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NATIONAL **BLUE CARBON** DECISION-MAKER SUMMARY

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Acknowledgements

The Ministry of Environment and Water (MOEW) and the Abu Dhabi Global Environmental Data Initiative (AGEDI) would like to thank each of the competent authorities including Environment Agency– Abu Dhabi, Dubai Municipality, Environment and Protected Areas Authority of Sharjah, Municipality and Planning Department Ajman, Environment Protection and Development Authority of Ras Al Khaimah and Umm Al Quwain Municipality for implementing this project in joint collaboration and for the expertise of the many staff involved, all of which were critical towards the success of this project. Thank you also to the two representatives of Blue Ventures Madagascar for cross capacity-building and sharing of experience.

A special thank you to EWS-WWF for their participation and facilitating access to their volunteer network. We would like to thank each volunteer for your wonderful engagement, time and dedication which you have extended to our project. We especially thank those volunteers who extended their time with us, joining us for our field work for multiple days and over weekends. You were truly essential team members that played an invaluable part in our work.

We would like to additionally thank the Principle Investigators for their passion towards assuring world class Blue Carbon science and methodologies. Your dedication to capacity building for the advancement of Blue Carbon science was felt throughout these efforts.

'Blue Carbon' refers to the functional attributes of coastal and marine ecosystems to sequester and store carbon. Blue Carbon ecosystems of the UAE include mangrove forests, salt marshes and seagrass beds. Another potential Blue Carbon ecosystem identified as a result of this project is cyanobacterial "blue-green algal" mats (hereafter referred to as algal flats). When these ecosystems are destroyed, buried carbon can be released into the atmosphere, contributing to climate change. In addition to their climate-related benefits, Blue Carbon ecosystems provide highly valuable 'Ecosystem Services' to coastal communities; they protect shorelines, provide nursery grounds for fish and habitats for a wide range of terrestrial and aquatic species, and support coastal tourism. They also have significant cultural and social values.

Project Context

A prior study, the Abu Dhabi Blue Carbon Demonstration Project, (ADBC) quantified carbon stocks and the other services provided by coastal and marine Blue Carbon ecosystems along the coast of the Abu Dhabi Emirate, and also contributed to the improved understanding of this relatively new concept on a regional and international level (Crooks et al., 2013; Crooks et al., 2014; Campbell et al., 2014). The project enhanced local capacity to measure and monitor carbon in coastal ecosystems and to manage associated data. In addition, it identified options for the incorporation of these values into policy and management to support sustainable ecosystem use and the preservation of their services for future generations.

Building on the results of the ADBC project, the National Blue Carbon Project extended the baseline assessment of the total carbon stocks of mangroves to the Northern and Eastern Emirates. This effort included field surveys that specifically quantify the carbon of mangroves ecosystems, capacity-building for those interested in learning Blue Carbon and mangrove ecology sampling approaches, and extensive laboratory and computer analysis to determine carbon stocks in a scientifically defensible manner.

Project Field Work

Carbon stocks of existing natural intertidal ecosystems mangroves were sampled from sites that were representative of the Northern and Eastern Emirates, including both from the Sea of Oman and the Arabian Gulf. Sites were selected to represent a range of environmental settings (e.g. islands, mainland coast line, and sheltered estuaries). The sites that were selected for survey were in consultation with local environmental agencies using the following criteria: (i) sample across as much of the study area as logistically possible, (ii) sample areas where the mangrove ecosystem has a large spatial extent.

The coastal wetlands of the area are flooded by a mixture of seawater from tidal fluxes and very infrequent rain showers, groundwater, locally freshwater run-off or groundwater from mountains (as at Khor Kalba) or anthropogenic sources of freshwater (sewer and storm runoff). Sampling of this project focused on the mangrove ecosystems with the exception of one algal flat. The climate of the UAE is hot and hyperarid. Salinity levels of soils and water can be high relative to marshes and mangroves in other areas of the world, which are typically around that of open ocean seawater salinities, and uncommonly more than twice that of ocean salinity.

The investigation provided a baseline assessment of carbon stocks at 10 mangrove areas and one algal flat of the Northern and Eastern Emirates, which is perhaps home to the largest carbon stocks of the UAE.

Project Team

The Project is a collaborative initiative managed and facilitated by a partnership between the UAE Ministry of Environment and Water (MOEW) and AGEDI, implemented in collaboration with Environment Agency– Abu Dhabi (EAD) and the other local competent authorities of each Emirate including Dubai Municipality, Environment and Protected Areas Authority of Sharjah, Environment Protection and Development Authority of Ras Al Khaimah, Umm Al Quwain Municipality, and Municipality and Planning Department Ajman.

The Principle Investigators of this study are members of the International Blue Carbon Scientific Working Group: Dr. Stephen Crooks and Dr. Boone Kauffman.

International Context

The Blue Carbon concept has strengthened interest in the management and conservation of coastal marine ecosystems, supporting climate change mitigation efforts. However, there are still gaps in the understanding of Blue Carbon, and incentives and policies are needed to ensure more sustainable environmental management practices.

The experience and knowledge gained from the project will help guide other Blue Carbon projects and international efforts, such as the International Blue Carbon Initiative[1] and the Global Environment Facility's (GEF) Blue Forests Project, for which AGEDI contributed co-financing as well as serving as an intervention site. This project also has helped develop Blue Carbon science and data management through the production of tools and the testing of methodologies that can be utilised and upscaled to the international arena to enhance international Blue Carbon cooperation and training.

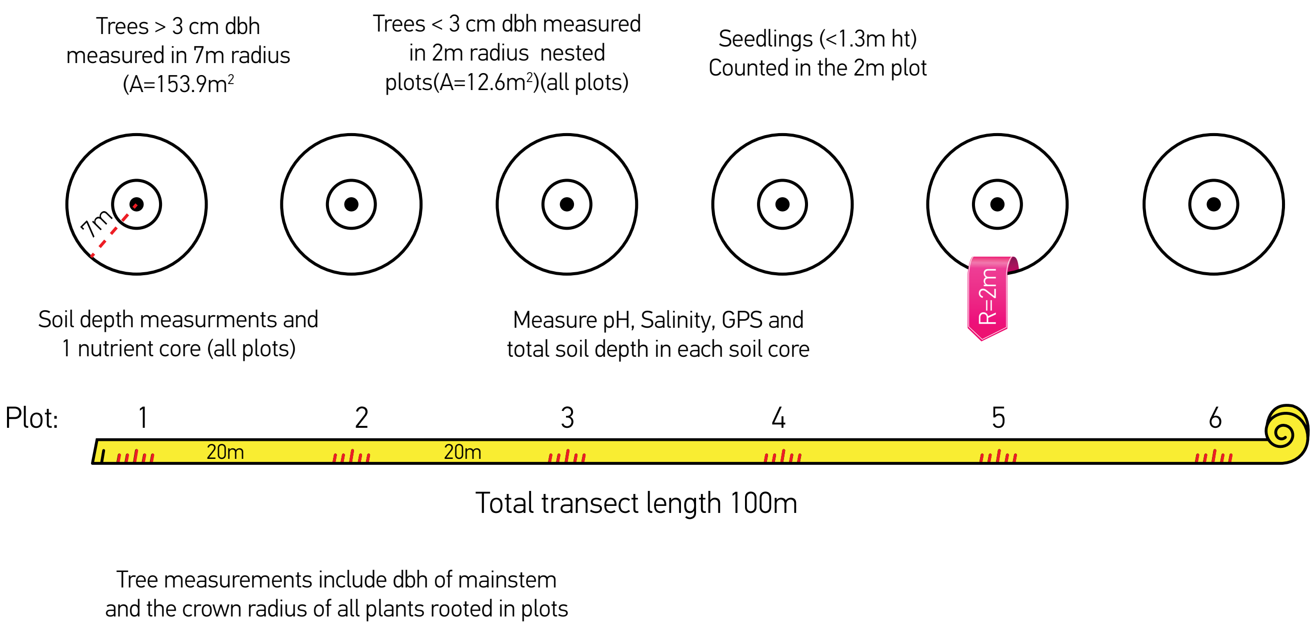
Field Sampling

The goals were to sample composition, structure, and total ecosystem carbon stocks of the mangroves of the Northern and Eastern Emirates of the UAE, including sites adjacent to both the Sea of Oman and the Arabian Gulf.

At each of the 10 selected mangroves whole-ecosystem carbon stocks were quantified following methodologies developed during the 2013 Abu Dhabi Blue Carbon Demonstration Project (Crooks, et al., 2014a,b). Methods also followed closely those described in Kauffman and Donato (2012), but modified for the unique scenarios of the UAE. At each of the 10 native mangrove sites, carbon (C) stocks were measured in six plots established 20m apart along a 100m transect. As protocols developed during the Abu Dhabi Blue Carbon Demonstration Project were followed, the data are statistically comparable to that collected in 2013. Data was collected necessary to calculate aboveground and belowground C stocks of trees and soils at each plot. In addition to carbon stocks, tree density and basal area of the mangrove stands were measured.

1 http://thebluecarboninitiative.org/

Plot layout for carbon stocks measurments of native mangrove stands in Northern and Eastern Emirates, UAE 2014



Experimental field design to determine forest structure and carbon stocks in natural mangroves of the UAE.

Results

Tree Density, Basal Area, and Biomass

While all mangroves in the UAE consist of a single plant species – Avicennia marina, there is tremendous variation in stand structure across this region. For example mangrove density ranged 3,613 trees/ha at Kalba West to 41,039/ha Khor Al Madar, Umm Al Quwain (UAQ). The stands of Kalba and Ras Al Khor were lowest in density, but were comprised of large statured mature trees. The high densities of stands at Khor Al Madar (UAQ) and Al Zorah (Ajman) are reflective of the low to medium statured stands (<3-5m in height) that were difficult to walk through. Al Rams was an open, low statured stand on an island but had very high seedling densities. In contrast the relatively open and smaller statured stands of Khor Al Jafra (UAQ) and Al Rams had the lowest basal area (<16 m^2/ha).

Closely related to basal area, is the calculation of aboveground plant mass. There was over an eight-fold difference in the aboveground biomass and carbon mass of the trees in the 10 sampled stands of the Northern and Eastern Emirates. Aboveground biomass of the mangroves ranged from 31 Mg/ha at the Khor Al Jafra (UAQ) site to 244 Mg/ha at the Kalba South site. Sites sampled with the greatest aboveground biomass included all of the Kalba sites as well as the Ras Al Khor and Ras Al Kamiah sites.

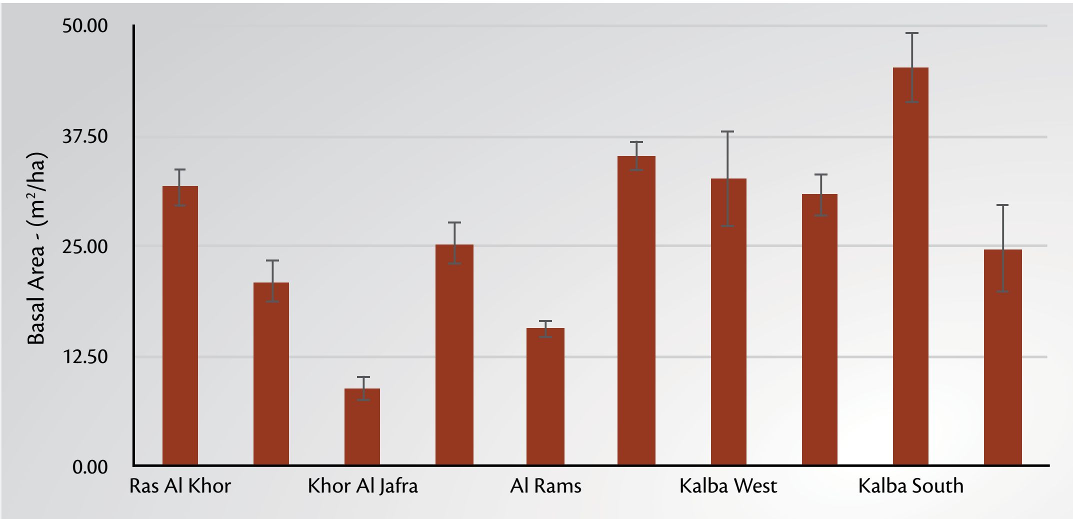
Mangrove Tree Carbon Pools

The mangrove of Ras Al Khaimah and Ras Al Khor, Dubai were also significantly large in the size of the mangrove carbon pool. The total mangrove plant carbon pool of the sampled mangrove at Ras Al Khaimah was 114 Mg/ha and at Ras Al Khor as 103 Mg/ha.

In comparing the four sampled sites of the Sea of Oman to the Arabian Gulf, it is clear that tree density of the Arabian Gulf sites were greater than those of the Sea of Oman. Mean density of the Arabian and Oman Sea sites were 22,898 Mg/ha and 7,442 Mg/ha, respectively. These are really dense forests compared to upland forests.

The Sea of Oman sites (Kalba) greatly exceeded the plant mass of the Arabian Gulf. Total mass of the Arabian and Oman Sea sites were 83 Mg/ha and 119 Mg/ha, respectively. But comparisons such as this are difficult given the wide range in variation of mangroves of the Arabian Gulf. Here, total plant carbon among sampled stands varied by over three-fold from 33 Mg/ha to 108 Mg/ha.

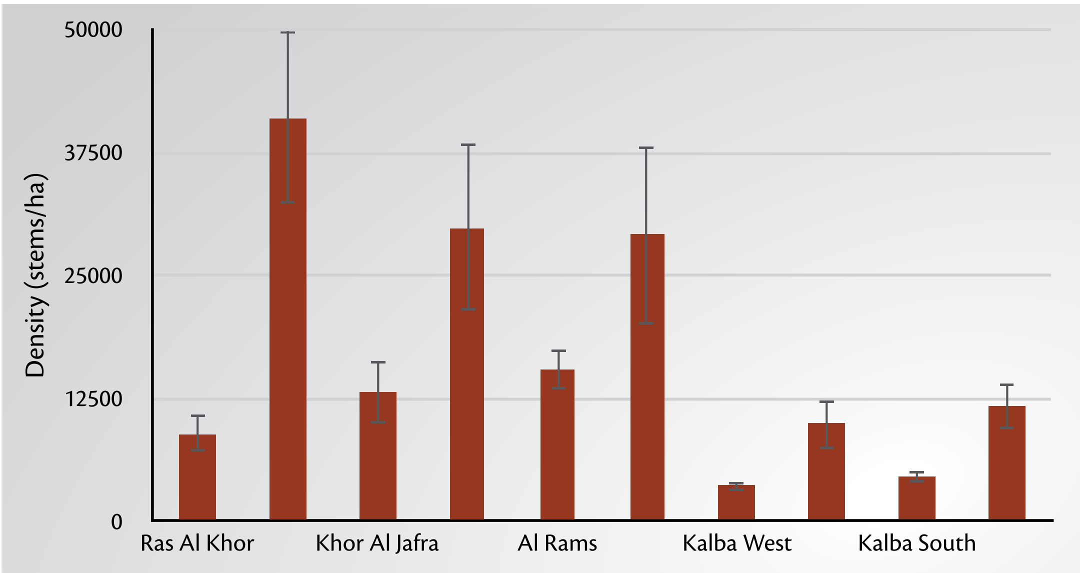
Basal Area (m^2/ha)



Note: Vertical bars represent one standard error.

Basal areas (m^2/ha) of sampled mangroves of the Northern and Eastern Emirates, UAE.

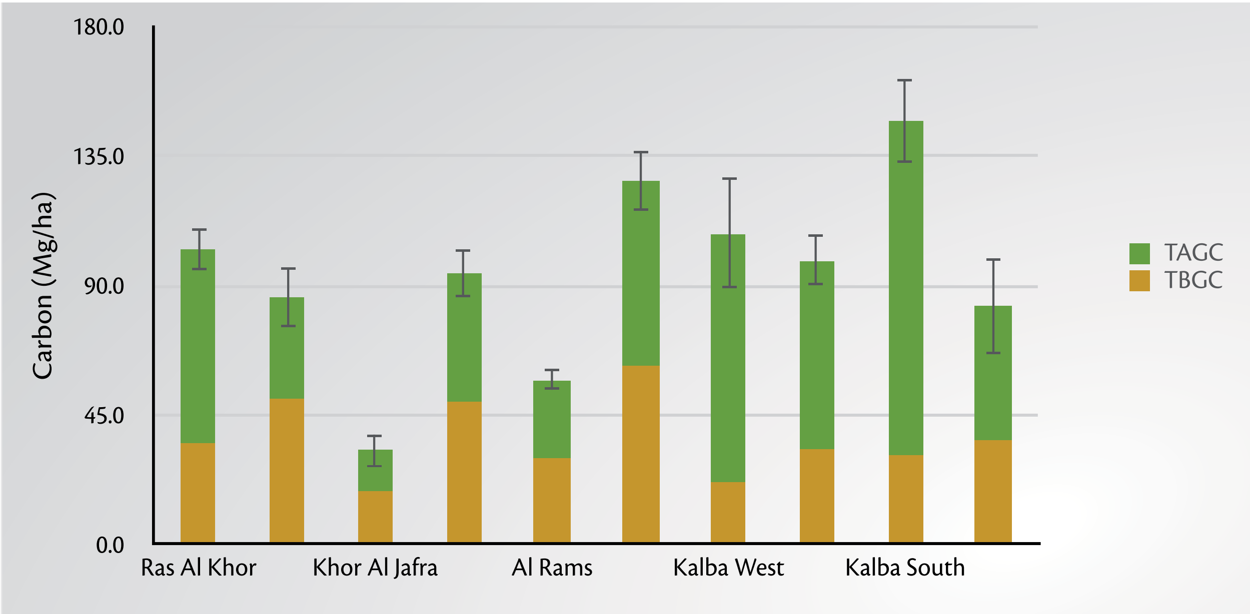
Density (numbers/ha)



Note: Vertical bars represent one standard error.

Mangrove tree density (stems/ha) of sampled mangroves of the Northern and Eastern Emirates, UAE.

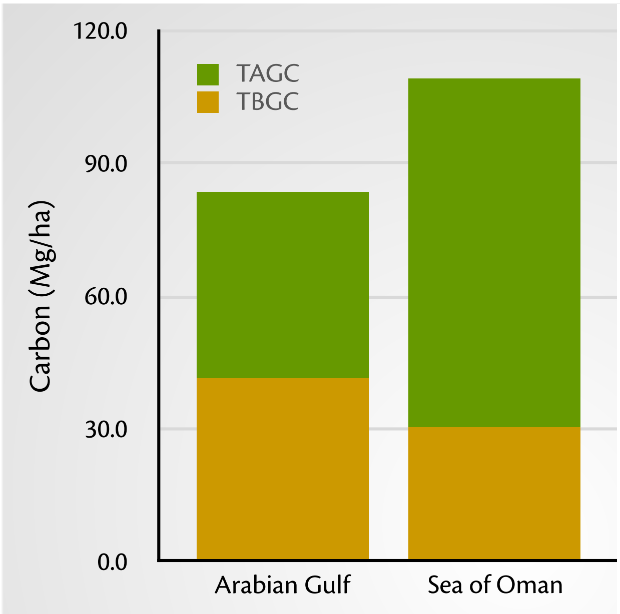
Total Plant Carbon



Note: Vertical bars represent one standard error.

Total carbon pools found in the mangrove trees (aboveground and belowground, Mg/ha) of sampled mangroves of the Northern and Eastern Emirates, UAE. The total carbon pools are broken down by Total aboveground carbon (TAGC) and total belowground carbon (TBGC).

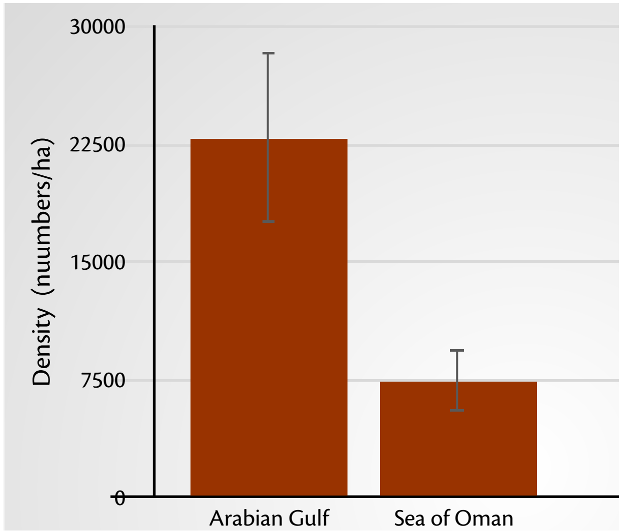
Total Plant Carbon



Note: Vertical bars represent one standard error.

Total carbon pools of mangroves of the Northern and Eastern Emirates, separated into those of the Arabian Gulf and those of the Sea of Oman.

Density



Note: Vertical bars represent one standard error.

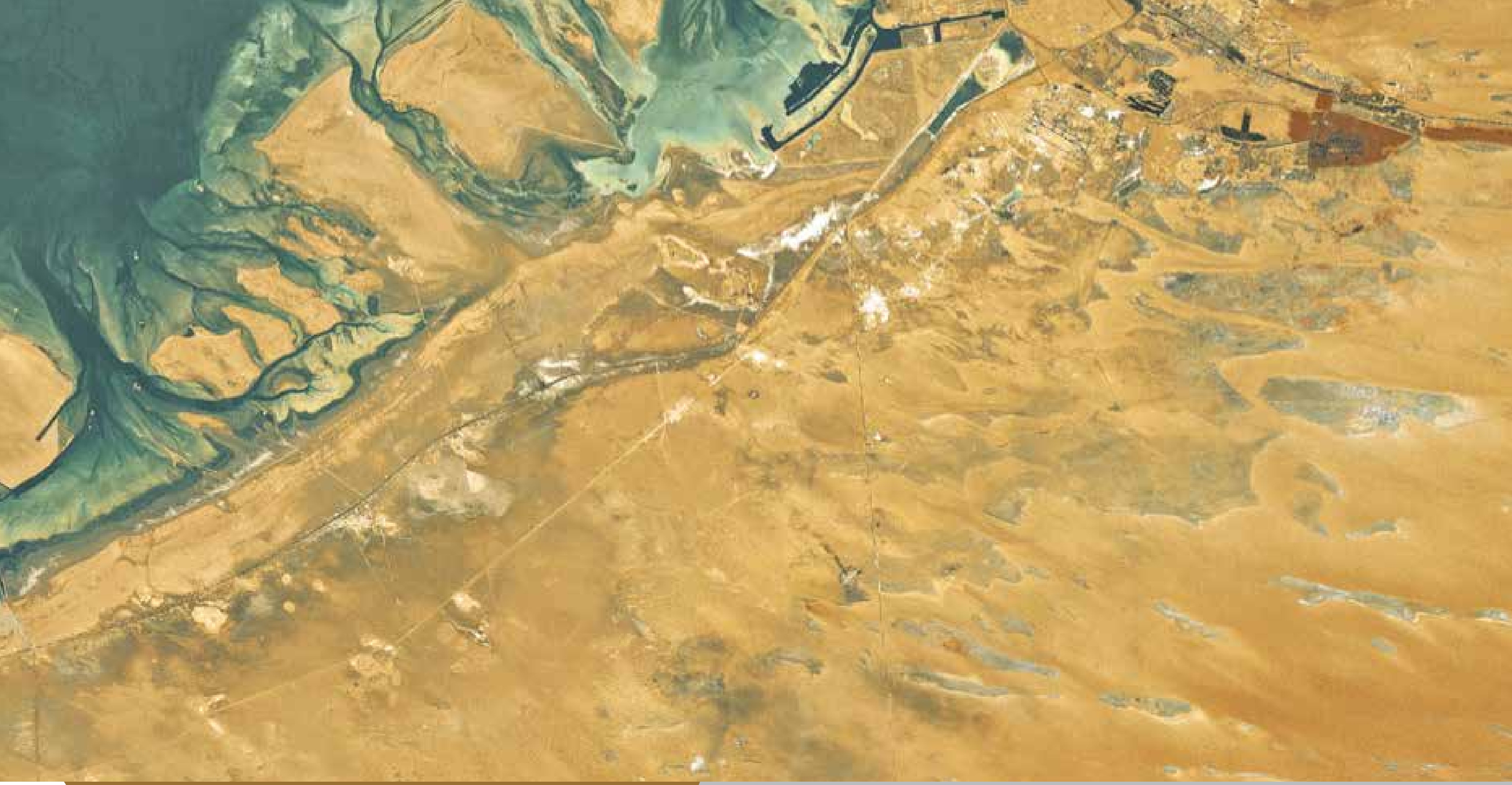
Density (numbers/ha) of mangroves of the Northern and Eastern Emirates, separated into those of the Arabian Gulf and those of the Sea of Oman.

Soil Carbon Pools

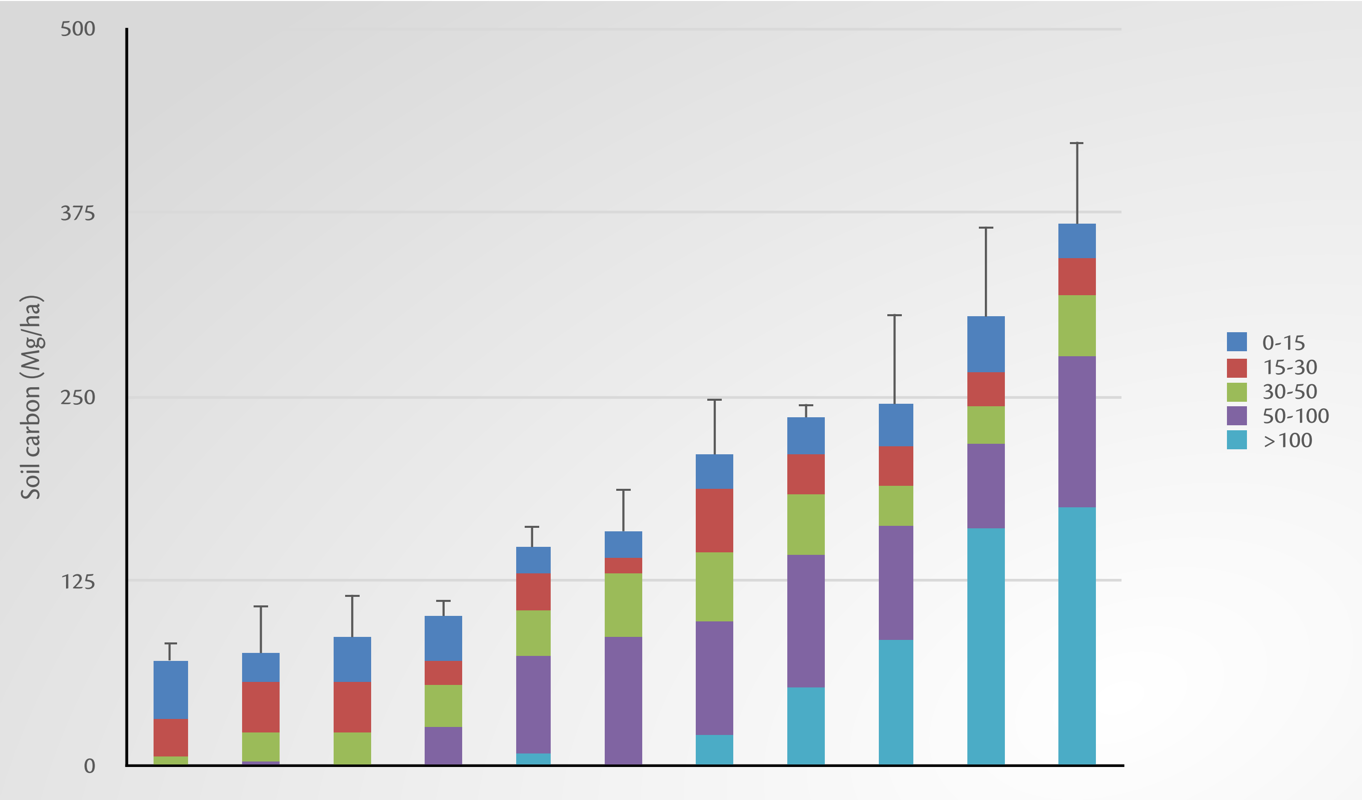
The components to measure carbon pools are organic matter concentration and soil bulk density. In general when soils are rich in organic matter or organic carbon they have a lower soil bulk density. Further, soils at the surface typically had a lower bulk density and higher organic matter concentration than soils deeper in the profile. The exception to this pattern was the Kalba sites where carbon concentration remained high throughout the soil profile. The lowest bulk densities in soils were found at the Khor Al Madar, UAQ and Ras Al Kaimah sites with mean bulk densities of 0.46 and 0.38 g/cm^3 respectively. The highest bulk densities were consistently found at the deepest depths of the soil profiles of the mangroves. For example, in those sites with soils >100cm, the mean bulk density at this depth was >1.1 to 1.5 g/cm^3.

The soil carbon concentration varied greatly among soil samples at the sampled mangrove sites. The highest mean carbon concentration was found in the surface soils of the Khor Al Madar, UAQ site where the mean carbon concentration was 8.6%. Similar high surface values were measured at Ras Al Kaimah with a mean surface concentration of 6.0%. The lowest concentrations of carbon were usually found within the deeper layers of the soil profile. For example, the carbon concentration at the lowest sampled depth at Khor Al Jafra, UAQ was 0.33% and was 0.75% at Al Zora, Ajman. This pattern was not observed at the Kalba sites. For example, the Kalba East site had a consistent and relatively high organic carbon concentration of the entire depth of the soil profile. Here organic carbon concentration was >1.6% throughout the profile depth to 160 cm. Similar results were observed at all of the Kalba sites.

There was a very broad range in soil carbon pools; the mean carbon pools of Khor Al Madar (UAQ), Khor Al Jafra (UAQ) and Al Rams (RAK) were <90 Mg C/ha while those of Ras Al Kaimah and Kalba South exceeded 300 Mg C/ha (Figure 10). The Kalba South site with relatively carbon-rich, deep soils was quite noteworthy with a mean carbon pool of 367 Mg C/ha. The Ras Al Khor site with deep soils had a soil carbon pool of 245 Mg C/ha. In these sites with large carbon pools the majority occurred in the deeper soil horizons. Among all sites there really is little difference in the carbon pools of the soils at depths of <30 cm. The largest differences in carbon stocks are largely related to soil depth and to a lesser degree soil carbon concentration. For these reasons it is important to measure soil carbon pools for the entire depths of the soil horizon.



Soil Carbon pools (mg C/ha) for the sampled mangrove sites of the Northern and Eastern Emirates, UAE.



Note: Vertical bars represent one standard error.

Total Ecosystem Carbon Stocks

The mean ecosystems carbon stock consisting of vegetation, downed wood, and soils was 293 Mg C/ha for mangroves of the Northern and Eastern Emirates.

The mean ecosystems carbon stock consisting of vegetation, downed wood, and soils was 293 Mg C/ha for mangroves of the Northern and Eastern Emirates. The wide diversity in soils, geomorphology, hydrology, and vegetation structure resulted in a very broad range of 109 Mg C/ha to 667 Mg C/ha. Soils comprised 45% to 78% of the total ecosystem carbon stocks. This is quite interesting as this suggests that the plant carbon pools comprise a greater percentage (22% to 55%) of ecosystem stocks than larger mangroves of areas such as that of the Indo-Pacific (Donato et al 2012, Kauffman et al. 2013). Downed wood in the UAE comprised a very small percentage with measurable amounts only observed at the Kalba sites.

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A highly significant relationship was found between aboveground plant carbon and total ecosystem carbon (r^2=0.88; Figure 12). This is not necessarily a common phenomenon among mangroves. For example such highly significant relationships did not exist between aboveground mangrove biomass and total ecosystem carbon stocks in either Mexico or the Dominican Republic (Kauffman et al 2014; Kauffman et al In press). For the mangroves of the Northern and Eastern Emirates, measurement of the aboveground biomass could yield good estimates of total ecosystem carbon stocks using the equation.

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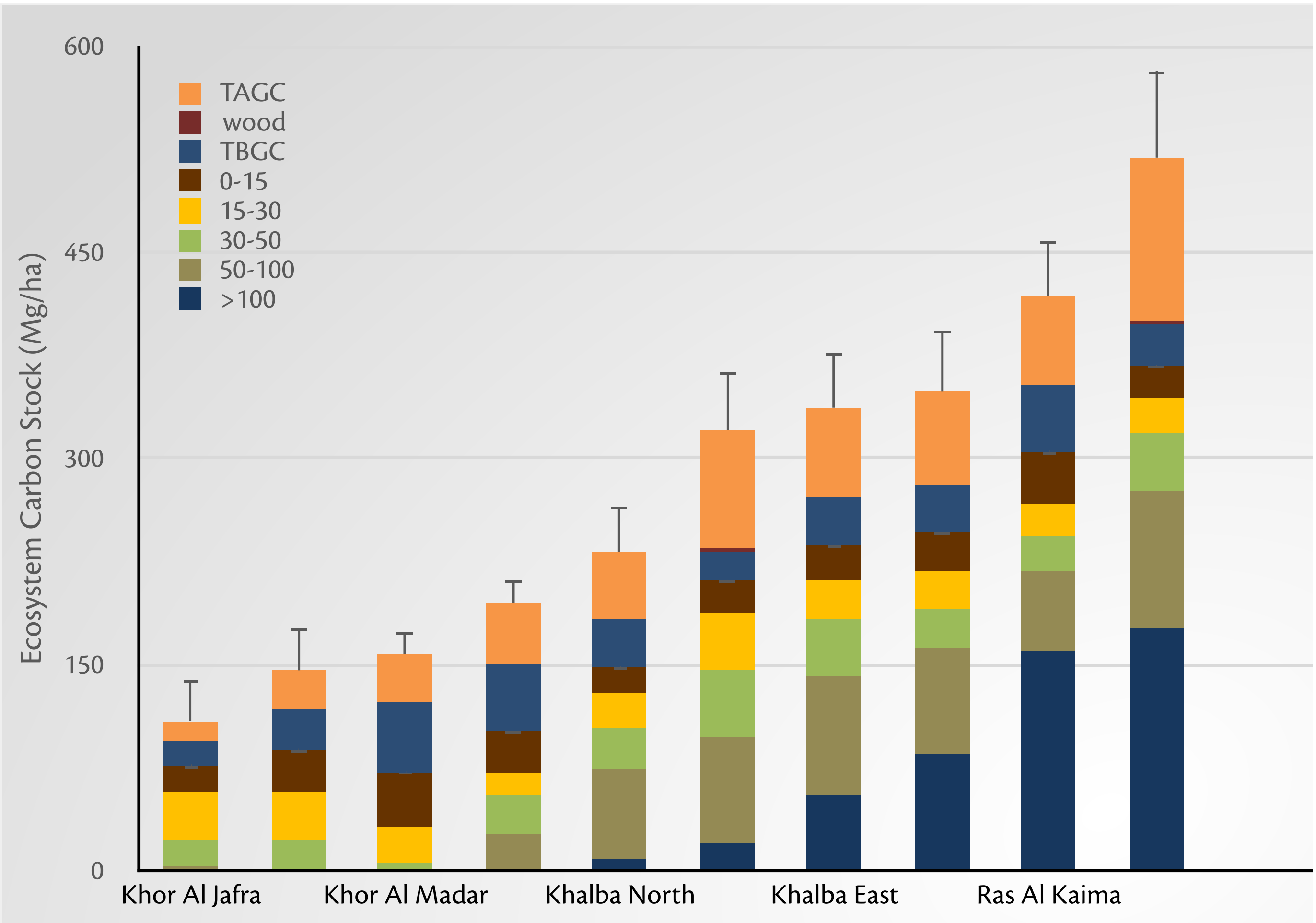
Total ecosystem carbon stocks (Mg/ha) of sampled mangroves of the Northern and Eastern Emirates, UAE.



Note: Vertical bars represent one standard error.

Discussion

The very high carbon stocks measured for Kalba South (518 Mg/ha) are similar to productive mangroves in many parts of the world (Adame et al. 2012, Kauffman et al. 2013).

As of 2015, the carbon stocks of 18 mangroves of the UAE have been quantified. This includes four in the Sea of Oman (Kalba), six in the Arabian Gulf of the Northern and Eastern Emirates, and eight in the Abu Dhabi Emirate. The data suggest that mangroves of the Northern and Eastern Emirates are generally larger than those of Abu Dhabi Emirate, but this does vary. The mean ecosystem carbon stock of the mangroves of the three areas are 389 (Sea of Oman), 229 (Northern and Eastern Emirates – Arabian Gulf), and 140 Mg C/ha, (Abu Dhabi mangroves). The mean ecosystem carbon stock of all Northern Emirate sites combined was 296 Mg C/ha. The carbon stocks of the Northern and Eastern Emirates were significantly different ($p<0.10$) than the mangroves sampled in Abu Dhabi.

The mean ecosystem carbon stock of the mangroves of the three areas are 389 (Sea of Oman), 229 (Northern and Eastern Emirates – Arabian Gulf), and 140 Mg C/ha, (Abu Dhabi mangroves)

The greatest differences among sites are in the plant carbon pools and in deeper soil layers. There were few differences in the carbon pools of soils 0-30 cm in depth. However, the plant carbon stocks of the Northern and Eastern Emirates greatly exceeded that of the Abu Dhabi mangroves (i.e. >80 Mg C/ha for the Northern and Eastern Emirates but <21 Mg C/ha for the sampled Abu Dhabi mangroves). Additional differences were found at greater soil depths. For example, the mean carbon pools of soils >50 cm in depth was 57 Mg C/ha for the Abu Dhabi mangroves but 185 Mg C/ha at the Sea of Oman sites. While there are significant site differences (i.e., some sites in Abu Dhabi do have larger carbon stocks than the Northern and Eastern Emirates and vice versa), in general the sites of the Northern and Eastern Emirates have larger carbon stocks than those of Abu Dhabi.

The greatest differences among sites are in the plant carbon pools and in deeper soil layers.

Globally, mangrove carbon stocks have been reported to be about 1000 Mg C/ha (Donato et al 2012, Alongi 2014, UNEP 2014). The carbon stocks of hyperarid/hypersaline mangroves of the UAE are at the lower end of carbon stocks. Interestingly they are similar in size to the carbon stocks of mangroves of sandy substrates such as has been reported for Madagascar. The very high carbon stocks measured for Kalba South (518 Mg/ha) are similar to productive mangroves in many parts of the world (Adame et al. 2012, Kauffman et al. 2013).

Umm Al Quwain was the only location sampled in the Northern and Eastern Emirates with an extensive algal flat area. Carbon stocks at this high intertidal algal flat were found to be low, but not insignificant. During the Abu Dhabi field campaign, relatively high carbon stocks were found in those algal flats at lower elevations relative to tides and where impaired circulation fostered hypersaline conditions (>150 psu).

It is also important to remember that these Blue Carbon ecosystems hold the largest carbon stocks found across the Arabian Peninsula. In addition to storing carbon, coastal wetlands, including algal flats, provide a source of carbon and other nutrients that support bird and nearshore food chains. It has been determined, for example, that the marine fisheries food chain in parts of arid Australian is supported by the capture of carbon by algal flat areas, which are subsequently released during storms to the marine environment (e.g. Adame et. al.2012). Such flows of carbon are likely occurring in the Arabian Gulf and Sea of Oman. Because of ecosystem services related to carbon cycling, the conservation and protection of these ecosystems is warranted.

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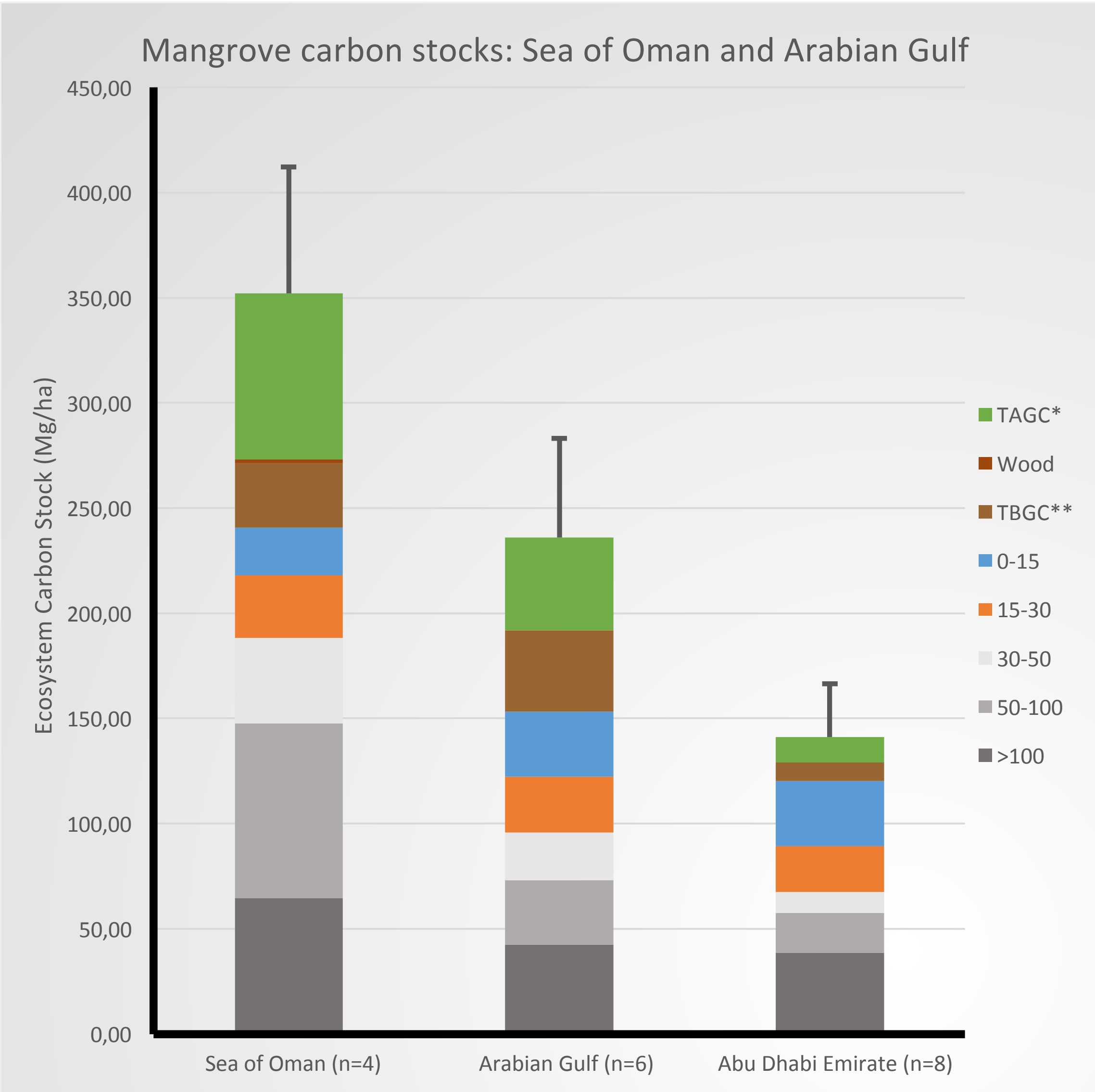


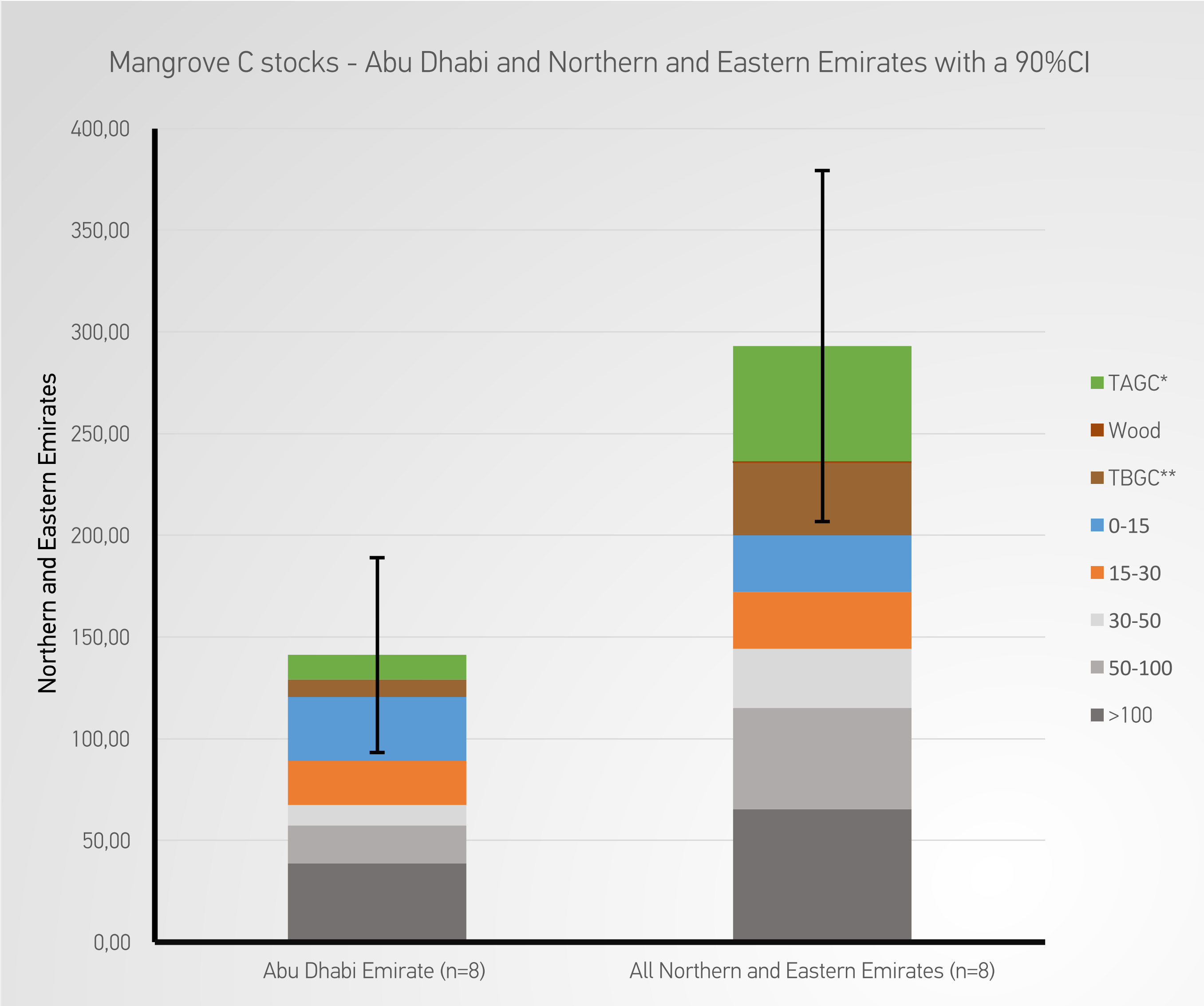
Note: Vertical bars represent one standard error.

Total ecosystem carbon stocks (Mg/ha) of sampled mangroves separated into those of the Sea of Oman, the Arabian Gulf (Northern and Eastern Emirates and those of Abu Dhabi Emirate, UAE.

The ecosystem carbon stocks (Mg/ha) of the mangroves of the UAE separated into those of the Sea of Oman (Kalba site), the Northern and Eastern Emirates on the Arabian Gulf, and those of the Abu Dhabi Emirate on the Arabian Gulf.

*TABC = Total Above Ground Carbon

**TBGC = Total Below Ground Carbon



Note: The carbon stocks are significantly different at the P<0.10 level. Vertical bars here represent the 90% confidence interval for mangroves sampled in these two regions.

Figure 1: Ecosystem Carbon stocks of the mangroves of the Abu Dhabi Emirate and the Northern and Eastern Emirates.

Moving Forward - Recommendations

It is very apparent that all the sites studied have been degraded to varying degrees, and that mangrove loss of these natural stands is ongoing; apparent degrading activities include construction, urban encroachment, land fill, pollution, trash, and hydrological disruptions.

Conservation measures to protect these high value ecosystems and restoration measures to recover degraded sites will bring benefits for the environment and for the people of the Emirates.

As such, the National Blue Carbon Project garnered the following recommendations for these crucial ecosystems:

- Environmental analyses (field and remote sensing) are needed to determine ongoing losses and predict future mangrove distribution to develop conservation/preservation plans
- All sites sampled offer a unique biodiversity providing the people of the UAE with a number of important ecosystem services. These are among the most magnificent natural ecosystems of the UAE. Conservation of these globally unique, important and valuable ecosystems is warranted
- In terms of conservation, restoration and preservation of the mangroves of the UAE, land managers and planners should consider the watershed level effects of ground and surface water disruption, influences on tidal patterns and pollution effects
- Because of the unique values and ecosystem services provided by mangroves, a moratorium on any further loss is recommended

The following observations and recommendations can be highlighted from the Project:

- In the case of unique mangrove systems that enjoy deep and highly carbon-rich soil and significant biodiversity, conservation efforts have resulted in ongoing recovery of both mangroves and other species (i.e. shellfish and fish resources) of the ecosystem ➡ Further conservation and public education opportunities are essential, as is careful consideration of any development opportunities or existing projects in surrounding areas
- For sites whose health has already been negatively impacted due to human activity ➡ Investigation into restoration opportunities is warranted
- Some at-risk sites situated close to population centres have the potential to serve as sources of both education and recreation ➡ Greater exposure is recommended to enhance public awareness about the importance and value of these ecosystems via education programmes and boardwalk accessibility
- Truly unique sites were identified, boasting rich and diverse ecologies and in close proximity to desert landscapes ➡ Such sites should be considered for high level conservation to protect their integrity

What is AGEDI?

Under the guidance and patronage of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the United Arab Emirates, the Abu Dhabi Global Environmental Data Initiative (AGEDI) was formed in 2002 to address responses to the critical need for readily accessible accurate environmental data and information for all those who need it.

With the Arab region as a priority area of focus, AGEDI facilitates access to quality environmental data that equips policy-makers with actionable, timely information to inform and guide critical decisions towards a sustainable future.

AGEDI is supported by Environment Agency - Abu Dhabi (EAD) on a local level, and supported by the United Nations Environment Programme (UNEP), regional and internationally.

FOR MORE INFORMATION

For more information or to view the full technical report, visit www.AGEDI.ae, or contact:
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