



VERTICAL AND HORIZONTAL DISTRIBUTION OF FORESTS IN UTTARAKHAND HIMALAYA: A GEOGRAPHICAL ANALYSIS

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ABSTRACT: Forests of Uttarakhand Himalaya are distributed vertically and horizontally. Their types and diversity vary according to climate and altitudes, the main drivers. This paper examines the vertical and horizontal distribution of forests in Uttarakhand Himalaya. Data was gathered from the secondary sources mainly from the Forest Survey of India 2005, 2011, and 2017. Forest density along with altitudinal gradient and horizontally was also analyzed. Our result shows that forest cover is high in the districts which are located in the mountainous mainland. In the meantime, the districts where the area under snow-clad is high, and which lie in the plain region, forest cover is less. In terms of altitude, the forest area below <500 m and above >3,000 m is less. Total forest area is 63% of the total area whereas forest cover is only 45%. Forest use is less in the highlands and its use is high in the middle altitudes and river valleys. The middle altitudes and the valleys region have a comparatively high population. Forest degradation has observed high in these locations. It is suggested that forest can optimally be used in the highlands and it can be conserved in and surrounding the rural and urban settlements.

Keywords: Forest, altitude, distribution, FSI, Uttarakhand.

UTTARAKHAND HİMALAYA'DA ORMANLARIN DÜŞEY VE YATAY DAĞILIMI: BİR COĞRAFİ ANALİZ

ÖZET: Uttarakhand himalaya ormanları dikey ve yatay olarak dağılmış bulunmaktadır. Türleri ve çeşitliliği, ana etken olan iklim ve rakımlara göre değişmektedir. Bu makale uttarakhand himalaya'daki ormanların dikey ve yatay dağılımını incelemektedir. Veriler, ikincil kaynaklardan temel olarak hindistan orman araştırması bölümünden 2005, 2011 ve 2017 yıllarında elde edilmiştir. Orman yoğunluğu, yükseklik eğimi ile birlikte ve yatay olarak da analiz edilmiştir. Sonuçlar dağlık anakarada yer alan ilçelerde orman örtüsünün yüksek olduğunu göstermektedir. Bu arada karla kaplı alanın yüksek olduğu ve ova bölgesinde kalan

ilçelerde orman örtüsü azdır. Rakım açısından, 500 m'nin altındaki ve 3.000 m'nin üzerindeki alanlarda orman daha azdır. Toplam orman alanı, toplam alanın % 63'ünü oluştururken, orman örtüsü yalnızca % 45'tir. Yaylalarda orman kullanımı az, orta rakımlarda ve nehir vadilerinde kullanımı fazladır. Orta rakımlar ve vadiler bölgesi nispeten yüksek bir nüfusa sahiptir. Bu yerlerde yüksek oranda orman bozulması gözlemlenmiştir. Ormanın yaylalarda en iyi şekilde kullanılabileceği, kırsal ve kentsel yerleşimlerde ve çevresinde korunabileceği önerilmektedir.

Anahtar kelimeler: Orman, yükselti, dağılım, FSI, Uttarakhand.

INTRODUCTION

Forests play a vital role in improving water, soil, and air quality, keeping climate cool, providing shelter for wildlife, and increasing recreational opportunities (Oguz et al., 2020). They vary from equatorial rain forests to deserts, subtropical, temperate, and Polar Regions horizontally at the global scale and from the river valleys to the highlands, and alpine pasturelands vertically in the mountainous region. Forests cover about 30% of the Earth's land area (FAO, 2012). The population has increased worldwide, which has caused forest depletion (FAO 1948). Further, forest cover has changed substantially. FAO (2015) has estimated that natural forests have decreased whereas planted forests have increased by 7% since 1990 (FAO, 2015). FAO (2010) has also developed a strategic plan for the sustainable management of forests.

The Indian Himalayan region has about 75.52% forest area (Sati 2017). It is the home for forest resources, which account for high diversity and dense forests. The role of Himalayan forests is significant in regulating river flow, reducing soil erosion, and sedimentation downstream (Negi et al., 2006). Uttarakhand has high floral diversity varies according to the altitudes. It obtains 62.1% forest area (Negi, 2009). Forest species vary from monsoon deciduous forests in the plain areas/Shivalik hills to scrubs and pine in the middle altitudes, mixed-oak forests and coniferous forests in the highlands, and alpine grasslands below the snowline (Sati, 2006; Champion et al., 1968; Dhar et al., 1997; Negi, 1990; Singh, 2004; Samal et al., 2002; Samal et al., 2004; Maikhuri et al., 1998; Dhyani, 2000). A wide variety of flora forms a gradient from tropical vegetation to alpine meadows (Singh, 1971).

Forests vary from very dense forest (VDF) to moderately dense forest (MDF), and open forest (OF). They support the livelihoods of a large population globally. In mountain regions, forests are the major source of livelihoods and economies (CEDAR, 2010). The rural people of Uttarakhand are dependent of forest resources for firewood, fodder, and food (Phartiyal et al., 2006; Singh et al., 2004; Singh et al., 2009; Kumari et al., 2009; Champion et al., 1968; UEPPCB, 2004). The local community has a peculiar system for conserving forests (Rao et al., 1999; Maikhuri et al., 1997; Saxena et al., 2001; Joshi, 2006; Malik and Bhatt, 2016; Kumar et al., 2005; Ram et al., 2004).

The Uttarakhand Himalaya has a vast area under forests. People's livelihood is dependent on agriculture, livestock, and forest products. Meanwhile, agriculture and livestock also depend on forests product. A large part of forests is unused because of its inaccessibility and remoteness. Forests lie in and surroundings of the settlements are overused because of human pressure. The main objective of this study is to analyze the vertical and horizontal distribution

of forests in the Uttarakhand Himalaya. It also aims to examine density-wise forest according to altitude and districts (latitude).

MATERIALS AND METHODS

Study Area

Uttarakhand Himalaya lies almost in the center of the Indian Himalayan region (Figure 1). An integral part of the Himalaya, it is also known as the Indian Central Himalayan Region (ICHR). It has about 53,483 sq km geographical area and of which, about 63% of areas are forested. Meanwhile forest cover is only 45% of the total area according to the latest survey (2017). Forest types and diversity in Uttarakhand vary according to climate and altitudes. The altitude varies from <500 m to >7000 m. Further, the climate varies from subtropical to temperate and cold. These driving forces determine the types, diversity, and density of forests. Forests in the plain and Shivalik ranges <500 m are densely distributed with high diversity. Scrubs and pine forests lie between 500 m and 2000 m, mixed-oak and coniferous forests are found between 2000 m to 3000 m and >3000 m, alpine pasturelands are found.

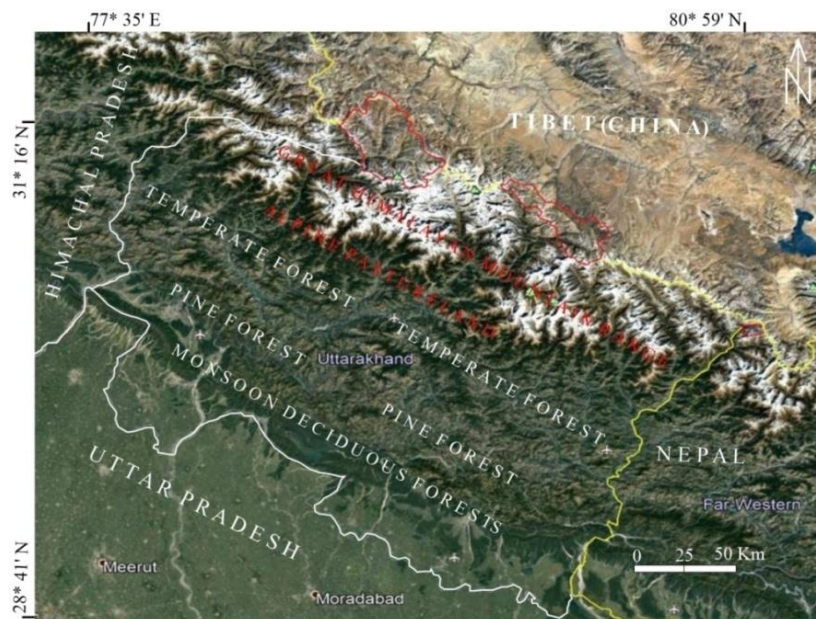


Figure 1. Location map of Uttarakhand Himalaya and forest distribution
Source: Google Earth 2020 and modified.

Methodology

This study was based on the use of both qualitative and quantitative methods. Data was gathered mainly from the secondary sources – Forests Survey of India 2005, 2011, and 2017. A participatory approach was also used after rapid field visits. Three time series data was analyzed using various methods and changes in forest areas were noticed and described. Forest types vary according to their vertical and horizontal distribution, which is shown through graphic representations. For example, monsoon forests are found in the river valleys, pine forests are found in the middle altitudes, mixed-oak forests are found in the temperate region, coniferous forests are found in the highland areas, and alpine meadows are found in cold area, which are covered by snow during the winter seasons. Altitude-wise density of forests and area – VDF, MDF, and OF, and district-wise density of forests and area, was described in detail.

Districts are categorized into indices and levels in terms of district wise forest cover, state forest share, and density of forests. Based on the forest cover, districts are categorized into ranks and shown on the map. Descriptive statistics are used to find out the mean value and standard deviation of district wise forest cover. Finally, changes in vertical distribution and district-wise distribution of forests based on density were noticed.

RESULTS

Forest Cover

Uttarakhand's forests are distributed vertically and horizontally. Their density varies from VDF to MDF, OF, and scrubs and from deciduous monsoon forests to pine forests, mixed oak forests, coniferous forests, and alpine grasslands. Figure 2 shows various types of forests according to their density and their proportion in the total forest cover. Forests' density varies in all the altitudinal zones and all the corresponding years. The highest proportion of forest cover is under MDF in all the years, followed by OF, and VDF. Scrub obtains a very small proportion of forest cover. Forest under VDF has increased whereas forest under MDF has decreased. OF has mixed results however there is a slight increase in OF from 2005 to 2017. With a small variation in the scrub during the three consecutive periods, the proportion of forest cover has remained similar from 2005 to 2017. MDF covered 52% of the total forest area in 2017. The second place was obtained by OF with 26%. VDF was 20% and Scrub covered only 2% of the forest area.

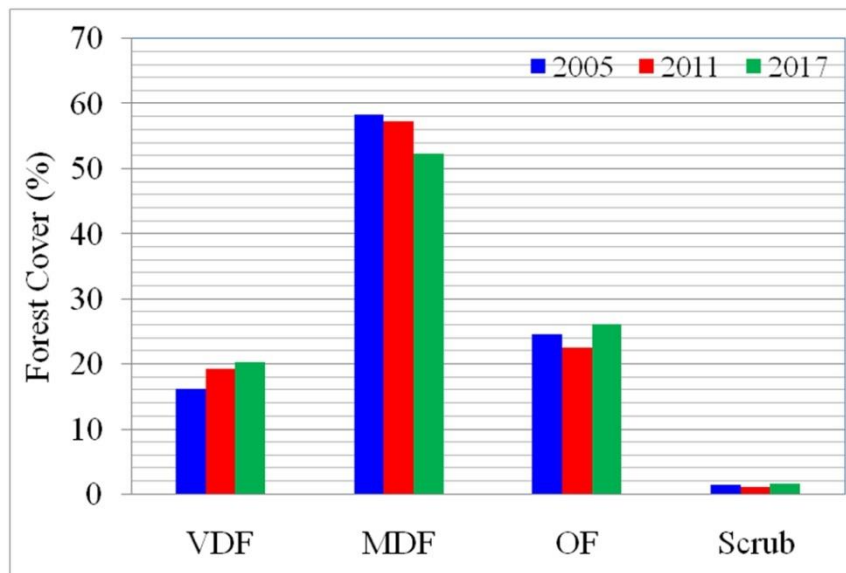


Figure 2. Forest types and their proportion of total forest cover

Vertical Distribution of Forests

Vertical distribution of geographical area and forest cover in Uttarakhand in 2011 and 2017 were described (Table 1). Forest cover is analyzed according to altitude. The further percentage share of forest cover from a total geographical area and total forest area was analyzed. Altitudinal zones vary from <500 m to >3000 m. The highest geographical area is found between 1000-2000 m, which is 32.83%, followed by area >3000 m with 28.11%. The lowest geographical area lies between 500-2000 m (10.66%), followed by area <500 m altitude (14.84%). In 2011, the percentage share of the geographical area within the altitude zone was

the highest between the altitudes 2000-3000, which was 80.81%, followed by the altitude 500-1000 m (69.59%), and 1000-2000 m (56.04%). The lowest percentage share of the geographical area lies >3000 m, which was 12.2%. The average forest cover was 45.8%. In terms of percentage share of forest cover, it was the highest at the altitude of 1000 m and 2000 m (40.17%), followed by the altitude 2000-3000 m (23.91%). The lowest forest cover lies >3000 m (7.49%), followed by 12.23% forest cover, lies <500 m. In 2017, the percentage share of geographical area decreased to 45.43% (0.37%). The percentage share was the highest between 2000 m and 3000 m (79.55%), with a little decrease than in 2011. The percentage share was 69.44% in 500-1000 m. At the altitude of 1000-2000 m, it was 57.11%. The lowest percentage share was >3000 m (10.93%). The percentage share of forest cover in 2017 was the highest in the altitude of 1000-2000 m (41.28%), followed by the altitude 2000-3000 m (23.73%), and 16.3% in the altitude of 500-1000 m. The lowest forest share was >3000 m, followed by <500 m (11.93%).

Table 1. The percentage share of total geographical area and total forest cover in 2011 and 2017

Altitude zone	Total geographical area	2011		2017	
		% share of the geographical area (within the altitude zone)	% share of forest cover	% share of the geographical area (within the altitude zone)	% share of forest cover
<500	7937 (14.84)	37.73	12.23	36.51	11.93
500-1000	5703 (10.66)	69.59	16.2	69.44	16.3
1000-2000	17560 (32.83)	56.04	40.17	57.11	41.28
2000-3000	7248 (13.55)	80.81	23.91	79.55	23.73
>3000	15035 (28.11)	12.2	7.49	10.93	6.76
Total	53483 (100%)		24496 45.8%	24295 45.43%	24295 (100%)

Source: Based on the SRTM digital elevation model, forest survey of India 2017

Figure 3 shows altitude wise forest cover different types of forests according to their density and species types. Forest cover extended from <500 m to >3000 m. In all the altitudinal zones, forests are extended as OF, MDF, and VDF while their proportion varies. Forest cover is the highest at the altitude of 1000-2000 m with a high proportion of OF and less proportion of VDF. It is followed by the altitude 2000-3000 m where the proportion of VDF is high and OF is low. Forest proportion is the lowest in the altitude of >3000 m with a low proportion of VDF. Similarly, area <500 m has a low proportion of forest cover whereas the portion of MDF and VDF is high. VDF is found in the altitude of 500-1000 m, although this region obtains the third place in forest cover. In terms of forest species, deciduous monsoon forests are found <500 m where biodiversity is high. Scrubs and bushes are found between 500 m and 1000 m although, in this zone, pine forests are sparsely found. Scrubs and bushes are found almost all the altitudinal zones however their proportion is significantly less. A large proportion of forest is covered by pine forests with high OF and less VDF. Pine is single specie, therefore,

biodiversity is less in this zone. Mixed oak forests and coniferous forests are found between 2000 m and 3000 m. The mixed oak forests have high biodiversity whereas coniferous forests have moderate biodiversity. The alpine grasslands are found >3000 m where natural vegetation is sparsely distributed.

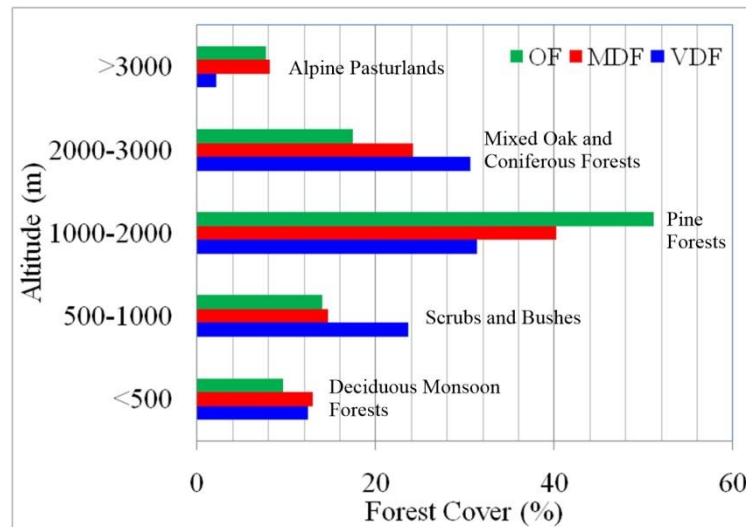


Figure 3. Percentage of forest covers under different forests and in different altitudes, 2017. The altitudinal zone and density-wise forest cover in 2011 and 2017 were analyzed (Table 2). Among all forests, MDF covers the highest area and VDF covers the lowest area. A total area under VDF was 19.44% in 2011, which increased to 20.45% in 2017. MDF had 57.83% cover in 2011 while it has decreased to 53.03% in 2017. Under OF, it was 22.73% in 2011 and 26.52% in 2017. Altitude wise VDF in 2011 was recorded 27.08% in 2011 at the altitude of 2000-3000 m whereas it was 29.62% (highest) in 2017. The lowest area under VDF was recorded as 7.96% >3000 m in 2011 and 6.39% in 2017 at the same altitude. In the altitude of 1000-2000, VDF was recorded as 15.71% and 15.15% in 2011 and 2017, respectively. MDF covers the highest area <500 m, which is 58.73%, followed by 56.50% between 1000 m and 2000 m, and 54.57% in the altitude of 500-1000 m. Its area >3000 m is the lowest (7.96%). In 2017, MDF covers 63.30% (highest) in the altitude of >3000 m, followed by 57.50% <500 m. OF covers almost equal areas in both years, variation is highest 32.85% in 2017 (1000-2000 m) and 14.61% (lowest) in 2011 (>3000 m).

Table 2. Altitudinal zone and density-wise forest cover 2011 and 2017 (area in sq km)

Altitudinal zone	2011			2017		
	VDF	MDF	OF	VDF	MDF	OF
<500	17.63	58.73	23.64	21.19	57.50	21.50
500-1000	24.09	54.57	21.34	29.62	47.63	22.75
1000-2000	15.71	56.50	27.79	15.51	51.65	32.85
2000-3000	27.08	27.08	17.23	26.40	54.08	19.53
>3000	7.96	7.96	14.61	6.39	63.30	30.31
Total	19.44	57.83	22.73	20.45	53.03	26.52

Source: Based on the SRTM digital elevation model, forest survey of India 2017

Horizontal Distribution of Forests

Horizontal distribution of forests in Uttarakhand is analyzed through district-wise forest cover, state and district shares of forest cover, and density-wise forest cover at the district level. District-wise forest cover varies from the districts of a mountainous mainland and plain regions (Figure 4) in three different periods. The highest forest cover was obtained by four districts – Nainital, Champawat, Pauri, and Bageshwar, which is higher than 60%. The above 40% of forest cover was obtained by Tehri, Rudraprayag, Dehradun, and Almora. All other districts – Uttarkashi, Chamoli, Pithoragarh, Haridwar, and USN have 20% to 40% forest cover. An increase in forest cover from 2005 to 2017 has obtained by Almora, Champawat, Pauri, and Tehri districts whereas five districts – Bageshwar, USN, Tehri, Uttarkashi, and Haridwar received a decrease in forest cover. There was almost no change in forest cover in Chamoli, Dehradun, and Pithoragarh districts.

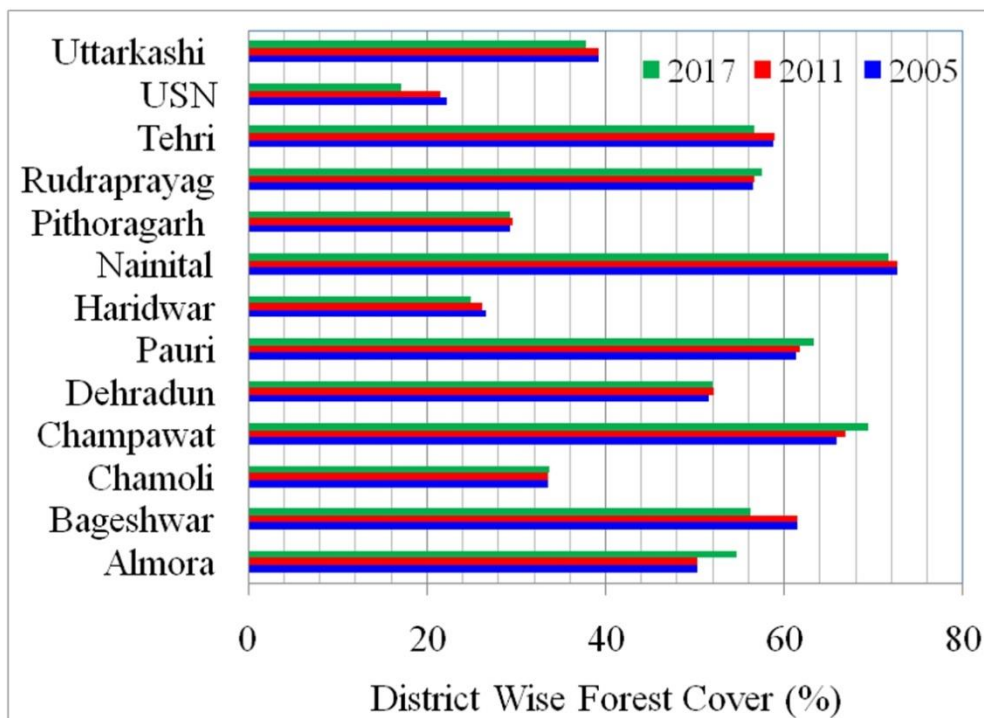


Figure 4. District wise forest cover in %

District-wise distribution of VDF, MDF, and OF in 2017 was analyzed (Table 3). The highest forest cover under VDF was obtained by Dehradun (39.63%) district, followed by USN (34.4%), and Champawat (29.98%) districts. VDF in Nainital and Rudraprayag districts is 25.1% and 24.3%, respectively. The Almora district has the lowest area (11.58%), followed by Haridwar district (12.76%), and Tehri district (13.2%). MDF obtained the highest area (53.03%), of which, 60.43% is obtained by the Bageshwar district, which is the highest. Chamoli district has the second-highest area under MDF (58.32%), followed by two districts – Pauri and Uttarkashi (56.72% and 56.77%, respectively). Meanwhile, the Dehradun district has the lowest area under MDF (39.1%). Other districts have an average area under MDF. OF has 26.52% (second highest) area. Under this category, Haridwar (40.14%) and Almora (39.7%) districts possessed the highest area, followed by Tehri (34.29%) and Pithoragarh (29.26%). The lowest area was possessed by three districts – Champawat, Dehradun, and USN equally.

Table 3. District-wise distribution of VDF, MDF, and OF, 2017

District	VDF	MDF	OF
Almora	11.58	48.72	39.7
Bageshwar	12.85	60.43	26.72
Chamoli	16.35	58.32	25.32
Champawat	29.98	48.45	21.57
Dehradun	39.63	39.1	21.37
Pauri	16.26	56.72	27.02
Haridwar	12.76	47.12	40.14
Nainital	25.1	57.15	17.75
Pithoragarh	24.3	46.44	29.26
Rudraprayag	22.1	50.83	27.1
Tehri	13.2	52.54	34.29
USN	34.4	44.27	21.33
Uttarkashi	19.52	56.77	23.71
Uttarakhand	4969 (20.45%)	12884 (53.03%)	6442 (26.52)

District and state share of forest cover in 2005 and 2017, respectively was analyzed (Figure 5; Table 4). Total forest cover is 45.43% (2017) with is less than the forest cover 45.70% in 2005. At the state level, forest cover varies from 71.7% in Nainital (highest) to 17.15% in USN (lowest). In terms of the state share of forests in 2017, it is the highest in the Pauri district (13.97%) and the lowest in USN which is 1.79%. Four districts – Nainital, Champawat, Bageshwar, and Pauri – have >60% forest cover, three districts – Pithoragarh, Haridwar, and USN districts of <30% forest covers and other six districts have between 30-60% forest cover. In terms of the state share of forest cover, Pauri, Uttarkashi, Nainital, and Chamoli district have >10% share, which is the highest. Champawat, Rudraprayag, Haridwar, and USN districts have <5% state share and 5-10% state share forests are obtained by Tehri, Pithoragarh, Dehradun, Almora, and Bageshwar districts. The figures are almost the same in all three years – 2005, 2011, and 2017 with small changes in their areas.

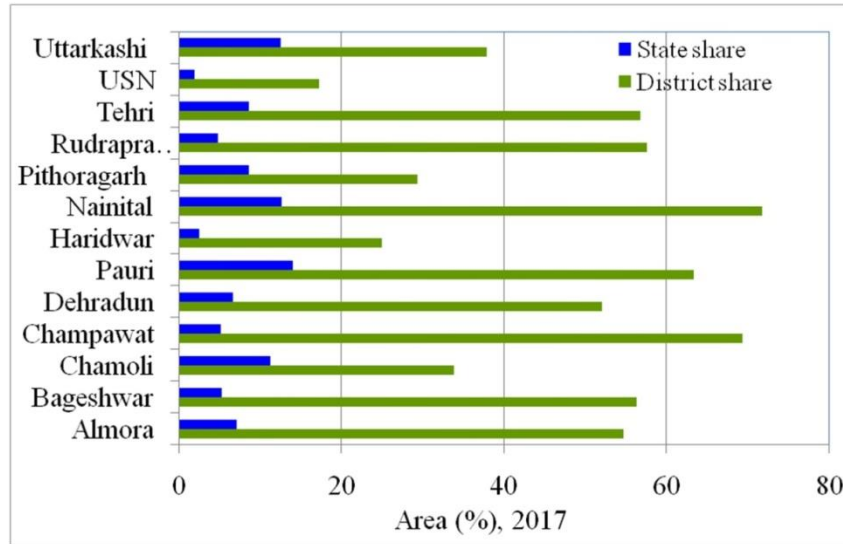


Figure 5. District and state share of forest cover

Table 4. District and state share of forest cover Uttarakhand

District share 2005		
Level	Indices (%)	Districts
High	>60	Nainital, Champawat, Bageshwar, Pauri
Medium	30-60	Tehri, Rudraprayag, Dehradun, Almora, Uttarkashi, Chamoli
Low	<30	Pithoragarh, Haridwar, USN
State share 2005		
Level	Indices (%)	Districts
High	>10	Pauri, Uttarkashi, Nainital, Chamoli
Medium	5-10	Tehri, Pithoragarh, Dehradun, Almora, Bageshwar
Low	<5	Champawat, Rudraprayag, Haridwar, USN
District share 2011		
Level	Indices (%)	Districts
High	>60	Nainital, Champawat, Pauri, Bageshwar
Medium	30-60	Tehri, Rudraprayag, Dehradun, Almora, Uttarkashi, Chamoli
Low	<30	Pithoragarh, Haridwar, USN
State share 2011		
Level	Indices (%)	Districts
High	>10	Pauri, Uttarkashi, Nainital, Chamoli

Medium	5-10	Tehri, Pithoragarh, Dehradun, Almora, Bageshwar
Low	<5	Champawat, Rudraprayag, Haridwar, USN

District share 2017

Level	Indices (%)	Districts
High	>60	Nainital, Champawat, Pauri
Medium	30-60	Rudraprayag, Tehri, Bageshwar, Almora, Dehradun, Uttarkashi, Chamoli
Low	<30	Pithoragarh, Haridwar, USN

State share 2017

Level	Indices (%)	Districts
High	>10	Pauri, Nainital, Uttarkashi, Chamoli
Medium	5-10	Pithoragarh, Tehri, Almora, Dehradun, Bageshwar, Champawat
Low	<5	Rudraprayag, Haridwar, USN

Data of 2017 on forest cover is presented in Figure 5. The districts where forest cover is >60% are Pauri, Nainital, and Champawat. The five districts – Bageshwar, Almora, Rudraprayag, Tehri, and Dehradun have forest cover between 40% and 60%. Forest cover between 20% and 40% is obtained by the districts Uttarkashi, Chamoli, Pithoragarh, and Haridwar, and USN obtains <20% forest cover.

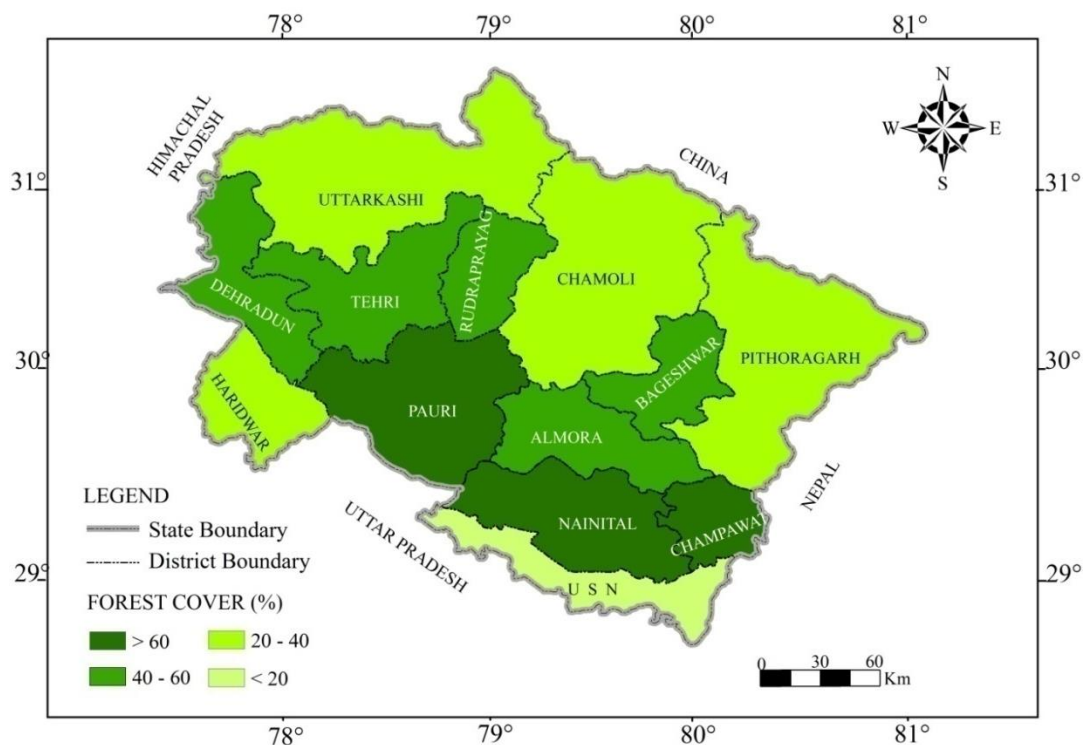


Figure 6. District wise horizontal distribution of forest (%) in Uttarakhand Himalaya

Mean value (sq km) and a standard deviation of different forest types in 2005, 2011, and 2017 in Uttarakhand have been illustrated (Table 5). VDF has increased from 307 in 2005 to 366 in 2011 and 382 in 2017. Meanwhile, MDF has decreased from 1107 in 2005 to 1089 in 2011, and 991 in 2017. In terms of open forest, it has decreased between 2005 and 2011 whereas in 2017 it has increased substantially. This similar situation was noticed in terms of scrub which has decreased from 2005 to 2011 and increased from 2011 to 2017. So there is an overall increase in OF and scrubs. The total forest area has decreased during the corresponding period.

Table 5. Mean value and standard deviation of different forest types (n=13 districts)

Variables	2005		2011		2017	
	Mean value	Std. Deviation	Mean value	Std. Deviation	Mean value	Std. Deviation
VDF	307	164	366	190	382	216
MDF	1107	637	1089	627	991	577
OF	464	198	428	148	495	245
Scrub	24.6	28.9	20.8	26.1	29.5	37.8
Total forests	1880	938	1884	943	1868	955

Change in Forest Cover

Altitudinal Change in Forest Cover

Altitudinal changes in forest cover between 2011 and 2017 were analyzed (Table 6). An increase in VDF was found between 500 m and 1000 m (highest) i.e. 22.7%. It was seconded by 16.29% increase <500. A small proportion of VDF has increased (0.58%) between 1000 m and 2000 m. VDF decreased substantially by 28.08% >3000 m. Between 2000 m and 3000 m, it has decreased by 4.04%. There was an overall increase in VDF (4.35%). MDF decreased in all the altitudinal zones which a decrease of 26.76% (highest) >3000 m. It decreased by 12.93% between 500 m to 1000 m. In other altitudes, it decreased by less than 7%. The overall decrease was 9.06%. Except for a decrease of 12.01% <500 m, OF registered an increase under its area with the highest increase by 85.82% >3000 m and 20.44% between 1000 m to 2000 m. An increase of 11.6% between 2000 m and 3000 m and 6.38% between 500 m and 1000 m was also registered. The overall increase was observed by 15.72% in OF.

Table 6. Altitudinal change in forest cover in percentage (2011-2017)

Altitude zone	VDF	MDF	OF
<500	+16.29	-5.57	-12.01
500-1000	+22.7	-12.93	+6.38
1000-2000	+0.58	-6.85	+20.44
2000-3000	-4.04	-4.41	+11.6
>3000	-28.08	-26.76	+85.82
Total	+4.35	-9.06	+15.72

Horizontal Change in Forest Cover

Density-wise horizontal changes in forest cover were described (Table 7). There was a decrease in total forest cover in entire Uttarakhand. District wise highest increase in forest cover was noticed in Almora district (8.94%) followed by Champawat (5.34%), and Pauri (3.76%). Other districts where an increase in total forest area was registered were Rudraprayag, Chamoli, Dehradun, and Pithoragarh. In the meantime, USN has registered the highest decrease (22.7%), followed by Bageshwar (8.62%), Haridwar (6.67%), Uttarkashi (3.69%), and Tehri (3.41%). Nainital district registered only a 1.3% decrease in forest cover. It has been noticed that VDF has an increase in all the districts of Uttarakhand. Haridwar district has registered the highest increase in VDF (158.62%) and the Bageshwar district obtained the lowest increase of 1.89%. In the meantime, except for the Chamoli district, which has obtained a small increase in MDF which is 1.41%, all other districts have registered a decrease in MDF, which varies from 21.54 (highest) in USN to 1.98% (lowest) in Champawat. OF has observed mixed change. Six districts registered an increase in open forests, 60.85% highest in Pithoragarh and 6.53% lowest in Uttarkashi district. On the other hand, seven districts have registered a decrease in OF cover, which varies from 22.4% highest in the Dehradun district to 2.6% lowest in the Bageshwar district.

Table 7. Change in forest cover in percentage (2005-2017)

District	Total forests	VDF	MDF	OF
Almora	+8.94	+18.45	-13.62	+55
Bageshwar	-8.62	+1.89	-12.91	-2.6
Chamoli	+0.41	+9.11	+1.41	-6.54
Champawat	+5.34	+12.23	-1.98	+14.78
Dehradun	+0.75	+30.6	-5.72	-22.4
Pauri	+3.76	+22.67	-6.78	+21.3
Haridwar	-6.67	+158.62	-15.29	-13.87
Nainital	-1.3	+39.6	-10.02	-10.43
Pithoragarh	+0.05	+7.45	-21.48	+60.85
Rudraprayag	+1.88	+40.78	-4.13	-8.04
Tehri	-3.41	+19.82	-13.55	+7.93
USN	-22.7	+4.17	-21.54	-46.55
Uttarkashi	-3.69	+44.85	-16.63	+6.53
Uttarakhand	-0.6	+24.16	-10.5	+6.59

DISCUSSION

It has been noticed that overall forest cover has decreased from 2005 to 2017 with a small proportion. VDF has increased during the period because they are located in remote areas, where human interference is less. Meanwhile, MDF has the highest cover whereas it has decreased largely during the period because they are located in and surroundings of the rural settlements and human pressure are high in these forests. OF occupies second place and its proportion is variable however, it has increased. Scrubs cover less area and unchanged during the period.

Percent share of geographical area and percent share of forest cover during 2011-2017 was the highest between 500 m and 3000 m because of area <500 m is densely populated and fertile agricultural plain. Further, the area >3000 m is no man land. It is alpine pastureland and forest cover is minimal. Altitude and density-wise forest cover reveal that VDF is found in <1000 m and 2000 m to 3000 m because in two zones forest diversity is high. The first zone is mixed sub-tropical deciduous forests and the second zone obtains mixed-oak forest with high diversity. Meanwhile, the pine forest, which is found between 1000 m and 2000 m, is OF, because pine forest is a single species. Similarly, area <3000 m is alpine pasturelands where vegetation cover is almost nil therefore the proportion of VDF is less in these areas. It is revealed from the analysis that altitude-wise forest density is dependent on its diversity. The areas where forest diversity is high, forest density is found high and vice-versa.

In terms of horizontal distribution of forests, two situations have been observed. The first one is that the districts, which are located in the plains region, have less forest cover because a large proportion of the area is under agriculture, and settlements are densely located. The second situation is of the districts, which have a large proportion of area under snow-clad and alpine pasturelands. The highest forest cover is found in Nainital, Champawat, Bageshwar, Pauri, Tehri, and Rudraprayag because they are mountainous districts and the forests are inaccessible and unused. Pauri, Almora, and Champawat districts received an increase in forest cover. From Pauri and Almora districts, the exodus population has out-migrated. Therefore, forest cover has increased. In Champawat district, an increase in the forest is due to its inaccessibility. Haridwar and USN registered a decrease in forests because of the in-migration and depletion of forests.

The state share of forest cover is the highest in Pauri, Uttarkashi, Nainital, and Chamoli districts because these districts have the highest geographical area and consequently their state share is high. Those districts are small; the state share of forests in these districts is less. Similarly, the state share of forest cover is the lowest in USN and Haridwar districts as they obtain a large arable land with less forest cover.

District-wise forest density reveals that VDF is highest in Dehradun, USN, and Champawat districts. Two national parks – Raja Ji in Dehradun and Corbett in USN are the reasons for VDF in these two districts. Further, forest type is deciduous monsoon forests with high biodiversity. Therefore, the area under VDF is high. Bageshwar, Chamoli, Nainital, and Pauri districts have a large area under pine forests and scrubs therefore MDF area is high in these districts. OF proportion is the highest in the Haridwar district, followed by Almora, and Tehri districts because a large area is under scrubs.

MDF is observed to be decreased at all altitudes. Meanwhile, OF has increased in all the altitudes except <500 m. As it has been discussed that MDF is found in and surrounding the human habitats where they have depleted largely. Similarly, VDF has increased in all the altitudes except above >3000 m. This increase took place mainly due to the rigorous implementation of forest act and also because VDF is the reserved forests and inaccessible. District-wise change in forest cover shows that VDF increased in all the districts whereas MDF decreased. Total forest cover decreased in some districts.

CONCLUSION

Vertical and horizontal distribution of forests in the Uttarakhand Himalaya was analyzed. This study reveals that vertical distribution of forest and forest density varies according to altitudes. Forest cover is the highest between 1000 m and 3000 m whereas forest cover is the lowest <500 m and >3000 m. In terms of density-wise forests, MDF cover is the highest followed by OP and the lowest is of the VDF. District-wise forest distribution also varies from the plain districts to mountain districts. Plain districts have less forest cover than to the mountain districts. Further, those mountainous districts, which have a vast area under snow-clad, forest cover is less. Forest cover increased in the highlands and it decreased in the middle altitude, the valley region, and in surroundings of human habitat, because of large forest depletion. Although, forest area increased by 1.4% in Uttarakhand during the last two years however, the increase was due to forestation program. It has been observed that forest management is practiced at the community level through *Van Panchayats* and as a result, forest area has increased.

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