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Carbon Storage Potential of Selected Trees in Sub-Tropical Zone of Himachal Pradesh

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ABSTRACT

The study was conducted with a purpose to compare above-ground biomass production and thereby the carbon sequestration potential of important thirteen tree species (20-30 years age) planted at 3mx3m spacing in the Nauni campus of Dr .Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) located at 30^{0} 51' N and 76^{0} 11' E with an altitude of 1250 m above mean sea level. The study concluded that above-ground volume mean annual increment per tree basis was maximum in Acrocarpus fraxinifolius (0.028 m^3) followed by *Eucalyptus* tereticornis (0.026 m^3), *Populus deltoides* (0.021 m^3), *Pinus roxburghi* (0.020 m^3), *Salix alba* (0.019 m^3), *Albizzia lebbek* (0.008 m^3), *Ulmus villosa* (0.008 m^3), *Melia composita* (0.008 m^3), *Grewia optiva* (0.007 m^3), *Acacia mollissima* (0.007 m^3), *Quercus leucotrichophora* (0.006 m^3), *Acacia catechu* (0.003 m^3) and *Punica granatum* (0.0003 m^3), whereas above-ground carbon mean annual increment among these tree species was maximum in *Acrocarpus fraxinifolius* (10.72 kg) followed by *Eucalyptus tereticornis* (8.60 kg), *Melia composita* (5.09 kg), *Pinus roxburghii* (5.08 kg), *Populus deltoides* (4.06 kg), *Ulmus villosa* (3.84 kg), *Salix alba* (3.65 kg), *Albizzia lebbek* (2.44 kg), *Acacia mollissima* (2.40 kg), *Quercus leucotrichophora* (2.43 kg), *Grewia optiva* (2.32), *Acacia catechu* (1.02 kg), and *Punica granatum* (0.13 kg).

Keywords:

Above-ground, biomass, carbon, volume, mean annual increment

INTRODUCTION

Carbon emission, supposedly the strongest causal factor for global warming is well discussed in Kyoto Protocol. Trees are amongst the most significant elements of any landscape, both due to biomass and diversity. Their key role in ecosystem dynamics is well known. However, it is paradoxical that the vegetation has undergone destruction and degradation in the modern times due to industrial and technological advancement achieved by human society. This advancement has resulted in emission of carbon in the ecosystem. The use of tree plantations for carbon sequestration can contribute to the mitigation of the increasing levels of carbon dioxide in the atmosphere. Therefore, there is need to address environmental issues related to them. Trees are important sinks for atmospheric carbon i.e. carbon dioxide, since 50% of their standing biomass is carbon itself (Ravindranath et al. 1997). Importance of forested

Table 1. Specific gravity used for different forest tree species.

Name of the species	Date of Planting	Specific gravity (g cm^{-3})
Pinus roxburghii	1980	0.49 (Sheikh et al. 2009)
Grewia optiva	1981	0.68 (Singh 1994)
Populus deltoides	1987	0.40
Albizzia lebbek	1988	0.55 (Singh 1994)
Eucalyptus tereticornis	1988	0.70 (Singh 1994)
Quercus leucotrichophora	1989	0.74 (Singh 1994)
Salix alba	1989	0.37 (Kurjatko and Pozgaj 1977)
Punica granatum	1989	0.99 (Felter and Lloyd 1898)
Melia composita	1990	0.93 (Mondhe and Rao 1993)
Acacia mollissima	1991	0.75
Acrocarpus fraxinifolius	1991	0.79
Acacia catechu	1992	0.67 (Chaturvedi and Khanna 1982)
Ulmus villosa	1992	0.90

areas in carbon sequestration is already accepted, and well documented (Tiwari and Singh 1987). Many attempts have been made (Devi et al. 2013; Koul and Panwar 2012; Pal and Panwar 2013) to study the potential of trees in carbon sequestration from plantations outside forests. The study constitutes an assessment of standing biomass of tree flora and their corresponding carbon sequestration potential in the sub-tropical region of mid Himalaya in Himachal Pradesh so as to make choice among plantation species based on their carbon sequestration potential in the present scenario of climate change.

MATERIALS AND METHODS

Study area

The study was carried out in Nauni campus of Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, located in the mid hill of Himachal Pradesh at 30°50 30″ to 30°52 0″ N latitude and 77°08 30″ to 77°11 30″ E longitude (Survey of India Toposheet No. 53F/1) with an elevation between 900-1300m. The climate is subtropical type experiencing monthly mean temperature ranges from 11.7°C to 26.3°C and the annual rainfall between 850-1300 mm of which 60-70 per cent is received during mid June to mid September. The area falls under sub-tropical pine forest (9a) forest category of Champion and Seth, 1968 classification with main species as *Pinus roxburghii*. The area had been afforested approximately 30 years before with species as: *Pinus roxburghii, Acacia catechu, Acer oblongum, Quercus leucotrichophora, Populus deltoides, Eucalyptus tereticoris, Salix alba, Acacia mollissima, Acrocarpus fraxinifolius, Melia azadarach, Ulmus villosa, Albizzia chinensis, Grewia optiva* and *Punica granatum*.

Biomass and carbon estimation

Three trees of each height class i.e. large, medium and small were selected as sample trees in different individual plantation blocks, raised at spacing of 3m x 3m during 1980-92. The height of each sample tree was measured and its corresponding basal area was determined. The volume of trees of each height class of individual plantation species was calculated using Pressler's formula (Pressler 1865) and mean volume for each plantation species was calculated. The volume of each plantation species was transformed thereafter into biomass by multiplying it with its corresponding specific gravity (Table 1). Specific gravity values were taken from the available

Table 2. Comparison of volume (m^3/tree), above-ground volume mean annual increment (m^3/year), above-ground biomass (Kg/tree), above-ground carbon (Kg/tree) and above-ground mean annual carbon increment (Kg/tree) of different forest tree species.

Treatment	Volume (m^3/tree)	Volume Annual Increment (m^3/tree/year)	Biomass (Kg/tree)	Carbon (Kg/tree)	Carbon Mean Annual Increment (Kg/tree/year)
Acrocarpus fraxinifolius	0.515	0.028	407.33	203.67	10.72
Eucalyptus tereticornis	0.539	0.026	378.33	189.17	8.60
Populus deltoides	0.493	0.021	187.33	93.33	4.06
Pinus roxburghii	0.649	0.020	304.67	152.33	5.08
Salix alba	0.414	0.019	151.33	76.67	3.65
Albizzia lebbek	0.195	0.008	107.00	53.67	2.44
Ulmus villosa	0.153	0.008	138.10	69.04	3.84
Melia composita	0.219	0.008	203.67	101.83	5.09
Acacia mollissima	0.130	0.007	101.33	50.33	2.40
Grewia optiva	0.199	0.007	134.43	67.22	2.32
Quercus leucotrichophora	0.138	0.006	102.14	51.07	2.43
Acacia catechu	0.055	0.003	36.90	18.43	1.02
Punica granatum	0.006	0.0003	5.59	2.80	0.13
CD (0.05)	0.31	0.01	201.9	101.0	4.7

literature (Table 1) and for *A. mollissima* (0.75), *A. fraxinifolius* (0.79), *P. deltoides* (0.40) and *U. villosa* (0.90), it was determined from stem core of wood using maximum moisture method given by Smith (1954).

Estimation of increment

The above-ground volume mean annual increment of tree species was computed by dividing volume of each plantation species with their corresponding present age (Equation 1). The age of each plantation were taken from the records in plantation register available in the Department of Silviculture and Agro-forestry of Y. S. Parmar University of Horticulture & Forestry, Nauni, Solan (Table 1).

$$\text{MAI} = \frac{\text{Volume (m}^3\text{)}}{\text{Age}} \quad \text{...... Eq. 1}$$

The above ground (stem) carbon of each plantation species was determined by multiplying stem biomass with carbon conversion factor of 0.5 (Koach 1989). Annual above-carbon mean increment of each plantation crop was thereafter determined by dividing carbon content with corresponding age of the plantation species at that time. Each tree species were treated as treatment which was replicated thrice. The data were subjected to statistical analysis using randomized block design.

RESULTS

The study revealed that above-ground volume on per tree basis varied significantly among tree species and it was maximum in *P. roxburghii* (0.649 m^3) followed by *E. tereticornis* (0.539 m^3), *A. fraxinifolius* (0.515 m^3), *P. deltoides* (0.493 m^3), *S. alba* (0.414 m^3), *M. composita* (0.219 m^3), *G. optiva* (0.199 m^3), *A.lebbek* (0.195 m^3), *U. villosa* (0.153 m^3), *Q. leucotrichophora* (0.138 m^3), *A. mollissima* (0.130 m^3), *A. catechu* (0.055 m^3) and *P. granatum* (0.006 m^3) in descending order (Table 2).

Similarly, the above-ground biomass and annual above-ground mean carbon increment varied significantly among plantation species (Table 2). A maximum above-ground biomass per tree basis was recorded in *A. fraxinifolius* (407.33 Kg) which was at par with *E. tereticornis* (378.33Kg), *P. roxburghii* (304.67 Kg) and *M. composita* (203.67 Kg) whereas rests of the species were at par in above-ground biomass production with minimum above-ground biomass in *A. catechu* (36.90 kg/tree) and *P. granatum* (5.59 Kg/tree).

The above-ground mean annual increment was maximum in *A. fraxinifolius* (0.028 m^3), though statistically at par with *E. tereticornis* (0.026 m^3), *P. deltoides* (0.021 m^3), *P. roxburghii* (0.020 m^3) and *S. alba* (0.019 m^3) yet significantly higher than rest of the tree species. Exceptionally, minimum above-ground volume mean annual increment reported in *P. granatum* (0.0003 m^3) was significantly inferior to all the tree species (Table 2). The annual above-ground mean carbon increment (Kg/year) was reported maximum for *A. fraxinifolius* (10.72 kg) which was at par with *E. tereticornis* (8.60 kg) and significantly superior to *M. composita* (5.09 kg), *P. roxburghii* (5.08 kg), *P. deltoides* (4.06 kg), *U. villosa* (3.84 kg), *S. alba* (3.65 kg), *A. lebbek* (2.44 kg), *A. mollissima* (2.40 kg), *Q. leucotrichophora* (2.43 kg), *G. optiva* (2.32 kg), *A. catechu* (1.02 kg), and *P. granatum* (0.13 kg) (Table 2).

DISCUSSION

Significant variation in volume among tree species was mainly due to individual growth behavior followed by age differences and their adaptability to the area. The age of *P. roxburghii* plantation was comparatively higher (Table 1) and the study area falls under sub-tropical region, where *P. roxburghii* is a dominating component of sub-tropical pine forests (Champion and Seth, 1968), and hence higher volume production.

P. deltoides, *A. lebbeck*, *Q. leucotrichophora*, *E. tereticornis, S. alba and P. granatum* were approximately of same ages and among them, *P. deltoides* and *E. tereticornis* fared well as these are well known for their fast growth. *Q. leucotrichophora*, *A. lebbeck*, and *S. alba* could not do well on account of their slow growth nature, poor soil condition and water deficient soils, respectively. *P. granatum* is short statured tree but it an important species for livelihood of farmers of the area. *M. composita*, *U. villosa*, *A. mollissima*, *G. optiva* and *A. catechu* were also approximately of the same ages, but they all resulted in poor volume production which may be attributed to various factors as explained earlier. Alder (1999)on the similar line while comparing the volume growth of five major plantation species of the lowland tropics namely; *Cedrelinga catenaeformis*, *Parkia multijuga*, *Jacaranda copaia*, *Cordia alliodora* and *Schizolobium parahybum* observed maximum MAI's of 20cm underbark volume at about $23m^3ha^{-1}yr^{-1}$ at 15 years for *Cedrelinga catenaeformis*, $16m^3ha^{-1}yr^{-1}$ at 15 years for *Jacaranda copaia*, $15m^3ha^{-1}yr^{-1}$ at 25 years for *Parkia multijuga*, and $8m^3ha^{-1}yr^{-1}$ at 10 years for *Cordia alliodora*. However, *Schizolobium parahybum* yields varied between 10 and $20m^3ha^{-1}yr^{-1}$, depending on the health of the stand.

Significant variations in annual above-ground carbon and carbon mean increment among different tree species may be explained in the light of variation in wood density (Table 2). Wood density is a key functional trait within forests (Swenson and Enquist 2007) in that it may influence woody biomass and ecosystem carbon stocks (Baker et al. 2004; Malhi et al. 2006). Baker et al. (2004) reported a positive correlation between mean tree community wood density and above-ground forest biomass.

A. fraxinifolius, *E. tereticornis* and *M. composita* are known for higher wood density, hence resulted in higher carbon production. *P. roxburghii* had an advantage of its habitat, fared well even having low wood density. On the other hand, despite higher wood density, the *U. villosa* and *A. mollissima* resulted in poor production of volume, biomass and carbon production in this region. *P. deltoides* and *Salix alba* known for their fast growth fared comparatively better in terms of volume and biomass production but resulted in poor carbon production. However, *Q. leucotrichophora*, *G. optiva*, *A. catechu* and *P. granatum* are slow growing species and therefore comparatively resulted in poor volume and carbon production (Table 2). Species with denser wood tend to grow more slowly (in height or diameter) because they invest more carbon in a given volume of stem relative to species with lighter wood, and because high sapwood density is associated with reduced conductance and thus reduced photosynthetic carbon gain (Enquist et al. 1999; Bucci et al. 2004; King et al. 2005; Chave et al. 2009; O'Grady et al. 2009).

CONCLUSION

In the present scenario of climate change, the carbon storage potential of tree species may be one of the important characteristics that be considered beside other factors of species selection while undergoing plantation programme in various part of the country. Therefore, for this sub-tropical region of Western Himalayas, the preference of the species should be in order of *A. fraxinifolius* > *E. tereticornis* > *M. composita* > *P. roxburghii* > *P. deltoides* > *U. villosa* > *S. alba* > *A. lebbek* > *A. mollissima* > *Q. leucotrichophora* > *G. optiva* > *A. catechu* > *P. granatum*.

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