Blue Carbon Assessment

for Mangrove Systems in Seychelles

FINIS·CORONAT·OPVS

Blue Carbon Lab

DEAKIN UNIVERSITY

Disclaimer: This report has been approved by the Seychelles' Ministry of Agriculture, Climate Change and Environment (MACCE) as part of the program "Blue Carbon Assessment for Mangrove Systems in Seychelles" funded by the World Bank through the Third South West Indian Ocean Fisheries Governance and Shared Growth Project (SWIOFish3).

About Deakin's Blue Carbon Lab: Deakin University's Blue Carbon Lab offers innovative research solutions for helping to mitigate climate change and improve natural capital, while also contributing to jobs, economic growth, capacity building and community wellbeing.

Compiled and prepared by: Melissa Wartman, Micheli Costa, Maria Palacios, and Peter Macreadie from Deakin University's Blue Carbon Lab (Australia), in collaboration with Barry Nourice from BARMO Consultancy (Seychelles). Important data contributions were made by Anabelle Constance.

Citation: Wartman M*, Costa MDP*, Palacios MM, Nourice B, Macreadie PI. 2022. Blue Carbon Assessment for Mangrove Systems in Seychelles. A report submitted to Seychelles' Ministry of Agriculture, Climate Change and Environment. Deakin University, Australia. 84 pp. *Co-first authorship

Acknowledgements:

Deakin University's Blue Carbon Lab team would like to acknowledge and thank Dr Barry Nourice for his dedication to this project. Barry was instrumental in delivering the fieldwork and lab work components of this project.

The whole team would like to thank the fieldwork team including Ms. Fatima Sinon, Mr Hendrick Youpa, Ms. Jill Esparon, Mr. Jean-Pascal Charlette, Ms. Alisha Belle and Dr. Ameer Ebrahim for their support in the successful field campaigns on both the inner and outer Islands.

A special thanks to Mr. Jean-Paul Geffroy and the engineering team at Geffroy's Farm for the fabricating of the metal soil corers used in this study. We also extend our gratitude to Geffroy's Farm for the use of their cold room facilities for sample storage.

We thank the SIF team on Aldabra for their support while on the island. A special thanks go to Mr. Sebastian and Mr. Esparon who wholeheartedly guided the fieldwork team to all sampling sites on the island and assisted with data collection.

We wish to thank Mrs Monette Nourice for her support in organizing all logistics for all the trips on the inner and outer Islands and ensuring that all the work was effectively delivered.

We would like to extend a big thank you to Ms. Nathalie Meme who supported the majority of the soil sample processing and analysis.

Finally, we would like to thank the Government of Seychelles, specifically the Ministry of Agriculture, Climate Change and Environment for their kind support of this project and for the use and access of the SAA laboratory facilities for sample processing and analysis.

Funding: "Blue Carbon Assessment for Mangrove Systems in Seychelles" funded by the World Bank through the Third South West Indian Ocean Fisheries Governance and Shared Growth Project (SWIOFish3).

Table of Contents

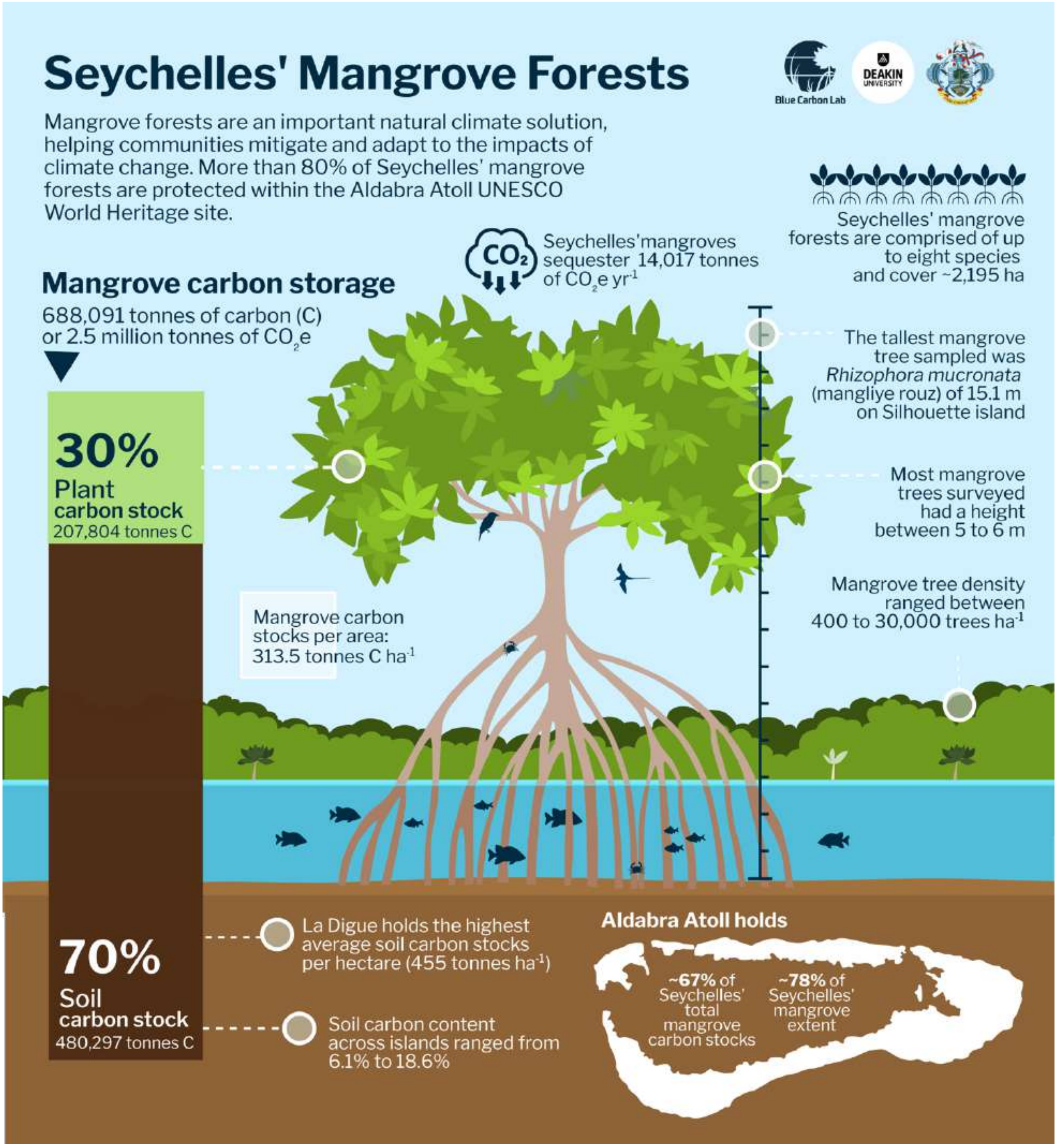
List of Figures

List of Tables

Executive Summary

Mangrove forests play an important role in climate change mitigation and adaptation, globally recognised as ‘Natural Climate Solutions’ (NCS). The protection and restoration of mangrove ecosystems are especially important to Small Island Developing States, like Seychelles, due to their vulnerability to the impacts of climate change, such as sea level rise and tropical cyclones. Therefore, it is crucial that countries like Seychelles develop baseline Information on the status of their mangrove forests to guide conservation and management actions. In this study, we conducted a fieldwork campaign to collect local scale data on plant (i.e., aboveground and belowground) and soil carbon for representative mangrove forests in the inner and outer islands of Seychelles. Furthermore, we used this data to develop, for the first time, a blue carbon assessment for Seychelles’ mangrove ecosystems. Seychelles' mangrove forests extend throughout 2,195 ha across the inner and outer islands, with Aldabra alone being home to ~80% of this total. Despite the limited distribution of mangroves within the country, these ecosystems are storing 2.5 million tonnes CO_2e (or 688,091 tonnes of organic carbon). Furthermore, we estimated that mangroves in Seychelles store an average of 313.48 tonnes of carbon per hectare, with 70% of their total carbon stocks stored in their soils. Due to its larger extent, Aldabra holds the highest total carbon stocks, accounting for 67% of Seychelles’ mangrove stocks. Seychelles protects ~84% of its current mangrove extent including the Aldabra Atoll, a UNESCO World Heritage and Ramsar site, and Port Launay, a Ramsar site. The current extent of total mangrove forests across Seychelles is sequestering an additional 14,017 tonnes of CO_2e annually, equivalent to ~3% of Seychelle's annual CO_2 emissions. The outcomes of this study demonstrate the important climate mitigation potential of Seychelle’s mangrove forests and the important role they play in supporting Seychelles to achieve its Nationally Determined Contributions commitments.

Graphical Abstract



Glossary and Acronyms

Term	Acronym	Definition
Aboveground biomass	AGB	Biomass contained within the plant's living leaves, branches, stems or aerial shoots. Values usually reported in ton DW ha^{-1} for mangroves and g DW m^2 for seagrasses.
Aboveground carbon	AGC	Organic carbon stored within the plant's AGB. Values reported in ton C ha^{-1}.
Allometric equations/models	-	Models for mangrove species are usually based on tree height, diameter at breast height (DBH). Equations can be species- or site-specific.
Belowground biomass	BGB	Biomass contained within the plant's living roots and rhizomes. May include necromass (litter or any detrital materials). Values usually reported in ton DW ha^{-1} for mangroves and g DW m^2 for seagrasses.
Belowground carbon	BGC	Organic carbon stored within plant's BGB. Values reported in ton C ha^{-1}.
Blue Carbon	-	Carbon captured and stored by marine and coastal ecosystems.
Carbon dioxide equivalent	CO_2e	Unit of measurement used to standardise the climate effects of various greenhouse gases. The conversion factor 3.67 is used for organic carbon, which represents the molecular weight ratio between CO_2 and C.
Carbon:Nitrogen Elemental analyser	CN analyser	A lab instrument used to measure carbon and nitrogen elemental concentrations in a given sample (such as soil)
Diameter at breast height	DBH	Forestry measure in which the diameter of the tree trunk is recorded at 137 cm from the ground. Values reported in cm and often used in allometric equations.
Greenhouse gases	GHG	Gases that absorb and emit radiant energy within the thermal infrared range, which can cause the greenhouse effect [e.g., carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)]
Ministry of Agriculture, Climate Change and Environment	MACCE	The Seychelles' MACCE is dedicated to enforcing environmental legislation, as well as developing, implementing and monitoring various environmental policies.

Nationally Determined Contributions	NDCs	Emission reductions commitments that countries need to submit to the United Nations Framework Convention on Climate Change (UNFCCC) under the Paris Agreement.
National Greenhouse Gas Inventory	NGGI	The NGGI Is an Inventory submitted to the United Nations In accordance with the Framework Convention on Climate Change. The gases Included in the Inventory are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride.
Seychelles' Marine Spatial Plan	SMSP	Seychelles' Marine Spatial Plan; with further information available at https://seymsp.com/.
Seychelles Agricultural Agency Soil and Plant Diagnostic Laboratory	SAA Lab	Laboratory used to process the samples taken during this project.
Soil organic carbon	SOC	Organic carbon stored within the soil/sediment. Values reported in ton C ha^{-1}. SOC is usually reported down to a specific depth (e.g., 100 cm depth).
Soil organic matter	SOM	Organic matter is any living or dead animal and plant material.
Standard Error	SE	Standard deviation of its sampling distribution or an estimate of that standard deviation
Third South West Indian Ocean Fisheries Governance and Shared Growth Project	SWIOFish3	This work was funded by the World Bank through the Third South West Indian Ocean Fisheries Governance and Shared Growth Project. SWIOFish is a long-term regional program of the World Bank that aims to increase the economic, social and environmental benefits for the countries of the South West Indian Ocean from sustainable marine fisheries

Introduction

Introduction

Tropical mangrove forests are an important natural climate solution. They help communities mitigate carbon emissions and adapt to the impacts of climate change.

Mangrove forests for climate mitigation and adaptation

Mangroves are extraordinary coastal forests located in the tropics and subtropics. They have special adaptations to thrive in tidal environments (saline or brackish) where they provide a multitude of ecosystem services helping us mitigate and adapt to the impacts of climate change (Atwood et al. 2017, Himes-Cornell et al. 2018b, 2018a, Friess et al. 2020). Globally, mangroves have been declining rapidly over the last century, mainly due to the increase of anthropogenic pressures (e.g., overexploitation, land-use change, pollution) (Duarte et al. 2020, Goldberg et al. 2020). However, in recent years, blue carbon ecosystems such as mangroves, have started to gain international attention due to their ability to help adapt and mitigate climate change (Mcleod et al. 2011, Duarte et al. 2013, Macreadie et al. 2021).

Recognised as one of the world's most effective carbon sinks, mangrove forests are capable of capturing and storing large amounts of carbon in the soils over millenary timescales. In contrast to terrestrial ecosystems, mangrove forests have complex root structures, high sedimentation rates, waterlogged conditions, and anoxic soils that can result in up to 40-times faster carbon sequestration rates and thousand times slower carbon decomposition rates (Mcleod et al. 2011, Atwood et al. 2017). A single hectare of mangrove forest can store on average 386 tonnes of carbon (IPCC 2014) and potentially sequester annually an additional 1.74 tonnes per hectare (Alongi 2014). By sequestering and locking important amounts of carbon in the soil for long-time scales, mangrove forests help reduce carbon emissions driving climate change.

In addition, mangrove forests can help local communities adapt to the impacts of climate change. With their complex root system, mangroves prevent soil erosion and protect the coastline against extreme weather events and sea level rise (Arkema et al. 2013, 2015). They also sustain wildlife biodiversity by providing habitat, nursery grounds and food to thousands of species and enhance local livelihoods, revenues and food security by boosting fisheries stocks and providing eco-tourism opportunities (Barbier et al. 2011, Himes-Cornell et al. 2018b, 2018a, Friess et al. 2020).

Mangroves in Seychelles

Seychelles' mangrove forests are comprised of up to eight species and cover approximately 2,195 ha (Walton et al. 2019, Smith et al. 2020, Constance et al. 2021). Although almost 80% of the mangroves are located in the Aldabra Atoll (1,720 ha; Walton et al. 2019), important mangrove stands are also present across the Seychelles including in Cosmoledo Atoll and Mahé's Port Launay.

Most of Seychelles' mangroves are governed and protected through international treaties to which Seychelles is a party (mainly the Ramsar Convention via the Ramsar sites Aldabra Atoll and Port Launay) and national legislation such as the Environmental Protection Act 2016 and the Physical Planning Act 2021. Seychelles lacks specific policies and plans pertaining to mangrove ecosystems. However, under the blanket definition of 'Wetlands' they are increasingly being incorporated into national documents (e.g., Seychelles Wetland Policy and Action Plan 2019- 2022). Seychelles' updated NDC (GoS 2021) explicitly aims to safeguard the carbon sink capacity of mangrove forests as a strategy for climate change mitigation and adaptation.

A recent literature review exploring Seychelles' mangrove literature (Palacios et al. 2021a), revealed that most of Seychelles' mangrove studies qualitatively describe the forest structure and composition (Macnae et al. 1971, Henriette 2015), but rarely include quantitative datasets of the plant carbon pool (e.g., via forestry measures such as tree DBH and height; see Constance 2016 for an exception) or the soil carbon pool (e.g., SOM%, SOC%; see exceptions in Nourice (2015b, 2015a, 2016) and Constance (2022). It is also noted that, little research has been published or peer-reviewed.

Baseline information on the status of mangrove forests is essential for conservation, management, and restoration. The objective of this study was to conduct a field campaign to collect local scale data on plant (aboveground and belowground) and soil carbon for representative mangrove forests in the inner and outer islands of Seychelles. Furthermore, we used this data to develop for the first time a blue carbon assessment for mangrove ecosystems in Seychelles.

Methods

Methods

Experimental design & sampling sites

Mangrove carbon stocks were surveyed at 27 different sites across Seychelles (**Table 1** and **Figure 1**). Twenty of the sites were located within the inner granitic islands (Mahé, Praslin, La Digue, Curieuse and Silhouette), while the 7 remaining sites were in the outer islands of Aldabra Atoll and Cosmoledo Atoll. The sampling locations were selected based on the existing knowledge of mangrove distribution in Seychelles (**Figure 1**). From the original sites selected for the field campaign, two sites (i.e., Baie Lazar and North Island) were not sampled due to mangrove forests not being present. Therefore, we included additional sites in Anse a La Mouche, Grand Anse, and La Digue.

At each mangrove site, transects not exceeding 100 m were set up running from the seaward edge towards the landward edge of the mangrove forest. Sampling plots were established at the 10 m and 40 m intervals along each transect. The length of the transect was determined by the size of the mangrove forest and accessibility, with one-third of the sampling plots located at 'high' elevation, one-third at 'mid' elevation, and one-third at 'low' elevation, to reduce spatial heterogeneity within each site (Howard et al. 2014). Most of the sampling effort (number of plots sampled and soil cores collected) was directed in Aldabra Atoll (**Table 1**), where almost 80% of Seychelles mangrove forests are located. At each plot, we surveyed mangrove trees and collected soil cores to estimate plant and soil carbon stocks (details in sections below). We additionally recorded GPS coordinates, took ground elevation using a total station (Topcon, Model GTS1002; Liyan et al. 2018), and noted a qualitative description of the site.

*Table 1: Sampling design for mangrove forests in Seychelles. The mangrove cover for each island is displayed in parenthesis and estimated according to Walton et al. (2019) and Smith et al. (2020). *Sites that included replicated cores.*

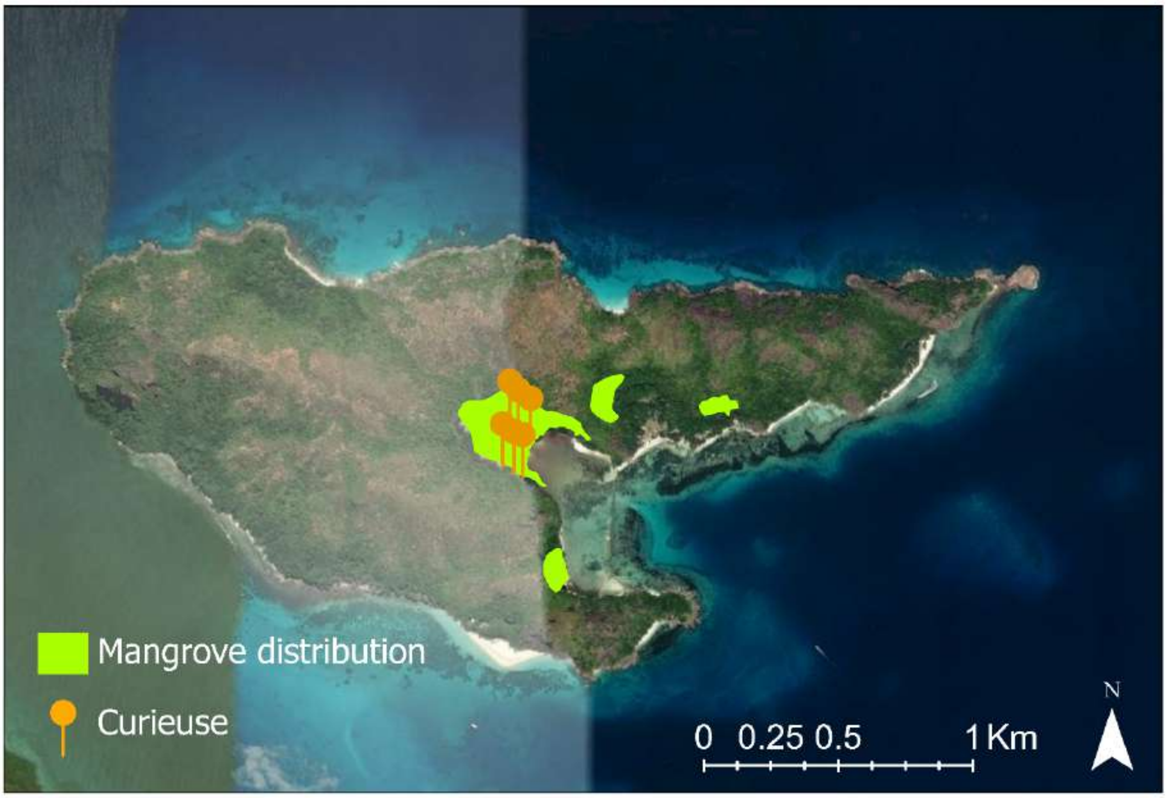
Sites	Name	GPS coordinates (UTM)		Plant carbon stocks [N]	Soil carbon stocks [N]
		Lat (Northing)	Long (Easting)		
Inner Islands (2.97 km²)					
Mahé (1.81 km²)					
1	Port Launay	9485294.50 9485271.72	323211.48 323086.77	2	2
2	Anse La Moushe	9476517.70 9476561.93 9476584.40 9476615.07	332735.31 332762.38 332791.55 332809.03	4	4
3	Avani	9482290.41 9482266.50 9482237.10	328586.04 328636.97 328681.36	3	3
4	Cap Ternay	9486273.81 9486292.13 9486320.35 9486487.56	320848.88 320843.31 320839.34 320849.63	4	4
5	Ephelia Port Glaud	9485110.02 9484847.23 9484883.58 9484902.94	323455.77 322862.42 322936.90 322965.76	4	4
6	Anse Boileau	9479912.56 9479927.16 9479934.42	330958.60 330932.26 330893.74	3	3
7	Anse Royale	9475649.18 9475764.24 9475729.95	335406.65 335323.54 335232.67	3	3
8	Grand Anse	9482686.79 9482721.17 9482772.02	328103.27 328070.50 328016.07	3	3
9	Point Larue	9482989.47 9482969.21 9482920.99	335853.66 335895.24 335935.58	3	3
10	Providence	9485730.31 9485719.46 9485719.46	331441.64 331421.58 331401.64	3	3
11	Petit Barbaron	9479764.46 9479793.26 9479803.87	330565.70 330561.05 330500.07	3	3
			Sub-total	35	35
Praslin (0.68 km²)					
12	Anse Gouvernman	9522275.70 9522244.51 9522208.99	362571.75 362541.85 362519.52	3	3
13	Cap Samy	9521078.46 9521086.26	362193.16 362168.48	3	3

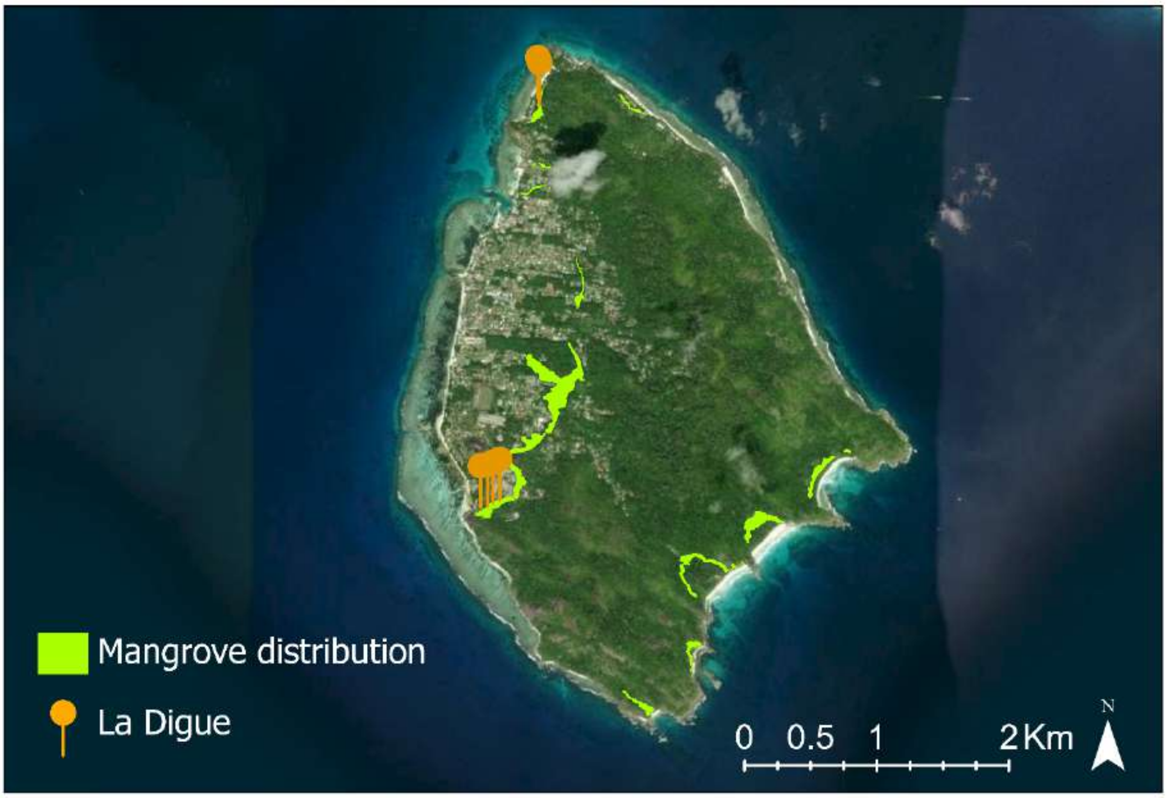
		9521089.07	362133.42		
14	Consolation	9519086.65 9519109.26 9519111.40	359911.50 359867.58 359820.41	3	3
	Grand Anse	9520617.55 9520642.16 9520685.61	358254.81 358278.37 358240.66	3	3
La Digue (0.23 km^2)					
16	Anse Severe	9520074.96 9520114.42	370309.34 370297.45	2	2
17	Anse Source D'argent	9517021.05 9517030.36 9517051.78 9517073.05	369862.42 369918.31 369958.90 370007.77	4	4
Curieuse Island (0.11 km^2)					
18		9526232.66 9526243.94 9526273.20 9526367.96 9526399.00 9526430.93	358778.49 358745.52 358703.65 358807.78 358761.47 358730.61	6	6
Silhouette Island (0.33 km^2)					
19	Anse Lascare	9503007.67 9502995.19 9502975.22	305902.22 305887.15 305872.55	3	3
20	Grand Barbe	9502102.48 9502145.34	303040.91 303053.80	2	2
			Sub-total	29	29
Outer Islands (18.36 km^2)					
Cosmoledo (1.36 km^2)					
21		8924095.08 8924070.00 8924106.06 8924120.96 8924183.75 8924198.85 8924217.76 8924226.24 8924210.08 8925995.74 8926037.55 8926090.91 8926126.62 8925858.85 8925848.00 8925836.57 8925839.40	775267.41 775218.41 775165.88 775111.77 775078.42 775116.36 775154.50 775196.71 775247.98 776507.72 776538.68 776612.03 776633.71 776624.97 776580.83 776536.67 776490.92	17	22*
Aldabra (17 km^2)					
22	Cinq Cases	8957969.47 8957969.85 8957953.95 8957959.13 8957976.36	663639.59 663627.29 663646.88 663418.15 663423.82	18	36*

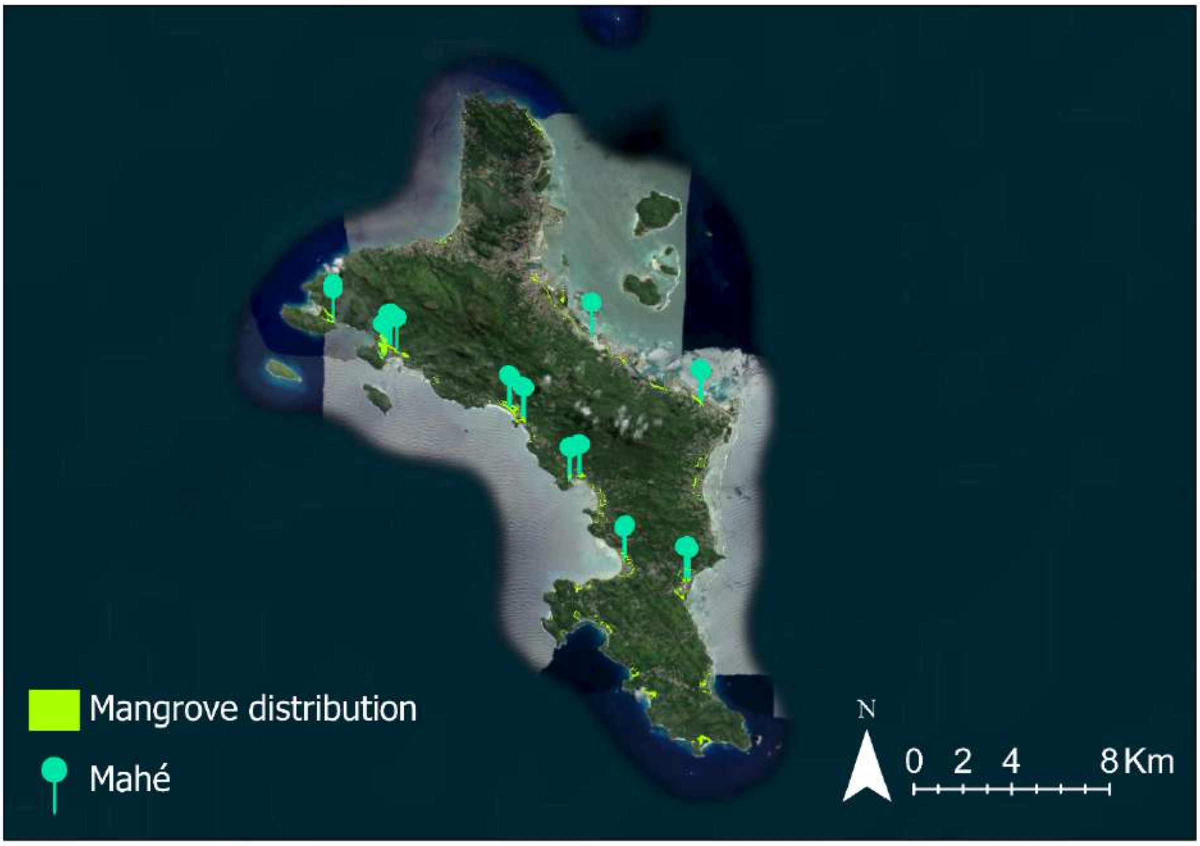
		8957931.98 8957884.03 8957893.75 8957898.09 8958339.03 8958359.00 8958317.35 8958168.39 8958182.32 8958178.21 8958168.80 8958155.41 8958140.84	663408.26 663236.96 663239.74 663259.09 663314.56 663327.16 663316.55 663286.05 663288.41 663266.10 663449.35 663477.63 663496.13		
23	Malabar	8962967.24 8963012.03 8963041.30 8963082.62 8963159.43 8963127.42	657673.17 657674.10 657674.23 657708.42 657747.97 657734.97	6	12*
24	Picard	8960845.00 8960836.00 8960949.22 8960938.13 8960963.22 8960869.12 8960872.35 8960894.39 8961757.08 8961766.86 8961730.39 8962193.04 8962240.90 8962227.29	633925.00 633914.00 633606.51 633611.55 633591.90 634410.13 634440.89 634444.44 633959.07 633945.16 633969.30 634582.94 634622.97 634591.73	14	28*
25	Picard (Bra Monsier Clement)	8960857.00	633938.00	1	1*
26	Picard (Jelly Fish Pond)	8961072.94 8961089.53 8961052.46 8961315.22 8961303.46 8961353.22	632944.61 632945.91 632904.78 633134.83 633139.16 633133.91	6	12*
27	Picard (La Gigi)	8960562.47 8960567.06 8960552.08 8960793.36 8960818.55 8960843.61	633194.71 633184.36 633165.78 633218.19 633206.21 633229.99	6	12*
			Sub-total	68	123
			Total	132	187


Mangrove distribution
Aldabra
N
0 2 4 8 Km


Mangrove distribution
Cosmoledo
N
0 1 2 4 Km


Mangrove distribution
Curieuse
0 0.25 0.5 1 Km
N


Mangrove distribution
La Digue
0 0.5 1 2 Km
N


Mangrove distribution
Mahé
N
0 2 4 8 Km

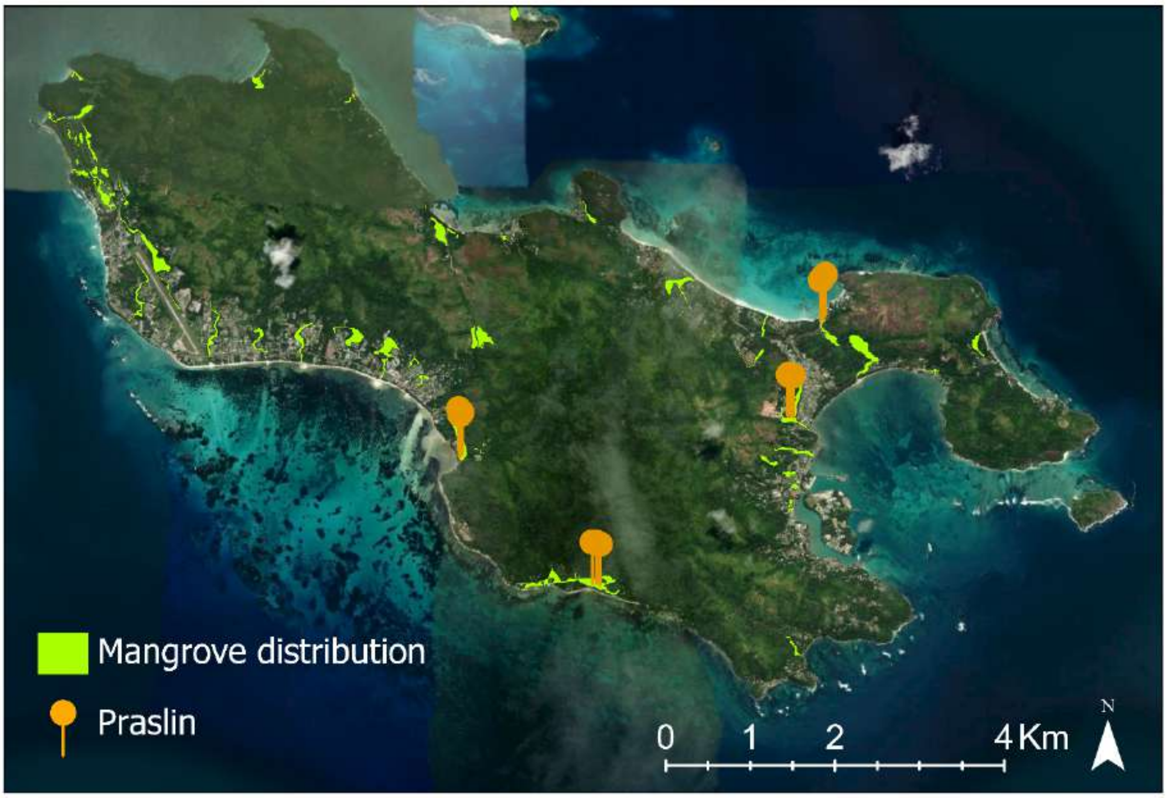

Mangrove distribution
Praslin
0 1 2 4 Km
N

Figure 1: Map showing the distribution of mangrove forests in Seychelles (Sources: mangrove distribution layer: Smith et al. 2020; mangrove distribution layer in Aldabra: Walton et al. 2019) and the mangrove sampling locations in different islands included in the field campaign.

Mangrove surveys

Mangrove forest characteristics were sampled at each site. Depending on the tree density at each site, the plot size (4 m^2 – 25 m^2) was adjusted to facilitate sampling. Following the international standards for blue carbon sampling (Kauffman and Donato 2012, Howard et al. 2014) and previous mangrove studies in the SWIO (Sitoe et al. 2014, Jones et al. 2015), the following measures were collected on each plot:

- Adult mangrove trees (> 1.3 m height) were identified to species level and counted. For each tree, we took morphometric measures such as total height using an extendable ruler (**Figure 2**) and total station (Topcon, Model GTS1002; Liyan et al., 2018) to measure plant height above 5 m (**Figure 2**), canopy width (two perpendicular measures), and stem diameter at 1.37 cm height (DBH; diameter at breast height).

- Standing dead mangrove trees and stumps were counted and categorised according to their degradation level. Following Kauffman and Donato (2012) and Howard et al. (2014), Status 1 refers to trees recently dead that have lost most of their leaves. Status 2 refers to trees that have lost all small branches and twigs. 3) Decay status 3 applies to standing 'snags', where most branches have been lost and only the main stem remains.

- Mangrove seedlings and saplings, classified as individuals less than 1.3 m in height, were counted across the whole plot, but not identified to species level due to the complexity of their species-specific identification.

- For most of the mangrove forest characteristics surveys on Aldabra Atoll, we used data collected from recent studies (Constance 2016, Constance et al. 2022) instead of resampling. In addition, the field team sampled 6 additional plots (ALDA_T46, ALDA_T47, ALDA_T48, ALDA_T49, ALDA_T50, and ALDA_T51) located in Malabar that had not been previously surveyed.

UAV Surveys

An unmanned aerial vehicle (UAV, DJI Mavic 2) was used to collect imagery of most mangrove sites included in this study. The UAV was set up at 56 m of flight altitude, with 80% of both front and side image overlay to obtain sufficient data for image processing. Aerial photos taken by the UAV during the flight used settings arranged with Pix4d enterprise. Furthermore, all aerial photographs were processed to create an orthophoto.

The images taken by the UAV were not used or processed as part of this study but have been included in the Submission Package to MACCE to support future analysis of Seychelles' mangroves.

Plant biomass and carbon stocks

Field measurements collected for mangrove trees (i.e., tree height, DBH) were used within species-specific allometric equations (Table 2

) to estimate the above- and belowground biomass per mangrove tree (Kg DW ha^{-1}).

At each sampling plot, the mangrove tree biomass per area (tonnes DW ha^{-1}) was estimated by summing the values of all mangroves within the plot and adjusting by plot size. Then, values for above- and belowground biomass were transformed to carbon (tonnes C ha^{-1}) using the conversion factors of 0.47 and 0.39, for above- and belowground, respectively (Kauffman and Donato 2012).

Figure 2: Measurement of mangrove tree biomass in Seychelles' mangrove forest.

Table 2: Species-specific allometric equations and parameters used to estimate above- and belowground mangrove biomass. Sources for each parameter are provided in the following order: aboveground (AGB), belowground (BGB) and wood density. Wood density is shown only for the species that the parameter has been required in the allometric equations. DBH= diameter at breast height; WD= wood density; H= tree height.

Mangrove Species	AGB allometric equation (Kg DW)	BGB allometric equation (Kg DW)	Wood density	Source
Avicennia marina	$0.25128*DBH^{2.24351}$	$1.42040*DBH^{1.44260}$	n/a	(Njana et al. 2016)
Bruguiera gymnorhiza	$0.186*DBH^{2.31}$	$0.199*(WD^{0.899}) * (DBH^{2.22})$	0.84	(Clough and Scott 1989, Komiyama et al. 2005, Gillerot et al. 2018)
Ceriops tagal	$0.189*DBH^{2.34}$	$0.199*(WD^{0.899}) * (DBH^{2.22})$	0.85	(Clough and Scott 1989, Komiyama et al. 2005, Gillerot et al. 2018)
Lumnitzera racemosa	$0.0214*(DBH^{2H})^{1.05655*WD}$	$0.199*(WD^{0.899}) * (DBH^{2.22})$	0.82	(Komiyama et al. 2005, Chave et al. 2005, Gillerot et al. 2018)
Rhizophora mucronata	$0.25128*DBH^{2.26026}$	$1.42040*DBH^{1.68979}$	n/a	(Njana et al. 2016)
Sonneratia alba	$0.19633*DBH^{2.04113}*H^{0.29654}$	$1.42040*DBH^{1.59666}$	n/a	(Njana et al. 2016)
unknown	$0.251*WD*DBH^{2.46}$	$0.199*(WD^{0.899}) * (DBH^{2.22})$	0.71	(Komiyama et al. 2005, Kauffman and Donato 2012)

Soil sampling

At each sampling plot, one sediment core (6 cm in diameter and up to a depth of 1 m) was collected with a hollow stainless-steel core that was locally fabricated by Geffroy's Farm under the guidance of the project consultant Dr Barry Nourice. The core was developed based on the PVC core model commonly used for soil sampling and modified to a marine grade stainless-steel device with 42 mm diameter holes in a linear orientation at 10 cm intervals (**Figure 3**). The core was manually pushed into the ground by hammering the top of the core using a rubber mallet. The core had a sharpened edge to help minimize core compaction. To account for soil compaction, compaction in and compaction out (**Figure 4**) were recorded once the core was hammered to the maximum depth possible.

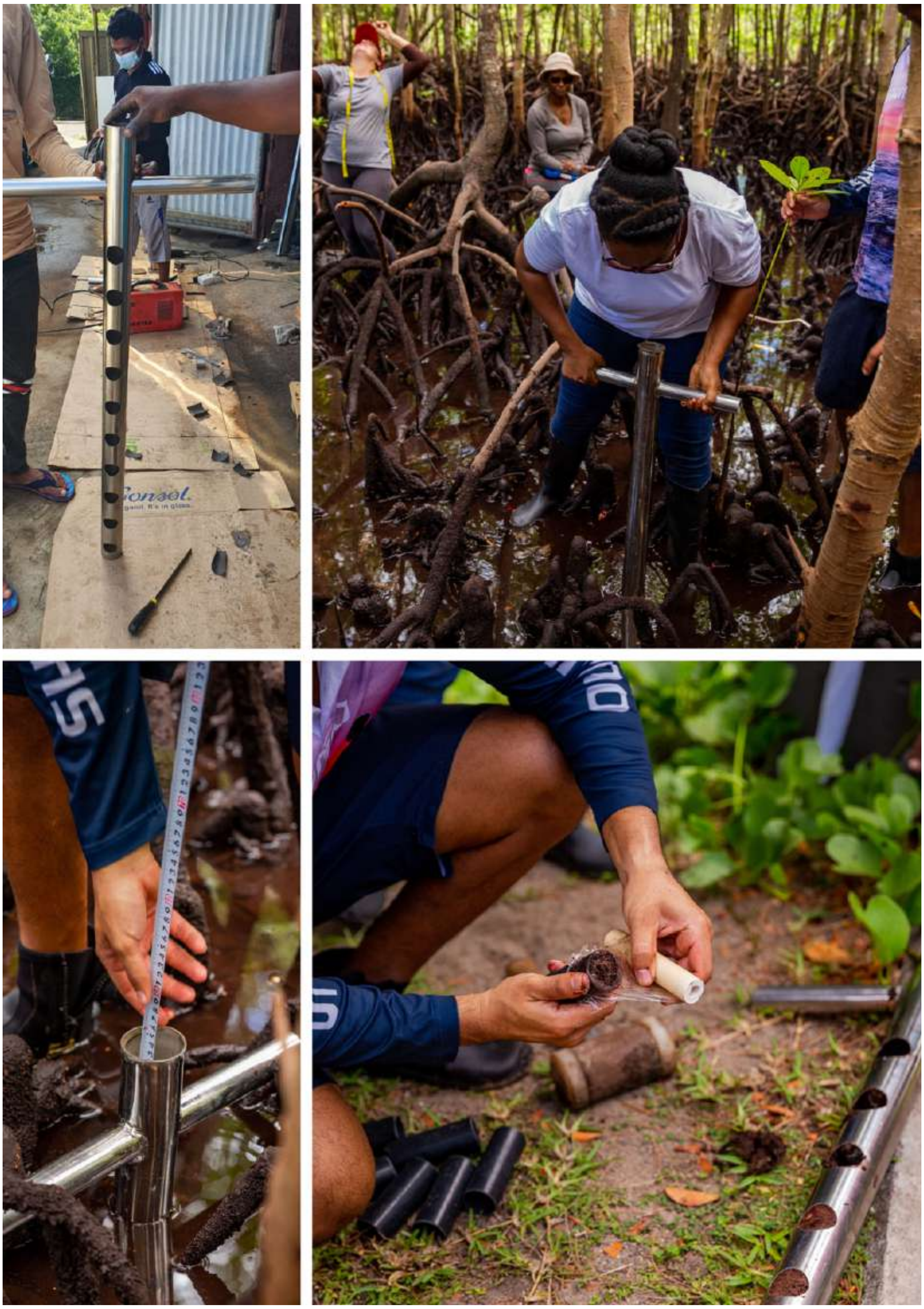


Figure 3: Collection of soil cores in Seychelles' mangrove forests.

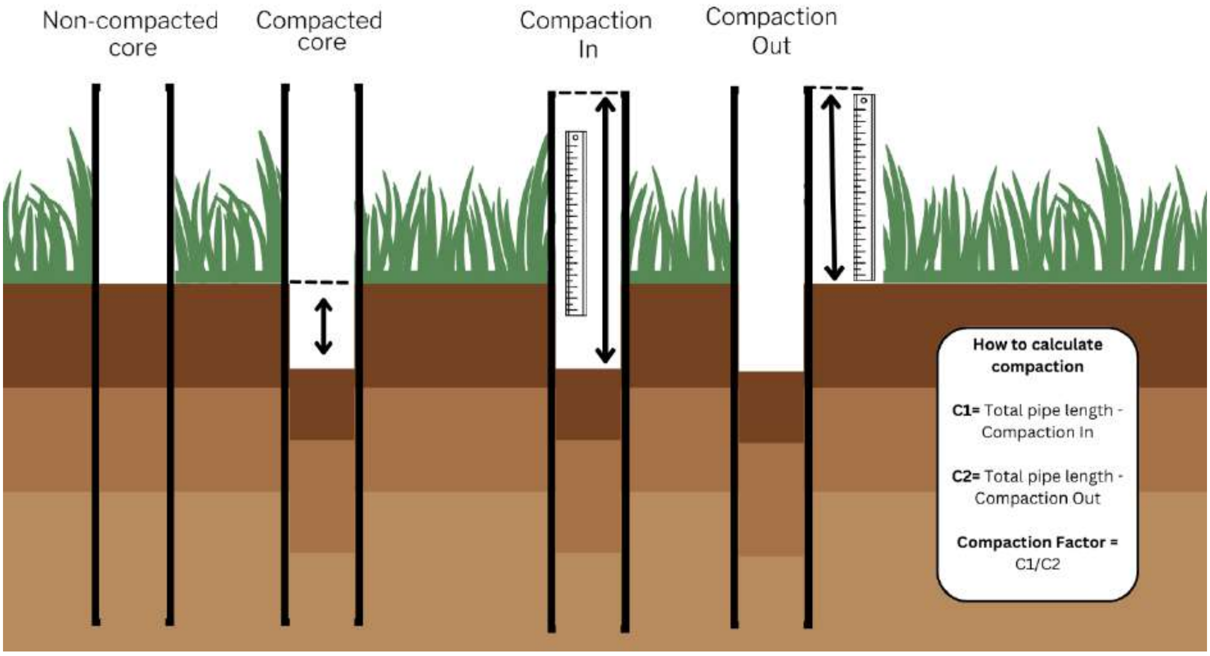


Figure 4: Schematic drawing demonstrating how compaction was measured during the field campaign.

Soil conditions, including shell hash or bedrock, limited core insertion depth at several of the sites sampled. Soil core lengths ranged from 10 cm to 100 cm based on site conditions. Once the core was extracted, it was subsampled in the field (**Figure 3**) at 10 cm intervals using miniature PVC cores (Ø = 40 mm length = 10 cm). The core generated the following depth ranges: 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm. The soil samples were then transported to a cold storage room and stored there until analysis. The samples were then taken from the cold room for analysis at the SAA Laboratory in Mahé.

Soil processing

All soil samples were processed at the **Seychelles Agricultural Agency Soil and Plant Diagnostic** (SAA Lab) in Grand Anse for soil bulk density and Soil Organic Matter (SOM%).

Soil bulk density

Soil samples for bulk density were processed following the gravimetric method. The stainless-steel ring was pre-weighed and then the soil from the miniature PVC tube was transferred into the pre-weighed stainless-steel ring. All rings containing the samples were dried at 105°C until they reached a constant weight. The constant weight was obtained within 48hrs. Both the weight before and after drying were recorded along with the weight of the ring and the foil that was used to secure the sample in the stainless-steel tube.

The volume of the ring was determined by the following formula: ($\pi * r^2 * h$), where r = radius of the inner section of the ring in cm, and h = the height of the inner section of the ring in cm. Bulk density was determined by dividing the oven-dry soil sample by the volume of the sample. The bulk density equation is as follows:

Soil bulk density (g cm^{-3}) = Mass of dry soil (g)/ original soil volume sampled (cm^3)

Soil organic matter and carbon content (%)

The oven-dry samples used to estimate bulk density were grounded and homogenised with a porcelain mortar and pestle. Soil Organic Matter (SOM%) was determined using the Loss-on-Ignition approach (LOI), in which soils are combusted at high temperatures allowing volatile components, such as organic matter to escape, until mass ceases to change (Nelson and Sommers 1996). In this case, ~5 g of each soil sample was weighted into crucibles and set in a muffle furnace (Thermo Scientific, Thermolyne F30430CM) at 550°C for 5 hrs, which combusted the organic matter in the sample, yielding ash and carbon dioxide. After this time, the ashed samples were cooled in a desiccator and weighed. Finally, the samples were heated at 950°C for 5 hrs, the temperature at which carbonates (i.e., calcium carbonate, $CaCO_3$) are decomposed into carbon dioxide. Weight losses during each heating stage were used to calculate the amount of organic matter (SOM%) and carbonates in the samples.

SOM% = [Dry mass before combustion (g) – Dry mass after 550°C combustion (g) / Dry mass before combustion (105°C) (g)] * 100

SOM to SOC relationship

To determine the relationship between SOM (contains carbon, hydrogen, nitrogen, oxygen, sulphur, etc) and Soil Organic Carbon content (SOC%), a limited number of samples were sent for organic carbon analysis. The SOC% of 200 samples was analysed at the Analytical

Services Unit at the University of Aberdeen, United Kingdom. Before SOC% was determined, all samples were exposed to an acid (HCl) fumigation process to remove any carbonates from the soil and leave only the organic carbon fraction (Harris et al. 2001). Then, 0.1 g of each fumigated soil sample was analysed in an elemental CN analyser (Fissions Instruments NA2500 NCS Analyser). A sediment standard was used for calibration (Soil 1016, Leco Corporation; 2.35% C). The coefficient of variation was 1%.

The 200 soil samples analysed for SOC% included samples from all islands (both inner and outer), across a range of depths (from 10 cm to 100 cm) and across all SOM% (0.2% to 81%). By combining the SOM% and SOC% datasets a carbon fraction was estimated to convert all the SOM values produced from this study into SOC.

Soil carbon pool

Following Kauffman & Donato (2012), the soil carbon mass per sampled depth interval was calculated as follows:

*Soil C pool (Mg ha^{-1}) = bulk density (g cm^{-3}) * soil depth interval (cm) *SOC%*

For each soil core, the total soil carbon pool was then determined by summing the carbon mass of all the sampled soil slices down to the sampled depth. Although it is common practice to estimate carbon stocks for the top 100 cm of soil (Kauffman and Donato 2012, Howard et al. 2014), the soil cores in Aldabra Atoll were particularly shallow (average < 37 cm) given that limestone and 'coral champignon' dominate the ground after 50 cm depth. In this case, we linearly extrapolated the data to 40 cm for Aldabra and to 100 cm for the rest of Seychelles, so the dataset is comparable. A major limitation of this approach is that this transformation could overestimate SOC stocks since the top sections are typically more organic than the deeper layers of the sediment; however, we minimised this risk by using the average sampling depth to calculate Aldabra's total soil carbon pool. For all other islands, the average sampling depth was approximately 65 cm, with several cores taken at deeper layers (> 70 cm).

Total carbon pool per site

The total carbon pool for each site was estimated by summing all the component pools. First, each of the component pools was averaged across all plots and in each study site. The averaged values were then summed together to obtain the total carbon pool.

Total carbon pool per site *(Mg ha^{-1})* = average AGC pool *(Mg ha^{-1})* + average BGC pool *(Mg ha^{-1})* + average Soil C pool *(Mg ha^{-1})*

Total ecosystem carbon pool

The total carbon stock for each island, or for all of Seychelles, was estimated by multiplying the average carbon pool* by the total mangrove cover.

Total carbon pool (Mg) = average carbon pool (Mg ha^{-1}) * mangrove area (ha)

The mangrove area was calculated from the best available mangrove distribution maps for Seychelles. For Aldabra Atoll, this meant the map layers developed by Walton et al. (2019), while for the rest of the islands we used the spatial maps from the Seychelles' Marine Spatial Plan Initiative (Smith et al., 2020). All the spatial layers were projected to the same coordinate system, and all spatial analyses were conducted in ArcGIS 10 (ESRI 2011).

Spatial explicit maps of mangrove carbon stocks

As part of this project, we aimed to use soil carbon stocks sampled throughout Seychelles to understand the influence of environmental variables in explaining the variability in soil organic carbon stocks. Furthermore, we aimed to produce spatially explicit maps of soil organic carbon stocks within the entire mangrove extent in Seychelles (such as the studies conducted globally by Sanderman et al. 2018, and in Australia by Ewers Lewis et al. 2020, Costa et al. 2021, Young et al. 2021). In this approach, we would have used the Boosted Regression Trees (BRT; Elith et al. 2008) to identify the main drivers of variability in soil carbon stocks in Seychelles' mangroves, and then create a heatmap of carbon stocks in the region. BRT is a machine learning approach and ensemble method for modelling the relationship between the response (i.e., soil carbon stocks) and predictors (i.e., variables known to influence soil carbon in mangroves, such as temperature, rainfall, land use, tidal range, and wave energy). We would then have used the relationship found in our models to predict soil stocks throughout the mangrove extent in Seychelles. However, this approach was not possible due to the lack of spatial layers for the main variables needed to model soil carbon stocks at the required scale (i.e., the entire distribution of mangroves in Seychelles). Table S2 shows the spatial data found during the data search for this analysis and their main gaps and limitations.

In this case, we used an area basis approach to create spatially explicit maps of mangrove carbon stocks by combining the average carbon stocks for each pool (i.e., aboveground, belowground, soil) and applied them to the distribution maps used in this study (Walton et al. 2019, Smith et al. 2020). Then, we multiplied the area (ha) of each polygon by the average carbon stocks. For islands that were not included in the field sampling, we used the total average carbon stocks to inform the calculations.

** Due to the lack of high-resolution maps for most of the mangrove sites and species, average carbon stocks had to be used to estimate potential total carbon stocks across the entire mangrove distribution in Seychelles. This approach is expected to produce conservative nationwide estimates, which can be updated once high-resolution maps are available.*

Results

Results

Mangrove forest characteristics

Six out of the eight mangrove species reported for Seychelles were sampled during the fieldwork campaign (Palacios et al. 2021a; **Figure 5** and **Table 3**). Mangrove species, *R. mucronata, A. marina* and *C. tagal were* the most abundant (**Table 3)** with *R. mucronata* present on all islands surveyed. *A. marina* was the second most abundant species and occurred on all islands except Silhouette; while *C. tagal* was the third most abundant species but its occurrence was restricted to the Aldabra Atoll and Mahé. Other species included *B. gymnorhiza*, *L. racemosa*, and *S. alba*, which were identified at lower numbers and their presence was restricted to two or three islands (**Table 3)**. We did not encounter individuals of *Xylocarpus granatum* or *Xylocarpus moluccensis* within our sampling plots.

Within Seychelles, mangrove tree density varied substantially across islands, ranging from 400 to 30,000 trees ha^{-1}. The granitic islands of Curieuse and Mahé recorded the highest average tree densities (30,000 and 26,666 trees ha^{-1}, respectively). Considering the different mangrove species, *R. mucronata* held the highest density across all islands (**Figure 6**).

Table 3: Mangrove species and the number of trees sampled in each Seychelles' island during the fieldwork campaign.

Mangrove Species	Local Name	ALD	COS	CUR	LD	MAH	PRA	SIL	TOTAL
Avicennia marina	Mangliye Blan	17	71	13	16	74	8		199
Bruguiera gymnorhiza	Mangliye Lat	29		3		36			68
Ceriops tagal	Mangliye zonn	173				5			178
Lumnitzera racemosa	Mangliye pti Fey				5	15	26		46
Rhizophora mucronata	Mangliye Rouz	558	116	60	1	312	179	43	1269
Sonneratia alba	Mangliye fler	1				23			24
unknown			2						2
	TOTAL	778	189	76	22	465	213	43	

ALD= Aldabra Atoll, COS= Cosmoledo Atoll, CUR= Curieuse, LD= La Digue, MAH= Mahé, PRA= Praslin, and SIL= Silhouette

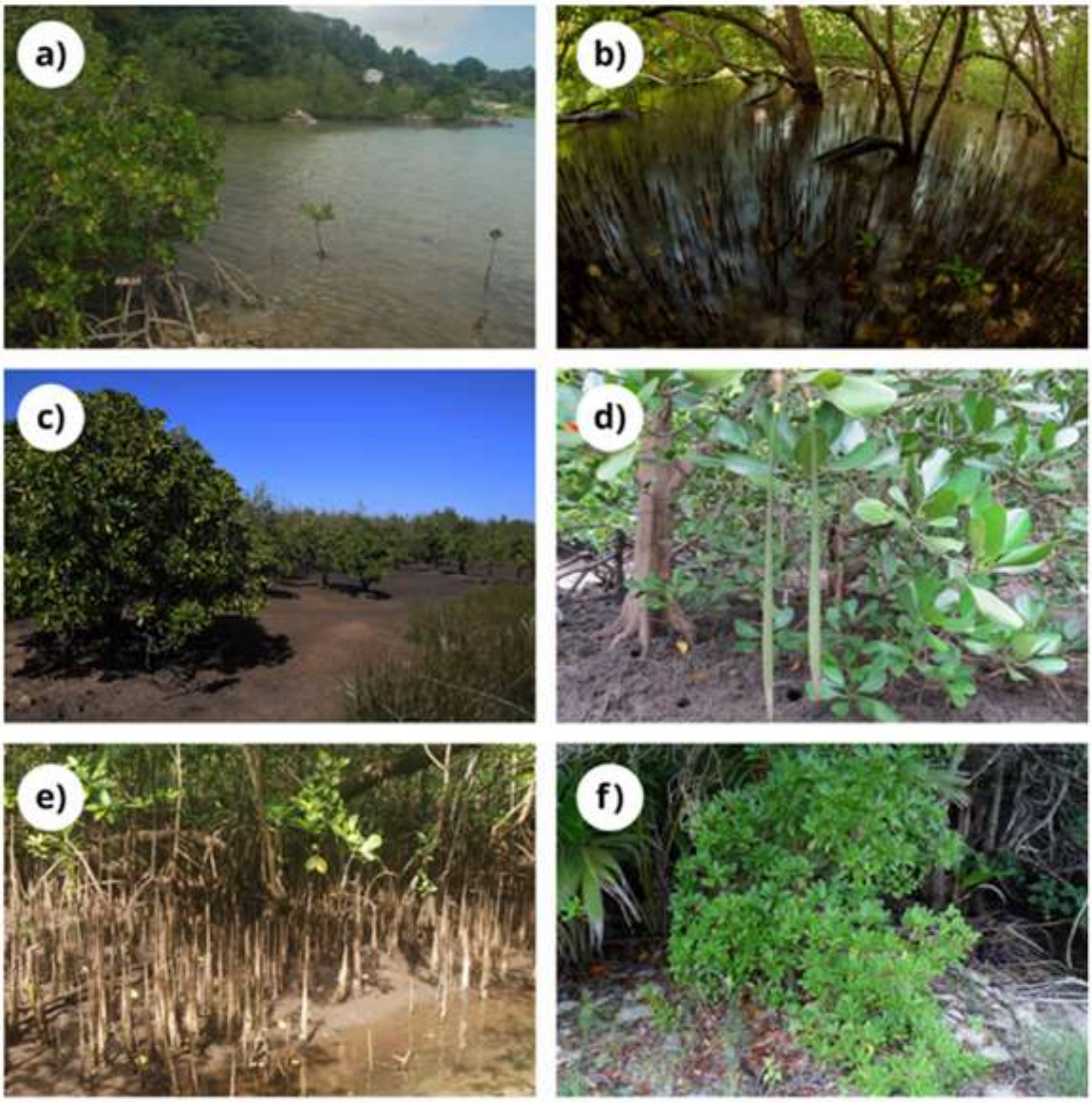


Figure 5: Mangrove species identified in Seychelles: a) Rhizophora mucronata, b) Avicennia marina, c) Bruguiera gymnorizha, d) Ceriops alba, e) Sonneratia alba, and f) Lumnitzera racemosa. Source: Photos from the Seychelles Plant Gallery taken by Bruno Senterre (a, e); Joe Daniels (b); Charles Morel (f). Elsewhere taken by Francois du Randt (c), and Silke Horakh (d).

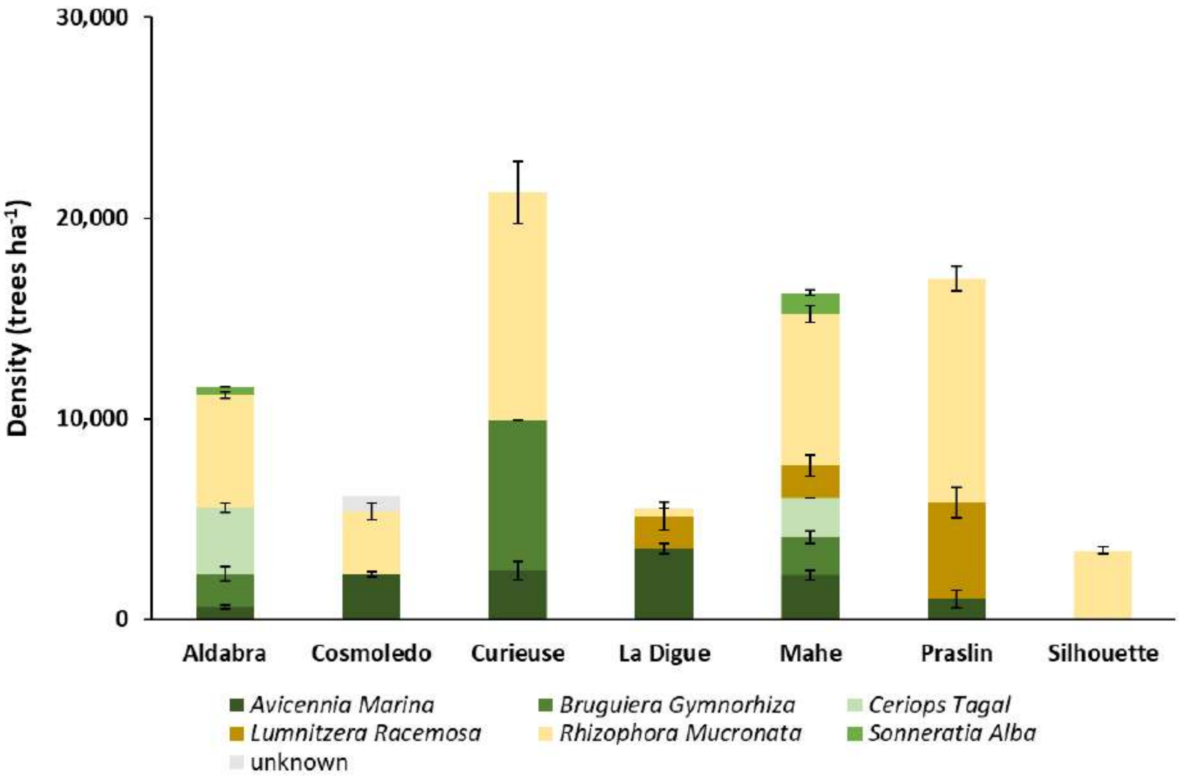


Figure 6: Mangrove tree density (average ± SE) for each island sampled during the field campaign in Seychelles, including the relative contribution of each mangrove species.

Average mangrove height varied between 4 to 5 meters in most of the islands, except in La Digue and Silhouette where mangrove trees tended to be higher (average tree height of 8m and 10 m, respectively: Table 4). Although *A. marina* showed the highest average height across Seychelles (Table 4), the tallest sampled tree (15.1 m) was an *R. mucronata* individual from Silhouette.

The density of mangrove seedlings varied from 2,100 to 32,000 seedlings ha^{-1} (Figure 7), while dying trees ranged from 39 to 2,600 individuals ha^{-1} (Figure 7). Overall, Aldabra showed the lowest seedling and dying tree density across the different islands (Figure 7). In contrast, La Digue recorded the highest density of both seedlings and dying trees (Figure 7).

Table 4: *Mangrove tree height (m; average and range) for each species in each Seychelles' island during the fieldwork campaign. The number of sampled trees per island and species (N) is displayed in* ***Table 3****. *Only one tree was surveyed.*

Mangrove Species	ALD	COS	CUR	LD	MAH	PRA	SIL
Avicennia marina	3.3 (1.1–7.6)	5 (2.4–10.7)	5.8 (2.4–10.6)	8.4 (6.5–9.2)	4.9 (1.7–13.2)	5.6 (1.5–9.2)	
Bruguiera gymnorhiza	5.1 (1.6–9)		2.7 (2.6–2.8)		6 (1–16.7)		
Ceriops tagal	2.5 (0.75–6)				12 (11.1– 12.1)		
Lumnitzera racemosa				7.8 (6–8.7)	4.6 (0.78–11)	6.8 (1.1–9.2)	
Rhizophora mucronata	4.4 (0.85–12.4)	4.2 (1.7–11.2)	3.9 (1.6–10.5)	2.8*	4.3 (1.4–21)	4.2 (1.5–11)	5.5 (1.4–15.1)
Sonneratia alba	3.3 *				7.8 (2.4–12.6)		
unknown		5.4 (4.8–6)					
Total	4.01	4.53	4.20	8.02	4.78	4.58	10.48

ALD= Aldabra, COS= Cosmoledo, CUR= Curieuse, LD= La Digue, MAH= Mahé, PRA= Praslin, and SIL= Silhouette

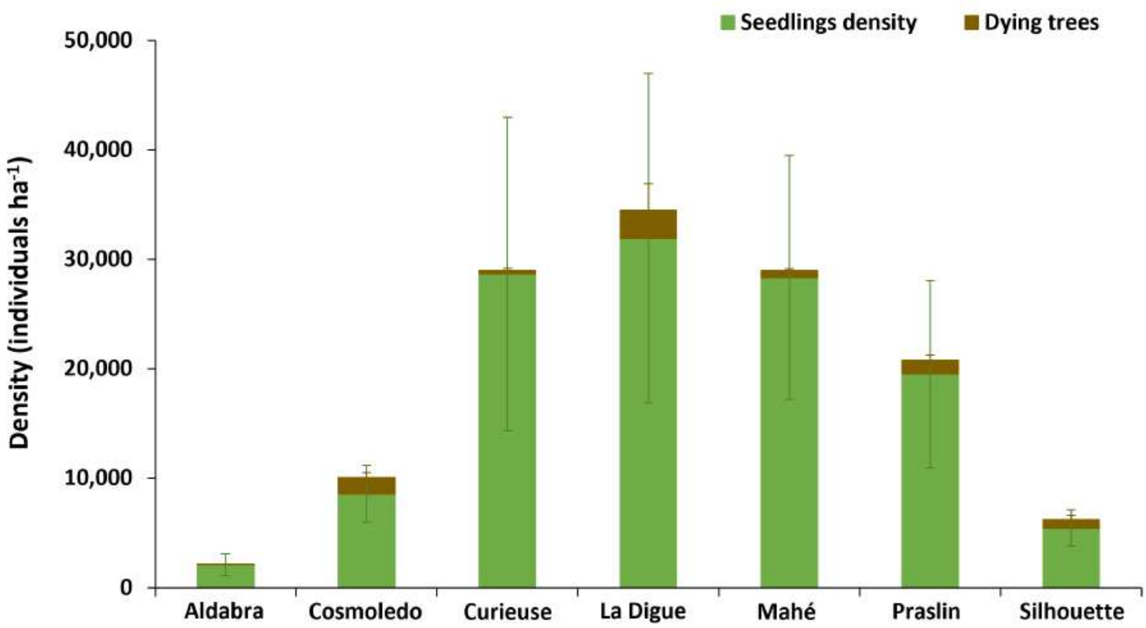


Figure 7: *Density of mangrove seedlings (i.e., individuals lower than 1 m without branches) and dying (i.e., standing individuals ranging from missing some branches and leaves to a standing stem only) trees (average ± SE) for each island sampled during the field campaign in Seychelles.*

Plant biomass and carbon stocks

Mangrove biomass and carbon stocks varied substantially among species and islands. Overall, *A. marina* showed the highest values of aboveground biomass, ranging from 23.1 ± 3.5 to 102 ± 19.9 kg DW tree^{-1} among different islands (Table 5). However, mature forests of relatively taller *R. mucronata* trees in Silhouette (Table 4) held higher total average biomass (> 100 kg DW tree^{-1}; Table 5). A similar pattern was found for belowground biomass with *A. marina* showing the highest values across species (Table 5).

Silhouette, La Digue and Curieuse had the highest plant carbon stocks in Seychelles despite having a relatively smaller extent of mangroves within their limits (Figure 8). In this case, the highest average values for plant carbon stocks in these islands might be a combination of the allometric equation used in this study with the lower number of trees sampled in these islands (Table 3). Based on the allometric equations used in this study (Table 2), the mangrove species *A. marina*, *B. gymnorhiza*, *C. tagal*, and *S. alba* hold most of their carbon stocks within their aboveground stems, branches, and leaves (48.5 ± 8.1, 42 ± 21.5, 19.6 ± 4.3, and 46.6 ± 10.1 tonnes ha^{-1} respectively: Figure 8). In contrast, most of the carbon stocks of *L. racemosa* and *R. mucronata* (28.3 ± 8.2 and 68 ± 6, respectively) are stored in the belowground carbon pool (i.e., stilt and root system; Figure 8).

Pooling the aboveground and belowground carbon stocks across the entire mangrove distribution in Seychelles (Table 6), suggests Seychelles' mangroves hold 207,804 tonnes of plant carbon stocks. More than 80% of these plant carbon stocks are located within Aldabra's mangrove forests (Table 6).

Table 5: Aboveground and belowground biomass (kg WD tree^{-1}) per species and island in Seychelles (average ± SE). The number of sampled trees per island and species (N) is displayed in ***Table 3****. * Only one tree has been surveyed.*

Mangrove Species	ALD	COS	CUR	LD	MAH	PRA	SIL
Aboveground biomass (kg DW tree^{-1})							
Avicennia marina	73.8 (±36.5)	64.6 (±13.5)	94.6 (±54.4)	102 (±19.9)	23.1 (±3.5)	68.8 (±32.7)	
Bruguiera gymnorhiza	45.7 (±15.6)		4.9 (±2)		30.9 (±14.1)		
Ceriops tagal	11.8 (±1.7)				48.6 (±14.2)		
Lumnitzera racemosa				68.3 (±17.7)	8.05 (±4)	13.1 (±1.9)	
Rhizophora mucronata	28.1 (±2.3)	14.2 (±2.9)	10.8 (±2.4)	0.8*	9.4 (±1.7)	9.7 (±2.5)	101.3 (±29.1)
Sonneratia alba	8.2*				107.5 (±20.2)		
unknown		26.2 (±9.2)					
Belowground biomass (kg DW tree^{-1})							
Avicennia marina	41.3 (±12.9)	40.4 (±5.1)	48.3 (±17.6)	63.4 (±8.1)	21.7 (±2.3)	44.3 (±14.5)	
Bruguiera gymnorhiza	27.1 (±8.8)		3.4 (±1.3)		18.2 (±7.9)		
Ceriops tagal	8.2 (±1.1)				33 (±9.2)		
Lumnitzera racemosa				107.2 (±35.8)	11.6 (±4.3)	18.8 (±2.6)	
Rhizophora mucronata	39.9 (±2.3)	22.1 (±3.5)	19.1 (±3.3)	3.48*	15 (±1.9)	16.1 (±2.5)	102.2 (±21.7)
Sonneratia alba	20.05*				110.6 (±16.5)		
unknown		13.1 (±4.2)					

ALD= Aldabra, COS= Cosmoledo, CUR= Curieuse, LD= La Digue, MAH= Mahé, PRA= Praslin, and SIL= Silhouette

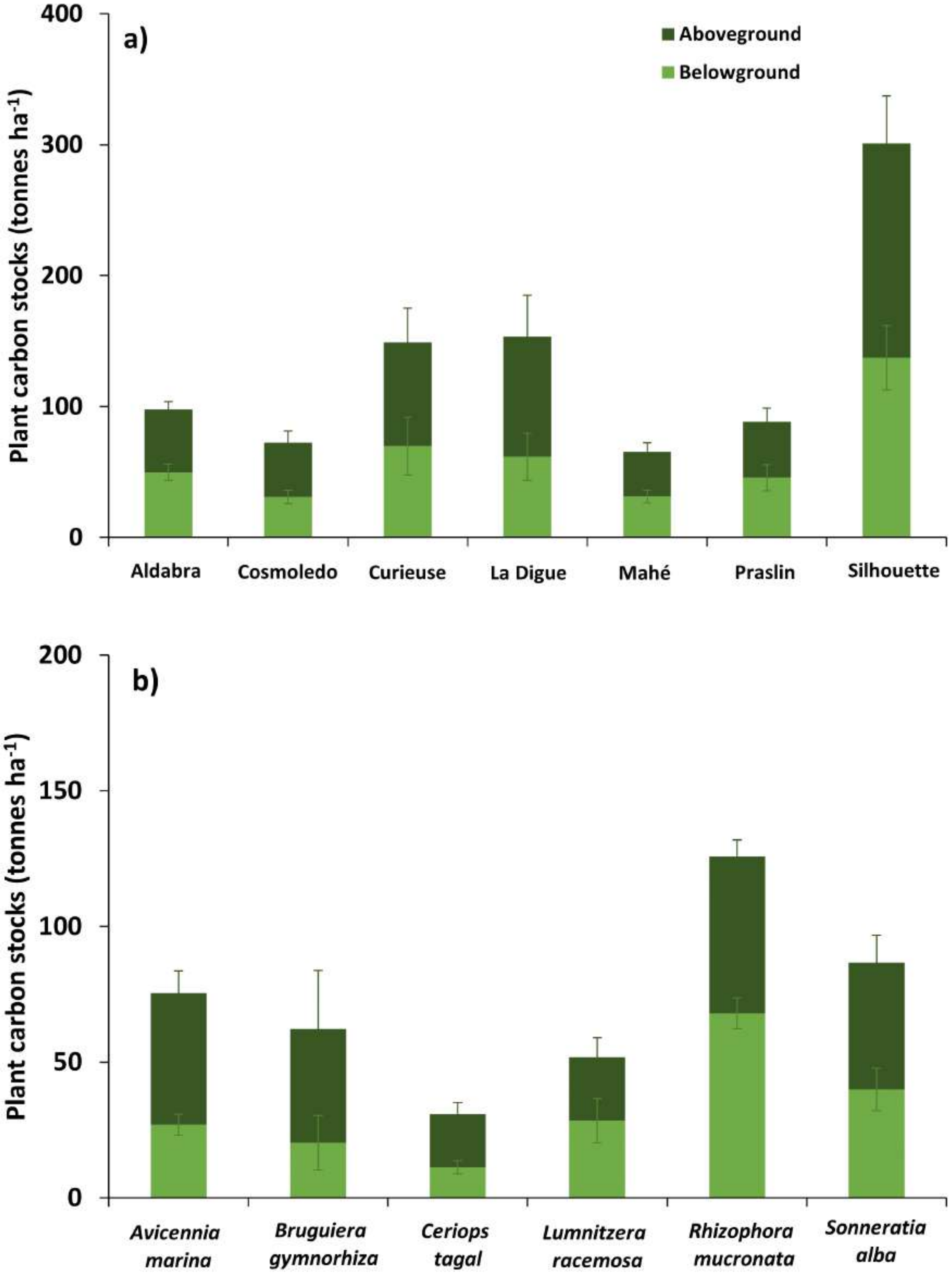


Figure 8: Mangrove plant carbon stocks (average ± SE) within Seychelles: a) within each island and b) per species. Above- (AGC) and belowground carbon stocks (BGC) according to each island and mangrove species. Values for above- and belowground biomass (tonnes DW ha^{-1}) were transformed to carbon (tonnes C ha^{-1}) using the conversion factors of 0.47 and 0.39, for aboveground and belowground, respectively (Kauffman and Donato 2012).

Table 6: *Total aboveground (AGC) and belowground carbon stocks (BGC) within the entire mangrove distribution in Seychelles. Mangrove extent (ha) was calculated based on Smith et al. (2020), except for Aldabra Atoll where it was based on Walton et al. (2019). Total carbon estimates assume the average (±SE) values of carbon stocks for each carbon pool (aboveground and belowground) and island. *For islands that were not included in the field sampling, we used the total average carbon stocks to inform the calculations.*

Island	Mangrove Area (ha)	Average AGC Stocks (tonnes ha^{-1})	Average BGC Stocks (tonnes ha^{-1})	Total AGC stocks (tonnes)	Total BGC Stocks (tonnes)	TOTAL (tonnes)
Mahé	181	34.20 ± 7.0	31.30 ± 4.7	6,190	5,665	11,856
Praslin	68	42.80 ± 10.4	45.60 ± 9.9	2,910	3,101	6,011
La Digue	23	91.80 ± 31.6	61.70 ± 17.9	2,111	1,419	3,531
Curieuse	11	79.30 ± 25.8	69.80 ± 22.1	872	768	1,640
Silhouette	3	163.90 ± 36.2	137.20 ± 24.6	492	412	903
North Island*	2	47.43 ± 4	44.01 ± 3.3	95	88	183
Therese*	0.4	47.43 ± 4	44.01 ± 3.3	19	18	37
Marianne*	0.1	47.43 ± 4	44.01 ± 3.3	5	4	9
Aldabra	1,720	48.30 ± 5.4	49.80 ± 6	83,076	85,656	168,732
Cosmoledo	112	41.50 ± 8.7	30.90 ± 6	4,648	3,461	8,109
Astove*	39	47.43 ± 4	44.01 ± 3.3	1,850	1,716	3,566
Farquhar*	25	47.43 ± 4	44.01 ± 3.3	1,186	1,100	2,286
St Joseph Atoll*	7	47.43 ± 4	44.01 ± 3.3	332	308	640
Île du Sud*	2	47.43 ± 4	44.01 ± 3.3	95	88	183
Poivre*	1	47.43 ± 4	44.01 ± 3.3	47	44	91
St. Francois*	0.3	47.43 ± 4	44.01 ± 3.3	14	13	27
			Total (tonnes)	103,942	103,861	207,804

Soil Organic Matter (SOM%) and Soil Organic Carbon (SOC%) Relationship

This project had 200 mangrove soil samples sent overseas for CN analysis to determine SOC%. The aim was to develop a Seychelles-specific equation between SOM% and SOC% for mangrove ecosystems. This equation would have allowed future mangrove projects to just measure SOM% in Seychelles and estimate SOC% using the equation without the need to send additional samples overseas. Unfortunately, the relationship between SOM% and SOC% was not a strong relationship (R^2=0.35), and the resulting equation (SOC% = 0.2096*SOM% + 8.3317) significantly overestimates SOC% (**Figure 9**). An equation (SOC%= 0.4241*SOM% + 0.8988) with a strong relationship (R^2= 0.81) was developed from soil samples collected from the mangrove forest of Grand Anse (Palacios et al. 2021a), using unpublished data (Sefton and Woodroffe 2021). However, all samples were surface samples (~5 cm) from one location, and we believe that this equation underestimates the soil carbon across all Seychelles' mangrove forests. Therefore, to estimate SOC% from the mangrove soil SOM% data, we used the equation (SOC% = 0.415 * SOM% + 2.89; R^2=0.59) developed by Kauffman et al. (2011) for mangrove ecosystems, outlined in the Blue Carbon Manual (Howard et al. 2014).

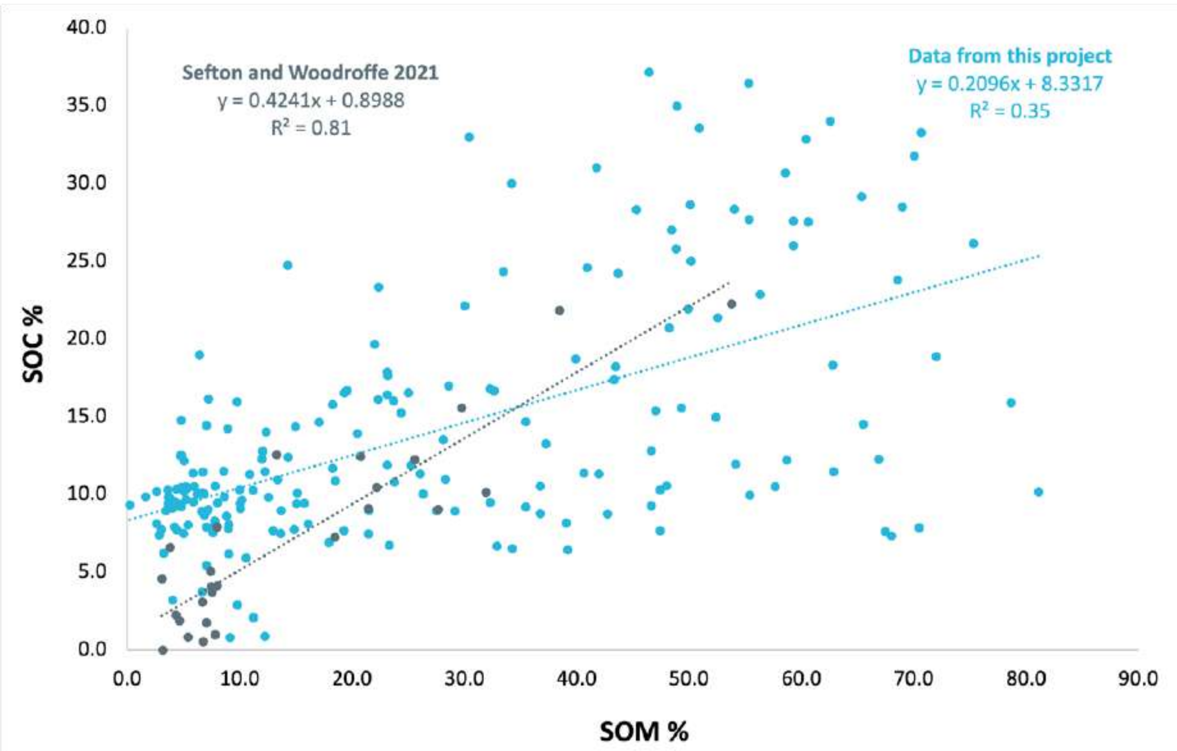


Figure 9: Relationship between soil organic matter (SOM%) and soil organic carbon (SOC%) for 200 mangrove soils collected during this project (light blue) and 25 samples

from surface soils (top 5 cm) from a mangrove forest at Grand Anse by Sefton and Woodroffe (2021) *(dark blue).*

Soil properties

Soil properties varied substantially among islands, mainly between the inner and outer islands (**Figure 10**). We found that Aldabra had the highest average soil organic carbon content and carbon density, along with the lowest average bulk density (**Figure 10**). In contrast, we found that Cosmoledo had the lowest average soil carbon density and content among all islands (**Figure 10**). Within the inner islands, average soil carbon density did not vary, ranging from 40 to 46 mg cm^{-3} while average soil bulk density varied from 0.49 to 0.62 g cm^{-3} (**Error! Reference source not found. 10**). Furthermore, average soil organic carbon content had the largest variation across the inner islands, with Curieuse and Silhouette having the lowest and highest bounds, respectively (i.e., 7.8% and 12.5%; **Figure 10**).

We also found that soil properties varied across depths (**Figures 11 and 12**). For example, the average carbon density did not vary substantially across depths within inner islands (**Figure 11**). In contrast, the average bulk density varied across depths and islands, with bulk density increasing with depth in Curieuse, La Digue, and Mahé (**Figure 11**). The outer islands showed a clearer pattern in soil properties across depths, with the carbon density increasing with depth in Aldabra, while in we found the opposite pattern in Cosmoledo (**Figure 12**). In addition, bulk density in Aldabra tended to be higher in shallower depths (**Figure 12**). Overall, soil organic carbon content was higher in shallower depths for most of the islands, except for Aldabra and Silhouette where carbon content increased with soil depth (**Figures 11 and 12**).

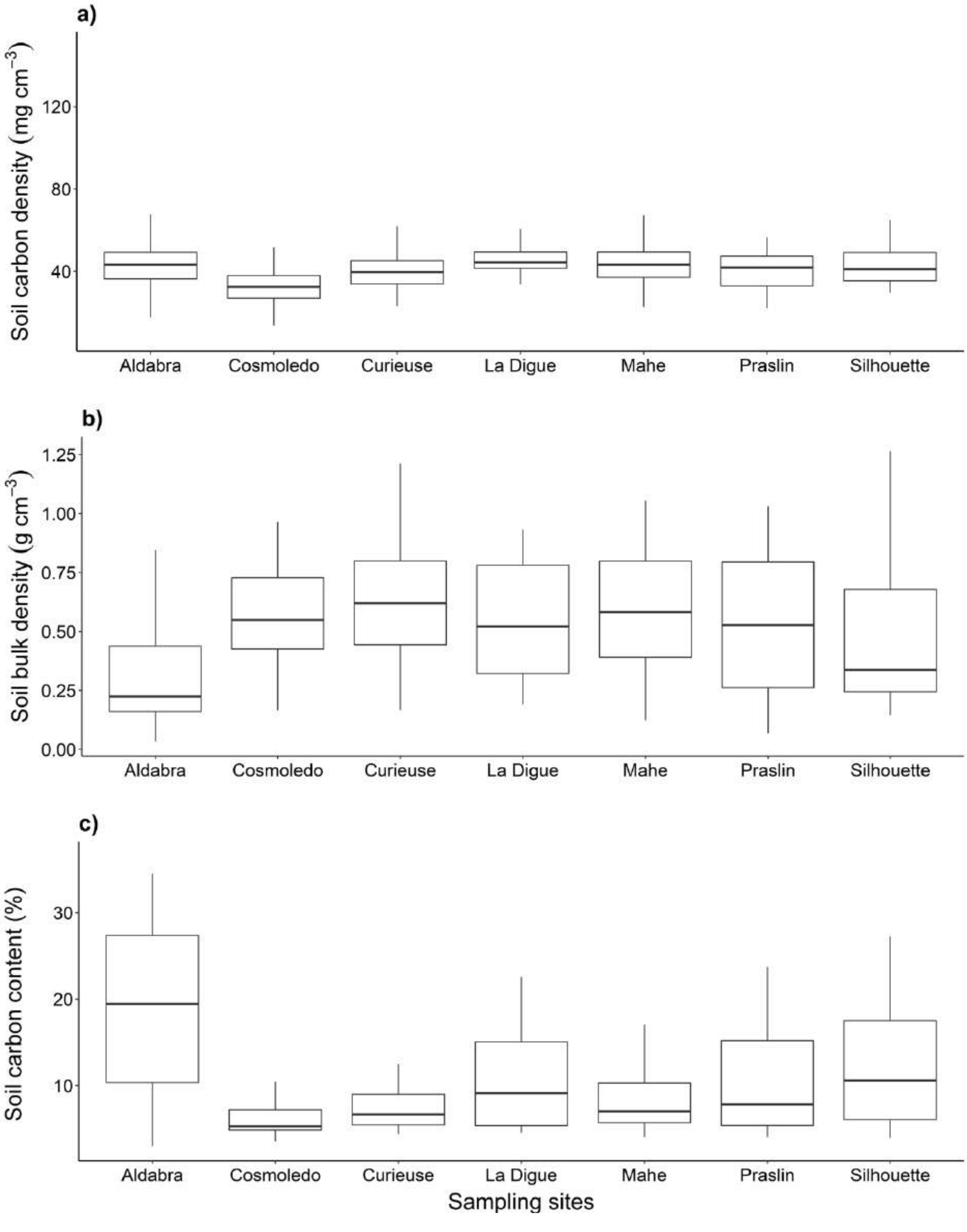


Figure 10: *Variation of soil properties within islands: a) soil carbon density (mg cm^{-3}), b) soil bulk density (g cm^{-3}), and c) soil carbon content (%).*

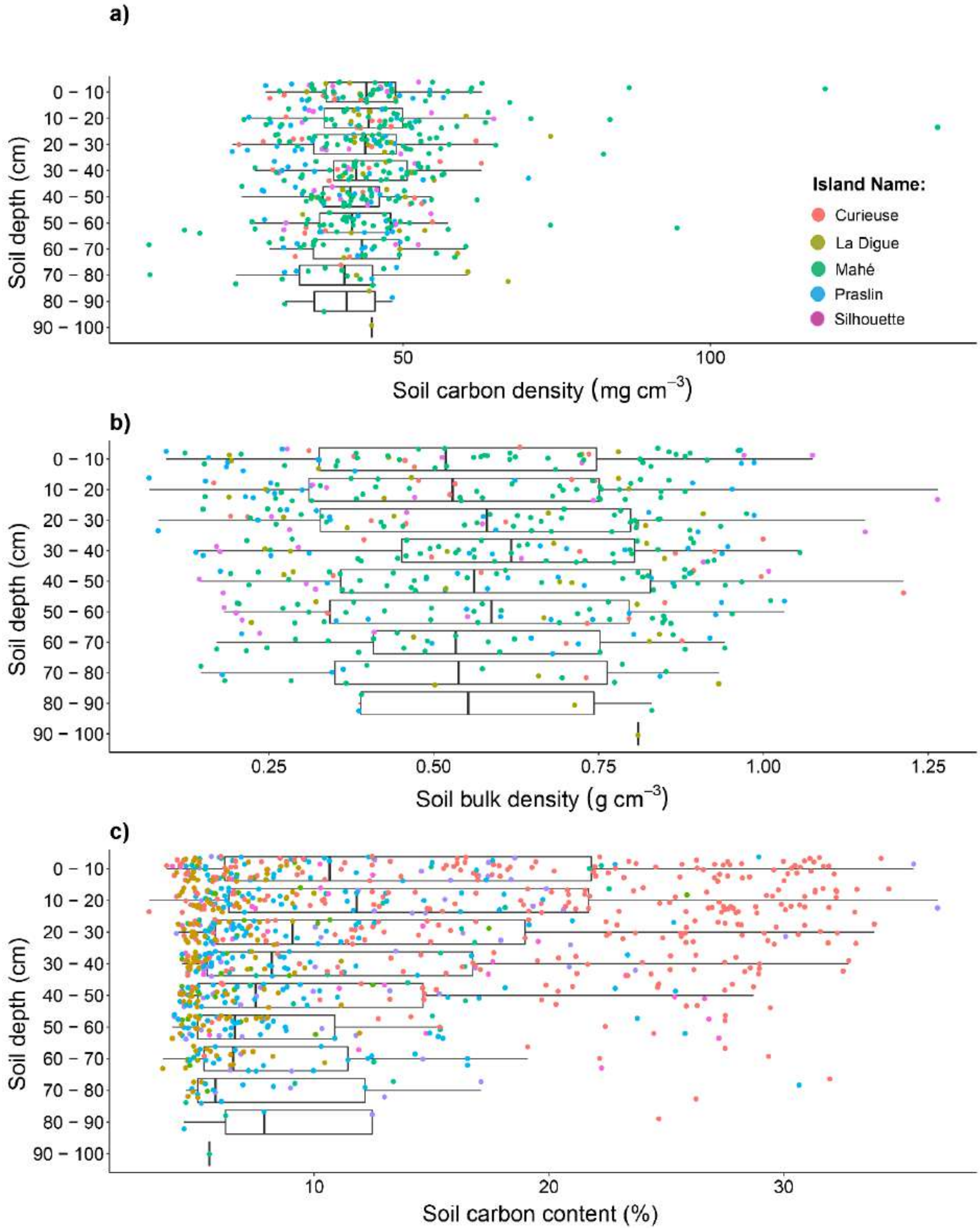


Figure 11: *Variation of soil properties toward depths for soil samples collected in mangroves within the inner islands: a) soil carbon density (mg cm^{-3}), b) soil bulk density (g cm^{-3}), and c) soil carbon content (%).*

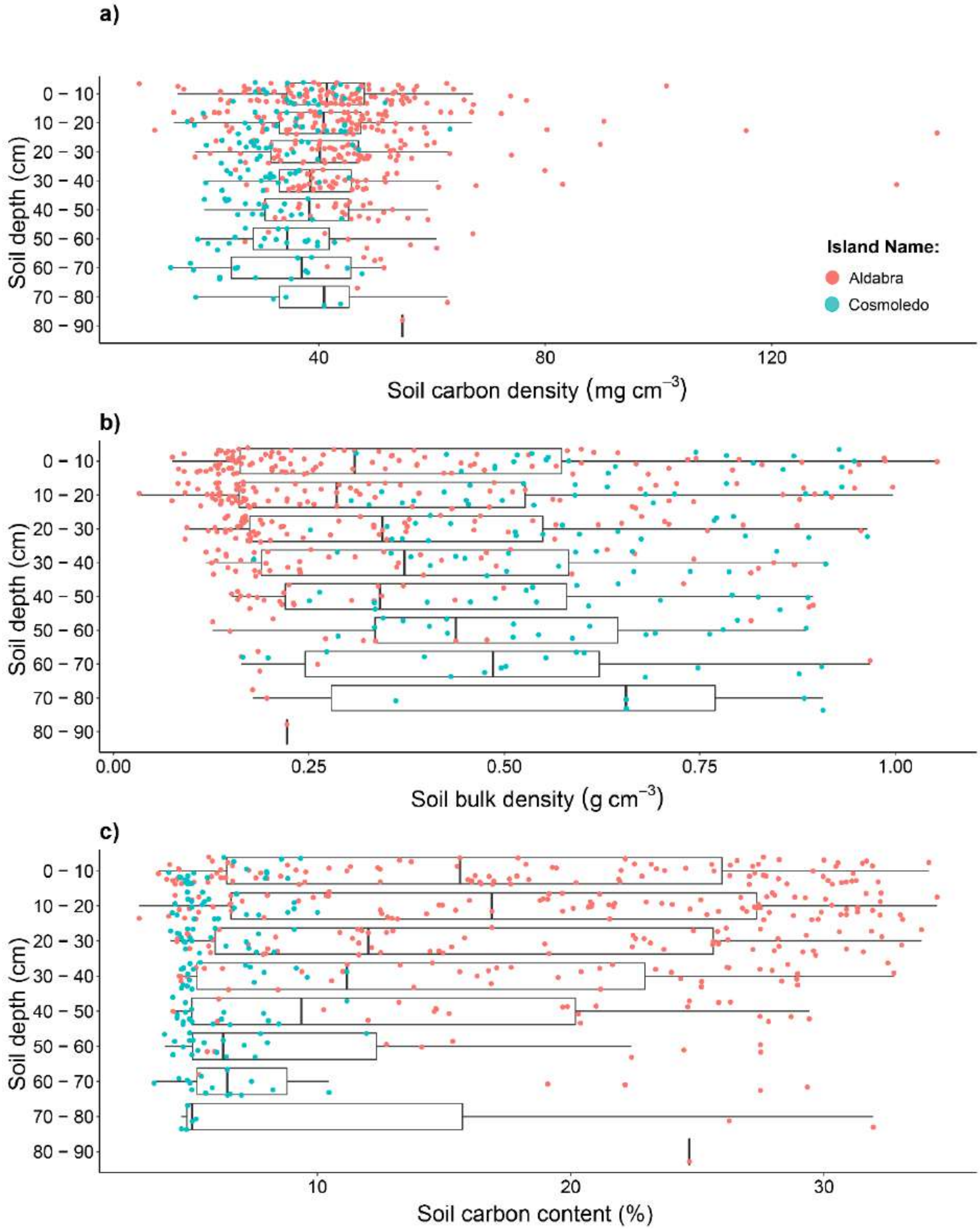


***Figure 12**: Variation of soil properties toward depths for soil samples collected in mangroves within the outer islands: a) soil carbon density (mg cm^{-3}), b) soil bulk density (g cm^{-3}), and c) soil carbon content (%).*

Soil carbon stocks

Soil organic carbon (SOC) stocks slightly vary among islands, with Seychelles' **average SOC stocks estimated at 319.76 ± 11.7 tonnes ha^{-1}**. Amongst islands, La Digue holds the highest average SOC stocks (455.55 ± 18.56 tonnes ha^{-1}), where individuals from *A. marina* dominated the sampling sites (**Figure 13**). We found that SOC stocks varied depending on the dominant species identified in the sampling point, with *R. mucronata* holding the largest average SOC stocks within most of the islands (**Figure 13**), except for Aldabra and La Digue, where *B. gymnorhiza* and *A. marina* hold the highest value, respectively (**Figure 13** and **Figure 14**).

Overall, the inner islands showed higher values of average SOC stocks, varying from 405.14 ± 19.62 tonnes ha^{-1} (Curieuse) and 455.55 ± 18.56 tonnes ha^{-1} registered for La Digue (**Figure 13**). In contrast, the outer islands showed the lowest average SOC stocks in the country, with Aldabra and Cosmoledo holding 170.77 ± 7.5 tonnes ha^{-1} and 324.91 ± 12.47 tonnes ha^{-1}, respectively (**Figure 13** and **Figure 14**). It is important to highlight though that SOC stocks in Aldabra were calculated up 40 cm due to the dominance of limestone and 'coral champignon' in the soils below that depth. When combining the average SOC stocks per hectare with the mangrove distribution extent (ha) within each island in Seychelles, we found that **Seychelles' mangroves hold 480,287 tonnes in their soils** (**Table 7**). Despite Aldabra holding the lowest average SOC stocks, the outer island holds approximately 61.1% of the total SOC stocks in the country due to its large mangrove extent (**Table 7**).

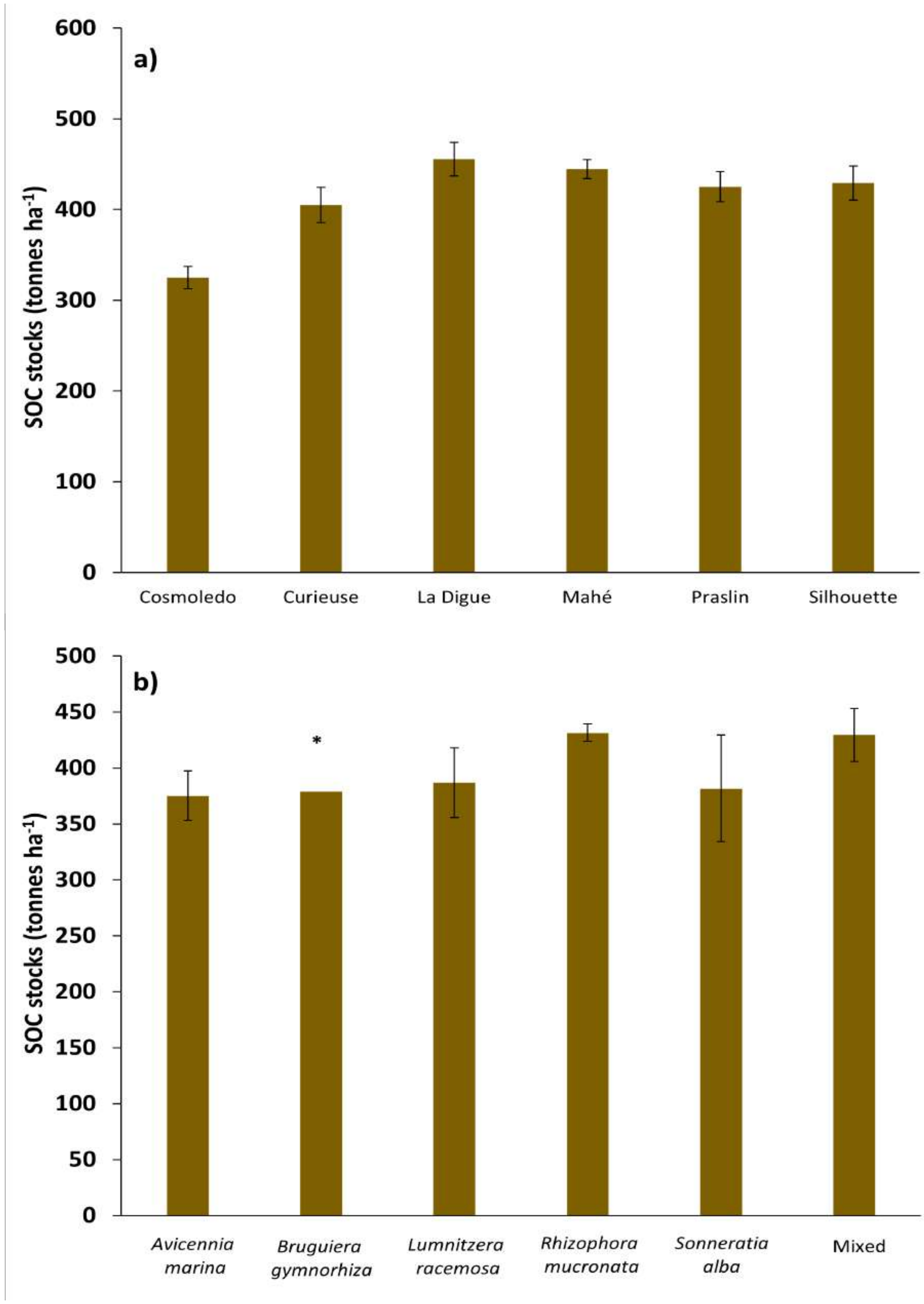


Figure 13: Mangrove SOC stocks (average ± SE) to a 1 m deep *within Seychelles: a) within each island* (*<u>except for Aldabra</u>*) *and b) for each dominant species within the sample plot. Here, dominant species were identified as those with > 60% of the trees registered within each plot. When* the *number of trees* of *each species* was *≤ 60%, we used 'Mixed forests' to classify the plot.* * Indicate species that registered only one individual. SOC *stocks were estimated to 1 m soil depth for all islands in Seychelles, except for Aldabra, in which SOC stocks were estimated to 40 cm.*

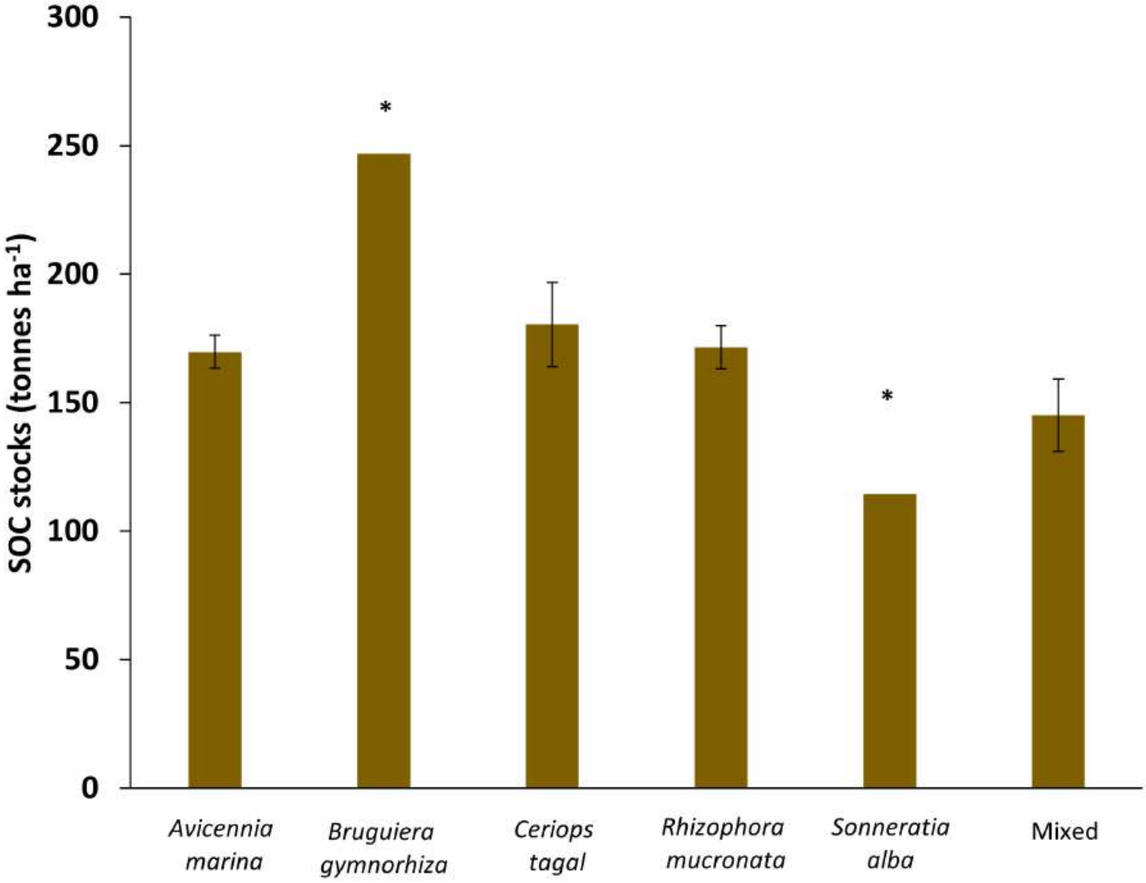


Figure 14: Mangrove SOC stocks (average ± SE) to 40 cm deep for each dominant species within Aldabra Atoll. Here, dominant species were identified as those with > 60% of the trees registered within each plot. When the number of trees of each species was ≤ 60%, we used 'Mixed forests' to classify the plot. * Indicate species that registered only one individual. SOC stocks were estimated to 40 cm deep in Aldabra.

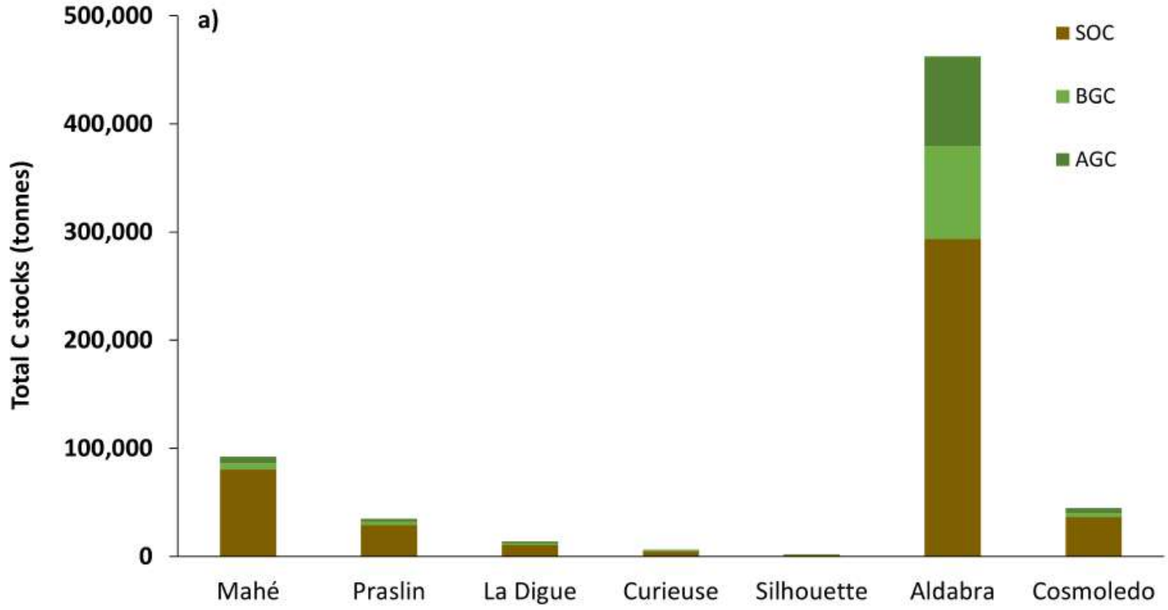
Total blue carbon stocks in Seychelles

Overall, Seychelles' mangroves store approximately 688,091 tonnes of organic carbon within their plant biomass and soils (Figure 15; Table S2), which is equivalent to ~2.5 million tonnes CO_2e. Mangrove soils account for ~70% of Seychelles' mangrove carbon stock, with the remaining 30% stored within the plant biomass. Aldabra Atoll holds the highest total carbon stocks in Seychelles, followed by the mangrove forests in Mahé (67% and 13% of Seychelles' mangrove stocks, respectively). These results are based on the existing information on mangrove distribution extent, and they can be improved once new distribution maps are produced in the coming years.

Figure 16 shows the spatial variation of total carbon stocks within Seychelles. Shapefiles with detailed estimates on soil and plant carbon have been produced as part of this project and delivered to MACCE as part of the submission package.

Table 7: Total *SOC stocks within the entire mangrove distribution in Seychelles. Mangrove extent (ha)* was *calculated based on Smith et al. (2020), except* for *Aldabra Atoll where we used distribution maps by Walton et al. (2019). Total carbon estimates were based on the average (±SE) values of SOC stocks for each island. *For islands that were not included in the field sampling, we used the total average SOC stocks to inform the calculations.*

Island	Mangrove Area (ha)	Average SOC Stocks (tonnes ha^{-1})	Total SOC Stocks (tonnes)
Mahé	181	444.67 ± 10.37	80,484.70
Praslin	68	425.21 ± 16.47	28,914.11
La Digue	23	455.55 ± 18.56	10,477.63
Curieuse	11	405.14 ± 19.63	4,456.55
Silhouette	3	429.14 ± 18.85	1,287.41
North Island*	2	319.76 ± 11.70	639.52
Therese*	0.4	319.76 ± 11.70	127.90
Marianne*	0.1	319.76 ± 11.70	31.98
Aldabra	1,720	170.77 ± 7.52	293,719.13
Cosmoledo	112	324.91 ± 12.47	36,389.92
Astove*	39	319.76 ± 11.70	12,470.62
Farquhar*	25	319.76 ± 11.70	7,993.98
St Joseph Atoll*	7	319.76 ± 11.70	2,238.32
Île du Sud*	2	319.76 ± 11.70	639.52
Poivre*	1	319.76 ± 11.70	319.76
St. Francois*	0.3	319.76 ±	95.93
			480,287



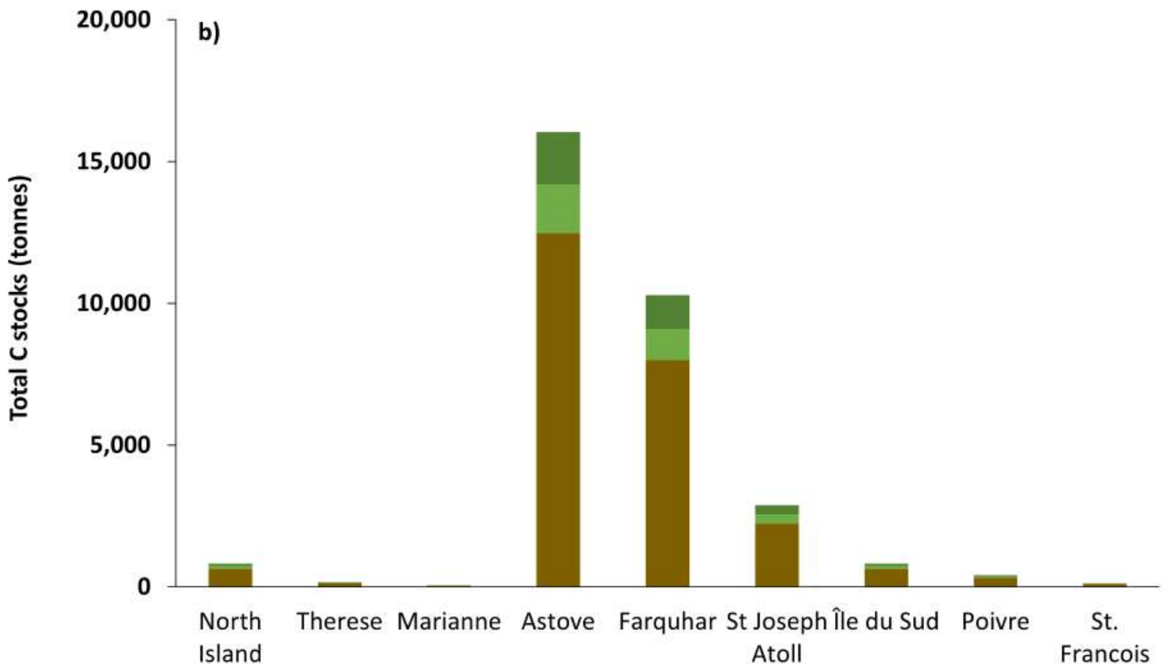
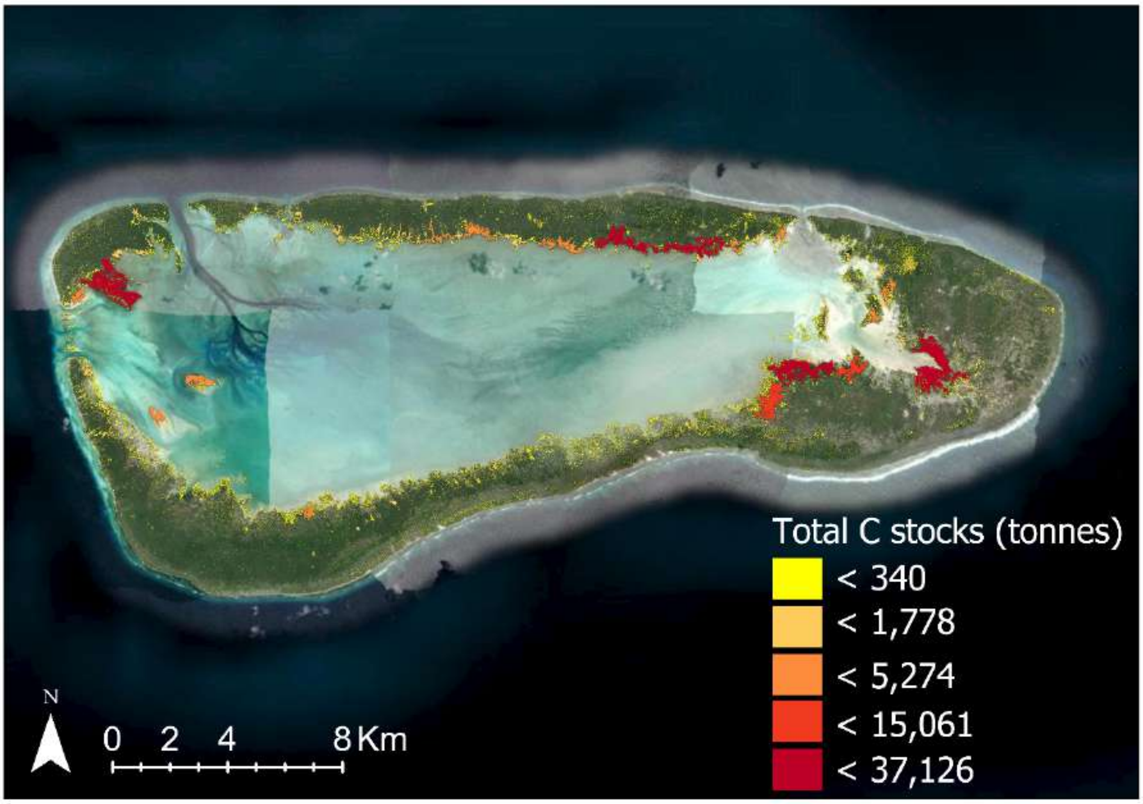
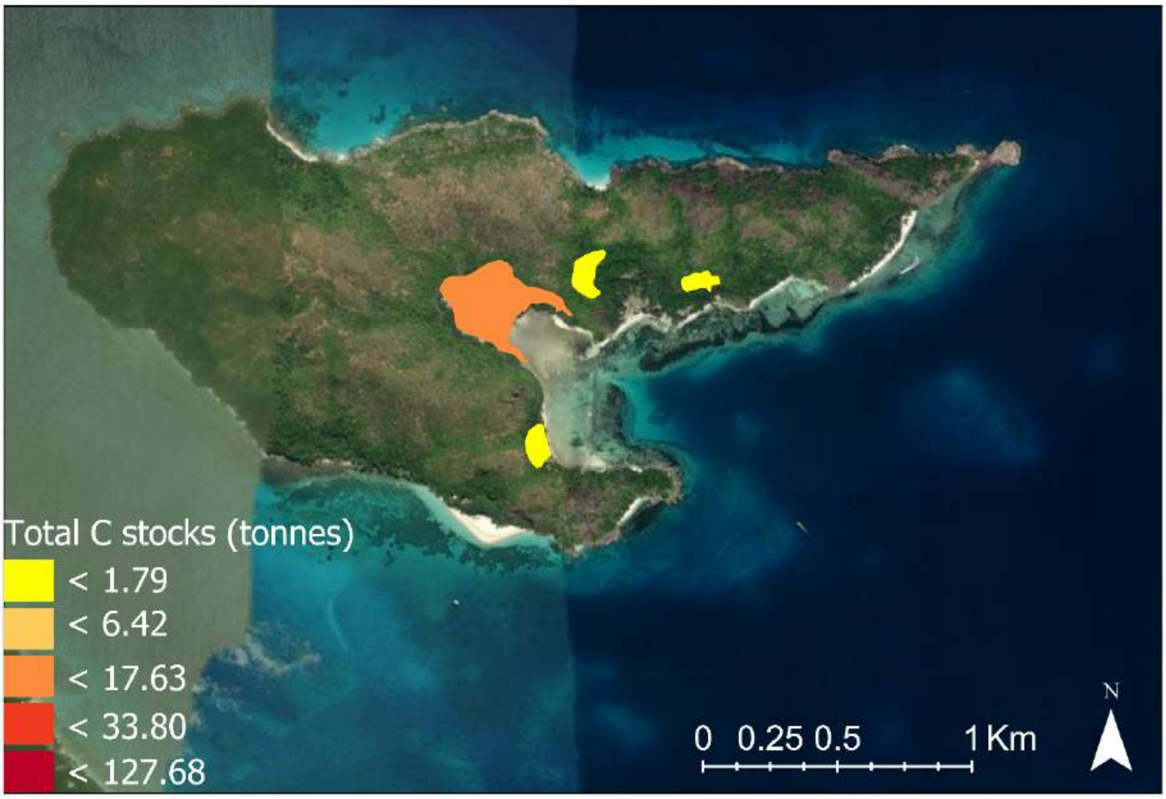
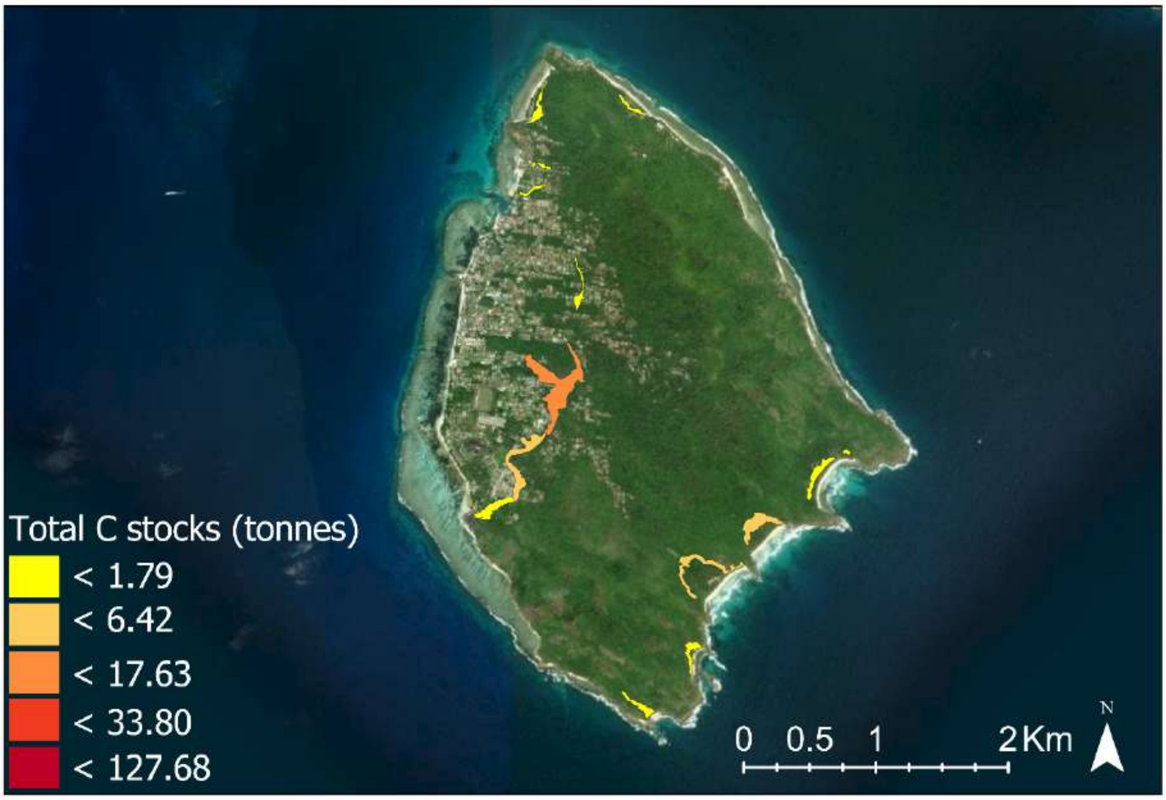


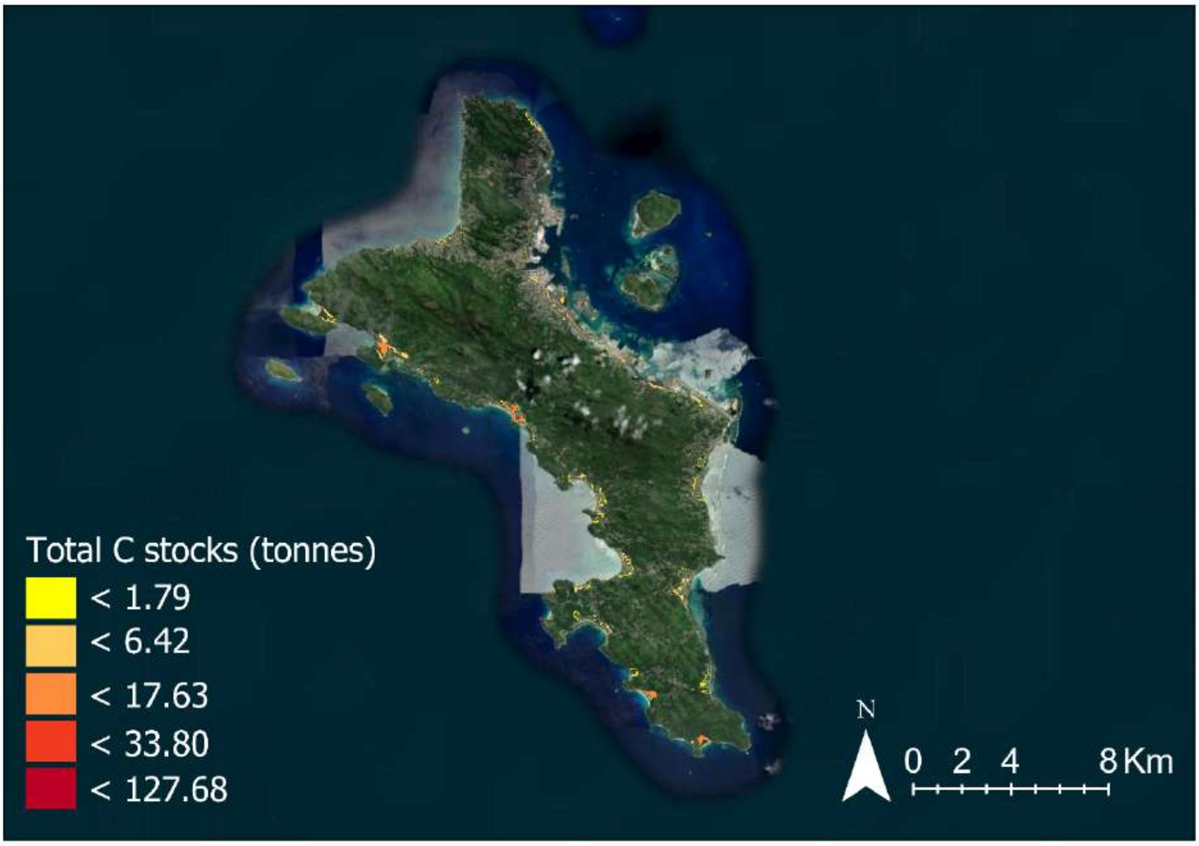
Figure 15: Total carbon stocks (tonnes) across islands within Seychelles: a) islands included in the fieldwork campaign, and b) islands not included in the fieldwork campaign, for which we used the total average SOC stocks to inform the calculations.

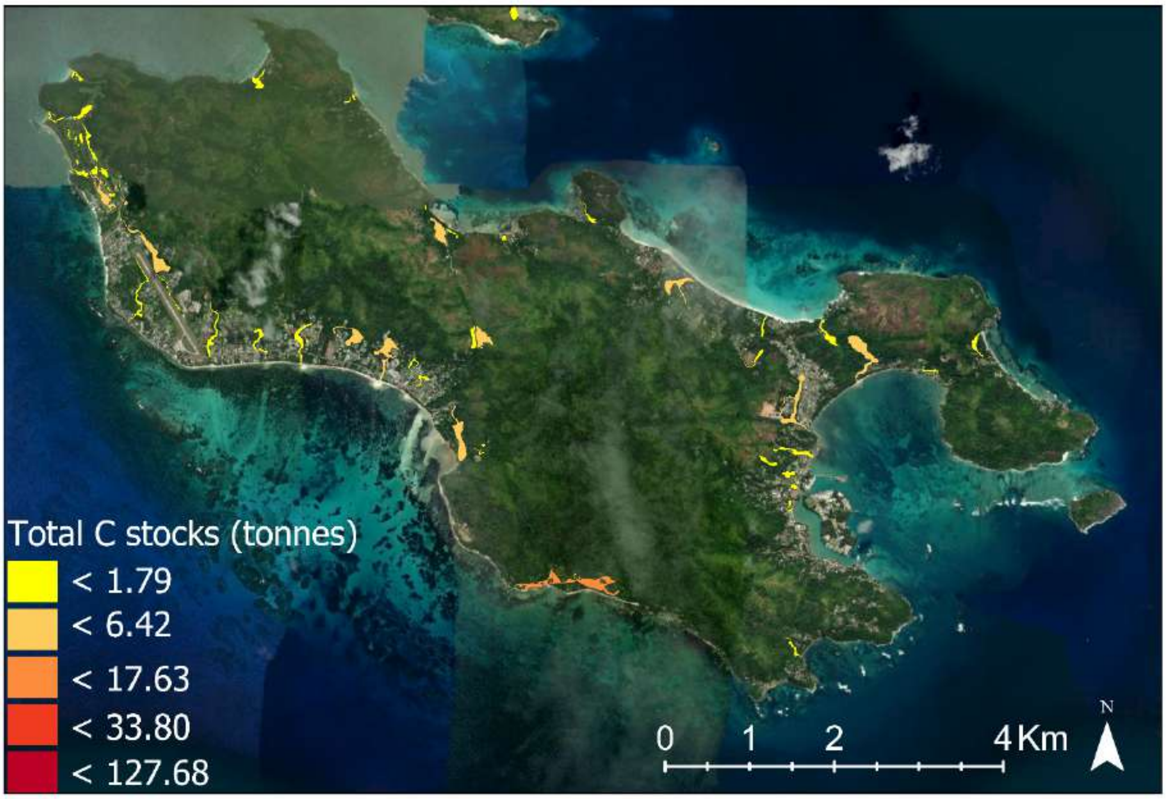

Total C stocks (tonnes)
< 340
< 1,778
< 5,274
< 15,061
< 37,126
N
0 2 4 8 Km


Total C stocks (tonnes)
< 1.79
< 6.42
< 17.63
< 33.80
< 127.68
N
0 1 2 4 Km


Total C stocks (tonnes)
< 1.79
< 6.42
< 17.63
< 33.80
< 127.68
0 0.25 0.5 1 Km
N


Total C stocks (tonnes)
< 1.79
< 6.42
< 17.63
< 33.80
< 127.68
0 0.5 1 2 Km
N


Total C stocks (tonnes)
< 1.79
< 6.42
< 17.63
< 33.80
< 127.68
N
0 2 4 8 Km


Total C stocks (tonnes)
< 1.79
< 6.42
< 17.63
< 33.80
< 127.68
0 1 2 4 Km
N

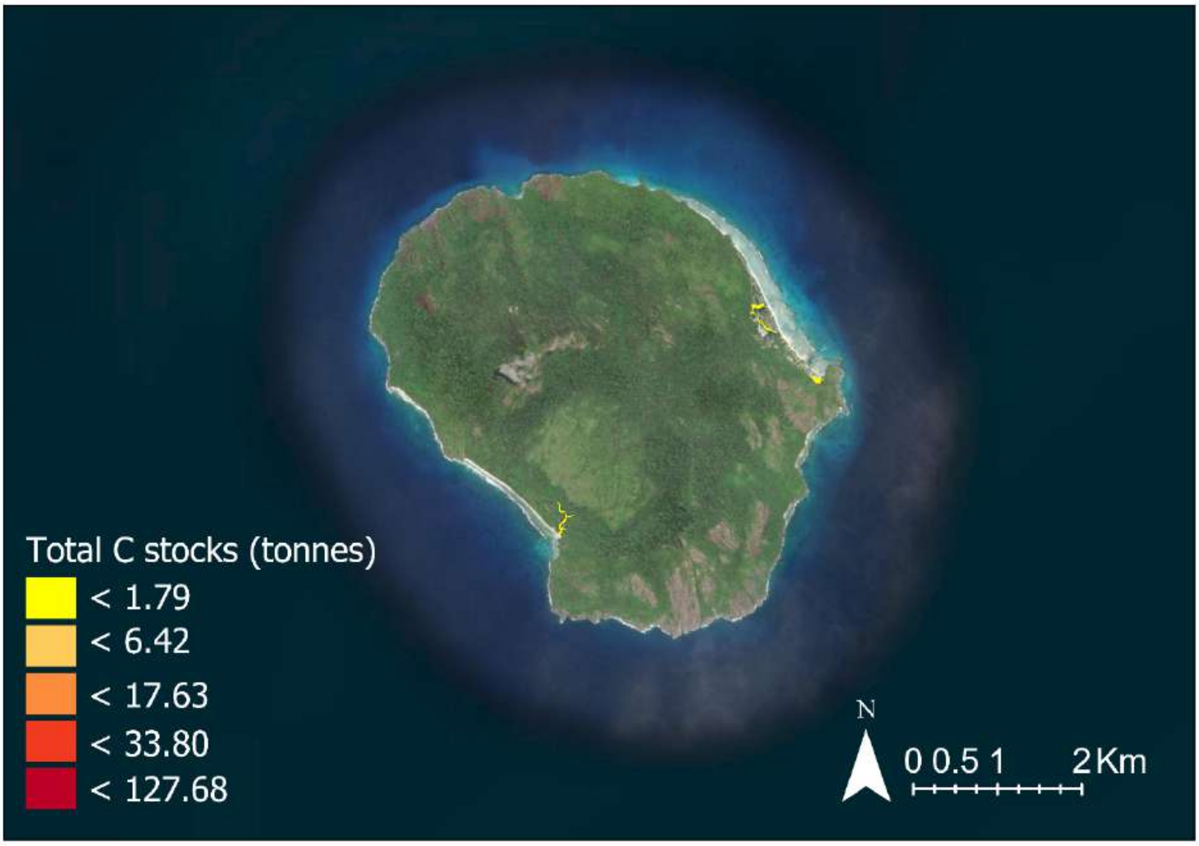


Figure 16: *Maps showing the distribution of total carbon stocks (above- and belowground and SOC stocks) from mangrove forests in Seychelles based on the average carbon stocks in each island and the area (ha) of each polygon. Here, we used the mangrove distribution map from Smith et al. (2020) and Walton et al. (2019). This figure focused on the islands included in the fieldwork campaign. In order: Aldabra, Cosmoledo, Curieuse, La Digue, Mahé, Praslin, and Silhouette.*

Stakeholder Workshop & Capacity Building

Stakeholder Workshop & Validation

Deakin University hosted a half-day stakeholder workshop on September 30, 2022, at Savoy Seychelles Resort to present the results of the Blue Carbon Assessment for Mangrove Systems in Seychelles. The workshop was attended by 30 participants from over 15 organisations including MACCE, Seychelles Islands Foundation (SIF), the University of Seychelles (UniSey), Nature Seychelles, Marine Conservation Society, among others. The workshop was opened by Minister Flavien Joubert the Minister for Agriculture, Climate Change and Environment. In his welcome, Minister Joubert spoke on the importance of mangrove ecosystems in climate change mitigation and adaptation and the integral need to protect and restore these ecosystems, highlighting Seychelles' new commitments in its updated NDCs. The Minister also noted the importance of the Seychelles' Blue Carbon Roadmap that was recently delivered in partnership with key partners including SeyCCAT, James Michel Foundation and Deakin University. Members of the news media were present at the workshop and reported on the results from the workshop in the Seychelles Nation and on the Seychelles Broadcasting Corporation (SBC; starting at 14:33 min).

There were four presentations over the course of the workshop including:

- the importance of blue carbon ecosystems and the results from the mangrove literature review presented by Dr Maria Palacios (Deakin University)
- fieldwork and laboratory methods used to quantify Seychelles' mangrove carbon stocks presented by Dr Barry Nourice (Local Consultant)
- Seychelles mangrove carbon stocks results presented by Dr Micheli Costa (Deakin University),
- discussion of how mangroves can help Seychelles tackle climate change presented by Dr Melissa Wartman (Deakin University).

There were several key points of discussion with the workshop participants:

- Aldabra carbon stocks. In her presentation, Dr Micheli Costa highlighted that Aldabra carbon stocks have been calculated only to 40 cm (standard is 1 m), as this was the average core depth sampled on Aldabra. Dr Costa noted that if she had calculated it the full 1m it would have been an overestimation of the actual carbon stock since that limestone and ‘coral champignon’ dominate the soils below that. There was no objection from the stakeholders and workshop participants to proceed as Dr Costa recommended. When Aldabra’s soil carbon stock value is referenced in other documents it needs to be noted with the value, that the carbon stock depth is 40 cm, not 1 meter.

- Soil sample and data storage. The second point of discussion was regarding the storage of soil samples and the housing of the data generated during this project. The data from this project, including raw and analysed values delivered as excel spreadsheets and drone imagery of the sampled sites unanalysed will be housed at the Climate Change Division with the MACCE. To access the mangrove carbon stock data or the drone imagery please contact Ms. Ashley Dias (a.dias@env.gov.sc), Director for Biodiversity Conservation Section, Environment Department, MACCE. The soil samples will be stored at the SAA laboratory for 5 years. To access the mangrove soil samples please contact Ms. Natalie Meme (nmeme30@gmail.com), Laboratory Technician at Seychelles Agricultural Agency. Action 1.2 in Seychelles Blue Carbon Roadmap (Palacios et al. 2022) suggests the establishment of a **national repository of blue carbon research** to enable sharing of data and knowledge.

- Blue Carbon Working Group. The third point of discussion related to the lack of coordination and communication between the various blue carbon initiatives happening in Seychelles. We suggested the idea to develop a Blue Carbon Working Group (BCWG). The BCWG could include key stakeholders from the government, academia, NGOs, industry, and the community. The working group would serve to promote collaborations, sharing of equipment, facilities, and resources, ensure alignment of research projects to avoid duplication and promote research outcomes. The establishment of a Blue Carbon Working Group was well received by workshop participants, with many supportive of the idea.

Participants of the workshop received by email a copy of all presentation slides, the Seychelles Blue Carbon Roadmap report, and the mangrove literature review (Palacios et al. 2021a).

Building Local Research Capacity in Blue Carbon

This project provided several opportunities to build blue carbon research capacity within Seychelles. Due to Covid-19 travel restrictions, Deakin University's Blue Carbon Lab research team was unable to travel to Seychelles to undertake the mangrove sampling fieldwork. The Deakin team worked closely with a local consultant Dr Barry Nourice to provide step-by-step guidance on the proper methods and equipment needed to obtain high-quality mangrove plant and soil carbon data. This project resulted in nine local researchers being employed and trained in mangrove assessment techniques. Researchers were trained up in field data collection (soil coring, species identification, aboveground biomass measurement) as well as soil processing (LOI, and dry bulk density). Developing this skillset in country will allow any future projects to be undertaken by local researchers. The key equipment for soil carbon stock assessment was fabricated in Seychelles. Geffroy's Farm, based in Anse Royale, fabricated seven 1.2 m stainless steel soil corers with sampling ports spaced every 10 cm (Figure 3). The five remaining corers from the field campaign will be stored at the SAA Lab, and available for use by other researchers. Additionally, this project highlighted that Seychelles has the capacity to measure SOM% of soil samples in Seychelles at the SAA Lab. Researchers can use a global mangrove equation referenced in the Blue Carbon Manual (Howard et al. 2014) to estimate the SOC% in their samples. Alternatively, a subset of soil samples could be sent overseas for analysis to determine organic carbon content on a CN analyser, as Seychelles does not have a CN analyser in the country.

Discussion

Discussion

Mangrove ecosystems play an important role in adapting and mitigating climate change impacts. The protection and restoration of these ecosystems are especially important to Small Island Developing States, like Seychelles, which are particularly vulnerable to the impacts of climate change. This study is the first to conduct a systematic field-based assessment of mangrove systems across both the inner and outer islands in Seychelles. Seychelles is home to 2,195 ha of mangrove forest distributed across the inner and outer islands (Walton et al. 2019, Smith et al. 2020). Despite the limited distribution of mangrove forests, we found that these ecosystems store 688,091 tonnes of carbon, or 2.5 million tonnes of CO_2e, within their soil and plant biomass. Our results showed that mangrove systems in Seychelles store an average of 313.48 tonnes C ha^{-1}, with 70% of their total carbon stocks stored in their soils. From a global perspective, Seychelles' mangroves contain lower total ecosystem carbon stocks than the global average, which has been estimated at 702 or 856 tonnes C ha^{-1} (Alongi 2020, Kauffman et al. 2020). This result highlights the need to invest in country-specific values for blue carbon assessments since using default values based on global averages would have overestimated the potential blue carbon stock in Seychelles.

Mangroves store more carbon in their aboveground biomass (i.e., the global average estimated at 109.5 ± 5 tonnes ha^{-1} by Alongi 2020) than any other blue carbon ecosystem (e.g., the global average for seagrasses estimated at 0.7 ± 0.1 by Fourqurean et al. 2012). Our results showed that above- and belowground plant carbon pools hold approximately 30% of the total carbon stocks in Seychelles' mangroves, which aligns with the global average (Donato et al. 2011, Hamilton and Friess 2018). Furthermore, we found that mangroves store an average of 48.3 tonnes C ha^{-1} and 49.8 tonnes C ha^{-1}, respectively, in their above- and belowground carbon pools. These results are relatively lower than previous studies conducted in different countries within the Western Indian Ocean (varying from 71.8 to 164 tonnes ha^{-1}; Palacios et al. 2021b, 2021a); however, are within the range found in Tanzanian mangroves (Cleyndert et al. 2020). Such variability indicates that these carbon pools are highly influenced by site-specific conditions, species and forest structure (Kamau et al. 2015, Simard et al. 2018). Despite using different allometric equations, our results agree with a recent study conducted in Aldabra's mangroves, which found their average aboveground carbon stocks at approximately 38.5 tonnes C ha^{-1} (Constance et al. 2022). While mangroves in Seychelles are exposed to different environmental settings across islands, it has been suggested that mangrove aboveground biomass in Aldabra is driven directly and indirectly by soil nutrient content and water level variation. We still need further studies to understand what drives above- and belowground biomass on other islands within Seychelles.

Aldabra Atoll, located in the outer islands, has the largest distribution of mangrove forests in Seychelles (~1,720 ha; Walton et al. 2019), and consequently, holds the highest total carbon stock (~293,719 tonnes), accounting for 67% of Seychelles' mangrove stocks. Despite the high total carbon stock value, the average soil carbon stock in Aldabra was the smallest across all islands (170.77 ± 7.52 tonnes ha^{-1}), likely due to the average core sampling depth on the Atoll being 40 cm. The field team encountered limestone and 'coral champignon' below the soil (Braithwaite et al. 1973), unsurprisingly given Aldabra is one of the world's largest coral atolls (Claudino-Sales 2019). However, the average value per hectare is still within the global range for mangrove systems (Howard et al. 2014). Although Aldabra's soil carbon stock value was low, its soils contained higher SOC% (18.6%) compared to other islands (which varied from 6% to 12.5%). The carbon stocks on Aldabra Atoll have been protected since 1982 when it was inscribed as a UNESCO World Heritage Site (UNESCO 2022) and designated as a Wetland of International Importance under the Ramsar Convention in 2010 (Ramsar Sites Information Service 2010). Recent research has shown the extent of mangrove forests on Aldabra has naturally varied through time, with the overall extent increasing by 60 ha over the past 20 years (Constance et al. 2021). In this study, the expansion of mangroves was mainly associated with landward migration into drought-stricken grassland, while mangrove loss was mainly along the seaward edge of forests (i.e., likely related to changes in coastal processes, such as waves, storms, sediment dynamics, sea level rise). Anthropogenic threats to Aldabra's mangrove forests have been historically limited due to both international protection and its remote location, however, these mangroves now face threats derived from climate change (e.g., sea level rise). Ongoing monitoring and management of these ecosystems are needed to maintain ecosystem health and the continued expansion of the mangrove forests.

In contrast to Aldabra Atoll, Mahé, Seychelles' largest inner granitic island is home to the second largest mangrove extent (181 ha) and total carbon stock (~80,485 tonnes), accounting for 12% of Seychelles' total mangrove carbon stocks. Most of the carbon stock on Mahé is stored within the soils (87.2%). In contrast, La Digue, Silhouette and Curieuse have higher plant carbon stocks per hectare (Figure 8). On Mahé, 69% of current mangrove forests are protected, as Port Launay Coastal Wetlands (124 ha) was designated a Wetland of International Importance under the Ramsar Convention in 2004 (Ramsar Sites Information Service 2013). Mahé supports the greatest diversity of mangrove species (6 species registered in this study), with Port Launay home to seven (Alcindor 2015) of eight species of mangroves found in Seychelles (Palacios et al. 2021a), which provide important habitats for species of industrial value (Senterre et al. 2015). A study investigating global patterns in mangrove soil carbon stocks found that mixed mangrove stands had 20% higher soil carbon stocks per unit area compared to monotypic stands (Atwood et al. 2017). As Mahé is home to ~86% of Seychelle's total population, mangrove forests face direct impacts from urban activities (i.e., coastal development, pollution, water quality), however, there is no available data or information on historical mangrove loss across Mahé. The mapping of mangrove distribution and species (Alcindor 2015), and temporal changes in extent (Constance et al. 2021) could be replicated across Mahé and many of the different islands in Seychelles. This information is essential so that these ecosystems can be properly managed and protected, and to support decision-makers and land managers to understand the restoration opportunities in the country.

The protection, conservation, and restoration of blue carbon ecosystems including mangrove forests are natural climate solutions and can play an important role in achieving the 1.5° Celsius pathway laid out by the Paris Agreement. As a small island developing state, Seychelles is giving high priority to climate adaptation strategies that will improve its resilience to climate change impacts (Herr and Landis 2016). Seychelles was one of 58 countries that added new blue carbon commitments in its updated NDCs in July 2021 (GoS 2021)). Under its Adaptation Contributions, Seychelles has committed to safeguarding blue carbon ecosystems by protecting at least 50% of its seagrass and mangrove ecosystems by 2025, and 100% of its seagrass and mangrove ecosystems by 2030 (GoS 2021). However, the NDC update did not reference a baseline extent for this commitment (e.g., based on the extent of mangroves from 1950). Based on the current extent of mangrove forests (2,195 ha, Walton et al. 2019, Smith et al. 2020), Seychelles has already achieved ~84% protection of mangrove ecosystems due to the protection of mangrove forests on Aldabra Atoll (1720 ha), a UNESCO World Heritage and registered Ramsar site, and Port Launay (124 ha) on Mahé, a registered Ramsar site. The long-term protection of mangrove ecosystems on Aldabra Atoll has contributed to an overall increase of 60 ha in mangrove extent over the past 20 years (Constance et al. 2021). Seychelles has already reached its NDCs 2025 mangrove protection targets and is well on its way to achieving 100% protection by 2030. By maintaining the protection of these mangroves, Seychelles is ensuring the long-term storage of 2.1 million tonnes of CO_2e. Innovative financial mechanisms (e. g, multilateral and bilateral funds, insurance products, debt-for-nature swaps, private investment, blue carbon credits and bonds) will be needed to achieve 100% protection and support the monitoring and management of Seychelles' mangrove ecosystems.

Additionally, within its updated NDCs, Seychelles has committed to incorporating the natural GHG sink capacity of Seychelles' mangrove ecosystems within its National Greenhouse Gas Inventory (NGGI) by 2025. Based on a global mangrove sequestration rate (Alongi 2014), mangrove forests in Seychelles are sequestering 3,819.3 tonnes of C ha^{-1} yr^{-1} or 14,016.83 tonnes of CO_2e yr^{-1}. To support the inclusion of the GHG sink capacity of mangrove forests in its NGGI, Seychelles will need to establish a long-term monitoring programme for mangrove ecosystems and map the full extent of mangrove ecosystems by 2025. A long-term monitoring program should be developed to monitor the changes to plant and soil carbon stocks and sequestration rates, changes to mangrove extent and the drivers (Constance et al. 2021), vulnerability and risks to mangrove ecosystems (Tjahjono et al. 2022), and the array of co-benefits (e.g., coastal hazard mitigation, fisheries enhancement, biodiversity benefit, social values, etc.) generated by these ecosystems to coastal communities (Carnell et al. 2019). Several recent studies have undertaken mapping mangrove distribution on Aldabra Atoll (Walton et al. 2019, Constance et al. 2021), approaches that could be replicated to support long-term monitoring and fully mapping the national extent of mangrove ecosystems at higher resolution across Seychelles (further details and recommendations available on Table 8).

The IPCC has guided the inclusion of coastal wetlands within national inventories through the 2013 Wetlands Supplement (Chapter 4). However, the supplement is limited to only a handful of land-use change activities (IPCC 2014), most of which are not relevant to Seychelles. Primarily, Seychelles will be estimating emissions and removals from managed coastal wetlands that remain coastal wetlands, as 84% of its mangrove extent is currently protected. To estimate net GHG emissions or removals, Seychelles could apply the stock-difference method using Tier 2 emissions factors (i.e., country-specific emissions factors), which involves estimating the difference in carbon stocks (sum of all carbon pools) measured at two points in time (Green et al. 2021). This study has established the initial assessment (time point 1) for mangrove carbon stocks. Another field-based campaign to measure all carbon pools again at the same sites would be required at a subsequent time (time point 2). For natural healthy mangrove ecosystems, measurements every 5-10 years would be valuable.

Conclusion & Recommendations

Conclusions and Recommendations

This field-based project delivered the first local-scale data on both plant and soil organic carbon for mangrove ecosystems in the inner and outer island systems of Seychelles. A literature review revealed many knowledge gaps in mangrove research and the need for quantitative datasets for plant and soil carbon pools (Palacios et al. 2021b). A local field-based team collected over 150 soil cores and measured 132 aboveground biomass plots across 27 sites located over 7 islands (Inner islands: Mahé, Praslin, La Digue, Curieuse Island, Silhouette Island, Outer Islands: Cosmoledo and Aldabra). We found that Seychelles' mangroves store approximately 688,091 tonnes of organic carbon within their plant biomass and soils, which is equivalent to ~2.5 million tonnes CO_2e. Mangrove soils account for ~70% of Seychelles' mangrove carbon stock, with the remaining 30% stored within the plant biomass. Aldabra Atoll holds the highest total carbon stocks in Seychelles, followed by the mangrove forests on Mahé (67% and 13% of Seychelles' mangrove stocks, respectively). In addition to holding significant carbon stocks, Seychelles' mangrove forests are sequestering an additional 3,819 tonnes of C ha^{-1} yr^{-1} or 14,017 tonnes of CO_2e yr^{-1}. Overall, the results from this project will support the Seychelles Government to deliver on its blue carbon NDCs commitments.

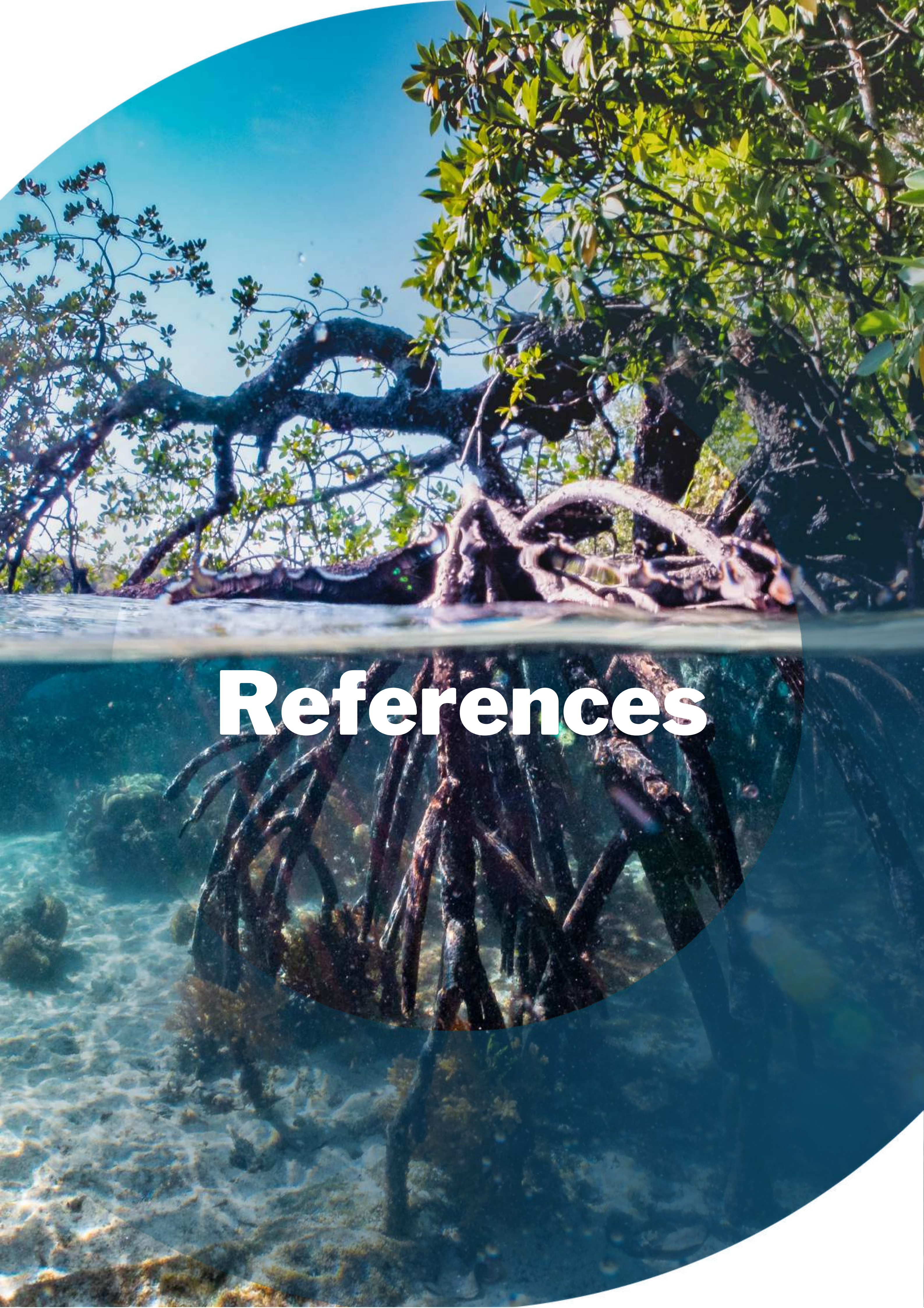
For Seychelles to benefit from the use of blue carbon ecosystems as a natural climate solution, continued advancement in mangrove research is needed. To support the advancement in research, we have made recommendations on priority areas (**Table 8**). Many of the recommendations are aligned with key objectives and actions, specifically Objective 1- advance blue carbon science and empower local scientists outlined in the Blue Carbon Roadmap (Palacios et al. 2021a). Additionally, these recommendations will support Seychelles NDCs commitment to fully map mangrove ecosystem and include the GHG sink capacity of mangrove ecosystems in the GHG inventory. The priority research areas include improving mangrove distribution maps and monitoring changes in ecosystem extent to accurately account for mangrove carbon stock. Measuring soil carbon sequestration in Seychelles mangrove soils is needed to determine how much additional carbon mangrove ecosystems are sequestering annually. Seychelles should establish a monitoring program of key indicators (biophysical, socio-economic, and climatic factors) to assess the risk of ecosystem degradation and the drivers of degradation. This information will support the development of blue carbon projects within Seychelles. Finally, the ecosystem services provided by mangrove forests should be quantified and valued to support the need for their protection and restoration, and access to alternative financial markets (e.g., payments for ecosystem services).

Table 8. Recommendations to advance mangrove research to support blue carbon as a natural climate solution in Seychelles.

Recommendations		Description
1	Improve mangrove ecosystem distribution maps	The current mangrove distribution maps (e.g., Smith et al. 2020) are likely to underestimate the extent mangrove area within Seychelles. There have been two successful and recent studies mapping mangrove distribution in Aldabra (Walton et al. 2019, Constance et al. 2021), which could be used to replicate their approach at a national scale (see Recommendation 2). Furthermore, there is the ecosystem mapping developed by Senterre and Wagner (2014), which has been successful in mapping mangroves across different inner islands. This same methodology has been currently used to develop a 2021 ecosystem mapping, which could then be used to compare the mangrove distribution extents with any future mapping. More information on Senterre's work is available at http://dx.doi.org/10.15468/q23r47.
2	Monitor changes in mangrove ecosystem extent	Investigate changes in the spatial extent of mangrove forests across Seychelles and the drivers of the extent change. This work has been recently completed for the Aldabra Atoll (Constance et al. 2021) but should be upscaled across all of Seychelles. The change in mangrove extent data is necessary to include mangrove ecosystems in Seychelles' GHG inventory.
3	Measure local mangrove soil carbon sequestration	There are currently no carbon sequestration datasets available from mangrove ecosystems in Seychelles. To estimate how much additional carbon mangrove ecosystems are drawing down each year we currently rely on a global value (1.74 tonnes ha^{-1} yr^{-1}) from Alongi (2014). To acquire local mangrove sequestration rates, we recommend the following methods to collect the data: age dating (e.g., Pb^{210}; Gulliver et al. 2020), soil marker horizons (e.g., feldspar; Krauss et al. 2003) or rod surface elevation tables (rSETS; Cahoon et al. 2002). This

		information would support determining changes in carbon stocks and modelling blue carbon sequestration and restoration potential in Seychelles.
4	Model blue carbon stocks and sequestration from mangrove ecosystems	Model and map mangrove carbon stock and sequestration and their drivers of change (Ewers Lewis et al. 2020, Costa et al. 2021, Young et al. 2021). To undertake this recommendation, additional data needs to be collected (outlined in Table S1).
5	Monitor changes in mangrove aboveground biomass	Seychelles' mangrove forests hold 31% of their carbon stock in their aboveground biomass (AGB). Therefore, it is important to continue to monitor and quantify changes to AGB periodically. Field-based measurements carried out in this project and Constance et al. (2022) are one method, but with improvements in technology there is a possibility to use unmanned aerial vehicles (UAV; Navarro et al. 2020), or remote sensing (Simard et al. 2019, Nguyen and Nguyen 2021) to estimate AGB in mangrove forests which could help reduce field and staff related costs. During this project's field campaign, UAV imagery was collected from most sites and is available for a researcher to process it.
6	Determine changes in carbon stocks/pools	In its updated NDCs, Seychelles committed to establishing a long-term monitoring programme for mangrove ecosystems and including the GHG sink of blue carbon ecosystems within the National Greenhouse Gas Inventory by 2025. Estimating net GHG emissions can involve estimating the difference in carbon stocks (the sum of all carbon pools) measured at two points in time. This study has established the initial assessment (time point 1) for mangrove carbon stocks. Another field-based campaign to measure all carbon pools again at the same sites would be required at a subsequent time (time point 2). For natural ecosystems measurements every 5-10 years would be valuable.
7	Establish a monitoring program for mangrove ecosystem degradation	A systematic collection of indicator data on the biophysical, socio-economic, and climatic factors that influence mangrove forests should be established to measure the vulnerability and risk to Seychelles mangrove ecosystems (Tjahjono et al. 2022). Quantitative models can also be developed using remote sensing to monitor and map mangrove ecosystem degradation (Lee et al. 2021). This information will be important for identifying blue carbon projects in Seychelles and identifying GHG emissions from mangrove ecosystem loss due to land-use change that need to be accounted for in the GHG inventory.
8	Quantify co-benefits provided by Seychelles' mangroves	In addition to carbon sequestration, mangrove ecosystems provide many benefits to humans such as supporting coastal fisheries, protecting coastlines, improving water quality, supporting biodiversity, and providing areas for tourism. It is important to map and quantify the range of ecosystem services that

		mangroves provide to Seychellois' (Carnell et al. 2019, Afonso et al. 2021). Economic valuations of mangrove ecosystem services provide compelling arguments for proper protection and management (Carnell et al. 2019, 2022, Costa et al. 2022b), but also create a market for payment for ecosystem services.
9	Map mangrove ecosystem restoration potential	Model blue carbon restoration opportunities using the Coastal Blue Carbon InVEST model to estimate future net carbon sequestration in mangrove ecosystems in Seychelles, considering different management scenarios at different spatial scales (Moritsch et al. 2021, Wedding et al. 2021, Costa et al. 2022a). Given that Seychelles has already protected ~84% of its mangrove ecosystems, this recommendation has lower priority over the others listed in the table.
10	Measure greenhouse gas fluxes from soil and vegetation from mangrove ecosystems.	Estimating net GHG emissions from mangrove ecosystems for the GHG inventory can also be estimated by measuring or modelling the GHG flux between the soil and vegetation and the atmosphere or water. The most common method is using static chambers described in Chapter 5 of the Blue Carbon Manual (Howard et al. 2014). Based on equipment availability in Seychelles we would recommend using the changes in the carbon stock approach outlined above.



References

References

Afonso, F., P. M. Félix, P. Chainho, J. A. Heumüller, R. F. de Lima, F. Ribeiro, and A. C. Brito. 2021. Assessing Ecosystem Services in Mangroves: Insights from São Tomé Island (Central Africa).

Alcindor, A. 2015. Mapping the distribution and composition of mangrove species: A case study in the Seychelles. Kingston University London.

Alongi, D. M. 2014. Carbon Cycling and Storage in Mangrove Forests. Pages 195–219 *in* S. Carlson, CA and Giovannoni, editor. ANNUAL REVIEW OF MARINE SCIENCE, VOL 6. ANNUAL REVIEWS, 4139 EL CAMINO WAY, PO BOX 10139, PALO ALTO, CA 94303-0897 USA.

Alongi, D. M. 2020. Global Significance of Mangrove Blue Carbon in Climate Change Mitigation.

Arkema, K. K., G. Guannel, G. Verutes, S. A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, and J. M. Silver. 2013. Coastal habitats shield people and property from sea-level rise and storms. Nature Climate Change 3:913–918.

Arkema, K. K., G. M. Verutes, S. A. Wood, C. Clarke-Samuels, S. Rosado, M. Canto, A. Rosenthal, M. Ruckelshaus, G. Guannel, J. Toft, J. Faries, J. M. Silver, R. Griffin, and A. D. Guerry. 2015. Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. Proceedings of the National Academy of Sciences 112:7390 LP – 7395.

Atwood, T. B., R. M. Connolly, H. Almahasheer, P. E. Carnell, C. M. Duarte, C. J. Ewers Lewis, X. Irigoien, J. J. Kelleway, P. S. Lavery, P. I. Macreadie, O. Serrano, C. J. Sanders, I. Santos, A. D. L. Steven, and C. E. Lovelock. 2017. Global patterns in mangrove soil carbon stocks and losses. Nature Climate Change 7:523–528.

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman. 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81:169–193.

Braithwaite, C. J. R., J. D. Taylor, W. J. Kennedy, and T. S. Westoll. 1973. The evolution of an atoll: the depositional and erosional history of Aldabra. Philosophical Transactions of the Royal Society of London. B, Biological Sciences 266:307–340.

Cahoon, D. R., J. C. Lynch, B. C. Perez, B. Segura, R. D. Holland, C. Stelly, G. Stephenson, and P. Hensel. 2002. High-precision measurements of wetland sediment elevation. II The rod surface elevation table. Journal of Sedimentary Research 72:734–739.

Carnell, P. E., S. E. Reeves, E. Nicholson, P. Macreadie, D. Ierodiaconou, M. Young, J. Kelvin, H. Janes, A. Navarro, J. Fitzsimons, and C. L. Gillies. 2019. Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature.

Carnell, P., R. McLeod, M. Young, C. Gillies, C. Obst, P. Macreadie, D. Ierodiaconou, S. Reeves, M. Eigenraam, H. Janes, J. Kelvin, and E. Nicholson. 2022. Prioritising the restoration of marine and coastal ecosystems using ecosystem accounting. PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1617940/v1].

Chave, J., C. Andalo, S. Brown, M. A. Cairns, J. Q. Chambers, D. Eamus, H. Folster, F.

Fromard, N. Higuchi, T. Kira, J. P. Lescure, B. W. Nelson, H. Ogawa, H. Puig, B. Riera, and T. Yamakura. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. OECOLOGIA 145:87–99.

Claudino-Sales, V. 2019. Aldabra Atoll, Seychelles BT - Coastal World Heritage Sites. Pages 265–270 *in* V. Claudino-Sales, editor. Springer Netherlands, Dordrecht.

Cleyndert, G. J., A. Cuni-Sanchez, H. A. Seki, D. D. Shirima, P. K. T. Munishi, N. D. Burgess, K. Calders, and R. Marchant. 2020. The effects of seaward distance on above and below ground carbon stocks in estuarine mangrove ecosystems. CARBON BALANCE AND MANAGEMENT 15.

Clough, B. F., and K. Scott. 1989. Allometric relationships for estimating above-ground biomass in six mangrove species. Forest Ecology and Management 27:117–127.

Constance, A. 2016. Mangroves on Aldabra – habitat change trends, stand structure and species composition. University of Zurich.

Constance, A. 2022. The Ecology of Mangrove and Coastal Ecosystems for Conservation. PhD thesis submitted to University of Zurich. Switzerland.

Constance, A., P. J. Haverkamp, N. Bunbury, and G. Schaepman-Strub. 2021. Extent change of protected mangrove forest and its relation to wave power exposure on Aldabra Atoll. Global Ecology and Conservation 27:e01564.

Constance, A., J. Oehri, N. Bunbury, G. L. B. Wiesenberg, F. Pennekamp, L. A'Bear, F. Fleischer-Dogley, and G. Schaepman-Strub. 2022. Soil nutrient content and water level variation drive mangrove forest aboveground biomass in the lagoonal ecosystem of Aldabra Atoll. Ecological Indicators 143:109292.

Costa, M. D. de P., C. E. Lovelock, N. J. Waltham, M. M. Moritsch, D. Butler, T. Power, E. Thomas, and P. I. Macreadie. 2022a. Modelling blue carbon farming opportunities at different spatial scales. Journal of Environmental Management 301:113813.

Costa, M. D. de P., C. E. Lovelock, N. J. Waltham, M. Young, M. F. Adame, C. V Bryant, D. Butler, D. Green, M. A. Rasheed, C. Salinas, O. Serrano, P. H. York, A. A. Whitt, and P. I. Macreadie. 2021. Current and future carbon stocks in coastal wetlands within the Great Barrier Reef catchments. Global Change Biology.

Costa, M. D. de P., M. Wartman, P. I. Macreadie, D. Ierodiaconou, R. L. Morris, E. Nicholson, A. Pomeroy, M. Young, and P. E. Carnell. 2022b. Mapping the benefits and costs of management actions for coastal wetlands in Victoria.

Donato, D. C., J. B. Kauffman, D. Murdiyarso, S. Kurnianto, M. Stidham, and M. Kanninen. 2011. Mangroves among the most carbon-rich forests in the tropics. NATURE GEOSCIENCE 4:293–297.

Duarte, C. M., S. Agusti, E. Barbier, G. L. Britten, J. C. Castilla, J.-P. Gattuso, R. W. Fulweiler, T. P. Hughes, N. Knowlton, C. E. Lovelock, H. K. Lotze, M. Predragovic, E. Poloczanska, C. Roberts, and B. Worm. 2020. Rebuilding marine life. Nature 580:39–51.

Duarte, C. M., I. J. Losada, I. E. Hendriks, I. Mazarrasa, and N. Marba. 2013. The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change 3:961–968.

Elith, J., J. R. Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. Journal of Animal Ecology 77:802–813.

ESRI. 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Redlands, CA.

Ewers Lewis, C. J., M. A. Young, D. Ierodiaconou, J. A. Baldock, B. Hawke, J. Sanderman, P. E. Carnell, and P. I. Macreadie. 2020. Drivers and modelling of blue carbon stock variability in sediments of southeastern Australia. BIOGEOSCIENCES 17:2041–2059.

Fourqurean, J. W., C. M. Duarte, H. Kennedy, N. Marba, M. Holmer, M. A. Mateo, E. T. Apostolaki, G. A. Kendrick, D. Krause-Jensen, K. J. McGlathery, and O. Serrano. 2012. Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5:505–509.

Friess, D. A., E. S. Yando, J. B. Alemu, L.-W. Wong, S. D. Soto, and N. Bhatia. 2020. Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes. Oceanography and Marine Biology: An Annual Review 58:107–142.

Gillerot, L., E. Vlaminck, D. J. R. De Ryck, D. M. Mwasaru, H. Beeckman, and N. Koedam. 2018. Inter- and intraspecific variation in mangrove carbon fraction and wood specific gravity in Gazi Bay, Kenya. Ecosphere 9:e02306.

Goldberg, L., D. Lagomasino, N. Thomas, and T. Fatoyinbo. 2020. Global declines in human-driven mangrove loss. Global Change Biology 26:5844– 5855.

GoS. 2021. Seychelles' Updated Nationally Determined Contribution: Submission under the Paris Agreement, July 2021.

Green, C., C. Es. S. Lovelock, V. Hagger, and S. Crooks. 2021. Coastal wetlands in National Greenhouse Gas Inventories: Advice on reporting emissions and removal from management of blue carbon ecosystems.

Gulliver, A., P. E. Carnell, S. M. Trevathan-tackett, M. D. de P. C. Costa, P. Masqué, and P. I. Macreadie. 2020. Estimating the Potential Blue Carbon Gains From Tidal Marsh Rehabilitation : A Case Study From South Eastern Australia. Frontiers in Marine Science 7:403.

Hamilton, S. E., and D. A. Friess. 2018. Global carbon stocks and potential emissions due to mangrove deforestation from 2000 to 2012. Nature Climate Change 8:240–244.

Harris, D., W. Horwath, and C. Kessel. 2001. Acid Fumigation of Soils to Remove Carbonates Prior to Total Organic Carbon or Carbon-13 Isotopic Analysis. Soil Science Society of America Journal - SSSAJ 65:1853–1856.

Henriette, E. 2015. Biodiversity assesment of the Port Launay mangroves, Mahé, Syechelles. Mahé, Seychelles.

Herr, D., and E. Landis. 2016. Coastal blue carbon ecosystems. Opportunities for Nationally Determined Contributions. IUCN and Washington, DC, USA: TNC, Gland, Switzerland.

Himes-Cornell, A., S. O. Grose, and L. Pendleton. 2018a. Mangrove Ecosystem Service Values and Methodological Approaches to Valuation: Where Do We Stand? Frontiers in Marine Science 5.

Himes-Cornell, A., L. Pendleton, and P. Atiyah. 2018b. Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. Ecosystem Services 30:36–48.

Howard, J., S. Hoyt, K. Isensee, M. Telszewski, and E. Pidgeon. 2014. Coastal blue carbon:

methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses. Conservation International, Intergovernmental Oceanographic Comission of UNESCO, International Union for Conservation of Nature, Arlington, Virginia.

IPCC. 2014. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Page (T. Hiraishi, T. Krug, K. Tanabe, N. Srivastava, J. Baasansuren, M. Fukuda, and T. G. Troxler, Eds.). IPCC, Switzerland.

Jones, T. G., H. R. Ratsimba, L. Ravaoarinorotsihoarana, L. Glass, L. Benson, M. Teoh, A. Carro, G. Cripps, C. Giri, S. R. Gandhi, Z. Andriamahenina, R. Rakotomanana, and P. S. Roy. 2015. The Dynamics, Ecological Variability and Estimated Carbon Stocks of Mangroves in Mahajamba Bay, Madagascar.

Kamau, J. N., J. C. Ngila, B. Kirui, S. Mwangi, C. M. Kosore, V. Wanjeri, and S. Okumu. 2015. Spatial variability of the rate of organic carbon mineralization in a sewage-impacted mangrove forest, Mikindani, Kenya. Journal of Soils and Sediments 15:2466–2475.

Kauffman, J. B., M. F. Adame, V. B. Arifanti, L. M. Schile-Beers, A. F. Bernardino, R. K. Bhomia, D. C. Donato, I. C. Feller, T. O. Ferreira, M. C. Jesus Garcia, R. A. MacKenzie, J. P. Megonigal, D. Murdiyarso, L. Simpson, and H. Hernández Trejo. 2020. Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients. Ecological Monographs 90:e01405.

Kauffman, J. B., and D. C. Donato. 2012. Protocols for the measurement, monitoring and reporting of structure, biomass, and carbon stocks in mangrove forests. Working Pa. CIFOR, Bogor, Indonesia.

Kauffman, J. B., C. Heider, T. G. Cole, K. A. Dwire, and D. C. Donato. 2011. Ecosystem Carbon Stocks of Micronesian Mangrove Forests. WETLANDS 31:343–352.

Komiyama, A., S. Poungparn, and S. Kato. 2005. Common allometric equations for estimating the tree weight of mangroves. Journal of Tropical Ecology 21:471–477.

Krauss, K. W., J. A. Allen, and D. R. Cahoon. 2003. Differential rates of vertical accretion and elevation change among aerial root types in Micronesian mangrove forests. Estuarine, Coastal and Shelf Science 56:251–259.

Lee, C. K. F., C. Duncan, E. Nicholson, T. E. Fatoyinbo, D. Lagomasino, N. Thomas, T. A. Worthington, and N. J. Murray. 2021. Mapping the Extent of Mangrove Ecosystem Degradation by Integrating an Ecological Conceptual Model with Satellite Data. Remote Sensing 13:2047.

Liyan, Y., F. Zhongke, L. Yingchun, L. Jincheng, and S. Renjie. 2018. Method of Measuring Tree Height and Volume Based on CCD SmartStation. Nature Environment and Pollution Technology:1305–1313.

Macnae, W., T. S. Westoll, and D. R. Stoddart. 1971. Mangroves on Aldabra. Philosophical Transactions of the Royal Society of London. B, Biological Sciences 260:237–247.

Macreadie, P. I., M. D. P. Costa, T. B. Atwood, D. A. Friess, J. J. Kelleway, H. Kennedy, C. E. Lovelock, O. Serrano, and C. M. Duarte. 2021. Blue carbon as a natural climate solution. Nature Reviews Earth & Environment 2:826–839.

Mcleod, E., G. L. Chmura, S. Bouillon, R. Salm, M. Björk, C. M. Duarte, C. E. Lovelock, W. H. Schlesinger, and B. R. Silliman. 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2.

Frontiers in Ecology and the Environment 9:552–560.

Moritsch, M. M., M. Young, P. Carnell, P. I. Macreadie, C. Lovelock, E. Nicholson, P. T. Raimondi, L. M. Wedding, and D. Ierodiaconou. 2021. Estimating blue carbon sequestration under coastal management scenarios. Science of the Total Environment 777:145962.

Navarro, A., M. A. Young, B. Allan, P. E. Carnell, P. I. Macreadie, and D. Ierodiaconou. 2020. The application of Unmanned Aerial Vehicles (UAVs) to estimate above-ground biomass of mangrove ecosystems. REMOTE SENSING OF ENVIRONMENT 242.

Nguyen, H.-H., and T. T. H. Nguyen. 2021. Above-ground biomass estimation models of mangrove forests based on remote sensing and field-surveyed data: Implications for C-PFES implementation in Quang Ninh Province, Vietnam. Regional Studies in Marine Science 48:101985.

Njana, M. A., H. Meilby, T. Eid, E. Zahabu, and R. E. Malimbwi. 2016. Importance of tree basic density in biomass estimation and associated uncertainties: a case of three mangrove species in Tanzania. Annals of Forest Science 73:1073–1087.

Nourice, B. 2015a. Soil sample analysis report for Petit Barbaron and Anse Royale, Mahé. Submitted to the Terrestrial Restoration Action Society Seychelles (TRASS) by the Soil and Plant Diagnostic Laboratory, Seychelles Agricultural Agency (SAA). Seychelles.

Nourice, B. 2015b. Soil sample analysis report for Curieuse and Praslin Sites. Submitted to the Terrestrial Restoration Action Society Seychelles (TRASS) by the Soil and Plant Diagnostic Laboratory, Seychelles Agricultural Agency (SAA). Seychelles.

Nourice, B. 2016. Soil sample analysis report submitted to Ephelia Resort and SPA.

Palacios, M., M. Costa, M. Wartman, A. Ebrahim, and P. Macreadie. 2021a. Seychelles' mangrove research and legislation.

Palacios, M. M., M. D. de P. Costa, M. Wartman, A. Ebrahim, and P. I. Macreadie. 2022. Seychelles' Blue Carbon Roadmap.

Palacios, M., P. Waryszak, M. Costa, M. Wartman, A. Ebrahim, and P. Macreadie. 2021b. Literature Review: Blue Carbon research in the Tropical Western Indian Ocean. Deakin University, Australia.

Ramsar Sites Information Service. 2010. Aldabra Atoll. https://rsis.ramsar.org/ris/1887.

Ramsar Sites Information Service. 2013. Port Launay Coastal Wetlands. https://rsis.ramsar.org/ris/1432.

Sanderman, J., T. Hengl, G. Fiske, K. Solvik, M. F. Adame, L. Benson, J. J. Bukoski, P. E. Carnell, M. Cifuentes-Jara, D. C. Donato, C. Duncan, E. M. Eid, P. Ermgassen, C. J. Ewers Lewis, P. I. Macreadie, L. Glass, S. K. Gress, S. L. Jardine, T. G. Jones, E. N. Nsombo, M. M. Rahman, C. J. Sanders, M. Spalding, and E. Landis. 2018. A global map of mangrove forest soil carbon at 30 m spatial resolution. Environmental Research Letters 13:55002.

Sefton, J. P., and S. A. Woodroffe. 2021. Assessing the use of mangrove pollen as a quantitative sea-level indicator on Mahé, Seychelles. Journal of Quaternary Science 36:311–323.

Senterre, B., E. Henriette, J.-C. Labrosse, J. Pinchart, and N. Senaratne. 2015. RAPID

BIODIVERSITY ASSESSMENT OF ANSE ROYALE AND NORTH-EAST POINT WETLANDS (MAHÉ, SEYCHELLES). GOS- UNDP-GEF. Mahé, Seychelles.

Senterre, B., and M. Wagner. 2014. Mapping Seychelles habitat-types on Mahé, Praslin, Silhouette, La Digue and Curieuse. Victoria, Seychelles.

Simard, M., L. Fatoyinbo, C. Smetanka, V. H. Rivera-Monroy, E. Castaneda-Moya, N. Thomas, and T. Van der Stocken. 2019. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. Nature Geoscience 12:40–45.

Simard, M., L. Fatoyinbo, C. Smetanka, V. H. Rivera-Monroy, E. Castañeda-Moya, N. Thomas, and T. Van der Stocken. 2018. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. Nat. Geosci. 12:40–45.

Sitoe, A. A., L. J. Mandlate, and B. S. Guedes. 2014. Biomass and Carbon Stocks of Sofala Bay Mangrove Forests.

Smith, J. L., R. Tingey, and H. E. Sims. 2020. Seychelles Marine Spatial Plan Atlas. Developed by The Nature Conservancy for the Seychelles MSP Initiative.

Tjahjono, R. E. P., Perdinan, K. G. Lestari, C. S. Putri, E. I. Putra, Yonvitner, S. B. Agus, Adriani, R. F. Adi, S. Aprilia, I. Mustofa, S. D. Pratiwi, R. A. Basit, A. Wibowo, Kardono, K. Wijanarka, Nuraeni, and Z. Imran. 2022. Defining indicators to measure risks of mangrove ecosystem in tropical region: case study Indonesia. IOP Conference Series: Earth and Environmental Science 959:12041.

UNESCO. 2022. Aldabra Atoll. https://whc.unesco.org/en/list/185/.

Walton, R., R. Baxter, N. Bunbury, D. Hansen, F. Fleischer-Dogley, S. Greenwood, and G. Schaepman-Strub. 2019. In the land of giants: habitat use and selection of the Aldabra giant tortoise on Aldabra Atoll. Biodiversity and Conservation 28:3183–3198.

Wedding, L. M., M. Moritsch, G. Verutes, K. Arkema, E. Hartge, J. Reiblich, J. Douglass, S. Taylor, and A. L. Strong. 2021. Incorporating blue carbon sequestration benefits into sub-national climate policies. Global Environmental Change:102206.

Young, M. A., O. Serrano, P. I. Macreadie, C. E. Lovelock, P. Carnell, and D. Ierodiaconou. 2021. National scale predictions of contemporary and future blue carbon storage. Science of The Total Environment 800:149573.

Supplementary Material

Supplementary Material

Table S1: List of variables (and original datasets) found during the data search to perform the Boosted Regression Trees analysis, their relationship with SOC stocks in mangroves, resolution of dataset, source., and their gaps that limited the analysis to be completed. Wave height (m), tidal range (m) and sediment type are other variables also known to explain the variability in SOC stocks in mangroves, however, no dataset have been identified for Seychelles.

Variable	Relationship with SOC stocks in mangroves	Resolution of the dataset	Source	Gaps/Limitations
Water depth (m)	Since mangroves situated within lower elevations are inundated more often, we usually find a stronger correlation with lower elevation and SOC stocks.	15 arc-second	GEBCO	Global; however, this is the source of the bathymetry layer used in the SMSP.
Elevation (m)		30 m	Shuttle Radar Topography Mission	Global; ideally, we would use the elevation layer used locally. We did not get access to the locally used layer.
Average monthly temperate (°C)	We expect to find higher SOC stocks associated with higher temperatures.	30 seconds (~ 1 km^2)	WorldClim	Global, partial coverage over Seychelles that could still be used for an initial assessment.
Average monthly precipitation (mm)	Higher precipitation rates are usually associated with an increase of SOC stocks due to an increase in freshwater runoffs.	30 seconds (~ 1 km^2)	WorldClim	Global, partial coverage over Seychelles that could still be used for an initial assessment.
Average monthly solar radiation (kJ m^{-2} day^{-1})	Plant productivity, and consequently SOC stocks, can be influenced by solar radiation.	30 seconds (~ 1 km^2)	WorldClim	Global, partial coverage over Seychelles that could still be used for an initial assessment.
Fetch (km)	Indicative of hydrodynamic energy; enhanced sediment export and erosion can	Estimated at the needed resolution through the	FetchR package	This variable can be calculated to any resolution needed.

	decrease SOC stocks.	fetchR package		
Island type (inner vs. outer; granitic, etc)	Island type and position can influence the amount of sediment trapped within mangroves, and therefore, influence the amount of SOC stocks.	Classification can be done at any resolution needed.	NA	This variable can be classified at any resolution needed.
Closest freshwater source (km)	Freshwater runoff can increase SOC stocks	Euclidean distance (km) calculated from the spatial layer showing the freshwater sources	HydroSHEDS at 3 arc-seconds	Global; limited coverage over Seychelles. We recommend the usage of a local dataset.
Annual average sea surface temperature (°C)	Changes in sea surface temperature and salinity may lead to changes in carbon stocks, which are likely to lead to species-specific responses.	5 arc-min	Bio-ORACLE v2.0	Global; no coverage over Seychelles
Annual average sea surface salinity (PPS)		5 arc-min	Bio-ORACLE v2.0	Global; no coverage over Seychelles
Annual average water current speed (m s^{-1})	Indicative of hydrodynamic energy; enhanced sediment export and erosion can decrease SOC stocks.	5 arc-min	Bio-ORACLE v2.0	Global; no coverage over Seychelles
Ocean currents during northwest and southwest monsoon (magnitude and direction)	Indicative of hydrodynamic energy; enhanced sediment export and erosion can decrease SOC stocks.	Not available within the SMSP spatial layer	SMSP	Global; but extracted at the Seychelles level. This layer was used in the SMSP.
Land use cover	Indicator of potential freshwater sources and the intensity of human-related activities	2.5 m	Homisland-IO	This layer only covers Mahé.

Table S2: Estimated total blue carbon stocks within the entire mangrove distribution in Seychelles. Mangrove extent (ha) for different islands from the Seychelles Archipelago were calculated based on Smith et al. (2020), except by mangrove extent in Aldabra Atoll, which was based on Walton et al. (2019). Total carbon estimates were based on the average (±SE) values of soil carbon stocks for each island. *For islands that were not included in the field sampling, we used the total average soil carbon stocks to inform the calculations.

Island	Mangrove Area (ha)	Total AGC stocks (tonnes)	Total BGC Stocks (tonnes)	Total SOC Stocks (tonnes)	TOTAL (tonnes)
Mahé	181	6,190	5,665	80,484	92,340
Praslin	68	2,910	3,101	28,914	34,925
La Digue	23	2,111	1,419	10,478	14,008
Curieuse	11	872	768	4,456	6,097
Silhouette	3	492	412	1,287	2,191
North Island*	2	95	88	639	822
Therese*	0.4	19	18	128	164
Marianne*	0.1	5	4	31.98	41
Aldabra	1,720	83,076	85,656	293,719	462,451
Cosmoledo	112	4,648	3,461	36,390	44,499
Astove*	39	1,850	1,716	12,471	16,037
Farquhar*	25	1,186	1,100	7,994	10,280
St Joseph Atoll*	7	332	308	2,238	2,878
Île du Sud*	2	95	88	639	822
Poivre*	1	47	44	320	411
St. Francois*	0.3	14	13	96	123
			Total		688,091

Project contacts

Dr Melissa Wartman
m.wartman@deakin.edu.au

Dr Micheli Costa
micheli.costa@deakin.edu.au

Professor Peter Macreadie
p.macreadie@deakin.edu.au

Blue Carbon Lab