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POPULATION STRUCTURE AND REGENERATION PATTERN OF TREE SPECIES ALONG THE ALTITUDINAL GRADIENT IN A TEMPERATE FOREST OF WESTERN HIMALAYA, UTTARAKHAND, INDIA

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ABSTRACT

Garhwal Himalaya is the part of the western Himalaya which is known for its unique vegetational wealth. We investigated the unexplored Radi top forest of Rawain range of upper Yamuna forest division in order to formulate plant conservation and management strategies. Several field expedition tours were undertaken during 2020 and 2023 for data collection in the study area.Ten quadrats of 10m×10m size were laid randomly in each study sites for tree layer, while 20 quadrats (size 5×5m) for saplings and 40 quadrats (size 1×1 m) for seedlings nested within each tree quadrat to study the regeneration status. The level of tree species appearing "good" regeneration differed from 22.2-50%. Albeit the general regeneration status was fairly high in the study region, there is a decent level of tree species in all the forest sites that showed "poor" (9- 25%), "fair" (22.2-44.4%), or "no" (12.5- 22.2%) regeneration. *Symplocos paniculata*, *Aesculus indica* and *Cornus macrophylla* are the prevailing species in the forest, showed "poor" regeneration. A majority of tree species exhibited the reverse j-shaped d-d curve in diameter class distribution that indicates good and fair regeneration status. Tree species which shows poor regeneration status should be conserved ex situ and some actions are needed for the maintenance of their population by foresters or forest official's significantly positive correlation of slopes, seedlings, saplings, trees with altitude was recorded. The study suggests that richness of seedling, sapling and adults of tree species are largely regulated by the altitude and climatic factors.

Keywords: Regeneration pattern; Radi top; altitudinal gradient; Uttarkashi; Uttarakhand.

INTRODUCTION

Regeneration potential is the capacity of a tree species to complete the life cycle.Regeneration of the tree species is significant in evaluating the capability of the forests to serve the general public on supported premise in present and future too. (Ao, Changkija & Tripathi, 2020). Regeneration is the most basic part of any forest eecosystem as it decides the presence of species and it plays a significant role in forest management and to the forest executives in a specific region (Saroinsong, 2020). Regeneration status of tree species inside a forest ecosystem is determined or evaluated by the density of seedling, sapling and population of higher daimeter class (Maua, Tsingalia, Cheboiwo, Odee, 2020). The higher density of seedlings and saplings, and the presence of youthful trees in lower girth class show a good regeneration status of forest though the shortfall of seedling brings about no regeneration (Chaturvedi, Raghubanshi, Tomlinson & Singh, 2017; Sharma, Mishra, Tiwari, Krishan & Rana, 2018). Forests stand structure and regeneration status of the species is a vital component to decide the health of forest ecosystem and furthermore significant parameters of stand biodiversity. (Rahman, Rahman & Chowdhury, 2019). Amount of seedling of any species can be considered as the regeneration ability of that species (Rawat, Dash, Sinha, Kumar, Banerjee & Singh, 2018b). The deficiency of tree species in a forest ecosystem is adverse to forest design and capacity, and can impede the forest ecosystem services provided by the Forests. (Tekalign, Meerbeek, Aerts, Norgrove, Poesen, Nyssen & Muys, 2017). Natural regeneration is a biological cycle by which a forest community replaces itself throughout the time (Rawat, Tiwari, & Uniyal, 2017). In the forest regeneration study depicts current status as well as hints about the possible changes in forests structure later on (Das, Panday, Rawat, Kumar, Lahiri, Sinha & Singh, 2021). The absence of unsettling influences in a forests, brought about stable vegetation with low enlistment of youthful ones because of canopy closure in future (Pradhan, Ormsby & Behera, 2018). Consideration is expected to work with the regeneration of species which are not performing great due to ecological obliges, especially light because of shade from canopy trees (Ao, Changkija & Tripathi, 2020). Focusing on various regions for protection in view of useful trees, their mortality or regeneration alongside other environmental traits like abundance, distribution, and dominance is need of great importance (Paul, Khan, & Das, 2018). Vegetation change initiated by climax species might prompt change in living space by modifying the microclimatic conditions (like soil properties) and may speed up forest development (Van, Cammeraat, Keesstra & Zorn, 2017). The variation in the different successional phases of the concentrated on destinations sites can be credited to both territory and landscape level variations in forests ascribes, thus creating spatial heterogeneity (Rawat, Tiwari, Das & Tiwari, 2020. Tree populace especially along higher heights (tree lines) play a critical role in the support of the natural biogeochemical cycles, fundamental living spaces, and ecosystem services for human communities through the various provisions for life substances (Cobb, Ruthrof, Breshears, Lloret, Aakala, Adams & Zeppel, 2017).in recent times, the use of factual procedures or statistical techniques in phytosociological or ecological studies, for example, classification and ordination of vegetation information has fundamentally or significantly improved on how we might interpret forest structure, composition and patterns which decide the extent of biodiversity more objectively (Haq, Rashid, Khuroo, Malik. & Malik, 2019).

The western Himalaya, one of the biodiversity-rich and ecologically significant mountainous regions in the Himalayan biodiversity hotspot and it harbor large tracts of Himalayan temperate forest types (Haq, Calixto & Kumar, 2021) with a forest cover of 51% (FSI, 2017). The Garhwal Himalaya is a fundamental part of the Himalayan mountain system, with social, biological and physiographic closeness. They cover around 24% of the complete earth's area. Around 10% of worldwide livelihoods and prosperity depends straightforwardly on mountainous resources, and they are significant sources of biological and socio-cultural diversity and are the most delicate, dynamic and sensitive landscapes of the world (Sati, 2015). In Garhwal Himalaya, the regeneration capability of tree species especially in sub-alpine, temperate forest, sub tempertare forest ecosystems relies for the most part upon three elements viz. density of new seedlings at various elevation, competence of seedlings and saplings to rise under various microclimatic condition and their capacity to grow as an adult individual (Mittal, Singh and Tewari 2020). Mountain forests of Garhwal Himalaya as a rule, have a critical issue of poor regeneration (Parveen et al. 2017; Rawat, Tiwari, Tiwari, Nautiyal, Praveen, & Singh, 2018a). Recent studies show that, primary foests of this locale have been progressively under danger because of high anthropogenic unsettling influence (Rawat, Tiwari, Das & Tiwari, 2020). Data on the compositional traits of vegetation, for example, the populace structure and biomass variations in temperate forests of Western Himalaya is satisfactorily available (Kumari, Mehta, Shafi & Dhiman, 2017 ; Shafi, Mehta, Kumari & Dhiman, 2017; Mir, Masoodi, Geelani, Wani & Sofi, 2017; Sharma, Samant, & Lal, 2017 ; Tiwari, Sharma, Rana & Krishan, 2019; Rawat, Tiwari, Das. & Tiwari, 2020 ; Dasila, Samant & Pandey, 2021; Rawat, Bagri, Singh, Tiwari & Tiwari, 2021; Singh, Tiwari, Bagri, Rawat, Rautela & Rawat, 2021, Rawat, Bagri, Parveen, Nautiyal, Tiwari & Tiwari, 2021; Bagri, Singh, Singh, Hussian, Dhingra & Tiwari, 2022). However complete record of the status of forests regeneration especially in temperate forests in Western Himalaya are dispersed and isolated (Ballabha, Tiwari & Tiwari, 2013; Malik, 2014; Parveen, Tiwari, Rawat & Tiwari, 2017;

Parveen, Tiwari, Nautiyal, Tiwari & Rawat, 2018; Rawat, Tiwari, Tiwari, Nautiyal, Praveen, & Singh, 2018a; Sharma, Mishra, Tiwari, Krishan, & Rana, 2018: Tiwari, Rana, Krishan,., Sharma, & Bhandari, 2018; Tiwari, Sharma, Rana & Krishan 2019; Thakur, Bisth, Kumar, Kumar & Sahoo, 2021). Thus, to comprehend the intricacy of the forest ecosystem function and to lay out an incorporated methodology for Conservation, reliable data on the health of these delicate biological systems is necessary. After that present study was conceptualized with a goal to analyze the population structure and regeneration status of tree species along the altitudinal gradient in a temperate forest (Radi forest) of Rawain range of Yamuna forest division of district Uttarakashi, Uttarakhand, India.

MATERIALS AND METHODS

A. Study area

The present study was conducted in the Radi forest of Upper Yamuna forest division, Uttarakashi, Uttarakhand, India. Upper Yamuma forest division occupies the total reserved forest area 74394 hactare.Upper Yamuna forest Division is geographically,divided into five forest ranges Yamunotri range, Mugarsanti range, Kuthnaur range, Nauganv range and Rawain range. Rawain range occupies 12965 hactare. Baukhtibba is the highest peak of Upper Yamuna forest division on which Baukhnath temple of lord Shiva is situated. Baukhtibba comes under the raditop forest area of Rawain range. The Radi area located in between two well known valleys (Bhagirathi and Yamuna) of western Himalaya. Radi top forest ranges from 30˚46'15.8"N to 78˚15'17.5" E. The forest is covered in the high altitude by *Abies pindrow* and *Quercus semecarpifolia*, in the middle by *Quercus floribunda*, *Rhododendron arboreum,* and mixed broad leave forest and in the lower altitude by *Quercus oblongata*, *Cedrus deodara.* Soil of the study area is brown to very dark brown in color and sandy loam in texture (Rawat, Bagri, Singh, Tiwari, Tiwari, 2021).

B. Data collection

The Radi forest area was divided into five elevation classes viz., Site I (2000–2200 m asl), Site II (2200–2400 m), Site III (2400–2600 m), Site IV (2600–2800 m)and Site V (2800–3000 m). Each elevation belt was considered as study site (Table 1). Composition of trees, saplings and seedlings were assessed through quadrat method.

Table 1. Characteristic of study sites.

Forest sites	**Aspect**	**Slope**	**Nature of slope**	**Altitude (m asl)**	**Common tree species**
Site I	NW	19˚	Moderate	2000–2200	*Cedrus deodara*, *Quercus oblongata*, and *Cupressus torulosa*.
Site II	NE	18˚	Moderate	2200–2400	*Quercus floribunda*, *Q. oblongata*, *Rhododendron arboreum*, and *Lyonia ovalifolia*.
Site III	SE	22˚	Moderate	2400–2600	*Picea smithiana*, *Quercus floribunda*, *Q. semecarpifolia* and *Rhododendron arboreum*,
Site iv	SW	30˚	Very steep	2600–2800	*Abies pindrow*, *Quercus semecarpifolia*, and *Taxus wallichiana*.
Site V	NW	37˚	Very steep	2800–3000	*Abies pindrow*, *Quercus semecarpifolia*, and *Taxus wallichiana*.

Ten quadrats of 10m×10m size were laid randomly in each study sites for tree layer, while 20 quadrats (size 5×5m) for saplings and 40 quadrats (size 1×1 m) for seedlings nested within each tree quadrat. The individuals with circumference (at 1.37m above ground level)> 30cm were considered as mature trees whilecircumference (colour height) <10cm taken as seedlings and individuals having circumference between seedlings and mature trees were considered as samplings (Knight, 1963). The individuals with exact 30 cm and 10cm circumference were placed under saplings and seedlings layers respectively (Tripathi, Rikhari, Bargali & Rawat, 1991).

C. Data analysis

The regeneration status of tree species was analyzed on the basis of population size of seedlings and saplings and adults following Khan and Tripathi (1987) and Shankar (2001) viz., 'Good regeneration' (if particular species is present in seedlings>saplings>trees); 'fair regeneration' (if species are present in seedlings > saplings <trees); 'poor regeneration' (if a species survives only in sapling stage, but not as seedling); 'not regenerating' (if a species is present only in adult form); 'new'(if the species has no tree representatives, but only saplings and/or seedlings).

RESULTS AND DISCUSSION

A. Population Structure

At site I, maximum density (756 Ind/ha) was recorded for 0–20 cm followed by 21–40 cm (214 Ind/ha), while 81–100 cm exhibited a very low density (3 Ind/ha) and found dominated by *Cedruss deodar*, *Quercus oblongata* and *Alnus nepalensis*. Population structure of dominated tree species is shown in Fig.5. At site II, maximum density (525 Ind/ha) was recorded for 0–20 cm followed by 21–40 cm (88 Ind/ha), while 81–100 cm exhibited a very low density (11Ind/ha) and found dominated by *Rhododendron arboreum*, *Quercus oblongata* and *Lyonia ovalifolia*. Population structure of dominated tree species is shown in Fig.6. At site III, maximum density (732 Ind/ha) was recorded for 0–20 cm followed by 21–40 cm (78 Ind/ha), while 81–100 cm exhibited a very low density (17 Ind/ha) and found dominated by *Quercus semecarpifolia*, *Quercus floribunda* and *Rhododendron arboreum*. Population structure of dominated tree species is shown in Fig.7. At site IV, maximum density (2200 Ind/ha) was recorded for 0–20 cm followed by 21–40 cm (450 Ind/ha), while 81–100 cm exhibited a very low density (22 Ind/ha) and found dominated by, *Quercus semecarpifolia*, *Quercus floribunda* and *Picea smithiana*. Population structure of dominated tree species is shown in Fig.8. At site V, maximum density (940 Ind/ha) was recorded for 0–20 cm followed by 21–40 cm (290 Ind/ha), while 81–100 cm exhibited a very low density (24 Ind/ha) and found dominated by *Abies pindrow*, *Taxus wallichiana* and *Acer acuminatum*. Population structure of dominated tree species is shown in Fig.6. Similar structure has been reported in Churdhar wildlife sanctuary of India (Thakur et al., 2021). Sharma et al., 2018 also found similar types of findings for some ridge forests of the Garhwal Himalaya Uttarakhand. Tiwari, et al., 2019 also reported similar type of results from temperate forests of Garhwal Himalaya, Uttarakhand, India.

The level of tree species appearing 'good' regeneration differed from 22.2–50%. *Alnus nepalensis, Cedrus deodara, Rhododendron arboreum, Q. oblongata* and *Lyonia ovalifolia*, *Q. semecarpifolia* and *Taxus wallichiana* are the prevailing tree species in study area and showed 'good' regeneration. Albeit the general recovery status was fairly high in the study region, there is a decent level of tree species in all the forest sites that showed 'poor' (9–25%), 'fair' (22.2–44.4%), or 'no' (12.5–22.2%) recovery (**Fig.3**). *Symplocos paniculata*, *Aesculus indica* and *Cornus macrophylla* are the prevailing species in the forest, showed 'poor' regeneration. The prevailing tree species in the radi forest, showed helpless recovery because of nonattendance of seedlings in respective forest sites. About 12–22% tree species showed 'no' recovery because of nonappearance of their seedlings and saplings stages.). A reasonable rate (11.1–12.5%) of species was addressed by those appearance 'new recovery' in the -study region. These are the fresh debuts in the study region and are addressed by seedlings or potentially saplings as it were. These species may have colonized this region by dispersal of their seeds through droppings or discharge of birds and animals. Subsequent to getting positive microsites, their seeds sprouted and have arrived at the seedling or sapling stage. These fresh debuts are attempting to get set up and in time they may frame a sub-canopy in the particular forest.The slopes, seedlings, saplings, trees showed positive correlation with altitude in the study

Table 2. Density (Ind/ha) of seedlings, saplings and trees of different species in the study area.

Plant Name	Site I			Site II			Site III			Site IV			Site V		
	TR	**SP**	**SD**	**TR**	**SP**	**SD**	**TR**	**SP**	**SD**	**TR**	**SP**	**SD**	**TR**	**SP**	**SD**
Abies pindrow	-	-	-	-	-	-	-	-	-	100	50	320	110	100	600
Acer acuminatum	-	-	-	-	-	-	-	-	-	20	60	90	60	10	60
Aesculus indica	-	-	-	-	-	-	10	30	-	-	-	-	-	-	-
Alnus nepalensis	40	50	90	30	60	100	-	-	-	-	-	-	-	-	-
Betula alnoides	-	-	-	-	-	-	60	60	200	-	-	-	-	-	-
Picea smithiana	-	-	-	-	-	-	50	40	150	30	60	180	-	-	-
Cedrus deodara	50	260	700	-	-	-	-	-	-	-	-	-	-	-	-
Cornus macrophylla	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-
Cupressus torulosa	30	-	220	-	-	-	-	-	-	-	-	-	-	-	-
Euonymus fimbriatus	-	-	-	-	-	-	-	-	-	20	-	50	-	-	-
Euonymus tingens	-	-	-	-	-	-	30	-	70	-	-	-	-	-	-
Eurya acuminata	-	-	-	30	-	70	-	-	-	-	-	-	-	-	-
Hydrangea aspera	-	-	-	-	-	-	-	-	-	10	40	60	-	-	-
Lindera pulcherrima	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-
Lyonia ovalifolia	-	-	-	50	90	200	-	-	-	-	-	-	-	-	-
Machilus duthiei King.	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinus wallichina .	-	-	-	30	80	60	-	-	-	-	-	-	-	-	-
Pistacia khinjuk	10	-	20	-	-	-	-	-	-	-	-	-	-	-	-
Populus ciliata	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prunus cerasoides	20	-	60	-	-	-	-	-	-	-	-	-	-	-	-
Pyrus pashia	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-
Quercus floribunda	-	-	-	50	-	200	78	50	350	-	-	-	-	-	-
Quercus oblongata	67	40	200	80	107	300	-	-	-	-	-	-	-	-	-
Quercus semecarpifolia	-	-	-	-	-	-	70	100	700	80	130	600	100	230	880
Rhododendron arboreum	-	-	-	50	96	500	40	60	280	-	-	-	-	-	-
Sorbus cuspidata	-	-	-	-	-	-	-	-	-	50	-	90	20	30	40
Symplocos paniculata	-	-	-	20	60	-	-	-	-	-	-	-	-	-	-
Taxus wallichiana	-	-	-	-	-	-	-	-	-	100	180	300	80	140	300
Ulmus wallichiana	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-
Vibernum grandiflorum	-	-	-	-	-	-	-	-	-	-	-	-	40	-	40
Total	267	350	1330	340	493	1433	318	340	1780	**450**	**520**	1690	410	510	**1920**

Table 3. Regeneration status of tree species in five sites of the study area.

Name of species	Family	Study sites				
		Site I	**Site II**	**Site III**	**Site IV**	**Site V**
Abies pindrow(Royle ex D.Don) Royle	Pinaceae	-	-	-	Fair	Fair
Acer acuminatum Wall. ex D.Don	Aceraceae	-	-	-	Good	Fair
Aesculus indica (Wall. ex Cambess) Hook	Hippocastanaceae	-	-	Poor	-	-
Alnus nepalensis D.Don	Betulaceae	Good	Good	-	-	-
Betula alnoides Buch-Ham. ex D.Don	Betulaceae	-	Fair	Fair	-	-
Cedrus deodara	Pinaceae	Good	-	-	-	-
Cornus macrophylla Wall.	Cornaceae	-	-	Poor	-	-
Cupressus torulosa D.Don	Cupresssaceae	Fair	-	-	-	-
Euonymus fimbriatus Wall.	Celasteraceae	-	-	-	Fair	-
Euonymus tingens Wall.	Celasteraceae	-	Fair	-	-	-
Eurya acuminate Buch-Ham. ex D.Don	Theaceae	-	Fair	-	-	-
Hydrangea aspera D.Don	Hydrangeaceae	-	-	-	Good	-
Lindera pulcherrima (Nees) Benth. ex Hook.	Luaraceae	-	-	New	-	-
Lyonia ovalifolia Wall.	Ericaceae	-	Good	-	-	-
Machilus duthiei King.	Lauraceae	Not	-	-	-	-
Picea smithiana Wall. ex Lindl.	Pinaceae	-	Fair	Fair	-	-
Pinus wallichina A.B.Jacks.	Pinaceae	-	Good	-	-	-
Pistacia khinjuk Stocks	Anacardiaceae	Fair	-	-	-	-
Populus ciliata Wall. ex Royle	Salicaceae	Not	-	-	-	-
Prunus cerasoides D.Don	Rosaceae	Fair	-	-	-	-
Pyrus pashia Buch-Ham. ex D.Don	Rosaceae	New	-	-	-	-
Quercus floribunda Lindl.ex A.Camus	Fagaceae	-	Fair	Fair	-	-
Quercus oblongata A. Camus	Fagaceae	Fair	Good	-	-	-
Quercus semecarpifolia Smith.	Fagaceae	-	-	Good	Good	Good
Rhododendron arboreum Smith.	Ericaceae	-	Good	Good	-	-
Sorbus cuspidata (Spach) Hedl.	Rosaceae	-	-	-	Fair	Good
Symplocos paniculata (Thunb.) Miq.	Symplocaceae	-	Poor	-	-	-
Taxus wallichiana Zucc.	Taxaceae	-	-	-	Good	Good
Ulmus wallichiana Planch.	Ulmaceae	-	-	-	Not	-
Viburnum grandiflorum Wall. ex DC.	Adoxaceae	-	-	-	-	Fair

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	Altitude	*Slope*	*Trees*	*Saplings*	*Seedlings*
Altitude	1				
Slope	**0.936329***	1			
Trees	0.856669	0.792081	1		
Saplings	0.611743	0.586824	0.848531	1	
Seedlings	0.929504	0.821213	0.63597	**0.303914**	1

Table 4. Correlation between different aspects.

* Positive correlation.

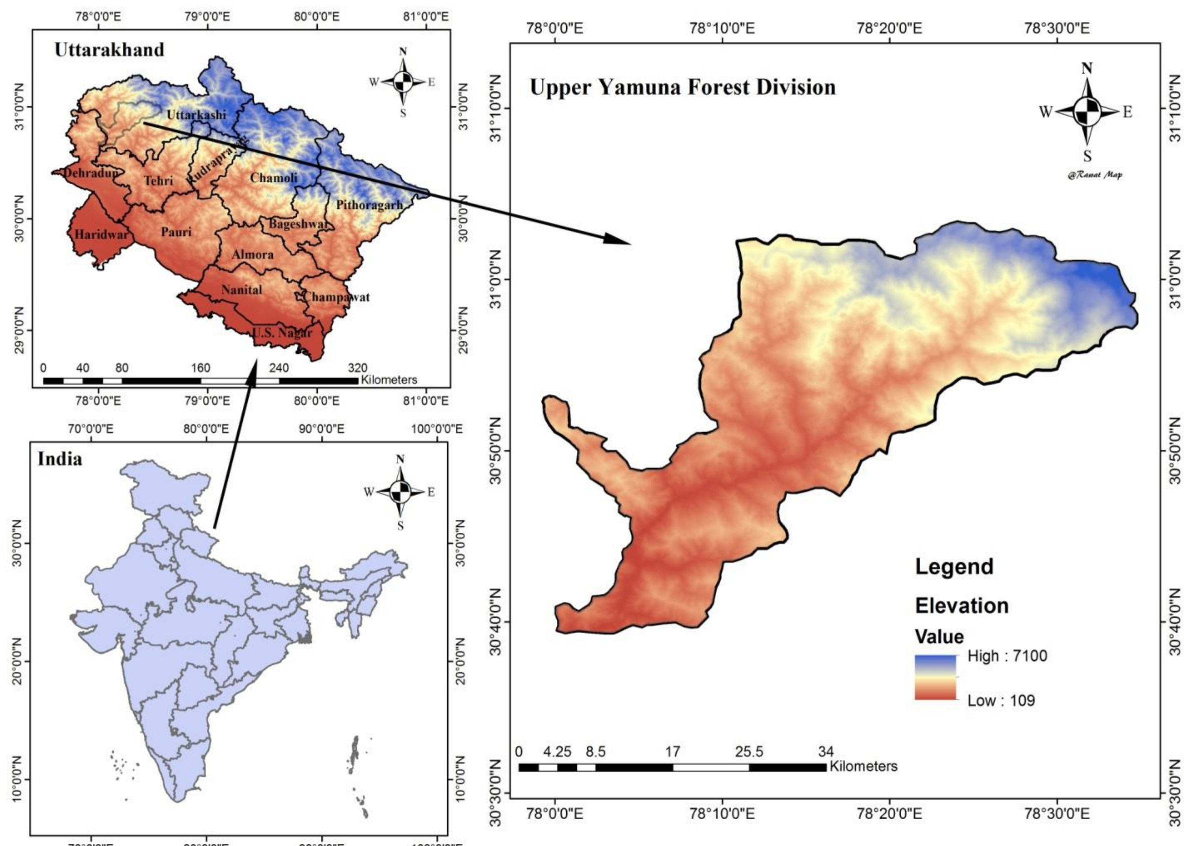

Figure 1. Map of the study area.

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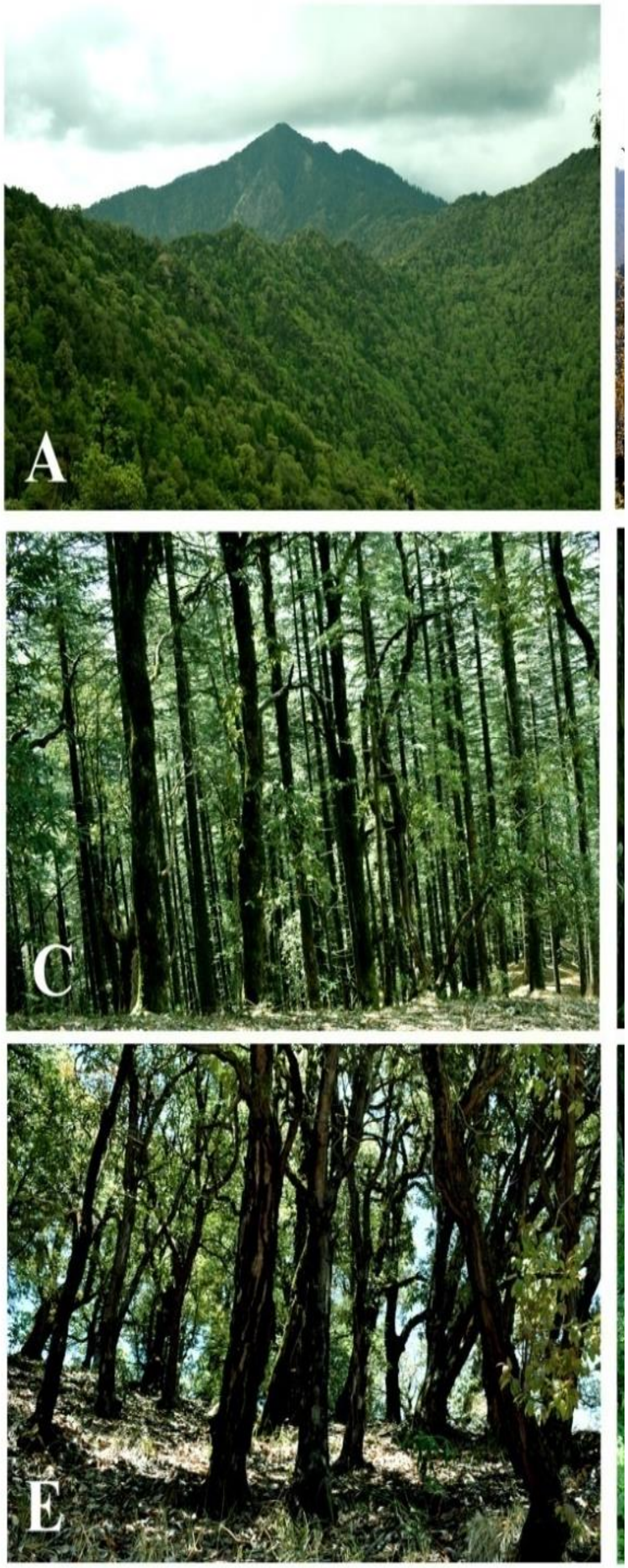

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Figure 2.(A)&(B). Far view of forest.(C)*Cedrus deodara* dominated site (D)*Quercus olongata* dominated site (E) *Rhododendron arboreum dominated site*

(F) *Abies pindrow dominated site*

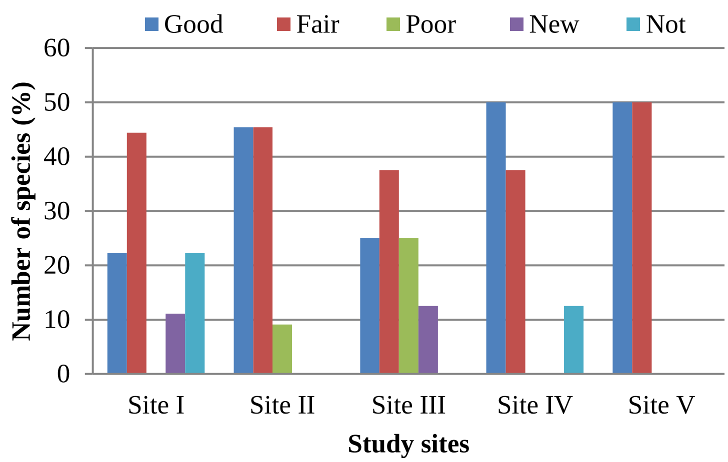
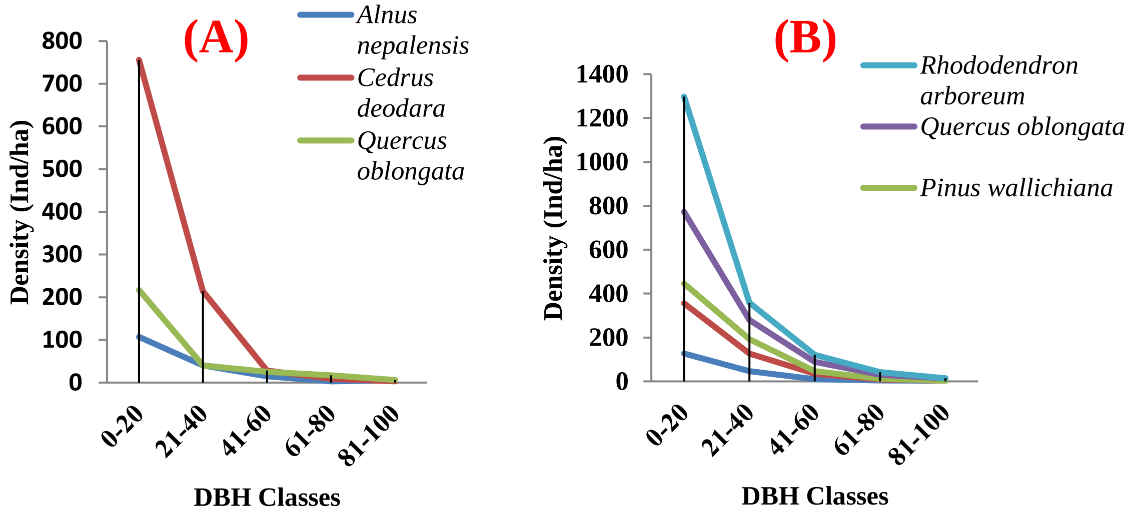


Figure 3. Regeneration status of tree species at different study sites.



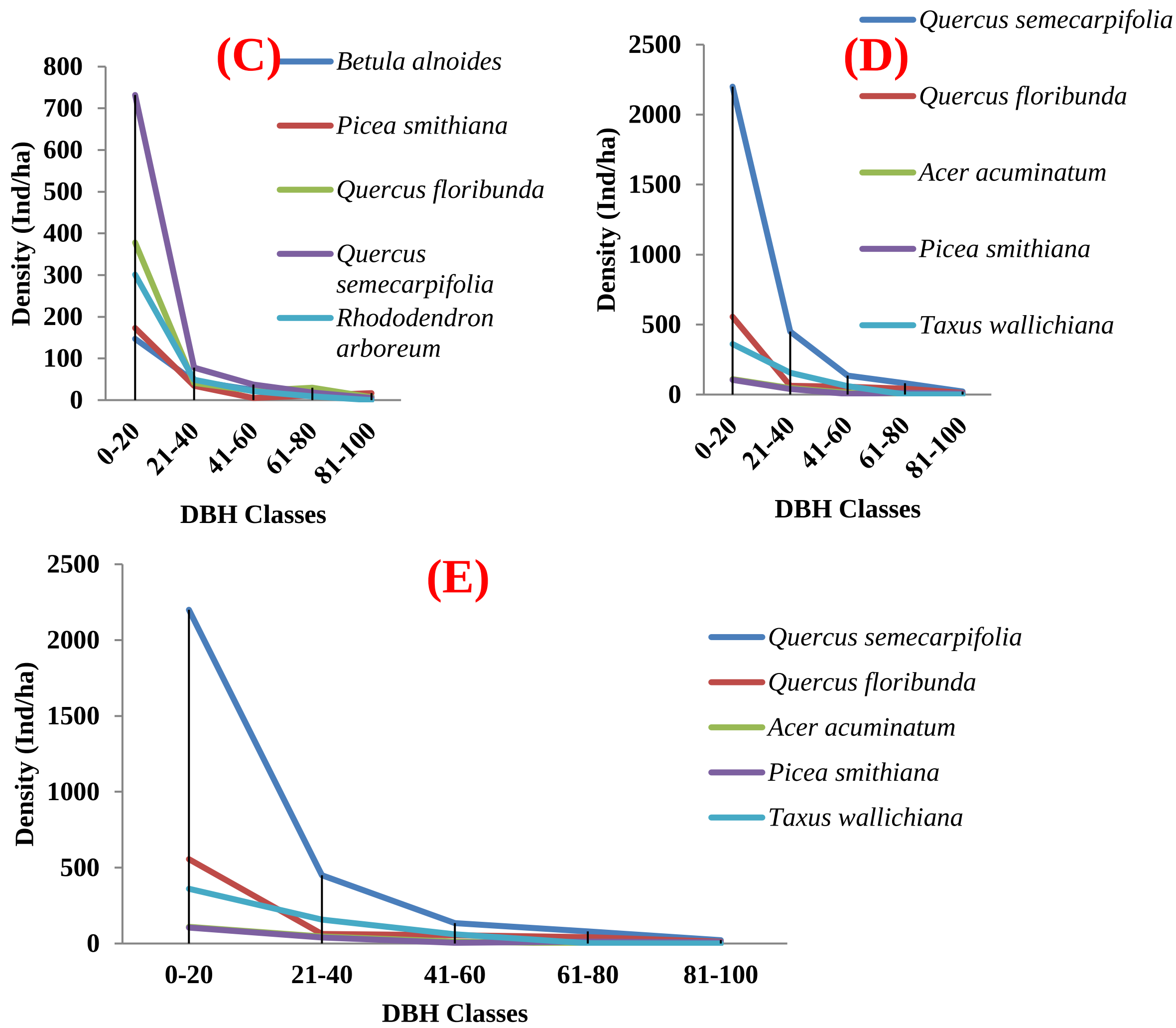


Figure 4. Diameter classes vs. Density of tree species at site different sites. (A). Site I (B). Site II (C). Site III (D).Site IV (E) Site V.

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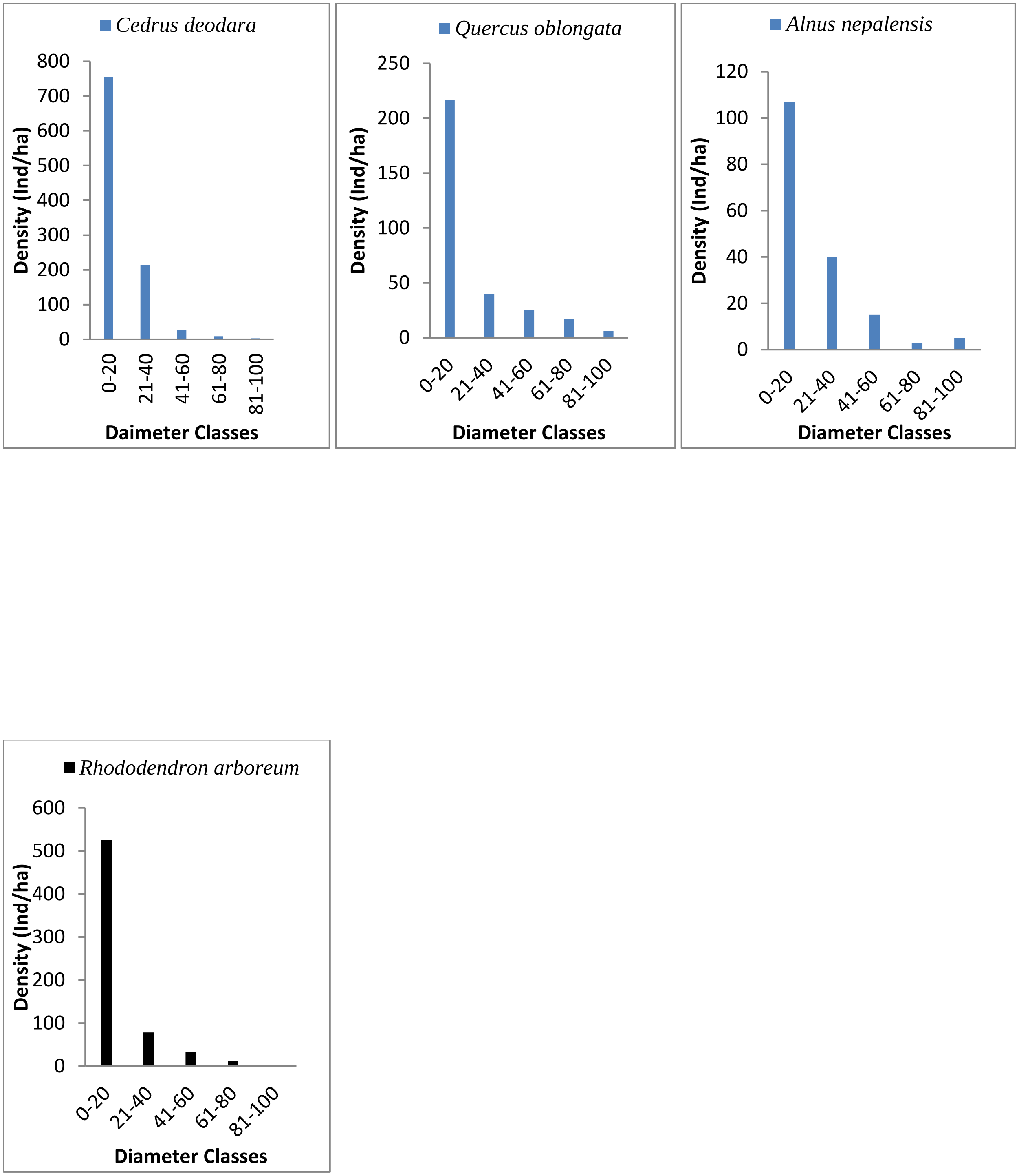

Figure 5. Major tree species available at Site I vs. tree diameter classes.

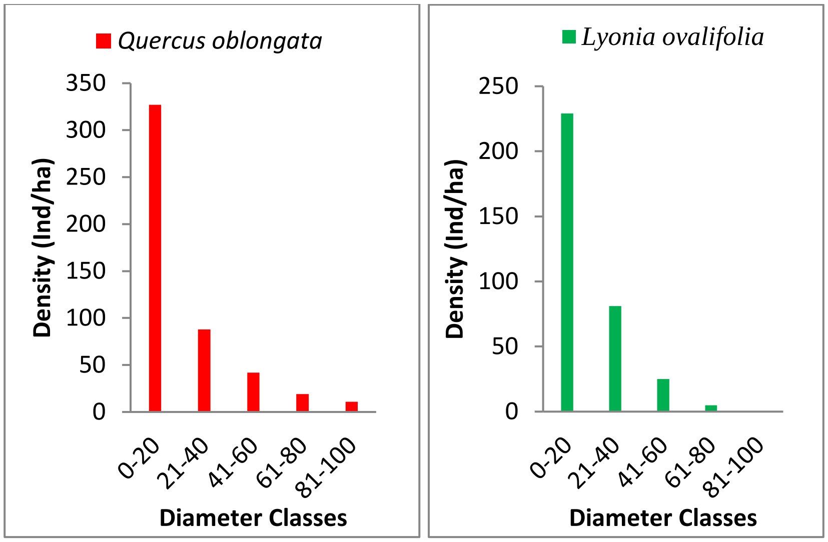

Figure 6. Major species available at site II vs. tree diameter classes.

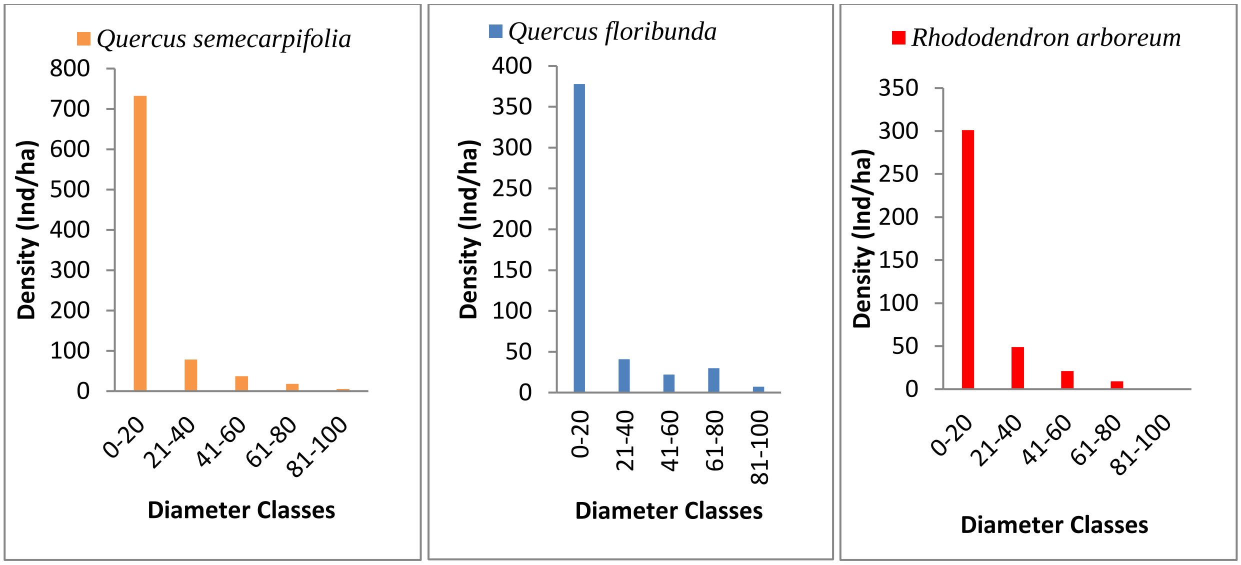

Figure 7. Major tree species available at site III vs. tree diameter classes.

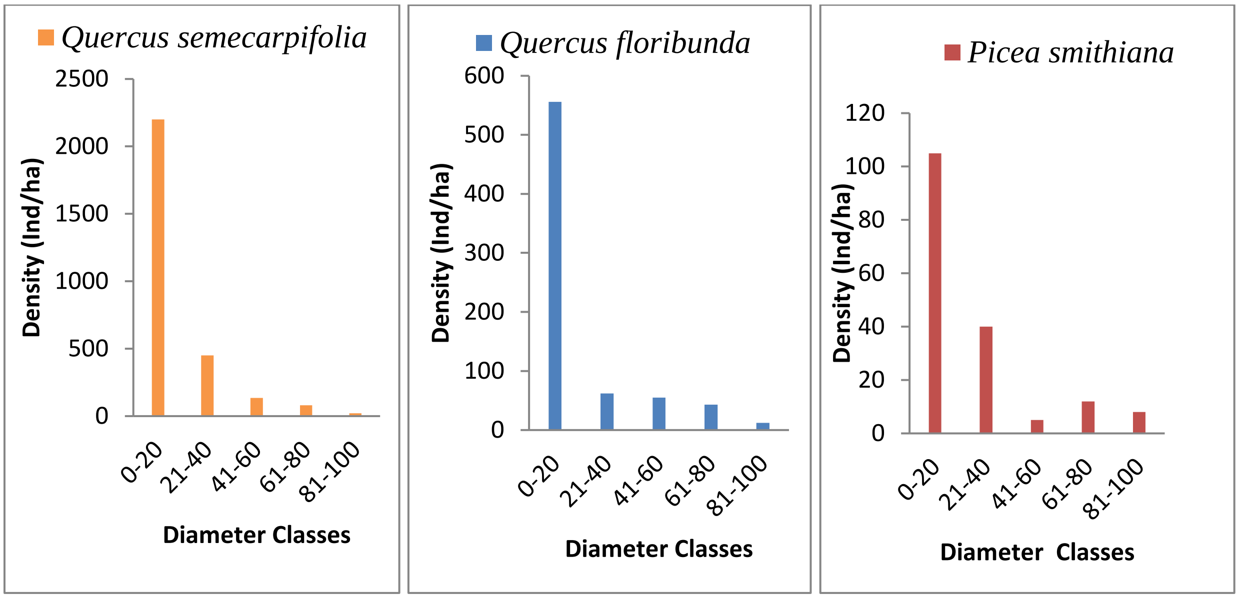

Figure 8. Major species available at site IV vs. tree diameter classes.

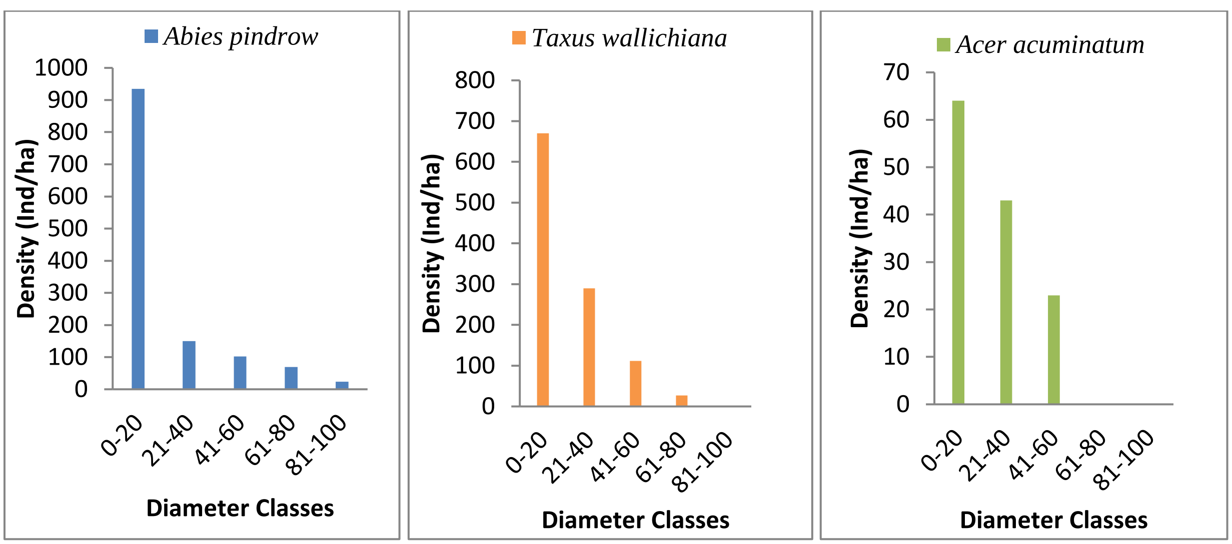

Figure 9. Major species available at site V vs. tree diameter classes.

(Table 4). The study suggests that richness of seedling, sapling and adults of tree species are largely regulated by the altitude and climatic factors.

CONCLUSION

The tree species showing poor or no generation status might be in danger in near future regardless of whether these are predominant as of now and alter the future composition of the forest. Accordingly, an orderly administration plan is needed for their conservation and sustainable use. The reason behind this might be some anthropogenic unsettling influences such as grazing and fuelwood assortment. The overgrazing by animals hurts the ground vegetation and blocks regeneration of predominant tree species and can cause serious damage to the new seedlings also. Plantation of the seedlings of the poor regenerating species can be the effective step in the maintenance of their population structure in near future. General regeneration status of tree species in the study area is 'good' and the future networks might be supported except if there is any major ecological pressure or impedance applied by human activities.

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