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Natural Carbon sequestration by dominant mangrove species *Avicennia marina* var. accutissima ex Staf & Moldenke ex Moldenke found across Thane creek, Maharashtra, India

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Abstract— Trees absorb carbon and assimilate it as a part of biomass through a process of photosynthesis. The current study focuses on carbon sequestration by dominant mangrove species across Thane creek. Thane city harbors Asia's largest industrial complex, effluent of which are released directly or indirectly to the creek, thereby increasing pollution, affecting growth of mangroves. Mangrove forests are considered as probable and efficient sink of atmospheric carbon. *Avicennia marina* var. *accutissima*Stapf & Moldenke ex Moldenke is the dominant species found on the banks of theThane creek. Approximately more than 20 % of carbon is stored in above ground biomass of which 2% - 3 % gets incorporated in sediments. The sequestration potential of entire creek is estimated allometrically. This will help in creating awareness of the most crucial and dominant mangrove species at the creek.

Index Terms—, *Avicennia marina* var *accutissima* , Carbon sequestration, dominant, mangroves , allometric.

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1 Introduction

The increasing concentration of atmospheric carbon dioxide (CO_2) levels and signs of climate change such as melting of glaciers, sea level rise, change in precipitation, etc.,has been the major concern today. In order to combat climate change forests might play an crucial role. The fact that forest sequester tons of carbon naturally in their biomass and in sediment through a phenomenon called 'Carbon Sequestration' has developed a hope to conserve natural ecosystems. IPCC [1] defined "Carbon sequestration as the process of increasing the carbon content of a reservoir/p(ool such as ocean, sediment/soil, forests) other than the atmosphere".

Trees are considered to be significant in terms of carbon storage as they absorb and store the key greenhouse gas 'CO_2' by the process of photosynthesis in their biomass. When these plant parts get buried in the soil, the organic carbon in their biomass undergoes decomposition and part of it gets stored in the soil/sediment of that ecosystem.

Mangrove forests and tidal salt marshes comprise special type of trees (vegetation) adapted to environmental extremes. Over a decade mangrove are known for their high potential of carbon sequestration [2],[3],[4],[5], despite representing smaller area on comparison with terrestrial forests. The carbon stored by mangrove forest might be compared to carbon sinks in different terrestrial ecosystems [6],[7],[8].

The sequestered carbon by various forest ecosystems including mangroves in plants and soil/sediment can be traded , just as any farm produce, as trading carbon credits is the rapidly growing industry in present and near future. [9],[10].Considering high carbon sequestration potential of mangroves , many researchers [11],[12],[13] believes that conservation of mangroves may serve as a valuable and useful tool in context of carbon trading and against preventing carbon release from deforestation.

The Thane creek located near Mumbai , Maharashtra ,India inhabits rich mangrove vegetation along its bank. The maximum carbon sequestration occurred by *Avicennia marina* var. *accutissima* Stapf & Moldenke ex Moldenke which is found to be the dominant species throughout the creek. It is commonly called as grey mangrove (local name 'Tivar') and belongs to family Avicenniaceae. It occurs in the intertidal zones of estuarine areas. It grows as a shrub or a tree upto height of 3-14 m in tropical regions. The tree form is a gnarled arrangement of multiple branches. It has smooth light-grey bark made up of thin, stiff, brittle flakes, which gives its common name. It has aerial roots (pneumatophores); these grow to a height of about 25 centimetres, and a diameter of one centimetre. These allow the plant to absorb oxygen, which is deficient in its habitat. These roots also anchor the plant during the frequent inundation of seawater in the soft substrate of tidal systems. The species can tolerate high salinity by excreting salts through its leaves. The present paper estimates the carbon sequestration by *A. marina var. accuttissima* .

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2 Study Area

2.1 Site Description

Thane Creek (Lat. 19º 00′N to 19º 13′N and Long. 72º 57′ E to 73º 00′E) is an inlet (26 km long stretch) along the coastline of the Arabian Sea that isolates the city of Mumbai from the Indian mainland on the one side and the city of Navi-mumbai

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(Trombay) on the other side.The creek is tidally influenced with dominance of neritic waters. The substratum of the creek in the mid-stream is made up of consolidated and unconsolidated boulders intermingled with loose rocks and rarely with sand and gravel. Extensive mudflats are formed along the banks of the creek and are characterized by the growth of luxuriant growth of mangroves.

The climate near creek is tropical, very humid, and warm. In the coastal area, the average daily maximum temperature in summer is 32.9°C and in winter average mean daily minimum temperature is 16.8°C. The average annual rainfall in the Thane district is 2293.4 mm. The creek being tropical in location, winter is not severe and three seasons can be distinguished viz., monsoon (June to September), post monsoon (October to February) and pre monsoon (March to May).

The present investigation was conducted by collecting two samples on each bank of the creek. (Refer fig. 1). Station 1 and Station 2 are located near *Bhandup* village and Station 3 and station 4 are located near *Airoli* village. The data obtained at Station 1 and station 2 were pooled together and station 3 and staion 4 were pooled together as no significant difference in the data of two stations was obtained. The study was conducted for 12 months, from May 2010 to April 2011.

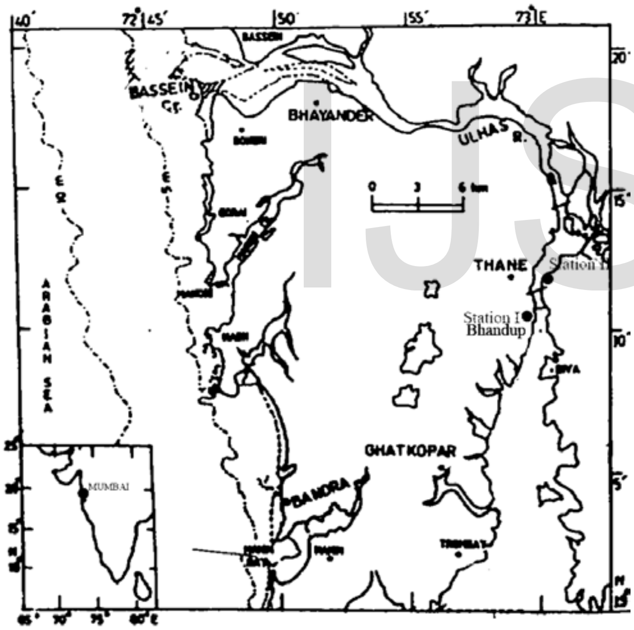

Fig. 1: Map showing locations of sampling stations

2.2 Materials and Methods

The green fresh leaves and dried fallen leaves (leaf litter) of *Avicennia marina* var *accutissima* was collected and immediately carried to laboratory. The leaf samples were properly washed to remove the sediment, blotted to remove excess water , oven dried at 60°C, powdered and then sieved through 0.4 – 0.5 mm sieve. This leaf powder was used to analyze the organic carbon content using Walkley and Black method [14],[15],[16].

The sediment samples were collected at different depth (15 centimeters approximately) by using 1.5 inch diameter, 1.5 feets long Polyvinyl chloride (PVC) pipes beneath *Avicennia marina* species. The pipes were then sealed with aluminium foil to avoid escape of any form of organic carbon and then kept in oven at 70°C for 72hours for drying. The sediment was then removed and divided into five centimeter each from top to bottom, pounded and analysed for organic carbon content by using Walkley and Black method [13]

The quadrat study was performed to find the dominance of mangrove species. Total six quadrats of 10m x10m were studied at each station (refer fig. 1). In each quadrat the vegetation was described (species cover and abundance) in order to determine species distribution along the transect.

3 RESULTS AND DISCUSSION

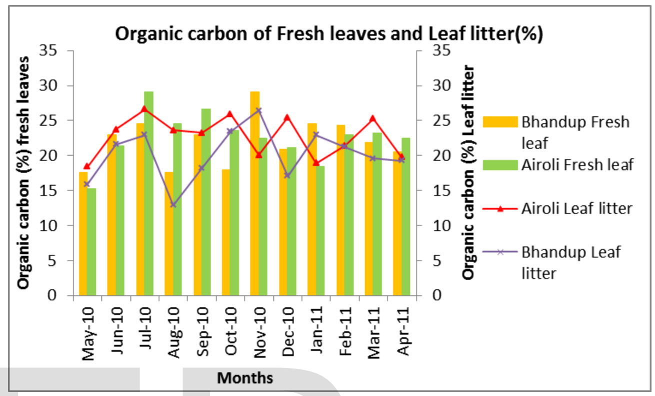

Fig. 2: Monthly variations in organic carbon content of Fresh leaves and leaf litter at both stations.

The fresh leaves and leaf litter of *Avicennia marina* var. *accutissima* Stapf & Moldenke ex Moldenke showed organic carbon ranged between 15% and 30%. From fig 2. No significant difference was obtained between the organic carbon content of different stations. The high values for leaf litter during few months might be due to complete assimilation of more carbon in it.

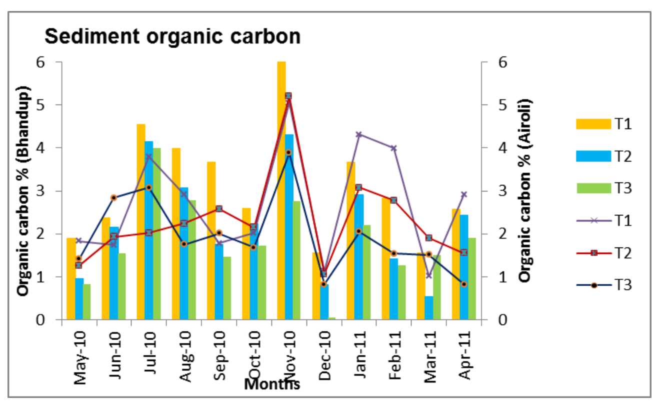

Fig. 3: Monthly variation in sediment organic carbon(%) at both stations.

Depth-wise estimation of sediment carbon revealed average organic carbon accumulation in T1 (first topmost layer) was found to be 3.02 % which decreased subsequently to 2.21% in T2 (middle layer) and upto 1.93 % in T3 (Third layer) layer at *Bhandup* and towards *Airoli* , it was found to be 2.65% in T1 layer, 2.31 % in T2 layer and 2.01% in T3 layer. The surface sediment in the topmost layer stored high percentage of organic carbon reaching upto 6 % sometimes. This might be due to leaf litter and the benthic fauna that inhabitats the surface sediment.

Kristensen and Alongi [17], estimated the organic carbon content of 10.1% to 10.9 % in the sediment beneath *Avicennia* species. Lacerda *et al*., [18], observed decrease in organic carbon by about 40% from the surface to a depth of 15 cm in the sediment beneath *Avicennia*. The present study suggests loss of some amount of carbon depth-wise and also indicates 2.01 % to 1.93 % of carbon storage for certain period of time. The sediment organic carbon content showed significant decrease depth-wise in the month of December 2010(Fig 3). Generally in the month of September infestation to mangroves by moth *Hyblaea puera* was observed, during which almost all green leaves are consumed by caterpillar of this moth and for new leaves to emerge it would take some time. Because of less litterfall, the organic carbon content of the sediment might have decreased in the month of December 2010.

4 Carbon Sequestration Using Allometric Equation

The amount of carbon sequestration by mangroves leaves and sediment was determined chemically but still it will estimates the entire carbon storage by the selected mangrove spcies. So in order to find the sequestration potential of *Avicennia marina* was estimated using allometric equations. The carbon stored by A. marina species , can be related to above ground and below ground biomass stored by any tree. In mangrove forest, below ground biomass that is the bottom part of the tree is found high itself to withstand in muddy sediment. The biomass of the tree represent the carbon sequestration capacity of the tree. In order to estimate biomass either destructive or non destructive technique is used. In destructive method, the entire tree is cut to obtain the biomass. Thus to avoid destruction of trees many scientist had developed the allometric equations to calculate the biomass. Thus by obtaining simple details like DBH, sometimes wood density, the biomass of the species can be calculated in a non-destructive way. In the case of allometric method, whole or partial weight of a tree is estimated with the help of measurable tree dimensions such as trunk diameter and height by using allometric equations. The allometric method is based on the assumption that one part of the organism is proportional to that of the another.Therefore the trunk diameter is correlated with the trunk weight.[19],[20],[21]. Using this method, the amount of carbon sequestered in the biomass is generally taken as 50% of the dry biomass [22],[23].

For the present study, allometric equation developed by Comley and McGuinness [24] for *Avicennia marina* is:

$$W_{top}(AGB) = 0.308 DBH^{2.11} \quad \text{......} 1$$

$r^2 = 0.97$, $n = 22$, $D_{max} = 35$ cm,
and

$$W_R(BGB) = 1.28 DBH^{1.17} \quad \text{......} 2$$

$r^2 = 0.80$, $n = 14$, $D_{max} = 35$ cm,

Where above ground biomass (AGB) and below ground biomass (BGB) is estimated in kg/tree and DBH is in cm.

From the above equation, the total above ground biomass was estimated to be 54.9 tons ha^{-1} and below ground biomass was 19.7 tons ha^{-1}, thus contributing total biomass of 74.6 tonsha^{-1} and total carbon content upto 37.6 tons ha^{-1}.

Avicennia marina (Forsk.)Vierh.dominated mangrove forest at BKPH Ciasem had potency of total biomass content and total carbon content of 364.9 ton/ha and 182.5 ton/ha, respectively[25].The carbon sequestration potential may differ in same species according to change in location and have different values for total biomass.

The total area covered by mangroves at Thane creek was calculated using Daftlogic google map area calculator software and was estimated to be 6391.87 hectares. Thus, the total area of Thane creek is estimated to have 476835.7 tonnes of biomass and 238417.9 tonnes of carbon in it considering 70% dominance. The total area covered under quadrat study was 1200 m^2which was correlated with the entire area as mangrove vegetation shows zonation depending on salinity and vegetation pattern remained quite similar in visual observation through boat rides that was commenced from Vashi area towards the interior of the creek. .

5 Conclusion

The fresh leaves and leaf litter of *Avicennia marina* var. *accutissima* Stapf & Moldenke ex Moldenke showed organic carbon ranging between 15% to 30%. The surface sediment in the topmost layer stored high percentage of organic carbon reaching up to 6 %. The total above ground biomass was estimated by using allometric equation as 54.9 tons ha^{-1} and below ground biomass was 19.7 tons ha^{-1}, thus contributing total biomass of 74.6 tons ha^{-1} and total carbon content upto37.3 tons ha^{-1}. The total area of Thane creek is estimated to have 476835.7 tonnes of biomass and 238417.9 tonnes of carbon in it considering 70% dominance. The values represented are only for *Avicennia marina* var. *accutissima* Stapf & Moldenke ex Moldenke. The creek also shows 30% dominance of other mangrove species, the biomass of which enhances the potential of carbon sequestration. Thus entire creek proves to be a valuable carbon sink and needs to be conserved.

Recently the creek is under major anthropogenic threat and is been destructed at an alarming rate. Unfortunately due to lack of awareness the ecosystem value of carbon sequestration is lost. Conservation of these esteemed ecosystems will not only give livelihood to local fishing community but will also earn carbon credits, which will definitely add value to nations economy.

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