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Carbon storage potential of shelter belt agroforestry system in northern transitional zone of Karnataka, India

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Abstract: Carbon sequestration has been suggested as a means to mitigate the increase in atmospheric carbon dioxide concentration. As agrisilviculture systems is one of the better options for stocking of carbon in plants and in soil. In the present study, carbon sequestration was quantified both biomass as well as in soil of agrisilviculture system six different tree species were selected such as, *Pongamia pinnata*, *Dalbergia sissoo*, *Acacia auriculiformis*, *Tectona grandis*, *Casuarina equisitifolia*, *Azadirachta indica* in shelterbelt of agroforestry system in arid region of Karnataka. Among six different tree species planted under shelterbelt, the growth performance with respect to gbh, height, clear bole height and basal area was highest in *A. auriculiformis* and *A. indica*. While maximum above ground biomass was observed in *A. auriculiformis* (59.75 t ha-1) followed by *T.grandis* (56.62 t ha-1), respectively. Whereas, below ground biomass was highest in *T. grandis* (20.25t ha-1) followed by *A. auriculiformis* (14.75t ha-1). Above ground carbon sequestration was highest in *A. auriculiformis* (13.30 t ha-1) followed by *T. grandis* (12.20 t ha -1), respectively. Whereas, below ground carbon sequestration was more in *T. grandis* (4.35 t ha-1) followed by *A. auriculiformis* (3.95 t ha-1). The Shelterbelt system sequestered 0.43 to 1.34% soil organic carbon stock in different depth. The carbon sequestered in different tree species was varying from 3.48 tons to 17.25 t ha-1.Growing tree crops in shelterbelts, bunds in the agroforestry systems will enhance accumulation of carbon stocking and provide additional benefits to the farmer's income. It also regulates microclimate and increases the tree cover in agricultural field.

Keywords: Agroforestry system, Biomass, Carbon sequestration, Shelter belt, Soil organic carbon

INTRODUCTION

Global warming may also have serious implications for forest ecosystems, especially for plantations and the matching of tree species with sites, which may be affected by changed climatic conditions. Forests play an important role in sequestration of carbon globally. The study of potential impact of climate change on existing forest ecosystem is inevitably required for the further mitigation to the problem (Rawat *et al.,* 2003). Climate change due to global carbon emission threatens to bring large-scale disruptions to the current pattern of life on earth. Current strategies for coping with global warming include reducing fossil fuel combustion as well as curbing emission of other GHGs and increasing carbon sequestration.Among all the land uses analyzing system agroforestry recognized as greatest potential for carbon sequestration.According to Land-Use Changes and Forestry report of the IPCC (2000), our understanding of carbon sequestration in specific agroforestry practices from around the world is rudimentary at best. Atmospheric carbon can be sequestered in long-lived carbon pools of plant biomass both above and below ground, recalcitrant organic and inorganic carbon in soils and deeper subsurface environments. Apart from offsetting CO_2 emissions and global warming, sequestration of carbon in soils also helps to improve soil quality and productivity by improving many physical, chemical and biological properties of soils such as infiltration rate, aeration, bulk density, nutrient availability, cation exchange capacity, buffer capacity, etc. Soil organic carbon sequestration is more important in arid regions, where soils are inherently low in organic carbon content. In arid regions agroforestry systems are important for carbon sequestration strategies of the Kyoto protocol provide rationale for the importance of managing dry lands to sequester carbon restoration of deserts land and plant-

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ing perennial tree. Systems involving trees act as carbon sinks due to their ability to sequester atmospheric carbon in deep soil profiles and various tree components. According to the Kyoto protocol, only carbon newly sequestered through agroforestry practices is considered as carbon credits and can be sold to industrialized countries to meet their emission reduction targets, although there is pressure to include soil carbon also.Ever since the Kyoto Protocol, agroforestry has gained attention as a strategy to sequester carbonfrom both developed and developing nations. The estimated Carbon stored in agroforestry range from 0.29 to 15.21 Mg C/ha/year above ground and 30-300 Mg C/ha up to 1m depth in the soil (Nair*et al.,* 2010). Total carbon stock including both above and belowground was 6754.77 tC/ha for agroforestry systems in villages of Karnataka and Tamil Nadu (Murthy *et al.,* 2013).

Agroforestry in India contributes to the target set by the Indian Council of Agricultural Research for increasing forest cover to 33%. The Report of the Task Force of Greening India for Livelihood Security and Sustainable Development (Planning Commission, 2001) has suggested that 10 million ha of irrigated land and 18 million ha of rain-fed land should be managed under agroforestry systems, proper land use management like maintaining or improving tree cover and proper forestry management can sequester and store the carbon in the soil reducing the amount in the atmosphere thereby playing an important role in the mitigation and adaptation to climate change (Vashum, *et al.,* 2016).

Agroforestry systems in India include the use of trees grown on farms, community forestry and a variety of local forest management and ethnoforestry practices (Pandey, 1998). The Indian Council of Agricultural Research has classified systems used in different agroclimatic zones as silvipasture, agrisilviculture and agrihorticulture based on irrigated or rain-fed conditions. Traditional agroforestry systems include such practice of growing trees on farmlands used for fodder, fuel wood, food and medicinal purposes and vegetables etc. along with shifting cultivation in the Northeast India and Taungya cultivation, this practice of growing scattered trees on farmland is quite old. The agroforestry sector has received recent attention for its enormous potential carbon pools that reduce carbon emissions to the atmosphere (Kumar *et al.,* 2009). Smallholder farming systems throughout the world are believed to be the potential sinks to remove atmospheric CO_2. (Nath and Das, 2011). Keeping this in view, the present study was carried out to assess the carbon sequestration potential of shelterbelt tree species of northern transitional zone of Karnataka.

MATERIALS AND METHODS

Study area: The present study was carried out in five year old existing shelterbelt agroforestry system raised by Agricultural Research Station at Hanumanamatti, Ranebennur Taluk of Haveri District, during 2009-10. The area falls under the Northern Transition (Zone-8) of Karnataka state.

Experimental details: In the present study, five year old existing tree species in the shelterbelt was selectedfor the study (2004-2008). The shelterbelt constitute six tree species *viz.,Pongamia pinnata, Dalbergia sissoo, Acacia auriculiformis, Tectona grandis, Casuarina equisitifolia, Azadirachta indica*, each species was considered as treatment,five trees were taken for observations in each treatment; likewise there were four replications in each treatment. Observations on growth parameters such as girth at breast height(GBH), and height were recorded. Later on destructive samplingswere collected by felling the trees based on mean stem diameter method. After felling the trees, above ground parts and below ground parts were separated and kept for oven dry weight at 80^{o}C expect leaves are kept at 60^{o}C and finally observed data were used to calculate the relative proportion of each component in a tree.

Carbon sequestration estimation by carbonization method: In the oven dried plant samples 100 gm of leaf, stem, bark and root were burnt in absence of oxygen. The charcoal left after burning was weighed and carbon content was estimated.Carbon sequestration in the shelterbelt plantation was calculated by multiplying total dry biomass and carbon concentration of different components separately for respective species and expressed in tons per hectare.

Soil organic carbon (%): The soil samples were collected from the shelterbelt and adjoining shelterbelt area in two different depths of 0-15 cm and 15-30 cm using the soil auger between two plants of same species.Prior to sample collection under growth vegetation and surface litter from the soil surface was removed properly. The soil samples were air dried, powdered and allowed to pass through 2mm sieve and were analyzed for organic carbon. Soil samples were analyzed for organic carbon content according to Walkley and Black (1965) rapid titration method.

RESULTS AND DISCUSSION

Growth performance of five year old different tree species under shelterbelt: In the present study the growth performance wassignificant infive year old existing tree species in the shelterbelt agroforestry system.The maximum gbh was recorded in *A. auriculiformis* (32.66 cm) followed by*A.indica*(29.96 cm) respectively and the minimum was recorded in *C. equisetifolia* (14.83 cm) this might be due to thespecies adopted for dry land nature which needs high temperature for its growth and development to performed well.Similar results were recorded in 5 years age *Pinuspetula* attained highest gbh followed by *Pinus-*

Table 1. Growth performance of five year old different tree species planted under shelter belt.

Species	Gbh (cm)	Height	Clear bole height	Basel area	Volume
Azadirachta indica	29.96*	5.07	2.00	0.070*	0.026*
Pongamia pinnata	18.32	3.48	1.39	0.028	0.009
Tectona grandis	28.88	6.62*	2.06	0.067	0.024
Acacia auriculiformis	32.66**	7.80**	2.28**	0.086**	0.033**
Dalbergia sissoo	28.41	6.27	2.10	0.063	0.020
Casuarina equisetifolia	14.83	6.05	2.20*	0.019	0.006
SEm±	2.61	0.49	0.16	0.011	0.046
C.D. @ 5%	7.20	1.35	0.45	N.S.	0.135
C.V.	14.62	12.24	11.29	25.51	36.41

Table 2. Biomass estimation of different tree species planted under shelter belt.

Species	Root biomass ($t\ ha^{-1}$)	Stem biomass ($t\ ha^{-1}$)	Bark bio-mass ($t\ ha^{-1}$)	Leaf biomass ($t\ ha^{-1}$)	Total biomass ($t\ ha^{-1}$)
Azadirachta indica	12.12	42.35	1.78*	3.75	60.00
Pongamia pinnata	5.75	14.75	1.20	1.95	23.65
Tectona grandis	20.25**	48.12*	1.05	7.45**	76.87**
Acacia auriculiformis	14.75*	52.40**	2.10**	5.25*	74.50*
Dalbergia sissoo	10.35	23.52	0.75	3.35	37.97
Casuarina equisetifolia	2.85	12.50	0.45	1.47	17.27
SEm±	0.45	0.80	0.02	0.46	1.22
C.D. @ 5%	1.07	2.03	0.07	1.31	3.05
C.V.	5.45	3.53	8.29	16.89	3.61

Table 3. Carbon sequestration ($t\ ha^{-1}$) estimation by carbonization method in shelterbelt tree species.

Species	Carbon ($t\ ha^{-1}$)						
	Root carbon ($t\ ha^{-1}$)	Stem carbon ($t\ ha^{-1}$)	Bark carbon ($t\ ha^{-1}$)	Leaf carbon ($t\ ha^{-1}$)	Total car-bon ($t\ ha^{-1}$)	Shoot to root ratio	Per cent of carbon (%)
Azadirachta indica	2.54	9.39	0.77*	1.18	13.88	1: 0.22	18.25
Pongamia pinnata	1.11	2.72	0.07	0.60	4.50	1: 0.28	16.01
Tectona grandis	4.35**	9.72*	0.52	1.96**	16.55*	1: 0.36	17.27
Acacia auriculiformis	3.95*	10.85**	0.95**	1.50*	17.25**	1: 0.30	19.67
Dalbergia sissoo	2.09	4.74	0.33	0.98	8.14	1: 0.32	18.37
Casuarina equisetifolia	0.64	2.21	0.17	0.46	3.48	1: 0.20	19.42
SEm±	0.30	0.36	0.02	0.13	0.49		
C.D. @ 5%	0.87	0.92	0.07	0.35	1.21		
C.V.	17.30	7.94	8.29	16.68	7.96		

Table 4. Effect of shelterbelt tree species on soil organic carbon.

Species	Organic carbon (%)	
	0-15 cm	15-30 cm
Azadirachta indica	1.13	0.80
Pongamia pinnata	0.80	0.43
Tectona grandis	1.34**	0.99**
Acacia auriculiformis	1.25*	0.83*
Dalbergia sissoo	1.10	0.68
Casuarina equisetifolia	1.02	0.71
Control	0.56	0.35
SEm±	0.14	0.12
C.D. @ 5%	0.36	0.31
C.V.	18.34	25.28

"*" 5% significance

carriabaea in Tamil Nadu (Ponnuswamy, 1982). Maximum height was recorded in *A.auriculiformis* (7.80 m) followed by *T. grandis* (6.62 m), respectively and minimum was recorded in *P. pinnata* (3.48 m). Similarly, superior performance in height was observed in *A. auriculiformis* and *C.equisetifolia* over other species, due to its fast growing ability Devaranavadgi and Murthy (1999).

However, maximum basal area was recorded in *A. auriculiformis* ($0.086m^2$) followed by *A.indica* (0.070 m^2), respectively and minimum was in *C. equisetifolia* ($0.019m^2$). Maximum volume was recorded in *A. auriculiformis* ($0.033m^3$) followed by *A. indica*(0.026 m^3) and *T. grandis*($0.024m^3$), respectively and minimum was in *C. equisetifolia* ($0.006m^3$).Similar results have been reported in 5 years age *A. auriculiformis* plantation (Jayaraman and Rajan 1991). In the present study maximum volume was recorded in *A.auriculiformis* and *A. indica* may be attributed to maximum utilization of nutrients by the species through decomposed leaf litter and other sources of nutrients such as fertilizers applied to the crops.

Biomass estimation: Maximum root dry biomass accumulation was recorded in *T. grandis* (20.25 $t\ ha^{-1}$)

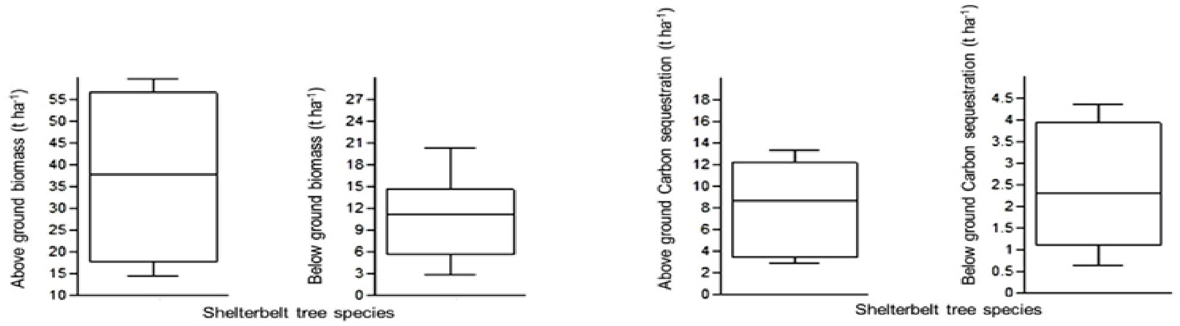

Fig. 1. *Assessment of above and below ground biomass and carbon sequestration in shelterbelt tree species.*

followed by *A.auriculiformis*(14.75 t ha^{-1}) and *A.indica* (12.12 t ha^{-1}) compared to other species. Maximum root dry biomass in *T. grandis* might be due to congenial condition to plant producing large root system for uptake of soil moisture and nutrients. Similarly *Acrocarpus fraxinifolius* attained highest root biomass followed by *Eucalyptus tereticornis* (Chauhan*et al*., 2009).

Maximum stem dry biomass accumulation was observed in *A. auriculiformis* (52.40 t ha^{-1}) followed by *T. grandis* (48.12 t ha^{-1}), respectively, compared to other species and minimum stem dry biomass was in *C. equisetifolia* (12.50 t ha^{-1}). Maximum stem biomass in *A. auriculiformis* might be due to its fast growing habit as these species usually produces more photosynthates per unit area and used for height growth. In nutrient rich soil, more of biomass is allocated to above ground parts (Yadava, 2010).

Maximum leaf dry biomass accumulation was observed in *T. grandis*(7.45 t ha^{-1}) followed by *A. auriculiformis* (5.25 t ha^{-1}), respectively, as compared to other species and minimum leaf dry biomass was recorded in *P. pinnata* (1.95 t ha^{-1}). The large and thick leaves of *T. grandis* might have increased the leaf biomass. Sahni(1998)reported similar results in *T. grandis*.

Maximum total dry biomass accumulation in destructive tree was observed in *T. grandis*(76.87 t ha^{-1}) followed by *A.auriculiformis*(74.50 t ha^{-1}), *A.indica*(60 t ha^{-1}) and *D. sissoo* (37.97 t ha^{-1}), respectively, least total dry biomass was recorded in *P. pinnata* (23.65 t ha^{-1}). Higher biomass production was recorded in *T. grandis*it might be due to increased biomass production in leaf and root. Maximum above ground biomass was recorded in *A. auriculiformis* (59.75 t ha^{-1}) followed by *T. grandis* (56.62 t ha^{-1}), respectively and least was recorded in *C.equisetifolia* (14.42 t ha^{-1}). However, maximum below ground biomass was recorded in *T. grandis*(20.25 t ha^{-1}) followed by *A.auriculiformis* (14.75 t ha^{-1}), respectively and least was recorded in *C.equisetifolia* (2.85 t ha^{-1}) (Fig. 1).Biomass stock is a direct indicator of carbon content of a forest (Sharma, 2012). Maximum biomass is attributed to total volume and wood density of the species (Swamy *et al.,* 2013). Rai *et al.,* (2000) and Rao *et al.,* (2000) reported that *Dalbergia sissoo* produced higher biomass among four species tried. Similar results were recorded by Swamy *et al.* (2015) at shelterbelt of Devaragudda and Hanumanamatti where maximum biomass was recorded in *Acaciaauriculiformis*. Ring basin found good for increasing growth of *Acacia auriculiformis* (Anju and Koppad, 2013). The average above ground biomass stocking in forests in Karnataka is 82.32 m^3/ha (Sharma, 2012), whereas in our study six different tree species in the shelterbelt agroforestry system recorded the average above ground biomass is 37.36 t ha^{-1}. The overall total standing biomass production increased with increasing in initial stage of tree growth then it starts to decline in silver oak from coffee based agroforestry system (Swamy *et al.,* 2013). In *Citrus reticulata* the mean aboveground biomass was 10.05±0.03 Kg $tree^{-1}$. The average aboveground allocation of biomass was nearly 76% and belowground biomass was 24%. The maximum carbon was stored by fruit biomass (2.10 Kg $tree^{-1}$) followed by roots (1.42 Kg $tree^{-1}$) and branches (1.11 Kg $tree^{-1}$) (Mehta, *et al*., 2016). Biomass production of horticultural and silvicultural species was higher in agroforestry plots as compared to respective control plot whereas, *P. cineraria* showed the highest biomass (14.02 kg per tree) and *Z. mauritiana* tree (2.07 kg per tree) lowest biomass in agroforestry system (Singh and Singh, 2015).

Carbon sequestration: In roots maximum carbon accumulation was recorded in *T. grandis* (4.35 t ha^{-1}). It might be due to higher allocation of resources to roots in teak as compared to other species which resulted in higher root biomass.Similarly, Ennik and Hofman (1983) reported that plant produce larger root system, resulting in higher root biomass, ultimately root carbon accumulation was more.

However, in the stem maximum carbon sequestration was recorded in *A. auriculiformis* (10.85 t ha^{-1}), followed by *T. grandis* (9.72 t ha^{-1}), *A. indica* (9.39 t ha^{-1}) respectively, and the least was recorded in *C. equiseti-*

folia (2.21 t ha^{-1}). It might be due to increased dry matter accumulation in branches and main stem and mainly through increase in growth parameters like height, gbh and crown width.

In bark maximum carbon sequestration was recorded in *A. auriculiformis* (0.95 t ha^{-1}) followed by *A. indica* (0.77 t ha^{-1}), *T. grandis* (0.52 t ha^{-1}), respectively and minimum carbon sequestration in bark was recorded in *P. pinnata* (0.07 t ha^{-1}). It might be due to thickness of the bark of *A. auriculiformis, A. indica* and *T. grandis*as compared to other species considered in the study.Maximum leaf carbon sequestration was recorded in *T. grandis* (1.96 t ha^{-1}) followed by *A. auriculiformis* (1.50 t ha^{-1}), respectively, whereas minimum leaf carbon sequestration was recorded in *C.equisetifolia* (0.46 t ha^{-1}). It might be due to larger leaf size and thickness of the leaf, similar result with respect to leaf carbon sequestration was recorded in*Tectona grandis* (Sahni, 1998). Maximum above ground carbon sequestration was recorded in *A. auriculiformis* (13.30 t ha^{-1}) followed by *T. grandis* (12.20 t ha^{-1}), respectively and least was recorded in *C.equisetifolia* (2.84 t ha^{-1}). However, maximum below ground carbon sequestration was recorded in *T. grandis*(4.35 t ha^{-1}) followed by *A.auriculiformis* (3.95 t ha^{-1}), respectively and least was recorded in *C.equisetifolia* (0.64 t ha^{-1}) (fig. 1). Among the plant parts in multipurpose tree species, wood stored the higher carbon (56.38 mg/g), leaf stored the minimum (53.27 mg/g) and bark had a medium storage (54.06 mg/g) (Miria and Khan, 2015). The carbon concentration in different parts of the tree showed the decreasing order as stem > root > branch > leaf in *Ailanthus excels* (Yashmita-ulman and Avudainayagam, 2012).

Carbon sequestration potential of fallow land and agriculture field is only 5.86% and 4.73%, respectively, compared to natural forest of *S. robusta*. Agroforestry systems, viz. tea garden and agri-horticulture contributed 24.24% and 9.09% carbon respectively, whereas pure plantation of *D. sissoo* and *T. arjuna* contributed 31.59% and 23.93% carbon, respectively, compared to natural forest of *S. robusta*. Though natural forest and pure plantation sequester more carbon and hence are better options for reducing atmospheric carbon, they cannot be extended to large areas due to population pressure and high demand of land for agriculture purposes. Therefore, agroforestry system seems to be the best alternative to minimize atmospheric carbon and simultaneously harness the opportunity for biodiversity conservation and economic benefits to the society (Koul and Panwar, 2008). Similarly, in our study the overall carbon sequestration potentialwas highest in the*A. auriculiformis* (17.25 t ha^{-1})followed by *T. grandis* (16.55 t ha^{-1}), *A. indica*(13.88 t ha^{-1}), respectively in shelterbelt agroforestry system.Whereas, minimum was noticed in *C.equisetifolia* (3.48 t ha^{-1}). Though *T. grandis* showed higher carbon sequestration in roots and leaf but due to lower carbon sequestration in stem it did not showed higher total carbon sequestration. The variation in carbon sequestration may be due to variation in the biomass production capacity of species which in turn depends on the growth habit of the species. Similar results were obtained in *Populus deltoids* by Huck (1983) and Swamy *et al.* (2003). The total biomass carbon pool varied from 57.36 to 135.99 tC/ha in *T. grandis* plantations (Banerjee and Prakasam, 2013).Among multipurpose trees plantation *Peltophorum pterocarpum* indicated highest total biomass carbon density (496 Kg/t) and *Azadirachta ndica* has the lowest value (462 Kg/t) (Miria and Khan, 2012). Carbon content (%) was highest in leaf and lowest in roots (Singh and Singh, 2015).Among the multipurpose tree species studied the fast growing tree *Syzigium cumini* with diameter (4.42 cm) stored maximum carbon (2.71 Kg/year) and biomass (4.9 Kg/year) and slow growing tree species *Milletia pinnata* with diameter (0.82 cm) stored the minimum carbon (0.67 Kg/year) and biomass (1.24 Kg/year) (Miria and Khan, 2015).

Maximum shoot to root ratio was observed in *T. grandis* (1:0.36) followed by *D. sissoo* (1:0.32), *A. auriculiformis* (1:0.30), respectively, and the least was recorded in *C. equisetifolia* (1: 0.20) (Table 3). Higher shoot to root ratio in *T. grandis* might be due to higher biomass production. Maximum per cent of carbon was recorded in *A. auriculiformis* (19.67%) followed by *C. equisetifolia* (19.42%), *D. sissoo* (18.37%), respectively, whereas, least per cent carbon was recorded in *P. pinnata* (16.01%). Photosynthetic assimilation of atmospheric carbon and the translocation of photo-assimilates to roots not only helps trap the excess CO_2 in deeper soil layers, but could partly replenish the soil organic carbon in the long run. Further-more, microbial action in the root-zone accounts for sequestration of atmospheric carbon in the soil in mineralized form (Lavania and Lavania, 2009). Mehta, *et al.* (2016) reported that the total carbon stored by 6 yr old *Citrus reticulata*plantation was 5.94 Kg tree^{-1} and 1.65 t C ha^{-1}.

Soil organic carbon: Soil organic carbonrecorded maximum under shelterbelt plantation as compared to the control. The soil under 5 years old shelterbelt plantation exhibited highest organic carbon in top 0-15cm under*T. Grandis* (1.34%) followed by *A. auriculiformis* (1.25%), respectively, whereas least soil organic carbon was recorded in control (0.56%). Similar trend was recorded at the depth of 15-30cm. The maximum soil organic carbon was recorded in *Tectona grandis* (0.99 %) followed by *A. auriculiformis* (0.83%), respectively, whereas, minimum soil organic carbon was recorded in Control (0.35%) (Table4). There was a significant variation for soil organic carbon in six different tree species of shelterbelt may be attributed to amount of litter fall, decomposition, and nutrient release to the soil. Carbon sequestration potential in soils might be strongly affected by root production and soil microbial activity proportional to inputs of soil organic carbon at the top layers. As the depth increases, the organic carbon was decreased due to low decomposition of organic matter.Similar results were reported by Verma *et al*., (1982) in *Acacia nilotica, Syzygium cumini* and *Dalbergia sissoo* and Ramachandran *et al*., (2007) in natural forest of Kohli hills of Tamil Nadu. Horticultural system is a better option to enhance the soil organic carbon if forestry is not feasible in the ferruginous soils (Chandran *et al.,* 2009). The sequestration of atmospheric CO_2 in the form of soil inorganic carbon and its subsequent important role in enhancing soil organic carbon in the drier parts of the country through management interventions, the soil can act as a potential medium for carbon capture and storage (Bhattacharyya *et al.,* 2008).

Conclusion

The present study concluded that the removal of CO_2 from the atmosphere may be done by shelterbelt planted in farmlands to protect the crops from flowing disastrous winds in Northern Transition (Zone-8) of Karnataka state. The total biomass in the area was estimated in *Tectona grandis* (76.87 t/ha) followed by *Acacia arculifomis* (74.50 t/ha) and the total carbon storage was also noticed higher in *A. arculiformis* (17.25 t/ha) and *T. grandis* (16.55 t/ha). Among the six different species *T. grandis* and *A. arculiformis* were best suitable species for agroforestry system. These two species are less competing for agricultural crop, because of their deeper rooting pattern and observe the nutrient and moisture from deeper depth of soil. The above mentioned species have less competing for other natural available resources. Hence, this will conclude that the shelterbelt was one of the promising agroforestry systems in dryer zone of Northern Karnataka.

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