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Evaluation of the Efficiency of Carbon Sequestration in *Simarouba glauca* DC

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Abstract

Trees act as a sink for carbon dioxide by fixing carbon during photosynthesis and storing excess carbon as biomass in different parts of the tree. Carbon sequestration rate was evaluated for *Simarouba glauca* DC in three different age classes (2, 5 and 10 years) under two site conditions viz., transition zone (Bengaluru urban district) and dry zone (Hassan district) by estimating above ground biomass. *S. glauca* is a new tree crop having multiutilities that can be tapped for production of biofuel in India. The specific objective of this study was to measure carbon sequestration rate and aboveground biomass carbon potential of *S. glauca*. The total aboveground biomass carbon stock per hectare as estimated for 2, 5 and 10 years old *S. glauca* tree under transition zone was found 0.33, 2.73 and 11.04 t, respectively and similarly 0.55, 1.99, 15.67 t under dry zone. The ability of sequestrating the carbon by this species is maximum in drier region with medium rainfall regime

Key words : Biomass, Carbon sequestration, Dry zone, Global warming, Organic carbon.

The global climate change and its vagaries are the hard realities today, which were only predictions couple of decades ago which people hardly took it seriously. At present it is one of the most important problem that world is facing. Green house gasses (GHG's) such as carbon dioxide, methane, carbon monoxide, sulfur dioxide, oxides of nitrogen, chlorofluorocarbons and amongst these, carbon dioxide is considered to be the most important, accumulating in the atmosphere in large quantities (1—3). In the past few decades the rate of increase in GHG's reached a concentration of more than one ppm per year, which was not seen to occur in the past (4). If this continues unabated at the same rate, there will be serious implications on the life on this earth. Some of the important concerns of GHG's are, increase in the global temperature, rise in the sea levels due to melting of glaciers, variations in the precipitation causing seasonal shifts that influence the cropping patterns (5). With the ratification of Kyoto protocol, the carbon stocks and carbon inventories of countries and ecosystems has gained lot of importance and there is, in fact, a shift to this field of research in the recent years.

Simarouba glauca DC., a native of EL–Salvador and commonly known as paradise tree. The tree is of evergreen in nature and grows up to 15 meters high with tap root system and cylindrical stem and unique branching pattern. It is a fast growing multipurpose tree species with a very high degree of adaptability and it has got fast biomass producing potential. Large scale planting in the wastelands facilitates wasteland reclamation, converts the accumulated atmospheric carbon dioxide into oxygen and contributes to the reduction of green house effect/global warming. In light of the above, the present study was initiated to evaluate the efficiency of carbon sequestration in *S. glauca* plantation of two different climatic conditions i.e. dry zone (Bengaluru urban district) and transition zone (Hassan district) and in three different age classes viz., 2, 5 and 10 years.

Methods

Study Area

The present study was carried out in two ecological zones i.e. dry zone and transition zone. *S. glauca* plantation at University of Agricultural Sciences, GKVK (Bengaluru) was considered as dry zone which is situated at a latitude of $12^0 58'$ N, longitude of $77^0 35'$ E and at an altitude of 870 m above MSL.

Table 1. Effect of age and zone condition on tree height.

Ecological zones	Age (years) 2	5	10	Mean
Transition	1.54	2.97	3.97	2.83
Dry	1.91	2.92	6.36	3.73
Mean	1.72	2.95	5.16	
	Age	Zone	Age × Zone	
F-value	*	*	*	
SE ±	0.16	0.13	0.23	
CD at 5% level	0.33	0.27	0.47	

Table 2. Effect of age and zone condition on tree girth.

Ecological zones	Age (years) 2	5	10	Mean
Transition	0.1	0.31	0.53	0.32
Dry	0.11	0.27	0.29	0.22
Mean	0.11	0.29	0.41	
	Age	Zone	Age × Zone	
F-value	*	NS	NS	
SE ±	0.01	0.01	0.02	
CD at 5% level	0.03	-	-	

The average annual rainfall of the experimental area was about 779.7 mm. Simarouba plantation at Hassan district was considered as transition zone which is situated at latitude of $13^0 01'$ N, longitude of $76^0 10'$ E and at an altitude of 943.05 m above MSL. The average annual rainfall was 900 mm.

Measurement of Above Ground Biomass

The amount of sequestered carbon in *S. glauca* plantation was assessed by adopting non-destructive method of biomass estimation. Sampling was carried out by randomly selecting twenty plants each, in three different age classes (2, 5 and 10 years) and in two different ecological zones (dry zone and transition zone). Collar girth, height of individual trees was recorded for 2 year age class plants. Where as, tree height and girth at breast height (gbh) was recorded for 5 and 10 year age class trees using measuring tape. The above ground biomass of standing trees was estimated by working out the basal area. The estimation of the biomass in the stem was done using tree height, girth and wood density of tree. By using basal area volume was calculated using the formula, Volume = Basal area × h. where, 'h' is the height of the tree. It is commonly accepted to speak of the weight of wood in terms of standard volume. Wood density is therefore defined as the mass per unit volume (kg/m^3). Wood density was calculated based on standard method (6) using following formula

$$\text{Wood density} = \frac{\text{Mass of oven dried wood sample}}{\text{Volume of oven dried wood sample}} \quad (\text{kg/m}^3)$$

Based on the obtained value of wood density, biomass was estimated by using the formula.

$$\text{Biomass} = \text{Volume} \times \text{Wood density}$$

Stored carbon in a tree is measured by knowing its biomass. Above ground stored carbon was measured by multiplying biomass with the value 0.5 (7).

Results and Discussion

Carbon Sequestration in Relation to Age and Zone Conditions

The measured above ground growth parameters and interaction between age and zones are presented in Tables 1—4. The results of above ground biomass and above stored carbon are presented in Figure 1 and 2. Density of *S. glauca* wood was found to be 536.22 kg/m^3.

The two year old plants showed better performance with respect to parameters like height (1.91 m), girth (0.11 m), basal area (0.0017 m^2), volume (0.005 m^3), above ground biomass (1.11 t/ha) and carbon sequestration (0.558 t/ha) and were found superior under dry zone plantations compared to height (1.54 m), girth (0.10 m), basal area (0.0013 m^2), volume (0.003 m^3), above ground biomass (0.67 t/ha) and carbon sequestration (0.338 t/ha) of transition zone. Intercrop cultivation was followed in 2 year old plantation of dry zone which might have improved the soil physico-chemical properties like total soil porosity,

Table 3. Effect of age and zone condition on basal area.

Ecological zones	Age (years) 2	5	10	Mean
Transition	0.003	0.025	0.103	0.043
Dry	0.005	0.018	0.146	0.056
Mean	0.004	0.021	0.124	
	Age	Zone	Age × Zone	
F-value	*	NS	*	
SE ±	0.008	0.006	0.011	
CD at 5% level	0.016	-	0.022	

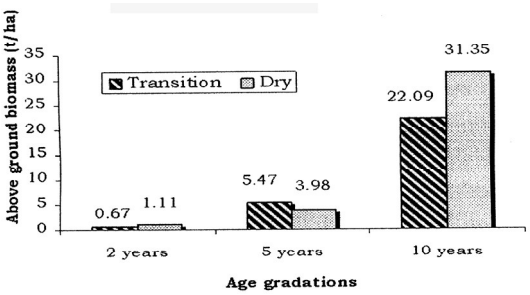

Figure 1. Above ground biomass (t/ha) in relation to age and zone conditions.

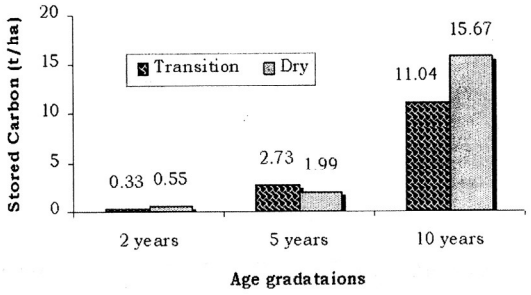

Figure 2. Above ground stored carbon (t/ha) in relation to age and zone conditions.

rich organic carbon content and soil bulk density. Similar findings have been reported earlier also (8). They have studied larch *(Larix gmelinii)*/soybean and ash *(Fraxinus mandshurica)* intercropping systems in the field to assess the effects of the intercropping on soil physico-chemical properties. The results showed that soil physical properties were improved after soybean intercropping with larch and ash in one growing season. In two year old plantations of transition zone, soil condition was very poor and impoverished. Competition with other plants like weeds and grasses might have suppressed growth of *S. glauca* plants subsequently. The results on the growth performance influenced by soil properties were in line with the earlier findings (9) in *Acacia auriculiformis* and *Acacia mangium* at the age of 4, 6, 8 and 10 years.

Five year old plantations under transition zone showed better performance with respect to parameters namely height (2.97 m), gbh (0.31 m), basal area (0.008 m^2), volume (0.025 m^3), above ground biomass (5.47 t/ha) and stored carbon (2.73 t/ha) when compared with trees of dry zone. Soil conditions were similar in both the zones but other climatic parameters like rainfall, relative humidity have favored the better growth in transition zone. Data indicates that the annual rainfall and the growth of the plants in the initial years are influenced by respective micro climatic conditions of the plantation. The report on *A. auriculiformis* showed that the species grows best in a humid climate, with rainfall of 1000 mm or up to 1800 mm and a dry period of 6 months (10).

Table 4. Effect of age and zone condition on volume.

Ecological zones	Age (years) 2	5	10	Mean
Transition	0.0013	0.0082	0.024	0.011
Dry	0.0017	0.0062	0.023	0.01
Mean	0.0015	0.0072	0.0237	
	Age	Zone	Age × Zone	
F-value	*	NS	NS	
SE ±	0.0013	0.001	0.0018	
CD at 5% level	0.0025	-	-	

The ten year old *S. glauca* plantations in transition zone exhibited better performance with respect to girth (0.53 m) and basal area (0.024 m^2), where as height (6.36 m), volume (0.146 m^3) above ground biomass (31.35 t/ha) and carbon sequestration (15.67 t/ha) was reported maximum in dry zone. The transition zone site was more of stony with highly eroded soil due to sloppy terrain. Since, site conditions were harsh tree didn't reach expected height but produced better girth intern basal area was slightly more than the trees of dry region. Even though the annual rainfall (779.7 mm) was less in dry zone compared to the transition zone (900 mm) the site condition of dry zone was better with red lateritic soil and with high amount of organic matter decomposition in the soil. The deep soils of this area may have offered better growth and carbon sequestration potentials than in the highly degraded and stony soil of the transition zone. The higher growth resulted in addition of more organic matter which in turn improved the soil organic carbon properties when compared to transition zone. This might be due to their poor fertility build up, competition for nutrients with the trees which in turn reduces the growth under transition zone. Similar studies carried out on the biomass accumulation in *Eucalyptus tereticornis,* less than 3 year to 9 year old plantation in different agro-ecological regions of India, where

Table 5. Different research works on carbon stock per hectare.

Species	Age (years)	Carbon sequestration rate (t/ha)	References
Eucalyptus grandis	2	9.15	Reported
Eucalyptus fastigata	4	30.9	,,
Eucalyptus nitens	4	40.9	,,
Eucalyptus globules	4	15.15	,,
Eucalyptus teriticornis	4	17.8	,,
Eucalyptus diversicolor	4	15.65	,,
Eucalyptus grandis	5	26.6	,,
Eucalyptus saligna	5	50.68	,,
Shorea robusta	6	5.22	,,
Albizzia lebbek	6	6.26	,,
Tectona grandis	6	7.97	,,
Artocarpus integrifolia	6	7.28	,,
American chestnut	8	2.07	,,
Black walnut	8	2.25	,,
Red oak	8	0.41	,,
American chestnut	12	6.28	,,
Black walnut	12	4.77	,,
Red oak	12	3.96	,,
Simarouba glauca (Transition zone)	2	0.33	Present study
Simarouba glauca (Dry zone)	2	0.55	Present study
Simarouba glauca (Transition zone)	5	2.73	,,
Simarouba glauca (Dry zone)	5	1.99	,,
Simarouba glauca (Transition zone)	10	11.04	,,
Simarouba glauca (Dry zone)	10	15.67	,,

biomass accumulation was more in cooler areas as compared to warmer areas (11).

In the present study the age group exhibited significant effect on all parameters. The interaction between the zone and age also showed significant effect on height and volume but was non-significant in expressions of girth and basal area due to variation in zone conditions. A comparison made with similar aged plantations across different zones exhibited significant difference with respect to all of the parameters. This is perhaps the first study of its kind in India for responses of *S. glauca* in different age classes and in different climatic conditions.

Different scientists all over the world reported carbon sequestration ability of various tree species (Table 5). Which revealed that carbon sequestering ability of trees differ with species, age class and also with site conditions.

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