

Carbon Sink potentiality of *Avicennia marina* along the Egyptian Red Sea Coast

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Research Article

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Abstract

Background Climate change is a global concern caused by increasing concentrations of carbon dioxide in the atmosphere, with many detrimental consequences. A potential approach to counter acting the effects of climate change is to actively remove carbon dioxide from the atmosphere. the biomass without damaging the vegetation.

Results Based on the allometric equation, the biomass has the highest value in wadi El-Gimal for the growth stages sapling, there for the largest number of sapling found in this area. Carbon sequestration in four different locations of *Avicennia marina* was estimated. The highest carbon storage in stands of Abu Ghuson was 30 kg/hectare than in these in other sites. the carbon dioxide absorption of trees in Sharm El-Bahary was higher than in the other studied sites is 24.8kg/hectare.

Conclusion These estimates suggest high Biomass and carbon sequestration potential despite the relatively small area of the *Avicennia marina* along the Red Sea Coast.

1. Introduction

Wetlands have a vital role in carbon dioxide sequestration, the major greenhouse gas in the atmosphere (Choi and Wang 2004). Conversion of wetlands to agricultural and other developmental purposes in several parts of the world should be banned, as wetlands will become a significant source of atmospheric CO₂ (Whiting and Chanton 2001). Wetland ecosystems are the greatest sinks for carbon comparing with all the terrestrial ecosystems. While wetlands comprise some 5–8% of the terrestrial land surface (Mitsch and Gosselink 2007), about 20–30% of the total global soil carbon pool (about 25×10^{11} Mega gram) is stored in them (Lal 2008).

Mangroves, found in various tropical and sub-tropical coastal regions, possess unique ecosystems (Santini et al., 2015). They exhibit adaptability to a wide range of salinity levels (Noor et al., 2015). These ecosystems offer numerous advantages to both the environment and human beings (Kauffman et al., 2011). Recently, mangroves have gained recognition for their ability to store carbon and sequester carbon dioxide (CO₂) from the atmosphere (Noor et al., 2015 and Ilman et al., 2016). The amount of carbon stored in mangrove forests surpasses that of terrestrial forests by two to three times (Tue et al., 2014). In comparison to many terrestrial systems, mangroves can store substantial amounts of carbon per unit area (Njana et al., 2015). As a result, mangrove forests play a significant role in the global carbon budget (Eid and Shaltout, 2016). *Avicennia marina* is one of the many species of mangroves and is widely distributed across multiple regions of the world (Reef et al., 2015).

Few studies have been conducted on the carbon sequestration potential of *Avicennia marina* in Egypt, along the northern coast of Red Sea, where the mean carbon stored was estimated as 85 Mg C ha⁻¹, while the mean carbon sequestration potential was 0.061 Mg C ha⁻¹ year⁻¹ (Eid and Shaltout 2016). Stored carbon in mangrove vegetation on Gulf of Aqaba–Egypt was estimated as 109.3, 41.9 and 70.3

Mg C ha⁻¹ for mangroves at intertidal, shoreline and salt plain habitats, respectively (Mashaly et al., 2016). Mangrove and other coastal ecosystems on the Gulf of Aqaba had carbon sequestration potential of 2.4, 0.545, 1.04, 0.14 and 0.81 Mg C ha⁻¹ year⁻¹ for mangrove of intertidal, shoreline, salt plains, mudflats and hypersaline ecosystems, respectively (El-Hussieny and Ismail 2017).

Present work is a complementary task to fill the gap in the estimation of carbon pool and carbon sequestration potential of mangrove ecosystem covering its geographical range along the Red Sea coast of Egypt. This provides one of the pioneer estimates for carbon sequestration potential of *Avicennia marina*, estimate the above-ground and root biomass and C-stocks to understand the blue carbon potential of the mangroves.

2. Materials and methods

2.1. Study area

The Red Sea coast of Egypt extends in SE–NW orientation for about 830 km, in addition to about 870 km of coastline of Suez and Aqaba Gulfs. This made the total length of Egyptian coasts along the Red Sea, including both Gulfs, is about 1700 km that almost equals the total eastern coastline of Red Sea in Saudi Arabia (Saifullah 1994 and El-Hussieny 2011). Four main locations encompass the entire coastlines of the Egyptian Red Sea, representing the natural variation of *Avicennia marina* populations subjected to different physiographic, climatic and human impact conditions were selected for this study (Shawky, 2021). The first transect was in Sharm El-Bahry (south El-Qusair), the second in Wadi El-Gimal (south Marsa Alam), the third Wadi Al-Qu'lan (north Hamata) and the fourth in Sharm El-Madfa'a (south Shalatein) shown in (Fig. 1).

Figure 1. Four Locations of Mangrove stands along the Red Sea coast, Egypt.

2.2. Methodology

Studying carbon sequestration requires fieldwork to estimate both above- and belowground biomass. Due to the surrounding environment, work in mangrove forests is largely inaccessible, making fieldwork and sampling a tedious task (Patil *et al.*, 2014). Over the past few years, forest ecologists have developed various methods for estimating forest biomass (Komiyama *et al.*, 2008). One of these methods is the use of allometric equations. This method has been widely used by researchers as a non-destructive method to estimate mangrove biomass (Komiyama *et al.*, 2008 and Fromard *et al.*, 1998). The estimation also relies on the measurement of tree characteristics such as trunk diameter (Fayad *et al.*, 2016).

2.2.1. use of allometric equations

A non-destructive method based on stem DBH (i.e., allometric equations) was used to estimate above- and below-ground biomass and thus carbon stocks. The basic theory of allometric relationships is that in many organisms, the growth rate of one part is proportional to the growth rate of another part. Relationships using diameter at breast height (DBH) have been developed by many researchers to predict

the above-ground biomass of mangroves in many parts of the world (Clough *et al.*, 1997 and Saenger & Snedaker, 1993).

2.2.2. Calculation of above ground biomass. Tree biomass was calculated using the Allometric Coefficient Value formula (a and b). To calculate the upper biomass based on tree species, a calculation formula that has been widely used by previous researchers was used, starting with felling and weighing trees (Kittredge, 1944). The formula is as follows:

$$B=a \times D^b$$

Where: Y is the Biomass, a and b constant and D is the Diameter

2.2.3. Calculation of above ground carbon

a. Calculation of above ground carbon

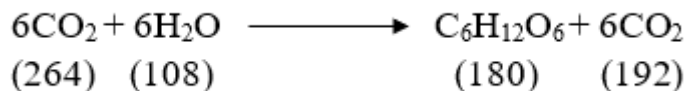
Calculation of above ground carbon using the following formula:

$$Cb = B \times \% C \text{ organic}$$

where: Cb = carbon content of biomass, expressed in kilograms (kg), B = total biomass expressed in kilograms (kg), %C organic: the percentage value of carbon obtained from the results of carbon measurements (Shawky, 2021).

b. Calculation of total carbon dioxide (CO₂) sequestration.

Carbon dioxide sequestration was calculated based on the mass ratio of the photosynthetic reaction equation:



Based on the photosynthetic reaction equation above, to produce 180 grams of biomass (C₆H₁₂O₆) it takes about 264 grams of CO₂. Therefore, CO₂ sequestration can be determined by the formula:

$$\text{CO}_2 = (264/180) \times \text{Biomass} = 1.4667 \times \text{Biomass}$$

3. Results and discussion

3.1. Biomass

Biomass is the mass of living organisms consisting of plants and animals that inhabit an area (Santosa et al., 2014). There are two types of biomass: aboveground biomass and belowground biomass. Biomass values were calculated using allometric equations. The biomass calculations were performed using the non-destructive method, a method that measures the biomass without damaging the vegetation. Based on the allometric equation, the stored biomass was found to be influenced by factors of vegetation diameter and density (Pratama and Sribudiani, 2016). The result in (Fig. 2) showed that highest value of Biomass recorded in wadi El-Gimal for the growth stages sapling, there for the largest number of sapling found in this area.

Figure 2. Above ground biomass of *Avicennia marina* at different localities.

3.2. Carbon stocks

Carbon is one of the elements stored on the soil surface as biomass of living plants, dead plant residues, and soil organic matter (Uthbah et al., 2017). Once the average biomass content has been determined, the next step is to determine the carbon stock value. The carbon stock value is obtained by multiplying the biomass content by the percentage value of carbon content. The results in (Table 1) showed that the that the highest carbon stock in the site of Abu Ghuson was 30 kg/hectare (Prahara et al., 2015). the diameter of the trees is small so that the carbon stocks is also small. In addition, the tree level also has a high biomass value. Adinugroho et al., (2012) stated that the larger the diameter of the trees that made up a stand with a large number of individuals and composed of species that had high wood density, the potential for biomass and carbon content was also greater. Hikmatyar *et al.*, (2016) stated that the larger the diameter of the tree, the more carbon would be absorbed. Tree stand biomass greatly affects the stored carbon potential.

3.3. Carbon sequestration

The carbon dioxide absorption is determined by comparing the formula for the photosynthetic process with the conversion factor for carbon dioxide absorption, which is 1.4667, and multiplying it by the biomass. The carbon dioxide absorption can be seen in (Table 1). The results show that the carbon dioxide absorption of trees in Sharm El-Bahary was higher than in the other studied sites is 24.8kg/hectare. This is due to the large diameter of the tree trunks and the fact that most of the results of photosynthesis are stored in the tree trunks. Carbon dioxide sequestration is determined based on biomass and tree age. The larger the diameter of the tree, the greater the amount of carbon dioxide absorbed. This is related to the results of photosynthetic processes in the form of cellulose and wood constituents, which increase the weight of organic matter and allow for horizontal and vertical growth. The same is also said by (Baderan, 2017) that the increase in tree diameter is due to the accumulation of biomass converted from CO₂, which increases as atmospheric CO₂ is absorbed by the tree. The same opinion is also expressed by Darmawan and Siregar in (Manafe et al., 2016).

Table 1

Total above ground biomass, carbon stock, annual carbon sequestration of *Avicennia marina* at different localities.

Sites	Aboveground Biomass (kg/m ³)	Belowground Biomass (kg/m ³)	Carbon Stock (kg/hectare)	Carbon Dioxide (CO ₂) sequestration (kg/hectare)
Sharm El-Bahary	17.08	3.08	28.0	24.9
Wadi El-Gimal	15.33	5.68	25.9	22.3
Abu Ghuson	17.06	3.32	30.0	24.8
Sharm El-Madfaa	14.08	2.99	23.9	20.4

Conclusion

This paper examines the carbon sink potential of *Avicennia marina* along the Red Sea Coast, Egypt. It estimates the biomass and carbon content of the mangrove vegetation in stand of Abu Ghuson has the highest carbon stock due to the largest number of trees in the site. The study suggests that the mangrove trees along the Red Sea Coast have a high potential for carbon sequestration.

Declarations

Authors' contributions

ASA and DC.: data collection and organization, formal analysis, writing (the original draft). CAK: data collection and methodology, organizing, formal analysis, and writing. AA: reviewing, and editing the manuscript. JCS contributes to the comments, editorial and writes a manuscript. AB. edited and reviewed the manuscript, proofread it for the final submission, and is the senior author. DZ. is co-initiator of the study, developed the research question, made significant contributions to, data collection, analysis, and write-up. All authors contributed to the writing of the manuscript. This is original research that has not previously been published and is not under consideration for publication elsewhere. All authors contributed to the writing of the manuscript.

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Data Availability

The attached supplementary file contains all data.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The author declares no competing interests.

Ethical guidelines

Not applicable.

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Figures

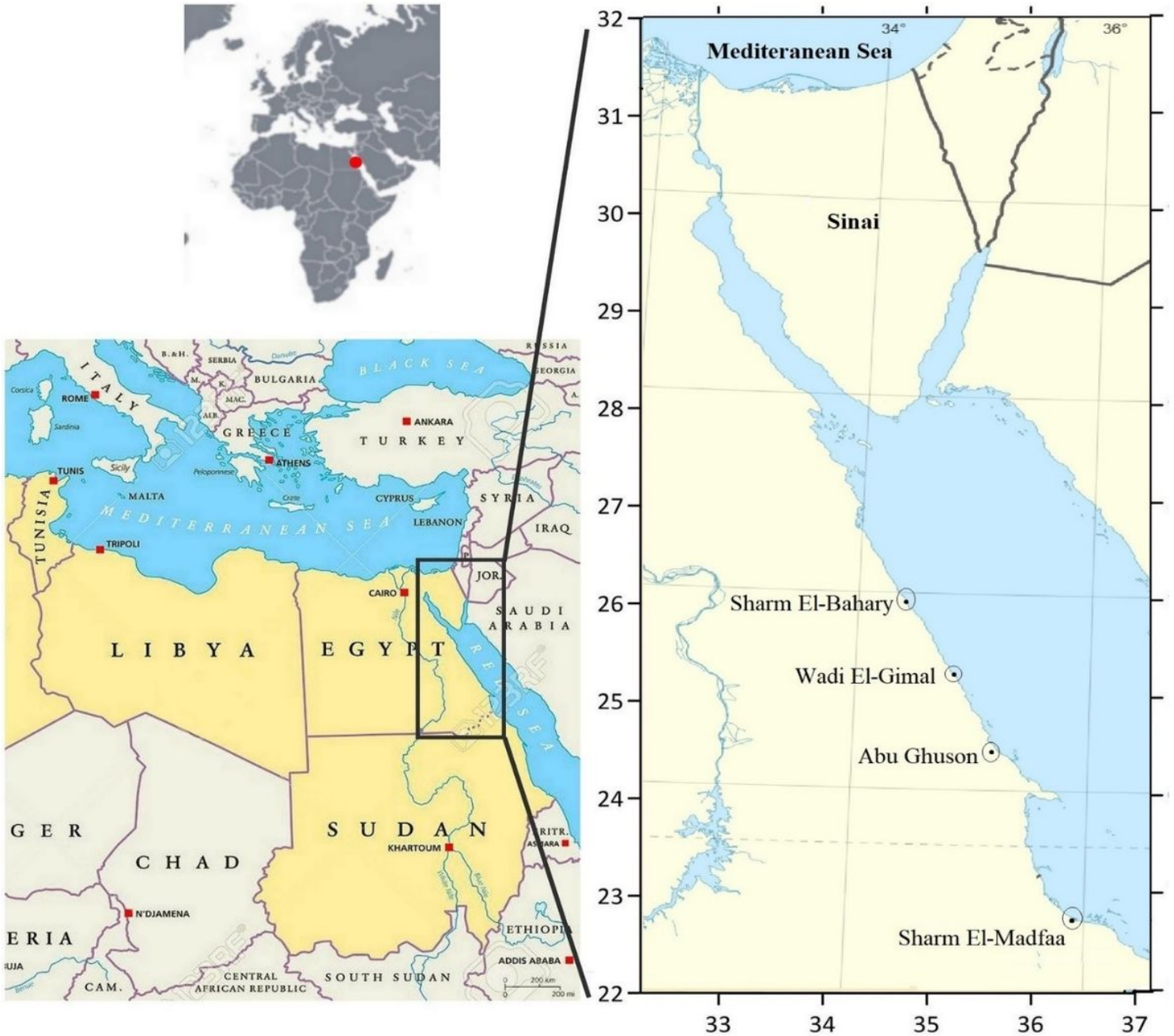


Figure 1

Four Locations of Mangrove stands along the Red Sea coast, Egypt.

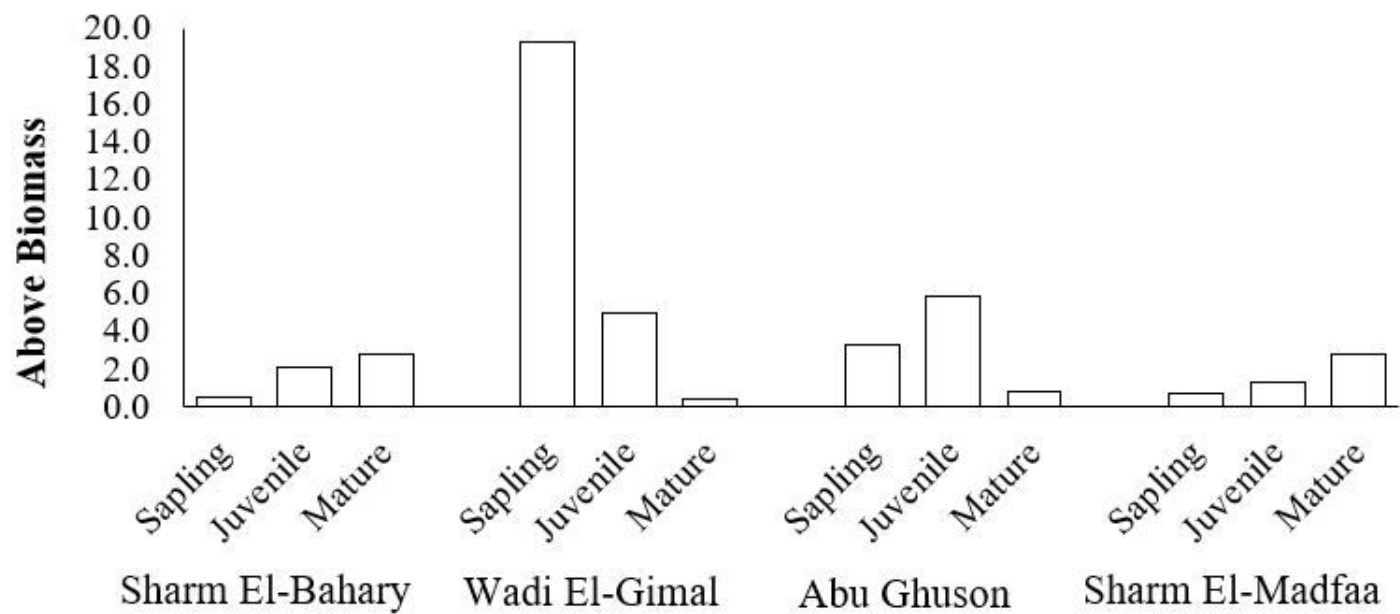


Figure 2

Above ground biomass of *Avicennia marina* at different localities.