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COMPARATIVE STATUS OF SEQUESTERED CARBON STOCK OF *Azadirachta indica* and *Conocarpus erectus* AT THE UNIVERSITY OF KARACHI CAMPUS, PAKISTAN

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Abstract

Carbon sequestration by trees is one of the most cost-effective and efficient methods to remove carbon dioxide from atmosphere since trees remove and store carbon at higher rates compared to other land covers. Carbon storage by trees typically ranges from 1 to 8 MgC ha^{-1} yr^{-1}.The carbon is sequestered in different parts of the trees as biomass. The measurements of biomass provide reasonably accurate estimate of the amount of carbon that was removed from lower troposphere over the years. Therefore, the present study investigates and compares the carbon stock of native *Azadirachta indica* and exotic *Conocarpus erectus*, which are extensively cultivated in the campus of the University of Karachi, Pakistan. The above-ground and below-ground biomass of 327 trees of *A. indica* and 253 trees of *C. erectus* were estimated by using non-destructive method. The average carbon content of *A. indica* is calculated to be 662.32 $\pm$ 1144.81 Kg while that of *C. erectus* is 192.70 $\pm$ 322.60 Kg. The independent t-test analysis showed significant difference ($p < 0.001$) between the means of the carbon content of both the species. The carbon contents of two different species were also correlated with bole's diameter at breast height (DBH) and tree's height. The analysis demonstrated greater correlation between the carbon content and the DBH of both the species compared to that with their height. The study will help to understand the carbon sequestration potential of two different types of species for planting particularly in urban area of the world.

Key words: *Azadirachta indica*, Biomass, Carbon sequestration, Carbon dioxide, *Conocarpus erectus*, Trees.

Introduction

The continuous increase in the atmospheric concentration of the greenhouse gases, particularly carbon dioxide, methane and di-nitrogen oxide is one of the major causes of global climate change (IPCC, *2007*). Cities are the main sources of the greenhouse gases. Many scientists suggest that 70-80% of the global greenhouse gases are generated within the boundaries of the cities (Satterthwaite, 2008). Among the greenhouse gases, the increasing concentration of atmospheric carbon dioxide is widely considered as the main driving factor that causes global warming (Florides and Christodoulides, 2009). Global annual mean concentration of carbon dioxide in the atmosphere has increased substantially since the Industrial Revolution from 280 ppm to 354 ppm in 1990 and 400 ppm in 2015 (NOAA/ESRL, 2015), mainly due to man-induced activities, particularly the combustion of fossil fuel and deforestation (Etheridge, et. al., 1996).

The concerns regarding the escalating concentration of carbon dioxide in the atmosphere, which causes global climate change, have led to a search for cost-effective technologies to sequester the atmospheric carbon (Montagnini and Nair, 2004). One of the low-cost mitigation options is terrestrial carbon sequestration by trees (Chavan and Rasal, 2010; 2011; 2012). Apart from providing a number of ecosystem services to the urban dwellers (Seamans 2013, Cilliers, et, al., 2013, Weber 2013), the trees in the urban landscape also remove the atmospheric carbon dioxide during photosynthesis and sequester it in the tissues of stems, roots, leaves, flowers and fruits and comprises the tree biomass.

Consequently, a number of studies have been conducted across the world to investigate the carbon sequestration and carbon storage attributes of the urban trees (Kiran and Kinnary, 2011, Chavan and Rasal, 2011; 2012, Stoffberg, et. al., 2010, Strohbach and Haase, 2012, Liu and Li, 2012, Nowak, et. al., 2001; 2013, Zheng, et. al., 2013). Chavan and Rasal (2012) estimated at an average of 33.85 tha^{-1} and 19.06 tha^{-1} by *Albizia lebbek* and *Delonix regia* respectively in Auragabad, India. Stoffberg et. al. (2010) estimated at 54,630 tonnes of carbon sequestration by planting 115,200 indigenous street trees in the city of Tshwane, South Africa during 2002-2008. Nowak et al. (2013) estimated at 25.6 million tonnes of annual carbon sequestration by US urban trees ($2 billion value). However, no work has yet been reported from any city of Pakistan. This is the first ever attempt to investigate and compare the sequestered carbon stock and carbon dioxide sequestration potential of native *Azadirachta indica* and exotic *Conocarpus erectus*, which are predominantly cultivated in the campus of the University of Karachi, Pakistan. For this study, a total of 327 trees of *A. indica* and 253 trees of *C. erectus* were randomly sampled from the campus to investigate and compare the carbon stock and carbon dioxide sequestration potential of both the species.

Azadirachta indica belongs to the family *Meliaceae*. It is an evergreen, medium size, native tree of the Indian sub-continent and China and is cultivated and naturalized through-out India, Malaysia and Pakistan. While *C. erectus* belongs to family *Combretaceae*. It is an evergreen, medium size, native tree of Tropical America and Africa. It is generally found growing in brackish water along shorelines but may also grow inland. It was introduced in Pakistan for use as an ornamental landscape species which quickly gained popularity owing to its fast growth and ability to grow in saline soils. A decade since it was introduced during the "Green Karachi campaign" by the City District Government Karachi, it still remains the most preferred species for planting along the streetscape, urban parks and open spaces of Karachi. Currently *C. erectus* is the most dominant species in the urban landscape of Karachi (Shams 2015). However, in 2000, not even a single plant of *C. erectus* was found to occur in Karachi (Shams and Beg 2000)

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Study area

The University of Karachi is the largest university of Pakistan. The university is located at 24.94ºN and 67.12ºE and is spread over an area of 1267 acre (5.18 km^2). The biotype of the study area is a fragmented shrub land. The university is situated in Karachi, which is the largest metropolitan city of the country. The city lies between 24°45' N to 25°37' N and 66°42' E to 67°34 E along 27 kilometre coastline of the Arabian Sea. Presently, the city houses over 20 million dwellers and is spread over an area of 3,530 Km^2 (Karachi Metropolitan Corporation 2015). Karachi is classified as arid hot desert (Kottek et al., 2006). The city is characterized by low annual average precipitation (250 mm per annum). However, the city experiences high southwestern wind and high relative humidity during long summers while it experiences northeastern wind and low relative humidity during short winters. The seasonal temperature typically varies from 13 °C to 36 °C.

Figure 1: University of Karachi spans over 5.18 $Km^{2,}$ which is surrounded by Suparco Road, University Road, Abul Hasan Isphani Road and Hijri Road.

Methodology

Tree Bole Diameter at Breast Height (DBH) and Tree Height:

The biomass of each tree of both the species was estimated on the basis of the diameter of the trees' bole at breast height (DBH) and the height of the trees. The DBH was determined by measuring the circumference of tree bole at breast height directly by using a measuring tape at approximately 1.3 metre from the ground. The tree's bole, having a diameter equal to or greater than 100 mm, were included in this study. The tree's height was estimated by measuring tree shadow and applying the following formula:

Tree height = Tree shadow x your height / your shadow

Biomass Estimation:

The above-ground biomass (AGB) was estimated using the non-destructive method, which was developed by Brown 1997. The literature reveals that the non-destructive method is reasonably the most suitable method for the estimation of the biomass of trees (Brown, 1997; Schroeder, 1992; Chavan and Rasal, 2010). The non-destructive method does not require the chopping of trees in order to estimate tree's biomass but instead relies on the use of equations and formulae. The above ground biomass of tree includes the whole shoot, branches, leaves, flowers, and fruits. It is calculated by using the following relation (*Hangarge et al., 2012*):

$$\text{AGB (Kg)} = \text{Volume of tree (V)} \times \text{Wood density (Kg/m}^3\text{)}$$

Where $V = \pi r^2 H$

V= Volume of tree

r = Radius of tree bole at breast height

H = Height of tree

The wood densities of *Azadirachta indica* and *Conocarpus erectus* were taken from the Global Wood Density Database and were found to be 660 Kg/m³ and 690 Kg/m³ respectively (Zanne et. al., 2009).

The Below Ground Biomass (BGB) includes the biomass of live roots excluding fine roots having less than 2mm diameter (*Chavan and Rasal, 2011; 2012*). Since the below-ground biomass estimation equations are relatively uncommon in the literature, we calculated the below ground biomass by multiplying above-ground biomass with 0.26 (default value), which was taken as the root to shoot ratio (*Cairns et al., 1997; Ravindranath and Ostwald, 2008*).

$$\text{BGB (ton/tree)} = \text{AGB (ton/tree)} \times 0.26$$

$$\text{Biomass} = \text{BGB} + \text{AGB}$$

$$\text{Carbon Sequestered} = \text{Biomass} / 2$$

The biomass of the sampled trees was divided by two to obtain the sequestered carbon in the trees of both the species since the trees contain on an average 50% carbon in different parts of their biomass (*Chavan and Rasal, 2011; 2012; Paladinic et al., 2009*).

Result and Discussion

The biomass estimation of *Azadirachta indica* and *Conocarpus erectus* was carried out by non-destructive method that requires the measurements of tree's height, bole's diameter at breast height and wood density of each species.

Table 1 shows the means of bole's diameter of sampled trees at breast height (DBH), the trees' height, above ground biomass, below ground biomass and carbon content in kilogram per tree of both the species. The mean diameter of the boles of *Azadirachta indica* at breast height was found to be 0.39 ± 0.20 meter while that of *Conocarpus erectus* was found to be 0.22 ± 0.14 meter. The independent t-test analysis reveals significant difference ($p < 0.001$) between the means of boles' diameters of *A. indica* and *C. erectus*. The mean height of the trees of *A. indica* was found to be 9.95 ± 4.29 meter while that of *C. erectus* was 8.27 ± 2.40 m. The independent t-test analysis demonstrated significant difference ($p < 0.001$) between the means of the height of the trees of *A. indica* and *C. erectus.*

Table 1: Statistical Analysis of Tree Species Sampled from University Campus

		Height (m)	DBH (m)	AGB (Kg)	BGB (Kg)	Carbon Content (Kg)
Azadirachta indica (n = 327)	Mean ± SD	9.95 ±4.29	0.39 ±0.20	1051.30 ±1817.17	273.34 ±472.46	662.32 ±1144.81
Conocarpus erectus (n = 253)		8.27 ±2.40	0.22 ±0.14	305.86 ±512.07	79.53 ±133.14	192.70 ±322.60
Azadirachta indica (n = 327)	Median	9.13	0.35	560.45	145.72	353.09
Conocarpus erectus (n = 253)		7.8	0.18	138.75	36.07	87.41
Azadirachta indica (n = 327)	Upper Quartile	11.57	0.49	1299.33	337.83	818.58
Conocarpus erectus (n = 253)		10.22	0.25	317.02	82.43	199.73
Azadirachta indica (n = 327)	Lower Quartile	6.82	0.24	236.17	61.40	148.79
Conocarpus erectus (n = 253)		6.475	0.13	66.20	17.21	41.71
Azadirachta indica (n = 327)	Maximum	38.40	1.90	25779.40	6702.64	2852.38
Conocarpus erectus (n = 253)		17.4	0.91	4152.49	1079.65	2616.07
Azadirachta indica (n = 327)	Minimum	3.43	0.10	18.14	4.72	11.43
Conocarpus erectus (n = 253)		3.65	0.1	23.66	6.15	14.91

Azadirachta indica was found to sequester 662.32 $\pm$ 1144.81 Kg of carbon per tree in the biomass of their shoots and roots while *Conocarpus erectus* was found to sequester 192.70 $\pm$ 322.60 Kg of carbon per tree in their shoots and roots. The independent t-test analysis showed significant difference ($p < 0.001$) between the means of the carbon sequestered in the biomass of both the species. The analysis shows that the total carbon stock of *A. indica* and *C. erectus*, which were sampled from the University of Karachi campus was calculated to be 205.07 and 48.75 metric tons respectively

Suryawanshi et al., (2014) estimated at 614 kg of carbon per tree of *Azadirachta indica,* which is comparable to the present study. However, Miria and Khan (2012) estimated at 462 kg of carbon per tree of *A. indica*. This may be due to the differences in the height and the diameter of boles of trees, which were sampled in these studies. For instance, 0.22 meter was the mean DBH of the trees of *A. indica* that were sampled by Suryawanshi, et. al., (2014) while the mean DBH of the trees of *A. indica* of the present study was 0.38 meter. However, the trees of *A. indica* of the present study were of lower height, compared to the sample of Suryawanshi, et. al., (2014).

The carbon sequestration of *Conocarpus erectus* has not yet been conducted elsewhere. Therefore, it is not possible to compare the present study with any other study of *C. erectus*. Both the species are fast growing and have greater carbon sequestration characteristics. Fast growing species are known to sequester carbon for longer periods of time (Guarna, 2012). The analysis demonstrates that the carbon sequestration of trees of *A. indica,* which are growing in the campus of the University of Karachi, is more than three times greater than that of the trees of *C. erectus*.

Table 2 demonstrates the correlation between different attributes of the species. The correlation coefficient between carbon content and the boles' diameter at breast height of the trees of *Azadirachta indica* was found to be 0.84 while that of *Conocarpus erectus* was found to be 0.92. This reveals a highly significant correlation ($p < 0.001$) between carbon content and the bole's diameter of the trees of both the species. The correlation coefficient between the carbon content and the tree height of *A. indica* was found to be 0.49 while that of *C. erectus* was found to be 0.26.

Table 2: Correlation Coefficient between Different Attributes of the Species Under study

		DBH (m)	Tree Height (m)
Azadirachta indica	Carbon Content	0.84	0.49
Conocarpus erectus	Carbon Content	0.92	0.26

The sequestration of carbon by urban trees and shrubs is currently an important tool to remove carbon dioxide from the urban areas since these areas are main contributor of tropospheric carbon dioxide. Therefore, the plant species should be studied for their carbon sequestration potential before planting them particularly in the urban landscape for maximum removal of carbon dioxide from the neighborhoods, which are principal contributor of carbon dioxide.

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