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An Assessment of the Annual Carbon Sequestration Potential of Urban and Peri-urban Water Bodies and Wetlands

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Abstract: Urban and peri-urban water bodies and wetlands play a significant role in carbon sequestration and long term storage of atmospheric carbon dioxide. Apart from performing various ecosystem services, they are natural carbon sinks that help in mitigating global warming and accumulation of green house gas emissions, primarily originating from cities. Yet their loss and degradation has not been aptly addressed so far. However, as the impacts of climate change are being increasingly realized, the conservation of water bodies and wetlands is drawing attention due to their ability to capture atmospheric carbon. This paper focuses on the annual carbon sequestration potential of four such water body and wetland based parks within and around the city of Kolkata, India and attempts to estimate their potential for carbon sequestration based on certain national and international standards suggested by researchers. The results are followed by suitable recommendations for implementation.

Keywords: Carbon sequestration, Water bodies and wetlands, Terrestrial soil, Trees, Grasses/lawns.

I. INTRODUCTION

The term "Carbon Sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils and sediments), and geologic formations (Sundquist et al., 2008). According to the Intergovernmental Panel on Climate Change, increasing concentration of GHGs, particularly CO_2 in the atmosphere could lead to a rise in average earth surface temperature by 0.17°C per decade and 0.5-1% of precipitation per decade in most of the Northern Hemisphere and 0.3% in tropics and sub-tropics. Sequestration of atmospheric carbon is one of the mitigation measures for countering the anthropogenic climate change due to excessive emission of greenhouse gases (Wani et al., 2015). While cities are major contributors to greenhouse gas emissions, water bodies and wetlands within and around cities play an important role as natural carbon sinks, where carbon sequestration occurs for a long period of time thereby mitigating global warming and accumulation of green house gas emissions. The contribution of lakes and artificial reservoirs in counteracting man made CO_2 emissions cannot be neglected as according to Einsele et al. (2001), present day carbon emissions due to the burning of fossil fuels amount to about 5.5 $x10^9$ tons C per year, while lakes and reservoirs remove about 0.3x 10^9 tons C per year, which is 5.5% of what we put into the atmosphere annually as a consequence of utilization of coal, gas and oil. However, water bodies and wetlands within and around cities are often found to be in a state of abuse. These vulnerable ecosystems often located within parks, besides rendering significant ecosystem services, also serve as nature-based destinations for the urban populace. As conservation of such water bodies and wetlands is of primary concern today, this paper seeks to highlight their carbon sequestration potentiality by estimating the approximate annual carbon sequestration rate of four such water body/wetland based parks of urban and peri-urban Kolkata, India.

II. CARBON SEQUESTRATION POTENTIAL OF WATER BODY/ WETLAND BASED PARKS: A LITERATURE REVIEW

A water body or wetland based park primarily comprises of the water body or wetland, terrestrial soil, trees, shrubs and herbs and grasses or lawns. Carnell et al. (2016) argue that though inland wetlands occupy a mere 6-8% of the land surface yet they are the largest store of terrestrial carbon as they contain 33% of the soil carbon pool. However, the annual rates and amounts of organic carbon burial in different water body systems vary (Boyd et al., 2010). Moreover, soil itself is recognised as a potential carbon sink that plays a vital role in slowing climate change. Scientists opine that

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more carbon resides in soil than in the atmosphere and all plant life combined. However, the world's cultivated soils have lost 50 to 70% of their original carbon stock (Schwartz, 2014). Lorenz and Lal (2015) emphasizes on the importance of urban soil C stock comprising of soil organic carbon (SOC) and soil inorganic carbon (SIC) for enhancing resilience of urban ecosystems, climate change adaptation and mitigation and human well-being. Moreover, Ugle et al., (2010) also emphasizes on the role of urban trees, which build the native biodiversity and also generate ecosystem services such as carbon sequestration within the urban landscape. The Green India Mission (GIM), one of the missions under India's National Action Plan on Climate Change (NAPCC), hopes to sequester 4.3 crore tones of greenhouse gases each year by 2020 and absorb 6.35 percent of annual emissions by enhancing tree cover. There are studies in India that have attempted to calculate the Carbon Sequestration Potential (CSP) of trees to combat C-emissions. Warran and Patwardhan (2001) calculated the C- emissions for Pune city and the carbon sequestration potential through trees in the city. Chavan and Rasal (2010) estimated the carbon stock of selected species of trees at the Aurangabad University Campus, Maharashtra. In the context of ecological benefits of urban forestry, it was found that the Kerwa Forest Area in Bhopal plays a critical role of a carbon sink with a total storage of about 19.5 thousand tons of aboveground carbon (Dwivedi et al. 2009). Similar studies have also been done by Rathore (2014) and Pandya et al. (2013) in Gujrat. Also, grasses and lawns can sequester carbon. Strout (2015) claims that one acre of well managed grass or lawn stores about 920 lbs of carbon per year.

III.THE CASE STUDY SITES

The four case study sites selected for the study reflects the diversities of water bodies and wetland within the parks of urban and peri-urban Kolkata. Although all of them with their environmental and ecological significance serve as nature based destinations, provide recreation and contributes to human well-being, yet they differ in terms of geographical size and area, wetland type, biodiversity, ecology, general resources and amenities and governance.

A. Nature Park, Taratala, Kolkata

Nature Park (NP) is a unique destination , located at 22°31'24"N 88°17'41"E within the Kolkata metropolis occupying about 82.5 hectares of wetland and a community driven venture operated by the Mudialy Fisherman's Cooperative Society Limited under the guidance of the Department of Fisheries and Aquaculture, Government of West Bengal. Waste water from the adjoining industrial areas is drained into the wetland, both for treatment and pisciculture. The treated water is then discharged into the Ganges. Being a huge repository of diverse flora and fauna, this entire wetland has also developed into a nature based tourism destination.

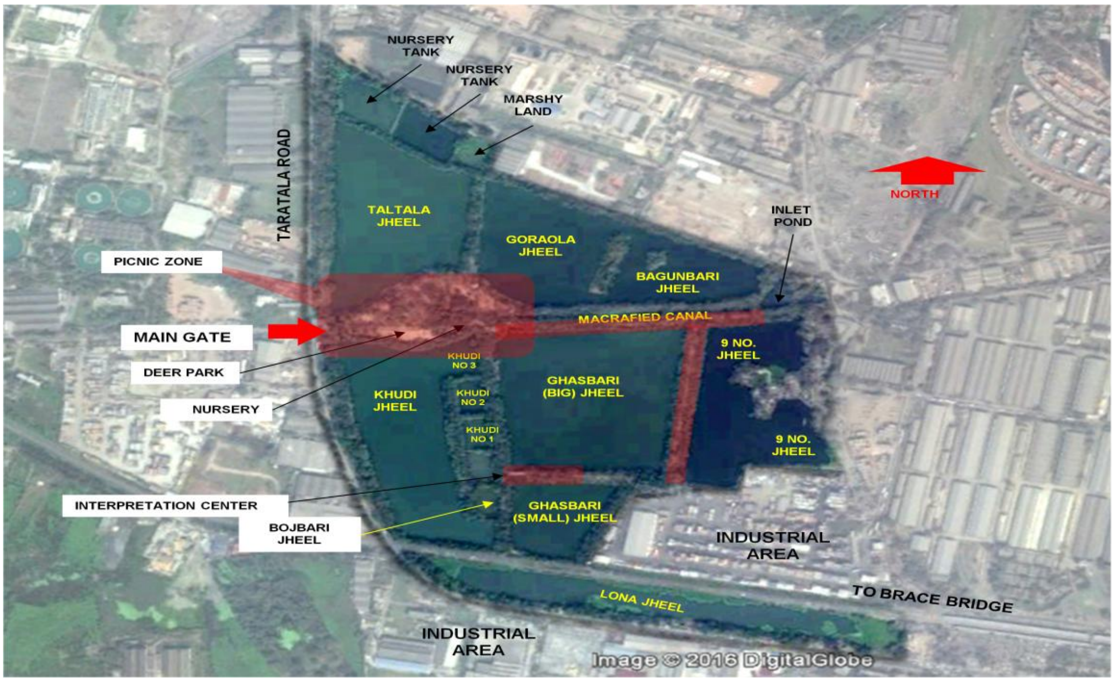

Fig.1. Nature Park, Taratala, Kolkata, Source: Google Earth

B. Rabindra Sarobar, Kolkata

Rabindra Sarobar (RS) is a man-made lake located at 22°34'N, 88°23'E in the southern corner of Kolkata City. It is an urban park maintained by the Kolkata Improvement Trust that acquired this marshy land in the 1920s and developed

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the lake. The water body extending over 29.54 hectares and situated in a total area of 77.80 hectares, is home to a huge variety of fishes. Countless shrubs and trees that are more than 100 years old surround the lake on all sides. During winter, many migratory birds are spotted here. An important recreational spot in the city, the site has also been included under the National Lake Conservation Plan (NLCP).

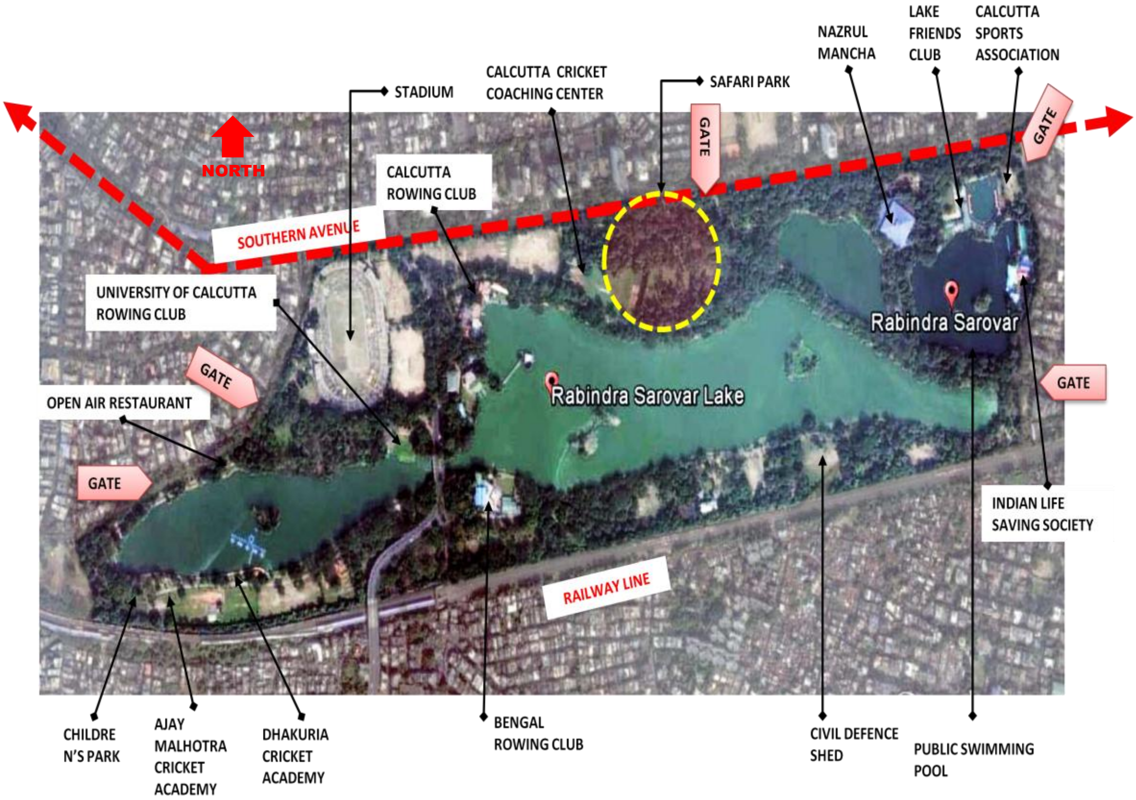

Fig.2. Rabindra Sarobar, Kolkata, Source: Google Earth

C. Jubilee Park, Gayeshpur, Kalyani

Jubilee Park (JP), a public private partnership venture initiated in 2009, is operated by Jubilee Parks & Resorts Pvt. Ltd. and located at 22°57'16"N 88°29'14"E. The property has been leased from Gayeshpur Municipality. Located in the northern fringe of Kolkata Metropolitan District, it is about 72 kms north of Kolkata city. The area of the park is near about 12.14 hectares including about 3.10 hectares of water body. The lake within the park, which is part of an array of wetlands, supports a very rich biodiversity with some of the rarest species of flora and fauna.

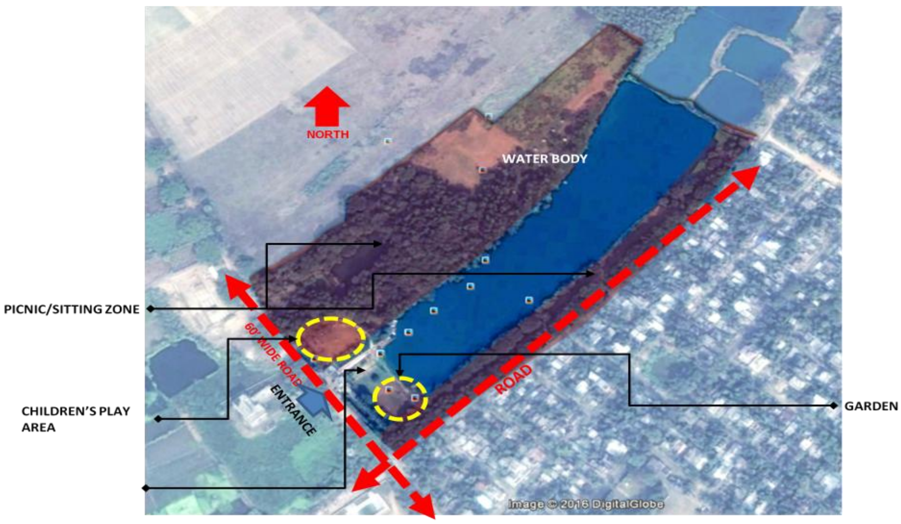

Fig.3. Jubilee Park, Gayeshpur, Kalyani, Source: Google Earth

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D. Millenium Science Park, Ashoknagar, Habra

The Millennium Science Park (MSP) at 22°50'47"N 88°38'13"E is located in Ashoknagar which is a city and a municipality in North 24 Parganas district. It is operated by the Ashoknagar-Kalyangarh municipality. The area of the Park is about 3.48 hectares which includes a natural water body of 0.66 hectares. The park with its lake, numerous trees, gardens and various amusement and recreational facilities is an attractive destination for visitors.

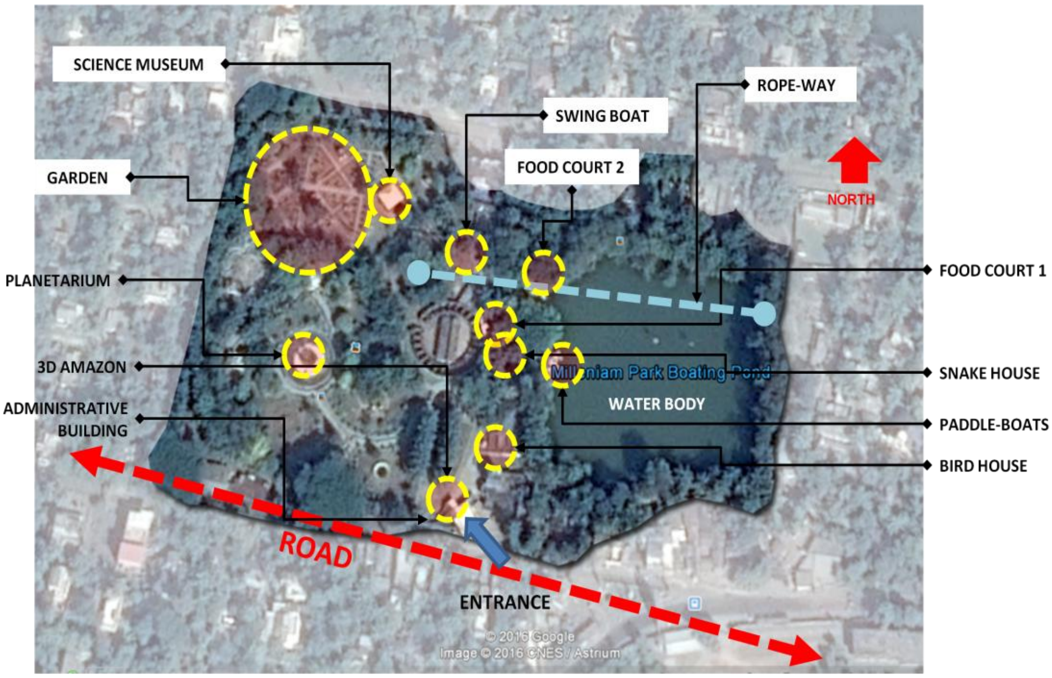

Fig.4. Millennium Science Park, Ashoknagar, Habra, Source: Google Earth

IV METHODOLOGY

A broad estimate of the Annual Carbon Sequestration Potential (ACSP) of the case study sites have been derived from the following major components:

1. ACSP (Carbon burial rate) of the Water Area
2. ACSP of Terrestrial Soil in the Park
3. ACSP of Trees within the Park.
4. ACSP of Grasses/Lawns within the Park

A. Standards Considered for Estimation of ACSP of the Water Area

A study by Adhikari et al. (2012) reveals that the total technical potential of C sequestration in 0.79 Mha of aquaculture ponds in India ranges from 0.6 to 1.2 Tg C/yr with an average of 0.9Tg C/ yr which is 0.2% of Indian current annual carbon emission. According to Boyd et al. (2010), aquaculture ponds sequester about 16.6 MT yr^{-1} of organic carbon worldwide representing around 0.21% of annual global carbon emissions. The carbon burial rate of different types of water-bodies across the world is shown in Table 1 below.

TABLE 1 GLOBAL AREAS OF INLAND WATER BODIES AND ANNUAL RATES AND AMOUNTS OF ORGANIC CARBON BURIAL IN THESE SYSTEMS

Water body	**Global area (Km^2)**	**Carbon Burial Rate (Tha^{-1} yr^{-1})**	**Global Carbon Burial ($MTyr^{-1}$)**
Large lakes and inland seas	2,180,000	0.05	11
Small lakes	320,000	0.72	23
Large reservoirs	400,000	4.0	160
Aquaculture ponds	110,800	1.5	16.6
(Freshwater)	(87,500)	(1.5)	(13.1)
(Brackishwater)	(23,330)	(1.5)	(3.5)
Agricultural impoundments	77,000	21.2	163

Source: Boyd et al., 2010.

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For the purpose of this research, the typology for water body or wetland at the case study sites is as follows: wetlands at NP are considered as “aquaculture ponds” while the water bodies at the other three case study sites have been considered as “small lakes.” Hence, according to Table 1, the carbon burial rate for aquaculture pond is considered as $1.5 Tha^{-1}yr^{-1}$, while that for small lakes is $0.72 Tha^{-1}yr^{-1}$.

B. Standards Considered for Estimation of ACSP of Terrestrial Soil

The case study sites are located in urban areas. Soils within cities in park areas, recreation areas, community gardens, green belts, lawns, septic absorption fields, sediment basins or other open or sealed soils are classified as urban soils (Svirejeva-Hopkins and Reis, 2011). Researches by Washbourne et al. (2014), prove that urban soil can sequester up to 85T CO_2 per ha annually or 23.18 TC $ha^{-1}yr^{-1}$. The ACSP of the terrestrial soil at the case study sites have been derived assuming this as a standard.

C. Standards Considered for Estimation of ACSP of Trees

Trees are important sinks for atmospheric carbon i.e. carbon dioxide, since 50% of their standing biomass is carbon itself (Ravindranath et al., 1997). In West Bengal, total carbon stock of Shorea robusta and Tectona grandis were 5.49MT in 1984 and 6.19 MT in 1994, and 0.29 MT in 1984 and 0.30MT in 1994, respectively (Manhas et al., 2006). Total carbon content of a few tree species in a plantation area of Budge Budge Generating Station of CESC Ltd in South 24 Parganas district of West Bengal has been recently studied (Biswas, 2015) the results of which are as follows: Acacia auriculiformis (22.891 Kg); Albizia lebbeck (15.169 Kg); Dalbergia sissoo (5.732 Kg); Eucalyptus sp. (81.517 Kg); Swietenia mahagoni (17.423 Kg); Tectona grandis (26.071Kg) and Terminalia arjuna (18.820 Kg).

The total number of tree species at NP, RS, JP and RS are 45, 55, 33 and 34 respectively. Correspondingly, the tree densities are 172 per ha, 53 per ha, 111 per ha and 201 per ha. Notably, the carbon sequestration rate per tree has been estimated about 7.86 Kg C per year for the average of India (Gujarat Forest Department, 2012; Parmar et al., 2014). Hence, this standard value has been used for estimating the total CSPs of trees at the case study sites.

D. Standards Considered for Estimation of ACSP of Grass or Lawns

It has been claimed that one acre of well managed grass or lawn stores about 920 lbs of carbon per year (Strout, 2015) or we can say one hectare of grass or lawn stores 1.13 tons of carbon per year.

E. Estimation of Total ACSP of an Ecosystem

After determining the ACSP of the water body, ACSP of terrestrial soil, ACSP of trees and ACSP of grass or lawns at each of the case study sites, the total ACSP of each case study site is estimated by:

$$\frac{\text{CSP of Water body } yr^{-1} + \text{CSP of Terrestrial soil } yr^{-1} + \text{CSP of Trees } yr^{-1} + \text{CSP of Grass/Lawns } yr^{-1}}{\text{Total Area of the park}}$$

V. RESULTS AND DISCUSSION

As is evident from Table 2, the estimated ACSP of water area is found to be the highest at NP. The estimated ACSP of terrestrial soil is found to be the highest at RS (Table 3), that of trees at NP (Table 4) and that of grass/lawns at RS (Table 5). Significantly, the total ACSP is found to be the highest at MSP, while it is found to be the lowest at NP (Table 6).

Table 2 Estimated ACSP of the Water Area

Case Study Sites	Area of the water body (ha)	Carbon Burial Rate ($Tha^{-1}yr^{-1}$)	Estimated CSP ($TCyr^{-1}$)
NP	58.50	1.5	87.75
RS	29.54	0.72	21.26
JP	3.10	0.72	2.23
MSP	0.66	0.72	0.47

TABLE 3 ESTIMATED ACSP OF TERRESTRIAL SOIL

Case Study Sites	Total Terrestrial Area ha)	Estimated CSP ($TCyr^{-1}$)
NP	23.99	556.08
RS	48.15	1116.12
JP	9.03	209.31
MSP	2.81	65.13

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TABLE 4 ESTIMATED ACSP OF TREES

Case Study Sites	Total Terrestrial Area (ha)	Terrestrial Area Surveyed (ha)	Tree Density	Estimated No. of Trees in Total Terrestrial Area	Estimated CSP ($TCyr^{-1}$)
NP	23.99	12 (50%)	172	4126	35.75
RS	48.15	42.20 (88%)	53	2552	22.11
JP	9.03	9.03 (100%)	111	1002	8.68
MSP	2.81	2.81 (100%)	201	565	4.90

TABLE 5 ESTIMATED ACSP OF GRASS/LAWNS

Case Study Sites	Total Terrestrial Area (ha)	Estimated Terrestrial Area Occupied by Grass/Lawn (ha)	Estimated CSP ($TCyr^{-1}$)
NP	23.99	19.20	21.70
RS	48.15	33.70	38.80
JP	9.03	8.13	9.18
MSP	2.81	1.68	1.90

TABLE 6 ESTIMATED ACSP OF THE ECOSYSTEMS

Case Study Sites	Total Area of Park (ha)	Estimated CSP ($TCha^{-1}yr^{-1}$)
NP	82.50	8.50
RS	77.80	15.40
JP	12.14	18.90
MSP	3.48	20.80

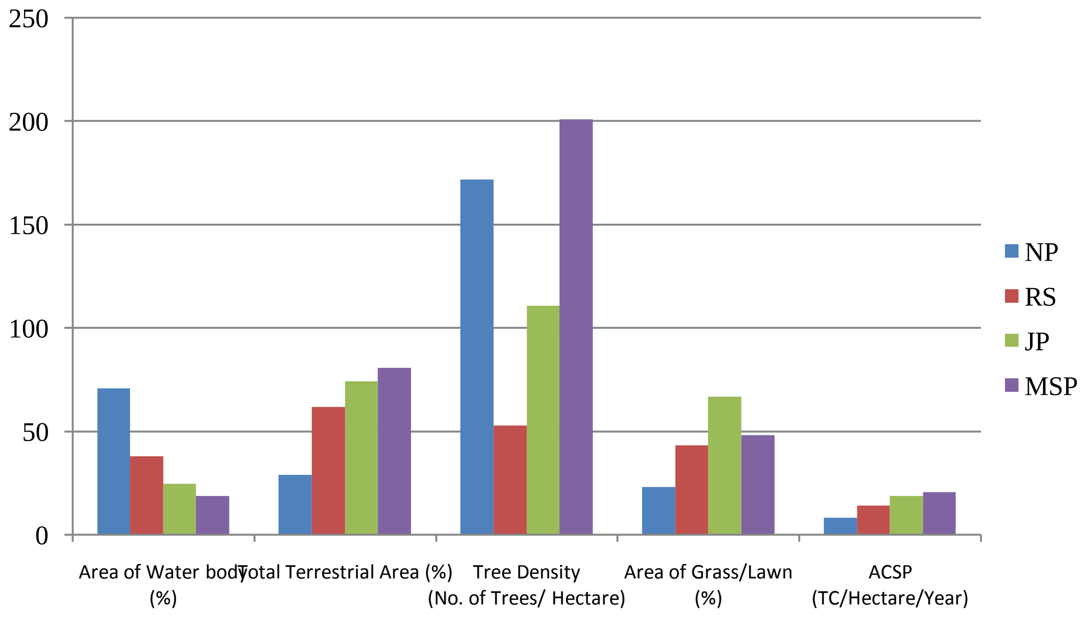

Fig. 5 ACSP and its Components at the Case Study Sites
NOTE: Units/ Metrics of individual components are mentioned along-side each component.

A comparative representation of the ACSP and the status of its components at the four case study sites are shown in Fig.5. The high ACSP of MSP may be attributed to a large extent to its high tree density of 201 trees per ha. However, the CSP of trees varies according to the species type. The dominant tree species, as found from physical survey at NP, RS, JP and MSP are Cocos nucifera (23.11%), Senegalia catechu (15.80%), Acacia auriculiformis (23.89%) and Roystonea regia (39.46%) respectivel. The average carbon stock of Cocos nucifera, Acacia auriculiformis and Roystonea regia were found to be 28.68 T, 21.94 T and 1.24 T (Rathore, 2014) while that for Senegalia catechu was

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0.87 T per species (Sharma and Sharma, 2016). So Roystonea regia and Senegalia catechu are found to have very low carbon stocks. According to observations by Rathore (2014) at the Gujrat University Campus, some native trees with relatively high carbon stocks indicating high carbon sequestration potential are: Terminalia chebula (76.928 T), Limonia acidissima (61.31 T), Ficus benghalensis (54.03 T), Tamarindus indica (52.84 T), Ailanthus excelsa (43.89 T), Syzigium cumini (43.64 T), Emblica officinalis (43.57 T), Azadirachta indica (43.11 T), Ficus religiosa (42.79 T), Cassia siamea (41.66 T), Albizia lebbeck (40.58 T), Terminalia arjuna (38.21 T), Magnifera indica (35.75 T) etc. However, some of them are already present at the case study sites, though in lesser numbers. With respect to Best Management Practices (BMPs) for enhancing soil C stocks, Lorenz and Lal (2015) opine that reduced soil disturbance, frequent fertilization, watering enhanced plant growth, which along with organic manure contributes to Soil Organic Carbon (SOC) accumulation while Soil Inorganic Carbon (SIC) stocks may be enhanced by mineral carbonation through the addition of Ca and or Mg –bearing demolition material.

VI CONCLUSIONS

The ACSP of Nature Park, Rabindra Sarobar, Jubilee Park and Millenium Science Park is estimated to be 8.50TCha^{-1}, 15.40TCha^{-1}, 18.90TCha^{-1} and 20.80 TCha^{-1} respectively. Given the existing area under water and terrestrial area in all the case study sites, to increase the CSP of the ecosystems, other than MSP, further planting of trees are strongly recommended at all the case study sites, particularly more so at NP. Further planting or replacement of trees at the case study sites should take into consideration the carbon sequestration rate of trees, with those having higher carbon sequestration capacities given preference. Moreover, BMPs should be adopted for enhancing soil carbon stocks through SOC and SIC accumulation. All urban and peri-urban water bodies and wetlands being potential carbon sinks, enhancing carbon removal from the atmosphere should be initiated through the selection of appropriate vegetation, restoration of the water-body or wetland (for increased SOC stock) as required, and through terrestrial soil management techniques.

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BIOGRAPHIES

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