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Disparity in Phytosociology, Biomass and Carbon Stock of Trees in Primary and Secondary Temperate Broadleaf Forest of Indian Himalayas

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Abstract: Estimation of carbon stocks in tree biomass is necessary to study climate change under UN Framework Convention on Climate Change. To understand diversity, community characteristics, biomass and carbon stock of trees in Indian Himalayas, two forests - primary (PF) and secondary (SF) temperate broadleaf forest were investigated in Arunachal Pradesh. Extensive field study was undertaken and 15 quadrats (20x20 m^2) each in the two study sites were laid randomly for the study. A total of 33 species of trees belonging to 26 genera and 17 families were recorded from the study sites. 26 species, 21 genera and 15 families were recorded from PF while 27 species, 20 genera and 13 families were recorded from SF. The study revealed higher biomass and higher Carbon stocks with good species richness, higher density and basal area in SF than PF. Forest clearing during *Jhum* may not be considered as deforestation but forest modification allowing forest regrowth during sufficient long fellow. It can be concluded that integration of indigenous knowledge can lead to the development of cost-effective, participatory and sustainable way to conserve biodiversity, to increase long term C sequestration in plants and to mitigate climate change.

Keywords: Arunachal Pradesh, Carbon sequestration, Climate change, Conservation, Jhum, Northeast India, Mitigation

The major concern which was highlighted in the Kyoto protocol was the ever-increasing carbon emission in the entire world (Parry et al 2017). One of the tangible solution for reduction of atmospheric carbon is through the mechanism known as carbon sequestration (Chavan and Rasal 2012). So, the forests play the major role as in sinks of greenhouse gases through changes in the overall carbon stocks of forests and supply of biomass which substitute the fossil fuel and energy-intensive material (IPCC 2006). In the healthy growing forest carbon sequestration act as the only known cost-effective option for mitigation of global warming and global climatic change overall. The study on climate change under UN Framework Convention on Climate Change has made mandatory to estimates carbon stocks and stock changes in tree biomass (Green et al 2007, Parry et al 2017). FAO (2006) estimated that the world's forest ecosystems store more carbon than the entire atmosphere. The role of forest in sequestration and storing of carbon is considered as the most significant in the present context for climate change mitigation strategies (Kishwan et al 2009). Natural forests possess high species diversity when compared with the plantation forests and they are increasingly recognized for their capacity to sequester atmospheric carbon (Baishya and Barik 2011). The sequestration potential varies with species level density change that leads to stratification of different carbon pools (Baishya and Barik 2011). Determination on the potentials of carbon sequestration by the terrestrial ecosystem through estimation of biomass is widely accepted and considered to be the most appropriate approach (Brown 1997). Northeast India represents only 8.0% of geographical area of India but accounts for nearly 25% of its forest cover of the country (FSI 2013). Northeast India is represented by a variety of forest ecosystems ranging from tropical rainforest to sub-tropical and temperate forests (Champion and Seth 1968). These forests are rich in biodiversity and fall into the Indo-Burma hot spot of the world biodiversity (Myers et al 2000). Temperate forests cover 767 million hectares worldwide and account for approximately 14 % of forest carbon storage (Pan et al 2011). The greatest potential for C storage in temperate forests is usually found within the tree biomass (Sonetal 2001, Peichl and Arain 2006). In India, including Northeast India, large areas of primary forests are degraded at to a varying extent and converted to other land uses including shifting cultivation (Behera and Misra 2006, Barik and Mishra 2008, FSI 2013). However, (Bhagawati et al 2015) claimed that contrary to modern belief, *Jhum* is carbon sink, maintains soil health, preserves biological diversity and sustains local climate. Many thorough studies on floral diversity and community characteristics of the temperate forests have been undertaken in Indian Himalayas including north eastern India (Mao et al 2009, Bharali et al 2011, Sharma et al 2014, Yam and Tripathi 2016, Thokchom and

Yadava 2017, Paul et al 2019). For effective C mitigation, it is pivotal to accurately quantify the C stocks of forests of NE India. However, only few studies have been reported on biomass and C stocks on forests of NE India (Thokchom and Yadava 2013, 2017, Waikhom et al 2018). Thus, this study was taken up to understand the tree diversity, community characteristics and to estimate the biomass and carbon storage of primary and secondary temperate broadleaf forest in Arunachal Pradesh, Indian Himalayas.

MATERIAL AND METHODS

The present study was conducted in Shi-Yomi district (newly created district) of Arunachal Pradesh, Indian Himalayas. Three major tribes *viz* Adi, Memba and Tagin inhabit the district. Two temperate broadleaf forests (with an altitude ranges from 1500-1900 m asl) were selected in the district - Gapo village forest (untouched community forest) (between latitude 28˚30´47.718´´ N and longitude of 94˚18´40.68´´E) as Primary forest (PF) and Kuak-Menying village forest (rejuvenated forest after *Jhum* cultivation in 1970s) (between latitude 28˚31´24.157´´ N and longitude of 94˚18´53.816´´E) as Secondary forest (SF). Extensive field survey was undertaken in these two forests in 2018-2019. Vegetation sampling of all the trees was done through random quadrats methods. A total of 15 quadrats (20 m x 20 m size) each were laid randomly in the selected plot for tree species and individuals with diameter at breast height (DBH) more than 5 cm where recorded directly using measuring tape. Trees with D<5 cm are excluded because such trees hold a small fraction of AGB in their habitat (Chidumayo 2002). Specimens of all tree species recorded were collected and herbarium specimens were prepared following (Jain and Rao1977) and identification was done following taxonomic literature and herbarium specimens of regional and national herbaria (ASSAM and ARUN). Important community characteristic of the selected sites like frequency, density, dominance, abundance, basal cover, Importance Value Index (IVI) were calculated using standard methods (Phillips 1959, Misra 1968). The Abundance – Frequency (AF^{-1}) ratio was calculated and used to interpret the distribution pattern of the species (Whitford 1949). Several indices were calculated to measure the species diversity (Shannon and Weiner 1949, Simpson 1949), species evenness (Pielou 1966); species richness (Margalef 1958) and similarity between the two forests (Sorensen 1957). The above ground biomass (AGB) of tree species was estimated by following the allometric equation of Chave et al 2005 i.e. $AGB (Kg) = \rho \times \exp(-1.499 + 2.148 \ln(D) + 0.207 (\ln(D))^2 - 0.0281 (\ln(D)^3))$, where, D is diameter and ρ is the wood specific gravity of tree species. Wood specific gravity of tree species had been taken from world agroforestry database (Chave et al 2009). Where ever the wood density of tree species was unavailable the standard average value of 0.62 gm cm^3 was used (IPCC 2003). Wood specific gravity is an important prediction of AGB (Baker et al 2004). The belowground biomass (BGB) of tree species was calculated by multiplying AGB taking 0.26 as the root shoot ratio (Zanne et al 2010). By summing the AGB and BGB, the total biomass (TB) was calculated. The total carbon stock (TCS) of each tree was calculated by multiplying the total biomass of the species by a conversion factor of 0.5 which represents that the carbon content is assumed as 50% of the total biomass (IPCC 2003).

RESULTS AND DISCUSSION

Phytosociology of the different tree species in PF and SF: A total of 33 species of trees belonging to 26 genera and 17 families were recorded from the study sites. 26 species, 21 genera and 15 families were recorded from PF while 27 species, 20 genera and 13 families were recorded from SF (Table 1). The findings of both PF and SF were comparatively less than that of temperate mixed Rhododendron forest of Arunachal Pradesh (72 species) (Bharali et al 2011); Talle Wildlife Sanctuary, Arunachal Pradesh (63 species) (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (320 species) (Sharma et al 2014). Total tree density of PF was 395.75 stem ha^{-1} with *Castanopsis indica* accounted for the highest density (43.25 ha^{-1}) followed by *Quercus lamellosa* and *Phoebe lanceolata* while, total tree density of SF was 425 stem ha^{-1} with *Myrica esculenta* accounted for the highest density (36.67 ha^{-1}) followed by *Alnus nepalensis* and *Quercus semiserrata* (Table 1 and 2). Total tree density was comparable to that of Talle Wildlife Sanctuary, Arunachal Pradesh (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (Sharma et al 2014) but less than that of temperate mixed

Table 1. Community characteristics of the study sites (PF and SF)

Parameter	PF	SF
No. of species	26	27
No. of genera	21	20
No. of family	15	13
Shannon Weiner index	3.10	3.21
Simpson dominance index	0.05	0.04
Margalef's richness index	4.57	4.33
Pielou's evenness index	0.95	0.97
Sorensen similarity index	79%	
Density (Stems ha^{-1})	395.75	425
Basal area (m^2 ha^{-1})	34.90	56.34

Table 2. Phytosociological attributes of the different tree species in PF and SF

Botanical name	PF						SF					
	F* (%)	D (ha)	TBC $m^2 ha^{-1}$	A	A/F	IVI	F (%)	D (ha)	TBC $m^2 ha^{-1}$	A	A/F	IVI
Acer acuminatum Wall. ex D.Don	20.00	6.75	0.32	1.33	0.07	5.87	20.00	8.33	0.61	1.67	0.08	5.56
Acer pectinatum Wall. ex G.Nicholson	-	-	-	-	-	-	20.00	5.00	0.74	1.00	0.05	5.01
Acer sp.	13.33	6.75	0.33	2.00	0.15	4.82	-	-	-	-	-	-
Alnus nepalensis D.Don	33.33	23.25	1.34	2.80	0.08	15.18	33.33	31.67	1.12	3.80	0.11	13.64
Balakata baccata(Roxb.) Esser	-	-	-	-	-	-	33.33	18.33	3.35	2.20	0.07	14.47
Beilschmiedia roxburghiana Nees	-	-	-	-	-	-	40.00	16.67	1.53	1.67	0.04	11.68
Castanopsis indica(Roxb. ex Lindl.) A.DC.	53.33	43.25	3.65	3.25	0.06	30.13	33.33	20.00	2.85	2.40	0.07	13.96
Castanopsis tribuloides(Sm.) A.DC.	26.67	16.75	1.58	2.50	0.09	13.08	26.67	20.00	6.80	3.00	0.11	20.14
Cinnamomum glaucescens (Nees) Hand.-Mazz.	33.33	15.00	1.62	1.80	0.05	13.87	33.33	16.67	1.08	2.00	0.06	10.04
Citrus hystrix DC.	6.67	1.75	0.06	1.00	0.15	1.67	-	-	-	-	-	-
Dodecadenia grandiflora Nees	20.00	18.25	1.06	3.67	0.18	10.94	13.33	5.00	0.82	1.50	0.11	4.32
Engelhardia spicata(Lindl. ex Wall.) Koord. & Valeton.	-	-	-	-	-	-	33.33	21.67	2.99	2.60	0.08	14.61
Eurya acuminata DC.	20.00	15.00	0.81	3.00	0.15	9.39	26.67	18.33	1.15	2.75	0.10	9.72
Exbucklandia populnea(R.Br. ex Griff.) R.W.Br.	20.00	11.75	0.81	2.33	0.12	8.52	33.33	13.33	2.80	1.60	0.05	12.31
Illicium griffithii Hook.f. & Thomson	26.67	10.00	0.76	1.50	0.06	9.06	26.67	11.67	1.75	1.75	0.07	9.21
Juglans regia L.	33.33	23.25	1.83	2.80	0.08	16.59	-	-	-	-	-	-
Lindera megaphylla Hemsl.	13.33	11.75	0.41	3.50	0.26	6.30	33.33	16.67	0.62	2.00	0.06	9.23
Listea sp.	20.00	6.75	0.55	1.33	0.07	6.52	20.00	10.00	0.91	2.00	0.10	6.48
Maesa indica(Roxb.) A. DC.	20.00	15.00	0.89	3.00	0.15	9.61	-	-	-	-	-	-
Magnolia champaca(L.) Baill. ex Pierre	20.00	16.75	5.43	3.33	0.17	23.05	33.33	21.67	4.33	2.60	0.08	16.99
Magnolia globosa Hook.f. & Thomson	26.67	16.75	1.32	2.50	0.09	12.35	26.67	13.33	2.83	2.00	0.08	11.52
Magnolia hodgsonii (Hook.f. & Thomson) H.Keng	26.67	21.75	1.87	3.25	0.12	15.18	26.67	11.67	0.86	1.75	0.07	7.63
Myrica esculenta Buch.-Ham. ex D. Don	13.33	5.00	0.58	1.50	0.11	5.11	46.67	36.67	2.56	3.14	0.07	19.05
Persea odoratissima(Nees) Kosterm.	20.00	6.75	0.50	1.33	0.07	6.38	33.33	15.00	1.87	1.80	0.05	11.05
Persea sp.	13.33	5.00	0.18	1.50	0.11	3.97	20.00	5.00	0.31	1.00	0.05	4.25
Phoebe lanceolata (Nees) Nees	26.67	30.00	2.78	4.50	0.17	19.90	20.00	13.33	2.82	2.67	0.13	10.66
Quercus lamellosa Sm.	40.00	31.75	3.14	3.17	0.08	23.53	26.67	11.67	3.20	1.75	0.07	11.79
Quercus semiserrata Roxb.	-	-	-	-	-	-	40.00	26.67	4.58	2.67	0.07	19.44
Salix tetrasperma Roxb.	20.00	13.25	0.90	2.67	0.13	9.20	20.00	6.67	0.60	1.33	0.07	5.15
Saurauria nepaalensis DC.	20.00	6.75	0.51	1.33	0.07	6.40	33.33	11.67	1.49	1.40	0.04	9.58
Schima wallichii Choisy	26.67	16.75	1.68	2.50	0.09	13.39	-	-	-	-	-	-
Toona sp.	-	-	-	-	-	-	40.00	18.33	1.77	1.83	0.05	12.49
Total		395.75	34.90			300.00		425.00	56.34			300.00

*F = Frequency, D = Density, TBC = Total basal cover, A = Abundance, A/F = Abundance: Frequency ratio, IVI = Importance Value Index

Rhododendron forest of Arunachal Pradesh (963 stem ha^{-1}) (Bharali et al 2011). The total basal cover of trees in PF was 34.90 m^2 ha^{-1}, with the maximum basal cover occupied by *Magnolia champaca* (5.43 m^2 ha^{-1}) followed by *Castanopsis indica* and *Quercus lamellosa* while, the total basal cover of trees was 56.34 m^2 ha^{-1}, with the maximum basal cover occupied by *Castanopsis tribuloides* (6.80 m^2 ha^{-1}) followed by *Quercus semiserrata* and *Magnolia champaca* (Table 1 and 2). The total basal cover of both the forest were comparable to that of Talle Wildlife Sanctuary, Arunachal Pradesh (43.02 m^2 ha^{-1}) (Yam and Tripathi, 2016) and temperate forest of Sangla Valley, Himachal Pradesh (8.70-42.42 m^2 ha^{-1}) (Sharma et al 2014) but less than that of temperate mixed Rhododendron forest of Arunachal Pradesh (74.6 m^2 ha^{-1}) (Bharaliet al 2011).Variation in tree density and basal area of different forest stand may be the result of species composition, age structure, successional stage of the forest and degree of disturbance (Swamy et al 2000). The highest IVI in PF was in *Castanopsis indica* (30.13) followed by *Quercus lamellosa* (23.53) and *Magnolia champaca* while, the highest IVI in SF was observed in *Castanopsis tribuloides* (20.14) followed by *Quercus semiserrata* and *Myrica esculenta* (Table 2). Higher IVI of a species indicated its good power of regeneration and wider ecological amplitude (Singh et al 1991). From the values of IVI of various tree species, it indicated that *Castanopsis indica* and *Castanopsis tribuloides* were the most dominant tree species in PF and SF respectively. The Shannon Weiner's Index of PF and SF were 3.10 and 3.21 respectively (Table 1) which were more than that of temperate mixed Rhododendron forest of Arunachal Pradesh (2.59) (Bharali et al 2011) and temperate forest of Sangla Valley, Himachal Pradesh (1.28) (Sharma et al 2014) but less than that of Talle Wildlife Sanctuary, Arunachal Pradesh (3.99-4.06) (Yam and Tripathi 2016). The Simpson's index value of PF and SF were 0.05 and 0.04 respectively (Table 1) which was within the range of different Indian forests between 0.03 and 0.92 (Deb and Sundriyal 2011). Margalef's richness index of PF and SF were 4.57 and 4.33 rspectively (Table 1) which were within the range between 4.54 and 23.41 for Indian forests (Sathish et al 2013). The Pielou's species evenness index of PF and SF were 0.95 and 0.97 respectively (Table 1) which was quite high. The higher evenness index value reveals more consistency in species distribution. Sorensen's similarity index of the study sites was quite high (79%) (Table1) as the two selected study sites were in the same altitude, topography and climatic zone. Both PF and SF did not follow Raunkiaer's frequency law (A>B>C>=<D<E). Calculated frequency class in PF was A>B>C and in SF was A<B>C. As per the Raunkiaer's law of frequency (Raunkiaer 1934) both the study sites represented heterogeneous vegetation. Understanding the pattern of distribution of organisms is a key aspect in conservation and management (Mao et al 2009). In PF, 96.15% of the tree species showed contiguous and 3.85% showed random distribution pattern while in SF, 77.78% of the tree species showed contiguous and 22.22% showed random distribution pattern (Table 2). This was generally due to uneven distribution of nutrients or other resources in the environment, resulting in the dominance of a contiguous distribution pattern.

Biomass and total C stock of the different tree species in PF and SF: Total AGB, total BGB and total TB of PF were 2068.32, 537.76 and 2606.08 Mg ha^{-1} respectively while SF were 3669.72, 954.13 and 4623.84 Mg ha^{-1} respectively (Table 3). Total AGB, total BGB and total TB of both the forests were comparatively higher than that of temperate forest of China (Zhu et al 2010); Garhwal Himalaya, India (Sharma et al 2010), temperate forest of Kedarnath Wildlife Sanctuary, Uttarakhand (Bhat et al 2013) and temperate forests of Kashmir Himalaya of India (Dar and Sundarapandian 2015). In both the forests, total AGB represented 79.36 % of the total biomass and total BGB 20.63% of the total biomass which were comparable to the finding of Indian forests (79 % and 21 %) (Chhabra et al 2002); Garhwal Himalaya, India (80.8.and 19.2) (Gairola et al 2011) and temperate forests of Kashmir Himalaya of India (80.1 % and 19.9 %) (Dar and Sundarapandian 2015). Most of the tree species present in both the forests had higher average diameter of girth in SF than in the PF. Average diameter of *Castanopsis tribuloides* in PF was 69.40 cm while in SF it was 131.67 cm, *Quercus lamellose* 71.05 cm and 118.27 cm, *Magnolia globasa* 63.50 and 104.00 cm respectively (Table 3). Only few tree species such as *Alnus nepalensis, Cinnamomum glaucescens, Magnolia champaca, Myrica esculenta* had lower average diameter of girth in SF than in PF (Fig. 1). The same pattern followed in TB and TCS. Higher average diameter of girth of most tree species in SF than in the PF could be due to avoiding of cutting certain big tree species during forest clearing for *Jhum* so as not to invoke the spirits of the forest, moreover, the locals knew the significance of trees to immediate ecosystem and sustainability (Bhagawati et al 2015). The highest TB and TCS in PF was in *Magnolia champaca* (449.75 Mg ha^{-1} and 224.87 Mg C ha^{-1}) followed by *Quercus lamellosa* and *Castanopsis indica* while the highest TB and TCS in SF was observed in *Castanopsis tribuloides* (625.94 Mg ha^{-1} and 312.97 Mg C ha^{-1}) followed by *Quercus semiserrata* and *Quercus lamellosa* (Table 3). The result of higher TB and TCS in *Magnolia champaca, Quercus* sp. and *Castanopsis* sp. could be due to higher girth size and higher

Table 3. Biomass and total C stock of the different tree species in PF and SF

Botanical name	Wood density g/cm^3	Primary forest Mg ha^{-1}				Secondary forest Mg ha^{-1}			
		AGB	BGB	TB	TCS	AGB	BGB	TB	TCS
Acer acuminatum Wall. ex D.Don	0.54	15.65	4.07	19.72	9.86	32.25	8.38	40.63	20.32
Acer pectinatum Wall. ex G.Nicholson	0.54	-	-	-	-	44.52	11.58	56.10	28.05
Acer sp.	0.54	16.44	4.27	20.72	10.36	-	-	-	-
Alnusne palensis D. Don	0.42	52.13	13.56	65.69	32.85	38.83	10.10	48.93	24.46
Balakata baccata (Roxb.) Esser	0.62	-	-	-	-	240.21	62.45	302.67	151.33
Beilschmiedia roxburghiana Nees	0.58	-	-	-	-	91.28	23.73	115.01	57.51
Castanopsis indica(Roxb. ex Lindl.) A.DC.	0.59	217.48	56.54	274.02	137.01	186.86	48.58	235.44	117.72
Castanopsis tribuloides (Sm.) A.DC.	0.59	96.61	25.12	121.73	60.87	496.77	129.16	625.94	312.97
Cinnamomum glaucescens(Nees) Hand.-Mazz.	0.49	84.00	21.84	105.84	52.92	50.69	13.18	63.87	31.93
Citrus hystrix DC.	0.69	3.44	0.89	4.33	2.17	-	-	-	-
Dodecadenia grandiflora Nees	0.62	60.96	15.85	76.82	38.41	58.18	15.13	73.31	36.65
Engelhardia spicata (Lindl. ex Wall.) Koord. and Valeton.	0.47	-	-	-	-	155.50	40.43	195.93	97.97
Eurya acuminata DC.	0.56	41.82	10.87	52.69	26.34	61.41	15.97	77.38	38.69
Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.	0.67	52.67	13.69	66.36	33.18	221.03	57.47	278.50	139.25
Illicium griffithii Hook. f. and Thomson	0.57	43.05	11.19	54.24	27.12	111.90	29.09	141.00	70.50
Juglans regia L.	0.52	94.45	24.56	119.01	59.51	-	-	-	-
Lindera megaphylla Hemsl.	0.51	17.36	4.51	21.87	10.93	26.74	6.95	33.69	16.85
Listea sp.	0.49	27.38	7.12	34.50	17.25	45.62	11.86	57.49	28.74
Maesa indica (Roxb.) A. DC.	0.67	55.95	14.55	70.49	35.25	-	-	-	-
Magnolia champaca (L.) Baill. ex Pierre	0.53	356.94	92.81	449.75	224.87	268.39	69.78	338.18	169.09
Magnolia globosa Hook.f. and Thomson	0.50	66.15	17.20	83.34	41.67	166.75	43.35	210.10	105.05
Magnolia hodgsonii (Hook.f. and Thomson) H.Keng	0.50	95.06	24.71	119.77	59.89	42.28	10.99	53.27	26.64
Myrica esculenta Buch.-Ham. ex D. Don	0.61	38.15	9.92	48.07	24.04	151.45	39.38	190.82	95.41
Persea odoratissima (Nees) Kosterm.	0.59	29.40	7.64	37.04	18.52	119.92	31.18	151.10	75.55
Persea sp.	0.52	8.01	2.08	10.09	5.04	15.35	3.99	19.34	9.67
Phoebe lanceolata(Nees) Nees	0.68	194.43	50.55	244.99	122.49	225.55	58.64	284.20	142.10
Quercus lamellosa Sm.	0.71	233.10	60.60	293.70	146.85	276.00	71.76	347.76	173.88
Quercus semiserrata Roxb.	0.71	-	-	-	-	372.16	96.76	468.93	234.46
Salix tetrasperma Roxb.	0.38	32.59	8.47	41.07	20.53	23.17	6.03	29.20	14.60
Saurauria nepaalensis DC.	0.43	21.85	5.68	27.53	13.76	69.80	18.15	87.95	43.98
Schima wallichii Choisy	0.64	113.27	29.45	142.72	71.36	-	-	-	-
Toona sp.	0.42	-	-	-	-	77.08	20.04	97.12	48.56
Total		2068.32	537.76	2606.08	1303.04	3669.72	954.13	4623.84	2311.92

*AGB = Above ground biomass, BGB = Below ground biomass, TB = Total biomass, TCS = Total Carbon stock

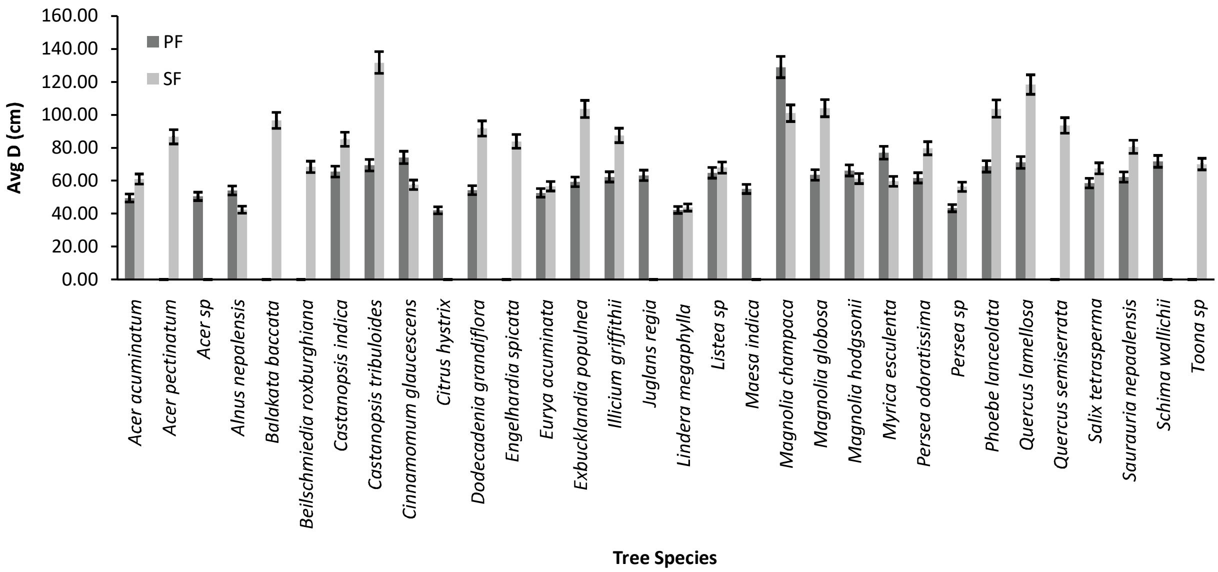

Fig. 1. Average diameter at girth (cm) of different tree species in PF and SF

wood density of these tree species. Wood specific gravity is an important prediction of AGB (Baker et al 2004). Total TCS of PF and SF were 1303.04 and 2311.92 Mg C ha^{-1}(Table 3) respectively which were comparatively more than that of Garhwal Himalaya, India (Sharma et al 2010); temperate forests of China (Zhu et al 2010); (Zhang and Wang 2010) and temperate forests of Kashmir Himalaya of India (Dar and Sundarapandian, 2015) which could be due to high density of many tree species with higher girth size and higher wood density. Tree species composition is an important criterion for carbon storage in regions of the same climate range (Chen et al 2011).

CONCLUSION

The higher biomass and higher C stocks with good species richness, higher density and basal area in Secondary Forest than Primary Forest. This could be attributed to management history, climate as well as biotic and abiotic factors of the area. Disturbance (forest clearing for *Jhum*) in SF could have attributed more opportunities for other species to thrived in the study area along with the creation of ecological niches and microhabitats, hence leading to more species diversity. Nevertheless, forest clearing during *Jhum* may not be considered as deforestation but forest modification allowing forest regrowth during sufficient long fellow that the involvement of the local communities along with their indigenous knowledge can lead to the development of effective and robust strategies in a very cost-effective, participatory and sustainable way to conserve biodiversity, to increase long term C sequestration in plants and to mitigate climate change.

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