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QUANTITATIVE DESCRIPTION, PRESENT STATUS AND FUTURE TREND OF CONIFER FORESTS GROWING IN THE INDUS KOHISTAN REGION OF KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

Forest structure unlocks our understanding of species distribution, function, history, and future prospects of an ecosystem. In this study, for determination of present status and future trend, the conifer forests of Indus Kohistan were quantitatively analyzed. *Cedrus deodara, Pinus wallichiana, Abies pindrow,* and *Picea smithiana* were the most common species, whereas *Taxus wallichiana* and *Pinus gerardiana* were observed in two and one sampling stands respectively. The *Pinus wallichiana*-deodar located in Semo dara forest occupied the highest density (461 plants ha^{-1}), whereas the highest basal area was occupied by Kolai forest (192.42 m^2ha^{-1}) with similar floristic composition. The lowest density (215.71 plants ha^{-1}) and basal area (45.71 m^2ha^{-1}) occupying forests were recorded from the Sharakot and Pattan sampling sites respectively. The pure forest of *Cedrus deodara* demonstrates a maximum number of trees in the medium and large size classes. *Abies pindrow* was observed in 11 sampling sites, showing the size class distribution in a haphazard way, whereas *Picea smithiana* showed a uniform distribution. Most of the forests revealed bell shape structures, indicating the highest individuals in the medium size classes, while fewer individuals in the small and old size classes. The gaps in the size class distribution indicating anthropogenic disturbance. Our findings show that regeneration potential and deforestation in the Indus Kohistan region are at an alarming rate, which needs prompt action for protection.

Key words: Density, Diameter size classes, Conifer forests, Present status, Future trend, Indus Kohistan.

Introduction

Forest structure plays a crucial role in species distribution, function, history, and prospects of an ecosystem. In addition, forest structures also intercept radiation and ground moisture, which support herbs, shrubs, and regeneration potential (Franklin & Spies, 1991). Therefore, knowledge of forest structure and species composition is vital.

The total forested area of Pakistan is about 2.5%, which is very low compared to 23-70% of other countries (Ahmed *et al*., 2010; Wahab, 2011; Khan, 2012). Besides this, the deforestation rate is more than 3% in a year (Anon., 2005; Cronin & Pandya, 2009). One-thirds of the forest area are facing anthropogenic disturbance and consider as a productive forest, while the remaining two-thirds are the protective forests (Sethi, 2001). The lesser Himalayas, Hindu Kush, and Karakoram Range possess tropical conifer forests and broad leaves species having a significant impact on productive forests (Khan *et al*., 2014). Abbasi (2006) explored that from 1990 to 2005 more than 24.7% of the total forest population was lost in Pakistan.

For the conservation and management of forests, quantitative information, structure, and estimation of tree populations are necessary. The population structure can be explored in terms of shape, size, and age (Harper & white, 1974). However, for the fecundity and survival of species in a particular area, the size classes of the trees are essential than age (Harper, 1977; Watkinson & White, 1986; Caswell, 1986; Weiner, 1986). According to Peter (1996), forest structure explains the past disturbance history, distribution, and event of particular species and the environment. The most essential character of forest structure is the size, shape, and distribution pattern of species *i.e.* vertical, horizontal, or spatial distribution (Spies, 1998). The information *i.e.* density, size class distribution, and edaphic factors have long been used by various researchers and foresters for the description of forest and its future trends (Ahmed, 1984). The forest structure is the important ecological attribute as well as the important signal of past environmental and anthropogenic disturbance (Timilsin *et al*., 2007; Gairola *et al*., 2008; Ahmed *et al*., 2010b). Some researchers studied structure of conifer forest from some specific regions of Pakistan (Ahmed & Qadir, 1976; Ahmed, 1988; Ahmed *et al*., 1990 a, b; Ahmed *et al.*, 1991, Ahmed *et al.*, 2006; Wahab *et al.*, 2008; Hussain *et al*., 2010; Akbar *et al.*, 2010; Khan *et al*., 2010; Akbar *et al*., 2014; Khan *et al.*, 2018). Though, these studies provided valuable information about size classes structure and species distribution confined at different localities of Pakistan. However, because of few studies, our understanding of forest structure, its dynamics, and its importance in ecosystem are scant. Therefore, for obtaining a clear picture of structure of Pakistan forests, more study is needed. Based on this context, conifer forests of Indus Kohistan were analyzed with the following specific objectives i) to carry out quantitative analysis various forests growing in the Indus Kohistan region in KP, Pakistan ii) to present structure and species composition of these ecological important forests iii) identify threaten forests of Indus Kohistan region and iv) to provide possible conservation strategy for the protection of these ecological important forests. The knowledge generated in this research have important implementation for the conservation and protection of conifer forest growing in Indus Kohistan region of KP, Pakistan.

Materials and Methods

Study area: This study was conducted in the Indus Kohistan region (34°.40´ to 35°.30´N; 75°.30´ to 75°.72´) of *Khyber Pakhtunkhwa*, northern Pakistan (Fig. 1). The total area covered by Indus Kohistan valley is about 2,893 Km^2. Geographically, the Indus Kohistan stretches from the border with Naran, Kaghan in the east, Districts Swat and Shangla in the west, Districts Mansehra and Battagram in the south while the Chilas, Darel, and Tangir valleys of Gilgit-Baltistan are located in the north. In this region, the terrestrial features of the world's largest three mountains system (*i.e.* Hindu Kush, Himalayan and Karakorum) boundaries with each other and serve as a natural vegetation and environmental region. Furthermore, Indus Kohistan consists of large dense conifers forests of Pakistan (Khan *et al*., 2016).

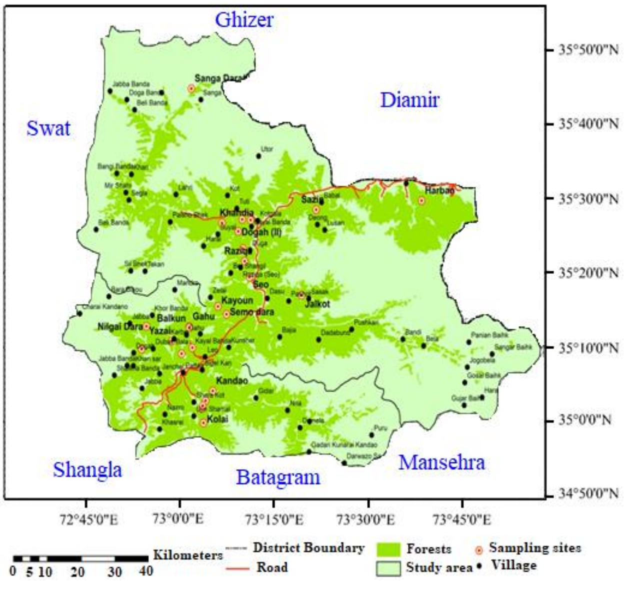

Fig. 1. Study area map extracted by Arc GIS showing sampling sites/stands from the Indus Kohistan region of KP, Pakistan.

Sampling methods and data collection: The conifer forests of the Indus Kohistan region are considered unprotected due to socioeconomic impact and lack of alternate energy sources in the region. In this study, a field survey was conducted in thirty different conifer-dominating forests of Indus Kohistan. Data was collected by using Point Center Quarter (PCQ) method of Cottam and Curtis (1956) with the modification of Ahmed & Ogden (1991). Diameters at breast height (dbh) of the tree were measured through dbh tape. For increasing the sampling size, the nearest tree to the previously measured tree was also measured followed by the method given in Ogden & Powell (1979).

Laboratory methods: Stands density (plants ha^{-1}) and basal area (m^2ha^{-1}) were calculated with the method given in Ahmed & Shaukat (2012). Density and basal area of each sampling sites were calculated (Ahmed & Shaukat, 2012). Based on dbh size classes (*i.e.* small class= 10-30 cm; medium class= 30.1-60 cm; large class= 60.1-90 cm; extra-large class= 90.1-120 cm & mature size class= 120.1-150 cm) were established (Parker & Peet, 1984; Rebertus & Veblen, 1993; Johnson, 1997; Rigg *et al*., 1998; Ahmed & Naqvi, 2005).

Results

Summary of sampling forest *i.e.* name of the sampling sites, geographical coordinates, ecological characteristic, dominant species, and absolute quantitative values are presented in Table 1. The size classes distribution structure and density of each stand are given in Fig. 2. Description of each sampling forest are following.

Pattan (Chawa dara) forest: In this forest, *Pinus wallichiana* and *Cedrus deodara* species were observed. Both species have an equal density (*i.e.* 168 plants ha^{-1}), whereas the basal area of both species were 28.33 m^2ha^{-1} and 36.64 m^2ha^{-1}respectively (Table 1). The forest structure of this forest explains 21.3% individuals in small class, 57.51% individuals in medium class, and 21.32% individuals in large size class. The structure of this forest indicates better recruitments (Fig. 2.1). However, the number of individual in the large class was comparatively low. Similarly, no individual seen in the extra-large and mature classes, indicating the uncertain structure.

Pattan (Yazai) forest: This forest was dominated by *Cedrus deodara* having a density of 128 plants ha^{-1} and a basal area of 28.33 m^2ha^{-1}.The co-dominant *Pinus wallichiana* occupied a density of 97 plants ha^{-1} with a basal area of 16.58 m^2ha^{-1}. The associated *Quercus baloot* obtained the lowest density and basal area (Table 1). The structure of this forest demonstrates 11.3% individuals in small class, 83.8% individuals in medium class, and 4.8% individuals in large class. In this forest, no seedlings were seen. The structure of this forest indicates only few individuals of *Quercus baloot* in the small size class (Fig. 2.2). The present status of this forest shows that both conifer species are struggling for survival.

Sharakot (Kandao) forest: Kandao forest comprises by five different trees species. *Cedrus deodara* was the dominant conifer species having a density of 146 plants $ha^{-1}$with a basal area of 23.86 m^2ha^{-1}. The co-dominant *Picea smithiana* occupied a density of 73 plants $ha^{-1}$with a basal area of 16.79 m^2ha^{-1}. The associated species occupied comparatively low density and basal area (Table 1). The structure of this forest explains 22.8% in small class, 54.8% individuals in medium class, and 22.6% individuals in large class. The structure of this forest demonstrates few individuals in the early and large classes (Fig. 2.3). Gaps in old size classes indicate socioeconomic disturbance in the area.

Table 1. Geographical information, species names, density and basal area of thirty sampling sites from the Indus Kohistan region of KP, Pakistan.

Sr. No	Name of sampling sites	Latitude (N)	Longitude (E)	Elev (m)	Slope	Cano	Spp names	Density (plants ha^{-1})	B.A (m^2ha^{-1})
1.	Pattan (Chawa dara)	35°10´05.02´´	72°58´38.08´´	2082	33°	Mod	*P.w*	168	36.64
							C.d	168	28.33
2.	Pattan (Yazai)	35°10´05.59´´	72°58´12.55´´	2082	33°	Open	*P.w*	128	21.27
							C.d	97	16.58
							Q.b	85	7.84
3.	Sharakot (Kandao)	35°01´52.07´´	73°03´18.12´´	2369	44°	Open	*P.w*	95	21.07
							P.s	57	15.22
							C.d	35	6.78
							Q.B	16	1.13
							A.p	14	3.23
4.	Sharakot	35°02´49.07´´	73°04´01.19´´	2540	37°	Mod	*C.d*	146	23.86
							P.s	33	16.79
							P.w	57	10.80
							T.w	49	8.81
5.	Sharakot Dot	35°02´08.03´´	73°03´34.12´´	2435	57°	Open	*A.p*	146	36.04
							P.w	31	19.69
							C.d	20	4.15
							P.s	10	1.64
6.	Khawargai	35°01´47.08´´	73°03´28.09´´	2727	48°	Mod	*P.w*	118	24.90
							A.p	79	18.89
							P.s	66	15.31
7.	Shirial (Kuz)	35°02´08.03´´	73°03´34.02´´	2369	30°	Open	*P.w*	104	42.26
							C.d	128	21.10
8.	Dubair Bala (Kuz Gaya)	35°09´44.09´´	72°53´49.09´´	2351	43°	Mod	*P.w*	178	83.39
							C.d	125	83.39
9.	Dubair (Nilgai Dara)	35°12´49.44´´	72°54´36.32´´	2671	35°	Open	*A.p*	140	49.18
							P.w	74	22.57
							C.d	67	13.50
10.	Kolai (Ujin shamal)	35°00´23.11´´	73°00´44.50´´	2085	40°	Close	*P.w*	283	96.12
							C.d	161	96.12
11.	Kayal (Balkun)	35°12´46.56´´	73°01´25.41´´	2180	39°	Mod	*C.d*	205	49.11
							P.w	137	31.62
							A.p	49	13.46
12.	Kayal (Gahu)	35°12´46.46´´	73°01´25.51´´	2390	49°	Mod	*C.d*	208	54.22
							P.w	170	38.43
13.	Kayal (Shangol)	35°12´38.56´´	73°01´35.31´´	2010	22°	Mod	*P.w*	250	55.24
							C.d	158	39.50
14.	Semo dara	35°12´46.46´´	73°´01´25.51´´	2180	25°	Close	*P.w*	377	84.04
							C.d	94	24.80

Table 1. (Cont'd.).

Sr. No	Name of sampling sites	Latitude (N)	Longitude (E)	Elev (m)	Slope	Cano	Spp names	Density (plants ha^{-1})	B.A (m^{2}ha^{-1})
15.	Semo (Kayoun)	35°13´56.44´´	73°01´35.41´´	2317	60°	Close	*C.d*	461	117.74
16.	Sanga Dara (I)	35°44´46.36´´	73°01´45.51´´	2475	59°	Open	*P.w*	121	54.88
							C.d	109	23.47
17.	Sanga Dara (II)	35°22´56.46´	73°03´35.1´´	2690	29°	Open	*P.w*	210	76.49
							A.p	34	9.83
18.	Sanga Galto	35°18´16.26´´	73°03´57.51´´	2780	45°	Open	*P.w*	163	77.19
							C.d	73	23.72
							A.p	42	14.41
19.	Sanga (Khanki)	35°09´56.56´´	73°01´55.51´´	2503	30°	Open	*A.p*	222	68.66
							P.w	90	35.14
							C.d	30	4.65
20.	Seo	35°02´08.03´´	73°03´34.02´´	2435	40°	Mod	*C.d*	353	5554
							P.w	47	16.38
							P.s	21	5.56
21.	Raziqa (Dhar)	35°02´55.7´´	73°02´2.25´´	2540	47°	Close	*A.p*	216	92.13
							P.s	193	55.07
							C.d	45	12.38
22.	Dogah (I)	35°01´52.7´´	73°03´18.2´´	3044	53°	Close	*P.s*	135	42.01
							C.d	122	33.14
							A.p	57	32.93
							P.w	35	13.83
23.	Dogah (II)	35°53´0.36´´	73°51´0.07´´	2635	58°	Close	*C.d*	345	96.76
24.	Dassu (Duga)	34°08´0.56´´	73°56´.54´´	3110	45°	Open	*A.p*	159	78.97
							P.s	111	31.60
							P.w	15	7.86
							C.d	11	2.84
25.	Gayal (I)	35°24´0.36´´´	73°36´0.50´´	3060	55°	Mod	*C.d*	256	77.45
							P.g	85	18.54
26.	Gayal (II)	34°01´0.55´´	73°36´0.09´´	3380	60°	Mod	*C.d*	254	37.64
							P.g	32	7.07
							A.p	32	4.25
27.	Khandia (Seyal)	35°01´42.57´´	73°02´5.62´´	2995	36°	Open	*C.d*	295	53.32
28.	Sazin	35°10´0 .54´	73°20´0.06´´	2680	60°	Open	*C.d*	232	42.7
29.	Harban	35°12´46.86´´	73°01´25.81´´	2317	29°	Open	*C.d*	152	39.91
							P.w	177	38.39
30.	Jalkot (sasak)	35°01´44.5´´	73°02´30.6´´	2375	37°	Mod	*P.w*	195	52.30
							A.p	84	16.72
							C.d	27	5.26

Key for abbreviation and species authority: *P.w*= *Pinus wallichiana* A.B. Jackson, *C.d*= *Cedrus deodara* (Roxb. Ex Lamb.) G. Donf., *A.p*= *Abies pindrow* Royle, *P.s*= *Picea smithiana* (Wall.) Boiss., *P.g*= *Pinus gerardiana*, T.s= *Taxus wallichiana* Zuccarini; *Q.b*= *Quercus baloot* Griff, Cano= Canopy and Mod= Moderate.

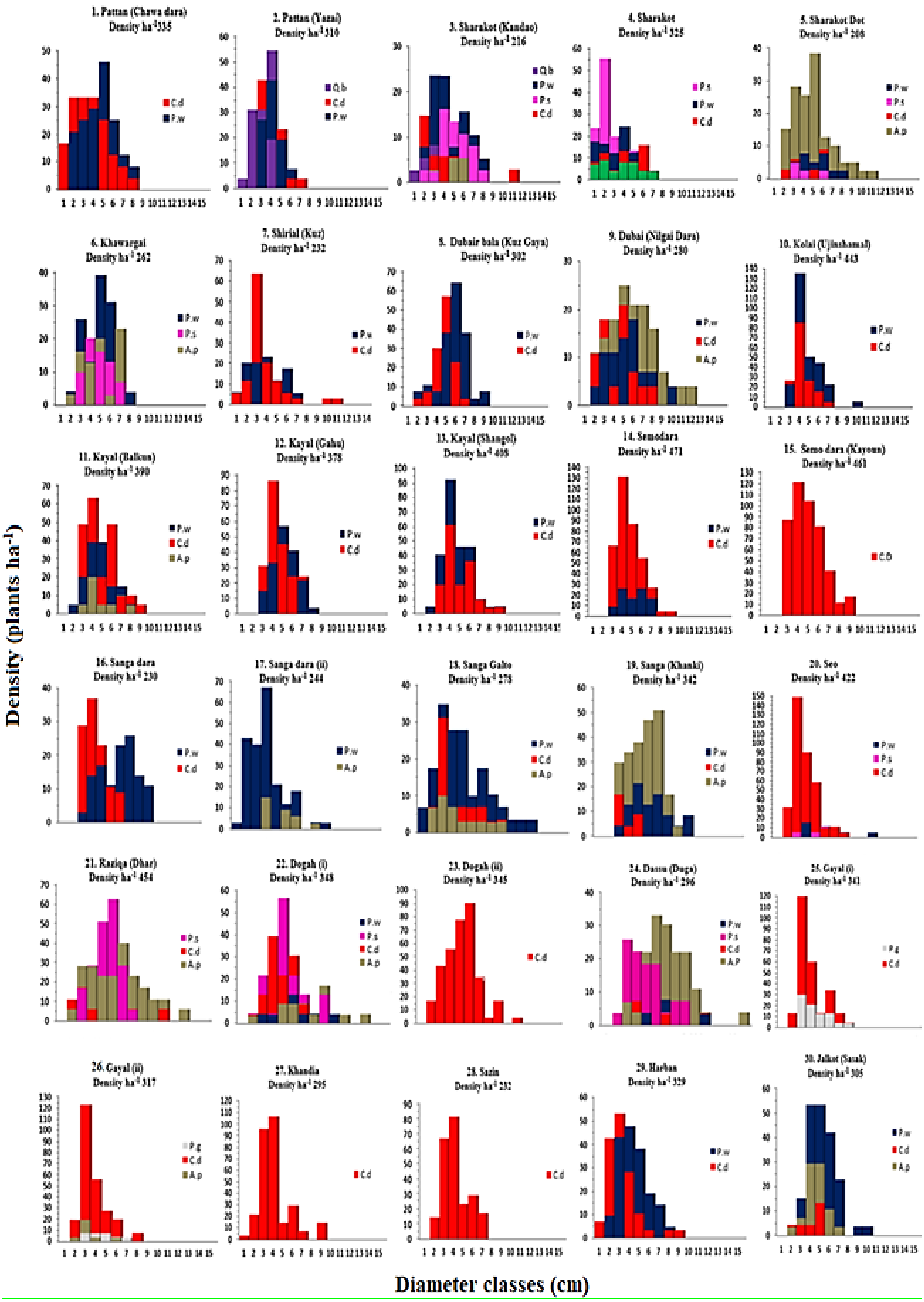

Fig. 2. Bar diagrams showed distribution of different size classes and their density in 30 different forests from Indus Kohistan region of Pakistan.

Main Sharakot forest: Sharakot forest comprised of four different species. *Cedrus deodara* was the dominant species having a density of 146 plants $ha^{-1}$with a basal area 23.86 m^2ha^{-1}, whereas the co-dominant *Picea smithiana* obtained a density of 73 plants ha^{-1} with 16.79 m^2ha^{-1} basal area. The associated species occupied comparatively low density and basal area (Table 1). The structure of this forest reveals 23.1% individuals in small class, 55.3% individuals in medium class, and 23.2% individuals in large class. Although, this forest indicates normal size class distribution in early class (Fig. 2.4). However, the less number of *Pinus wallichiana* and *Taxus wallichiana* shows the unstable structure.

Sharakot (Dot) forest: In this forest, *Abies pindrow* was dominant with a density of 146 plants ha^{-1} and a basal area of 36.04 m^2ha^{-1}, whereas *Pinus wallichiana* was the co-dominant with a density of 31 plants ha^{-1} and 19.69 m^2ha^{-1} basal area (Table 1). In this forest, 9% individuals occurred in the small class, 61.1% individuals in medium class, 25.2% in large class, and 5.3% individuals in extra-large class (Fig. 2.5). The bell shape structure of this forest indicates that there are few individual in early and mature classes.

Khwargai forest: In this forest, *Pinus wallichiana* was dominant with a density of 118 plants ha^{-1} and a basal area of 24.90 m^2ha^{-1}. The co-dominant *Abies pindrow* obtained a density of 79 plants ha^{-1} and 18.89 m^2ha^{-1} basal area. The associated species occupied the lowest density and basal area (Table 1). The structure of this forest demonstrates, 3.1% individuals in small class, whereas 66.4% and 31.3% individuals in medium and large classes respectively (Fig. 2.6). The structure of this forest indicated that medium-size trees are comparatively in better condition. However, the small and large trees need proper protection.

Shirial (Kuz) forest: In the Kuz Shirial conifer forest, the dominant *Pinus wallichiana* obtained a density of 104 plants ha^{-1} and a basal area of 42.26 m^2ha^{-1}, while the co-dominant *Cedrus deodara* occupied a density of 128 plants ha^{-1} and 21.10 m^2ha^{-1} basal area. The structure of this forest explains 19.1% individuals in small class, 65.3% individuals in medium class, 14.1% individuals in large class, and 2.1% individuals in extra-large class (Fig. 2.7). The structure of this forest indicates less individuals in old classes, and scattered distribution of *Pinus wallichiana*.

Dubair Bala (Kuz Gaya) forest: In this forest, *Pinus wallichiana* occupied a density of 140 plants ha^{-1}, whereas *Cedrus deodara* occurred with a density of 74 plants ha^{-1}. Both species occupied the same basal area (*i.e.* 83.39 m^2ha^{-1}) (Table 1). This forest has 6.1% individuals in small size class, 50.4% individuals in medium class, and 44.3% individuals in large class. The structure of this forest explains that *Pinus wallichiana* throughout all classes are in better condition however, a gap in the early size class indicates poor recruitment.

Dubair (Nilgai Dara) forest): Dubair forest was dominated by *Abies pindrow* with a density of 140 plants ha^{-1} and a basal area of 49.18 m^2ha^{-1}. The co-dominated *Pinus wallichiana* occupied a density of 74 plants ha^{-1} and a basal area of 22.57 m^2ha^{-1}. The structure of this forest demonstrates 9.3% individuals in small class, 48.2% individuals in medium class, 38.1% individuals in large class, 5.1% individuals in extra-large class, and 1.4% individuals in mature class. The gap in the early class indicates poor recruitment, whereas the absence of *Pinus wallichiana* and *Cedrus deodara* in the old classes demonstrates the socioeconomic activity.

Kolai (Ujin Shamal) forest: The Ujin Shamal forest of Kolai area was dominated by *Pinus wallichiana* having a density of 283 plants ha^{-1}. The co-dominant *Cedrus deodara* attained a density of 161 plants ha^{-1} (Table 1). The basal area of both species was same (*i.e.* 96.12 m^2ha^{-1}). This forest has 78.6% individuals in medium class, 20.2% individuals in large class, and 1.4% individuals in extra-large class. The bell shaped structure demonstrates less individual in early and mature classes (Fig. 2.10). Further, gaps in old classes indicates the socioeconomic disturbance.

Kayal (Balkun) forest: Balkun forest was dominated by *Cedrus deodara* with a density of 205 plants $ha^{-1}$and a basal area of 49.11 m^2ha^{-1}. The co-dominated *Pinus wallichiana* occupied a density of 137 plants $ha^{-1}$and a basal area of 31.62 m^2ha^{-1}. The associated *Abies pindrow* occupied the lowest density and basal area (Table 1). The structure of this forest explains 1.2% individuals in small class, 66.2% individuals in medium class, 31.2% individuals in large class, and 1.2% individuals in extra-large class (Fig. 2.11). Further, it also indicates low recruitment and less individuals in old classes.

Kayal (Gahu) forest: In this forest, *Cedrus deodara* was dominant with a density of 208 plants $ha^{-1}$and a basal area of 55.24 m^2ha^{-1}, whereas *Pinus wallichiana* was the co-dominant and occupied a density of 170 plants ha^{-1} and a basal area of 38.43 m^2ha^{-1} basal area (Table 1). In this forest, no individual was seen in the early classes. Both species occupied 69.4% individuals in the medium size classes, while 30.5% individuals in the large classes (Fig. 2.12). The structure of this forest demonstrates bell-shaped distribution, indicating the absence of recruitment and old size classes.

Kayal (Shangol) forest: In the Shangol forest, the dominant *Pinus wallichiana* occupied a density of 250 plants ha^{-1} and a basal area of 55.24 m^2ha^{-1}. The co-dominant *Cedrus deodara* obtained a density of 158 plants ha^{-1} with 39.50 m^2ha^{-1}basal area. The structure of this forest shows 1.3% individuals in small class, 68.8% individuals in medium class, 27.5% individuals in large class, and 2.5% individuals in extra-large class (Fig. 2.13). This forest demonstrates no recruitment and uneven distribution of size classes.

Semo dara forest: In this forest, *Pinus wallichiana* was dominant having a density of 377 plants ha^{-1} with 84.04 m^2ha^{-1}basal area. *Cedrus deodara* was the co-dominant with a density of 94 plants ha^{-1} and basal area of 24.80 m^2ha^{-1}. In this forest, no individual was seen in the early and mature classes (Fig. 2.14). The structure of this forest explains 71.1% individuals in medium class, 27.6% individuals in large class, and 1.1% individuals in extra-large class.

Semo (kayoun) forest: This monospecific forest of *Cedrus_deodara* occupied a density of 461 plants ha^{-1} and a basal area of 117.74 m^2ha^{-1}. The structure of this forest explains 45% individuals in medium class, 48.7% individuals in large class, and 6.24% individuals in extra-large class. The structure diagram (Fig. 2.15) of this forest indicates no recruitment and fewer individuals in the old classes.

Sanga dara forest: In this forest, *Pinus wallichiana* occupied the dominant position having the highest density (121 plants ha^{-1}) and basal area (54.88 m^2ha^{-1}). *Cedrus deodara* was the co-dominant with a density of 109 plants $ha^{-1}$and basal area of 23.47 m^2ha^{-1}. The entire population of this forest has 53.6% individuals in medium size, 34.9% individuals in large, and 11.3% individuals in extra-large size class (Fig. 2.16). The lack of small and mature classes in this forest indicates the uncertain structure.

Sanga dara (II) forest: This forest was dominated by *Pinus wallichiana* having the highest density (210 plants ha^{-1}) and basal area (76.49 m^2ha^{-1}). The co-dominant *Abies pindrow* obtained a density of 34 plants $ha^{-1}$and a basal area of 9.83 m^2ha^{-1}. The structure of this forest demonstrates 18.8% individuals in small class, 58.7% individuals in medium class, 18.8% individuals in large class, and 3.7% individuals in extra-large class. The structure diagram of this forest reveals that the small and medium classes are in better condition (Fig. 2.17). However, gaps in old classes, and few individuals in extra-large indicates socioeconomic disturbance.

Sanga (Galto) forest: In this forest, the dominant *Pinus wallichiana* obtained a density of 210 plants $ha^{-1}$and a basal area of 77.19 m^2ha^{-1}. The co-dominant species *Cedrus deodara* occurred with a density of 73 plants ha^{-1} and a basal area of 23.72 m^2ha^{-1}. *Abies pindrow* was the associated species having the lowest density and basal area (Table 1). In this forest, 13.7% individuals occurred in small class, 53.7% individuals in medium class, 23.7% individuals in large class, and 7.5% individuals in extra-large class (Fig. 2.18). Though, there is no gap in the classes however, recruitment is poor.

Sanga (Khanki) forest: This forest was dominated by *Abies pindrow* with a density of 222 plants ha^{-1} and basal area of 68.66 m^2ha^{-1}. The co-dominant *Pinus wallichiana* attained a density of 90 plants ha^{-1} with a 35.14 m^2ha^{-1} basal area. The associated *Cedrus deodara* obtained the lowest density and basal area (Table 1). This forest has 50.1% individuals in medium class, 45.4% individuals in large class, and 5.1% individuals in extra-large class. The structure diagram (Fig. 2.19) indicates no evidence of recruitment and no individual in mature class.

Seo forest: In this forest, *Cedrus deodara* was dominant with a density of 353 plants ha^{-1} and a basal area of 55.54 m^2ha^{-1}. *Pinus wallichiana* was co-dominant, which occupied a density of 47 plants ha^{-1} and a basal area of 16.38 m^2ha^{-1}. The associated *Picea smithiana* occurred with the lowest density and basal area (Table 1). In this forest, 7.5% individuals occurred in small class, 78.8% individuals in medium class, 12.5% individuals in large class, and 1.3% individuals in mature class (Fig 2.20). The structure diagram of this forest indicates gaps in old size classes, showing unstable condition.

Raziqa (Dhar) forest: This forest was dominated by *Abies pindrow*, which occupied a density of 222 plants ha^{-1} with a basal area of 92.13 m^2ha^{-1}. The co-dominant *Picea smithiana* occurred with a density of 193 plants $ha^{-1}$and a basal area of 55.07 m^2ha^{-1}. The associated *Cedrus deodara* obtained the lowest density and basal area (Table 1). This forest demonstrates 3.7% individuals in small class, 43.8% individuals in medium class, 41.3% individuals in large class, 10% in extra-large class, and 3% individuals in mature class. The structural diagram (Fig. 2.21) of this forest shows gaps in young and old classes.

Dogah (I) forest: In this forest, *Picea smithiana* was the dominant species with a density of 135 plants ha^{-1} and basal area of 42.01 m^2ha^{-1}, whereas *Cedrus deodara* was the co-dominant with a density of 122 plants ha^{-1} and a basal area of 33.14 m^2ha^{-1}. *Abies pindrow* and *Pinus wallichiana* were the associated trees with the lowest density and basal area (Table 1). The total population of this forest has 2.5% individuals in small class, 50.1% individuals in medium class 33.7% in large class, 11.2% individuals in extra-large class, and only 2.5% individuals in mature class (Fig. 2.22). The forest structure shows gaps in early and old classes, indicating low regeneration and anthropogenic disturbance.

Dogah (II) forest: This monospecific forest of *Cedrus deodara* attained a density of 345 plants ha^{-1} and a basal area of 96.76 m^2ha^{-1}. The forest demonstrates 5% individuals in small class, 51.2% individuals in medium class, 37.5% individuals in large class, and 6.2% individuals in extra-large class. The forest structure (Fig. 2.23) shows gaps in young and mature classes. In addition, the fewer individuals in old class indicate uneven size class structure of this forest.

Dassu (Doga) forest: In this forest, *Abies pindrow* was the dominant species with a density of 159 plants $ha^{-1}$and basal area of 78.97 m^2ha^{-1}. The co-dominant *Picea smithiana* attained a density of 111 plants $ha^{-1}$and a basal area of 31.60 m^2ha^{-1}. The associated *Pinus wallichiana* and *Cedrus deodara* occupied the lowest density and basal area (Table 1). The structure of this forest indicates 1.3% individuals in small class, 37.3% individuals in medium class, 42.5% individuals in large class, 17.5%

individuals in extra-large class, and 1.3% individuals in mature class (Fig. 2.24). The structure diagram shows gaps in early and mature classes. The fewer individual of *Cedrus deodara* and *Pinus wallichiana* demonstrates that these species were cut down because of the expensive wood and market value.

Gayal (I) forest: In this forest, *Cedrus deodara* was the dominant species having a density of 256 plants ha^{-1} with a basal area of 77.45 m^{2}ha^{-1}. The co-dominant *Pinus gerardiana* obtained a density of 85 plants ha^{-1} and a basal area of 18.54 m^{2}ha^{-1}. The forest structure shows 3.8% individuals in small class, 75.1% individuals in medium class, and 21.1% individuals in large class. Although, the structure of this forest indicates a little regeneration, however, it should be protected by increasing seedling in the area.

Gayal (II) forest: In this forest, *Cedrus deodara* was the dominant species with a density of 254 plants ha^{-1} and basal area of 37.64 m^{2}ha^{-1}. The co-dominant *Pinus gerardiana* attained a density of 32 plants ha^{-1} and a basal area of 7.07 m^{2}ha^{-1}. *Abies pindrow* was the associated species with lowest density and basal area (Table 1). This forest has 7.5% individuals in small class, 80.1% individuals in medium class, and 12.5% individuals in large class. The structure diagram (Fig. 2.26) of this forest demonstrates few individuals in the young class however, *Pinus gerardiana* was absent in this class. Further, no individual was seen in the old class.

Khandia (Seyal) forest: The density of this monospecific *Cedrus deodara* forest was 295 plants ha^{-1} with 53.32 m^{2}ha^{-1}basal area. The forest structure indicates 8.8% individuals in small class, 73.8% individuals in medium class, 12.5% individuals in large class, and 5% individuals in extra-large size class. The structure diagram (Fig. 2.27) shows fewer individuals and a gap in the extra-large class, indicating that the larger tree has been cut down.

Sazin forest: This monospecific *Cedrus deodara* forest occupied a density of 295 plants ha^{-1} and a basal area of 53.32 m^{2}ha^{-1} (Table 1). The structure of this forest indicates 6.3% individuals in small class, 73.8% individuals in medium class, and 20% individuals in large class. The structure diagram demonstrates no individual in old classes (Fig. 2.28). Further, the forest needs proper conservation and protection of seedling.

Harban: In this forest, *Cedrus deodara* was the dominant species with a density of 152 plants ha^{-1} and basal area of 39.91 m^{2}ha^{-1}. The co-dominant *Pinus wallichiana* occupied a density of 177 plants ha^{-1} and a basal area of 39.91 m^{2}ha^{-1}. The forest structure indicates 18% individuals in small class, 67.2% individuals in medium class, 13.7% individuals in large size class, and 1.1% individuals in extra-large size class. The structure diagram of this forest demonstrates better recruitment. Therefore, this forest may prevail in near future.

Jalkot (Sasak) forest: This forest was dominated by *Pinus wallichiana* with a density of 195 plants ha^{-1}and basal area of 52.30 m^{2}ha^{-1}. *Abies pindrow* was the co-dominant species, which attained a density of 83.92 plants ha^{-1} and basal area of 16.72 m^{2}ha^{-1}. The associated *Cedrus deodara* obtained lowest density and basal area. The forest structure demonstrates 2.7% individuals in small class, 68.8% individuals in medium class, 26% individuals in large class, and 2.5% individuals in extra-large class. The structure diagram (Fig. 2.30) of this forest indicates fewer individuals in early and old classes. Further, a gap in the mature class shows socioeconomic impact.

Discussion

Forest host numerous of biodiversity and ecosystem. The forest structure is mostly controlled by socioeconomic history. Further, the size class distribution of trees are strongly linked with many other feature including regeneration potential, human interference, overgrazing and conservation strategy. As for the understanding of forest structure size class distribution are the most common feature. Therefore, for the determination of forest structure and their future prospect 30 conifer forests, located in Indus Kohistan region, KP, Pakistan were analyzed. The study area consist of 6 conifer species including *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow*, *Picea smithiana*, *Pinus gerardiana*, *Taxus wallichiana* and one angiosperm species (*Quercus baloot*). Though, these species were widely distributed in Indus Kohistan region. However, due to socioeconomic influence most of the forest showed open canopy and uneven structure. Study showed that forest structure could explain the present status and past disturbance (Chetri, 2004). The present status of Indus Kohistan forests demonstrated that wood logger and local community have been cut most of the older trees. Further, due to intensive grazing recruitment in these forests are comparatively low.

A number of studies conducted at various location and climate zone of Pakistan explained that the unstable structure of forests are due to anthropogenic disturbance (Ahmed *et al*., 1990a, b, 1991a; 2006; 2009c; Wahab *et al*., 2008; Khan *et al*., 2010; Siddique, 2011; Khan, 2011; Wahab, 2011; Hussain *et al*., 2011, 2013; Akbar *et al*., 2013). Among these studies, the highest density (679 plants ha^{-1}) of *Cedrus deodara* was recorded from Kalash Birir valley of Chitral on 2022 meter elevation (Khan, 2011), whereas he reported the highest basal area (153.5 m^{2}ha^{-1}) of this species from Gohkshal valley. Wahab *et al*., (2008) presented the lowest density (95 plants ha^{-1}) of *Cedrus deodara* from Surgalo Sar valley of Afganistan on 2246 meter elevation. Similarly, the lower density (3 plants ha^{-1}) of this specie was reported from Suddhan Gali on 2500 meter elevation (Siddiqui, 2011). In this study highest density (353 plants ha^{-1}) and basal area (96.12 m^{2}ha^{-1}) were obtained in Seo (elevation= 2503 meter) and Ujin shamal (elevation= 2085) valleys respectively. The lowest density (73 plants ha^{-1}) and basal area (21.11 m^{2}ha^{-1}) were reported from Galto (elevation= 2780) and

Nilgai (elevation= 2671) valleys respectively. Ahmed *et al*., (2006) explored the highest density (170 plants ha^{-1}) of *Pinus wallichiana* and demonstrated that the density of this specie decrease when turn from young to old classes. Akbar *et al.*, (2010) explored *Pinus wallichiana* dominating seedlings in 10 stands at Sakardu district. Our results are in the range of these studies however, we notice that forests own least socioeconomic impact have highest density and basal area than other one. Similar to this study, *Abies pindrow* were reported from different regions of Pakistan (Ahmed *et al*., 2006; Wahab, 2011; Khan, 2011; Siddqui, 2011). Among these studies the highest density (293 plants ha^{-1}) with 142 m^2 ha^{-1} basal area of this species was recorded from Ghora Dhaka (elevation= 2500 meter) of Hazara division (Siddiqui, 2011), whereas the lowest density (4 plants ha^{-1}) with 11 m^2 ha^{-1} basal area was recorded from plain area of Kumrat valley (Wahab, 2011). *Picea smithiana* is also one of the most important conifer species, which are widely distributed from moist to dry region of Pakistan. Ahmed *et al*., (2006) explored highest density (333 plants ha^{-1}) and a basal area of 167 m^2ha^{-1} from the Nalter valley (3500 meter) of Gilgit-Baltistan. The lowest density (35 plants ha^{-1}) of this species was reported from Sheshan valley (2529 meter) of Afghanistan (Wahab *et al*., 2008). In our study highest density (193 plants ha^{-1}) and basal area (55.1 m^2ha^{-1}) were recorded from Dhar (elevation= 2540 meter) valley of upper Indus Kohistan, whereas lowest density (10 stem ha^{-1}) and basal area (1.64 m^2 ha^{-1}) of this species were reported from Sharakot Dot (elevation= 2435 meter). *Pinus gerardiana* are the dry temperate species, which are distributed in Zhob District of Balochistan, Gilgit-Baltistan, Dir and Chitral region of Pakistan (Ahmed *et al*., 1990a; Ahmed *et al*., 2012; Khan, 2011; Wahab, 2011). In this study *Pinus gerardiana* were reported at two different sampling sites of Indus Kohistan. Comparable to other region of Pakistan this species were in disturbance condition and need proper attention for conservation. Same is the case for *Taxus wallichiana* which was reported from the Sharakot valley of Indus Kohistan. In this study, we also observed *Quercus baloot* with conifer species at two different sampling sites. Khan *et al*., (2010) explored pure forest of *Quercus baloot* from Chitral with a density of 311 plants ha^{-1} and a basal area of 24.9 m^2ha^{-1}. Comparable to their study the density and basal area of our study were low.

It has been investigated that out of 30 sampling sites 16 and 6 showed no individual in young class. Further, 6 sampling sites showed no individual in the first two classes. This condition demonstrates the absence of regeneration potential. The middle classes also shows gap for 5 sampling sites. Similarly, gaps are also found in most of the mature class. The possible reason for gaps in different classes are socioeconomic impact on forests. Further, the less individuals in early class demonstrated less recruitment and overgrazing. Studies showed that forest showing similar structure that are in unstable condition (Knight, 1975; Ahmed, 1984; Wahab *et al*., 2008; Khan *et al*., 2010; Akbar *et al*., 2010; Hussain *et al*., 2013; Khan *et al*., 2018). Such forest could be protect by proper conservation policy and increasing of seedling and sapling in the area. Among the conifer forest *Pinus wallichiana* showed higher individuals in early and medium classes, showing good recruitment and stable distribution. As most of *Pinus wallichiana* forest were located in moist sites of Indus Kohistan. Therefore, it might be possible that the higher individuals in early class may be associated with moisture condition, as seedling required moisture condition and shaded place for their survival. However, some seedling needs more sunlight for their growth or development (Ahmed, 1984). Normally when conifer turn from middle class to mature and over mature classes, the number of individuals ultimately decrease with time. There are two possible reasons *i.e.* when species turn from young to higher classes they compete for nutrient, sunlight, and even for space. So that species, which shows good ecological niches, continue their life cycle while the remaining species eliminate with time as observed in *Agathis australis* forest of New Zealand (Ahmed, 1984; Ahmed & Ogden, 1987; Ogden *et al*., 1987). Because in normal and natural condition there is less space left for the survivalship of all seedling thus with slow growth a few individual able to reach the size of large and mature trees with J shape structure. The other reason is socioeconomic disturbance as wood logger target that tree which produce high yield and have highest market value. Therefore, sometime they cut all classes of a single species. Additionally, the local community of Indus Kohistan also depend on forest for fuel and building timber, as there is no alternate energy source nor other resources for the building construction. Therefore, it is the responsibility of government and relevant Departments to provide alternate energy sources and other possible solution for the protection and conservation of these ecological important forests of Pakistan. Studies conducted in other regions of Pakistan also revealed same conclusions (Beg & Khan, 1984; Ahmed, 1984; Wahab *et al*., 2008; Siddiqui *et al*., 2009; Khan *et al*., 2010; Khan *et al*., 2011; Hussain *et al*., 2013). Studies shows that socioeconomic impact is not only the key factor for the uneven structure of forest. Some other important environmental gradients (topographic variables, temperature and precipitation) have also a significant impact on forest structure (Block & Treter, 2001). As the tree growing in optimum and suitable environmental condition show normal growth comparable to the tree growing in harsh climate and nature disaster area. This condition was observed in Raziqa valley whereas the glacier effects the forest structure. In addition, Holloway (1954) and Wardle (1963) explained that climatic change are the major cause of less regeneration potential. While Robbins (1962) revealed that competition among angiosperms over gymnosperm plants are the main reason. However, concerned to this points no such studies have been conducted in Indus Kohistan forest of Pakistan. Further, tree population have direct relationship with fidelity, fecundity and immigration, which ultimately controlled by various physiological and biological factors (Watkinson & Powell, 1997; Chhetri, 2004). If the fecundity and number of individuals in the early class of a forest are abundant than the future of this forest will be bright otherwise, it will vanish with time. The overall scenario of this study demonstrated that conifer forest of

Indus Kohistan possess unstable condition. Therefore, prompt action is necessary for the increasing of seedling propagation and proper recruitment.

Conclusions

It is concluded that the conifer forests of Indus Kohistan are in unstable condition and needs proper attention for the protection of seedling, sapling and large tree. Most of the trees have threaten for survival. If the illegal cutting of trees were not prohibited these ecological important forests of Pakistan will vanished in near future. It is also recommended to government organization and wildlife and forests conservation Departments, to provide alternate energy sources to local communities and improve the seedling of conifer species. The local forest Department also needs to conduct awareness programs regarding importance of forest and natural resources.

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