. *Abies pindrow community*

Data was collected from 11 forest compartments covering an area of 1,609.82 ha, at altitude range of 2000-3000m above mean sea level,for pure *Abies pindrow* stands.As illustrated in Figure 5, in its dominant tree community, density of *Abies pindrow* increased from 1.59Ind/ha to 1.7 Ind/ha between 1949 and 1994. In these forest compartments, representation (density) of other species is as follows – from 1949 to 1994, density of *Cedrus deodara* and *Picea smithiana*increased from 0.01Ind/ha to 0.03 Ind/ha, and 0.44Ind/ha to 0.5Ind/ha respectively; while for *Pinus wallichiana*density remained the same at 0.04 Ind/ha,and for Broad-leaved, density declined from 0.91Ind/ha to 0.8Ind/ha respectively.

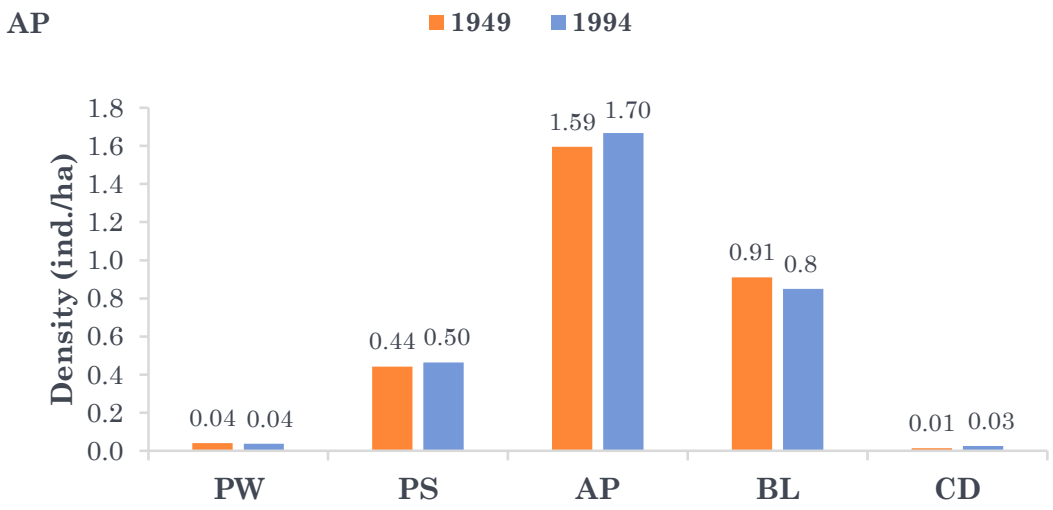


Figure 5:Density Variations in Species Composition in *Abies pindrow*community, Kullu Forest Division, 1949-1994

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

Source: HPSCCC, 2018

4. *Picea smithiana community*

Data was collected from 53 forest compartments covering an area of 2,395.31 ha, at altitude range of 1500-3000m above mean sea level,for pure *Picea smithiana*stands.As illustrated in Figure 6, in its dominant tree community, density of *Picea smithiana* increased from 44.6Ind/ha to 46.4Ind/ha from 1949 to 1994. In these forest compartments, representation (density) of other species between 1949 and 1994 is as follows – for *Pinus wallichiana, Cedrus deodara, Taxus baccata,* and Broad-leaveddensity increased from 4.5Ind/ha to 5.5 Ind/ha, 2.9 Ind/ha to 2.7 Ind/ha, 0.17Ind/ha to 1.61Ind/ha, and 0.6 Ind/ha to 0.7 Ind/ha respectively. Tree density of *Quercus semecarpifolia*and *Quercus floribunda* increased slightly between 1949 and 1994. Only *Abies pindrow* witnessed a decline in tree density from 1.5 Ind/ha to 0.8 Ind/ha.

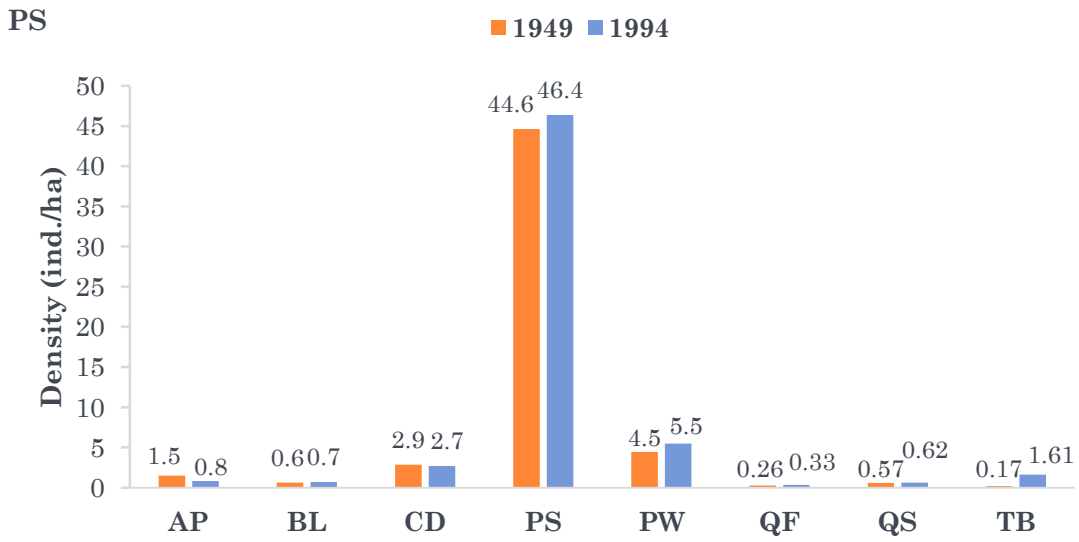


Figure 6: Density Variations in Species Composition in *Picea smithiana* community, Kullu Forest Division, 1949-1994

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

Source: HPSCCC, 2018

5. *Quercus semecarpifolia community*

Data was collected from 6 forest compartments covering an area of 365.55 ha, at altitude range of 1500-3000m above mean sea level,for pure *Quercus semecarpifolia*stands.As illustrated in Figure 7, in its dominant tree community, density of *Quercus semecarpifolia*increased from 2.2Ind/ha to 2.3 Ind/ha from 1949 to 1994. In these forest compartments, representation (density) of other species between 1949 and 1994 is as follows –*Cedrus deodara, Picea smithiana,* and *Abies pindrow* all showed an increase in density moving from 0.8Ind/ha to 1.2Ind/ha, 1.5Ind/ha to 1.7Ind/ha, and 0.2Ind/ha to 0.4Ind/ha respectively; while for Broad-leaved density decreased from 1.9Ind/ha to only 0.3Ind/ha.

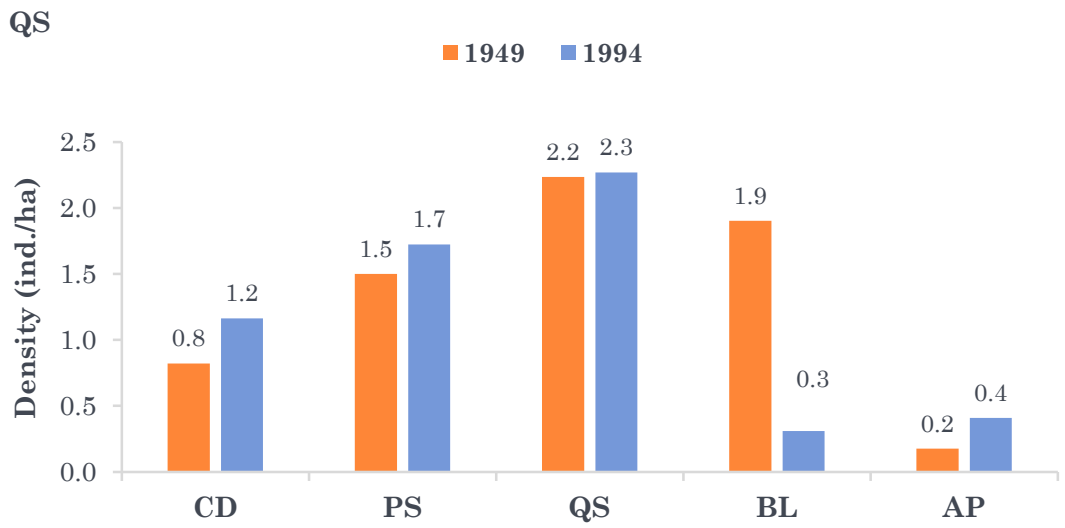


Figure 7: Density Variations in Species Composition in *Quercus semecarpifolia* community, Kullu Forest Division, 1949-1994

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

Source: HPSCCC, 2018

6. Broad-leaved community

Data was collected from 13 forest compartments covering an area of 959.99 ha, at altitude range of 2000-3000m above mean sea level,for pure broad-leavedstands. As illustrated in Figure 8, in its dominant

tree community, density of Broad-leaved increased from 2.0Ind/ha in year 1949 to 2.3Ind/ha in year 1994. In these forest compartments, representation (density) of other species between 1949 and 1994 is as follows – density of all other species i.e. *Quercus semecarpifolia, Cedrus deodara, Pinus wallichiana, Picea smithiana,* and *Abies pindrow* increased from 0.5Ind/ha to 0.7Ind/ha, 0.01Ind/ha to 0.03Ind/ha, 0.001Ind/ha to 0.01 Ind/ha, 0.6Ind/ha to 0.7Ind/ha, and 0.7Ind/ha to 0.8Ind/ha.

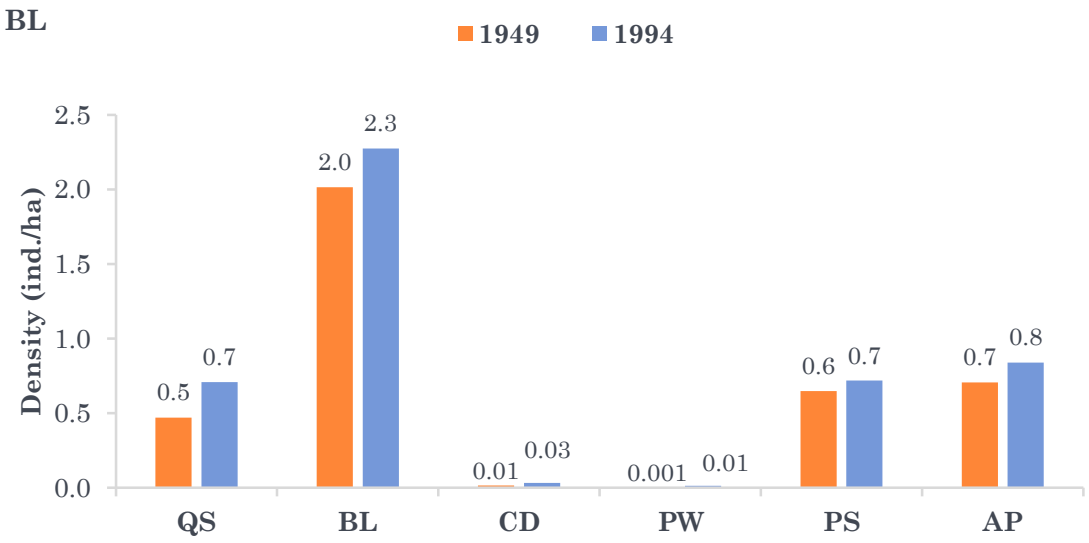


Figure 8:Density Variations in Species Composition in Broad-leavedcommunity, Kullu Forest Division, 1949-1994
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*; **PS**=*Picea smithiana*; **AP**=*Abies pindrow*; **BL**= Broad-leaved; **QS=** *Quercus semecarpifolia*
Source: HPSCCC, 2018

7. *Cedrus deodara-Picea smithiana* mixed community

Data was collected from 4 forest compartments covering an area of 135.70 ha, at altitude range of 2000-3000m above mean sea level, for*Cedrus deodara-Picea smithiana* mixed community. The tree density of *Cedrus deodara*increased from 11.9 Ind/ha to 12.6Ind/ha; while for *Picea smithiana*the density increased from 7.3Ind/ha to

7.9Ind/ha. *Abies pindrow* and Broad-leaved showed an inclined density from 3.7Ind/hato 4.0Ind/ha, and 2.2Ind/ha to 2.6Ind/ha, respectively; while for *Pinus wallichiana,*thedensity declined from 4.1Ind/ha to 3.5Ind/ha during the study period.

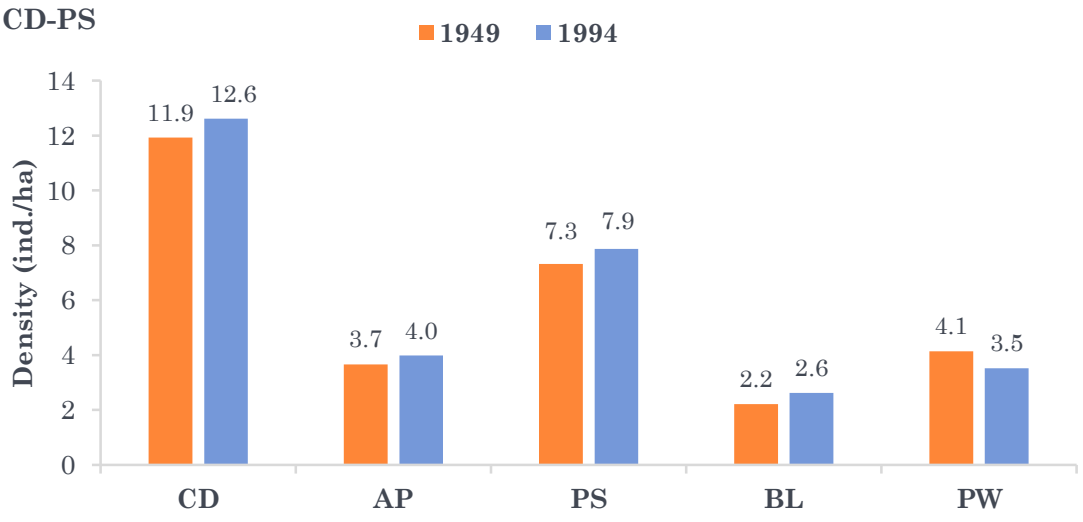


Figure 9: Density Variations in Species Composition in *Cedrus deodara-Picea smithiana* community, Kullu Forest Division, 1949-1994
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*; **PS**=*Picea smithiana*; **AP**=*Abies pindrow*; **BL**= Broad-leaved
Source: HPSCCC, 2018

8. *Pinus wallichiana-Cedrus deodara* mixed community

Data was collected from 4 forest compartments covering an area of 107.28 ha, at altitude range of 2000-2500m above mean sea level, for*Pinus wallichiana-Cedrus deodara*mixed community. The tree density of *Pinus wallichiana*decreased from 23.7Ind/hato 16.6Ind/ha; while for *Cedrus deodara,* density decreased from 19.3Ind/ha to 19.0Ind/ha.In these forest compartments, representation (density) of other species between 1949 and 1994 is as follows – decline in density was observed for *Picea smithiana*(8.6 Ind/ha to 7.4Ind/ha), *Abies pindrow* (3.3 Ind/ha to 2.8Ind/ha), and Broad-leaved (8.8Ind/ha to 8.3Ind/ha).

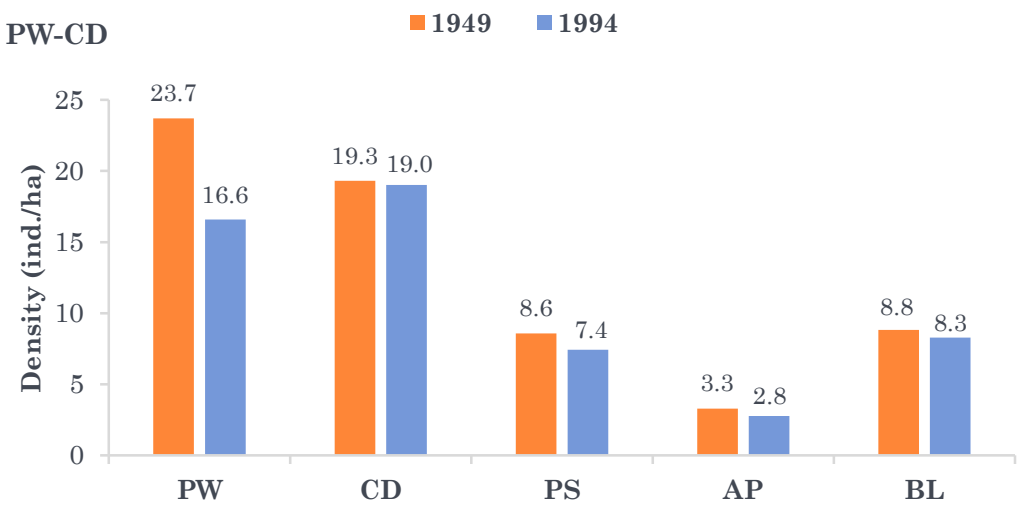


Figure 10: Density Variations in Species Composition in *Pinus wallichiana-Cedrus deodara*community, Kullu Forest Division, 1949-1994
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*; **PS**=*Picea smithiana*; **AP**=*Abies pindrow*; **BL**= Broad-leaved
Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study, the forests compartments of Kullu Forest Division were divided into3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500-3000m. The forests in particular altitudinal range were categorized species wise, then their total number was calculated for both years i.e. 1949 and 1994. The density (individual per hectare) was then calculated for all species at respective altitudesrepresenting individuals per hectare.

1. 1500-2000m

There are 6 forest compartments at this altitude gradient with a total area of 189.79ha falling under Naggar, Bhutti, and Patlikuhl forest ranges. At 1500-2000m altitude range, all species witnessed increased density with maximum representation of *Pinus wallichiana*whose density increased from 57.9Ind/ha to 58.5 Ind/ha from1949 to 1994. *Cedrus deodara* showed a slight increase in value

from 24.4Ind/ha to 25.6Ind/ha;similarly for *Abies pindrow,*density increased from 0.8 Ind/ha to 1.2Ind/ha.

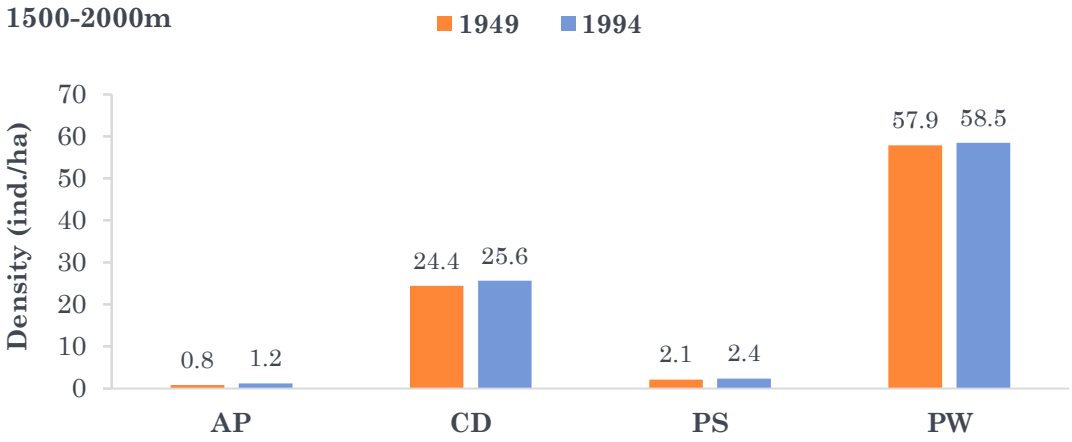


Figure 11: Density Variations in Species Composition at1500-2000m Altitude, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

2. 2000-2500m

There are 30 forest compartments at this altitude gradient with a total area of 1,065.77ha falling under all five forest ranges i.e. Kullu, Naggar, Bhutti, Manali, and Patlikuhl. At 2000-2500m altitude, majority of species witnessed a decline in density – for *Abies pindrow* individuals per hectare declined from 0.5Ind/ha to 0.1 Ind/ha; density for *Picea smithiana*declined from28.2 Ind/ha to 26.3 Ind/ha. Meanwhile, density of Broad-leaved and *Quercus floribunda*increased from 0.1 Ind/ha to 0.2Ind/ha, and 0.2 Ind/ha to 0.3 Ind/ha, respectively. Density for *Cedrus deodara* increased from 28.5 Ind/ha to 38.9 Ind/ha, and for *Pinus wallichiana,* density increased from 19.1Ind/ha to 29.1Ind/ha between 1949 and 1994.

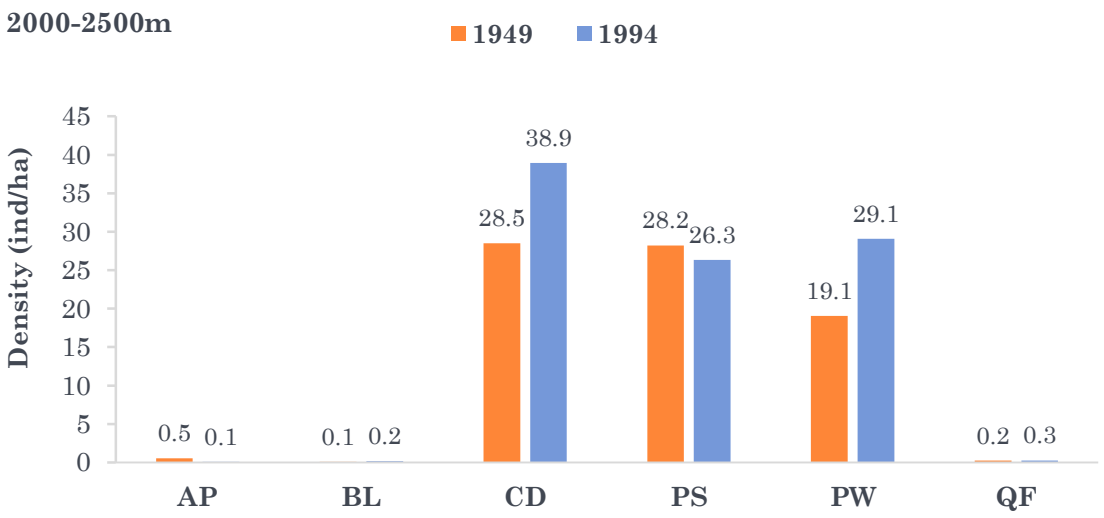


Figure 12: Density Variations in Species Composition at 2000-2500m Altitude, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

3. 2500-3000m

There are 23 forest compartments at this altitude gradient with a total area of 1,135.47ha falling under all five forest ranges i.e. Kullu, Naggar, Bhutti, Manali, and Patlikuhl. At the study's highest altitude range, individuals per hectare of *Cedrus deodara*increased sharply from 1.6Ind/ha to 12.5Ind/ha; for *Picea smithiana,*density jumped from 20.7 Ind/ha to 23.1 Ind/ha; for *Pinus wallichiana, Quercus semecarpifolia,* and*Taxus baccata*density increased from 5.7Ind/ha to 8.2Ind/ha, 8.2 Ind/ha to 8.9 Ind/ha, and 1.9 Ind/ha to 2.7 Ind/ha, respectively. Broad-leaved density changed from 3.4 Ind/ha in 1949 to 3.6 Ind/ha in 1994. Meanwhile,individuals per hectare for *Abies pindrow* declined from 12.1 Ind/ha to 8.1Ind/ha.

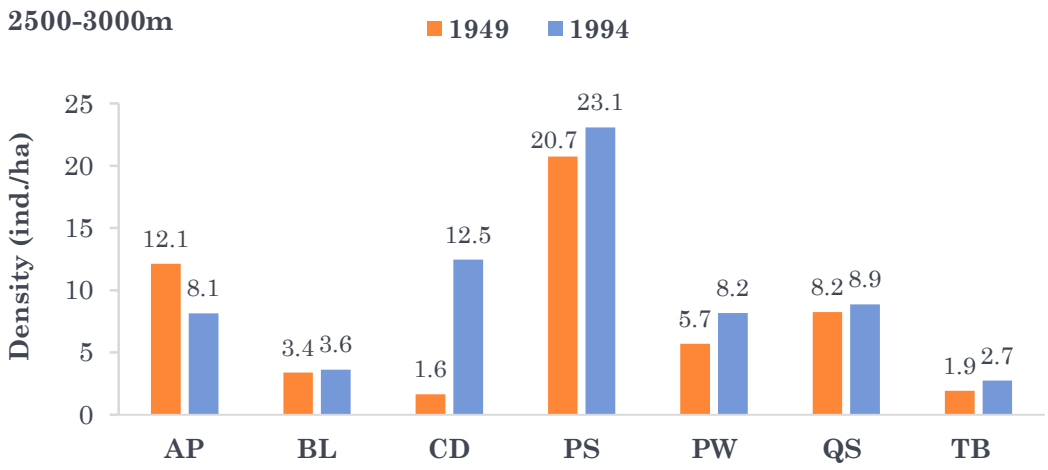


Figure 13: Density Variations in Species Composition at 2500-3000m Altitude, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Table 5 below gives information on suitable altitude ranges for tree species identified in the three forest divisions under Kullu Forest Circle juxtaposed with observation made for the Kullu Forest Division.

Table 2: Suitable Altitude Range for Different Tree Species in Kullu Forest Division

Species	Suitable Altitude	Observed Changes		
		1500-2000m	2000-2500m	2500-3000m
Cedrus deodara	1800 – 3000m	Increased	Increased	Increased
Pinus wallichiana	1800 – 3000m	Increased	Increased	Increased
Abies pindrow	2000 – 3300m	Increased	Decreased	Decreased
Picea smithiana	2100 – 3600m	Increased	Decreased	Increased
Quercus semecarpifolia	1830 – 3050m	Not observed	Not observed	Increased
Broad leaved (temperate)	2000 – 3300m	Not observed	Increased	Increased

Note:
Increased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1949 and 1994.
Decreased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1949 and 1994.
Not observed signifies the cases where a given species was not found at a particular altitude between 1949 and 1994.

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Kullu Forest Division, its density was observed to increase at all altitudinal ranges with maximum increase of 681 per cent observed at high altitudinal range of 2500-3000m.

*Pinus wallichiana*is found between 1800m and 3000m altitude above sea level, and in the Kullu Forest Division, its density increased across all altitudinal ranges exhibiting maximum increase of 52 per cent at 2000-2500m altitude, followed by 44 per cent at higher altitudes, and marginal 1 per cent at 1500-2000m.

*Abies pindrow*grows at 2000-3300m altitude, and in this divisionthe species registered a significant decline at 2000-2500m and 2500-3000m of 80 per cent and 33 per cent, respectively. At lower altitudes, the density increased by 50 per cent.

*Picea smithiana*thrives at 2100-3600maltitude, and in the Kullu Forest Division it wasobserved in higher density at 1500-2000m and 2500-3000m with respective increases of 14 per cent and 12 per cent between 1949 and 1994. At the mid altitudinal range, its density decreased by 7 per cent.

*Quercus semecarpifolia*grows at 1830-3050m altitude range, and in the Kullu Forest Division the altitudinal changes were captured for 2500-3000m only, where it showed an increase of 9 per cent (lower altitudinal data was not enumerated for the study period).

Broad-leaved species in temperate forests thrive at 2000-3000m altitude range, and in Kullu Forest Division its density showed 100 per cent increase at 2000-2500m, and 6 per cent at 2500-3000m (lower altitudinal data was not enumerated for the study period).

To get a better insight in to the specific kind of species that had undergone temporal change between 1949 and 1994, diameter class wise variations were cross referencedwith different altitude ranges. The next section presents the findings of the specific changes for each species in the Kullu Forest Division.

Diameter Class-wise Variations with Altitude Gradient

For the mentioned altitudinal gradients i.e. 1500-2000m, 2000-2500m, 2500-3000m, data from different forest compartments was analysed for variation in diameter classes of 10-20cm, 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, 90-100cm, >100cm for each of the identified species in the Kullu Forest Division.

Cedrus deodara

Density of *Cedrus deodara* increased at all altitude gradients, as seen in the previous section. Nevertheless, steep increases were recorded for 10-20 cm categories at 2000-2500m and 2500-3000m from 4.89 Ind/ha to 14.05 Ind/ha and 0.30 Ind/ha to 7.72 Ind/ha, respectivelyas illustrated in Figure 14.Density of trees within diameter classes 20-30cm and 30-40cm too showed significant increase in both altitudinal ranges. This increase in density of younger trees of *Cedrus deodara* signifies regeneration at higher altitudes, which is necessary for the species' continued existence in the forest division. Meanwhile, at lower altitudes of 1500-2000m trees within diameter classes30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, 90-100cm witnessed increased density between 1949 and 1994, signifying growth of mature trees and sustainability of tree community in the forest compartments of Kullu Forest Division.

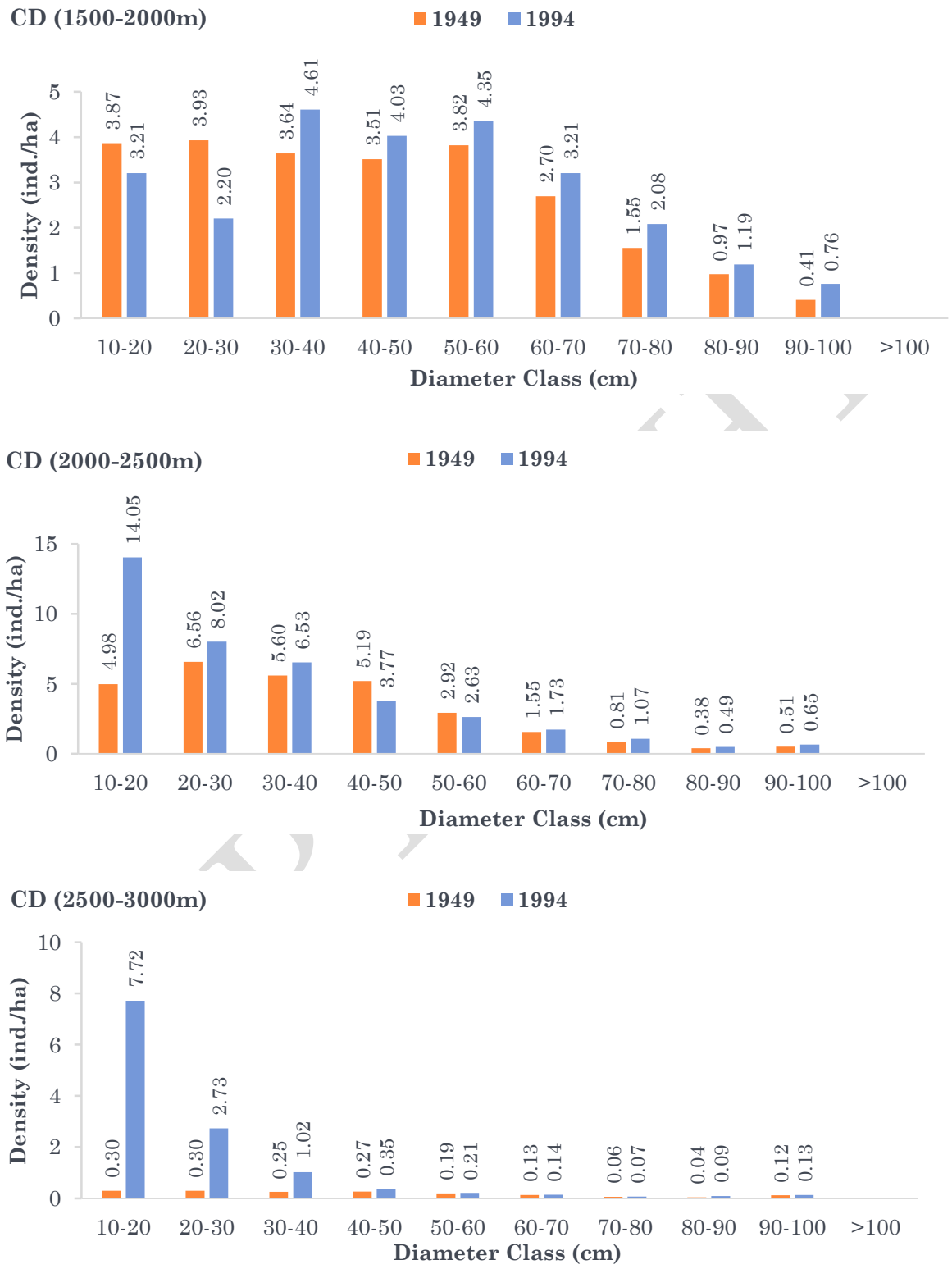
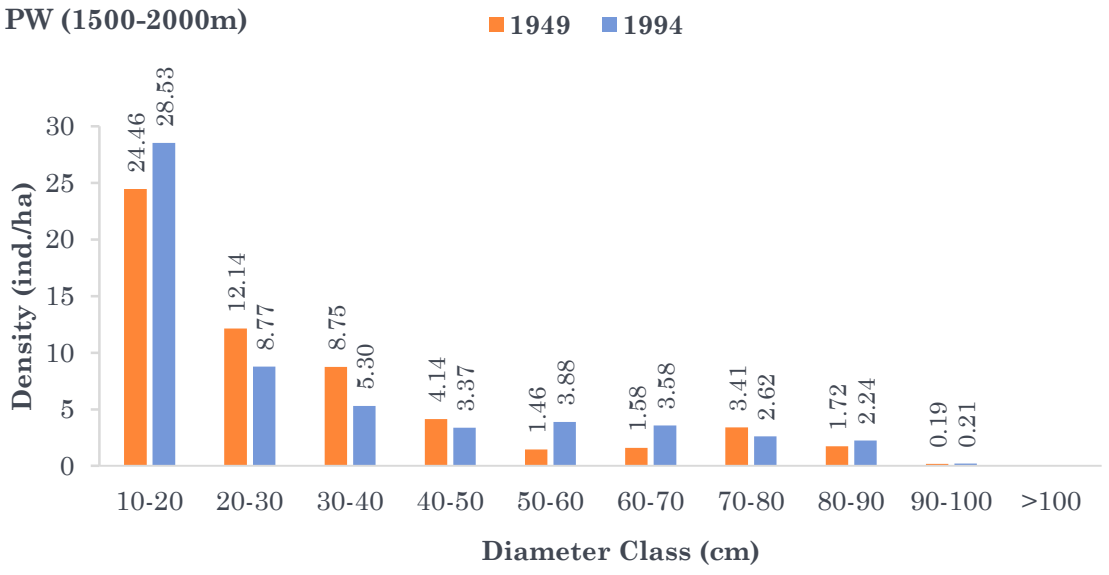


Figure 14: Density Variations in *Cedrus deodara*community at Different Diameter Classes, Kullu Forest Division, 1949-1994

Source: HPSCCC, 2018

Pinus wallichiana

Density of *Pinus wallichiana*also experienced an increase at all altitude gradients.Similar to *Cedrus deodara,* sharp increases were recorded for 10-20 cm diameter class (1.99 Ind/ha to 10.08 Ind/ha and 0.45 Ind/ha to 4.26 Ind/ha respectively) at 2000-2500m and 2500-3000m. However, at these altitude gradients, density oftress within diameter classes 40-50cm and above witnessed a continued decline (see Figure 15). This trend signifies regeneration of younger trees at higher altitude for *Pinus wallichiana*.At 1500-2500m altitude, mixed outcome was recorded. While the density of trees within diameter classes 10-20cm, 50-60cm, 60-70cm, 80-90cm, and 90-100cm increased significantly, those in remaining diameter classes declined. Therefore, at lower altitudes, regeneration along with sustainable growth of *Pinus wallichiana* communitycontinues in the Kullu Forest Division.



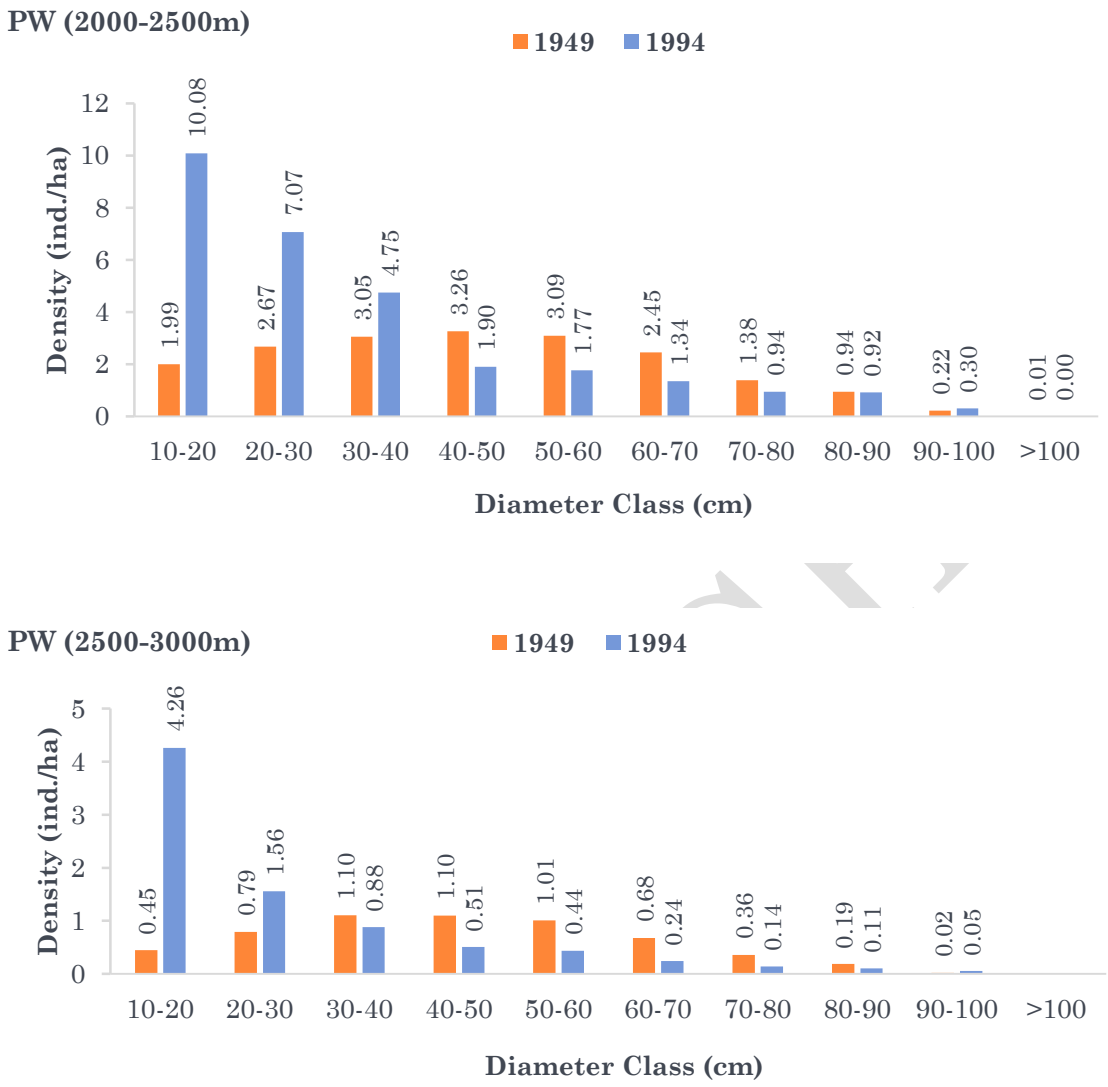
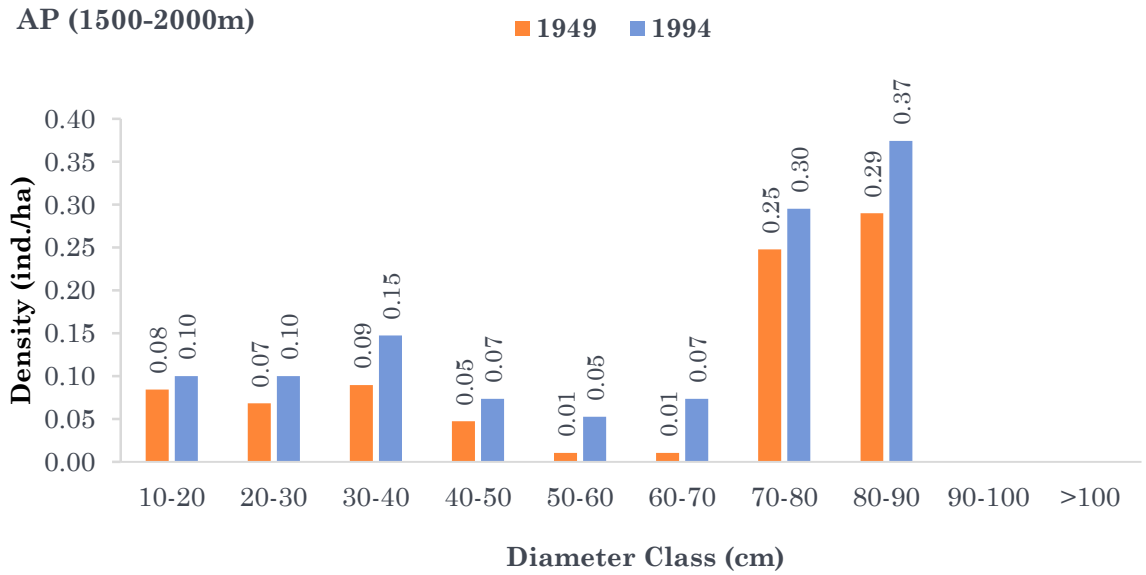


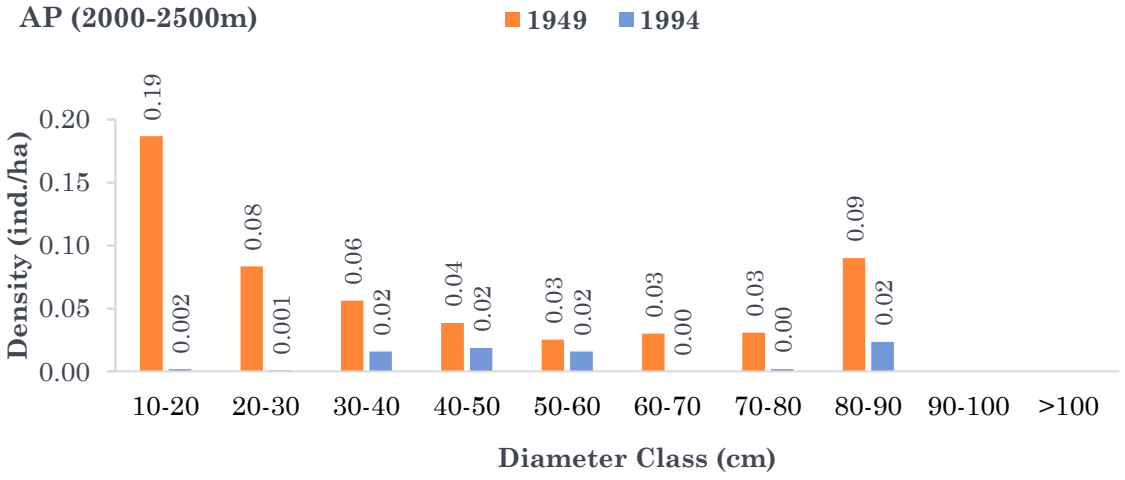
Figure 15: Density Variations in *Pinus wallichiana* community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Abies pindrow

Abies pindrow community'sconducive altitude range is 2100-3300cm, and in Kullu Forest Division at lower altitude of 1500-2000m its density in all diameter classes increased, specifically of those falling within diameter classes 70-80cm and 80-90cm, which were already in higher concentrationincreased from 0.25 Ind/ha to 0.30 Ind/ha and 0.29

Ind/hato 0.37 Ind/ha, respectively. At mid altitudes of 2000-2500m, steep decline in density of trees in all diameter classes was seen between 1949 and 1994, especially for those within 10-20cm and 20-30cm, where density declined from 0.19 Ind/ha to 0.002 Ind/ha, and 0.08 Ind/ha to 0.001 Ind/ha respectively. See Figure 16.





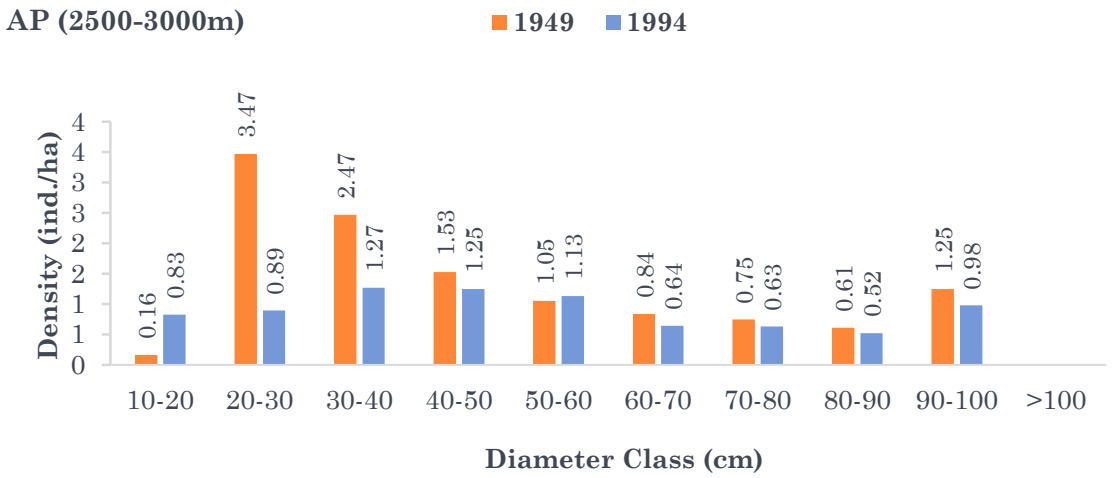


Figure 16: Density Variations in *Abies pindrow* community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Picea smithiana

*Picea smithiana*community thrives at 2000-3600m, and in this forest division at lower altitudes of 1500-2000m, density of trees within diameter classes 10-20cm, 80-90cm, and 90-100cm declined; while within other diameter classes tree density increased. Nonetheless, density of younger trees within diameters 10-20cm increased at bothaltitude ranges of 2000-2500m and 2500-3000m.

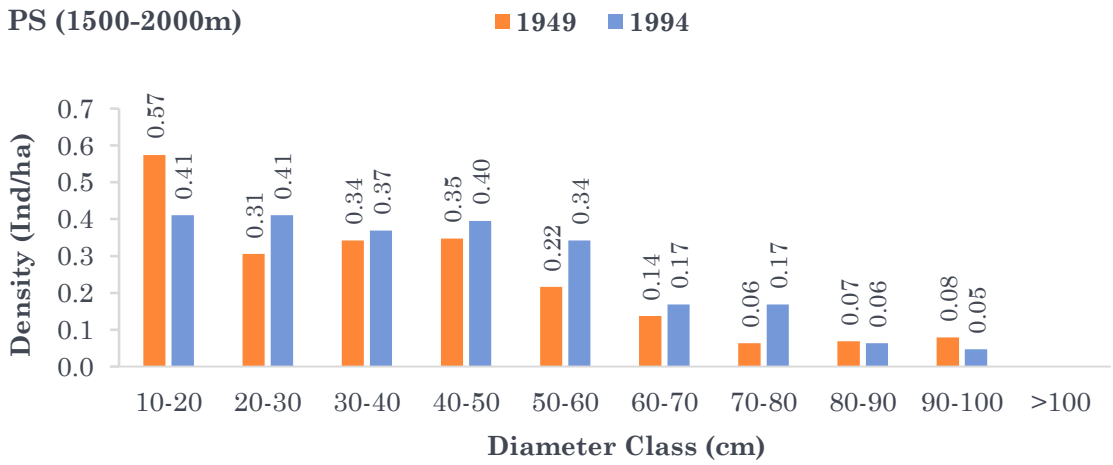


Figure 17: Density Variations in *Picea smithiana*community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Quercus semecarpifolia

*Quercus semecarpifolia*grows at 1830-3050m, and in the Kullu Forest Division based on the enumerated data, trees density at 2500-3000m exhibited varied changes across different diameter classes, with increases seen for 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, and 90-100cm; decrease for 10-20 cm, and no change in density for trees with diameter more than 100cm.

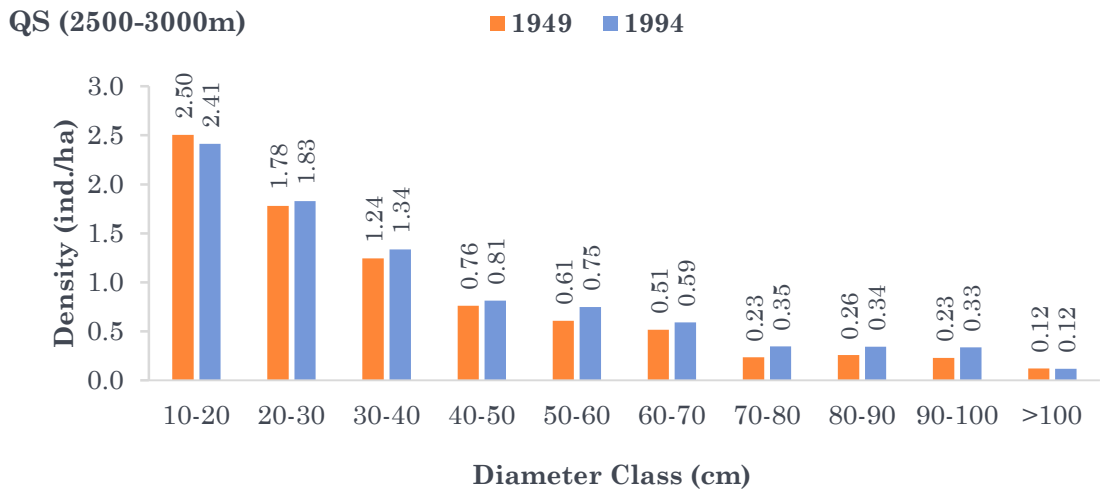


Figure 18: Density Variations in *Quercus semecarpifolia* community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Broad-leaved

Broad-leaved community in temperate forests thrives at 2000-3000m, and in in this forest division as per the enumeration data available for the study period, tree density at 2000-2500m increased for diameter classes 10-20cm, 20-30cm, 30-40cm, 40-50, and 60-70cm. At higher altitudes, 2500-3000m, density of trees within the diameter classes 10-20cm, 20-30cm, 30-40cm, 90-100 cm, and above increased. For those under 40-50cm, 50-40cm, 60-70cm, 70-80cm, and 80-90cm diameter classes,tree density showed a marginal decline. This outcome indicates toward both regeneration and continued growth of matured trees at higher altitudes.

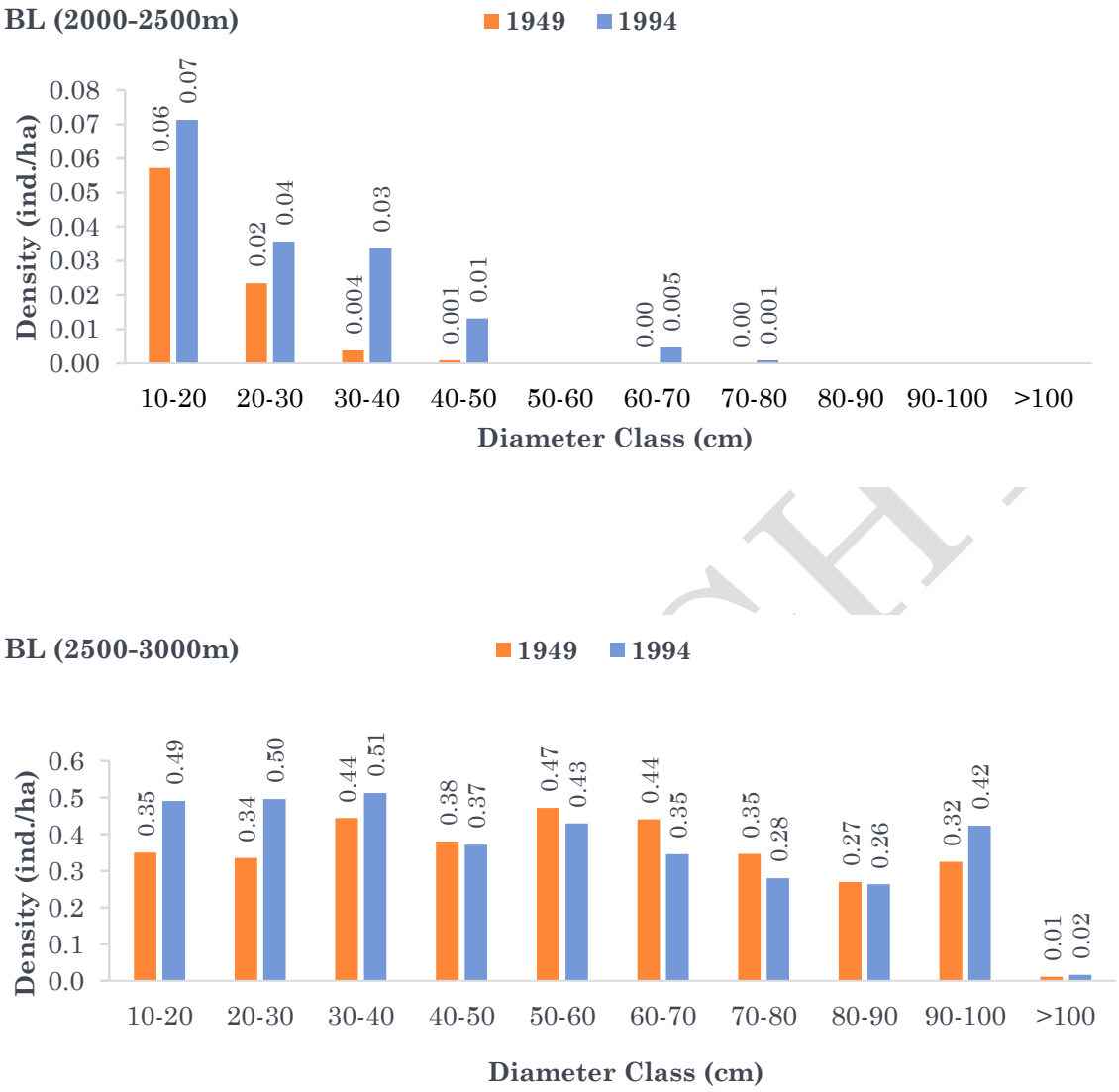


Figure 19: Density Variations in Broad-leavedcommunity at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Quercus floribunda and *Taxus baccata*

*Quercus floribunda*and *Taxus baccata* thrive at 2000-2500m and 2100-3200m altitudes, respectively. In the Kullu Forest Division, as per the enumerated data, density of trees for *Quercus floribunda* within diameter classes 20-30cm, 30-40cm, 70-80cm, and 90-100cm increased at 2000-2500cm, while those under 10-20cm and 60-70cm decreased, and within 40-50cm, 50-60cm, and 80-90cm remained the same from

1949 to 1994. For *Taxus baccata,* significant increase in density at altitude 2500-3000m was seen for diameter classes 10-20cm to 50-60cm between 1949 and 1994.

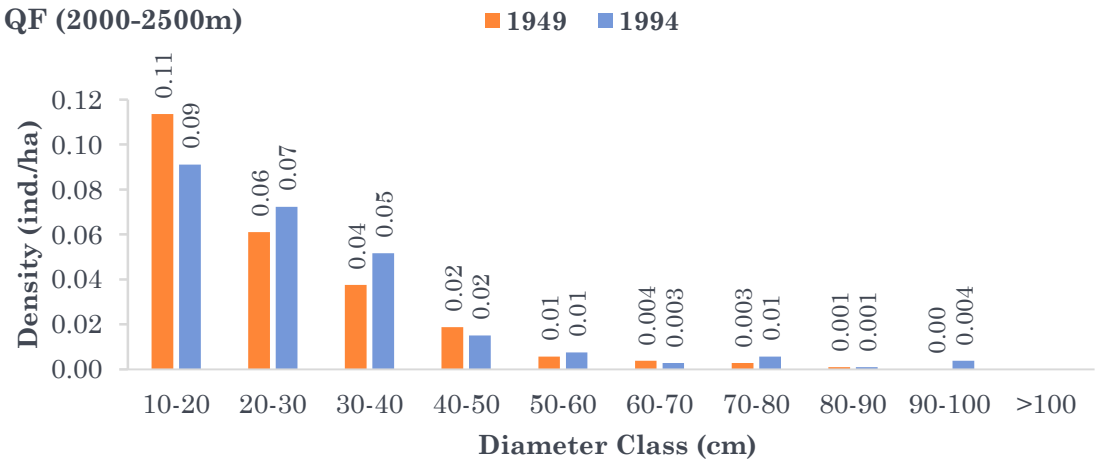


Figure 20: Density Variations in *Quercus floribunda* community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

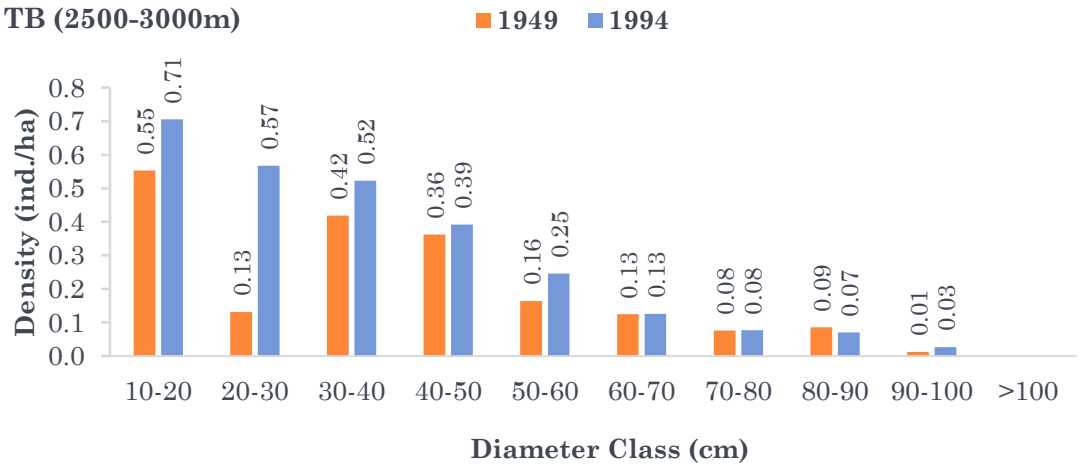


Figure 21: Density Variations in *Taxus baccata*community at Different Diameter Classes, Kullu Forest Division, 1949-1994
Source: HPSCCC, 2018

Banjar / Seraj Forest Division

For Seraj Forest Division, enumerated information in the Working Plans from Himachal Pradesh Forest Department and Compartment History files was taken for 1986 and 2013. As per the assessment, 5 pure tree communities i.e. where for a single species the relative density was more than 50 per cent, which are - *Cedrus deodara (CD), Pinus wallichiana (PW),Pinus roxburghii(PR), Quercus leucotrichophora(QLs), Picea smithiana(PS),*and14 mixed tree communities –Broad-leaved-*Abies pindrow ,Cedrus deodara-Pinus wallichiana, Abies pindrow-Taxus baccata, Abies pindrow-Picea smithiana, Abies pindrow*-Broad-leaved, *Taxus baccata-Abies pindrow, Quercus leucotrichophora-Pinus wallichiana, Quercus semecarpifolia-Quercus leucotrichophora, Picea smithiana-Taxus baccata, Taxus baccata-Picea smithiana, Quercus semecarpifolia-Taxus baccata,* Broad-leaved-*Picea smithiana, Quercus semecarpifolia-Taxus baccata-Abies pindrow, Picea smithiana-Abies pindrow-Pinus wallichiana*were identified.

As highlighted earlier in **Error! Reference source not found.**these tree communities were assessed from 85 forest compartments spread over a total area of 2891.12ha.

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 22 forest compartments covering an area of 454.47 ha, at altitude range of 1645-2621m above mean sea level. As illustrated in Figure 22, in its dominant tree community, density of *Cedrus deodara*declined from 159.5Ind/ha to 98.5Ind/ha. In these

forest compartments, representation (density) of other species is as follows – density of *Pinus wallichiana* declined from 49.2Ind/ha in 1986 to 22.9Ind/ha in 2013, density of *Picea smithiana, Quercus leucotrichophora,* and Broad-leaved also declined from 19.2Ind/ha to 12.3Ind/ha, 6.7 Ind/ha to 1.4 Ind/ha, and 1.8Ind/ha to 0.9Ind/ha, respectively.

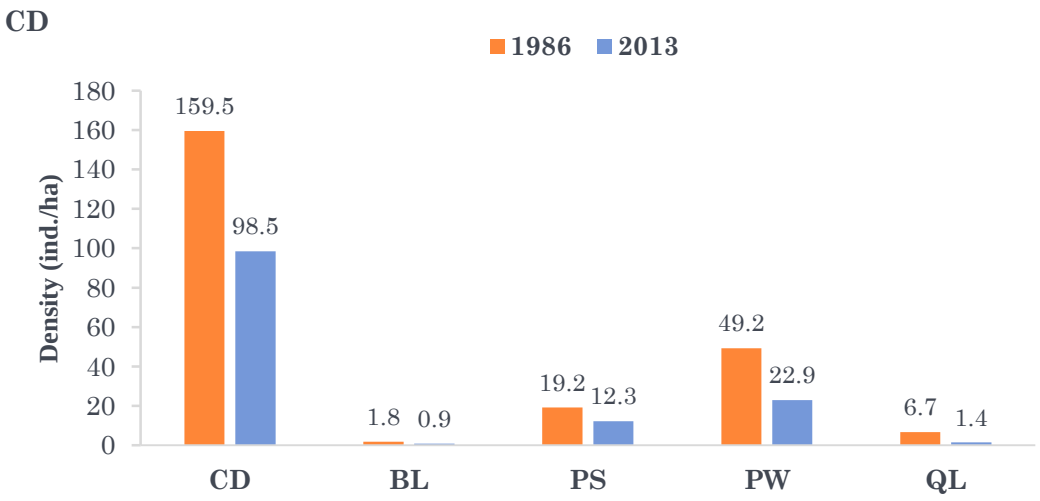


Figure 22: Density Variations in Species Composition in*Cedrus deodara* community, Seraj Forest Division, 1986-2013
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora*
Source: HPSCCC, 2018

2. *Pinus wallichiana* community

Data was collected from 15 forest compartments covering an area of 486.8 ha, at altitude range of 1645-3108m above mean sea level. As illustrated in Figure 23, in its dominant tree community, density of *Pinus wallichiana*declined significantly from 140.1Ind/ha to 58.8Ind/ha between 1986 and 2013.In these forest compartments, representation (density) of other species is as follows – all species i.e. *Abies pindrow, Cedrus deodara,Picea smithiana, Quercus leucotrichophora,* and Broad-leaved registered a decline in density

from 6.9 Ind/ha, 23.7Ind/ha, 27.1Ind/ha, 5.7Ind/ha and 19.8Ind/hain 1986 to 3.2Ind/ha, 19.3Ind/ha, 16.4Ind/ha, 2.3 Ind/ha and 8.6Ind/ha in 2013 respectively. Density of *Pinus roxburghii*increased from at 0.7Ind/hato 0.8 Ind/ha from 1986 to 2013.

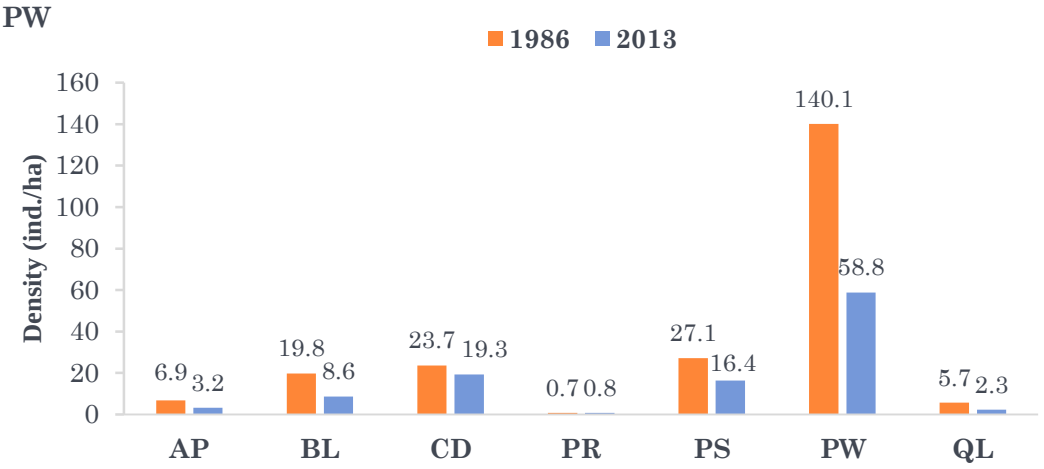


Figure 23: Density Variations in Species Composition in*Pinus wallichiana*community, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

3. *Pinus roxburghii*community

Data was collected from 5 forest compartments covering an area of 178.47 ha, at altitude range of 1432-2118m above mean sea level. As illustrated in Figure 24, in its dominant tree community, density of *Pinus roxburghii*registered a sharp decline from 88.9Ind/ha in 1986 to only 30.4Ind/hain 2013. In these forest compartments, representation (density) of other species is as follows – only *Cedrus deodara* showed a slight increase in density moving from 3.2Ind/ha to 4.0Ind/ha; while for *Pinus wallichiana,* Broad-leaved and *Quercus leucotrichophora*, density declined from 12 Ind/ha to 8.5 Ind/ha, and 6.7Ind/ha to 2.5 Ind/ha, 1.2 Ind/ha to 0.7 Ind/ha, respectively.

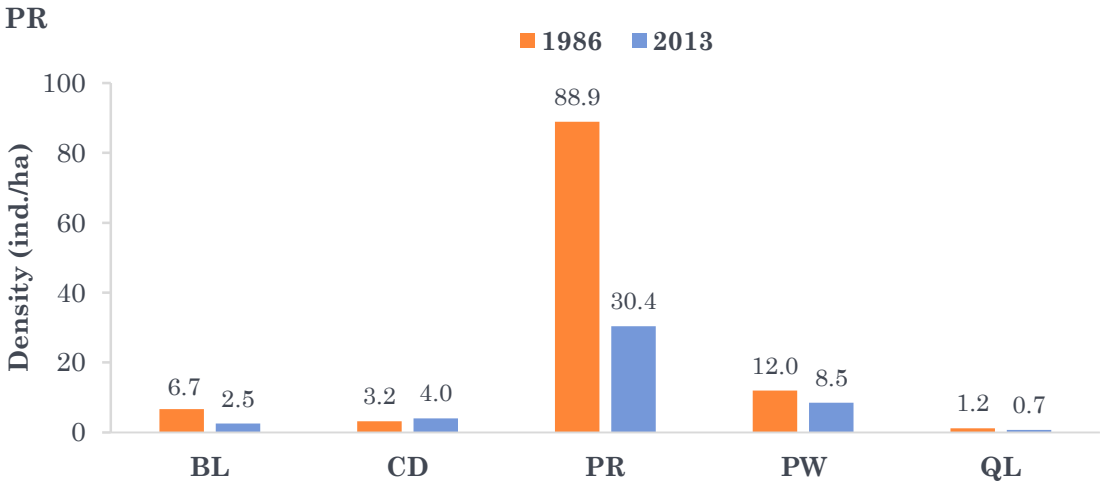


Figure 24: Density Variations in Species Composition in*Pinus roxburghii*community, Seraj Forest Division, 1986-2013
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **BL**= Broad-leaved; **QL**=*Quercus leucotrichophora;* **PR**=*Pinus roxburghii;* **AP**=*Abies pindrow*
Source: HPSCCC, 2018

4. *Picea smithiana* community

Data was collected from 10 forest compartments covering an area of 266.68 ha, at altitude range of 1584-2956m above mean sea level. As illustrated in Figure 25, in its dominant tree community, density of*Picea smithiana*increased from 159.7 Ind/ha in 1986 to 186.9Ind/ha in 2013. In these forest compartments, representation (density) of other species is as follows– all species witnessed increased tree density where density of*Abies pindrow* increased from 28.6Ind/ha to 35.2Ind/ha, for *Cedrus deodara* from 18.8Ind/ha to 26.0Ind/ha., for *Pinus wallichiana, density* increased from 72.9Ind/ha to 89.5Ind/ha, Broad-leaved increased from 7.5Ind/ha to 10.7Ind/ha., and *Taxus baccata,* the densityincreased from 2.5 Ind/ha to 2.8Ind/ha.

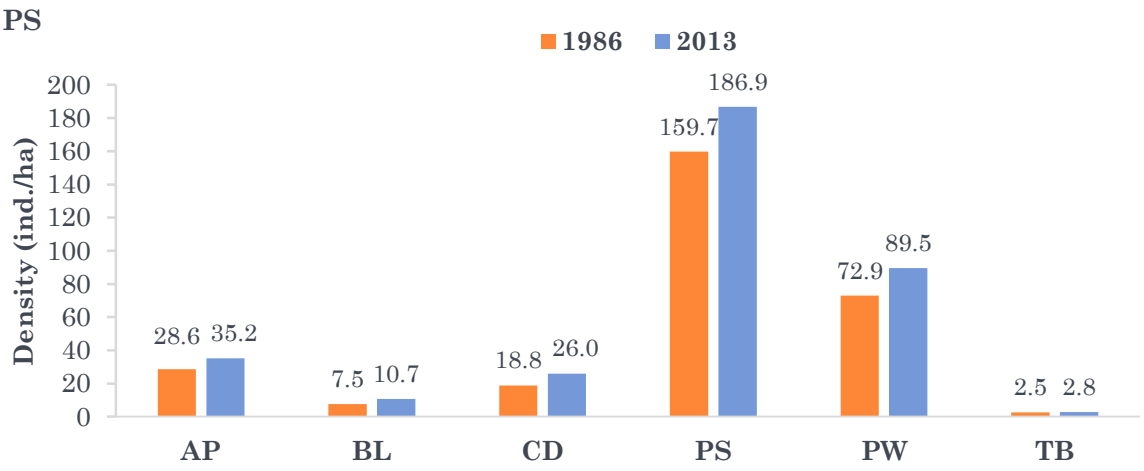


Figure 25: Density Variations in Species Composition in*Picea smithiana*community, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

5. *Quercus leucotrichophora* community

Data was collected from 2 forest compartments covering an area of 79.27 ha, at altitude range of 1447-2316m above mean sea level. As illustrated in Figure 26, in its dominant tree community, density of*Quercus leucotrichophora*plummeted from 327.8 Ind/ha in 1986 to only 90 Ind/ha in 2013. In these two forest compartments, representation (density) of other species is as follows – Broad-leaved, *Cedrus deodara, Pinus wallichiana,* and *Taxus baccata* decreased from 39.9 Ind/ha, 9.7 Ind/ha, 5.8 Ind/ha, and 0.5 Ind/ha in 1986 to 12.7 Ind/ha, 6.0 Ind/ha, 2.7 Ind/ha, and 0.3 Ind/ha, respectively. Meanwhile, density of *Picea smithiana*remained unchanged at 0.3 Ind/ha for both the years.

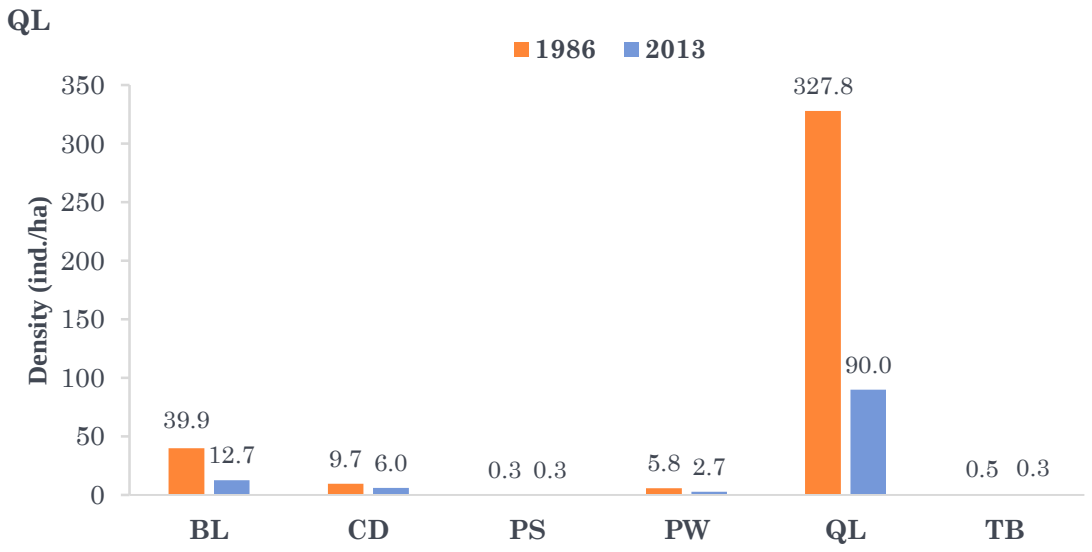


Figure 26: Density Variations in Species Composition in *Quercus leucotrichophora* community, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

6. Broad leaved-*Abies pindrow* community

Data was collected from 3 forest compartments covering an area of 120.08 ha, at altitude range of 2392-3078m above mean sea level. As illustrated in Figure 26, in its dominant tree community, density of *Abies pindrow* increased from 236.2 Ind/ha to 301.5 Ind/ha between 1986 and 2013. In these three forest compartments representation (density) of other species is as follows – Broad-leaved density increased from 300.8 ind/ha to 438.6 Ind/ha, density of *Taxus baccata* increased from 46.0 Ind/ha to 62.5 Ind/ha, density of *Pinus wallichiana, Quercus semecarpifolia,* and *Cedrus deodara* inclined from 7.3 Ind/ha to 8.8 Ind/ha, 1.1 Ind/ha to 5.2 Ind/ha, and 3.8 Ind/ha to 4.1 Ind/ha respectively. Meanwhile, tree density of *Picea smithiana* declined from 42.4 Ind/ha to 35.9 Ind/ha between 1986 and 2013.

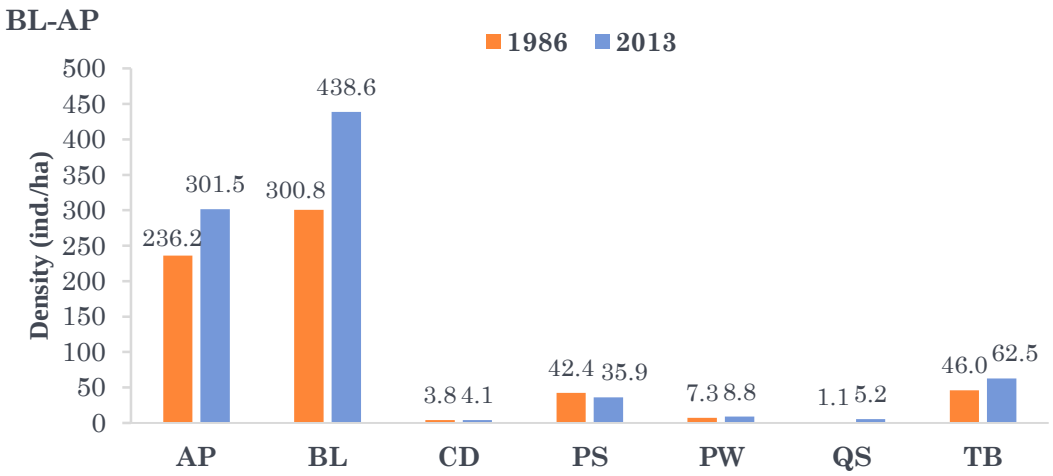


Figure 27: Density Variations in Species Composition in Broad leaved-*Abies pindrow* community, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

7. *Cedrus deodara-Pinus wallichiana* community

Data was collected from 4 forest compartments covering an area of 74.87 ha, at altitude range of 1828-2686m above mean sea level, for*Cedrus deodara- Pinuswallichiana* mixed community. The total tree density of *Cedrus deodara*increased from 98.3Ind/ha in year 1986 to 144.0Ind/ha in year 2013; while for *Pinuswallichiana* the density increased from 97.3Ind/ha to 119.8Ind/ha. In this mixed community, density of *Picea smithiana*and *Quercus leucotrichophora*also increased; while for Broad-leaved a decline was witnessed between 1986 and 2013, as illustrated in Figure 28.

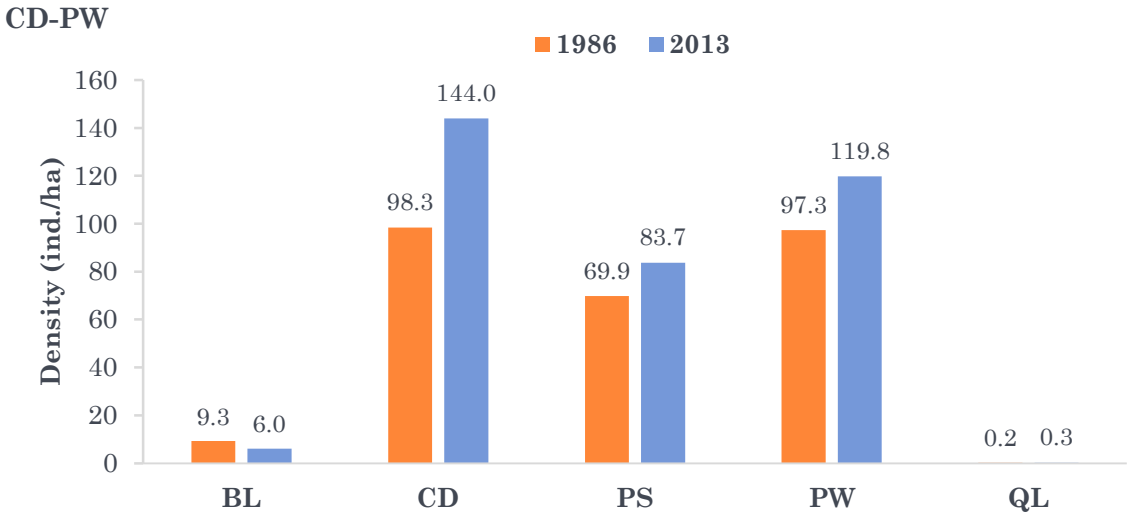


Figure 26: Density Variations in Species Composition in*Cedrus deodara – Pinus wallichiana* mixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

8. *Abies pindrow- Taxus baccata* community

Data was collected from 6 forest compartments covering an area of 266.68 ha, at altitude range of 2270-3048m above mean sea level, for*Abies pindrow-Taxus baccata* mixed community. Tree density of *Abies pindrow*declined from 107 Ind/ha in year 1986 to 91.7Ind/ha in year 2013; while for *Taxus baccata,*the density declined from 77.1Ind/ha to 64.8Ind/ha. In this mixed community, density of Broad-leaved, *Cedrus deodara, Pinuswallichiana,*and *Quercus semecarpifolia*all registered a decline, while for *Picea smithiana*tree density increased between 1986 and 2013, as illustrated in Figure 29.

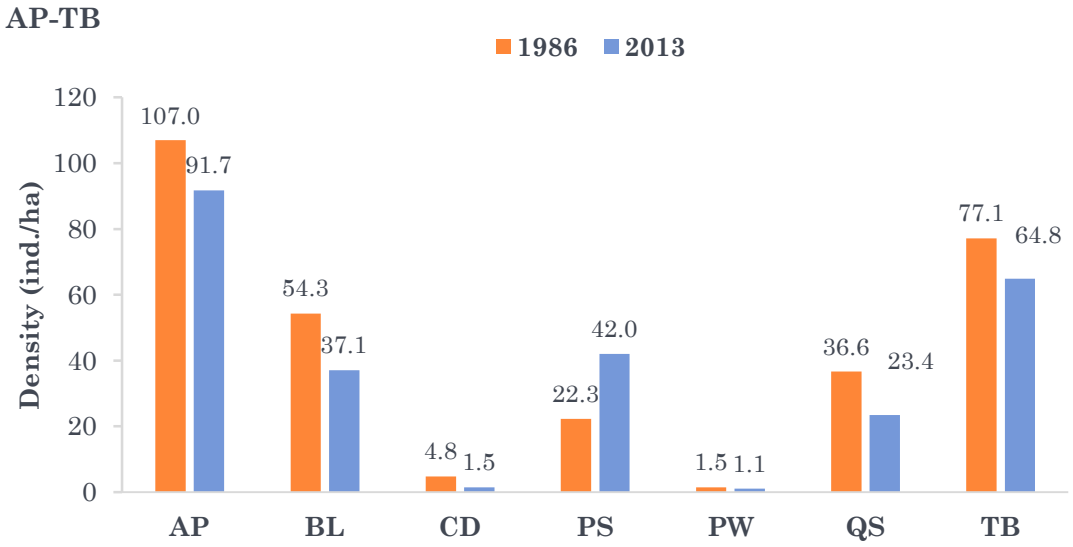


Figure 27: Density Variations in Species Composition in*Abies pindrow–Taxus baccata* mixedcommunity, Seraj Forest Division, 1986-2013
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **BL**= Broad-leaved;**AP**=*Abies pindrow;* **TB**=*Taxus baccata;* **QS**=*Quercus semecarpifolia*
Source: HPSCCC, 2018

9. *Abies pindrow-Picea smithiana* community

Data was collected from 6 forest compartments covering an area of 232.62 ha, at altitude range of 2225-2987m above mean sea level, for*Abies pindrow-Picea smithiana*mixed community. The tree density of *Abies pindrow*increased from 95.7Ind/ha in year 1986 to 123.7Ind/ha in year 2013; and for *Picea smithiana*the density increase was from 83.9 Ind/ha to 103.0Ind/ha. In this mixed community, density of Broad-leaved, *Cedrus deodara, Pinuswallichiana, Quercus semecarpifolia,* and *Taxus baccata* all registeredan increase between 1986 and 2013, as illustrated in Figure 30.

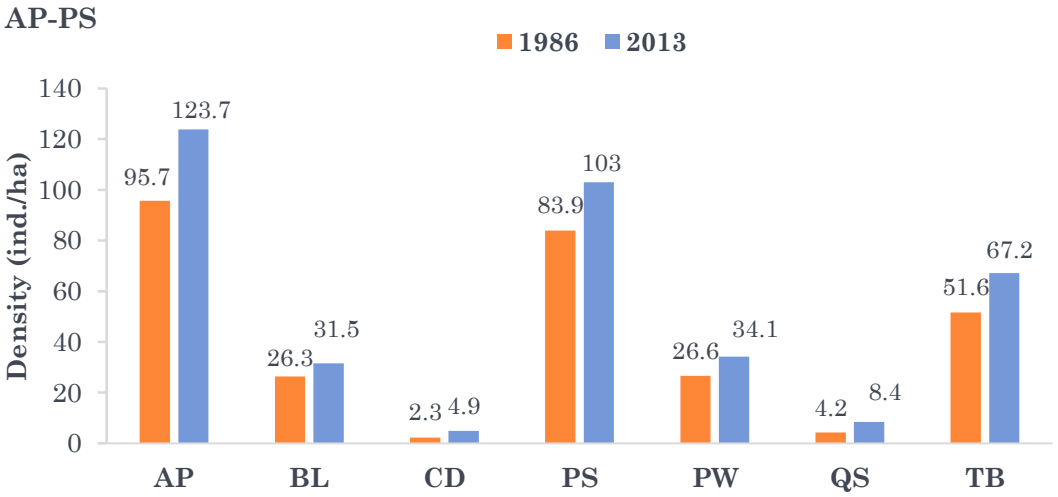


Figure 28: Density Variations in Species Composition in*Abies pindrow – Picea smithiana* mixedcommunity, Seraj Forest Division, 1986-2013

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

10.*Abies pindrow*-Broad-leavedcommunity

Data was collected from 2 forest compartments covering an area of 106.59 ha, at altitude range of 2392-3078m above mean sea level, for*Abies pindrow*-Broad-leavedmixed community. The tree density of *Abies pindrow* increased from 90.8 Ind/ha in year 1986 to 108.6 Ind/ha in year 2013; and for Broad-leaved,the density increased from 100Ind/ha to 147.3Ind/ha. In this mixed community, density of *Picea smithiana, Pinus wallichiana, Quercus semecarpifolia,*and *Taxus baccata*all registered an increase between 1986 and 2013, as illustrated in Figure 31.

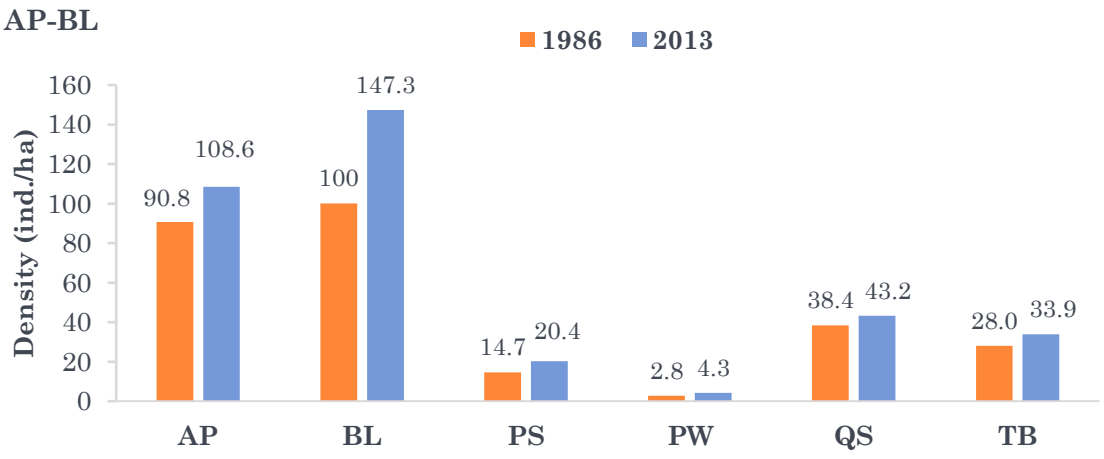


Figure 29: Density Variations in Species Composition in*Abies pindrow* – Broad-leavedmixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

11. *Taxus baccata-Abies pindrow* community

Data was collected from 2 forest compartments covering an area of 74.87 ha, at altitude range of 2225-2987m above mean sea level, for*Taxus baccata-Abies pindrow*mixed community. The tree density of *Taxus baccata*plummeted from 379.5 Ind/ha in year 1986 to 188.1 Ind/ha in year 2013; and for *Abies pindrow,* the density decreased from 247.9 Ind/ha to 149.4 Ind/ha. In this mixed community, density of Broad-leaved and *Quercus semecarpifolia*reduced while for *Pinuswallichiana,Picea smithiana,* and *Cedrus deodara* increased marginally between 1986 and 2013, as illustrated in Figure 32.

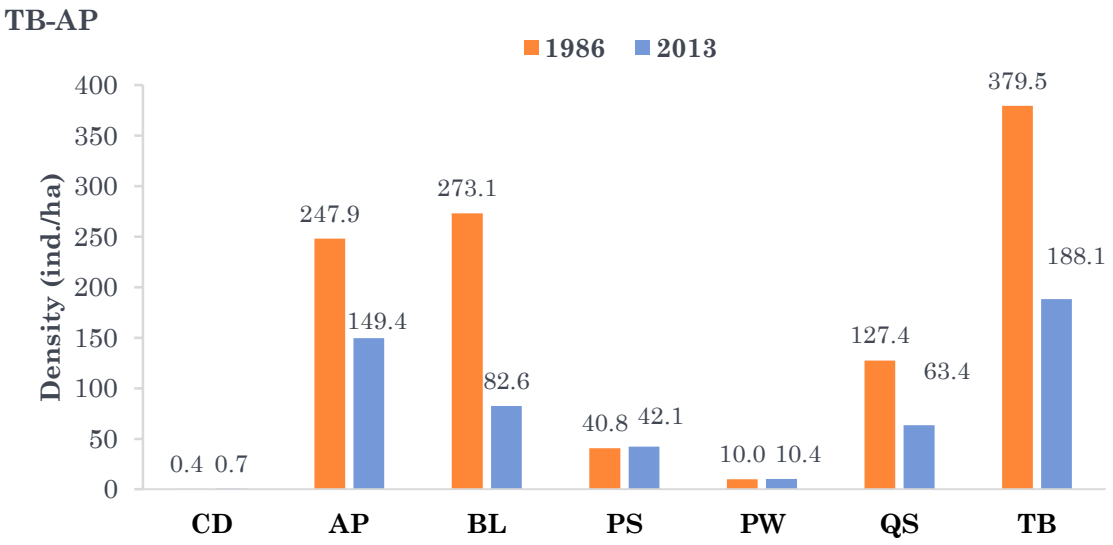


Figure 30: Density Variations in Species Composition in*Taxus baccata - Abies pindrow* mixedcommunity, Seraj Forest Division, 1986-2013
Abbreviations:CD= *Cedrus deodara;* **PW=***Pinus wallichiana,* **PS=***Picea smithiana*; **BL=** Broad-leaved;**AP=***Abies pindrow;* **TB=***Taxus baccata;* **QS=***Quercus semecarpifolia*
Source: HPSCCC, 2018

12. *Quercus leucotrichophora-Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 116.59 ha, at altitude range of 1859-2788m above mean sea level, for*Quercus leucotrichophora-Pinus wallichiana*mixed community. The tree density of *Quercus leucotrichophora*declined significantly from 70.4Ind/ha in year 1986 to only 20.6 Ind/ha in year 2013; and for *Pinus wallichiana,*the density decreased from 13.5Ind/ha to 11.0Ind/ha. In this mixed community, density of Broad-leaved,*Quercus semecarpifolia,*and *Cedrus deodara*all registered adecline between 1986 and 2013, as illustrated in Figure 33.

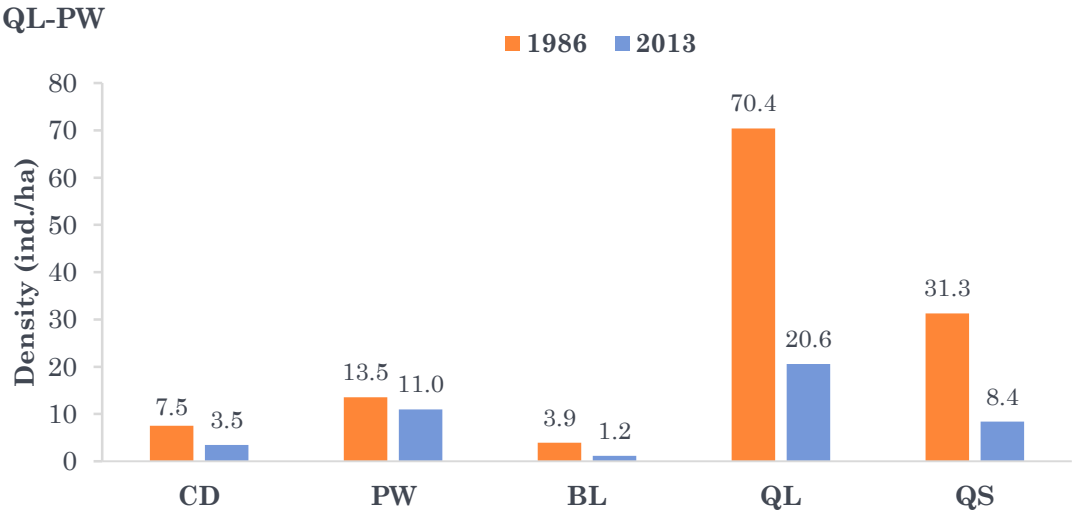


Figure 31: Density Variations in Species Composition in*Quercus leucotrichophora-Pinus wallichiana* mixedcommunity, Seraj Forest Division, 1986-2013

Abbreviations:CD=*Cedrus deodara;* **PW=***Pinus wallichiana;* **BL=**Broad-leaved;**QL=***Quercus leucotrichophora;* **QS=***Quercus semecarpifolia*

Source: HPSCCC, 2018

13. *Quercus semecarpifolia-Quercus leucotrichophora* community

Data was collected from 1 forest compartment covering an area of 92.68 ha, at altitude range of 1859-2760m above mean sea level, for*Quercus semecarpifolia-Quercus leucotrichophora* mixed community. The tree density of *Quercus semecarpifolia* declined significantly from 53.3 Ind/ha in year 1986 to 14.9 Ind/ha in year 2013; and for *Quercus leucotrichophora,*the density decreased from 33.0 Ind/ha to 10.4 Ind/ha. In this mixed community, density of Broad-leaved,*Pinus wallichiana,* and *Taxus baccata*all registered adecline between 1986 and 2013, as illustrated in Figure 34.

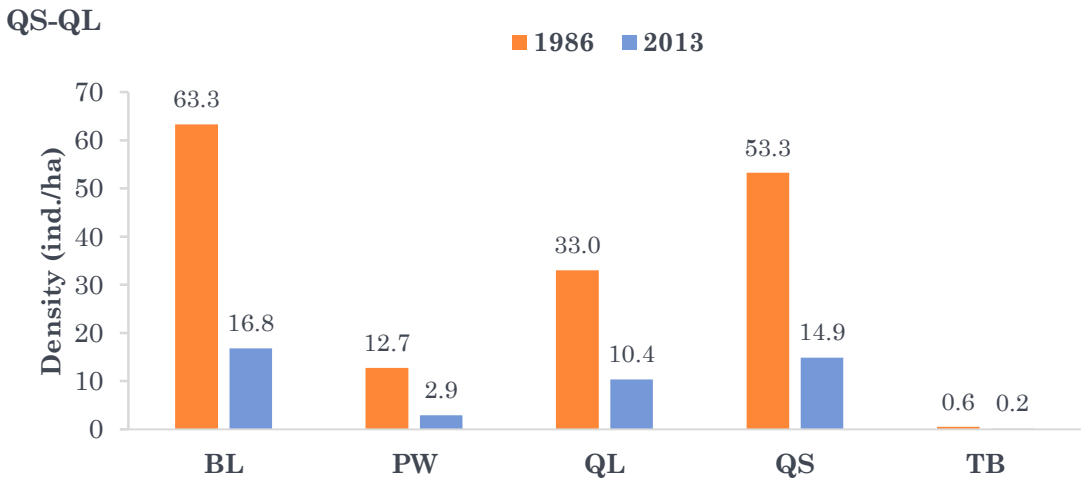


Figure 32: Density Variations in Species Composition in*Quercus semecarpifolia - Quercus leucotrichophora*mixedcommunity, Seraj Forest Division, 1986-2013

Abbreviations:PW=*Pinus wallichiana;* **BL**=Broad-leaved;**QL**=*Quercus leucotrichophora;* **QS**=*Quercus semecarpifolia;* **TB=** *Taxus baccata*

Source: HPSCCC, 2018

14.*Picea smithiana-Taxus baccata* community

Data was collected from 1 forest compartment covering an area of 29ha, at altitude range of 2631-3352m above mean sea level, for*Picea smithiana-Taxus baccata*mixed community. The tree density of *Picea smithiana*increased considerably from 50.9 Ind/ha in year 1986 to 128.3 Ind/ha in year 2013; and for *Taxus baccata,*the density increased from 88.2 Ind/ha to 91.8 Ind/ha. In this mixed community, density of Broad-leaved and *Cedrus deodara* inclined; for *Pinus wallichiana*and *Abies pindrow* declined; and for*Quercus semecarpifolia,*density remained the same between 1986 and 2013, as illustrated in Figure 35.

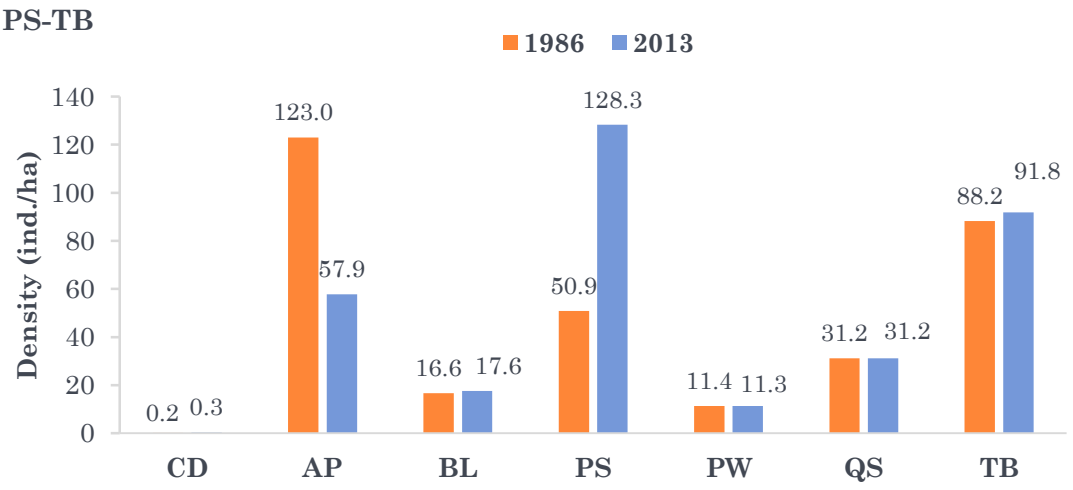


Figure 33: Density Variations in Species Composition in*Picea smithiana-Taxus baccata*mixedcommunity, Seraj Forest Division, 1986-2013
Abbreviations:CD=*Cedrus deodara;* **AP=** *Abies pindrow;* **PW=***Pinus wallichiana;* **BL=** Broad-leaved;**QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata*
Source: HPSCCC, 2018

15. *Taxus baccata- Picea smithiana*community

Data was collected from 1 forest compartment covering an area of 37.49 ha, at altitude range of 2407-3185m above mean sea level, for*Taxus baccata-Picea smithiana*mixed community. The tree density of *Taxus baccata*increased from 164.2 Ind/ha in 1986 to 166.8 Ind/ha in 2013; and for *Picea smithiana,*the density appreciated from 13.4 Ind/ha to 100.9 Ind/ha. In this mixed community, density of Broad-leaved and*Quercus semecarpifolia* inclined; for *Abies pindrow* noticeably declined; and for *Pinus wallichiana*and *Cedrus deodara* remained the same between 1986 and 2013, as illustrated in Figure 36.

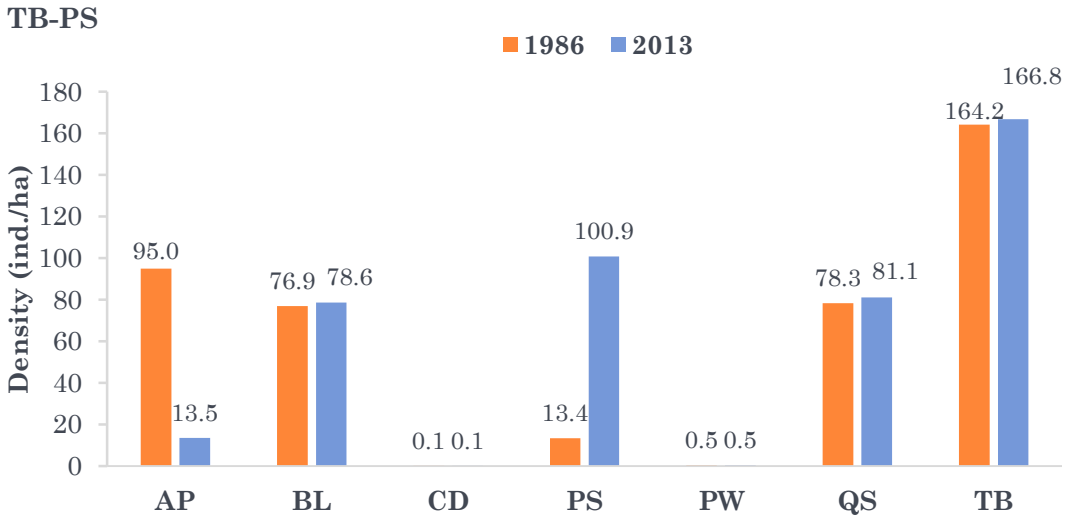


Figure 34: Density Variations in Species Composition in*Taxus baccata - Picea smithiana* mixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

16. *Quercus semecarpifolia-Taxus baccata* community

Data was collected from 1 forest compartment covering an area of 86.5ha, at altitude range of 2286-2577m above mean sea level, for*Quercus semecarpifolia-Taxus baccata*mixed community. The tree density of *Quercus semecarpifolia*augmented from only 43.9Ind/ha in 1986 to 104.5Ind/ha in 2013; and for *Taxus baccata,*the density marginally increased from 71.6Ind/ha to 75.7Ind/ha. In this mixed community, density of Broad-leaved,*Cedrus deodara,* and *Pinus wallichiana*inclined; for *Picea smithiana*declined; and for *Abies pindrow*remained same between 1986 and 2013, as illustrated in Figure 37.

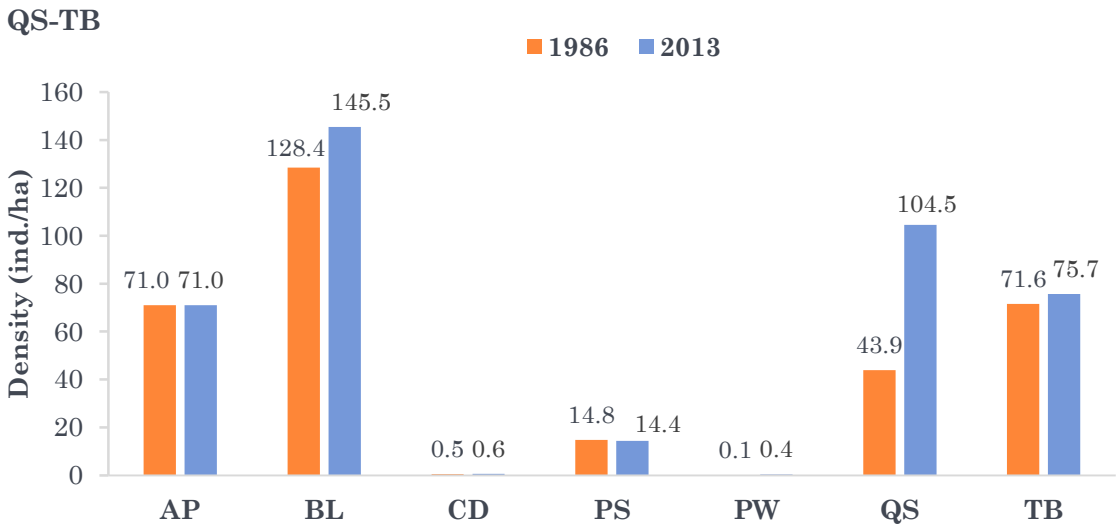


Figure 35: Density Variations in Species Composition in*Quercus semecarpifolia- Taxus baccata* mixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

17. Broad-leaved-*Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 91.11 ha, at altitude range of 2148-2606m above mean sea level, forBroad-leaved-*Picea smithiana*mixed community. The tree density of Broad-leavedrose from 74.6 Ind/ha in 1986 to 92.2 Ind/ha in 2013; and *Picea smithiana*,registered a steep jump from only 2.0 Ind/ha to 51.6 Ind/ha. In this mixed community, density of *Taxus baccata* increased; of *Abies pindrow* considerably declined; and for *Quercus semecarpifolia*remained the same between 1986 and 2013, as illustrated in Figure 38.

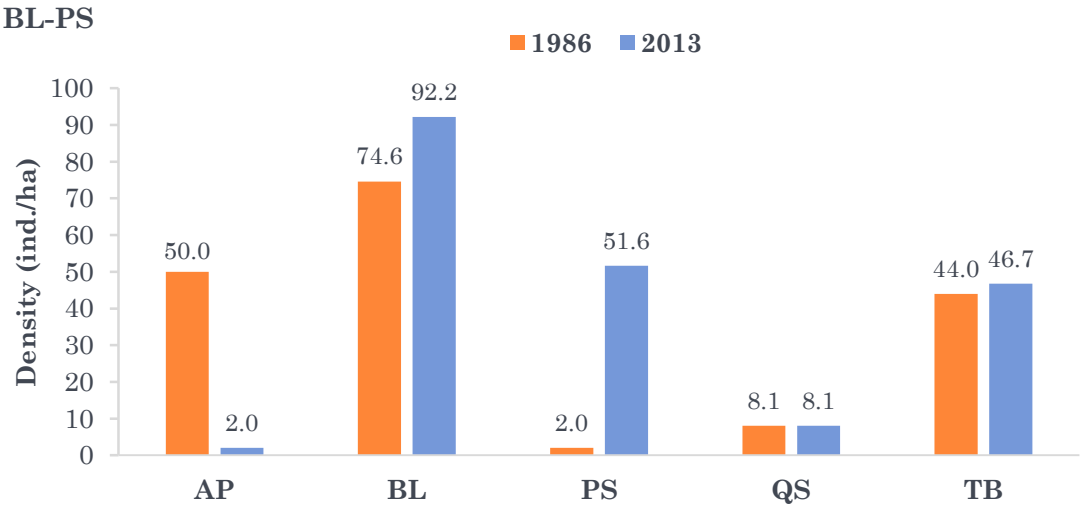


Figure 36: Density Variations in Species Composition inBroad-leaved - *Picea smithiana* mixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

18. *Quercus semecarpifolia-Taxus baccata-Abies pindrow*community

Data was collected from 1 forest compartment covering an area of 36.02 ha, at altitude range of 2392-3078m above mean sea level, for*Quercus semecarpifolia-Taxus baccata-Abies pindrow*mixed community. The tree density of *Quercus semecarpifolia*soared from 198.9 Ind/ha in 1986 to 269.7 Ind/ha in 2013; of *Taxus baccata* also increased from 122.1 Ind/ha to 208.4 Ind/ha,and for *Abies pindrow,*itregistered an increase from 114.6 Ind/ha to 193.2 Ind/ha. In this mixed community, density of Broad-leaved, *Picea smithiana*surged, and of *Pinus wallichiana*was halvedbetween 1986 and 2013, as illustrated in Figure 39.

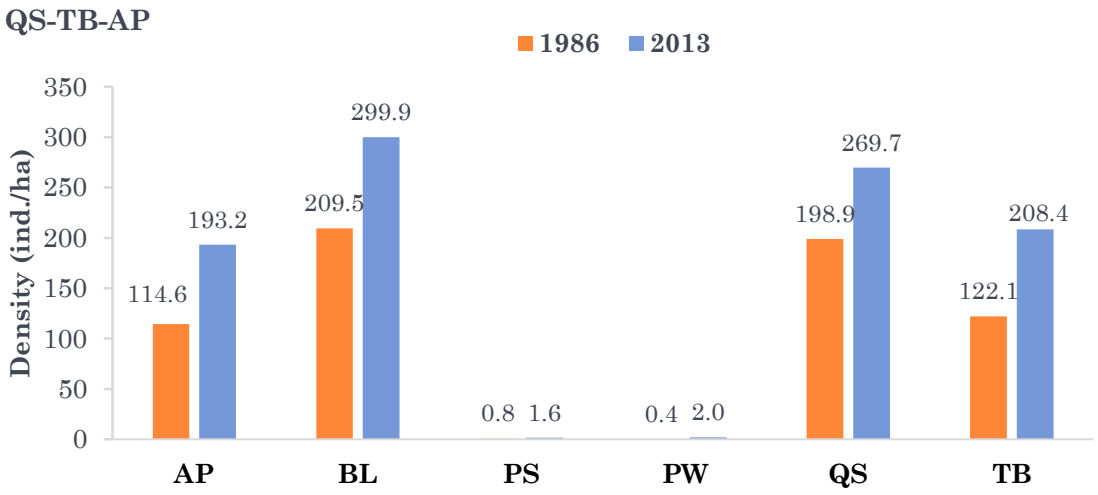


Figure 37: Density Variations in Species Composition in*Quercus semecarpifolia-Taxus baccata-Abies pindrow* mixedcommunity, Seraj Forest Division, 1986-2013
Abbreviations: CD= *Cedrus deodara;* **AP=** *Abies pindrow;* **BL=** Broad-leaved;**QS=***Quercus semecarpifolia;* **TB=** *Taxus baccata;* **PS=***Picea smithiana*
Source: HPSCCC, 2018

19.*Picea smithiana -Abies pindrow-Pinus wallichiana*community

Data was collected from 1 forest compartment covering an area of 53.41 ha, at altitude range of 2270-2926m above mean sea level, for*Picea smithiana-Abies pindrow-Pinus wallichiana*mixed community. The tree density of *Picea smithiana*increased from 12.5Ind/ha in 1986 to 18.6Ind/ha in 2013; of *Abies pindrow* declined from 52.6Ind/ha to just17.1 Ind/ha,and the tree density of *Pinus wallichiana*noticeablyincreasedfrom 0.7Ind/ha to 16.9Ind/ha. In this mixed community, density of *Cedrus deodara* and *Picea smithiana*increased;of Broad-leaved, and *Taxus baccata*declinedbetween 1986 and 2013, as illustrated in Figure 40.

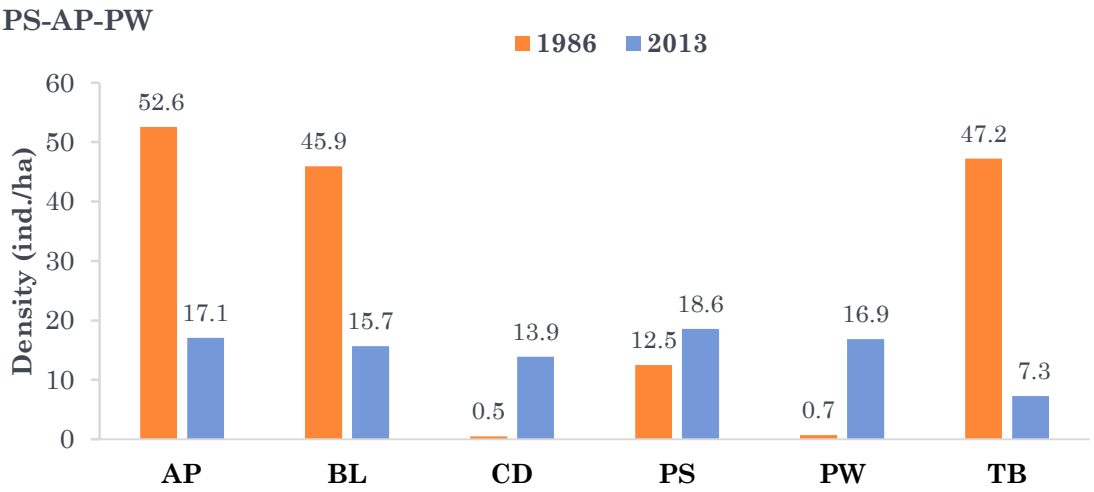


Figure 38: Density Variations in Species Composition in*Picea smithiana -Abies pindrow-Pinus wallichiana* mixedcommunity, Seraj Forest Division, 1986-2013

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

Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study the forests compartments of Banjar/Seraj Forest Division were divided into 3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500-3000m.The forests in particular altitudinal range were categorized species wise, then their total number was calculated for both of years i.e. 1986 and 2013. The density (individual per hectare) was then calculated for all species at respective altitudesrepresenting individual in one hectare.

4. 1500-2000m

There are 18 forest compartments at this altitude gradient with a total area of 426.96 ha falling under Banjar, Sainj, and Tirthan forest ranges. At 1500-2000m altitude, most of the species witnessed a decline in density expect for *Abies pindrow* (1.7 Ind/ha to 2.0 Ind/ha)and *Picea smithiana* (9.6 Ind/ha to 15.9 Ind/ha). *Pinus wallichiana* that has highest representation at this altitude, its density declined from 72.8 Ind/ha in 1986 to 43.8 Ind/ha in 2013. Similarly, for Broad-leaved, *Cedrus deodara, Pinue roxburghii, Quercus floribunda,* and*Quercus leucotrichophora,*areduced density was registered between 1986 and 2013 at 1500-2000m altitude.

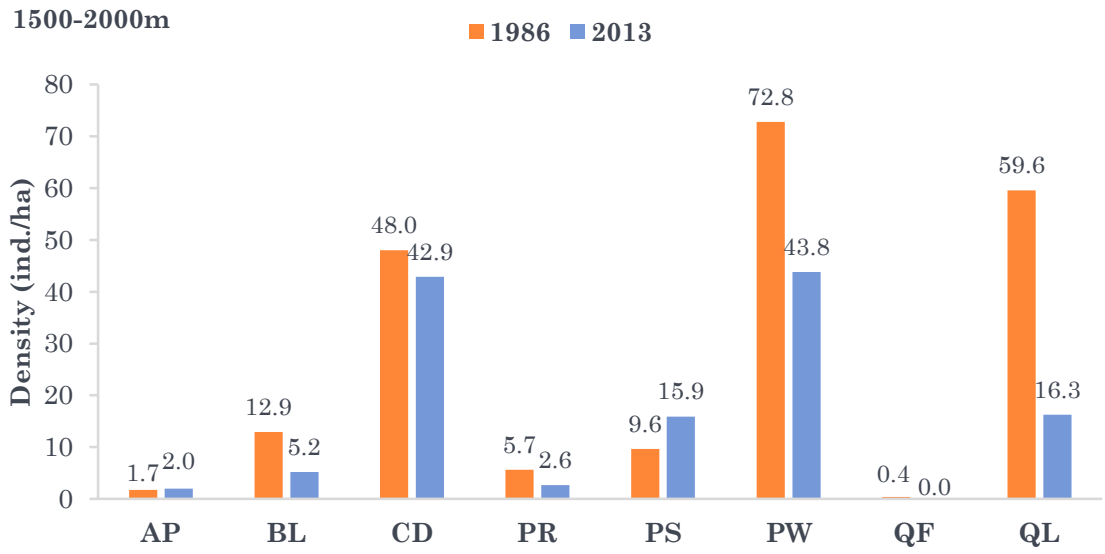


Figure 39: Density Variations in Species Composition at1500-2000m Altitude, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

5. 2000-2500m

There are 42 forest compartments at this altitude gradient with a total area of 1,413.36ha falling under forest ranges of Banjar, Sainj, and Tirthan. At 2000-2500m altitude, majority of species witnessed a decline in density, with *Pinus wallichiana* that has the highest representation at this altitude, declined from 66.2 Ind/ha in 1986 to 32.5 Ind/ha in 2013. For other species - *Abies pindrow'*sindividuals per hectare declined from 13.9Ind/ha to 11.3Ind/ha; density for Broad-leaved declined from 23.3 Ind/ha to 17.2 Ind/ha; density for *Cedrus deodara* plunged from 53.3 Ind/ha to 36.6 Ind/ha; *Picea smithiana* witnessed slight decrease in density from 34.6 Ind/ha to 33.0 Ind/ha; density of *Quercus leucotrichophora*and *Quercus semecarpifolia*fell from 12.8 Ind/ha to 4.0 Ind/ha, and 10.2 Ind/ha to 9.3 Ind/ha, respectively. Meanwhile, density of *Quercus floribunda*and *Taxus baccata* registered a slight increase between 1986 and 2013 at altitude 2000-2500m, as exhibited in Figure 42.

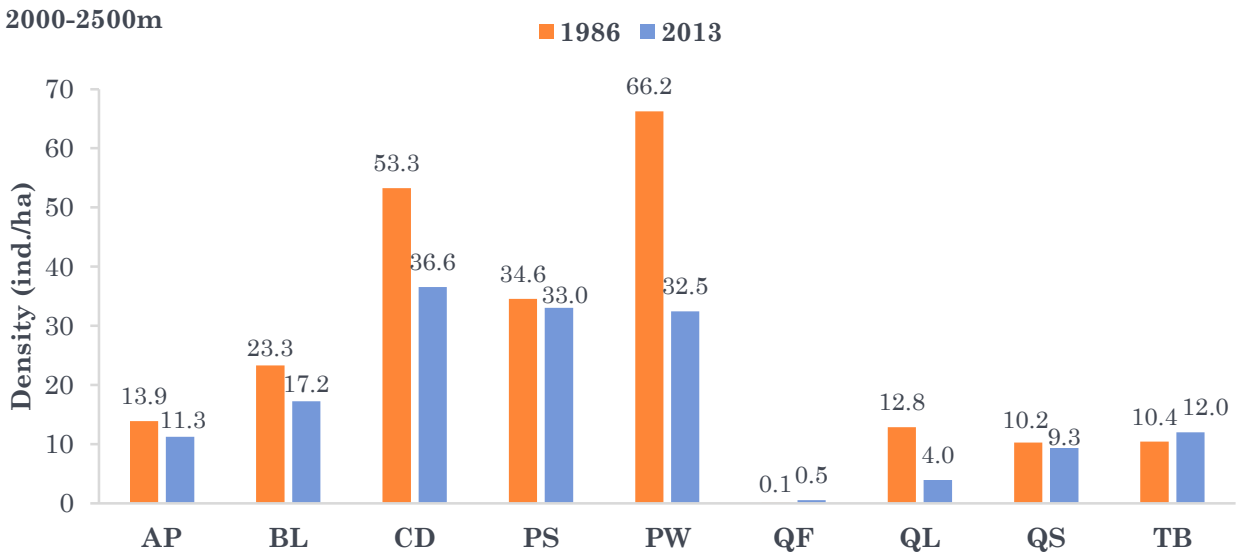


Figure 40: Density Variations in Species Composition at 2000-2500m Altitude, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

6. 2500-3000m

There are 30 forest compartments at this altitude gradient with a total area of 1,138.78ha that fall under Banjar, Sainj, and Tirthan forest ranges. At the study's highest altitude range,*Abies pindrow*assumed highest concentration, and witnessed a slight decrease in density from 112.1 Ind/ha to 111.4 Ind/ha between 1986 and 2013. Broad-leaved, *Taxus baccata,* and *Quercus semecarpifolia*too experienced a drop in density, as exhibited in Figure 43. Nevertheless, all of the remaining species registered an increase in density from 1986 to 2013 with *Cedrus deodara*increasing from 5.6 Ind/ha to 7.3 Ind/ha; *Picea smithiana's* from 60.8 Ind/ha to 74.5 Ind/ha; *Pinus wallichiana*from 24.2 Ind/ha to 28.5 Ind/ha.

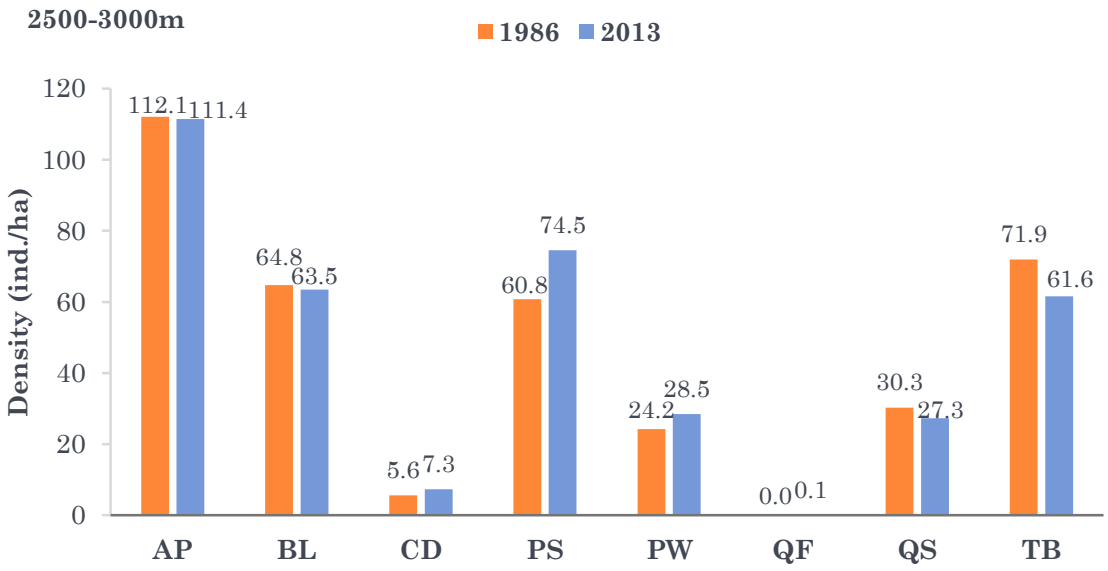


Figure 41: Density Variations in Species Composition at 2500-3000m Altitude, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Table 6 below gives information on suitable altitude ranges for tree species identified in the three forest divisions under Kullu Forest Circle juxtaposed with observation made for the Seraj Forest Division.

Table 3: Suitable Altitude Range for Different Tree Species in Banjar/Seraj Division

Species	Suitable Altitude	Observed Changes		
		1500-2000m	2000-2500m	2500-3000m
Cedrus deodara	1800 – 3000m	Decreased	Decreased	Increased
Pinus wallichiana	1800 – 3000m	Decreased	Decreased	Increased
Abies pindrow	2000 – 3300m	Increased	Decreased	Decreased
Picea smithiana	2100 – 3600m	Increased	Decreased	Increased
Pinus roxburghii	1000 – 2000m	Decreased	Not observed	Not observed
Quercus leucotrichophora	1800 – 2250m	Decreased	Decreased	Not observed

Note:
Increased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1986 and 2013.
Decreased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1986 and 2013.
Not observed signifies the cases where a given species was not found at a particular altitude between 1986 and 2013.

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Seraj Forest Division, its density was observed to decrease at lower to mid

altitudes, with a steep decline of 31 per cent at the mid altitude rangeof 2000-2500m. While at high altitude of 2500-3000m, its individuals per hectare increased.

*Pinus wallichiana*is found between 1800m to 3000m altitude above sea level, and in theSeraj Forest Division, its density too declined at 1500-2000m and 2000-2500m altitude ranges,exhibiting a sharp fall of 40 per cent and 50 per cent, respectively. At higher altitude, its density increased by only 11 per cent.

*Abies pindrow*grows at 2000-3300m altitude, and in this forest division, the species registered an increase of 18 per cent at 1500-2000m; 18 per cent decline at 2000-2500m; and, a nominal fall of 1 per cent at 2500-3000m.

*Picea smithiana*thrives at 2100-3600maltitude, and in the Seraj Forest Division it was observed in higher density at 1500-2000m and 2500-3000m with respective increases of 66 per cent and 23 per cent between 1986 and 2013. At the middle altitudinal range, the density decreased by 4.6 per cent.

*Pinus roxburghii*grows at 1000-2000m altitude range, and in the Seraj Forest Division, its density significantly declined by 54 per cent between 1500 and 2000m altitude range.

Quercus leucotrichophora thrives at 1800-2250m altitude range, and 73 per cent of its concentration vanished at 1500-2000m altitude gradient, and 69 per cent at the 2000-2500m from 1986 to 2013.

To get a better insight in to the type of species that had undergone temporal change between 1986 and 2013, diameter class wise variationswere cross referenced at different altitude ranges. The next

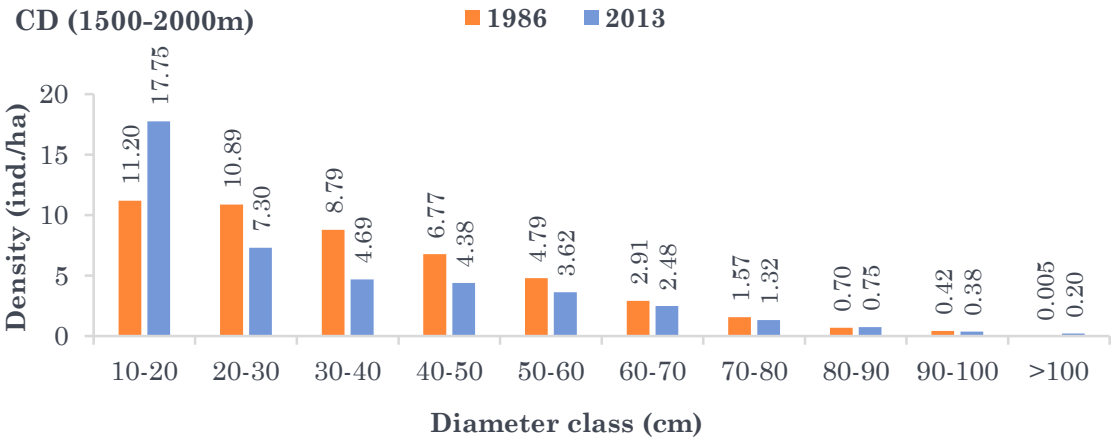
section presents the findings of the specific changes for each species in the Seraj Forest Division.

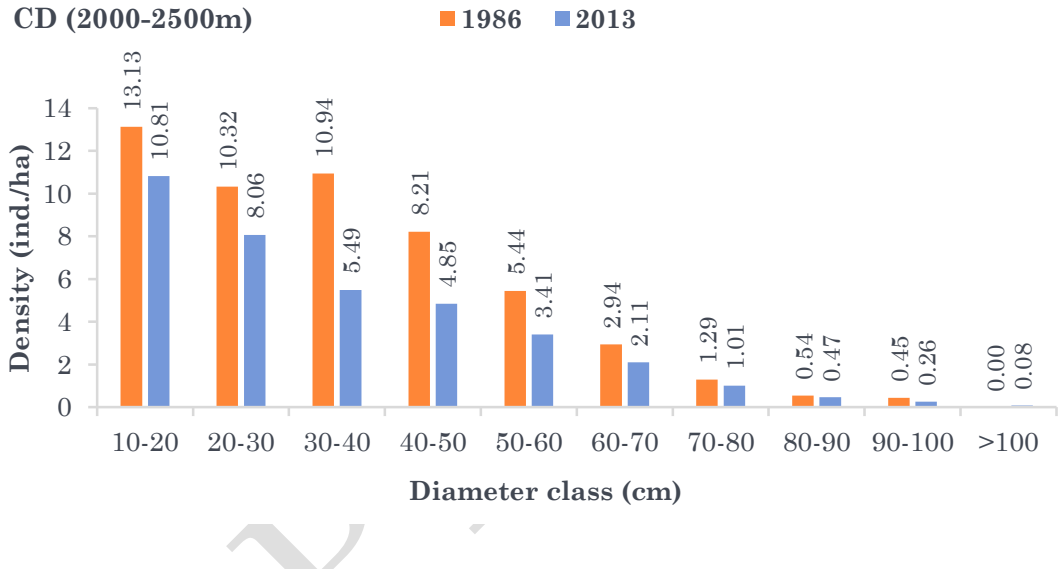
Diameter Class-wise Variations with Altitude Gradient

For the mentioned altitudinal gradients i.e. 1500-2000m, 2000-2500m, 2500-3000m, data from different forest compartments was analysed for variations in diameter classes of 10-20cm, 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, 90-100cm, >100cm for each of the identified species in Seraj Forest Division.

Cedrus deodara

Density of *Cedrus deodara* while increased at higher altitudes, it experienced a decline at 1500-2500m altitude ranges, as seen in the previous section. At 1500-2000m, despite the overall reduction in tree density, concentration within 10-20cm, 80-90cm, and over 100cm diameter classesincreased from 11.20 Ind/ha to 17.75 Ind/ha, 0.70 Ind/ha to 0.75 Ind/ha, and 0 Ind/ha to 0.20 Ind/ha respectively. At higher altitudes (2500-3000m) as well, density of *Cedrus deodara* increased across a majority of diameter classes i.e. 10-20cm, 20-30cm, 40-50cm to 80-90cm, and over 100cm. However, maximum increase (65 per cent) was within the diameter class 10-20cm. The increase in density of younger trees of *Cedrus deodara* signifies ongoing regeneration of species at lower as well as higher altitudes; while those of mature trees points towards existence of suitable conditions for sustainable growth. However, at lower to mid-altitudes, concentration of mature trees was found to be on a consistent decline contributing to the overall decline in density of *Cedrus deodara* in Seraj Forest Division.





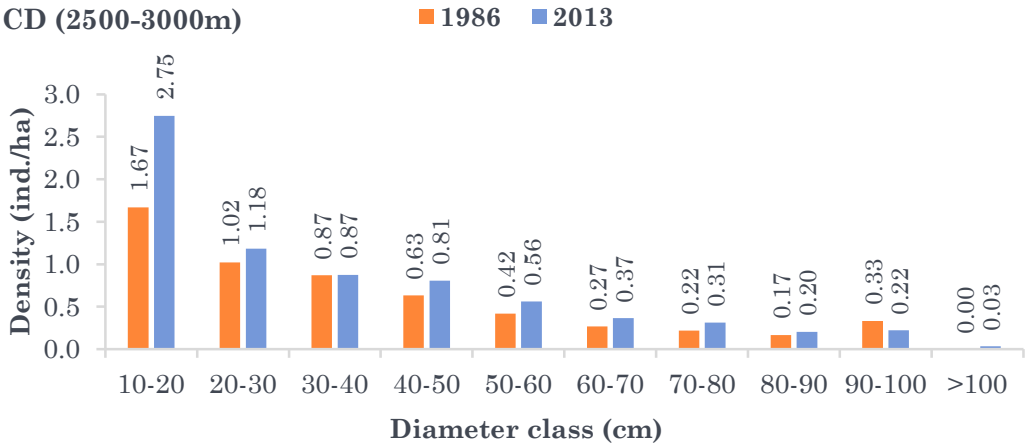


Figure 42: Density Variations in *Cedrus deodara*community at Different Diameter Classes, Seraj Forest Division, 1986-2013

Source: HPSCCC, 2018

Pinus wallichiana

Density of *Pinus wallichiana*too exhibited a significant decline at the lower altitude range 1500-2500m, while at higher altitude, its density increased. In Seraj Forest Division, the species witnessed an overall decline of around 58 per cent in its dominant community. At 1500-2000m, this decline was largely driven by decline in density within diameter classes 20-30cm to 90-100cm. At 2000-2500m altitude, tree density declined across all diameter classes except for over 100cm, with significant decline registered within diameter classes 10-20cm (60 per cent), 60-70cm (56 per cent), 80-90cm (56 per cent), and 90-100cm (67 per cent). Thus, indicating towards a loss of both younger and mature trees at this altitude range. At higher altitude range of 2500m and above, around 18 per cent surge in tree density in its dominant community was observed. With reference to diameter classes, positive changes were seen at extreme ends of spectrum i.e. for 10-20cm (38 per cent), 20-30cm (40 per cent), and 80-90cm (18 per cent), 90-100cm (56 per cent), >100cm (138 per cent). This trend indicates towards both regeneration of younger trees and growth of mature trees at higher altitudes for *Pinus wallichiana* in the Seraj Forest Division.

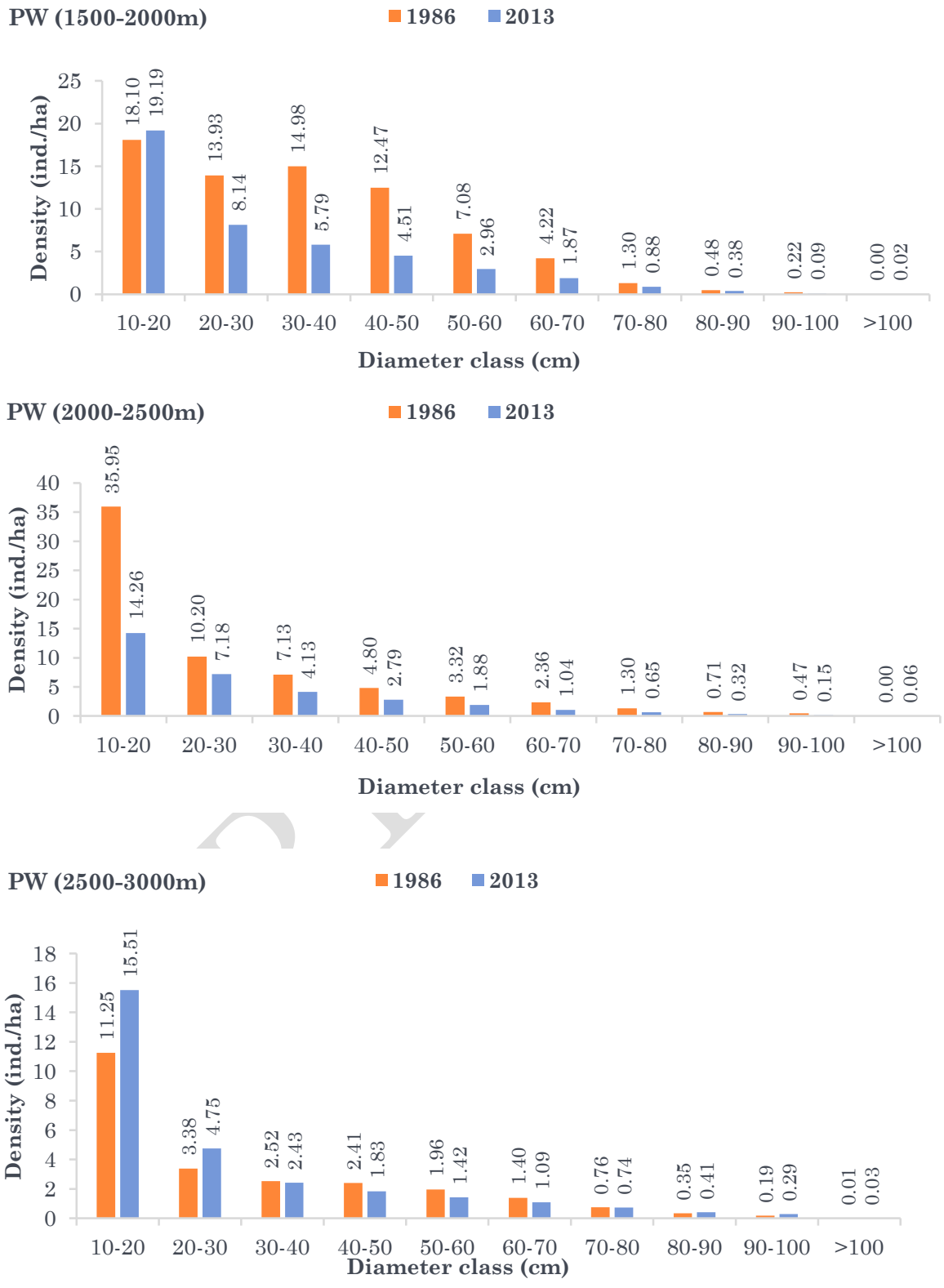
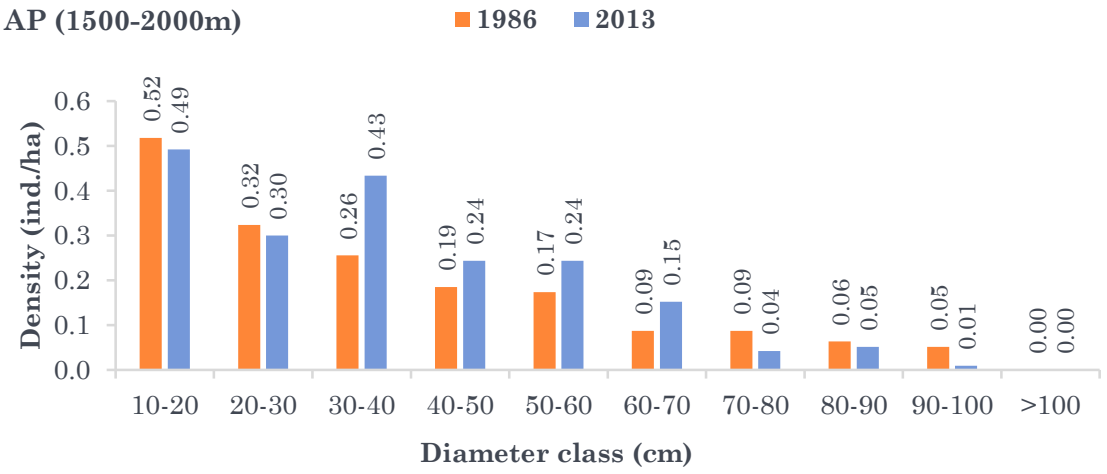


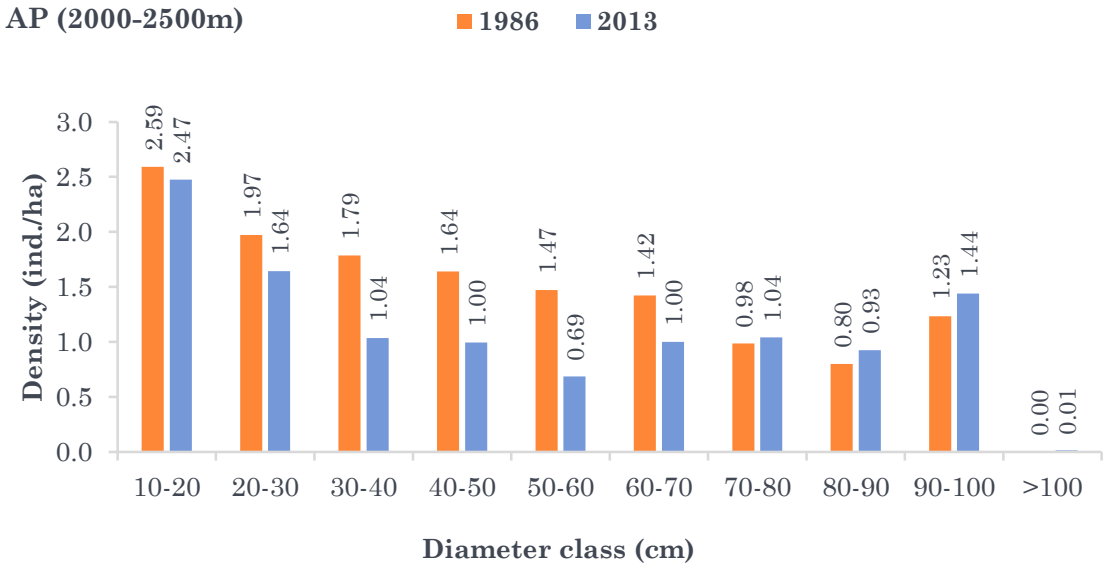
Figure 43: Density Variations in *Pinus wallichiana*community at Different Diameter Classes, Seraj Forest Division, 1986-2013

Source: HPSCCC, 2018

Abies pindrow

Abies pindrow communityis found at an altitude range of 2000-3300m and in the Seraj Forest Division its overall density increased by 28 per cent in its dominant community. At lower altitude of 1500-2000m, predominant increase was seen specifically for trees within diameter classes of 30-40cm, 40-50cm, 50-60cm, and 60-70cm. Meanwhile, at 2000-2500m altitude, individuals per hectare declined by almost 19 per cent between 1986 and 2013, which was largely driven by reduction in trees within diameter classes 10-20cm to 60-70cm. Only the density of matured trees with diameters 80cm and above had increased. At 2500cm and above, a decline in density was seen for trees within diameter classes 10-20cm to 30-40cm, and 50-60cm; rest all diameter classes registered an increase, with maximum increase seen for mature trees with diameters 80 cm and above. In the Seraj Forest Division, the density of younger trees appears to be on a decline while those of mature trees had been gradually rising.





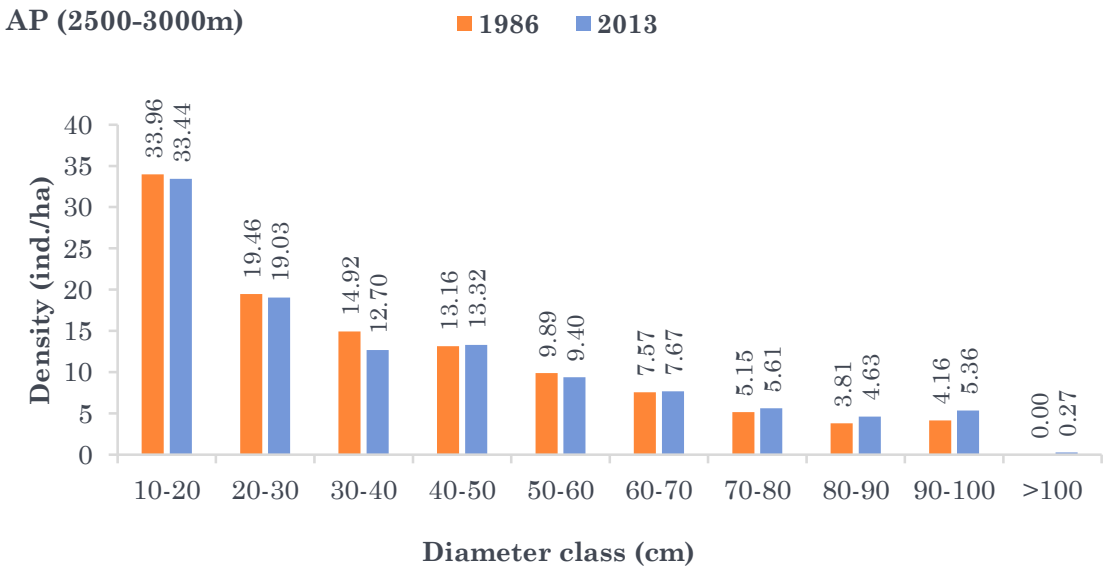
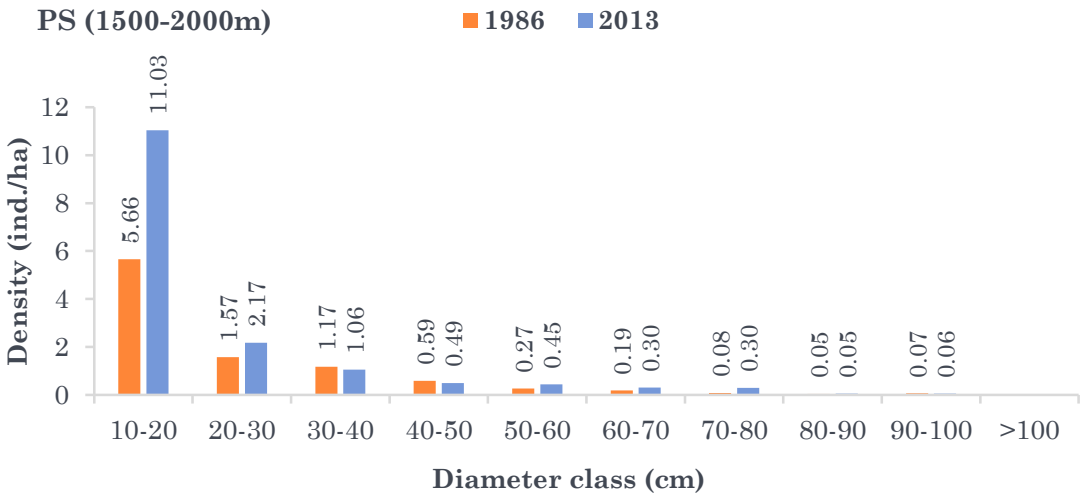


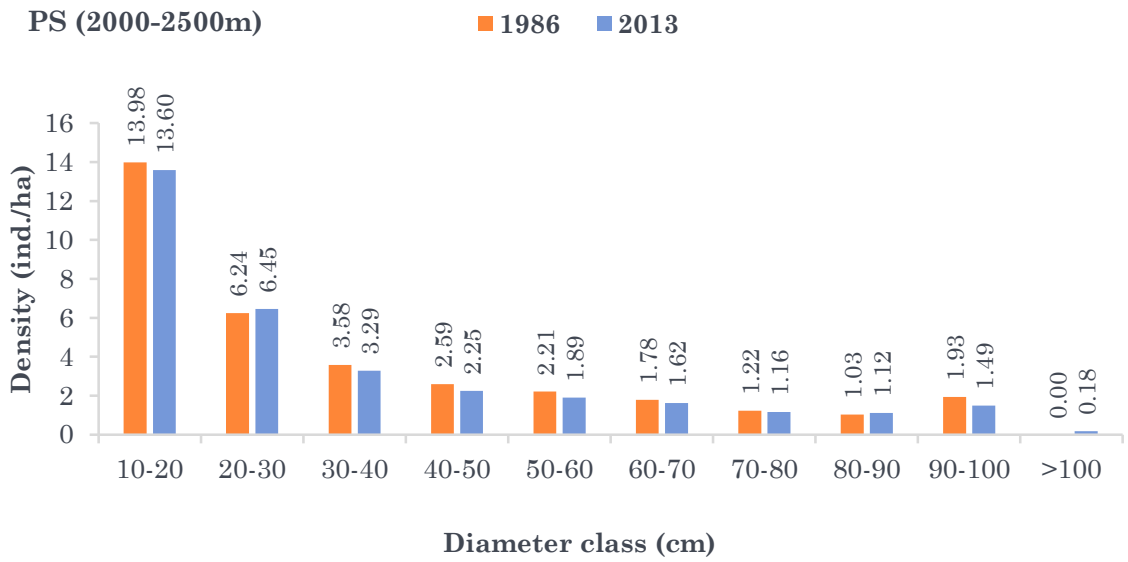
Figure 44: Density Variations in *Abies pindrow*community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Picea smithiana

Picea smithiana communitythrives at 2000-3600m and in this forest division its overall density increased backed by surge in tree density at 1500-2000m, and 2500-3000m altitudes. At both altitude ranges, significant increase was seen within diameter classes 10-20cm, i.e. 95

per cent at 1500-2000m, and 20 per cent at 2500-3000m. Thus, indicating toward regeneration at lower and higher altitudes between 1986 and 2013. Further, at higher altitudes, tree density within diameter classes 60-70cm to 80-90cm also increased, as exhibited in figure 47. Meanwhile, at mid altitude range, consistent decline was registered in all diameter classes except for 20-30cm, 80-90cm, and over 100cm.





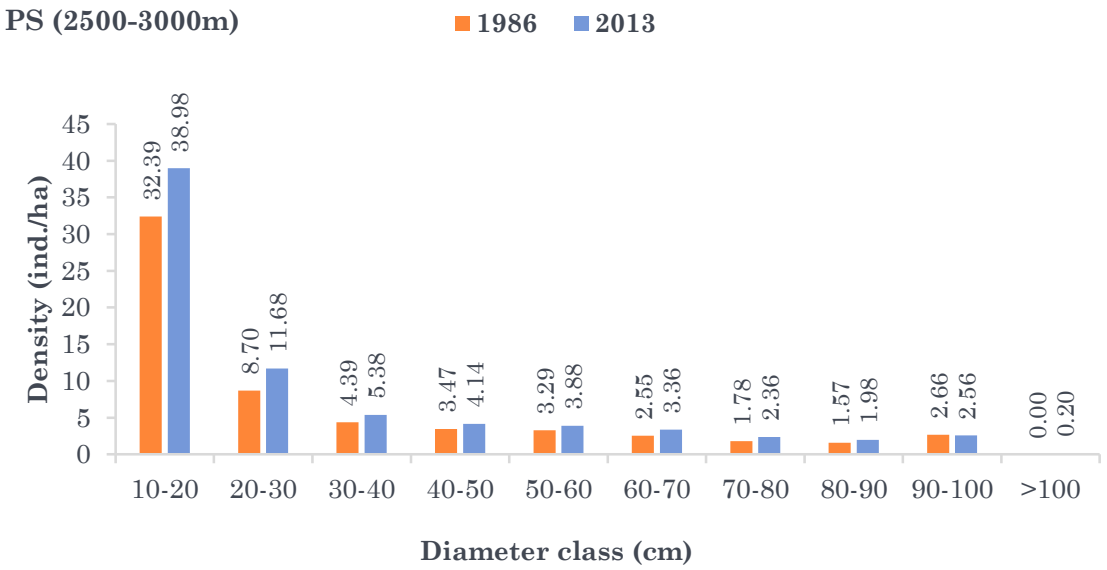


Figure 45: Density Variations in *Picea smithiana*community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Pinus roxburghii

Pinus roxburghii grows at 1000-2000m and in Seraj Forest Division its density was observed to decline by 65 per cent between 1986 and 2013 at 1500-2000m altitude range. Significant decline of 64 per cent, 65 per cent, 59 per cent, and 57 per cent was recorded for diameter classes 10-20cm, 20-30cm, 30-40cm, and 40-50cm, respectively. Meanwhile, sharp increase was seen for density of mature trees within diameter classes 60-70cm, 70-80cm, and 80-90cm, as illustrated in Figure 48.

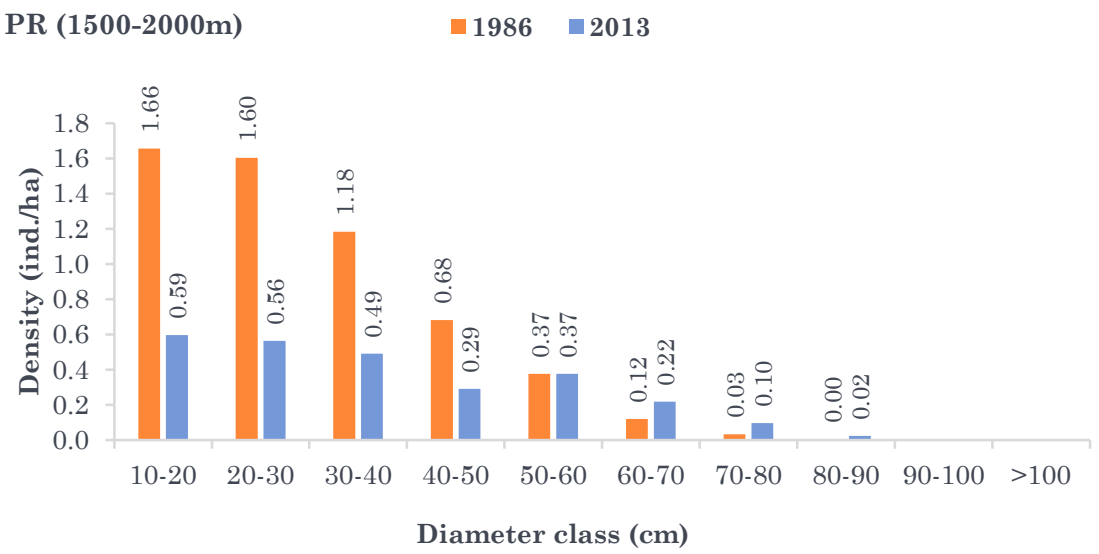


Figure 46: Density Variations in *Pinusroxburghii* community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Quercus leucotrichophora

Quercus leucotrichophora thrives at 1800-2250m altitude range, and in our study area its density took a nose dive from 327.8 Ind/ha in 1986 to only 90 Ind/ha in 2013. At both 1500-2000m and 2000-2500m,a steep decline was recorded across all diameter classes except for those greater than 100 cm. On average three-quarters of density had vanished across the said diameter classes at 1500-2500m altitude for *Quercus leucotrichophora* in the Seraj Forest Division between 1986 and 2013.

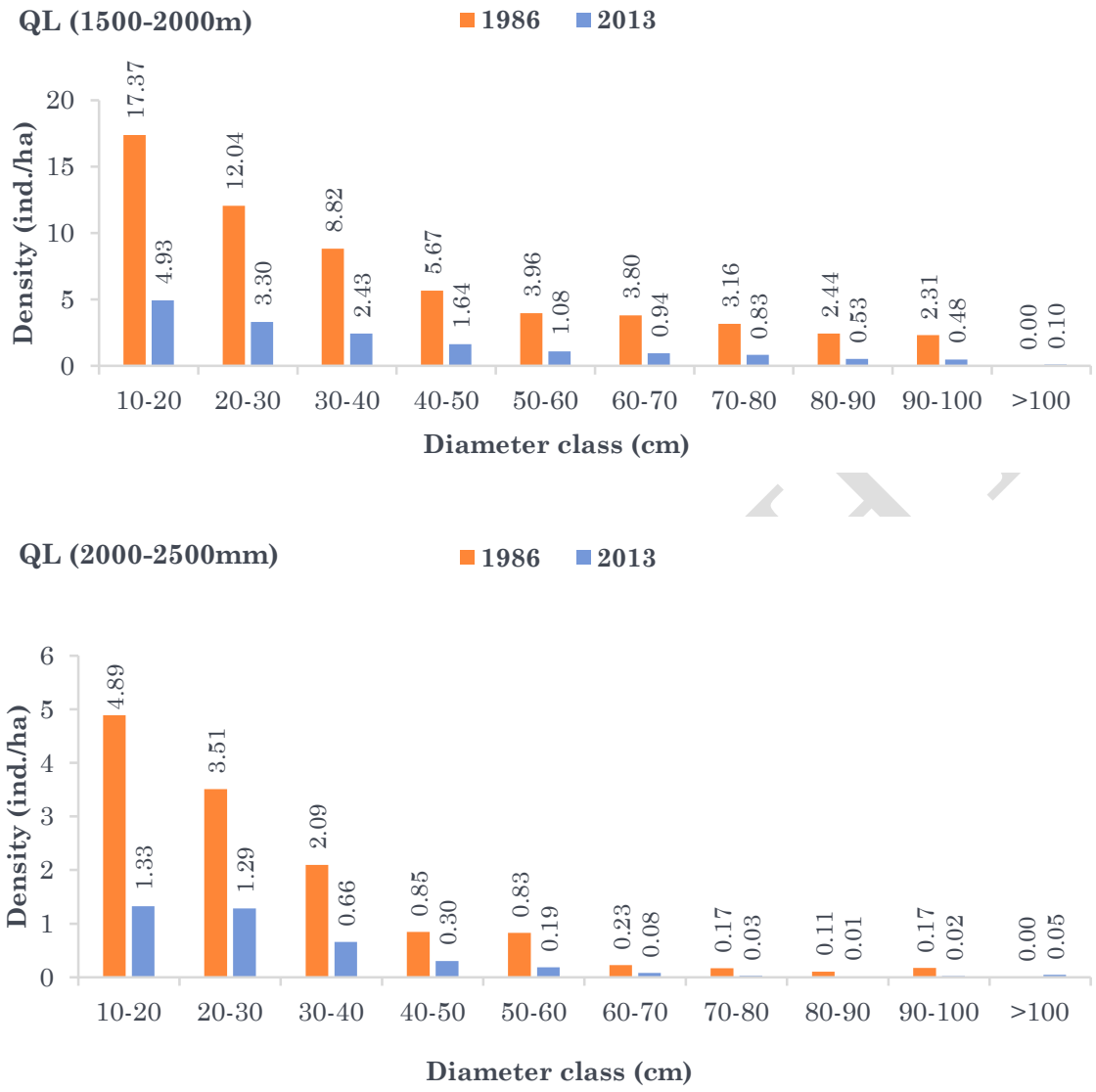
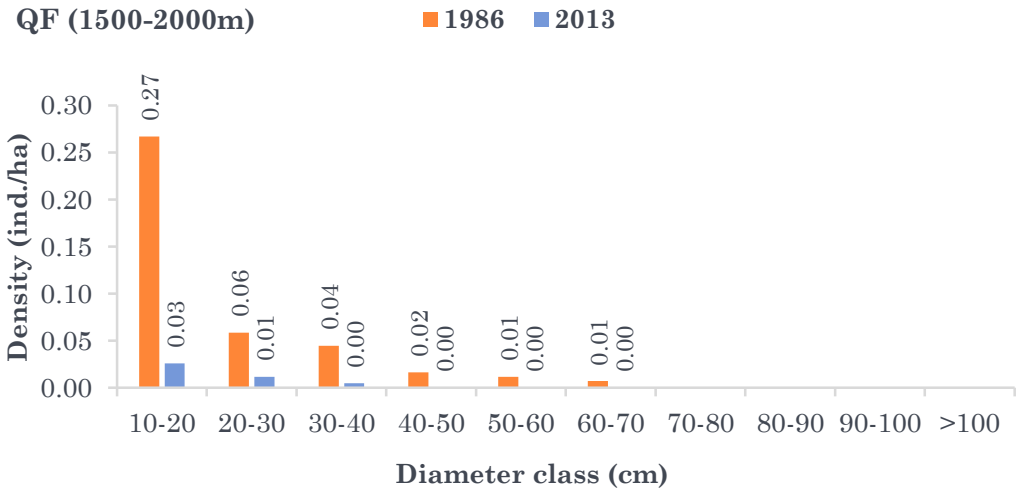


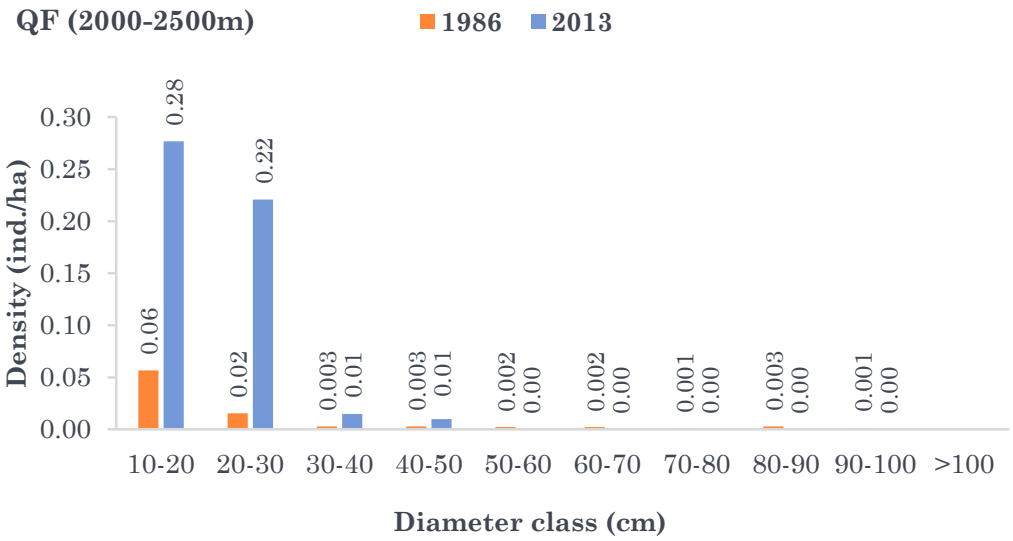
Figure 47: Density Variations in *Quercus leucotrichophora* community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Quercus floribunda and *Taxus baccata*

*Quercus floribunda*and *Taxus baccata* thrive at 2000-2500m and 2100-3200m altitudes respectively, and in the Seraj Forest Division for the former, density of trees within diameter class 10-20cm recorded a sharp decrease of 89 per cent at 1500-2000m; while it surged by steep 367 per cent at 2000-2500m, and 300 per cent at 2500-3000m. Thus,

indicating towards a possible shift in regeneration toward mid and higher altitudes for *Quercus floribunda (*see Figure 50).For *Taxus baccata,* prominent increase in density was seen for trees within in diameter classes 40-50cm to 90-100cm at 2000-2500m and 2500-3000m altitude range, as illustrated in Figure 51.





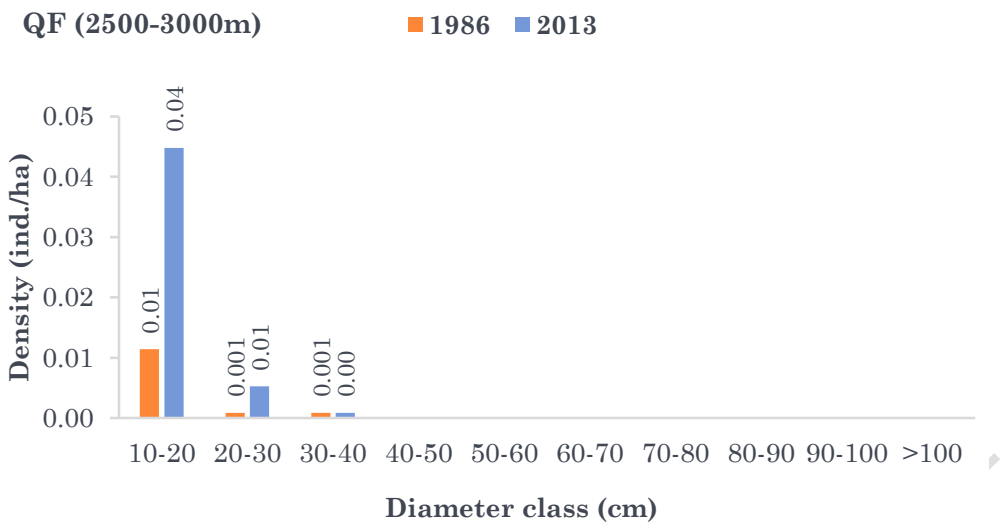
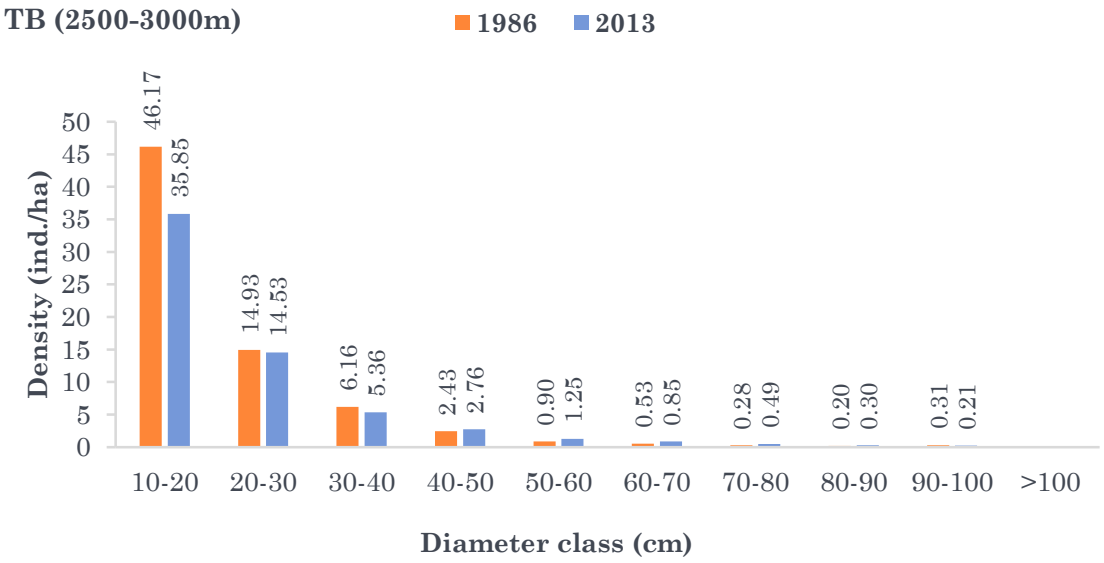


Figure 48: Density Variations in Quercus floribunda community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018



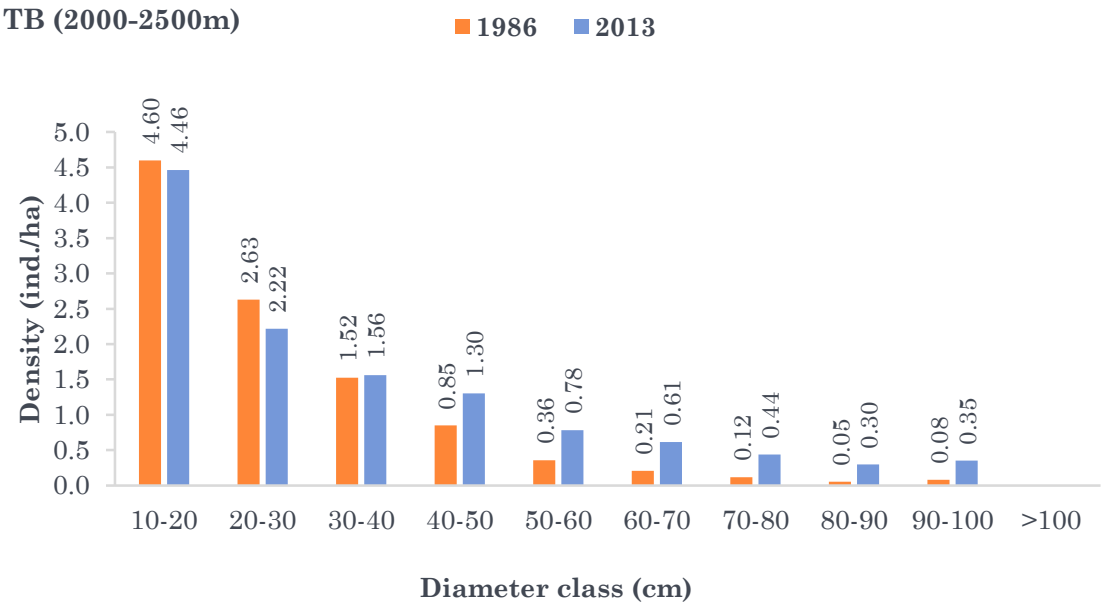


Figure 49: Density Variations in *Taxus baccata*community at Different Diameter Classes, Seraj Forest Division, 1986-2013
Source: HPSCCC, 2018

Parvati Forest Division

For Parvati Forest Division, enumerated information in the Working Plans from the Himachal Pradesh Forest Department and Compartment History files from 4 forest ranges (Hurla, Jari, Parvati, Kasol) was taken for 1948 and 1996. As per the assessment, 6 pure tree communities i.e. where for a single species the relative density was more than 50 per cent, which are - *Cedrus deodara (CD), Pinus wallichiana (PW),Abies pindrow (AP), Picea smithiana (PS), Pinus roxburghii (PR),* andBroad-leaved,and 7 mixed tree communities –*Abies pindrow-Picea smithiana, Picea smithiana-Cedrus deodara, Picea smithiana-Pinus wallichiana, Pinus wallichiana-Cedrus deodara,* Broad-leaved-*Picea smithiana, Pinus wallichiana-Pinus roxburghii,* and *Cedrus deodara-Picea smithiana* were identified.

As highlighted in**Error! Reference source not found.**earlier these tree communities were assessed from 72 forest compartments spread over a total area of 4343.66 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 20 forest compartments covering an area of 833.87 ha, at altitude range of 1400-2773m above mean sea level. As illustrated in Figure 52, in its dominant tree community, density of *Cedrus deodara*increased from 89.7 Ind/ha to 92.7 Ind/ha. In these forest compartments, representation (density) of other species is as follows – density of *Pinus wallichiana* declined from 33Ind/ha in 1948 to 12Ind/ha in 1996, density of *Picea smithiana,*Broad-leaved,

and *Abies pindrow* also declined from 7Ind/ha to 2.7Ind/ha, 9Ind/ha to 6.6Ind/ha, and 2.2Ind/ha to 2.0Ind/ha, respectively. Only the tree density of *Pinus roxburghii* increased from 1.3 Ind/ha to 4.0 Ind/ha between 1948 and 1996.

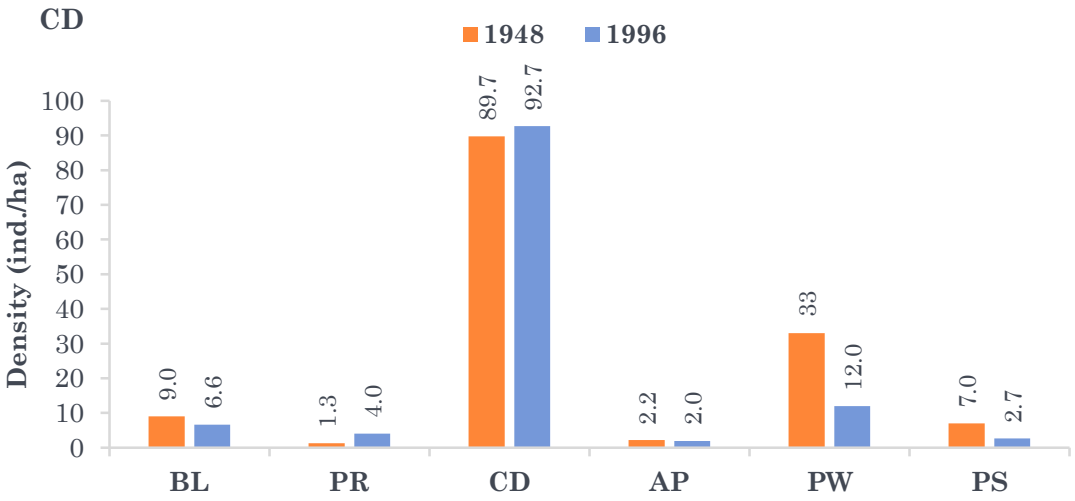


Figure 50: Density Variations in Species Composition in *Cedrus deodara* community, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies pindrow;* **PR=** *Pinus roxburghii*
Source: HPSCCC, 2018

2. *Pinus wallichiana* community

Data was collected from 21 forest compartments covering an area of 1335.14 ha, at altitude range of 1280-3440m above mean sea level. As illustrated in Figure 53, in its dominant tree community, density of *Pinus wallichiana*declined significantly from 62.7Ind/ha to 43.3Ind/ha between 1948 and 1996. In these forest compartments, representation (density) of other species is as follows – tree density of Broad-leaved plummeted from 6.2 Ind/ha in 1948 to only 0.3Ind/ha in 1996; density of *Abies pindrow* and *Picea smithiana* too declined from 21.1 Ind/ha to 7.2 Ind/ha, and 11.2 Ind/ha to 7.1 Ind/ha, respectively. Meanwhile, tree density of *Pinus roxburghii*

and *Cedrus deodara* increased from 0.2 Ind/ha to 1.3 Ind/ha, and 3.3 Ind/ha to 6.6 Ind/ha, respectively from 1948 to 1996.

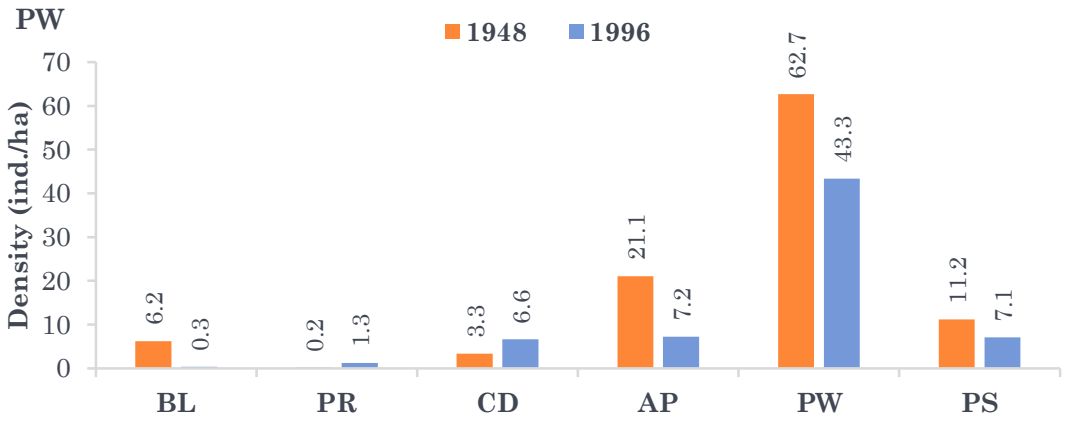


Figure 51: Density Variations in Species Composition in *Pinus wallichiana* community, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **BL**= Broad-leaved; **AP=** *Abies Pindrow;* **PR=** *Pinus roxburghii*
Source: HPSCCC, 2018

3. *Picea smithiana* community

Data was collected from 3 forest compartments covering an area of 214.28 ha, at altitude range of 1905-3017m above mean sea level. As illustrated in Figure 54, in its dominant tree community, density of*Picea smithiana*increased from 25.9 Ind/ha in 1948 to 49.4 Ind/ha in 1996. In these forest compartments, representation (density) of other species is as follows – tree density of Broad-leaved plummeted from 37.5 Ind/ha in 1948 to only 12.4 in 1996; density of *Pinus wallichiana* too declined from 8.2 Ind/ha to 3.7 Ind/ha. Meanwhile, density of *Cedrus deodara* and *Abies pindrow* increased from 15.5 Ind/ha to 18.3 Ind/ha, and 10.7 Ind/ha to 11.1 Ind/ha, respectively between 1948 and 1996.

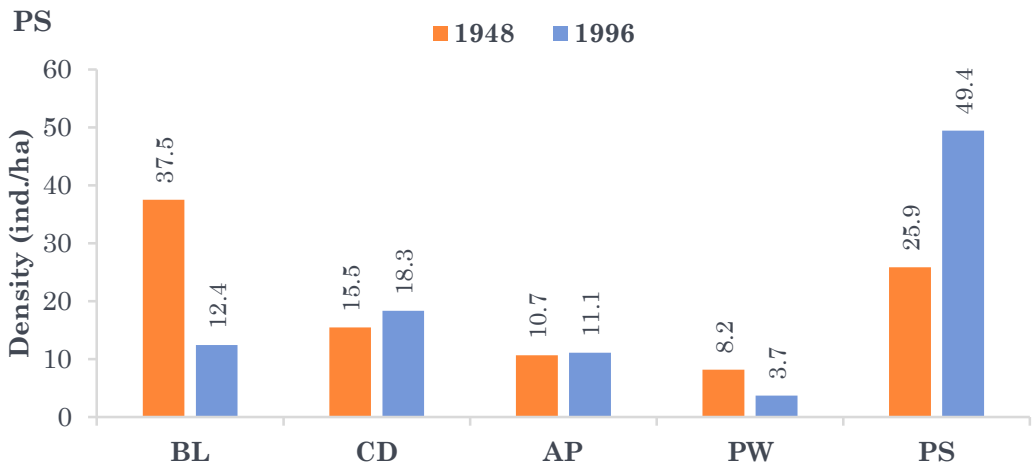


Figure 52: Density Variations in Species Composition in *Picea smithiana* community, Parvati Forest Division, 1948-1996

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

Source: HPSCCC, 2018

4. *Abies pindrow* community

Data was collected from 12 forest compartments covering an area of 945.12ha, at altitude range of 1611-3450m above mean sea level. As illustrated in Figure 55, in its dominant tree community, density of*Abies pindrow*declined from 27 Ind/ha to 15.9 Ind/ha between 1948 and 1996. In these forest compartments representations (density) of other species are as follows – all species recorded a decline in tree density. Density of *Cedrus deodara* decreased from 0.7 Ind/ha to 0.5 Ind/ha; tree density of *Pinus wallichiana* plummeted from 3 Ind/ha to 1.9 Ind/ha; and density of *Picea smithiana* decreased to 7.1 Ind/ha.

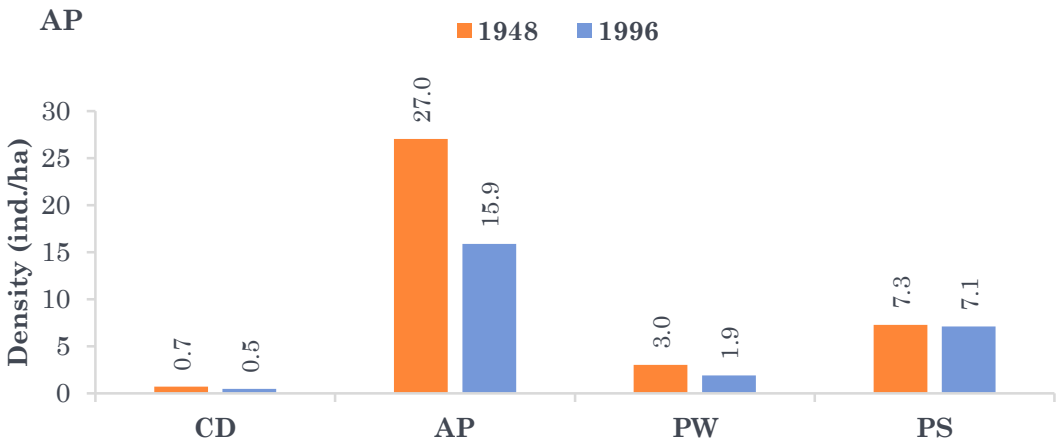


Figure 53:Density Variations in Species Composition in *Abies pindrow* community, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*, **AP=** *Abies pindrow;*
Source: HPSCCC, 2018

5. *Pinus roxburghii* community

Data was collected from 1 forest compartment covering an area of 12.95ha, at altitude range of 1768-2152m above mean sea level. As illustrated in Figure 56, in its dominant tree community, density of *Pinus roxburghii*declined from 60.2Ind/ha to 86.6Ind/ha between 1948 and 1996. In this forest compartment, representation (density) of other species is as follows – tree density of *Cedrus deodara* declined from 1.8 Ind/ha to 1.6 ind./h, and that of *Pinus wallichiana* also decreased from 8.3 Ind/ha to 5.6 Ind/ha between 1948 and 1996.

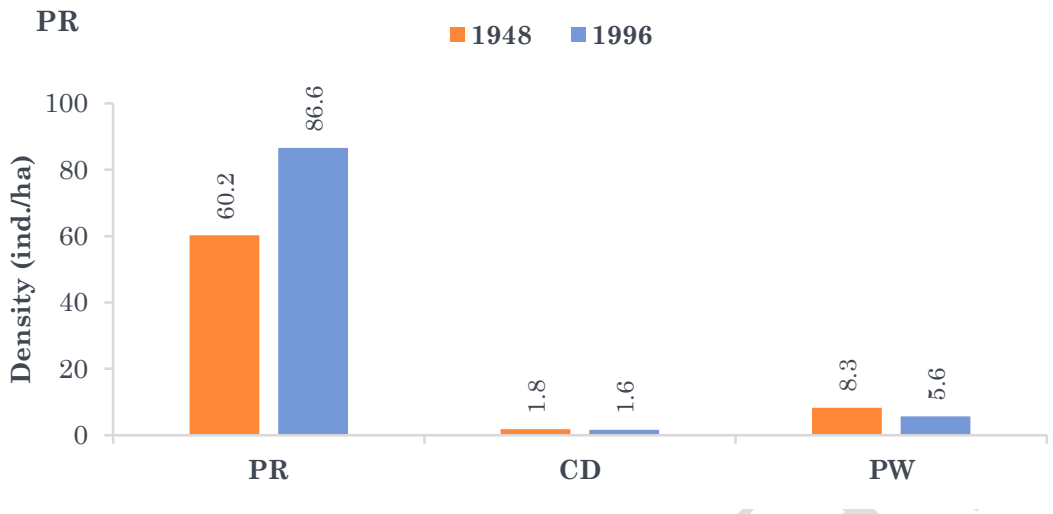


Figure 54: Density Variations in Species Composition in *Pinus roxburghii* community, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PR=** *Pinus roxburghii*
Source: HPSCCC, 2018

6. Broad-leaved community

Data was collected from 4 forest compartments covering an area of 275.58ha, at altitude range of 1430-3000m above mean sea level. As illustrated in Figure 57, in its dominant tree community, density of Broad-leavedincreased from 83 Ind/ha to 100.6 Ind/ha between 1948 and 1996. In these forest compartment, representation (density) of other species is as follows – tree density of *Cedrus deodara* declined from 1.8Ind/ha to 1.3Ind/ha; while for *Abies pindrow*, *Picea smithiana, Pinus roxburghii,*and *Pinus wallichiana* increased from 3.9 Ind/ha, 14 Ind/ha, 0.01 Ind/ha, and 5.9 Ind/ha to 8.9 Ind/ha, 17.4 Ind/ha, 0.1 Ind/ha, and 7.2 Ind/ha, respectively between 1948 and 1996.

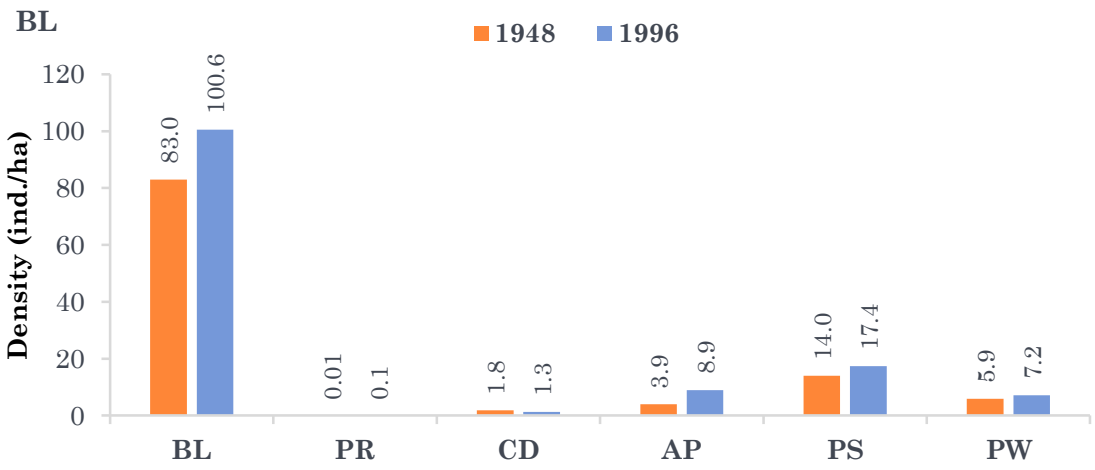


Figure 55: Density Variations in Species Composition in Broad-leavedcommunity, Parvati Forest Division, 1948-1996

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

Source: HPSCCC, 2018

7. *Abies pindrow-Picea smithiana*community

Data was collected from 2 forest compartments covering an area of 153.75ha, at altitude range of 2012-2470m above mean sea level, for*Abies pindrow-Picea smithiana*mixed community. The tree density of *Abies pindrow* plummeted from 38Ind/ha in year 1948 to 18.7Ind/ha in year 1996; and for *Picea smithiana* too,the density decreased from 21.1 Ind/ha to 15.9Ind/ha. In this mixed community, density of*Cedrus deodara* increased, while for *Pinus wallichiana* a decline was witnessed between 1948 and 1996, as illustrated in Figure 58.

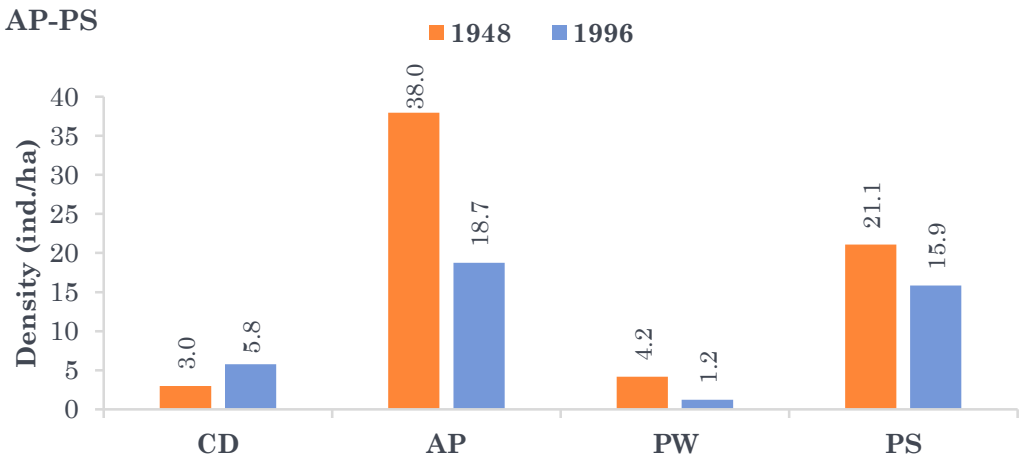


Figure 56: Density Variations in Species Composition in *Abies pindrow-Picea smithiana* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

8. *Picea smithiana-Cedrus deodara* community

Data was collected from2 forest compartments covering an area of 143.48ha, at altitude range of 2130-2811m above mean sea level, for *Picea smithiana-Cedrus deodara*mixed community. The tree density of *Picea smithiana* declined from 36.5 Ind/ha in year 1948 to 33.3Ind/ha in year 1996; and for *Cedrus deodara,* the density increased from 12.5Ind/ha to 26.6Ind/ha. In this mixed community, density of *Pinuswallichiana*registered a noticeable increase from 4.5 Ind/ha to 20.8 Ind/ha; and that of *Abies pindrow* declined from 15.9 Ind/ha to 9.4 Ind/habetween 1948 and 1996, as illustrated in Figure 59.

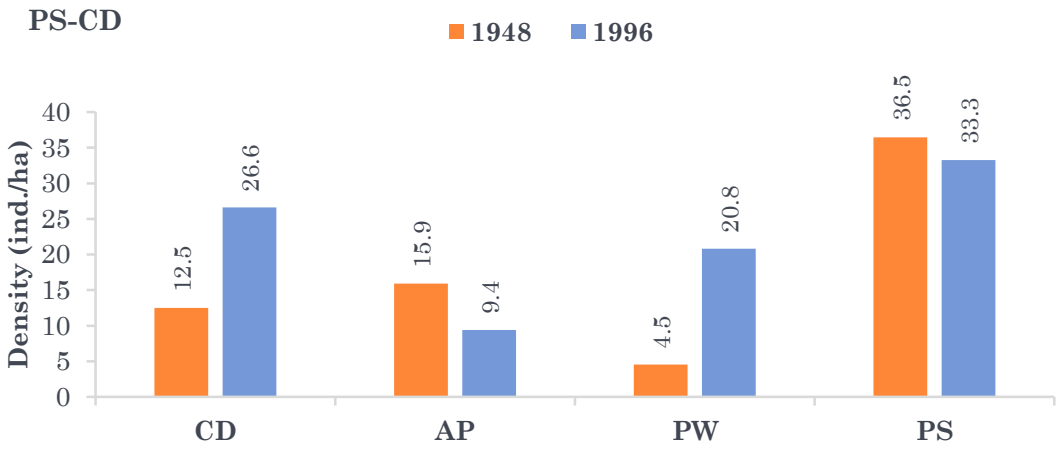


Figure 57: Density Variations in Species Composition in *Picea-smithiana- Cedrus deodara* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

9. *Picea smithiana-Pinus wallichiana* community

Data was collected from 1 forest compartment covering an area of 29.5 ha, at altitude range of 2133-2575m above mean sea level, for *Picea smithiana-Pinus wallichiana* mixed community. The tree density of *Picea smithiana* increased from 104.8 Ind/ha in year 1948 to 112.2 Ind/ha in year 1996; and for *Pinus wallichiana,* the density plummeted from 160.6 Ind/ha to 102.3 Ind/ha. In this mixed community, density of *Cedrus deodara* registered a noticeable increase from just 1 Ind/ha to 66.1 Ind/ha; and that of *Abies pindrow* increased from 11 Ind/ha to 24.8 Ind/habetween 1948 and 1996, as illustrated in Figure 60.

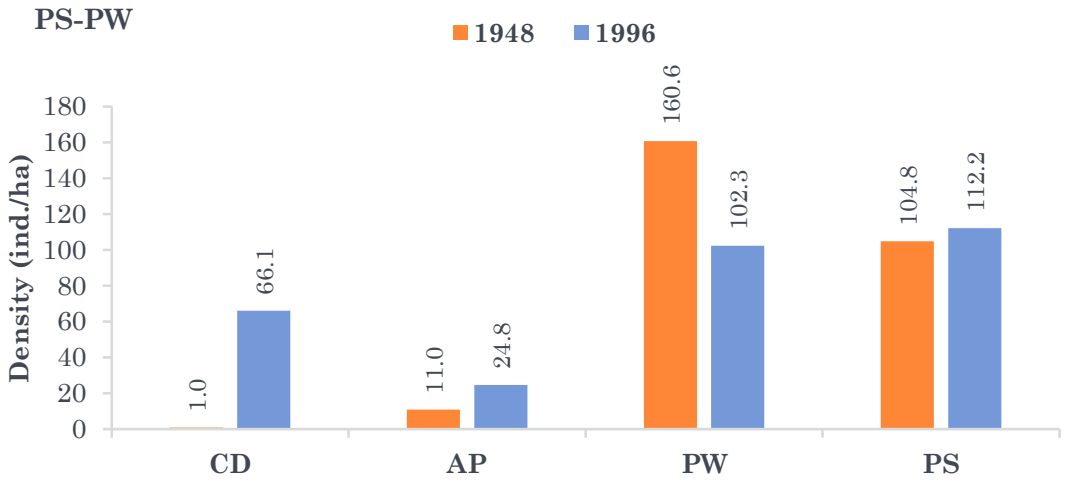


Figure 58: Density Variations in Species Composition in *Picea-smithiana- Pinus wallichiana* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

10.*Pinus wallichiana-Cedrus deodara* community

Data was collected from 2 forest compartments covering an area of 103.19 ha, at altitude range of 1920-2670m above mean sea level, for *Pinus wallichiana-Cedrus deodara* mixed community. The tree density of *Picea wallichiana* remained static at 41.1 Ind/ha between 1948 and 1996; and for *Cedrus deodara,* the density jumped from 18.3 Ind/ha to 33.2 Ind/ha. In this mixed community, density of *Abies pindrow* registered a considerable increase from just 0.9 Ind/ha to 7.4 Ind/ha; and that of *Picea smithiana*increased from 16.3Ind/ha to 26Ind/habetween 1948 and 1996, as illustrated in Figure 61.

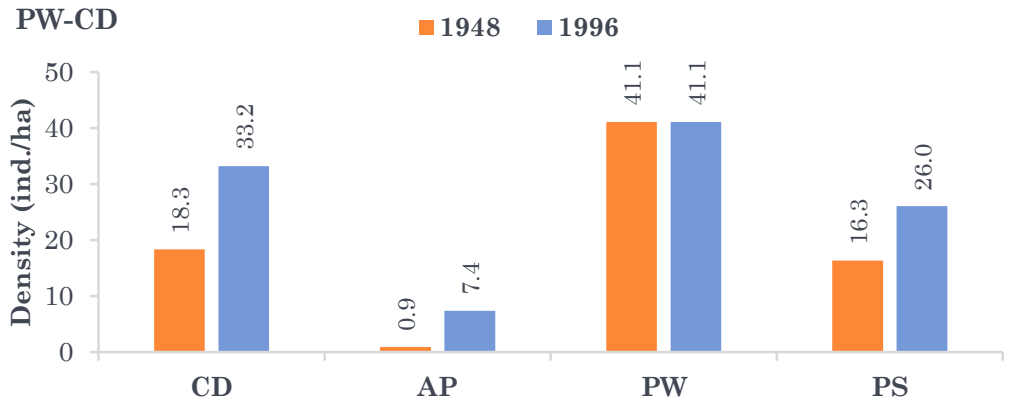


Figure 59: Density Variations in Species Composition in *Pinus wallichiana- Cedrus deodara* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

11. Broad-leaved-*Picea smithiana* community

Data was collected from 1 forest compartment covering an area of 112.09 ha, at altitude range of 1930-3000m above mean sea level, forBroad-leaved-*Picea smithiana*mixed community. The tree density of Broad-leaved declined from 52.5 Ind/ha in 1948 to 41.2 Ind/ha in 1996; and for *Picea smithiana*, the density increased from 26.4 Ind/ha to 27.8 Ind/ha. In this mixed community, density of *Abies pindrow* declined; while that of *Pinus wallichiana* recorded a sharp increase between 1948 and 1996, as illustrated in Figure 62.

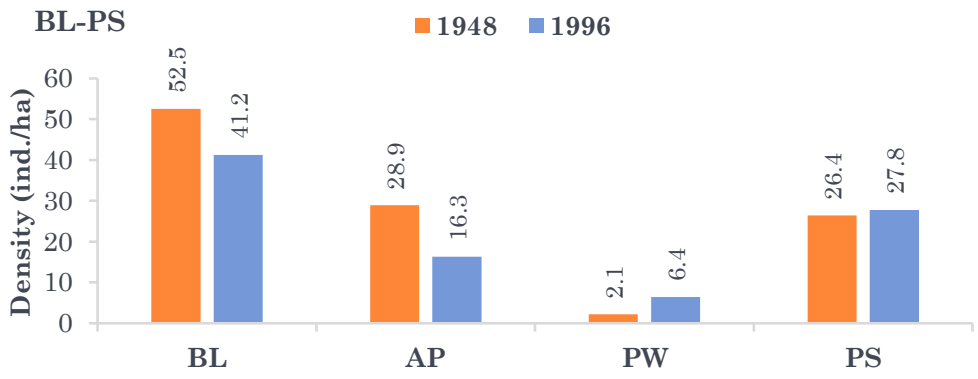


Figure 60: Density Variations in Species Composition in Broad-leaved-*Picea-smithiana* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: BL=Broad-leaved; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

12. *Pinus wallichiana-Pinus roxburghii* Community

Data was collected from 1 forest compartment covering an area of 48.97 ha, at altitude range of 1768-2652m above mean sea level, for *Pinus wallichiana-Pinus roxburghii*mixed community. The tree density of *Pinus wallichiana* surged from 29.6 Ind/ha in 1948 to 41.8 Ind/ha in 1996; and for *Pinus roxburghii* too**,** the density increased from 13.4 Ind/ha to 34.4 Ind/ha. In this mixed community, density ofother species i.e. *Picea smithiana* and *Cedrus deodara* bothincreased between 1948 and 1996, as illustrated in Figure 63.

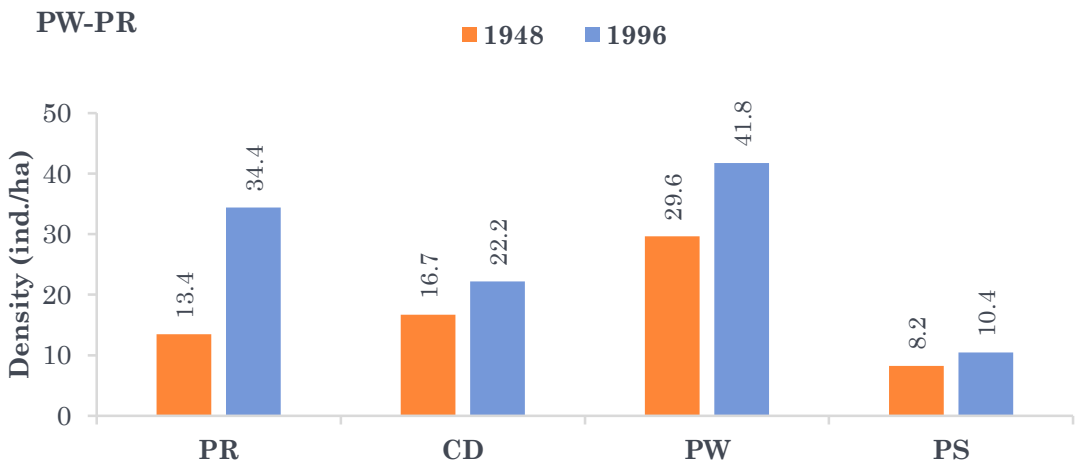


Figure 61: Density Variations in Species Composition in *Pinus wallichiana- Pinus roxburghii* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW=***Pinus wallichiana*, **PS=***Picea smithiana*; **PR=** *Pinus roxburghii*
Source: HPSCCC, 2018

13. *Cedrus deodara-Picea smithiana* community

Data was collected from 2 forest compartments covering an area of 135.74 ha, at altitude range of 2133-2650m above mean sea level, *Cedrus deodara-Picea smithiana*mixed community. The tree density of *Cedrus deodara* significantly increased from 13.2 Ind/ha in 1948 to 49.9 Ind/ha in 1996; and for *Picea smithiana*too**,** the density increased from 27.3 Ind/ha to 41 Ind/ha. In this mixed community, density ofother species i.e. *Abies pindrow* and *Pinus wallichiana* decreased and increased, respectivelybetween 1948 and 1996, as illustrated in Figure 64.

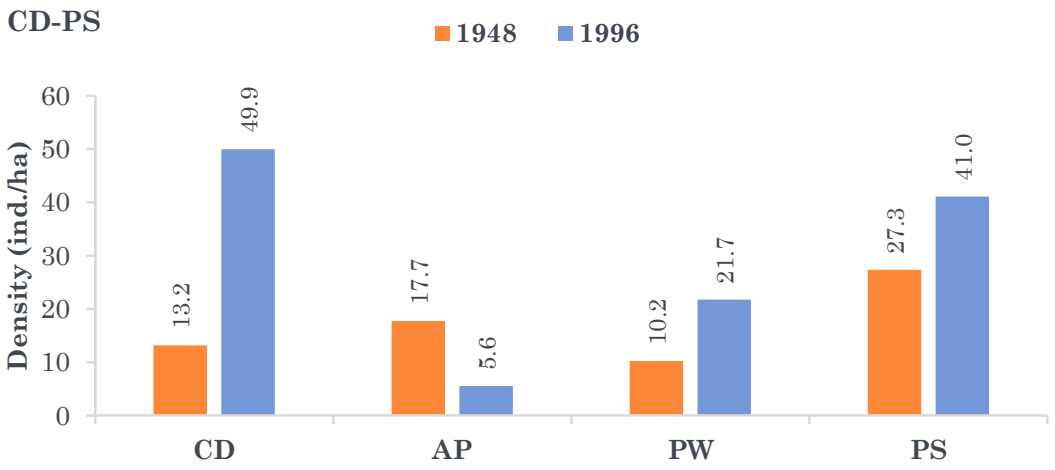


Figure 62: Density Variations in Species Composition in *Cedrus deodara- Picea smithiana* mixedcommunity, Parvati Forest Division, 1948-1996
Abbreviations: CD=*Cedrus deodara*; **PW**=*Pinus wallichiana*, **PS**=*Picea smithiana*; **AP=** *Abies pindrow*
Source: HPSCCC, 2018

Altitude Gradient driven Variations

In this study the forests compartments of Parvati Forest Division were divided in 3 altitudinal ranges i.e. 1500-2000m, 2000-2500m, and 2500and above. The forests in particular altitudinal range were categorized species wise, then their total number were calculated for both of years i.e. 1986 and 2013. The density (individual per hectare) is calculated for all species at respective altitudes, representing individual in one hectare.

7. *1500-2000m*

There are 23 forest compartments at this altitude gradient with a total area of 880.9 ha falling under Hurla, Parvati, Jari, and Kasol forest ranges. At 1500-2000m altitude, varied density trends were witnessed for tree species. While the density of *Cedrus deodara, Pinue roxburghii,* and Broad-leavedincreased from 71.4 Ind/ha to 75.8 Ind/ha, 2.4 Ind/ha to 5.0 Ind/ha, and 28.6 Ind/ha to 28.8 Ind/ha between 1948 and 1996, respectively; those of *Pinus wallichiana* (32 Ind/ha to 19.4 Ind/ha) and *Picea smithiana* (5.7 Ind/ha to 1.8

Ind/ha)drastically declined at 1500-2000m altitude, as exhibited in Figure 65.

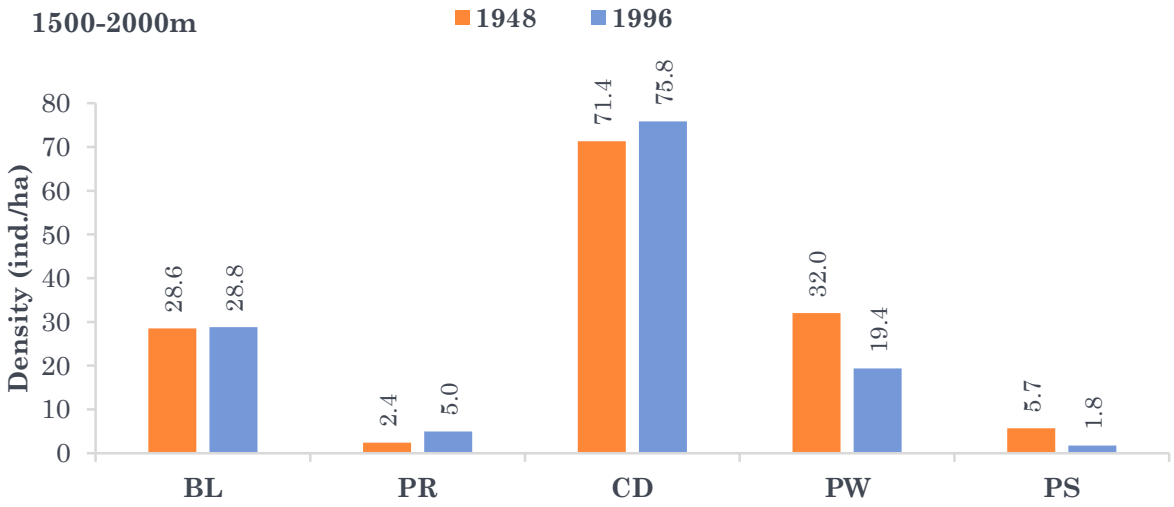


Figure 63: Density Variations in Species Composition at 1500-2000m Altitude, Parvati Forest Division, 1948-1996
Source: HPSCCC, 2018

8. 2000-2500m

There are 25 forest compartments at this altitude gradient with a total area of 1710.5 ha falling under forest ranges of Hurla, Parvati, Jari, and Kasol forest ranges. At 2000-2500m altitude too mixed outcomes for density variations were recorded. While, individuals per hectare of Broad-leaved, *Abies pindrow,* and *Pinus wallichiana* recorded a comprehensive decline of 43 per cent, 30 per cent, and 16 per cent respectively; the density of *Pinus roxburghii, Cedrus deodara,* and *Picea smithiana* registered a sharp increase of 175 per cent, 48 per cent, and 23 per cent, respectively between 1948 and 1996 at 2000-2500m altitude range. See Figure 66.

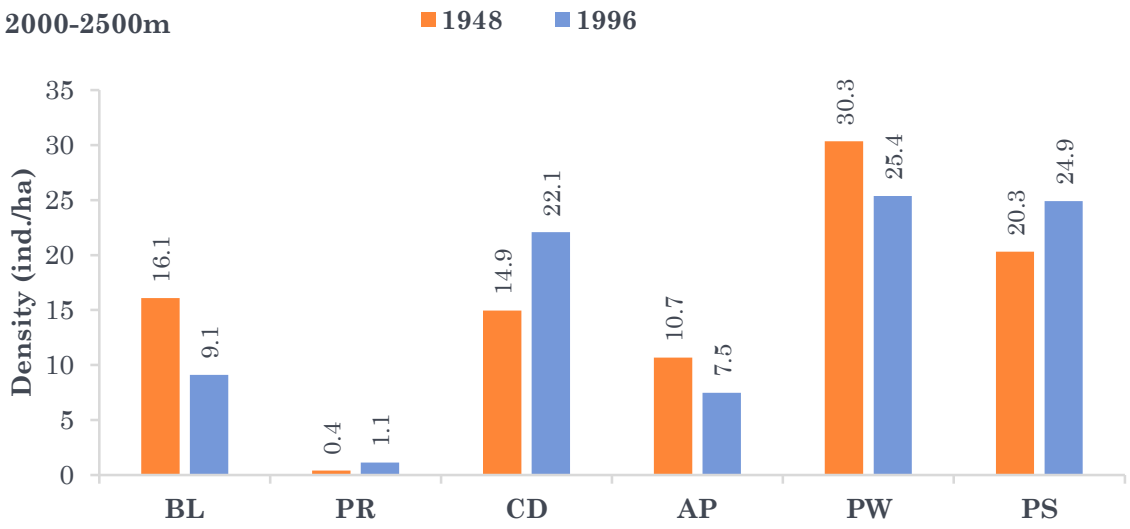


Figure 64: Density Variations in Species Composition at 2000-2500m Altitude, Parvati Forest Division, 1948-1996
Source: HPSCCC, 2018

9. 2500-3000m

There are 19 forest compartments at this altitude gradient with a total area of 1481.93 ha falling under all Hurla, Parvati, Jari, and Kasol forest ranges. At the study's highest altitude range,*Abies pindrow*assumed highest concentration and recorded a declineof 18 per cent in its tree density between 1948 and 1996. Density of *Pinus wallichiana*and *Picea smithiana* too recorded a decline of 31 per cent and 27 per cent respectively. Meanwhile, individuals per hectare for*Cedrus deodara* increased from 1.2 Ind/ha to 2.9 Ind/ha.

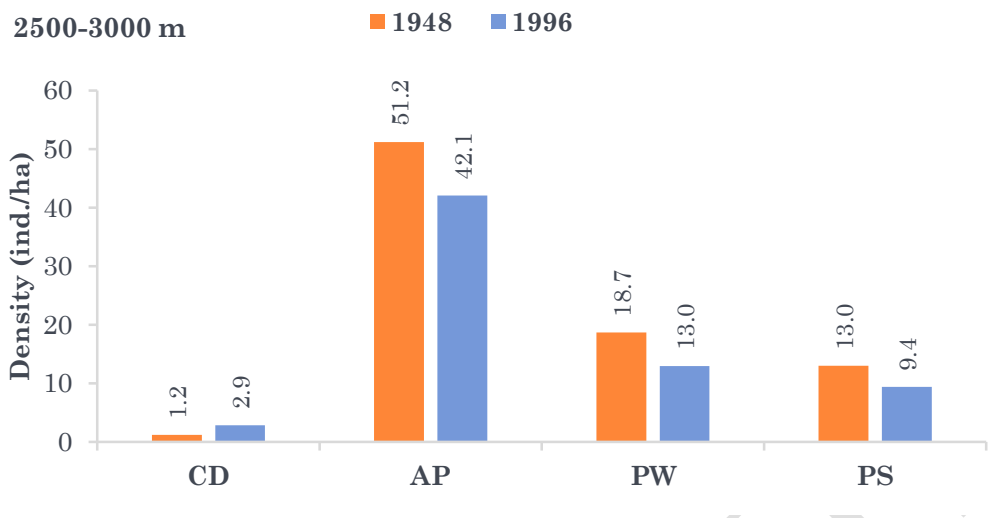


Figure 65: Density Variations in Species Composition at 2500-3000m Altitude, Parvati Forest Division, 1948-1996
Source: HPSCCC, 2018

Table 7 below gives information on suitable altitude ranges for tree species identified in the three forest divisions under Kullu Forest Circle juxtaposed with observation made for the Parvati Forest Division.

Table 4: Suitable Altitude Range for Different Tree Species in Parvati Forest Division

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

Note:
Increased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1948 and 1996.
Decreased signifies the increase in tree density (individuals/ha) for a given species at a particular altitude between 1948 and 1996.
Not observed signifies the cases where a given species was not found at a particular altitude between 1948 and 1996.

Key Observations

Cedrus deodara thrives at 1800-3000m altitude range, and in the Parvati Forest Division, its density was observed to increase across all

altitude ranges. Specifically, at 2500-3000m altitude range where its density increased by 133 per cent between 1948 and 1996.

*Pinus wallichiana*is found between 1800m and 3000m altitude above sea level, and in Parvati Forest Division, its density declined at all altitude ranges, exhibiting a sharp fall of 41 per cent, 16 per cent, and 31 per cent at 1500-2000m, 2000-2500m, and 2500-3000m, respectively.

*Abies pindrow*grows at 2000-3300m altitude, and in this forest division, the species registered decline of 30per cent at 2000-2500m; and 18 per cent decrease at 2500-3000m between 1948 and 1996. The species was not found at lower altitude of 1500-2000m.

*Picea smithiana*thrives at 2100-3600maltitude, and in the Parvati Forest Division, its density plummeted at 1500-2000m and 2500-3000m with respective declines of 69 per cent and 27 per cent between 1948 and 1996. At the mid altitudinal range, the density increased by 23 per cent.

Pinus roxburghii grows at 1000-2000m altitude range, and in the Parvati Forest Division, its density registered over 100 per cent increase at 1500-2000m(111 per cent) and 2000-2500m (175 per cent) altitude range between 1948 and 1996.

Broad-leaved species in temperate forests thrive at 2000-3000m altitude range, and in Parvati Forest Division its density showed nominal 1 per cent increase at 1500-2000m, and a sharp 43 per cent decline at 2000-2500m altitudes between 1948 and 1996. The species was not found at higher altitudes in this forest division.

The Working Plans and Compartment files did not provide information on diameter class based enumeration for the study time period.

Therefore, cross-reference analysis between variations in diameter classes with altitude gradients could not be conducted.

CONCLUSION

The temporal study was commission with a view to get a preliminary insight in to the current statusof vegetation viz. species composition in the three forest divisions - Kullu Forest Division, Seraj Forest Division, and Parvati Forest Division under the Kullu Forest Circle. To ascertain the temporal changes, three-tiered assessment was carried out: *1) tree community based variation; 2) altitude gradient driven variation; and 3) diameter class wise variations in tree composition.*

Kullu Forest Division

Six pure communities of*Cedrus deodara* (CD), *Pinus wallichiana* (PW), *Abies pindrow* (AP), *Picea smithiana* (PS), *Quercus semecarpifolia* (QS), Broad leaved (BL); and 2 mixed tree communities - *Cedrus deodara-Picea smithiana* and *Pinus wallichiana-Cedrus deodara* were identified in the Kullu, Manali, Bhutti, Patlikuhl, and Naggar forest ranges between 1949 and 1994.

***Cedrus deodara* community**registered an increased density in its dominant community (101 Ind/ha to 132.2 Ind/ha); and also at all altitude ranges of 1500-2000m, 2000-2500m, and 2500-3000m. Sharp increases were recorded for trees within diameter classes 10-20cm categories at 2000-2500m and 2500-3000m from 4.89 Ind/ha to 14.05 Ind/ha and 0.30 Ind/ha to 7.72 Ind/ha respectively, signifying regeneration at higher altitudes. Meanwhile, at lower altitudes of 1500-2000m trees within diameter classes30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, 90-100cm witnessed increased density between 1949 and 1994.

***Pinus wallichiana*community** registered anincreased density in its dominant community (40.1 Ind/ha to 59.7 Ind/ha); and at all altitude ranges with maximum increase of 52 per cent at 2000-2500m altitude, followed by 44 per cent at higher altitudes, and marginal 1 per cent at 1500-2000m. Similar to *Cedrus deodara,* steep increases were recorded for 10-20cm diameter classes at 2000-2500m and 2500-3000m, from 1.99 Ind/ha to 10.08 Ind/ha and 0.45 Ind/ha to 4.26 Ind/ha, respectively.

***Abies pindrow* community**registered an increased density in its dominant community (1.59 Ind/ha to 1.7 Ind/ha). However, the species recorded significant decline at 2000-2500m and 2500-3000m of 80 per cent and 33 per cent, respectively. At lower altitudes, the density had increased by 50 per cent, where density of trees in all diameter classes increased, specifically of those falling under diameter classes 70-80cm and 80-90cm that were already in higher concentration, increased from 0.25 Ind/ha to 0.30 Ind/ha and 0.29 Ind/ha to 0.37 Ind/ha respectively. Atmid to higher altitudes, steep decline in density of trees in all diameter classes was seen between 1949 and 1994 especially for 10-20cm *(not at 2500-3000m)* and 20-30cm categories.

***Picea smithiana*community** registered an increased density in its dominant community (44.6 Ind/ha to 46.4 Ind/ha) with 14 per cent and 12 per cent increase inconcentration at 1500-2000m and 2500-3000m between 1949 and 1994. At the middle altitudinal range, the density decreased by 7 per cent. At 1500-2000m, density of trees within diameter classes 10-20cm, 80-90cm, and 90-100cm declined; while within other diameter classes tree density increased. Nonetheless, density of younger trees of diameter 10-20cm increased at the altitudes 2000-2500m and 2500-3000m.

***Quercus semecarpifolia*community** registered increased density in its dominant community (2.2 Ind/ha to 2.3Ind/ha). Altitudinal changes are captured for 2500-3000m only, where it showed an increase of 9 per cent (lower altitudinal data was not enumerated for the study period), with variable manifestation in different diameter classes. While, density of trees within diameters 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm, 80-90cm, and 90-100cm increased; those under 10-20 cm decreased, and for those with diameters greater than 100cm, density remained the same.

Broad-leaved community registered increased density in its dominant community (44.6 Ind/ha to 46.4 Ind/ha) with 100 per cent increase at 2000-2500m, and 6 per cent at 2500-3000m (lower altitudinal data was not enumerated for the study period). With respect to variations in diameter classes at the two altitude ranges, at 2000-2500m altitude, density increased for diameter classes 10-20cm, 20-30cm, 30-40cm, 40-50, and 60-70cm. While, at higher altitudes, the broad-leaved tree density within the diameter classes 10-20cm, 20-30cm, 30-40cm, 90-100 cm and above increased, and for those under 40-50cm, 50-40cm, 60-70cm, 70-80cm, and 80-90cm witnessed a marginal decline.

Seraj Forest Division

Five pure communities of*Cedrus deodara (CD), Pinus wallichiana (PW),Pinus roxburghii(PR), Quercus leucotrichophora(QLs), Picea smithiana (PS),*14 mixed tree communities – Broad leaved-*Abies pindrow, Cedrus deodara-Pinus wallichiana, Abies pindrow-Taxus baccata, Abies pindrow-Picea smithiana, Abies pindrow*-Broad-leaved, *Taxus baccata-Abies pindrow, Quercus leucotrichophora-Pinus wallichiana, Quercus semecarpifolia-Quercus leucotrichophora, Picea*

smithiana-Taxus baccata, Taxus baccata-Picea smithiana, Quercus semecarpifolia-Taxus baccata, Broad-leaved-*Picea smithiana, Quercus semecarpifolia-Taxus baccata-Abies pindrow, Picea smithiana-Abies pindrow-Pinus wallichiana* were identified in the Banjar, Sainj, and Tirthan forest ranges between 1986 and 2013.

***Cedrus deodara* communityregistered** reduced density in its dominant community (159.5 Ind/ha to 98.5Ind/ha) where decline was at lower to mid altitudes with a steep decline of 31 per cent at the mid altitude range of 2000-2500m.While at high altitude of 2500-3000m, its individuals per hectare increased. With respect to variations across diameter classes, across the three altitude ranges, at lower to mid-altitudes, concentration of mature trees was found to be on a consistent decline contributing to the overall decline in density. Nevertheless, at 1500-2000m, concentration within 10-20cm, 80-90cm, and over 100cm diameter class increased from 11.20 Ind/ha to 17.75 Ind/ha, 0.70 Ind/ha to 0.75 Ind/ha, and 0.0 to 0.20 Ind/ha, respectively. At higher altitudes (2500-3000m) as well, density of *Cedrus deodara* increased across majority of diameter classes i.e. 10-20cm, 20-30cm, 40-50cm to 80-90cm, and over 100cm. However, maximum increase (65 per cent) was within the diameter 10-20cm.

***Pinus wallichiana*community** registered a significantly reduced density in its dominant community (140.1 Ind/ha to 58.8 ind./h) with sharp fall of 40 per cent and 50 per cent at 1500-2000m and 2000-2500m altitude range, respectively. At higher altitude, its density increased by only 11 per cent. At 1500-2000m, this decline was largely driven by decline in density within diameter classes 20-30cm to 90-100cm. At 2000-2500m altitude, trees density declined across all diameter classes except for over 100cm, with significant decline registered for diameter classes 10-20cm (60 per cent), 60-70cm (56 per

cent), 80-90cm (56 per cent), and 90-100cm (67 per cent). Thus, indicating toward loss of both younger and mature trees at this altitude range. At 2500m and above altitude, positive changes were observed at extreme ends of spectrum i.e. for 10-20cm (38 per cent), 20-30cm (40 per cent), and 80-90cm (18 per cent), 90-100cm (56 per cent), >100cm (138 per cent).

***Abies pindrow*community** registered increased density in its dominant community (236.2 Ind/ha to 301.5Ind/ha); where at 1500-2000m the species registered an increase of 18 per cent, while at higher altitude ranges its density declined.At lower altitude of 1500-2000m, predominant increase was seen specifically for trees within diameter classes of 30-40cm, 40-50cm, 50-60cm, and 60-70cm. Meanwhile, at mid-altitude range, decline in density was largely driven by reduction in trees within diameter classes 10-20cm to 60-70cm. Only the density of matured trees with diameters 80cm and above had increased.At 2500m and above, a decline in density was seen for trees within diameter classes 10-20cm to 30-40cm, and 50-60cm; rest all diameter classes registered an incline, with maximum increase seen for mature trees with diameters 80 cm and above (as for the altitude 2000-2500m).

***Pinus roxburghii* community**registered a sharp decline in its dominant community (88.9 Ind/ha to 30.4 Ind/ha) that was manifested at 1500-2000m altitude range where its density declined by 54 per cent. Significant decline of 64 per cent, 65 per cent, 59 per cent, and 57 per cent was recorded for diameter classes 10-20cm, 20-30cm, 30-40cm, and 40-50cm respectively. Meanwhile, sharp increase was seen for density of mature trees within diameter classes 60-70cm, 70-80cm, and 80-90cm.

***Picea smithiana*community** registered increased density in its dominant community (159.7 Ind/ha to 186.9Ind/ha) categorically at 1500-2000m and 2500-3000m with respective increases of 66 per cent and 23 per cent between 1986 and 2013.At both altitude ranges, significant increase was seen within diameter class 10-20cm, i.e. 95 per cent at 1500-2000m, and 20 per cent at 2500-3000m.At the mid altitudinal range, the density decreased by 4.6 per cent where consistent decline was registered in all diameter classes except for 20-30cm, 80-90cm, and over 100cm.

***Quercus leucotrichophora* community** declined drastically in its dominant community (327.8 Ind/ha to 90 Ind/ha) where 73 per cent of its concentration vanished at 1500-2000m altitude gradient, and 69 per cent at the 2000-2500m from 1986 to 2013. At both 1500-2000m and 2000-2500m, a steep decline was recorded across all diameter classes except for those greater than 100 cm. On average, three-quarters of density vanished across the said diameter classes at 1500-2500m altitude.

Parvati Forest Division

Six pure tree communities of*Cedrus deodara (CD), Pinus wallichiana (PW), Abies pindrow (AP), Picea smithiana (PS), Pinus roxburghii (PR),* andBroad-leaved, and 7 mixed tree communities – *Abies pindrow-Picea smithiana, Picea smithiana-Cedrus deodara, Picea smithiana-Pinus wallichiana, Pinus wallichiana-Cedrus deodara,* Broad-leaved-*Picea smithiana, Pinus wallichiana-Pinus roxburghii,* and *Cedrus deodara-Picea smithiana* were identified in the Hurla, Jari, Kasol, and Parvati forest ranges under the Parvati Forest Division between 1948 and 1996.

***Cedrus deodara* community** registered increased density in its dominant community (89.7Ind/ha to 92.7Ind/ha) driven by increments across all altitude ranges, especially at 2500-3000m where density increased by 133 per cent between 1948 and 1996.

***Pinus wallichiana* community** registered sharp decline in density in its dominant community (62.7 Ind/ha to 43.3 Ind/ha) driven by reductions of 40 per cent, 16 per cent, and 13 per cent at 1500-2000m, 2000-2500m, and 2500-3000m, respectively.

***Picea smithiana*community** recorded a 48 per cent decline in its dominant community where its density plummeted at 1500-2000m and 2500-3000m with respective declines of 69 per cent and 27 per cent, respectively between 1948 and 1996. At the mid altitudinal range, the density increased by 23 per cent.

***Abies pindrow*community** registered a decline in density in its dominant community (27 Ind/ha to 15.9 Ind/ha), where at 2000-2500m and 2500-3000m altitude gradient a decline of 30 per cent and 18 per cent was recorded, respectively. The species was not found at lower altitude of 1500-2000m.

***Pinus roxburghii* community** registered significantly increased density in its dominant community (60.2Ind/ha to 86.6Ind/ha) where over 100 per cent increase at 1500-2000m(111 per cent) and 2000-2500m (175 per cent) altitude range was recorded between 1949 and 1996.

Broad-leaved community registered increased density in its dominant community (83 Ind/ha to 100.6 Ind/ha), where nominal 1 per cent increase at 1500-2000m, and a sharp 43 per cent decline at 2000-

2500m altitudes was recorded between 1948 and 1986. The species was not found at higher altitudes in this forest division.

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