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DYNAMICS OF HIGHLY DISTURBED PINE SPECIES AROUND MURREE HILLS OF PAKISTAN: A PRELIMINARY STUDY

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Socioeconomic influences of tourism on four conifer tree species i.e. *Pinus wallichiana* A.B.Jackson, *Pinus roxburghii* Sarg, *Cedrus deodara*. (Roxb.) G. Donf and *Abies pindrow* (Royle ex D.Don) Royle of Murree and its associated Galyat of Himalayan ranges were studied through dendrochronological techniques to infer precise age and growth rate. Highest Diameter at breast hieght (Dbh) was observed in *C. deodara* i.e. 51.2 cm whereas oldest tree species in the study area was *P. roxburghii* (217 years). *Cedrus deodara* occupied the fastest growth rate (1.22yr/cm). Correlation between age and growth rate and Dbh and growth rate determined highly significant relationship ($p < 0.001$) for *P. roxburghii* (Chir pine), *P. wallichiana* (Kail/ Blue pine) and *C. deodara* (Deodar/ Cedar) whereas non-significant correlation observed for *A. pindrow* (Fir). *Pinus wallichiana* and *P. roxburghii* contributed a wide range of tolerance and resilience under such disturbed environment and found invading forest composition by replacing older composition of *A. pindrow* and *C. deodara*. It is concluded that deforestation has brought an evident change in forest structure that has been overcome by the resistant pines to some extent in sustaining mosaic forest cover. But still it will be an alarming point for future of conservational practice which has not been applied yet.
Keywords: Growth rate, correlation, Himalayan forest, forest health, dendrochronology, highly disturbed sites.

INTRODUCTION

Forest health is one of the major issues in developing countries and Pakistan is one of them. Present study is a preliminary step towards forest health assessment by finding maximum and minimum age, diameter of trees and their growth rate occupied by conifers in disturbed sites. As conifers are thriving under great environmental stress due to anthropogenic disturbances as a main cause in lower Himalayan regions hence forest management principally requires growth estimation of trees to analyze forest cover that leads to the assessment of forest health (Worrell and Malcolm, 1990a, b; Khan *et al*, 2020). Growth stipulation is a major factor which affects the maximum age of a tree (Castagneri *et al.*, 2013). In the past years, forest managers rely on conventional ecological methods which were non quantitative and roughly estimated ages and growth rates of trees. Dendro-ecology is a sub-branch of dendrochronology that deals with the exploration of forest structure and dynamics (Metsaranta and Lieffers, 2009). Growth rings can be studied by coring or by using a whole disc to investigate growth rate (Stahle *et al.*, 1999). Age and growth rate of trees are sensitively indicated by the annual rings during the course of their radial growth (Warming and Pitman, 1985). Vegetation undergoes alterations in its structure due to several natural and unnatural disturbances like anthropogenic activities, competition etc, hence the plant species which survive become dynamic (Boisvenne and Running, 2006, Abrams and Nowacki, 2008).

Tree population dynamics in a forest can be projected by defining age structure and age distribution pyramids in a design of forest management strategies to configure future trend of forest health (Agren and Zackrisson, 1990). According to Fricker *et al.* (2006) the study of ecological processes in archeological specimen, age structure is a helpful tool. Lanner (2002) suggested that the vigor of trees is a response of fast growth rates and the radial growth of trees. Therefore, in the fields of ecology, forestry and silviculture; age and growth rates are considered as the precursors for assessments of these aspects.

Dendrochronological methods produce a powerful demonstration of forest's age and growth rate structure and their relationship with climatic impacts (Ogden and Innes, 2007). Nowadays, forest management strategies are principally designed by using a forest structure model which may be established on the basis of age and growth rate estimation of the trees. Ecologists are trying to examine degree of forest loss by using dendrochronological techniques. Ahmed *et al.* (1990a, 1990b, 1991) initiated and applied these techniques first time in conifer forest of Pakistan to describe species dynamics. So far many studies are presented on undisturbed and least disturbed conifer forest of Pakistan and no one studied highly disturbed conifer forests. Unsustainable use of forest resources reduce biodiversity, removal of rare species, promote invasive species, reduce natural regeneration, delay recruitment of plants and destroy the ecosystem. It also alters the weather pattern and increases soil erosion which leads to landslide causing great loss of human life and its infrastructure.

Bearing these points in mind, present investigation is conducted in most famous tourist place of Pakistan to explore its present dynamics. This paper provides information about forest resilience and status of conifer forests around Murree. Main objective of this study is to provide a comprehensive picture of forest structure retained by conifers. Moreover, in presence of certain disturbance like cutting, grazing, construction and other related activities, how conifers respond and maintain their existence. This paper provides the description of age and growth of conifer tree species, forest resilience towards changing environment condition and status of conifer forests of Galyat of Murree mountains.

MATERIALS AND METHODS

Study area**:** This study was conducted in lower Himalayan mountains of Murree, Pakistan. Murree and its surrounding Galyat region are located in foot hills of Himalayan region of the Pir Panjal mountain system, Pakistan.

However, our study sites also covered Galyat from Ayubia in KPK province in addition to Murree hills (Punjab province) to cover the connecting sequence of disturbance in this region. Hence, our study area ranged from Ghora gali at 1636 m and ended at Nathiagali-Ayubia at 2672 m above sea level. The criteria of site selection was based on disturbed nature i.e. close to roads, buildings, residential area, grazed area, site with cut stumps and main tourist points with some growing conifer trees.

Data collection**:** In each location, site (stand) sampling was performed by constructing 100 x 100 m Quadrats following Cottom and Curtis (1956). Thirty stands were established for data acquisition. From each Quadrat ten healthy conifer trees of different size classes were selected and wood samples (cores) 2 from each tree were obtained using Swedish increment borer. In each site (stand) Dbh of each tree was measured and different Dbh size classes were established following Ahmed and Shaukat (2012) i.e. class 1 consists of 10.1 to 20 cm saplings, class 2 consists of 20.1 to 30 cm poles, class 3 consists of 30.1 to 40cm reckers, 40.1 to 50 cm trees, 50.1 to 60 cm mature trees and more than 60 cm trees would be considered as older trees.

Data analysis**:** The core samples, obtained in the field were brought from field to laboratory. The cores were air dried and left for 2- 3 days. After air-drying the core samples were polished with different graded sand papers. When visually distinct rings appeared, the ring-widths of each core sample were measured by using a ring-width measurement machine attached with computer and camera. The age and growth rate of tree species were calculated using the following standard methods given in Ahmed (2014).

$$\text{Growth rate (cm/year)} = \frac{\text{Dbh (cm)}}{\text{Age (years)}}$$

$$\text{Growth rate (year/cm)} = \frac{\text{Age (years)}}{\text{Dbh (cm)}}$$

$$\text{Reliability of core} = \frac{\text{Core length}}{\text{Radius}} \times 100$$

Probability function of Dbh, age and growth rate was obtained by using equation

$$Y = \{ 1/ [\sigma * \text{sqrt} (2\pi)] \} * e\text{-}(x - \mu) 2/ 2\sigma 2$$

Figure 1. Geographical location of study area in Pakistan

RESULTS

The studied samples were collected from thirty highly disturbed stands and geographical details of these stands are expressed in Table 1 following Khan (2019). The core samples showed that the forest consisted of only four conifer tree species in this study area i.e. *P. wallichiana*, *P. roxburghii*, *C. deodara* and *A. pindrow*. With the help of recorded tree trunk sizes and wood samples of four species, following results of estimated age, reliability and growth rate were produced and incorporated in Table 2, 3, 4 and 5 for each species. Fig. 2 and 3 are showing age and growth rates in different size classes of each species respectively. The regression results of *P. wallichiana* trees in correlation with Dbh and age are presented in Fig. 4(a), correlation between *P. wallichiana* trees Dbh with growth rate is presented in Fig. 5(a) while correlation between age and growth of *P. wallichiana* is explained in Fig. 6(a). Similarly, Fig. 4(b), 5(b) and 6(b) presented correlation between Dbh and age, Dbh and growth

Table 1. Geographical location of study area followed by Khan (2019)

Stand	Location	Longitude (East)	Latitude (North)	Elevation above sea level (m)	Aspect (Facing)	Canopy
1	Lower topa close to P.A.F base	073◦26'05.6"	33◦53'54.3"	1956	South	Open
2	Lower topa close to P.A.F base	073◦25'57.6"	33◦53'52.6"	2022	South	Open
3	Khanaspur	073◦25'73.6"	34◦01'25.7"	2155	North	Open
4	Khanaspur	073◦25'39.0"	34◦01'27.0"	2213	North	Open
5	Ghordadhaka	073◦25'40.9"	34◦01'29.4	2129	North	Open
6	Nathiagali behind Chairlift	073◦23'55.2"	34◦01'65.7"	2628	South	Open
7	Nathia gali,Ayubia (Dairy farm)	073◦23'59.5"	34◦01'73.0"	2672	North	Open
8	Koozagali	073◦23'58.6"	34◦00'91.5"	2460	North	Open
9	Koozagali	073◦23'49.8"	34◦00'89.2"	2464	South	Open
10	Changlagali	073◦23'43.7"	34◦01'02.4"	2435	South	Open
11	Dunga gali	073◦23'74.7"	34◦03'01.2"	2327	North	Open
12	Dunga gali	073◦23'90.2"	34◦03'03.3"	2328	South	Open
13	Thana phagwari-Kohala Road	073◦26'63.5"	33◦55'02.3"	1858	South	Open
14	Thana phagwari-Kohala Road	073◦26'46.7"	33◦54'92.0"	1869	North	Open
15	Kasari Town-Murree Road (Patriata)	073◦26'31.4"	33◦54'75.8"	1883	South	Open
16	Kasari Town-Murree Road (Patriata)	073◦26'37.7"	33◦54'68.4"	1893	North	Open
17	Serbagla	073◦26'48.0"	33◦54'43.5"	1919	South	Open
18	Serbagla	073◦27'51.3"	33◦55'28.9"	1787	North	Open
19	Sunny Bank-Jhika gali	073◦24'95.6"	33◦55'25.9"	2044	South	Open
20	Sunny Bank-Jhika gali	073◦25'74.4"	33◦55'16.8"	2087	North	Open
21	Kondla-Changla gali	073◦24'03.2"	35◦55'16.6"	2063	South	Open
22	Kondla-Changla gali	073◦24'03.8"	33◦55'09.5"	2072	North	Open
23	Bhurban	073◦27'09.2"	33◦56'69.2"	1918	North	Open
24	Bhurban	073◦27'27.7"	33◦57'54.3"	1841	South	Open
25	Bansra gali	073◦22'12.6"	33◦53'91.8"	1781	North	Open
26	Bansra gali	073◦27'64.9"	33◦27'61.9"	1699	South	Open
27	Ghora gali	073◦20'89.5"	33◦52'80.7"	1636	North	Open
28	Forest house-Ghora gali	073◦20'82.5"	33◦52'77.9"	1638	South	Open
29	T-Base-Dewal Road	073◦25'76.6"	33◦52'38.9"	1858	South	Open
30	T-Base- Dewal Road	073◦25'79.0"	33◦52'44.0"	1789	North	Open

Table 2. Dbh, reliability, age, growth rate (cm/year) and growth rate (year/cm) estimated from *Pinus wallichiana* samples found in 21 stands out of 30 stands.

Stand No.	DBH range (cm)	Reliability range (%)	Age range (years)	Growth rate (cm/year) Mean±S.E	Growth rate (year/cm) Mean±S.E	Growth rate range (year/cm)
1	12.8-35.2	43-100	49-208	0.26±0.08	5.48±1.0	1.39-8.7
2	16-20	57-100	50-73	0.31±0.01	3.24±0.14	2.71-3.7
3	12.8-24	54-98	47-100	0.28±0.04	4.11±0.52	2.0-6.0
4	11.2-19.2	50-89	40-108	0.21±0.02	5.1±0.45	3.6-7.0
5	19.2-20.8	71-94	18-34	0.90±0.10	1.2±0.17	0.93-1.65
6	19.2-28.48	20-97	33-87	0.44±0.07	2.67±0.35	1.14-4.35
7	14.0-19.02	12-99	46-93	0.32±0.05	3.44±0.28	2.41-4.86
9	10.1	84	56	0.34±0.00	2.93±0	2.93
10	12.8-29.76	24-90	37-71	0.44±0.07	2.8±0.52	1.5-5.5
11	17.28-22.4	69-88	21-36	0.80±0.06	1.33±0.1	1.08-1.62
12	19.2-25.5	20-94	43-70	0.42±0.05	2.5±0.4	1.95-3.62
14	29.76-31.36	22-58	61-136	0.32±0.08	3.5±0.72	2.04-4.33
15	19.2-25.6	58-99	101-157	0.17±0.01	5.81±0.23	5.13-7.05
16	20.48-28.8	45-92	74-132	0.23±0.03	4.78±0.44	2.6-6.24
19	19.2-27.2	59-99	54-157	0.30±0.03	3.82±0.51	2.0-7.3
20	25.0-25.6	52-87	110-139	0.21±0.02	4.9±0.55	4.3-5.4
21	22.4-28.16	21-79	117-167	0.19±0.01	5.22±0.41	4.5-5.92
23	11.2-20.8	55-90	42-90	0.24±0.01	4.34±0.3	3.73-5.8
24	13.76-18.88	12-97	44-91	0.30±0.02	3.42±0.26	2.39-4.84
25	12.16-18.56	56-90	41-95	0.27±0.03	3.8±0.44	3.22-5.12
27	19.2-24.96	51-85	86-128	0.21±0.03	5.1±0.69	3.45-6.66

Table 3. Dbh, reliability, age, growth rate (cm/year) and growth rate (year/cm) estimated from *Pinus roxburghii* samples found in 9 stands out of 30 stands of study area.

Stand No.	DBH range (cm)	Reliability range (%)	Age range (years)	Growth rate (cm/year) Mean±S.E	Growth rate (year/cm) Mean±S.E	Growth rate range (year/cm)
13	19.2-36	73-74	91-104	0.4±0.04	5.09±0.33	4.76-5.42
14	22.4-31.36	31-90	35-134	1.19±0.39	2.77±0.32	1.51-4.27
17	22.08-32	18-87	46-172	1.0±0.3	4.27±0.45	1.45-5.66
18	19.84-32	49-92	58-138	0.52±0.1	3.34±0.24	2.48-4.32
25	13.76-28.88	15-68	36-217	0.13±0.03	1.62±0.53	1.24-6.83
27	17.28-31.36	16-98	35-143	0.16±0.02	4.07±0.63	2.02-6.22
28	13.76-25.6	19-71	60-121	0.1±0.02	4.83±0.65	3.56-6.65
29	13.44-30.4	36-62	62-139	0.11±0.02	5.08±0.51	2.15-6.81
30	13.76-26.56	48-88	54-113	0.11±0.01	5.0±0.5	3.6-7.35

Table 4. Dbh, reliability, age, growth rate (cm/year) and growth rate (year/cm) estimated from *Abies pindrow* samples found in 4 stands out of 30 stands of study area

Stand No.	DBH range (cm)	Reliability range (%)	Age range (years)	Growth rate (cm/year) Mean±S.E	Growth rate (year/cm) Mean±S.E	Growth rate range (year/cm)
10	22.24	68	72	0.16±0	3.25±0	3.25
12	21.44-36.48	66-89	58-86	0.55±0.2	2.63±0.15	2.35-2.84
20	12.8-25.6	57-92	34-122	0.60±0.04	3.4±0.35	2.42-4.8
22	28.8-28.36	9-56	35-127	0.12±0.03	2.75±0.66	1.22-4.41

Table 5. Dbh, reliability, age, growth rate (cm/year) and growth rate (year/cm) estimated from *Cedrus deodara* samples found in 7 stands out of 30 stands of the study area.

Stand No.	DBH range (cm)	Reliability range (%)	Age range (years)	Growth rate (cm/year) Mean±S.E	Growth rate (year/cm) Mean±S.E	Growth rate range (year/cm)
4	19.2-32	46-96	24-58	0.63±0.1	1.75±0.35	1.24-2.8
5	13.2-19.2	80-99	22-35	0.6±0.03	1.69±0.07	1.59-1.84
8	16-28.8	47-100	26-71	0.52±0.06	2.07±0.26	1.34-3.35
9	30.4-44.8	53-58	30-56	0.64±0.10	1.22±0.1	1.22-1.24
11	13.2-32	73-100	21-61	0.55±0.06	1.9±0.23	1.5-2.52
12	32-51.2	72-92	67-70	0.61±0.15	1.75±0.44	1.31-2.21
28	20.8-30.72	31-88	44-132	0.33±0.05	3.6±0.54	1.63-6.35

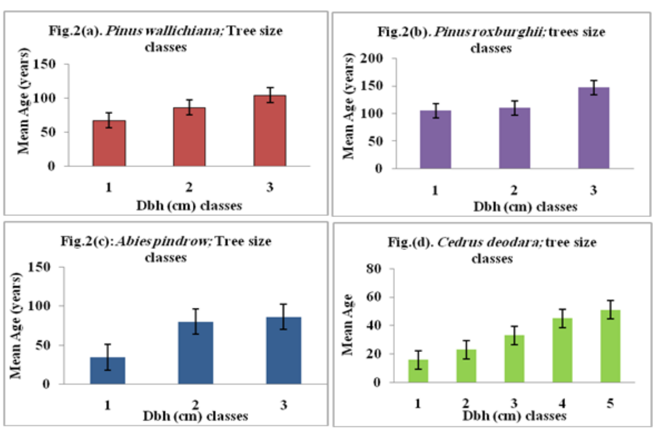

Figure 2. (a-d) Mean age (years) in tree Dbh size classes of *Pinus wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara*

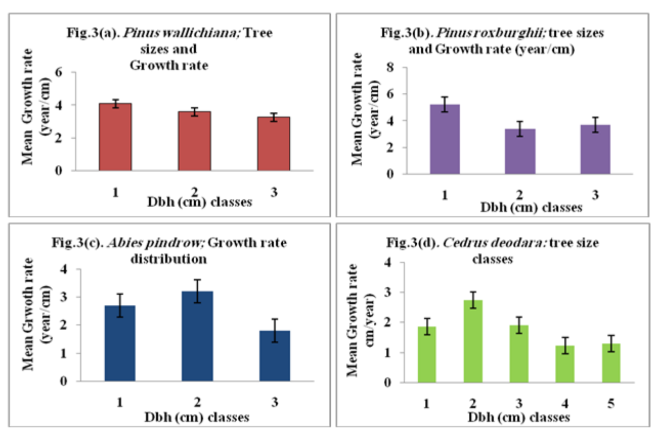

Figure 3. (a-d) Mean growth rate (year/cm) in tree Dbh size classes of Pinus *wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara* respectively

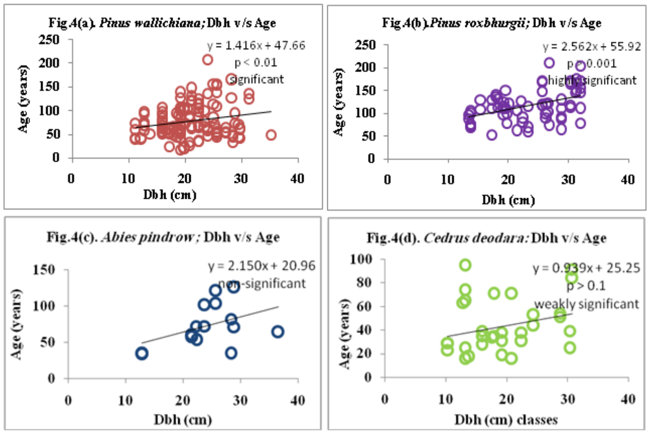

Figure 4. **(a-d) Regression between age and Dbh of *Pinus wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara* respectively**

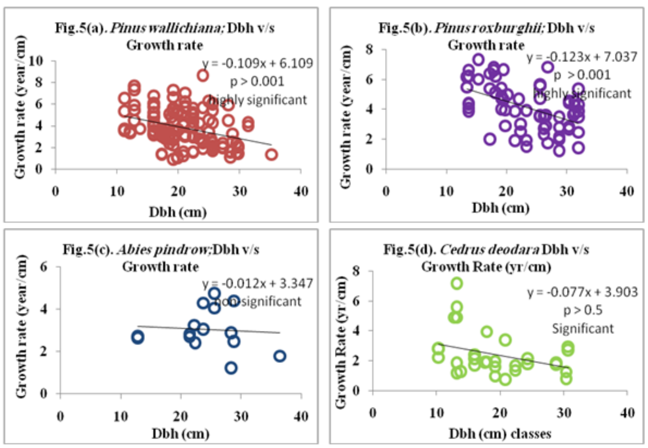

Figure 5. **(a-d) Regression between Dbh and growth rate of *Pinus wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara* respectively**

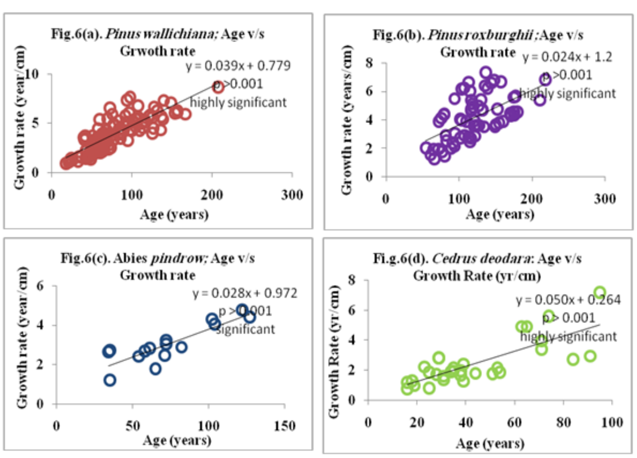

Figure 6. **(a-d) Regression between age and growth rate of *Pinus wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara* respectively**

rate and age and growth rate respectively. *A. pindrow* correlation also presented in Fig. 4 (c), 5 (c) and 6 (c) with Dbh and age, Dbh and growth rate and age and growth rate, respectively. In case of *C. deodara*, Fig. 4 (d), 5(d) and 6(d) presented correlations between Dbh and age, Dbh and growth rate and age and growth rate respectively. Fig. 7 showed minimum and maximum probability range of Dbh, age and growth rate of each pine species.

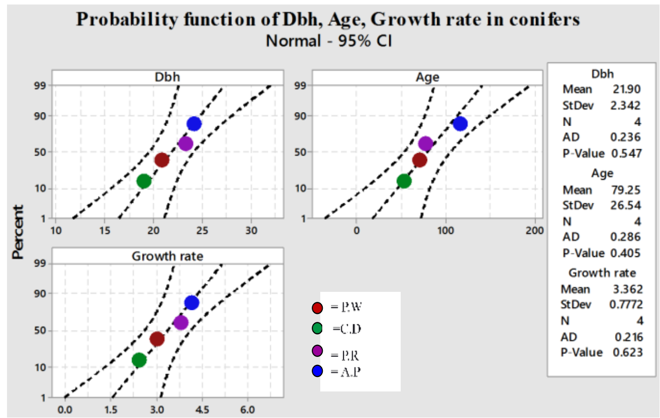

Figure 7. Probability function of conifers

Pinus wallichiana **(Kail/ Blue pine):** *P. wallichiana* was found dominant in Galyat of Murree forests; hence the largest number of core samples belonged to this species has been presented in Table 2. Statistics of core samples revealed highest diversity in Dbh range of *P. wallichiana* trees found in Lowertopa as well as their reliability range was variable in this stand i.e. 12.8 to 35.2 cm Dbh with 43 to 100% reliability. This stand also contributed the second highest range in age from 49 to 208 years. Growth rate (year/cm) was found slowest in the stand of Kaseri Town Murree road Patriata with 5.81±0.23 years/cm as mean growth rate and range started from 5.13 to 7.05 year/cm. Growth rate (cm/year) was fastest in Ghor Dhaka i.e. 0.91±0.1 cm/year. Age structure of *P. wallichiana* trees with respect to diameter at breast height (Dbh) classes were presented in Fig. 2 (a) which showed an increase in stem Dbh size with increase in age. *P. wallichiana* attained Class 1 (10.1 to 20.0 cm Dbh) which represented saplings. This species was also present in Class 2 (20.1 to 30.0 cm Dbh) which represented poles and Class 3 (30.1 to 40 cm Dbh) which represented reckers (young trees) in the disturbed sites, whereas the further age classes of medium trees (Class 3 = 40.1 to 50.0 cm) and mature trees (Class 4 = 50.1 cm and above Dbh) were absent.

This showed that the premature Dbh class (class 3) was present which promised the existence of dominated condition of the species in future but the disappearance of older age classes (class 4 and 5) in the area indicated past deforestation practices. Fig. 3 (a) showed an estimation of mean growth rate (year/cm) carried out by different stem sizes. *P. wallichiana* showed significant correlation between diameter at breast height (Dbh) and age, Dbh and growth rate, age and growth rate as shown in Fig. 4, 5 and 6, respectively. The Dbh of this species ranged from 12.2 cm to 35.2 cm, whereas the growth rate ranged from 0.93 years per centimeter to 8.7 years per centimeter. Reliability found to be from 12% to 100% as shown in Fig. 5 (a & b) which showed the average age, Dbh, reliability and growth rate of all pine species of this tract.

Consequently *P. wallichiana* showed second highest average age 77±3 years, average Dbh was found to be 20.89±0.46 cm, and average growth rate was 3.83±0.15 yrs/ cm which depicted this pine as second slowest growing species among the other pine species and the highest average reliability 74%.Dbh, age and growth rates of this pine showed significant ($p < 0.05$) relation among each other.

***Pinus roxburghii* (Chir pine):** *P. roxburghii* (Chir pine) appeared as the widely distributed species at lower elevation in Murree forest. Table 3 showed Dbh, age, reliability and growth rate estimates. Highest Dbh range of *P. roxburghii* was observed in Stand 14 (Thana Phagwari-Kohala Road) i.e. 19.28 to 36 cm, reliability was highest in Ghora Gali (stand 27) i.e. ranged from 16 to 98%. Age range of 36 years to 217 year of *P. roxburghii* was found in Stand 25 (Bansra Gali) as the widest age range. Growth rate (year/cm) observed fastest in the same stand i.e. 1.62±0.53 years/cm. This stand also contributed widest range of growth rate from 1.24 to 6.83 year/cm (Table 3). Fig. 2b elaborated three size classes occupied by the species with the oldest conifer of the area (217 years) while Fig. 3b, explained fastest growth rate 1.24yr/cm and slowest was 7.35yr/cm. The relationship between Dbh and growth rate, age and growth rate as shown in Figure 5 (b) and 6 (b) appeared to be highly significant while Dbh and age relationship was also estimated as significant (Fig. 4 b) also listed in Table 6. Moreover, Fig. 7 mentioned that 54 years old as the minimum age of *P. roxburghii* and maximum was 217 years. The minimum Dbh of the species was found as 13.44 cm and maximum was 32 cm. The slowest growth rate of this species was 7.35 years per centimeter and fastest was 1.24 years per centimeter. The overall reliability range of *P. roxburghii* was 15 to 98%. This species possessed slowest mean growth rate i.e. 4.15±0.19 year/cm in the disturbed sites whereas the oldest tree (217 years old) and the highest mean age (116 years) also belonged to this species as presented in Figure 7.

***Abies pindrow* (Fir):** The trees and seedlings of *A. pindrow* (Fir) were found in lower number than other pine species. It may be due to cutting of trees or frequent forest fire hazards. Fifteen (15) core samples obtained from the disturbed sites as shown in Table 3. In stand 12 (Dunga Gali), *A. pindrow* possessed highest range of Dbh (21.44 – 36.48cm), reliability of 57–92% and mean Growth rate 0.60 ± 0.04 cm/year. Mean age range was highest in stand 22 (Kondla-Changla Gali) from which 35 to 127 years old trees were identified as well as mean growth rate (year/cm) range (1.22 to 4.41 year/cm) was the broadest range of this species from the same stand. Fig. 2c showed appearance of Fir trees in only 3 classes and absence of older Firs from the study area while Fig. 3c showed slowest growth from trees of class 2 i.e. 3.4±0.35 All the correlations were found to be non-significant other than age and growth rate correlations which were highly significant as shown in Table 5 and Figures 4, 5 and 6 (c). Figure 7 showed the minimum and maximum age of this species as 34 years to 127 years respectively. The Dbh ranged from 12.8 cm to 36.48 cm, while growth rate range was 1.22 years/ cm to 4.77/ cm. The reliability of the cores ranged from 9 to 92%. The overall average age of *A. pindrow* was estimated as 71±7 years while the average Dbh of trees of this species was highest among other conifer species which was 24.2±1.56 cm as shown in Figure 7. It

Table 6. Correlation, regression values and respective significant levels of all four dominant conifers from highly disturbed sites of Murree

Species name	Regression equation	Correlation value	P-value	Significant level
Dbh v/s Age				
Pinus wallichiana	1.416x+47.66	0.2430	$p < 0.050$	Significant
Pinus roxburghii	-2.562x+55.92	0.5090	$p < 0.010$	Significant
Cedrus deodara	0.939x+25.25	0.3460	$p < 0.100$	Weakly Significant
Abies pindrow	2.150x+20.96	0.3470	$P > 0.100$	Non Significant
Dbh v/s Growth rate				
Pinus wallichiana	-0.109x+6.109	0.4341	$p < 0.001$	Highly Significant
Pinus roxburghii	-0.123x+7.037	0.7217	$p < 0.001$	Highly Significant
Cedrus deodara	-0.977x+3.903	0.4615	$p < 0.500$	Significant
Abies pindrow	-0.012x+3.347	0.5770	$p > 0.100$	Non Significant
Age v/s Growth rate				
Pinus wallichiana	0.039x+0.779	1.5334	$p <0.001$	Highly Significant
Pinus roxburghii	0.024x+1.200	0.9007	$p < 0.001$	Highly Significant
Cedrus deodara	0.050x+0.264	0.8381	$p < 0.001$	Highly Significant
Abies pindrow	0.028x+0.972	0.8570	$P < 0.001$	Highly Significant

was estimated to be a normal probability distribution among all three parameters of this species having significant results ($p < 0.05$).

***Cedrus deodara* (Deodar/ Cedar):** Thirty two (32) core samples of *C. deodara* (Deodar/ Cedar) were collected from different locations in Galyat as shown in Table 5 and their age, growth rate and reliability were estimated by using standard dendrochronological methods. According to the table, Cedar trees showed their highest Dbh range from stand 12 (Dunga Gali) consisted of 35 to 51.2 cm stem size while mean age range recorded 44 years to 132 years from Ghora Gali (stand 28). Slowest mean growth rate (3.6±0.54 years/cm) and slowest growth rate range (1.63 to 6.35 years/cm) were recorded from the same stand, while fastest mean growth rate (0.64±0.10 cm/year) was observed from Koozah Gali (stand 9). Reliability range (47 to 100%) was highest in stand 8 (Koozah Gali). Fig.2 (d) showed that *C. deodara* trees appeared at young tree stage in Class 1 (10.1cm to 20 cm) as well as poles in Class 2 (20.1 cm to 30 cm), reckers in Class 3 (30.1 cm to 40 cm), medium trees Class 4 (40.1cm to 50 cm) and also in the form of mature trees in Class 5 (50.1 and above). The results showed that only *C. deodara* found in a wider range of age classes (class 1 to 5) in the disturbed sites. The relationship between Dbh and age was found to be weakly significant as shown in Figure 4 (d). Figure 5 (d) showed significant correlation between Dbh and growth rate while Figure 6 (d) showed highly significant correlation between age and growth rate as listed in Table 6. Figure 7 showed the minimum and maximum age was 21 years to 132 years, Dbh range started from 13.2 to 51.2cm, growth rate ranged from 0.77 to 6.75 years per cm and reliability ranged from 28% to 100%. The average dendrochronological parameters presented in Figure 7 showed an average age of *C. deodara* to be 43±4 years, average Dbh of this species was found lowest in the forest which was 19.09±1.16 cm, the average growth rate was found to be 2.43±0.26 years per cm and average reliability was found to be 69%. Statistics concluded that this Deodar species occupied lowest average Dbh and age while fastest average growth rate among other conifers. The null hypothesis results were significant ($p < 0.05$).

***Status of conifers and degree of resilience*:** By analyzing the above results, status of conifers has been summarized in Table 7 that can determine the level of resistance in conifers against the changing condition. During the course of development in this forest, pine species found in competing condition while Cedar and fir even possessed older Dbh classes and a well defined growth rate in the few cases where they escaped from cutting. Khan *et al.*, (2018) recruited density of conifers with respect to Dbh classes from disturbed forests of Murree. Disturbance in the forest like construction of roads and buildings brought drought, soil and vegetation removal have also caused changes in the habitat. Under such condition *P. roxburghii* occurred as the most resilient species, as it expanded its distribution steadily despite of all the environmental imbalances. *C. deodara* have also persisted under disturbance by enhancing growth rate when allowed to grow or escaped from cutting. Hence the tolerance range strengthened their survival adaptability. Normal probability distribution presented in Fig.7, analyzed the attributes of pine species. This showed all four conifers strictly fitted normal distribution curve proving their adaptability in the area. Dbh, age and growth rates were significant ($p < 0.05$), hence their presence in these forests showed their greater tolerance mechanism (Table 6). *Cedrus* and *Abies* showed a lower and upper higher fitted response respectively that could be due to low representation in the forest but attained well fitted position that confirmed their

Table 7. Comparison between different attributes of mosaic stands of four key species of conifers from highly disturbed sites of Murree.

Attribute	*Pinus roxburghii*	*Pinus wallichiana*	*Abies pindrow*	*Cedrus deodara*
DBH Range (cm)	10.1-35.2	12.2-35.2	12.8-36.48	13.2-51.2
DBH Average (cm)	23.4 ± 0.74	20.89 ± 0.46	24.2 ± 1.56	19.9 ± 1.16
Age Range (yrs)	54-217	18-208	34-127	21-132
Age Average (yrs)	116 ± 0.0	77.0 ± 3.0	71.0 ± 7.0	43.0 ± 4.0
Reliability Range %	15-98%	12-100%	09-92%	31-100%
Reliability Ave %	57%	74%	63%	69%
Growth Rate (cm/yr)	0.20 ± 0.03	0.27 ± 0.03	0.33 ± 0.04	0.36 ± 0.05
Growth Rate (yrs/cm)	4.15 ± 0.19	3.83 ± 0.15	3.04 ± 0.25	2.43 ± 0.26
Growth Rate Range (yrs/cm)	1.24-7.35	0.93-8.7	1.22-4.77	0.77-6.35
Saplings	Present	Present	Present	Present
Poles	Present	Present	Present	Present
Reckers (Young Trees)	Present	Present	Present	Present
Medium Trees	Absent	Present	Present	Present
Mature Trees	Absent	Absent	Absent	Present
Significance in Correlation among attributes	Dbh & growth rate, Age & growth rate	Dbh &age, Age & growth rate	age & growth rate	Age & growth rate, Dbh & growth rate,

existence and sustainability if allowed to grow. Pines were the most fitted species under such highly disturbed sites around Murree hills. Hence, the persistency of conifers, showed resilient nature of conifers that has benefited themselves under such rapidly changing environment. Eventhough, forest cover is in threat as only less mature trees have left in the forest and mature ones have removed but these juvenille trees are the future of this forest that have to be conserved and maintained.to avoid further events of diversity loss in future.

DISCUSSION

Age of conifers: As far as we move backward in years, at present no tree was found above 217 years except *P. roxburghii* as it seems to be a loss of over mature trees. *A. pindrow* attained maximum age upto 127 years while Ahmed *et al.* (1991) claimed *A. pindrow* tree aged upto 150 years in the same area. The trees recorded by Ahmed *et al.* (1991) have age of 175 years approximately while in the current study there was a clear evidence of higher rate of stem cutting in this disturbed area. They also recorded 277 years maximum aged trees of *A. pindrow* from Ayubia whereas the disturbed sites of this study showed no sign of mature and over mature trees. Ahmed *et al.* (2009) observed 533 years old deodar trees from Ziarat (Drosh) while most of the trees were 79 years to 319 years old in the area whereas Murree represented 21 years to 132 years old deodar trees from its disturbed sites. Siddiqui (2011) found 35 to 422 years old deodar trees from least disturbed sites of Murree. He explored a wide range of *C. deodara* trees of different ages while in current study the forest possessed low density and frequency of this species. As deodar was the only main conifer tree species formerly present in the area (Farjon, 2013).

A wide distribution of *P. wallichiana* was observed in study area occupying different age classes. Pine tree species were reported in the past as younger but now Fir and Deodar were found well distributed hence their density and age structure is expected to be sustained in future if logging or any other harmful factor would not disturb the growth and population of these forest stands. Iqbal *et al.* (2017) reported 326 years old *P. wallichiana* trees from Shangla district having 143cm of mean diameter wood. Siddiqui (2011) and Siddiqui *et al.* (2013) recorded 97 years old maximum aged trees of *P. wallichiana* in the area. Ahmed *et al.* (2009) observed *P. wallichiana* from another moist temperate zone i.e. Sudhan Gali in Azad and Jammu Kashmir and recorded 85 years old tree of this species.

P. roxburghii has been cited in very few studies in Pakistan. This species exhibited larger frequency with middle age classes upto 184 years in current study rather than older conifers that were formerly present in the same location recorded by Siddiqui *et al.* (2013).

***Growth rate of conifers*:** Bigler and Veblen (2009) considered as the fitness criterion of the trees implies to their faster growth rate which corresponds to their increase in size by the time. Their relationship develops in the response of competition under the influence of different environmental factors. The current statistics showed highest growth rate year/cm achieved by *C. deodara* while *A. pindrow*, *P. wallichiana* and *P. roxburghii* were at second, third and fourth position respectively. Sites of lower elevation showed higher growth rate of *P. wallichiana* and *P. roxburghii* due to extensive moisture consumption at lower sites. In addition, *P. roxburghii* is sub-tropical species while *P. wallichiana* grows in moist to dry temperate areas hence their growth requirements are different. Species from higher elevations i.e. *A. pindrow* and *C. deodara* possessed lower growth rate as presented in the findings which might be due to presence of different kinds of stresses in the area and competition of other broad leaved tree species. *A. pindrow* occupied higher elevations than *P. wallichiana* while *C. deodara* prefer dry temperate climate. In *P. wallichiana* dominated sites both the species are present as isolated and beyond their distributional limit. Current findings showed significant correlations between Dbh and age in *P. wallichiana*. Ahmed and Sarangzai (1991) while working in Zhob district concluded highly significant correlations between Dbh & age and age & growth rate of *P. wallichiana* where $r = 0.93$, $p < 0.001$. The species consisted of 230 years old trees and the growth rates varied from 3.13 to 14.28 year/cm. The maximum Dbh recorded was 60 cm. Study conducted on *Agathis australis* by Ahmed and Ogden (1987) showed up to 600 years older trees with 130 to 150 cm Dbh range. They found significant correlation between Dbh and age and a wide range in growth rate of the trees i.e.7.5±2.9 to 21.3±12.5 years/cm. Therefore, Ahmed (1984) suggested that in multi-aged and sized forests largest tree is not necessarily the oldest one and vice versa. In another study conducted by Siddiqui *et al.* (2013) reported that *P. wallichiana* was the fastest growing species in Murree, specifically tree cores from Patriata showed highest growth rate. Ahmed and Sarangzai (1992) and Ahmed *et al*. (2009) considered *P. wallichiana* as the fastest growing species in Murree and Dir District respectively as the competitive mechanism of this species was better adapted than other conifers.

Although, elevation and aspect play important role in predicting the growth output in pines and the response of pines may vary from species to species. Current study showed higher growth rate of *P. wallichiana* from Ghor Dhaka while the average fastest growth rate was achieved by *C. deodara* which was also reported by Ahmed and Sarangzai (1991) and Siddiqui *et al.* (2013) from Swat valley and Shinu and Naran area respectively. Deodar (Cedar) is the species which on higher elevations and low competitive condition grows very well same as in case of our study, as there was less competition in the area due to logging. *A. pindrow* was concluded as the slowest growing conifer in the disturbed environment of Murree. Similarly, Ahmed *et al.* (2009) and Ahmed and Sarangzai (1991) also determined *A. pindrow* (Fir) as a slow growing conifer species. Siddiqui (2011) observed high growth rate of *A. pindrow* from Malam Jabba. In different studies Chir pine (*P. roxburghii)* was observed as the faster growing species among all pines at lower elevations as Bhuju and Gaire (2012) proved in their study from Khatmandu valley in Nepal. In the current study *P. roxburghii* showed a moderate growth condition which may be due to high altitude with northern aspect and high infrastructure in the form of buildings and small industries. Ahmed *et al.*(2009) claimed *Pinus roxburghii* and *Picea smithiana* as the faster growing conifers at northern aspects of their respective altitudes but in current situation, the edaphic and other disturbance creating factors were more involved in the growth of *P. roxburghii*.

Dbh, age and growth rate correlations: Sometimes pine trees of similar diameter and height differ in their age. Mc Carthy and Weetman (2006) observed after gaining differential dendrochronological age estimation from same sized trees and concluded negatively significant relationship between age and diameter of trees. Current findings showed significant correlations in most of the cases. Mature trees could give the best description of tree growth than younger ones, thus this size-age relationship is a challenging criterion in the old growth forest (Gates and Nichols 1930, Parish *et al.,* 1991). Many workers found significant correlations between diameter and age like Khan (1968), Ahmed and Ogden (1987). Ahmed (1988) found significant correlation from pine species. Ahmed *et al.* (1990) found non-significant correlation in age/ Dbh from *P. wallichiana, C. deodara* and *A. pindrow* while *P. roxburghii* appeared to be significant throughout its natural distribution zones. In addition, even significant relation between diameters and age show wide variance therefore it is not advisable to predict age from diameters claimed by Ahmed (1984).The significance level varies among species but now there are chances of opportunities of better growth if forest logging and related disturbance factors by the locals of the area would be avoided.

***Resilience and Conclusions*:** Keeping in view results and discussion, current status of these forests revealed a vulnerable situation of conifer trees claiming a big loss in wood and biomass production. An overall decline in conifer addition is observed indicating severe anthropogenic disturbances in this area. This decline in wood production is projecting an alarming threat to this fragile watershed for water harvesting and biodiversity conservation in future. *P. roxburghii* (Chir pine) and *P. wallichiana* (Blue pine/ Kail) are concluded to be resistant pines under such severe anthropogenic disturbance and should be promoted quickly and extensively on respective aspects to sustain and improve health of these stands. While *A. pindrow* (Fir) and *C. deodara* (Deodar) are less resistant as compared to pines due to restricted distribution, presence in small patches (except Nathia Gali) or isolated trees around Murree hills, and are under logging threat due to their high quality wood in demand. Hence it is a clear indication to foresters and ecologists to develop strategies for the conservation and longevity of these declining mosaic forests, and rapidly eroded land mass around Murree settlement.

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