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Perspectives

Oak Forest is in the process of being replaced by *Pinus* in Nainital

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Abstract: An oak forest is an extremely important component of the hill forest ecosystem but on account of anthropogenic changes, this is under a process of replacement by *Pinus roxburghii*, a much tougher and adaptable species in times of climate change. Foresters are responsible to hasten this process without understanding the repercussions of an irreversible and undesirable change in the ecosystem. The forest fire schemes have not been able to contain the spread of forest fire across the country, therefore, it needs an effective structural change. The oak forest of Sat Tal-8 and Sat Tal-9 would have been converted into a complete oak forest, which was initiated and would have been brought to a logical conclusion. But this could not happen and it also failed on account of lack of interest in the successors. Oak forest is very rich in flora and fauna and this is estimated that the herb layer density is higher (234.5 m^{-2}) when compared to Chir forest (119.58 m^{-2}). The biomass is also reportedly higher in Oak than in the Chir forest. Today, Nainital hill forests have become infested with alien invasive flora, destroying the essence of pristine hill forests. Temperature is also rising fast with the rainfall receding substantially in Nainital over a period of the last thirty years therefore, impacting its flora and fauna adversely. The moisture regime of the topsoil in the Oak Forest has also come down remarkably and they all combinedly bring in a change in its species composition.

Keywords: Oak Forest ecosystem; Climate change; Nutrient cycle; Forest floor diversity; Net primary productivity; Forest types; Forest fire; Wildlife

1. Introduction

1.1 Structure of Oak Forest

Oaks are very important and constitute the dominant and climax forest ecosystem of the moist temperate of the Himalayan region [1]. Oak forests provide innumerable ecosystem services besides, being rich in wildlife and other floral diversity. There are as many as 35 species of *Quercus*, diversely distributed between an altitude of 1000 and 3500 m from the mean sea level. Of the 35 species of oak, Kumaon Himalayas is home to five species namely, *Quercus glauca*, *Q. leucotrichophora*, *Q. lanuginosa*, *Q. foribunda* and *Q. semecarpifolia*. Oak assumes larger significance in Kumaon Hills because this not only provides a life support system to hundreds and thousands of people in providing food and water but also sustains their cattle and agriculture. Of the five species of oak found in Kumaon hills, three of them namely, (*Q. leucotrichophora*, *Q. floribunda*, and *Q. semecarpifolia*) are very closely knit with their agriculture and food [2]. Oaks have also been found occurring on cool, moist, and lower elevations of the western Himalayas. In an extensive study on Oak by Troup (1921), he also states that the Oak may be found in a lower elevation of 600 m provided it is a moist ravine and this range is not different from that of *Pinus roxburghii*. *Q. glauca* and *Q. leucotrichophora* are found to be on the lower elevation compared to the other *Quercus* spp. as seen in Table 1. *Q. Ianuginosa* and *Q. floribunda* are dominant species but they are always confined in smaller patches which rarely exceed 12-15 ha area in one stretch. The remaining species do not attain dominance. The Himalayas is home to many diverse cultures and human groups living in and around rivers. Their life revolves around the forest and its resources therefore, the diversity of oak forest flora and fauna is extremely important for their long-term sustainability and survival.

1.2 Composition of Oak Forests

The species composition varies with the elevation and species of oak. On an elevation of 1500 m, Banj oak exists with *Pinus* roxburghii whereas around 2200 m Banj oak and Tilonj oak are found to be flourishing well. At a height of around 2400 m, Kharsu oak is found growing well with *Pinus wallichiana* and as it goes above 2500 m Kharsu oak combines with *Abies pindrow*. Among the tree associates, *Rhododendron arboreum* and *Lyonia ovalifolia* occurred in all oak forests.

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Table 1. Pattern and distribution of Oak in Kumaon Himalaya

Name of species	Vernacular name	Altitudinal range	Pattern of distribution
Q. Glauca	Banj	900-1800	Member of mixed broad-leaf forests but inconspicuously present
Q. leucotrichophora	Banj	1200-2300	Extensive in presence
Q. lanuginose	Rianj	1800-2400	Found as pure crop
Q. floribunda	Tilonj	2100-2700	Pure or mixed forest
Q. semicarpifolia	Kharsu	2400-3600	Extensive forest-forming species

1.3 Disruption in Oak Forest ecosystem

Oak forest is an extremely important ecosystem in the Himalayas but today it is threatened not only by excessive lopping but to a large extent by climate change also. The process of deforestation has not been set in on account of the increasing population only but this marks the failure of forest mismanagement and inadequate forest policies to contain this rot. Therefore, the deterioration in the Oak forests in the Nainital forest division (Figure 1) is mainly because of the institutional deficiencies and policy deficit at the governmental level at large. This has been found in many studies that population growth at a faster pace poses difficulties in resource sharing but if worked scientifically and mutually then this can be managed in a much better way between the local communities and the forest department [3].

Many factors have led to the shifting of Oak to the higher altitude and one of them is the nutritional stress. Temperature and rainfall are the key factors that regulate the other parameters of climate change in the oak forest ecosystem. Most of the dominant species have been shifting on the hills on account of the rapid rise in temperature and rainfall deficit occurring over time, more so after 1990. With the change in temperature and rainfall pattern oak has been showing a varying stage of vivipary in the hills and larger seeds of oak have been observed which indicates warmer summers in the recent past compared to early times [4]. In a study, Parris and Bazzaz (1982) suggested that there is a strong co-relationship between the two species

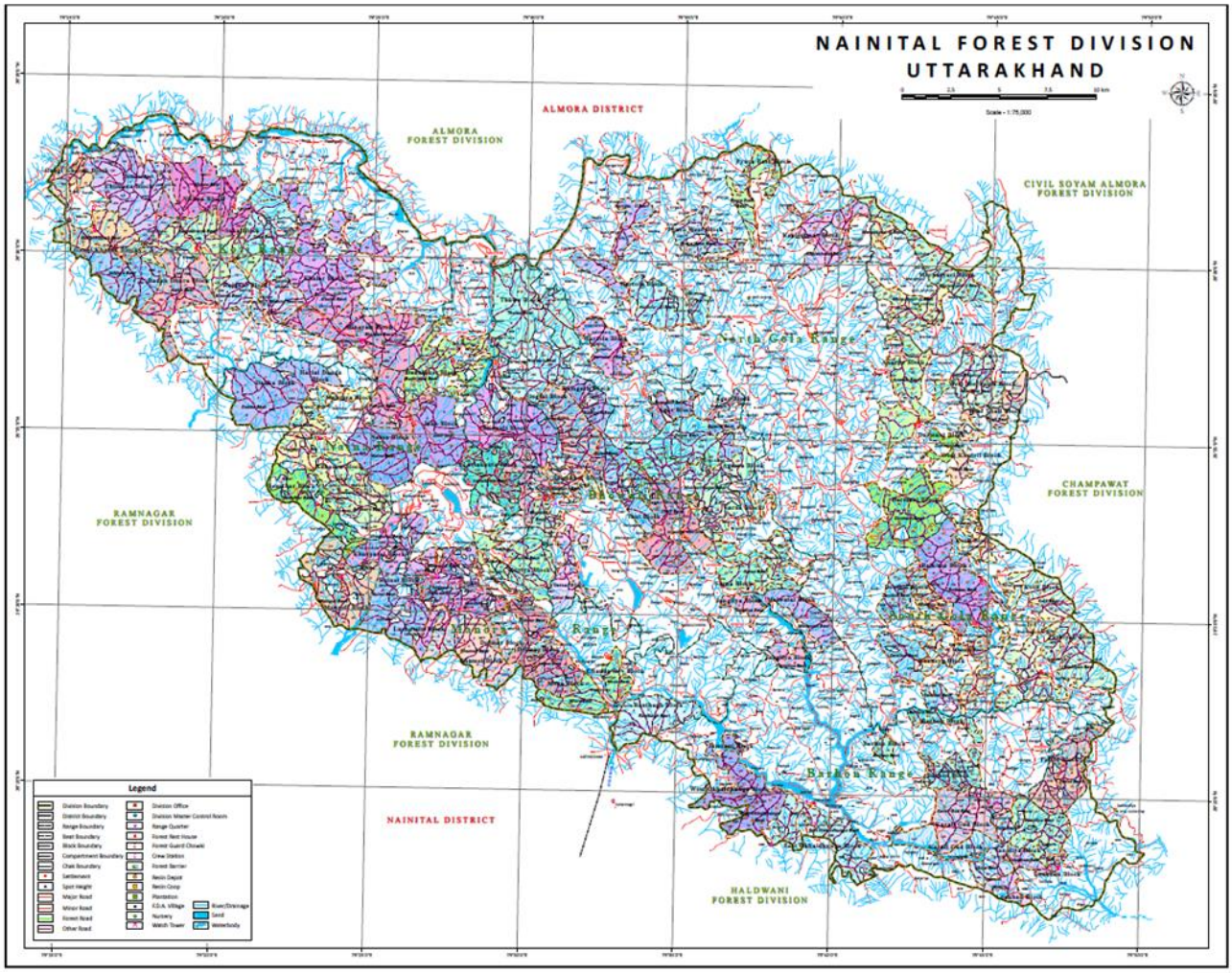

Figure 1. Map of Nainital forest division in Uttarakhand (Source: Nainital Working Plan 2020-2030).

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Table 2. Area statement of Nainital forest division by species (Source: Nainital Forest Management Plan)

	Vernacular name of the main species	**Botanical name**	**Gross area (in hectares)**	**Percent of the total area**
	Coniferous species			
1	Chir	*P. roxburghii*	29,734.6	49.93
2	Kail	*P. wallichiana*	77.2	0.13
3	Deodar	*C. deodara*	104.8	0.18
4	Surai	*Cupressus torulosa*	56.1	0.09
5	Fir and Spruce	*Abies* sp. and *Picea* sp.	36.1	0.06
	Sub-total		30,008.80	50.39
	Broad leaf species			
6	Banj	*Q. leucotrichophora*	12,755.7	21.42
7	Tilonj	*Q. floribunda*	1,900.1	3.19
8	Riyanj	*Q. lanata*	882.2	1.48
9	Kharsu	*Q. semecarpifolia*	212.4	0.36
10	Highland miscellaneous species		605.8	1.02
11	Sal	*S. robusta*	2,371.2	3.98
12	Khair and Shisham	*S. catechu/ D. sissoo*	10.0	0.02
13	Lowland miscellaneous species		6,592.5	11.07
	Sub-total		25,329.90	42.54
14	Open-land, landslide area, rivers, etc.		4,213.8	7.07
	Total		59,552.50	100.00

and their nutrition uptake and the inter-specific competition becomes severe as the nutrient levels go up [5]. With the nutrient level up in the soil, the nutrient uptake in Chir is much higher and faster than the oak and this is one reason for the oak to be replaced by the Chir [6].

The other very significant reason for oak being replaced by chir is the consistent forest fire in the oak forest, which depletes the soil moisture and makes it conducive for *P. roxburghii* seeds to germinate and spread faster than Oak. Besides, Oak leaves are heavily lopped as animal feed on account of being nutritionally rich and as a result of this act, many gaps are created in the oak forest and these gaps help chir pine to establish fast. This is interesting to observe that if Van Panchayat and protected forests are lying adjacent to each other then the extent of forest degradation in protected forests was more compared to Van Panchayat (VP) forests. This has also been reflected in a study conducted in the two types of forests namely, Van Panchayats and protected forests in Uttrakhand where many parameters were used as indicators for forest degradation like lopping, grazing, canopy cover, forest density, etc., and their findings suggested that forests managed by villagers (Van Panchayats) had less than 20-30% lopping when compared to the forest managed by the government [7].

As a result of the excessive lopping huge gaps in the forest are created and this gives rise to an opportunity for other light exotic and demander species to step in. *Pinus* is otherwise, a successional species, and being a strong light demander, it grows very fast in case it gets any opening in the crown only because these gaps make sunlight available for the successful establishment of chir in its early period. This has been found that oak trees are a high nitrogen demander and grow well in nitrogen-rich soil, unlike Chir. Forest fire has become a consistent phenomenon in the hills on account of climate change therefore, frequent forest fires deplete the oak forest floor of nitrogen through a process called volatilization and the absence of nitrogen in the forest floor reduces the fertility of soil therefore, making soil conducive for Chir [8].

2. Floor diversity and climate of Oak Forest in the Western Himalayas

Not much study has been done on the Oak Forest in the Himalayas therefore, adequate scientific data is not in the public domain. Oak forests are representative of the climax evergreen vegetation between 1000 and 3600 m in the western Himalayas. The Oak Forest has well-developed layers namely, the ground, middle and top canopy. The shrub layer is well developed with the prevailing phanerophytes (50-60%). A study was carried out to find out the ground flora and biomass pattern in some of the oak and Chir (*P. roxburghii*) forests in the western Himalayas in an altitudinal range between 1450 m and 1950 m and this was found that herb richness is a little higher in the oak forest than Chir forest (Table 2). The herb layer density was found higher (234.5 m^{-2}) in Oak Forest when compared to the Chir Forest (119.58 m^{-2}). The biomass was also higher in oak than in the Chir forest [9]. In yet another study this is found that the forest biomass ranges between 294-787 t/ha/year and the net primary productivity generally between 16-21 t/ ha/year [8]. Oak has not been important from the diversity richness point of view but also its survival is endangered on account of its large-scale usage

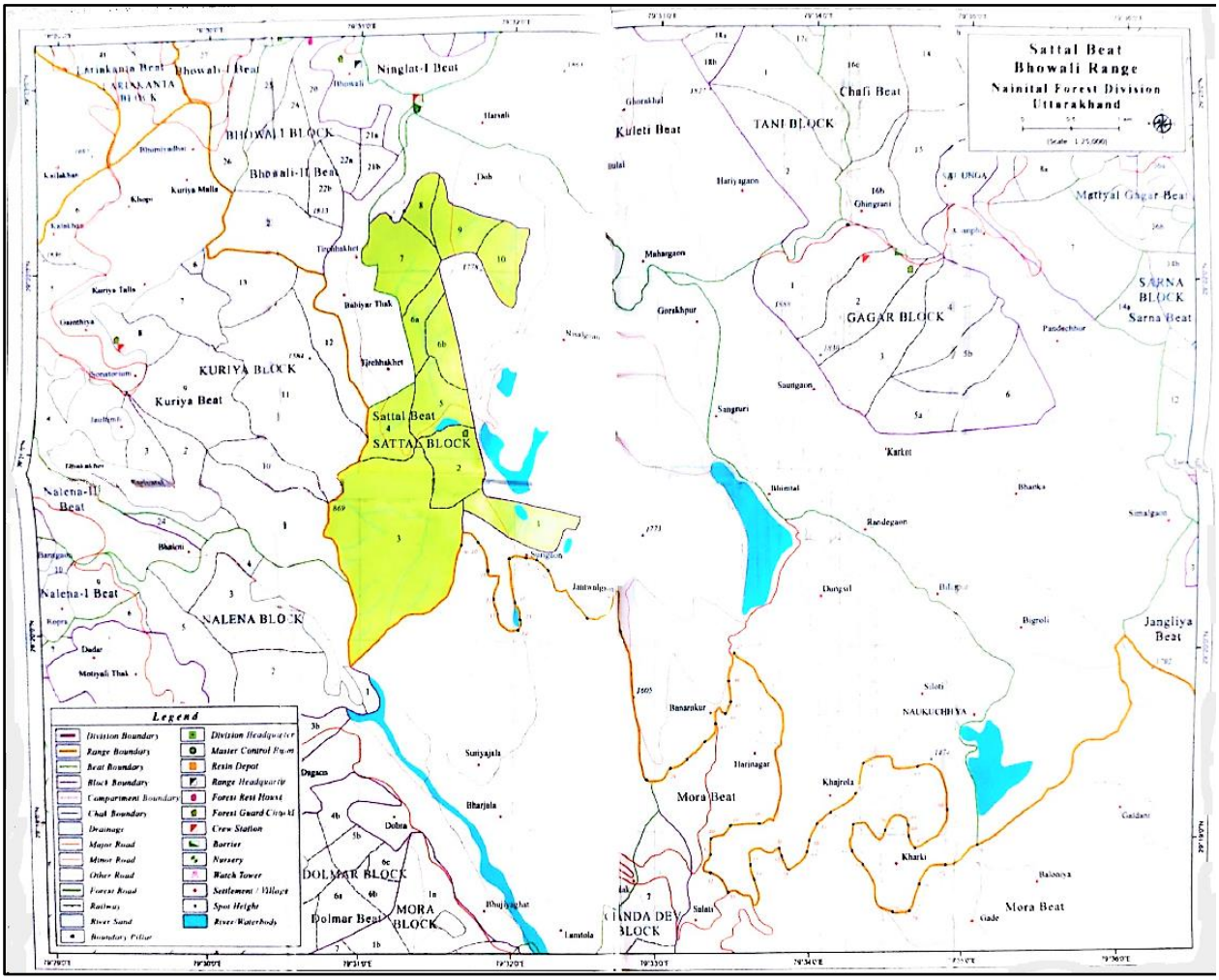

Figure 2. Map of compartment Sat Tal 8 and 9 (Source: Nainital Working Plan 2020-2030).

as fodder by the villagers living in and around forest compartments. Oak forest supports a diverse variety of wildlife which signals a healthy ecosystem. Chir (*P. roxburghii*) has been the dominant species constituting around 49.3% of the total geographical area of Nainital forest division and its forest quality lies in the category of II/III as per Champion and Seth (1968) classification [10]. Twisted Chir has been reported from the north Gola range whereas the Sal (*Shorea robusta*) is confined to the foothills of the Himalayas, further south of the Nainital forest division.

The main forest type to which the forest of Sat Tal-8 and Sat Tal-9 (Figure 2) belongs is the sub-tropical pine forest (9/C.I.B) [10]. This type of forest is found between 750 m and 2000 m in elevation with chir as the dominant species. *P. roxburghii* has been found growing on every soil in Kumaon hills but it grows best on quartzite's soil.

The temperature in the Nainital has been observed to rise very fast since 1990 and as the record shows, the mean temperature has gone up by 0.46 °C in the last decades. Nainital receives around 2357.6 mm and the statistics tell that more than 75% of its rain occurs during July and August. Rainfall has also shown a declining trend since 1990 and the record shows that on average the State of Uttarakhand has recorded a rainfall deficit of 13.05 mm. Uttarakhand has 13 districts but all the districts except Haridwar have recorded rainfall deficit.

3. Study Site

The Nainital Forest Division is placed between 29011'30'' - 29034'N latitude and 79014'23'' - 79050'10'' E longitude. This is situated at 1930 m from the mean sea level. In its north lies east and west Almora Forest division and in the south this has Haldwani forest division whereas in the west we have Pithoragarh forest division and part of east Almora Forest division. In its west lies the Ramnagar forest division. The entire forest division is full of small and large lakes which are the major attractions of the tourists from all around. Bhawali is a small satellite township of Nainital districts. This is 11 km away from the city of Nainital at an average elevation of 1654 m from the sea level. The total recorded forest area of the Nainital forest division is 59552.5 ha which constitutes 14.01% of the district's total geographical area. There are seven forest ranges in the Nainital forest division from an administrative point of view and the Bhawali range is the second largest of them in an area with 11531.20 ha and the Badhoun range is the smallest one (6016.80 ha). Forest compartments of Sat Tal-8 & 9 of Bhawali range (Nainital Forest Division)

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Table 3. Number of trees in Sat Tal 8 and 9 compartments (Year 1988-89 to 1997-98).

Lake Compartment	Species	Diameter Classes (in cm)								Total
		0-20	20-30	30-40	40-50	50-60	60-70	70-80	Above 80	
Sat Tal 8	*P. roxburghii*	214	611	446	319	118	27	3	2	1740
	Q. leucotrichophora	1	2	2	2	-	1	-	-	8
	Other	23	29	14	2	-	-	-	-	68
Total		**238**	**642**	**462**	**323**	**118**	**28**	**3**	**2**	**1816**
Sat Tal 9	*P. roxburghii*	932	1911	1252	370	108	14	-	3	4590
	Q. leucotrichophora	74	114	37	19	6	-	-	-	250
	T. sinensis	-	1	-	-	-	-	-	-	1
	Other	168	195	27	6	232	42	3	5	678
Total		**1174**	**2221**	**1316**	**395**	**346**	**56**	**3**	**8**	**5519**

Table 4. Number of trees in Sat Tal 8 and 9 compartments (Year 2023, January).

Lake Compartment	Species	Diameter Classes (in cm)								
		0-20	20-30	30-40	40-50	50-60	60-70	70-80	80-09	Above 90	Total
Sat Tal 8	*P. roxburghii*	1428	850	835	749	518	228	123	63	14	4808
	C. deodara	9	11	2	-	-	-	-	-	-	22
	Juglans sp.	2	5	6	-	-	-	-	-	-	13
	M. esculenta	9	-	3	-	-	-	-	-	-	12
	C. torulosa	-	1	2	-	-	-	-	-	-	3
	Q. leucotrichophora	-	1	2	-	-	-	-	-	-	3
	Total	**1448**	**868**	**850**	**749**	**518**	**228**	**123**	**63**	**14**	**4861**
Sat Tal 9	*P. roxburghii*	2068	1343	1380	915	743	401	215	110	54	7229
	M. esculenta	1193	411	425	13	-	-	-	-	-	2042
	C. deodara	-	15	6	-	-	-	-	-	-	21
	Juglans sp.	2	12	2	-	-	-	-	-	-	16
	C. torulosa	0	10	4	-	-	-	-	-	-	14
	D. regia	6	5	-	-	-	-	-	-	-	11
	Q. leucotrichophora	606	116	25	5	-	-	-	-	-	752
	M. philippensis	29	36		-	-	-	-	-	-	65
	R. arboreum	-	11	14	-	-	-	-	-	-	25
	Total	**3904**	**1959**	**1856**	**933**	**743**	**401**	**215**	**110**	**54**	**10175**

were selected randomly way back in 1991 to understand the growth of oak if grazing and lopping are stopped completely. Both the compartments are situated at a height of 1716 m and currently, *P. roxburghii* is found to be the dominant species. The germination of Oak is almost absent. This was observed way back in 1991 that both the forest compartments had plenty of oak regeneration but the trees were stunted in growth on account of being lopped profusely by the villagers living in and around the forest areas. Both the forest compartments were open from all around and this allowed cattle from the nearby villages to flock freely to graze and it seemed no restrictions were imposed to check their entry. Therefore, it added a series of other compounding problems which were found to be irreversible. Both the compartments were predominantly

oak forests with the occasional presence of Surai, Devdar, Akhrot, Angu, and only a few *P. roxburghii*.

4. Methodology

Two forest compartments were chosen for the study in 1991 namely, Sat Tal-8 (5 ha) and Sat Tal-9 (10 ha). The reasons for having chosen these two compartments were:

(I) The areas were heavily grazed on account of being very close to villages with a very high amount of cattle population.

(II) The area was predominantly an oak forest and oak being a good fodder was grazed profusely.

(III) On account of severe and repeated forest fires, seedlings were converted into bushes

The entire study area was closed by loose stone walls of 1.25 m height and singling was carried out by sharp secateurs in all the bushes of oak. In the process of singling a leading and healthy shoot was left growing and the rest all the lateral branches were cut. Forest fire lines were cleared and maintained to stop a forest fire from spreading in the rest part in the forest compartment namely Sat Tal-8 and Sat Tal-9. The study area is located between 290 20' and 290 30' N latitude and 790 23' and 790 42' E longitude between 1650 m and 1950 m elevations in the Nainital district of Kumaun Himalaya. Both the forest compartments are oak forests but today, it has *Pinus roxburghii* Roxb. (Chir pine) as the dominant species. A complete enumeration was carried out in 2023 in both the compartments and compared with the data available of total enumeration in the year between 1988 and 1998 to understand how the oak stand has been replaced by *P. roxburghii* for 33 years. The number of other external factors like the incidences of forest fire, grazing, and lopping were also taken into consideration.

5. Result and Discussion

On a visit to the two compartments namely Sat Tal-8 and 9 of the Bhawali range way back in 1989, this was found that oak forests in those two compartments were heavily grazed leading to stunted growth in oak trees. Therefore, it was decided to fence the area, and a scientific way of singling was to be carried out immediately to allow the leading shoots to grow stoutly. The results in 2-3 years were very encouraging and almost all the oak seedlings reached a height of 7-8 feet, way above the level where they could be grazed by the cattle. The same compartments were re-visited between 28th June and 3rd July 2022 and it was found that no trace of a wall existed. Both the compartments were fully infested with *Lantana* to the extent that walking in the compartments was impossible. The oak was reduced to less than 10% and *P. roxburghii* expanded to more than 90%. The Sat Tal-8 and 9 compartments were looking dry even though both of them are north facing and should have been moist. Nainital which receives pre-monsoon shower but has been going dry and it is stated that there were no rains in the last fifteen days therefore, this area looked vulnerable to forest fire. Both the compartments are predominately oak forest and two villages namely, Lyosal and Bhaktura with 1000 families each are situated on the fringes of these compartments. The inhabitants are agriculturists. They stopped lopping oak and prevented their cattle from grazing in the area after having understood the importance of oak forest with the frequent interactions and seminars with the forest departments once the project was taken up by the Nainital forest department.

As a part of the project both the forest compartments were fenced and forest fire incidences were also contained fully well. This exercise was initiated in 1991 and the results were found to be astonishingly well. The stunted and bushy oak trees started to grow and attained a height of 7-8 ft. in two years. After sometimes both the compartments were abandoned and its deterioration started to set in. The lopping began, cattle were allowed to roam freely and graze as they like, and repetitive forest fires also made the situation worse than ever before. When both the compartments were visited in June 2022 they were found with *Lantana*, and the ground flora almost vanished. The oak trees were mostly replaced by Chir. This situation was further aggravated on account of anthropogenic reasons over the last three decades therefore, the air temperature rose leading to moisture loss from the topsoil. This had an impact on ground flora and this either led to a total loss of ground flora or they shifted upward to some congenial cool and moist place. The oak forest is replaced by Chir in most of the areas and possibly this process is hastened by the repetitive forest fire, unregulated lopping, and moisture loss from the topsoil in a very short time therefore, making the place conducive for Chir to replace oak. This has also resulted in another catastrophe on account of several water springs which were present about thirty years ago have dried up therefore, leading to drinking water problems for the villagers living in the near vicinity. This area would have flourished as an oak forest ecosystem had this been protected from lopping and forest fire, an activity which is very much doable. The enumeration in Table 3 has been taken from the Nainital Forest Management Plan (1988-1998). The enumeration shown in Table 4 was done in January 2023 by the author of this paper. The following features have been observed

1. Compared to the year 1988-1998, there is a sharp rise in the *P. roxburghii* population, and this amount to 176.32% in Sat Tal-8 compartment and 57.49% in Sat Tal-9 compartment.

2. The trees of *P. roxburghii* in all the diameter classes rose but the maximum number of trees were registered in the diameter classes of 80-90 cm in Sat Tal-8 which simply explains that mother trees for *P. roxburghii* are abundant in number and natural regeneration will keep going unless the trees or uprooted. The same picture exists in Sat Tal-9 compartment where the trees in diameter classes of 60-70 cm and 80-90 cm are more in number and they grew at a rate of 2764.29% and 3566% respectively compared to the year 1988-98.

3. The state of oak presence in Sat Tal-8 is very poor in the year 2023 when compared to what they were in the year 1988-98. Oak has declined by (-) 62.5% for 35 years. There

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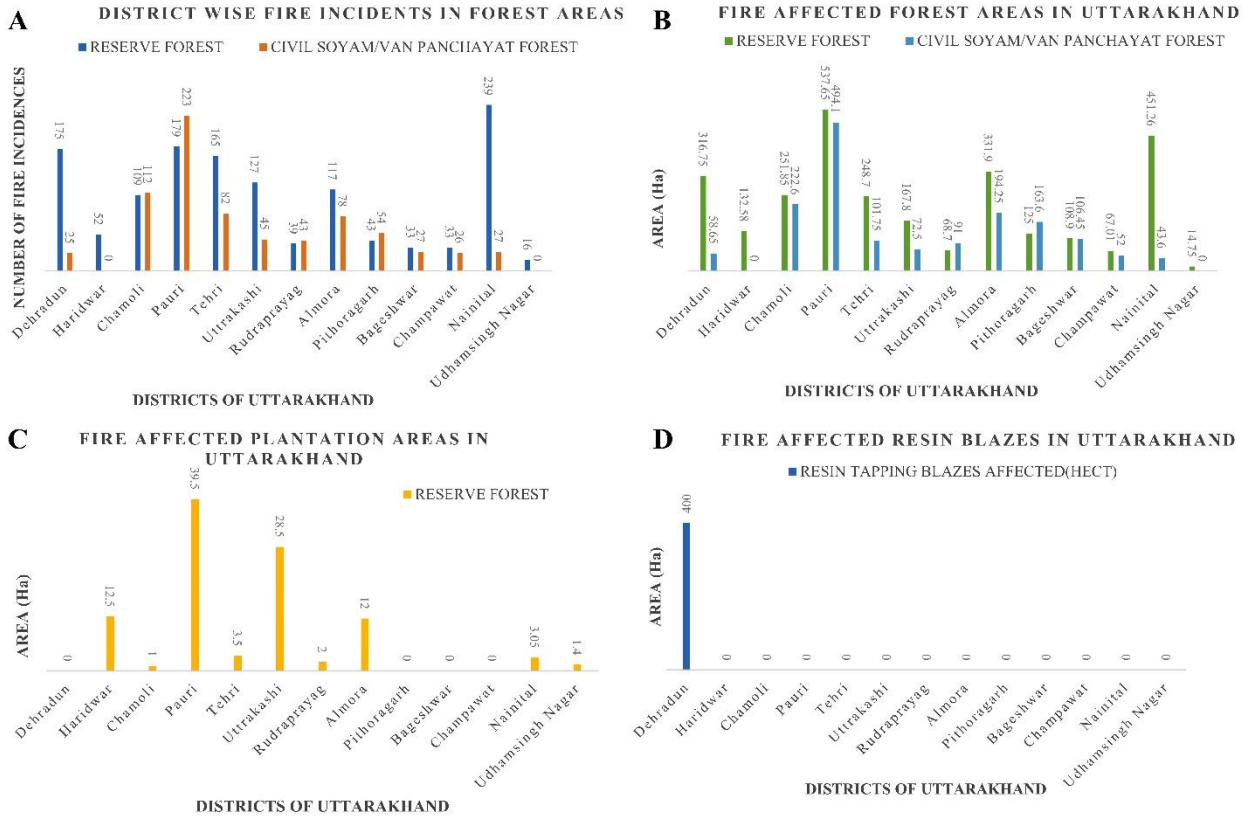

Figure 3. Summary of district wise fire incidents. (A) District wise fire incidents in forest areas; (B) Fire affected forests areas in Uttarakhand; (C) Fire affected plantation areas in Uttarakhand; (D) Fire affected resin blazes in Uttarakhand.

were 8 oak trees of varying diameter classes in the year 1988-98 which were reduced to only 3 in number and that too spread over two diameter classes of 20-30 cm and 30-40 cm. This simply explains that these three young oak saplings have no future and natural regeneration is not possible because the area is devoid of mother trees.

4. The picture in Sat Tal-9 is different because oak regeneration has gone up in the year 2023 by 718.92% when compared to what it was in the year 1988-98 but when examined from a close quarter this is repeating the same story as what was seen in Sat Tal-8. The number of trees in the diameter classes of 30-40 cm and 40-50 cm has declined by -32.4% and -73.68% respectively. The maximum number of trees (606) were found in 0-20 cm diameter classes and they were also highly lopped and stunted therefore, there is every possibility that these saplings will also die their death.

5. The presence of *Mallotus philipinensis*, *Delonix regia*, and *Myrica esculenta* explains that the oak ecosystem is changing and paving the way for dry deciduous types of forest species. *M. philippensis* is a small to medium-sized monoecious tree. It is commonly found in tropical to subtropical Sal forests in India. This has been found that *M. esculanta* grew well in both compartments in association with the *P. roxburghii*. Many studies support that this species performs best in *P. roxburghii* forests, where its density correlates with *Pinus* tree biomass [11].

Observations suggesting temperature rise in Nainital hills

The cobra sightings have increased in the recent past with a very high frequency on the higher reaches of hills (at the height above 2000 m). This has never been heard before. Snakes are cold-blooded reptiles and they are unable to regulate their internal body temperature with the change in the environment. Indian cobras are known to be well-adapted to both tropical and subtropical climates, where the air is generally warm and damp. They are found in a temperature range between 24 °C and 30 °C.

In a study carried out on the distribution of King cobra in the Nainital hills, this has been found that between the years 2006 and 2017, 18 King cobra nests and numerous sightings have been reported. A king cobra hatchling has been reported in the year 2012 on the premises of the Indian Veterinary Research Institute (IVRI), Mukteshwar, Nainital at an altitude of 2303 m, the highest recorded elevation for the King Cobra in its worldwide range [12]. This also explains in itself that the temperature of these areas has gone up substantially well. The Uttrakhand forest department claims over 132 sightings of King Cobra between 2015 and 2020 and the maximum number of sightings has been recorded in Nainital in the last 5 years. Mosquitoes, like many insects, are cold-blooded creatures. As a result, they are incapable of regulating body heat and their temperature is essentially the same as their surroundings. Mosquitoes function best at 26 °C and undergo hibernation between 15-17 °C, and become functionless below 10 °C. Yet another study on the

distribution of mosquito in Nainital suggests that the temperature of Nainital has risen over the past hundred years, which help the transmission of mosquito-borne disease and widen its geographical distribution [13].

Reasons for species shifting

The incidences of forest fire in the entire country have gone up by more than 200% in the last three years and if it is seen from the historical perspective of forest fire in the state of Uttrakhand, then the years 1995, 1999, and 2009 were extremely important where forest fire ravaged the entire forest. In 1995, a severe forest fire in Uttrakhand in the early summer caught the attention of the nation and the center asked the state government to submit a comprehensive plan to nip the problem in the bud while releasing nine crores immediately as additional central assistance to the state of Uttar Pradesh to contain the forest fire (Figure 3 and Table 5). This was found that the state government could not come up with a structural change to combat forest fires in the state to stop the repetition of forest fires of this scale in the future. Forest fire has become recurrent in the Nainital forest during March and June and sometimes in the later part of winter also [14]. The total area under the pine forest is 50.06% of the total geographical area of the Nainital forest and this has been widely reported in many studies that about 4 lakh tonnes of pine needles are dropped every year in Uttrakhand which becomes perfectly lethal to spread forest fire at a much faster pace when it combines with the resin protruding out from Chir trees during its extraction.

constitute 22.64% of the total Uttrakhand forest area. Out of the total burnt area, about 1225 km^2 was severely burnt [16] compared to 1995 forest in which 19.3% of the Uttrakhand forest area was burnt (NRSA report). Incidents of forest fires are very conservatively reported by the foresters across the country in general and UP &Uttrakhand in particular, therefore, this is extremely difficult to get a clear picture. The forest fire alert system has also been found faulty at the ground level and many a time not seriously attended to by foresters. Forest fires are on the rise recently because of climate change and if it is examined minutely in a period between 2005 and 2015, a total of 10473 incidents of forest fire occurred in Uttrakhand. The year 2009 is considered to be the hottest year in the country across states since the year 2000 and many studies have revealed that the maximum number of forest fire incidences (3767) took place in that year followed by 264 incidents in the year 2012 and 1554 incidences in the year 2010. As regards the districts, Pauri registered the maximum number of fire incidences (2364) followed by 1693 incidents of forest fire in Nainital, and the least number of forest fires was reported from the Pithoragarh (186). The incidence of forest fire in Nainital was the highest so far affecting an area of 6099 hectares. In the last fifteen years, the incidences of severe forest fire in Uttrakhandthat took place were in the years 2002-03, 2003-04, and 2008-09 affecting an area of 4983, 4850, and 4116 hectares respectively. Forest fires continue to scorch several hectares of green cover in Uttarakhand and Himachal Pradesh. In April 2022, Uttarakhand recorded over 1,500 such fire incidents.

Table 5. Summary of district wise fire incidents reported till June 2016 in Uttarakhand.

District	Number of fire incidences		Total	Affected forest area (Ha)		Total	Affected Plantation Area (Ha)	Resin Tapping Blazes Affected (Ha)	Value of loss (in Rs.)
	Reserve Forest	VP Forest		Reserve forest	VP Forest		Reserve Forest	VP Forest	
Dehradun	175	25	200	316.75	58.65	375.40	0.00	400	320200.0
Haridwar	52	0	52	132.58	0.00	132.58	12.50	0	66665.0
Chamoli	109	112	221	251.85	222.6	474.45	1.00	0	56000.0
Pauri	179	223	402	537.65	494.10	1031.75	39.5	0	898975.0
Tehri	165	82	247	248.7	101.75	350.45	3.50	0	222625.0
Uttrakashi	127	45	172	167.8	72.5	240.30	28.50	0	260125.0
Rudraprayag	39	43	82	68.70	91.0	159.7	2.0	0	221050.0
Almora	117	78	195	331.9	194.25	526.15	12.0	0	694825.0
Pithoragarh	43	54	97	125.00	163.6	288.6	0.00	0	372650.0
Bageshwar	33	27	60	108.90	106.45	215.35	0.00	0	321025.0
Champawat	33	26	59	67.01	52.00	119.01	0.00	0	130755.00
Nainital	239	27	266	451.26	43.60	494.86	3.05	0	545930.0
Udhamsingh Nagar	16	0	16	14.75	0.00	14.75	1.40	0	9000.0
Total	**1327**	**742**	**2069**	**2822.85**	**1600.50**	**4423.35**	**103.15**	**400**	**4629825.0**

Today every type of forest has become vulnerable on account of climate change. Under continuous anthropogenic reasons and recurrent forest fires, the early successional Chir pine has already expanded into the oak forest [15]. Yet another forest fire in 1999 was devastating in the history of the state of Uttrakhand and this is estimated that it burnt around 5058.6 km^2 of forest areas which

On April 30, 2022, Uttarakhand alone witnessed 51 large fire incidents, the maximum by any Indian state. In Nainital, the maximum temperature in June 2022 so far has been 29.8 °C and the minimum 25.4 °C, according to Hydromet, a local weather-monitoring system. It was milder in 2021 when the maximum temperature in June was 25.5 °C and the minimum 16.1 °C. The hills of Uttarakhand are getting

Figure 4. Images indicating the presence of *Pinus* in the Oak Forest of Nainital. (A) Sat Tal-8 containing only Chir (*Pinus roxburghii*) trees; (B) Remnants of stone wall put up in 1991 in Sat Tal-8; (C & D) The plate shows alien invasive ground flora that includes *Lantana* in Sat Tal-8; (E) Oak tree on extreme right side, severely lopped by villagers in Sat Tal-9; (F) Resin extraction from Chir tree by cup and cone method in Sat Tal-9, which helps forest fire spread very fast, this is highly inflammable; (G) Remnant of stone wall put up in Sat Tal-9 in 1991; (H) The plate shows Oak is replaced by Chir in Sat Tal-9; (I) The ground flora has been replaced by alien invasive species in Sat Tal-9.

warmer very fast. A study was carried out by the state pollution control board in 2020 on temperature and rainfall data over 100 years, from 1912-2012, and it stated that the mean annual temperature of Uttrakhand went up by 0.46 °C. The change in the temperature and rainfall though looks smaller but its implications have much larger manifestations across the region of the ecosystem of Uttrakhand. The data shows that there wasn't much of a visible change between 1970 and 1990 it dipped but this showed a spike after 1990. Before 1950, the report says, there were no notable changes in temperature. Within the state, Pithoragarh witnessed the highest spike (0.58 °C), followed by Chamoli (0.54 °C), Rudraprayag (0.53 °C), Bageshwar (0.52 °C), Uttarkashi (0.51 °C) and Nainital (0.44 °C) in all hill districts. Yet another study was carried out on the annual rainfall over two districts namely, Almora and Nainital from 1992-2005, and the result showed a decline in annual and monsoon rainfall at both stations [17].

6. Conclusion

Lopping of oak has been an age-old problem and this was only because adequate attention was not given by the foresters therefore, a kind of degradation has set in which has brought in an irreversible change in the oak forest ecosystem. This has been a continuous tug of war between foresters and villagers in the Nainital hills over lopping of oak forest but lopping could not be stopped. The government of the day also could not do much on this issue because the Indian Forest Act 1927 in its essence was prohibitive and it laid down rules on reserve forests, and their boundaries and prevented villagers from farming forested land, grazing and lopping in reserved forests [18, 19]. The FRI was aware of the degradation of the oak forest way back in 1937 because Goorie in his paper claimed that continuous lopping of oak has reached a stage where they are rapidly dying [20]. Oak forest is very rich in nutrients and its leaves are lopped massively because of very rich in content and considered as good livestock feed [8]. Controlled lopping also promotes regeneration but today, it has reached such a disproportionate proportion on account of consistently uncontrolled lopping that judicious forest management policies and appropriate actions are needed to contain it otherwise the forests across Kumaon hills are on the verge of being over forever [21].

Today, the problem has compounded on account of climate change and repeated forest fires in the Nainital forest division and this is visible on the ground. The author of this article was posted as a Divisional Forest officer of Nainital during 1989-1993, a period which witnessed foresters of old school always ready to spend more time in the forest than in the office. On a visit to Sat Tal-8 and Sat Tal-9 compartments of Bhawali forest, this was found that the area is full of oak regenerations and many coppices of oak are coming up profusely in both the compartments. The area was ravaged by the lopping of oak trees by people from nearby villages and livestock grazing was unrestrictive. The lopping had turned the young oak regenerations into bushy and stunted growth besides trampling of forest floor which make them compact and impervious thereby making it unsupportive of any regeneration. This was decided to fence the two compartments completely to stop villagers from lopping the oak trees and letting in stray cattle. Regular seminars were also organized in the villages bordering the oak forests to be able to let them understand the importance of oak forests in their vicinity and the kind of ecosystem services it provides to them in the form of water conservation and wildlife conservation. A scientific method of singling was also employed in the stunted and bushy oak in which all the lateral branches were cut by very sharp secateurs leaving a healthy leading shoot to grow. The fire lines were kept clean throughout the year to stop forest fires

to spread from one place to another. The young oak regeneration started to grow very vigorously and in a couple of years, it attained a height of 8-10 ft. and was beyond grazing level. The author was posted out in 1993 and when the areas were revisited after a gap of 29 years, this was found to be in far more bad shape than was ever expected. The stone wall was almost finished, the oak regeneration was almost over and the oak forests were replaced by Chir (*P. roxburghii*) to a very large extent.

Declarations

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References

[1] Troup RS (1921). Silviculture of Indian Trees. Vol. I-III. Clarendon Press, Oxford.

[2] Singh SP (1981). Rural ecosystem and development in the Himalaya. In Singh JS, Singh SP, Shastri C (eds.) *Science and Rural development in Mountains*, Gyanodaya Prakashan, Nainital, India.

[3] Somanathan E (1991). Deforestation, property rights and incentives in Central Himalaya. *Econ Polit Week*; 26(4):PE37-46.

[4] Singh SP, Singh V, Skutsch M (2010). Rapid warming in the Himalayas: Ecosystem responses and development options. *Clim Dev*; 2:221-232. [CrossRef]

[5] Parrish JAD, Bazzaz FA (1982). Competitive interactions in plant communities of different successional ages. *Ecology*; 63:314–320. [CrossRef]

[6] Singh SP, Bisht K (1992). Nutrient utilization in Quercus leucotrichophora and Pinus roxburghii seedlings at five soil fertility levels. *J Veget Sci*; 3(5):573-578. [CrossRef]

[7] Baland J, Bardhan P, Das S, Mookherjee D (2010). Forests to the people: decentralization and forest degradation in the Indian Himalayas. *World Develop*; 38(11):1642-1656. [CrossRef]

[8] Singh SP, Singh JS (1986). Structure and function of the Central Himalayan oak forests. *Proc Plant Sci*; 96:159-189. [CrossRef]

[9] Chandra JV, Sundriyal RC, Arya D (2021). Forest floor diversity, distribution and biomass pattern of Oak and Chir-pine forest in the Indian Western Himalaya. *Ind J Ecol*; 48(1):232-237.

[10] Champion HG, Seth SK (1968). A revised survey of forest types of India. Government of India Press, New Delhi; pp 404.

[11] Bhatt ID, Rawal R, Dhar U (2009). The availability, fruit yield, and harvest of Myrica esculenta in Kumaun (West Himalaya). *Mount Res Dev*; 2009:146-153. [CrossRef]

[12] Dolia J (2018). Notes on the distribution and natural history of the King Cobra (Ophiophagus hannah Cantor, 1836) from the Kumaon Hills of Uttarakhand, India. *Herpetol Notes*; 11:217-222.

[13] Reiter P (2001). Climate change and mosquito-borne diseases. *Environ Health Perspect*; 109:141-16. [CrossRef] [PubMed]

[14] Sharma S, Joshi V, Chhetri RK (2014). Forest fires as a potential environmental threat in recent years in Sikkim, Eastern Himalayas, India. *Clim Change Environ Sustain*; 2(1):55-61. [CrossRef]

[15] Singh JS, Rawat YS, Chaturvedi OP (1984). Replacement of oak forest with pine in the Himalaya affects the nitrogen cycle. *Nature*; 311:54-56. [CrossRef]

[16] State of Forest Report 1999 (2000). Forest Survey of India, Ministry of Environment and Forests, Dehra Dun, India.

[17] Joshi S, Kumar K, Joshi V, Pande B (2014). Rainfall variability and indices of extreme rainfall analysis and perception study for two stations over Central Himalaya, India. *Nat Hazards*; 72:361-374. [CrossRef]

[18] Tucker RP (1984). The historical context of social forestry in the Kumaon Himalayas. *J Develop Areas*; 18(3):341–356.

[19] Rawat AS (1989). History of Garhwal, 1358–1947: an erstwhile kingdom in the Himalayas. New Delhi, India: Indus Pub Co.

[20] Gorrie RM (1937). Tree lopping on a permanent basis. *Indian Forester*; 63:29–31.

[21] Lodhiyal N (2015). Species diversity and regeneration of Tilonj Oak (Quercus floribunda Lindl.) dominated forests of Nainital in Kumaun Himalaya. *Int J Biodiver Conserv*; 7(1):21-27. [CrossRef]