Original Research Article

Carbon Sequestration Potential of Roadside Trees in Southern Punjab, Pakistan

ABSTRACT

Plantation along the roadside support the ecosystem and play an important role in climate change mitigation through carbon sequestration. Present study was conducted to observe the role of trees grown along roadside and their underneath soil are efficient in carbon storage at four different sites of Multan city. A total number of three plant species having 10 replications along with soil samples at two depths viz., (0-20) (20-40) were recorded during the field visit. The study calculated biomass using allometric equations while soil organic carbon and organic carbon was assessed using Walkely Black method. Although species have different height and diameter, hence, their sequestration rate was also different. Data revealed that in all four sites the carbon sequestration rate remained higher in *E. camaldulensis* as compared to others. Whereas regarding soil data *E. camaldulensis* remained higher in three site. This research concluded that *E. camaldulensis* species should be planted along the roadside due to its higher carbon sequestration rate. It is helpful in removal of traffic emission and safe for the roadside ecosystem.

Keywords: Climate change, mitigation, transport, biomass, vegetation

UNDER PEER REVIEW

1. INTRODUCTION

Vegetation growing along roadside perform an ecological function not only on reducing pollution load but also sequester carbon and help mitigate climate change [1]. Depending upon the types of species and their composition different land uses differ in carbon storage potential as well as their ecological functions [2]. Roadside plantation can be potential contributor in decreasing the amount of CO_2 in atmosphere by collecting in the form of biomass. The importance of plantation in cities along the roadside should not be neglected as it improves the pollution caused by automobile. The roadside plantation additionally has friendly and attractive means to inhabitants and great ecological value to cities as portion of green set-up. However, in urban areas plantation are affected by human due to degradation of urban forest and decrease the life span of trees as compared to trees in rural areas. The main stressor of urban trees is air pollution, it has negative impact on tree health and reduce the life of tree. Removal of pollution through plants can be undying, although plants naturally work as a provisional preservation place for dust particles. During stormy winds detached particles return to the atmosphere, carry off through precipitation, or released to the ground surface with stem fall and leaf [3].

For appropriate repair of roadsides, there is need to know the ecological relationship of roadside plantation and their part in carbon storage plantation of an area [4]. Depend on the types of species and their structure different land uses change in carbon storage potential as well as their ecological functions [2]. Therefore, maintains the roads and their construction are very important perception of the economy, government, and country's development [5].

Now a day climate change is the main issue of all around the world and it give great importance, caused by excessive energy use and anthropogenic activities [6,7]. Since the industrial revolution total annual absorption of atmospheric carbon dioxide has noticeably increased mainly anthropogenic activities. Carbon sequestration is extremely important as climate change and global warming up of the earth surface. Carbon sequestration is defined as the process in which carbon is sequester to the atmosphere and removed carbon dioxide through naturally or artificially. Biomass of plant indicate the sequestration rate of carbon in plants. In plant the density of wood plays a major role of carbon sequestration. By adding the ornamental beauty of urban life plants play an important role in cooling effect as transpiration rate and through photosynthesis carbon dioxide sequestration and release of oxygen in the atmosphere [8]. Carbon sequestration by plantations is a low cost and profitable technology to remove carbon dioxide from the atmosphere since plant supply and sequester carbon at greater amount as compare to other technologies. The range of carbon supply by one plant is

UNDER PEER REVIEW

from 1 to 8 MgC ha-1 yr-1. Different part of trees sequesters carbon as biomass. Terrestrial carbon sequestration is a low cost mitigation option by trees. The accurate amount of carbon removed from the atmosphere was measured through tree biomass that provide accurate estimation [9]. Trees in urban environment provide a lot of ecosystem services to the residents also remove carbon dioxide from the atmosphere during photosynthesis and tree also sequester carbon in different parts as biomass.

In view of the above and based on potential of tree species to sequester carbon for emission mitigation, the focus of this study is to understand role of trees in sequestering carbon in woody biomass growing along roadsides.

2. MATERIALS AND METHODS

2.1. Location

The study was conducted in district Multan, province of Punjab, Pakistan. Multan is the fifth biggest population city of Pakistan and it is also known as the city of Saints. It is located in a corner generated by five rivers of central Pakistan. The city has developed to become a powerful political and economic epicenter for the country, with a dry port and admirable transport link. According to the Köppen–Geiger classification, Multan district fall within the desert climate (BWh). The average annual precipitation is 175mm and average annual temperature is 25.6 ^{o}C.

2.2. Sampling

Four different road sites [*Khanewal* road (Site1), *Nangshah* road (Site2), *Shujabad* road (Site3) and *Bosan* road (Site 4)] were selected for sampling and data collection. The data were collected from 100 square meter along the roadside. Furthermore, three different trees species *V.nilotica* locally called as *Kikar*, *D.sissoo* locally called as *Shisham* and *E.camaldulenses* locally called as *sufaida* comprised of ten replications totaling twelve trees species along the road side with a total of 120 trees were selected from four different road side to estimate the carbon in biomass and soil. Tree heights were measured by clinometer and girth measured by steel tape. Girth at 1.37m above the ground level and terminal height for each tree's species were measured and

UNDER PEER REVIEW

recorded with in the 100 square meter along the roadside. For above ground and below ground biomass soil sample were collected through the equipment name auger. Soil sample was collected at the depth of 20cm and 40cm.

2.3. Biomass Determination

By using the allometric equation above ground and below ground biomass was estimated from collected data, belowground biomass was calculated from the above ground biomass supposed to be 26%. [10]. By adding the above and below ground biomass the total biomass was obtained. For all tree species trees allometric equations was used to analyzed above ground and below ground biomass. From the growth parameter of trees (DBH and height) above ground and below ground biomass was calculated. The tress biomass was calculated in kgs which was then converted to biomass in Mg per hectare and Mg per hectare in carbon estimation.

Allometric equation were used to calculate the above and belowground biomass of tree species.

Table 1 -21Allometric equation for the calculation of above and below ground biomass

Species	component	Allometric equation	Source
D. sissso	AGB BGB	$e^{-3.1141} * D^2H^{0.9719}$ AGB*0.26	[11]
V. nilotica	AGB BGB	$\log Y = -1.0646+0.9098\times \log D^2H$ $\log Y = -1.3952+0.8253\times \log D^2H$	[12]
E. camaldulenses	AGB BGB	$\ln Y = -2.2660+2.4663\times \ln D^2H$ BGB = AGB×0.26	[13] [10]

2.4. Estimation of Total Biomass

UNDER PEER REVIEW

Total biomass was calculated by adding the above and below ground biomass

Total biomass= AGB +BGB

2.5. Carbon Stock Estimation

Measuring the potential of carbon capture and storage in forests, accurate assessment of carbon in live tree tissue is required. Mostly regional and global scale assessments, carbon content has been assumed to 50% of tree biomass that is not accurate because of the great variation in carbon content among tree species. According to [14], Angiosperms in subtropical climate has a carbon content of approximately 48.1% in species biomass. As Pakistan has a subtropical type of climate and the study deals only with broad leaved species, so tree biomass was multiplied by 48.1% (0.475× biomass) for calculating carbon storage.

Carbon = 0.475 × biomass

2.6. Soil Carbon Estimation

Soil carbon was assessed by the formula.

$$SC\ (\text{Mg per hectare}) = 10 \times \text{Bulk Density} \times 15 \times \text{Carbon}/100 \times 10000/1000$$

Soil samples were collected from four different roadside at two depth (0-20cm) (20-40cm) by using soil auger. A total of 120 sample ,60 for each depth were collected. Sample were collected in polythene bags. Bulk density was measured by using 100 cm^3 stainless steel cylinder. Organic matter was measured by using [15] method, soil parameters used for the analysis were Soil pH. EC, Soil organic matter percentage, Soil carbon and Bulk density

2.7. Statistical Analysis

All the data were analyzed by using Statistics 8.1 software. Furthermore, one way ANOVA including LSD (least significant difference between means) were also applied to analyze the difference between average values of the data.

3. RESULTS

UNDER PEER REVIEW

3.1. Tree Height and Diameter

Results pertaining to diameter and height are presented in Table-2. Results revealed that in all the four site *E.camaldulensis* species had maximum height having 16.36m, 12.96m, 16.61m and 16.25m respectively, whereas for diameter, *E.camaldulensis* had maximum diameter in S1-3, except S4 wherein *D.sissoo* showed higher diameter (37.04cm) to all species

Table 2: height and diameter of tree species

Site	Area	Species name	Height (m)	Diameter (cm)
1	S1	*D.sissoo*	$11.24^{b} \pm 1.64$	$25.64^{b} \pm 4.21$
		V. nilotica	$9.96^{c} \pm 0.70$	$21.35^{c} \pm 2.26$
		E.camaldulensis	$16.36^{a} \pm 0.94$	$40.93^{a} \pm 3.56$
2	S2	*D.sissoo*	$11.64^{ab} \pm 1.38$	$25.12^{b} \pm 4.20$
		V. nilotica	$10.14^{b} \pm 0.88$	$26.31^{b} \pm 4.00$
		E.camaldulensis	$12.95^{a} \pm 2.23$	$38.11^{a} \pm 7.42$
3	S3	*D. sissoo*	$11.15^{b} \pm 1.50$	$25.72^{b} \pm 3.95$
		V. nilotica	$9.63^{b} \pm 1.47$	$22.40^{b} \pm 3.47$
		E.camaldulensis	$16.61^{a} \pm 2.20$	$37.61^{a} \pm 3.70$
4	S4	*D.sissoo*	$11.12^{b} \pm 3.07$	$37.04^{a} \pm 8.04$
		V.nilotica	$11.24^{b} \pm 2.50$	$29.36^{b} \pm 7.98$
		E.camaldulensis	$18.01^{a} \pm 2.08$	$16.25^{c} \pm 3.47$

S1, Khaniwal road; S2, Nangshah road; S3, Shujaabad road; S4, Boson road

UNDER PEER REVIEW

3.2. Species Biomass Estimation

The average biomass was recorded in S1 of species *E. camaldulensis* 13.7 Mg ha^{-1}, *V. nilotica* contain 0.98 Mg ha^{-1}, *D. sissoo* 1.01 Mg ha^{-1}**.** In S2, average biomass of *E. camaldulensis* 7.19 Mg ha^{-1}, *V. nilotica* contain 1.52 Mg ha^{-1}and *D. sissoo* 1.02 Mg ha^{-1}**.**

Whereas, in S3, *E. camaldulensis* showed average biomass of 13.05Mg ha^{-1}, *V. nilotica* contain 1.05 Mg ha^{-1} and *D. sissoo* 0.98 Mg ha^{-1}**.** However, **in S4,** *E. camaldulensis* showed biomass of 6.55 Mg ha^{-1}, *V. nilotica* contain 2.41 Mg ha^{-1} and *D. sissoo* 2.06 Mg ha^{-1} (Table-3)

Table 3. Biomass of different tree species along the roadside

Site	**Area**	**Scientific name**	**AGB Mg ha^{-1}**	**BGB Mg ha^{-1}**	**TB Mg ha^{-1}**
1	**S1**	*D. sissoo*	0.80^b±0.32	0.20^b ± 0.08	1.01^b ± 0.40
		V. nilotica	0.78^b ± 0.00	0.20^b±0.00	0.98^b±0.00
		E. camaldulensis	10.45^a ±2.08	2.71^a±0.54	13.17^a±2.62
2	**S2**	*D. sissoo*	0.81^b ± 0.27	0.21^b ±0.07	1.02^b ±0.34
		V. nilotica	1.21^b±0.00	0.31^b ±0.00	1.52^b±0.00
		E. camaldulensis	5.70^a±2.67	1.48^a±0.69	7.19^a±3.36
3	**S3**	*D. sissoo*	7.85^a ± 2.90	0.20^b ± 0.07	0.98^b ± 0.00
		V. nilotica	0.83^b±0.00	0.21^b±0.00	1.05^b±0.00
		E.camaldulensis	10.35^a±4.26	2.69^a±0.00	13.05^a±0.00
4	**S4**	*D. sissoo*	1.63^b ± 0.74	0.42^b ± 0.19	2.06^b ± 0.94
		V. nilotica	1.91^b±1.37	0.43^b±0.00	2.41^b±1.72
		E.camaldulensis	5.25^a±0.00	1.35^a±0.00	6.55^a±0.00

3.3. Species Carbon Estimation

Data regarding above ground, below ground carbon estimation is presented in Table4. *E. camaldulesnses* showed higher above ground carbon (AGC) contents (5.01^a±1±1.00), Below Ground (BGC) contents (1.30^a±0.26), Total carbon (TC) contents (6.32^a±1.26) and Carbon sequestration (23.5^a±4.62) than *V.nilotica* and *D.sissoo* in all

UNDER PEER REVIEW

four sites, whereas *V.nilotica* showed lowest values AGC, BGC, TC and Co$_2$ to all species in all sites

Table 4. Above ground, below ground, total carbon and carbon sequestration of different tree species along the roadside.

Site	Area	Species	AGC kgha^{-1}	BGC kg hac^{-1}	TC kg hac^{-1}	CO_2
1	**S1**	*D. sissoo*	0.38^{b} ± 0.15	0.10^{b}± 0.04	0.48^{b} ± 0.19	1.77^{b}±0.71
		V. nilotica	0.37^{b}±0.00	0.09^{b}±9.96	0.47^{b}±0.00	1.76^{b}±0.44
		E. camaldulensis	5.01^{a}±1.00	1.30^{a}±0.26	6.32^{a}±1.26	23.5^{a}±4.62
2	**S2**	*D. sissoo*	0.39^{b} ±0.13	0.10^{b} ± 0.03	0.49^{b} ±0.16	1.80^{b}±0.60
		V. nilotica	0.60^{b}±0.21	0.15^{b}±0.00	0.75^{b}±0.21	2.78^{b}±0.97
		E.camaldulensis	2.73^{a}±1.28	0.71^{a}±0.33	3.45^{a}±1.61	12.64^{a}±5.91
3	**S3**	*D.sissoo*	3.76^{a} ± 1.39	0.09^{b} ± 0.00	3.86^{b} ± 1.39	14.16^{b}±5.24
		V. nilotica	0.41^{b} ±0.15	0.10^{b}± 0.04	0.52^{c}± 0.19	1.90^{c}±0.72
		E.camaldulensis	4.97^{a}±0.00	1.29^{a}±0.53	6.26^{a}±2.57	22.94^{a}±9.44
4	**S4**	*D. sissoo*	0.78^{b} ± 0.35	0.20^{b} ± 0.09	0.99^{b} ±0.42	3.63^{b}±1.65
		V.nilotica	0.92^{b} ±0.65	0.23^{b} ±0.17	1.15^{b}± 0.82	4.24^{b}±3.03
		E.camaldulensis	2.52^{a}±0.84	0.65^{a}±0.21	3.18^{a}±1.06	11.65^{a}±3.88

3.4. Organic Carbon and Soil Organic Carbon Estimation

Li *et al*., (2010) revealed that soil organic carbon density depend on layers of soil, changing in weather pattern and soil texture. Soil carbon density is different in first layer of soil as compare of the deeper layer of the soil in the roadside due to maximum occurrence of sand component in the soil.

Organic carbon and siol organic carbon were determined from four different roadside. Two depth soil sample were determined first depth (0-20) and second depth (20-40) their result are as shown in table no 5. The method used by measuring the soil organic carbon by Walkely Black Method .

UNDER PEER REVIEW

Table 5. Organic carbon and soil organic carbon of different tree species

Site	Area	Species name	OC 0-20	OC 20-40	0-20 SOCMgh^{1}	20-40 SOCMgh^{1}
1	**S1**	*D. sissoo*	0.56^{a}	0.39^{b}	13.8^{a}	7.86^{a}
		V. nilotica	0.61^{a}	0.42^{ab}	15.0^{a}	11.0^{a}
		E.camaldulensis	0.113^{b}	0.55^{a}	2.66^{b}	17.1^{a}
2	**S2**	*D. sissoo*	0.51^{a}	0.48^{a}	12.3^{a}	12.5^{a}
		Vachellia nilotica	0.39^{ab}	0.28^{b}	9.78^{ab}	7.56^{b}
		E.camaldulensis	0.24^{b}	0.35^{ab}	5.80^{b}	8.53^{ab}
3	**S3**	*D. sissoo*	0.44^{a}	0.37^{a}	10.82^{a}	9.62^{a}
		V. nilotica	0.59^{a}	0.29^{a}	14.61^{a}	7.65^{a}
		E.camaldulensis	0.55^{a}	0.37^{a}	13.51^{a}	9.05^{a}
4	**S4**	*D. sissoo*	0.42^{b}	0.53^{a}	10.47^{b}	13.86^{a}
		V. nilotica	0.58^{ab}	0.53^{a}	14.56^{ab}	13.99^{a}
		E. camaldulensis	0.66^{a}	0.48^{a}	15.89^{a}	11.67^{a}

UNDER PEER REVIEW

4. DISCUSSION

Present study aimed to assess the potential of forest tree species along roadsides in Pakistan. The rate of carbon sequestration depends on growth factors of the plants. The major anxiety between policy maker and scientist monitoring the current level of atmospheric carbon dioxide through constraining harm of biodiversity, increase afforestation, decrease deforestation and reforestation [17,18]. Individual trees of similar species may vary in their biophysical and biomass structure in various sites. Different researcher stated that number of plants and species diverse with the nature of species, grade of biotic disruption, edaphic condition, stand condition and structure of species [16]. Urban areas are associated with increased emissions due to heavy traffic load and industrial development. Last few years in urban cities increasing population but also the transportation emission and industrialization the carbon dioxide level increase in the atmosphere [19]. To build up the proper structure in Pakistan, it is important to aware the climate change mitigation and understand the advantages of mitigation among government sector and local people, through campaign among different areas, provincial level, as district-wise climate change systems bring source to express policy systems for advanced tendencies by distributing data near the effectiveness, climate change influences and acknowledgement of perception response choices [20]. Pakistan has a well-developed transport system for public and cargo and thus emit lion share of greenhouse gases. Trees being perennial vegetation can store large quantities of carbon in their above and below ground biomass and the same found true when tree species sequester large quantities of carbon [21] and help in mitigating vehicular emissions

5. CONCLUSIONS

The current study acts as a good point to know how species perform along roadsides in areas of vehicular pollution. Additional and more work is needed to test more species to lay a foundation of growing them across roadsides for the growth of vegetation for mitigating emissions. This research shall also work twofold, not only to mitigate emissions but also to withstand hard weather wherein high temperature and scantic precipitation is a norm. Moreover, species identified such could also be used around other problem sites like that of industries to resolve environmental problems in Pakistan

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UNDER PEER REVIEW