Impact of Forest fire and aspect on phytosociology, tree biomass and carbon stock in Oak and Pine mixed Forests of Kumaun central Himalaya, India

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Abstract: Fire is one of the main factors causing biodiversity losses, its main effect on ecological process in the forests are losses in stocks of biomass, change in hydrological cycle and nutrients, forest fires are growing in their size and frequency. Forest fire frequencies, aspect, phytosociological analysis, and population structure of the forest of the two community managed forest locally called (Community Forests) of Almora district, in Kumaun Central Himalaya were studied. The sites were divided into two different aspects i.e. South West (SW) and North West (NW). Based on the phytosociological analysis of four sites represented two major forest types: Pure oak forest and mixed oak-conifer forest. The total basal cover of trees ranged from 4.44 m^2 ha^{-1} to 46.52m^2 ha^{-1}.Total tree densities varied from 160 ind ha^{-1} to 230ind ha^{-1}. Sapling density varied from 360ind ha^{-1} to 610 ind ha^{-1} and seedling density from 120 ind ha^{-1} to 530 ind ha^{-1}. *Pinus roxburghii* was the dominant species in SW aspect and *Quercus leucotrichophora* in NW aspect. The total tree biomass ranged between 9.47 t ha^{-1} to 62.54 t ha^{-1} in all aspect of the forests, and the maximum tree biomass was found in north-western aspect of Dhaili van Panchayat forest (62.54 t ha^{-1}). Fire was a strong agent of reducing the number of seedlings and saplings and the biomass stock as well in the studied forest sites, it was observed that those studied sites where fire frequency was regular (every year) the number of sapling and seedling count was 360 ind ha^{-1} and 370 ind ha^{-1} in south-eastern aspect for both study sites respectively, while this number increased to 610 and 530 ind ha^{-1} for the north-western aspect where fire occurred once in a five year.

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Key words: Aspect, Biomass, Carbon, Forest fire, Regeneration, Community.

INTRODUCTION

The Central Himalaya, accounts for 8.68% of the total Indian Himalayan area (59436 km^2) and harbor rich biodiversity due to geographical and geological peculiarities subtending a wide range of vegetation types (Rikhari *et.al.,* 1997). The Himalayan biodiversity is severely threatened by natural and anthropogenic means. The various disturbances present in the area are eroding this rich biological diversity day by day and has led to the expansion of xerophytic conditions (Singh and Singh, 1987). The majority of the population in the region is agricultural and pastoral. Forests present around the agricultural fields are highly degraded due to continuous anthropogenic disturbances. A large number of cattle are kept for manure production. Villagers frequently graze their cattle in the adjoining forest which increases the pressure beside fodder and fuel wood extracted from oak forest and accidental fires (Singh and Singh, 1984). Forest biodiversity is the main source of livelihood of the people of Uttrakhand. The exploitive management practices and the biotic stress exerted by hill population in relation to oak species have encouraged the pine in various ways (Saxena and Singh, 1984). Much of the area now occupied by pine was originally under the potential natural vegetation of oaks (Champion and Seth, 1968). Conversion of oak forests to pine is still proceeding on larger scale this trend may lead to severe reduction in the oak forest area in the region. A reversal of this trend requires a thorough evaluation of current management practices including local people participation. Conservation of biological resources under community based conservation system is a key tool to lessen the depletion of biodiversity. Various programme have been implemented for the conservation of biological resources in the Indian Himalaya under the protected area network. The active participation and involvement of local people either at community or individual level is essential towards conservation of the forest and other natural resources.

Because of its aggressiveness and capacity to colonize disturbed areas, chir pine (*Pinus roxburghii*) is spreading at the expanse of Banj oak (*Qurecus leucotrichophora)* forests the latter being under immense biotic pressure(Singh et al,1984), recently, chir pine has also been planted as monoculture in many areas. However, plantations involved high costs in comparison to natural regeneration. It is, therefore desirable that a forest is allowed to regenerate naturally without large inputs of material and labour. Inorder to develop proper management chir pine forests at low inputs, it is necessary to document its regeneration status under current management practice. From the view point, this study was done on phytosociological analysis, population structure, and regeneration status, species diversity, species richness of constituent species of the forest occurring along elevational gradients. Some outstanding contributions on phytosociology (Knight 1975, Saxena and Singh, 1982, Rahlan et al. 1982).

Uttrakhand the newly created state in central Himalaya, forest fire are common as a result of which vast tracts of forest land in the 1,000-1,800 m range are covered by fire –adapted chir pine (*Pinus roxburghii*) forests. Almost all fires are man-caused (intentional or accidental). Local people of the region burn chir pine forests in controlled way during summers to enhance the growth of the succulent herbaceous fodder during monsoon. In addition to this grazers, school boys and forest personnel also causes forest fires for various purposes. Accidental fires takes place mainly in during burning of crops remains in agricultural fields located near forests in April- May, flames that escape during controlled burning done by department a live cigarette or bidi butt thrown by a careless passerby, motor road repairs, cooking and campfire activities of pilgrims and tourists etc.

Among disasters, the forest fire has been emerging as the most common disaster since last decade, disturbing the bio-diversity, the ecology and environment of a region. The forests of Western Himalayas are more frequent vulnerable to forest fire as compared to those in Eastern Himalayas. In 1995 forest fire had destroyed more than 3.75 million hectares of forest wealth in Uttaranchal alone. Of the total inventoried forest area of the country, on an average 8.92% is affected by frequent fire and 44.25% by occasional fire. Today, the most forest fires are the result of human neglect. The best way to control a forest fire is to prevent it from spreading by creating Fire Breaks in the shape of small clearings of ditches in the forests. Burning of forests and grasslands add also to already serious threat of global warming and pollution and may be a global source of methyl bromide, which is ozone, depleting substance. In India there is as yet no proper action plan to control forest fires. In Himalayan states, the involvement of the people under Joint Forest Management may certainly be helpful in preventing forest fires by using the modern fire fighting methods.

In the central Himalayan region, every year forest fires leave a devastating impact on the regional landscape affecting flora, fauna, human livelihoods, and the local climate. Although fire may be both of natural and anthropogenic origin, the limited studies on this subject suggest that in this region fire is entirely of anthropogenic origin. In this region fire is used as a tool to meet several objectives, both by the local inhabitants and the Forest Department. On the one hand, the local people harvest good growth of fodder grasses after fire, and on the other the Forest Department uses fire as a tool (by controlled burning or to "fight fire with fire") to reduce the severity of fire during the summer season. In a study in the Garhwal hills by Semwal it was reported that 63% of the total fire incidents were intentionally man-made and the remaining 37% were accidental. The Chir Pine (Pinus roxburghii) forests are more prone to forest fire as they shed their resin-containing leaves during summer. These forests are mostly spread over the middle altitudinal zone of the region (1000-2000 masl), the fire cycle is repeated every 2-5 years, and about 11% forest area of the region faces fire every year. The main reasons for intentional forest fire were: the amusement of livestock herders and children, to hide the realities of forest operations by some interest groups/individuals, driving game animals, and driving away honey bees. Among the reasons for accidental fires were: clearing weeds from the crop fields for crop cultivation, the spread of intentional fires to nearby forests during road repairs, carelessness by travellers (e.g., discarding an ignited cigarette butt), camp fires, etc.

Fire is a common feature in Indian Himalayan forests every year, causing incalculable damage to the forest wealth and ecosystem. High proportions of fires are attributed to man made reasons either deliberately or accidentally. Normal fire season in India is from the month of February to mid- June. Human induced fires are common in early summer months in the forests of Uttrakhand. The local people deliberately set fires in Chir Pine (*Pinus roxburghii*) forests to promote growth of understory herbaceous species comprehensively used for fodder by local people.

MATERIALS AND METHOD

Study Area

The present study has been carried out in the Two Van Panchayat forest situated between 29°32.98'-29°34.32' N latitudes and 79°41.44'-79°43.2' E longitude of Lamgara Developmental Block of Almora District (Uttarakhand). The basic climate pattern is governed by the monsoon rhythm. The annual rainfall varied from 832.0 mm to 921.9 mm, mean maximum temperature from 16.7°C to 32.6°C and the mean minimum temperature from 5.8°C to 19.5°C (Jina, 2008). Rock types mainly comprises of schist, micaceous quartizimeta morphism, plutonic bodies of granodiorites and granites (Valdiya, 1980). The vegetation type mainly comprises Himalayan moist temperate Oak forest, subtropical pine forest. The dominated tree species of the Van Panchayat are *Quercus leucotrichophora*, *Pinus roxburghii, Rhododendron arboreum,* and *Myrica esculenta*.

Methods

Phytosociological Analysis:

Information regarding different landscapes and vegetation was collected through questionnaires which were distributed to the villagers and members of the Community Forests. Two aspects South-West and North-West were identified with in each aspect trees were analysed by placing randomly 10, 100m^2 circular quadrats, the size and number of samples was determined following MacDicken (1997). Sapling and seedling were studied in 10, 5×5 m^2 quardrats placed randomly. The vegetational data were calculated for density, frequency, abundance, mean basal area, total basal area (Curtis and McIntosh, 1950). Importance value index for trees was determined as the sum of the relative density relative frequency, relative dominance (Curtis, 1959). Individuals of the tree species were divided in to three classes, Trees were consider to be individual >30cm cbh (Circumference at breast height), Sapling 10-30cm cbh and seedling <10cm cbh (Saxena and Singh, 1984).

Tree Biomass and Carbon

The d.b.h. and height of the tree were measured using diameter tape and Clino master respectively in the selected plots, placed randomly in 2010. The data was then subjected to regression model developed by (Rawat and Singh, 1988) and are applied to mean d.b.h of each tree species to calculate the biomass accumulation in different tree components. The average biomass attained was then multiplied to the tree density in the diameter classes. The half of thus obtained tree biomass is the total carbon stock for all tree species. Analysis for Biomass and carbon stock was done using R-statistical software (R development Core Team 2009).

RESULTS

Tree layer-:

The total tree density ranged between 160 to 230 ind ha^{-1} and total basal area ranged between 4.44 and 46.52m^2 ha^{-1} among all the aspects (Table-1). The highest tree density was that of *Pinus roxburghii* (230 ind ha^{-1}) at south-west facing aspect, where the lowest tree density was that of *Myrica esculenta* (10 ind ha^{-1}each) south-west aspect. *Pinus roxburghii* was the most dominant species in term of the total basal area and it also shows the maximum IVI (i.e. 46.52 m^2 ha^{-1} and 300) at south-western aspect respectively.

Sapling layer

The total sapling density ranges from 360 to 610 (ind ha^{-1}) in south-western and north western aspect respectively. *Pinus roxburghii* and *Quercus leucotrichophora* shows the maximum density in both south-western and north-western aspect i.e. (360 ind ha^{-1}and 500 ind ha^{-1}) respectively. The most dominant species was *Pinus roxburghii* (IVI=300) in south-western aspect in both the van Panchayat forests, however the total basal area was highest for Quercus leucotrichophora (18.31m^{2}ha^{-1}) at north-western aspect (Table-1).

Seedling layer

The total seedling density varied from 120 to 530 ind ha^{-1}at south-western to north-western aspect of both Community Forests. The seedling density was highest for *Pinus roxburghii* at the south western aspect (350 ind ha^{-1}) and lowest on north facing aspect for *Rhododendron arboreum* (10 ind ha^{-}1 in both Community Forests it was also observed that total number of seedlings found highest in south-western aspect (400 to 530 ind ha^{-1}) respectively (Table-1).

Regeneration status

The population structure of the all species is given in Figure 3. The number of seedlings and saplings of *Pinus roxburghii* were quite higher among all the aspect(720 ind ha^{-1}) *Quercus leucotrichophora* seedlings, saplings and tree were present only on north western aspects, while *Pinus roxburghii* was encountered in both south western and north western aspects. Majority of trees was of the younger size class of 31-60 cm (Fig. 3).

Biomass and carbon distribution in the forest site

The total tree biomass and carbon (values inside the bracket) content ranged between 9.47(4.73) t ha^{-1} to 62.54(31.27) t ha^{-1} in SW and NW aspect of Dhaili Van Panchayat. The plots in NW aspects of Dhaili CF have most spreading biomass values as compared to the plots in SW aspect of Dhaili CF (Figure.1).Similarly the total tree biomass and carbon (values inside the bracket) content in Two different aspects of Toli CF ranged between and 38.54(19.27) t ha^{-1} to 49.53(24.76) t ha^{-1}. Plots in Toli CF NW aspects of have most spreading biomass values as compared to the plots in SW aspect of Dhaili CF (Figure.2).The maximum tree biomass was found in north-western aspect of Dhaili van Panchayat forest (62.54 t ha^{-1}) while the minimum tree biomass was found in pine mixed forest in SW aspect of Dhaili VP forest 9.47 t ha^{-1}(Table-2 and Table-4). Only a plot in SW aspect of Dhaili CF and NW aspect of Toli CF shows the outlier plots also the both of these aspect in both CF shows the highest sampling precision values i.e. above 10% which might be due to the fact that for sampling survey might need to be optimized in order to achieve higher accuracy.

DISCUSSION

Among disasters, the forest fire has been emerging as the most common disaster since last decade, disturbing the bio-diversity, the ecology and environment of a region. In the central Himalayan region, every year forest fires leave a devastating impact on the regional landscape affecting flora, fauna, human livelihoods, and the local climate. Fire was a strong agent of reducing the number of seedlings and saplings in the studied forest sites. It was observed that those studied sites where fire frequency was every year the number of sapling and seedling count was 360 ind ha^{-1} and 120-370 ind ha^{-1} in south-eastern aspect for both study sites respectively. While this number increased to 400-610 and 400-530 ind ha^{-1} for the north-western aspect where fire occurred once in a five year. The amount of fuel load on the forest floor was more in NW aspects for all forest sites, where fire occurs once with in five year. These community managed forests contains immense amount of dry mass in the form of standing biomass. Any time any accidental fires takes place in these fire regime may cause disasters and there is a possibility of loss of immense biomass stock and carbon content in the atmosphere emitting huge amount of CO_2 causing incalculable damage to the forest wealth and ecosystem loss of bio-diversity, deteriorating the ecology and environment of a region. The alternate strategies i.e. utilization of pine needles (locally called Pirul) as an alternate source of energy, for economic purpose (like packing cases) will play significant role in reducing the constantly accumulating fuel load, reduce the dependence of rural population on other ecologically valuable forests like (*Quercus leucotrichophora)* and gain economic upliftment. The total tree density (160 ind ha^{-1} to 230ind ha^{-1}) reported in the present study falls within the range of values 280-1680 ind/ha reported earlier by Singh et.al. (1994), Jina (2006), Kharkwal (2009) for different central Himalayan oak and pine forest. In the four aspects the density of *Quercus leucotrichophora* seedling were highest *(*640ind ha^{-1}) followed by sapling and young trees indicating an expanding type of population pattern. Fire regimes play an important role in biomass allocation patterns. For example, in fire- prone ecosystems, total plant biomass, growth rates, and distribution of biomass between roots and shoots is influenced by fire intensity and frequency (Pare and Bergeron 1995, de Vinas and Ayanz 2000, Dijkstra et al. 2002, Day et al. 2006, Mack et al. 2008).The tree biomass stock and carbon in north-western site for each forest shows higher values (62.54 $tha^{-1}$and 49.93tha^{-1}) as compared to the south-western sites(9.47 tha^{-1} and 38.54 t ha^{-1}) respectively. The forest tree biomass also decreased in south-western aspects of both Community Forests where fire frequency is every year. While it was found significantly higher in north-western aspects for both sites .It is interesting that the previous researches on chir pine forests indicates that pine is good reproducer not only in its own forest but also in other forest (Saxena and Singh, 1982) and is invading the oak forest area due to which the replacement of the oak forest by pine has become a common and ever-increasing phenomenon (Saxena and Singh, 1984). From this study it is clear that if the forests are managed properly the regeneration of Banj-oak will occur particularly in good seed years. The total basal area of the present study for tree layer varied from 4.44m^2 ha^{-1} and 45.52m^2 ha^{-1} which have been reported earlier by Saxena and Singh (1982), Upreti, (1985), Ralhan et al. (1982) for young forests. These values are generally comparable with the values reported earlier for sub-tropical forests (Rawat and Chandhok, 2009, Srivastawa et. al., 2008, Kharkwal, 2009). These facts suggest that forest types of the study area are highly representative in their composition. The distribution, ecosystem functions and occurrence of species had been affected by human interventions (Singh and Singh, 1987). Among human influence, commercial exploitation, agricultural requirements, forest fire, and grazing pressure, reckless lopping is the important source of disturbance (Singh and Singh, 1992). *Pinus roxburghii* which is reported to invade most of the oak forest as a consequence of disturbance in terms of tree removal and burning has failed to establish itself in the present study site. It appears that although some individuals of *Pinus roxburghii* reached the periphery of the forests, subsequently to a major disturbance, it could not regenerate in the relatively undisturbed conditions thereafter (Singh, et al 1987).Repeated disturbances release carbon directly in to the atmosphere. The availability of carbon is important in controlling nutrient cycling and soil biological activity. Soil stores 2.5 to 3.0 times as much as that stored in plants in the terrestrial ecosystem (Post, et.al., 1990). In the present day situation of increasing atmospheric level of CO_2 and continued accelerated rate of deforestation, finding simple and low cost management strategies for enhancing carbon sequestration rates of forests is important worldwide. Sustainable management and participatory conservation of forests is therefore an important strategy for dealing with climate change. Forests are a much cheaper and easier way to store biomass and carbon than industrial capture and storage, local community involvement is inevitable for reducing the fire as the forest department has shortage of staffs and economic assistance to the community will enhance a sense of ownership towards the forest.

Table-1Vegetation analysis of Dhaili and Toli Community Forests.

Dhaili VP		**Tree**			**Sapling**			**Seedling**
Stand 1and 2	**Every year fire**	**Density (ind/ha)**	**TBA (m^2ha^{-1})**	**IVI (%)**	**Density (ind/ha)**	**TBA (m^2ha^{-1})**	**IVI (%)**	**Density (ind/ha)**
Aspect	**Species**							
SW	*Pinus roxburghii*	230	46.52	300	360	7.14	300	350
	Myrica esculenta	-	-	-	-	-	-	20
Total		**230**	**46.52**	**300**	**360**	**7.14**	**300**	**370**
Fire occurred once in a five year								
NW	*Quercus leucotrichophora*	140	13.61	203.56	500	18.31	226.60	430
	Rhododendron arboretum	-	-	-	30	1.07	18.29	10
	Myrica esculenta	-	-	-	50	1.79	36.4	30
	Pinus roxburghii	60	6.72	96.40	30	0.44	19	60
	Pinus wallichiana	-	-	-	-	-	-	-
Total		**200**	**20.43**	**299.96**	**610**	**21.63**	**299.8**	**530**
Toli VP	**Tree**	**Tree**			**Sapling**			**Seedling**
Aspect	**Stand 3 and 4**	**Density (ind/ha)**	**TBA (m^2/ha)**	**IVI (%)**	**Density (ind/ha)**	**TBA (m^2/ha)**	**IVI (%)**	**Density (ind/ha)**
Every year fire								
SW	*Pinus roxburghii*	150	3.12	249.78	360	14.15	300	120
	Myrica esculenta	10	1.31	50.2	-	-	-	-
Total		**160**	**4.44**	**299.98**	**360**	**14.15**	**300**	**120**
Fire occurred once in a five year								
NW	*Quercus leucotrichophora*	50	7.80	168.75	300	7.18	198.62	210
	Pinus roxburghii	110	31.36	131.2	100	2.44	86.48	90
	Myrica esculenta	-	-	-	-	-	14.84	-
Total		**160**	**39.17**	**299.9**	**400**	**9.63**	**299.9**	**300**

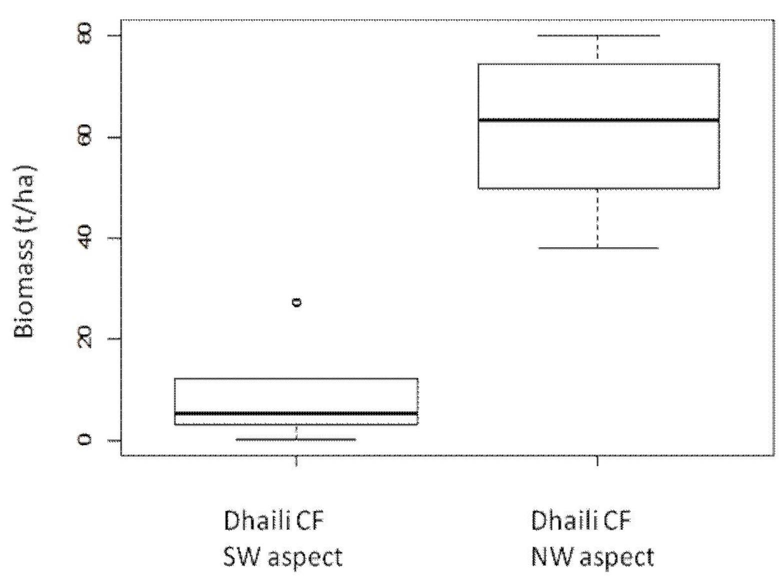

Figure 1: Box-and-whisker plot of above ground tree biomass for Dhaili CF showing five-number summaries and outliers.

Table -2 Tree biomass and carbon stock distribution Dhaili CF

S.no	Site	Aspect	Forest stand	Biomass(t ha^{-1})	Carbon(t ha^{-1})
1	Dhaili VP	SW	Pine mixed	9.47	4.73
2	Dhaili VP	NW	Oak mixed	62.54	31.27

Table-3. Summary statistics of sampling of trees Dhaili CF

Aspe ct	Variable unit	Number of plots	Mean	Std. deviation	Half width of confidence interval	Max	Min	Median	Sampling precision
SW	Biomass [t ha^{-1}]	10	9.48	9.92	7.09	27.30	0.24	5.44	33.09
NW	Biomass [t ha^{-1}]	10	62.54	14.12	10.10	80.00	37.91	63.33	7.14

Table -4 Tree biomass and carbon stock distribution in Toli CF

S.no	Site	Aspect	Forest stand	Biomass(t ha^{-1})	Carbon(t ha^{-1})
1	Toli VP	SW	Pine mixed	38.54	19.27
2	Toli VP	NW	Oak mixed	49.93	24.96

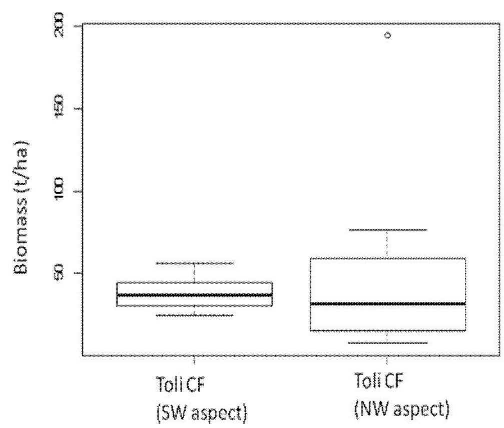

Figure 2: Box-and-whisker plot of above ground tree biomass for Toli CF showing five-number summaries and outliers.

Table-5. Summary statistics of sampling of trees Toli CF

Aspect	Variable unit	Number of plots	Mean	Std. deviation	Half width of confidence interval	Max	Min	Median	Sampling precision
SW	Biomass[t ha^{-1}]	10	38.52	9.43	6.74	55.98	25.14	36.68	7.74
NW	Biomass[t ha^{-1}]	10	49.94	55.02	39.36	194.43	8.01	31.76	34.84

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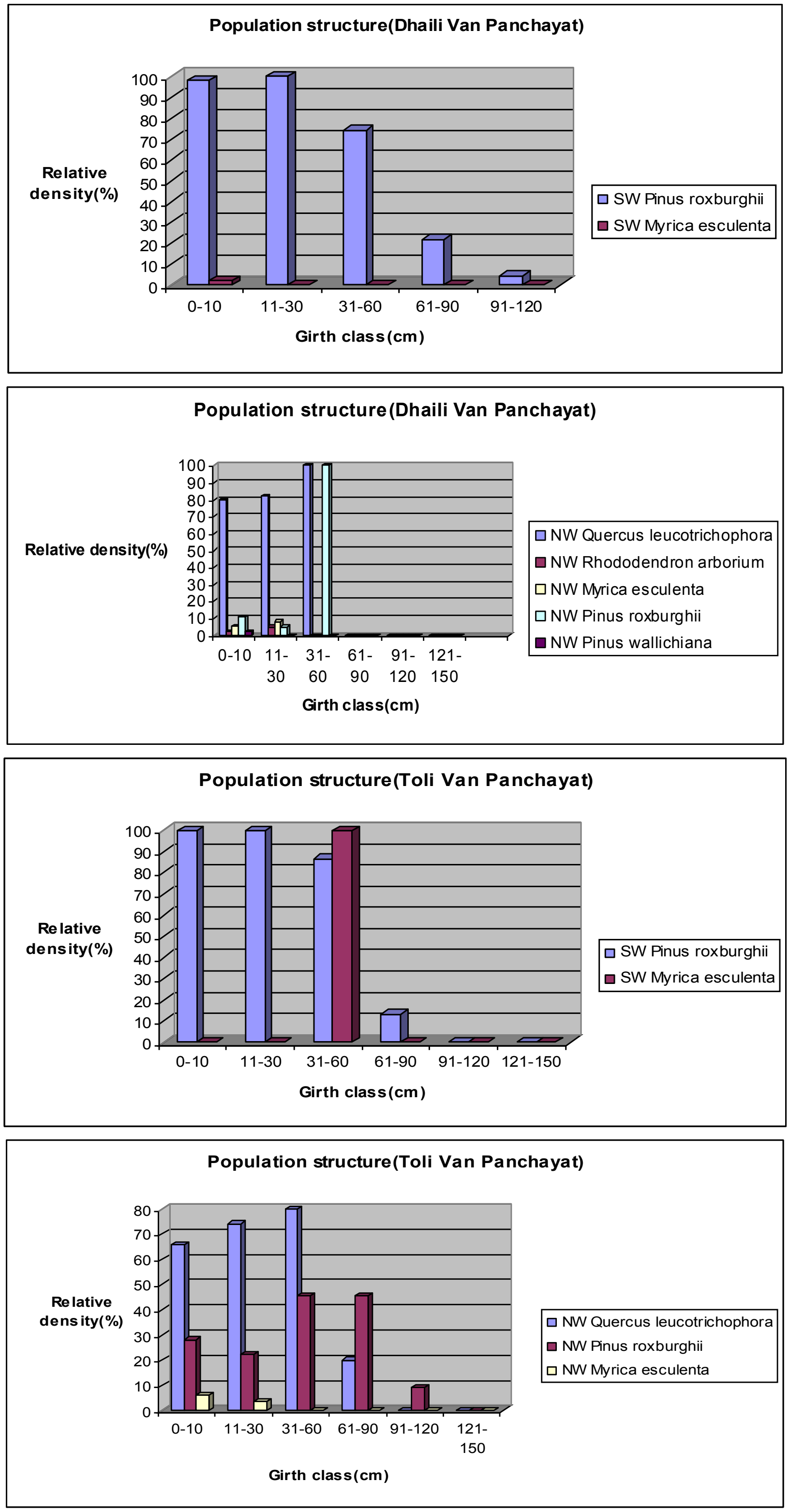

Figure- 3 Population structures of dominant species on four different community forests and two different aspects ; the relative density is on y-axis and the diameter classes on x-axis; 0-10cm = Seedlings, 11-30cm = Saplings, Trees = 31-60 cm, 61-90 cm, 91-120 cm,121-150 cm.

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