The Potential of Blue Carbon Project in Mozambique:

A Feasibility Assessment of the Primeiras and Segundas Environmental Protected Area

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Cover: Mangrove of Angoche, Mozambique. Photo by **James Kairo**

About the Blue Forests Project

The Global Environment Facility's (GEF) Blue Forests Project is a global initiative focused on harnessing the values associated with coastal marine carbon and ecosystem services to achieve improved ecosystem management and climate resilient communities. The project is implemented by the United Nations Environment Programme (UNEP) with partners worldwide. Project sites include locations in Ecuador, Kenya, Madagascar, Mozambique, Indonesia, the United Arab Emirates, Thailand, and the United States of America. The project also addresses key 'blue forests' knowledge gaps, as well as providing experience and tools to support greater global replication and application of the blue forests methodologies and approaches.

Project website: www.gefblueforests.org

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Executive Summary

Continued loss and degradation of mangroves have heightened attention by management agencies and policy makers across the board to come up with different innovative management approaches which aims at preventing, halting and reversing mangrove degradation. Payments for ecosystem services (PES) schemes, such as Reduced Emissions from Deforestation and forest Degradation (or REDD+) are emerging as new market-based approaches for forest conservation and management in the tropics. Unfortunately, a majority of PES projects, either running or in development, concern terrestrial forests. This is despite mangroves and associated ecosystems containing substantial quantities of organic carbon

The feasibility of a mangrove REDD+ project (or Blue Carbon Project) was assessed in Primeiras and Segundas Environmental Protected Area (PSEPA) in Northern Mozambique. The following activities were undertaken: (i) determination of mangrove carbon stocks and their sequestration potential (ii) identification drivers of mangrove deforestation and degradation (iii) reviewing legal, institutional, and regulatory instruments governing mangrove management in the Mozambique

There are 53,582 ha of mangroves in PSEPA, distributed in Angoche, Larde, Moma and Pebane districts. These forests serve as habitats for fish and other wildlife, protect the shoreline from erosion, as well as providing harvestable wood and non-wood products to thousands of communities in the area. However, mangroves in PSEPA have been lost and degraded due to a combination of human and natural factors, including over-exploitation of wood resources, habitat conversion and climate change. At least 11,244.5 ha of mangroves were lost between 1998 and 2018; representing a decline of 562.2 ha/yr. This could have activated greenhouse emissions from the lost vegetation cover as well as from the top 1.0m of sediments. Setting aside only 10% of PSEPA mangroves for blue carbon project would abate emissions of 165,376.7 CO_2e/yr thus generating an income of US$ 1,653,766.5/yr plus other benefits such as shoreline protection and biodiversity conservation. The next step would be to prepare Project Idea Note (PIN) and Project Design Document (PDD) detailing institutional, policy and legal capacity to support a blue carbon project; as well as benefit-sharing scheme.

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Abbreviations and Acronyms

AFOLU	Agriculture, Forestry and other Land Use
AGB	Aboveground Biomass
ANAC	National Administration of Conservation Areas
BAF	Blue Action Fund
BGB	Below-ground Biomass
CBD	Convention on Biological Diversity
CCP	Conselho Comunitários de Pesca (Community Fisheries Council)
CGRN	Comité de Gestão de Recursos Naturais (Natural Resource Management committee)
DBH	Diameter at Breast Height
EIA	Environmental Impact Assessment
ES	Ecosystem services
FAO	Food and Agriculture Organization
GEF	Global Environmental Facility
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
IV	Importance Value
KMFRI	Kenya Marine and Fisheries Research Institute
LDC	Least Developed Country
MPA	Marine Protected Area
MICOA	Ministry for Coordination of Environmental Affairs
MITADER	Ministry of Land, Environment and Rural Development
NCCAMS	National Climate Change Adaptation and Mitigation Strategy
NCE	National Commission on Environment
PES	Payment for Ecosystem Services
PSEPA	Primeiras and Segundas Environmental Protection Area
REDD	Reducing Emissions from Deforestation and Forest Degradation
SADC	Southern African Development Community
SBEC	Sustainable Blue Economy Conference
SRTM	Shuttle Radar Topography Mission
ToR	Terms of Reference
UNEP	United Nations Environment Program

UNFCCC	United Nations Framework Convention on Climate Change
VER	Verifiable Emission Reduction
WIO	Western Indian Ocean
WRC	Wetlands Restoration and Conservation
WWF	World Wide Fund for Nature
WWF-MCO	World Wide Fund for Nature- Mozambique Country Office

Conversion Table

Value (grams)	**Unit**	**Name**
10^3	Kg	Kilogram
10^6	Mg	Megagram (tonne)
10^9	Gg	Gigagram
10^{12}	Tg	Teragram
10^{15}	Pg	Petagram
10^{18}	Eg	Exagram
10^{21}	Zg	Zettagram

One Gigatonne = 1000 Teragrams
One hectare = 10,000 square meters

Glossary

Afforestation: Is the establishment of a forest or stand of trees in an area where there was no forest

Biomass: The weight of all parts of the tree, not only the trunk but also the bark, the branches, the leaves, and even the roots

Carbon credit: a commodity traded on the carbon market and that permits a country or entity to emit one tonne of carbon dioxide or carbon dioxide equivalent (tCO_2e)

Carbon offset: is as an instrument representing the reduction, avoidance or sequestration of one metric tonne of carbon dioxide or greenhouse gas equivalent

Carbon Sequestration: The removal of carbon from the atmosphere and long-term storage in sinks, such as marine or terrestrial ecosystems

Carbon stock: The total amount of organic carbon stored in an ecosystem

Compliance Carbon Market: is a marketplace through which regulated entities obtain and surrender emissions permits (allowances) or offsets in order to meet predetermined regulatory targets.

Deforestation: The clearing of forests or conversion of forest land to non-forest uses.

Forest degradation: The reduction of the capacity of a forest to provide goods and services. It involves biotic or abiotic processes that result in the loss of productive potential of natural resources in areas that remain classified as forests.

Natural regeneration: Is a process where propagules or seeds of mangroves are naturally recruitment. This may occur in both degraded and non-degraded forest

Reforestation: Is the reestablishment of forest cover, either naturally (by natural seeding, coppice, or root suckers) or artificially (by direct seeding or planting)

Voluntary Carbon Market: Are offset markets created outside of governmental regulatory schemes by firms and individuals voluntarily buying carbon offsets to reduce their greenhouse gas (GHG) emissions for learning, image management, or regulation anticipation purposes.

1.0 INTRODUCTION

1.1 Background and Purpose

This feasibility report is for the establishment of a blue carbon project within the Primeiras and Segundas Environmental Protected Area (PSEPA) of Mozambique. The area is endowed with a diversity of habitats, such as mangrove forests, seagrass beds, and coral reefs that support high biodiversity and community livelihood. However, the region is extremely vulnerable to changes occurring due to increased frequency and intensity of extreme events such as floods, droughts, and cyclones. For instance, in 2019, cyclones Idai and Kenneth caused massive damages to infrastructure and affecting community wellbeing and livelihood within PSEPA.

World Wide Fund - Mozambique Country Office (WWF-MCO) is implementing a project on “Mozambique Blue Forests”. The Project is part of a global initiative by Global Environment Facility (GEF) focusing on the application of ‘blue forests methodologies and approaches for valuing carbon and other ecosystem services (ES)’. Component 2 of the GEF’s Blue Forest Project describes the application of blue forest methodologies for carbon accounting and ecosystem services valuation. This is achieved through; (i), improving understanding of ecosystem services, carbon capture and storage, and avoided degradation of blue carbon ecosystems; (ii), facilitating knowledge and the management of carbon storage/sequestration and ecosystem services; (iii), capacity development on ecosystem management of blue carbon, and (iv), facilitating knowledge management for replications and upscaling blue carbon projects.

Together with provisions of multiple goods and services to humanity, mangroves and associated blue carbon ecosystems capture and store vast quantities of carbon in both above-and below-ground components (Laffoley & Grimsditch, 2009; Donato *et al.,* 2011). This carbon risks being released into the atmosphere when blue carbon ecosystems are lost or degraded thus, significantly contributing to global warming (McIvor *et al.,* 2012). A recent assessment by Thomas *et al.* (2017) estimated that close to 20% of the original mangrove cover has been lost around the world as a result of human induced stresses mainly through over-harvesting of wood products and conversion of mangrove area to other land-uses.

In Mozambique, mangroves cover a total extent of 305,400 ha (Fatoyinbo & Simard, 2013); equivalent to approximately 2.3% of global mangroves area (Giri *et al.,* 2011). These forests play an important role in the national and regional economies through the provision of wood and non-wood products to the people, supporting fisheries, coastal protection and stability as well as contributing to biodiversity conservation (Macamo *et al.,* 2016). Despite the immense benefits mangroves provide to human society, they continue to suffer high rates of degradation and destruction, with regional losses exceeding 20% in the last two decades (Fatoyinbo & Simard, 2013; Bunting *et al.,* 2018). Traditional conservation and legal instruments appear insufficient and new approaches are required to improve their management.

Payments for ecosystem services (PES) schemes, such as Reduced Emissions from Deforestation and forest Degradation (or REDD+) are emerging as new market-based approaches for forest conservation and management in the tropics. Unfortunately, a majority of PES projects, either running or in development, concern terrestrial forests. This is despite mangroves and associated ecosystems containing substantial quantities of organic carbon (Donato *et al.,* 2011). Mangroves are known to capture and store 3-4 times more carbon than any productive terrestrial forests (Kauffman & Donato, 2012; Gress *et al.,* 2017).

To safeguard the marine biodiversity in Mozambique, the government, in collaboration with the Blue Action Fund (BAF) of Germany, WWF and other partners are executing conservation and restoration activities aimed at reversing the degradation of coastal and marine ecosystems within PSEPA. The development of a blue carbon project for PSEPA would complement ongoing mangrove conservation activities by promoting an incentive-based scheme that allows communities in the area to receive direct cash payments through the sale of mangrove ecosystem services, in this case, carbon credits.

1.2 Mangroves and Climate Change

Vegetated coastal wetlands, such as mangrove forests, seagrasses and saltmarshes (commonly referred to as ‘blue carbon ecosystems’) contain substantial quantities of “blue carbon” which can be released to the atmosphere when these ecosystems are lost or degraded (Donato *et al.,* 2011). Although they occupy less than 0.5% of the world’s ocean surface area, blue carbon ecosystems are estimated to bury nearly 70% of the carbon sequestered in the world oceans (Mcleod *et al.,* 2011).

Blue carbon ecosystems are being degraded globally at an alarming rate of 1-7% per year, which is much higher than the global loss of tropical forests, estimated at 0.5% per year (Pendleton *et al.,* 2012). When blue carbon ecosystems are degraded, they not only stop taking up more carbon, but also release the already stored carbon back to the atmosphere leading to global warming (Murdiyarso *et al.,* 2012; Adame *et al.,* 2021). The “carbon sink” service is one of the numerous important benefits these ecosystems provide to human well-being, along with food security, water quality improvement, raw materials and shoreline protection among others. When degraded, co-benefits provided by mangroves are greatly diminished along with the ecosystems’ capacity to sequester carbon. Restoration and protection of blue carbon ecosystems is, therefore, recognized as a priority for both community development and climate change agendas; and carbon capture can provide sustainable income to communities through carbon credit markets. (Nellemann *et al.,* 2009; Murdiyaso *et al.,* 2015).

1.3 Mangroves in Mozambique

Mangroves occur in creeks, estuaries of major rivers, lagoons, and protected bays, distributed along the entire 2,770 km coastline (Figure 1). The total area of mangroves in Mozambique has been estimated at 305,400 ha (Fatoyinbo & Simard, 2013); representing 2.3% of global mangrove coverage (Giri *et al.,* 2011). In terms of cover, the mangroves of Mozambique are ranked the 13th largest mangrove area in the world, and the second in Africa after Nigeria (Giri *et al.,* 2011). The Zambezi river delta presents the largest mangrove coverage and the second largest continuous mangrove habitats in Africa whose mangrove extends for 180 km along the coast and 50 km inland (Barbosa *et al.,* 2001; Ferreira *et al,* 2009; Fatoyinbo & Simard, 2013).

Some eight mangrove species occur in Mozambique, including; *Rhizophora mucronata, Ceriops tagal, Sonneratia alba, Lumnitzera racemosa, Xylocarpus granatum, Bruguiera gymnorhiza, Heritiera littoralis,* and *Avicennia marina,* with the largest concentration being along river estuaries (Fatoyinbo *et al.,* 2008). *Pemphis acidula* Forst is sometimes cited as a ninth mangrove species occurring in Mozambique (Barbosa *et al.,* 2001). However, this is considered an associated species by scientists, rather than a true mangrove tree (Beentje & Bandeira, 2007; Bosire *et al.,* 2016). The country has many trans-boundary rivers draining into the Indian Ocean thus making the mangroves highly productive. Largest blocks of mangroves are found within central Mozambique, and in deltas and large river estuaries (Barbosa *et al.,* 2001), such as in Beira and the Save Rivers where mangroves extend up to 50 km inland. The northern coast is predominantly coraline, with coral reefs normally bordering the clear water subtidal areas of these locations. Mangroves are common and grow in the estuaries of the rivers, embayments and some areas protected from direct ocean currents. Extensive mangrove areas are Pemba town bay with 33,600 ha (Ferreira *et al.,* 2009) and the coastline of Nampula. Along the northern and central coastlines, mangroves can be found growing in continuous forms, however mangroves are scanty in the southern areas (Taylor *et al.,* 2003; Figure 1).

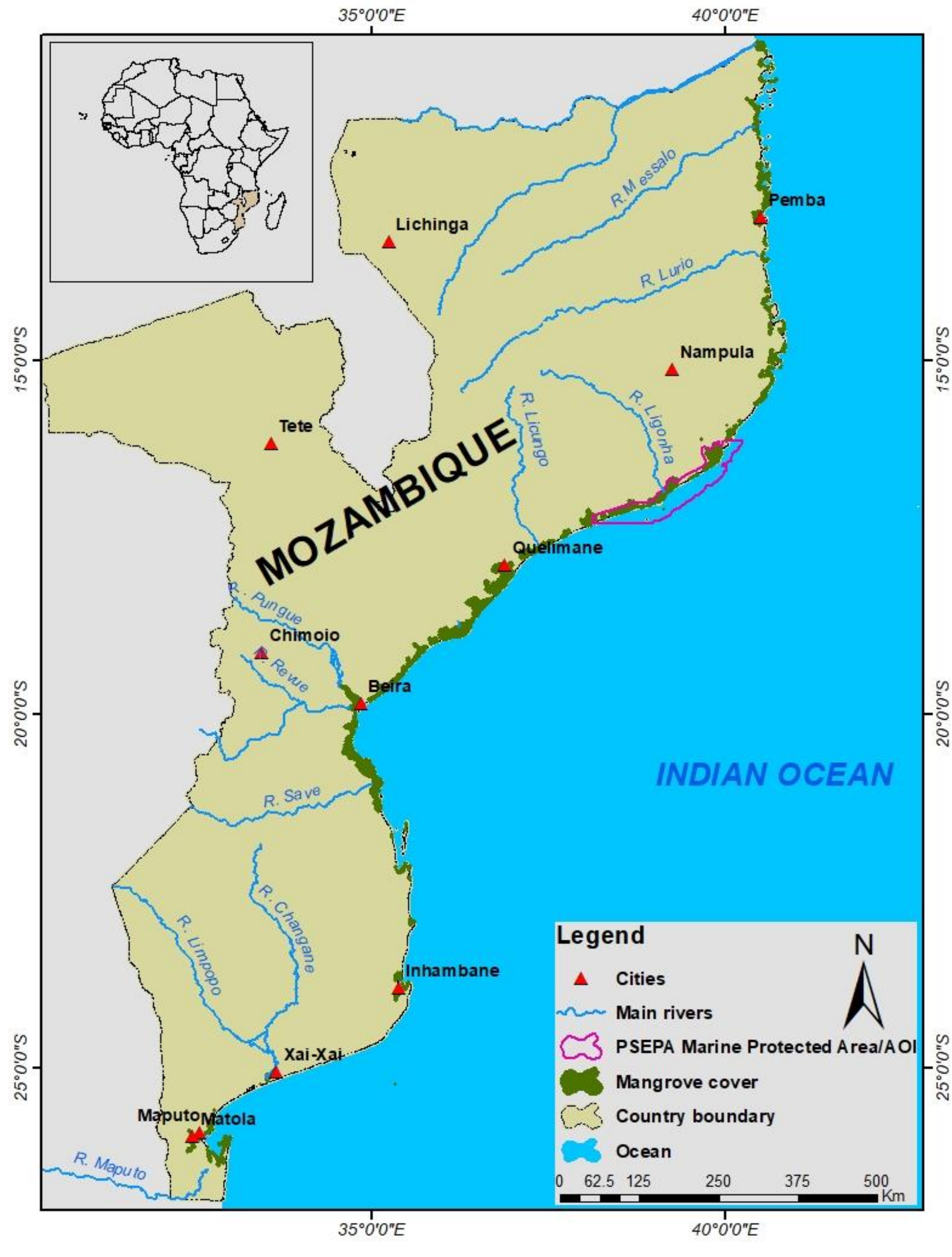

Figure 1: Distribution of mangroves along Mozambique coastline

1.3.1 Drivers of mangrove loss in Mozambique and trends

Mangroves are dynamic ecosystems; exhibiting losses and gains attributed to both human and natural causes. An annual loss of 1821 ha of mangroves in Mozambique was reported between 1972 and 1999 (Barbosa *et al.,* 2001). This was compensated by an annual gain of 786 ha of mangroves between 1994 and 2018 (WWF, 2018). It now clear that mangrove loss is outpacing gains in several areas, including protected areas such as the Zambezi Delta and PSEPA region (WWF, 2018).

More than 50% of the total human population live in coastal districts in Mozambique. As a result, population growth exerts pressure on the use of natural capital through the over-exploitation of resources, conversion pressure, pollution, mining activities, and pollution, thus contributing to their loss and degradation (Chevallier, 2013). Macamo *et al.* (2016) identified the root causes of loss and degradation of the mangroves in Mozambique as: increased population, poverty and inequality, pressure for economic growth, lack of awareness of the true value of mangroves, climate change, and poor governance. Poor governance manifests itself through habitat encroachment and illegal harvesting of mangroves (UNEP, 2012).

1.3.2 Conservation efforts of mangroves in Mozambique

The government of Mozambique has supported the conservation of mangroves through legislation and involvement of other stakeholders. This has been achieved through the development of a national mangrove management strategy (2017-2027) that aims to improve the productivity and resilience of mangrove forests for biodiversity conservation and community benefits (MITADER, 2017). During the Sustainable Blue Economy Conference (SBEC) held in Nairobi, Kenya (2018), the government committed to restore 5,000 ha of degraded mangrove areas (SBEC, 2018). Development and implementation of a blue carbon project will ensure communities in Mozambique benefit from non-consumptive uses of mangrove services including the sale of carbon credits.

In order to enhance the resilience and the productivity of mangrove forests, several mangrove conservation activities have been carried out in Mozambique. In 2010, the government initiated a reforestation project in lower Limpopo and Save rivers in order to recover the mangrove destroyed by flooding event in the year 2000. This initiative was spearheaded by the Ministry of Land, Environment and Rural Development (MITADER), and involved trial plantation of 26.3 ha of degraded intertidal area with *A. marina, B. gymnorhiza, R. mucronata, C. tagal* and *X. granatum* (Macamo *et al.,* 2016).

In central Mozambique, Stringer *et al.* (2015) assessed vegetation carbon stocks of mangrove forests. Shapiro *et al.* (2015) provided the first comprehensive estimate of mangrove coverage in Zambezi delta. With the support from government agencies, CARE-WWF Alliance formulated a management plan for PSEPA (2017-2027). This management plan aimed to establish:

(a) Nature Reserves,
(b) Sanctuaries to conserve important species for the biological and ecological balance of the region based on the Connectivity between the mangrove and Coral reefs.
(c) Formal Community Conservation Areas
(d) Tourism Investment Areas
(e) Multiple use zones

Through Blue Action Fund (BAF) of Germany, WWF and other agencies are executing conservation activities aimed at safeguarding biodiversity within and adjacent to PSEPA. Notable community-based conservation activities include; mangrove reforestation, monitoring and surveillance, as well as establishment of fish refugia within mangrove channels. Development of a Blue Carbon Project will complement on-going marine conservation activities in PSEPA through the generation of Verifiable Emission Reductions (VERs) from mangrove conservation activities.

2.0 STUDY APPROACH AND METHODOLOGY

This feasibility report is based on review and analysis of primary and secondary data on mangroves of PSEPA, site visit, community consultations and expert knowledge. The coverage of mangroves within PSEPA was established using remotely sensed data and GIS. A desktop review was carried out to establish the root causes of loss and degradation of mangroves within PSEPA. Primary data on mangroves provided by WWF and University of Edwardo Mondlane allowed the analysis of the structural attributes of the forest in terms of species richness, stocking density, biomass, natural regeneration etc. using standard procedure for mangroves. Detailed information on the methodology used in this assessment is provided in Annex 1.

The total duration of the assignment was 45 days spread over the period of November 2020 to March 2021. Due to COVID 19 disruption, part of the work was done remotely (Kenya) with limited travel. The Consultant visited Mozambique between 11th and 24th December 2020 in order to familiarize with field conditions and discuss with project proponents (Annex 2). During the mission, the Consultant met and was greatly supported by personnel from WWF-Mozambique, government officials, and the local communities. A list of persons met during the entire assignment is presented in Annex 3.

2.1 Description of the project area

The focus area of this feasibility study was Primeiras and Segundas Environmental Protected Area (PSEPA), located within Zambezia and Nampula provinces of Northern Mozambique; Latitudes 16 ° 12'S and 17 ° 17'S. Established in 2012, PSEPA is one of the largest marine protected areas in Africa with a coverage of 1,040,926 ha (WWF, 2019). The region is comprised of a chain of ten islands, two coral reef complexes and a lowland coastal region. The lowland coastal region runs approximately 10 km inland from the tide line and spans 205km along the coastline covering three districts in Nampula (Angoche, Larde and Moma) and Pebane district in Zambezia (Figure 2).

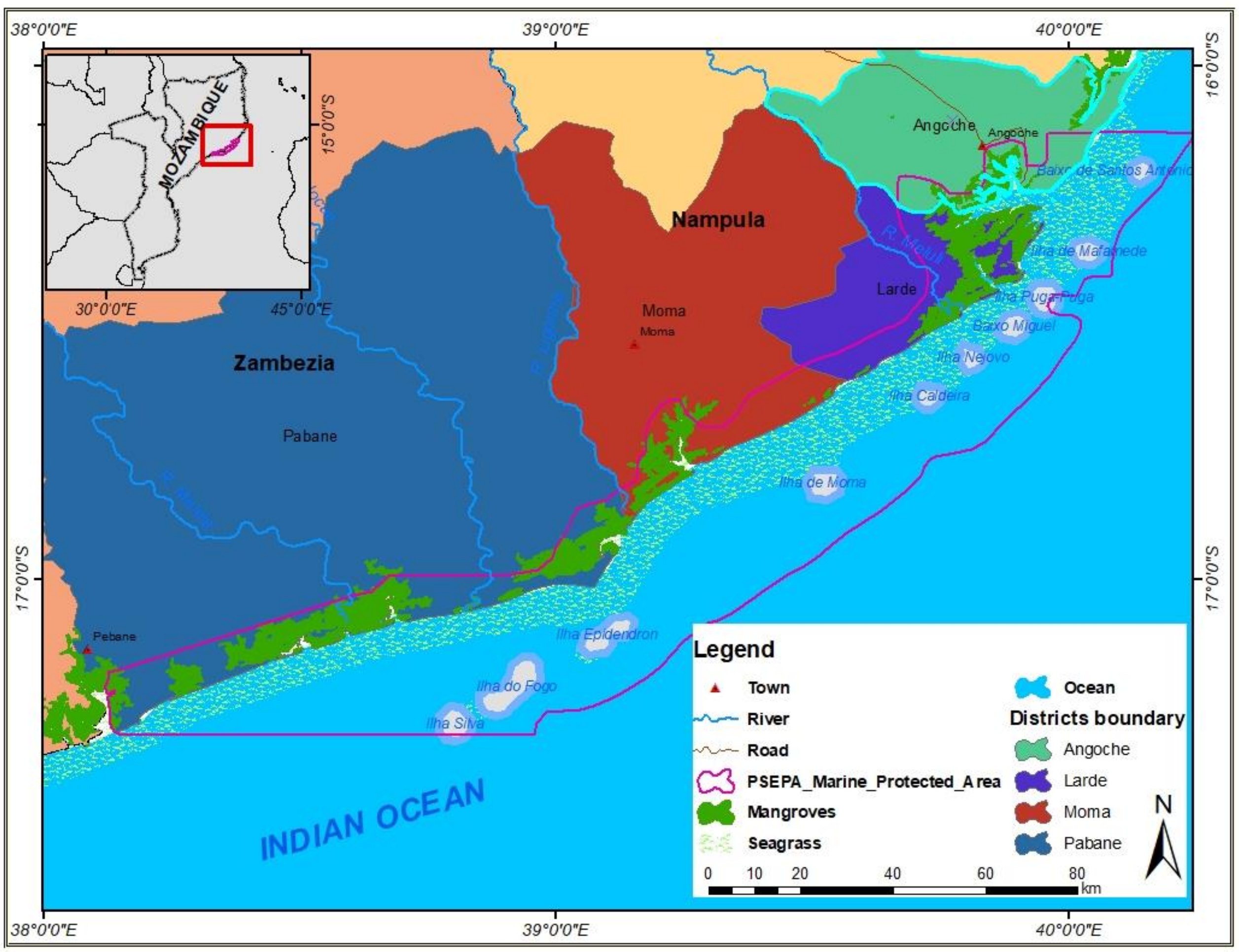

Figure 2: Primeiras and Segundas Environmental Protected Area of Mozambique

2.1.1 Climate

The region experiences a humid, subtropical, bimodal climate that starts with a hot and humid season followed by a cold and dry season. The hot and humid season is heavily influenced by the East African Monsoon Systems resulting in long rains occurring from January to April and the short rains between November to December while the dry season runs from June to October (Hoguane, 2007). The average annual rainfall in Angoche, Moma and Pebane is 800, 1,000 and 1,286 mm respectively with temperature ranges of 27 to 33 °C during the rainy season and 17 to 25°C during the dry season (Figure 3) and a relative humidity of 78% (Van Wyk & Smith, 2001). PSEPA is within the dune coast of Mozambique; as such, it is characterized by shifting shorelines (Macamo *et al.,* 2016).

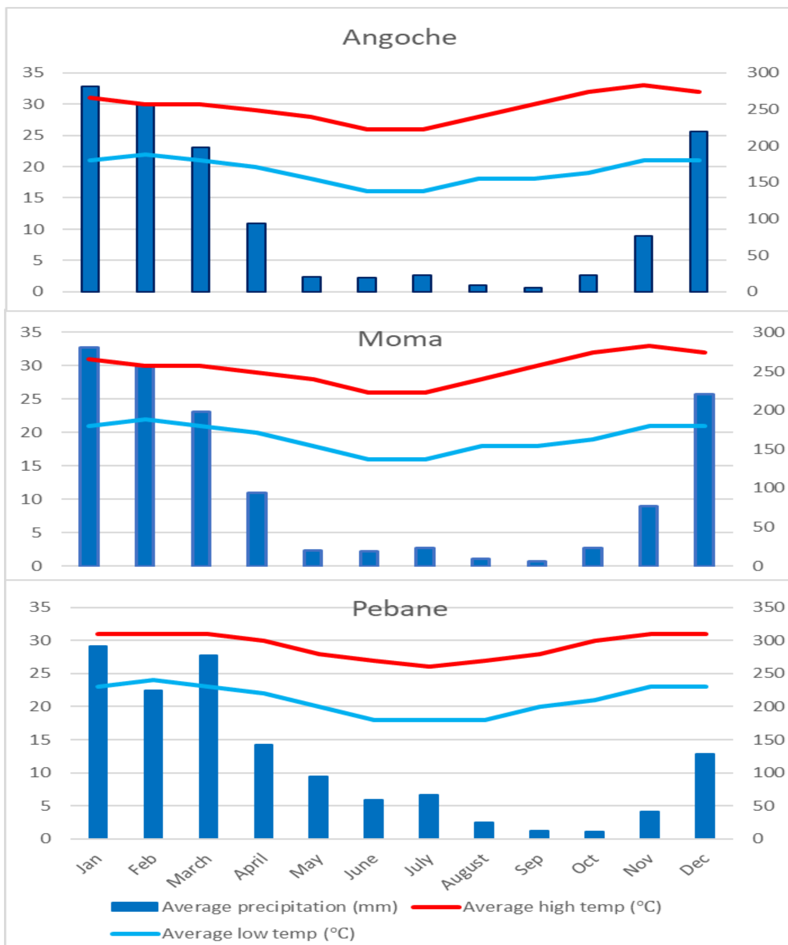

Figure 3: Climate diagrams of Angoche, Moma and Pebane Districts in PSEPA (Source: climatedata.eu)

2.1.2 Hydrology

Marine environment within PSEPA receives fresh water inputs from four main rivers; Meluli, Ligonha, Molocue and Melela (Figure 4). These rivers register maximum flows between February and March and the minimums between November and December; coinciding with long and short rains (Sætre & Silva, 1979; Silva *et al.,* 1981). Average annual fresh water discharge from the rivers is 3,494.3 Million m^3; that also carry large sediment loads leading to the formation of sandbanks (Hoguane, 2015). These waters generally have higher temperatures compared to sea water and are rich in nutrients (Sætre & Silva, 1982; Gammelsrød & Hoguane, 1995) hence influencing distribution of fauna and flora, including mangroves within the protected area.

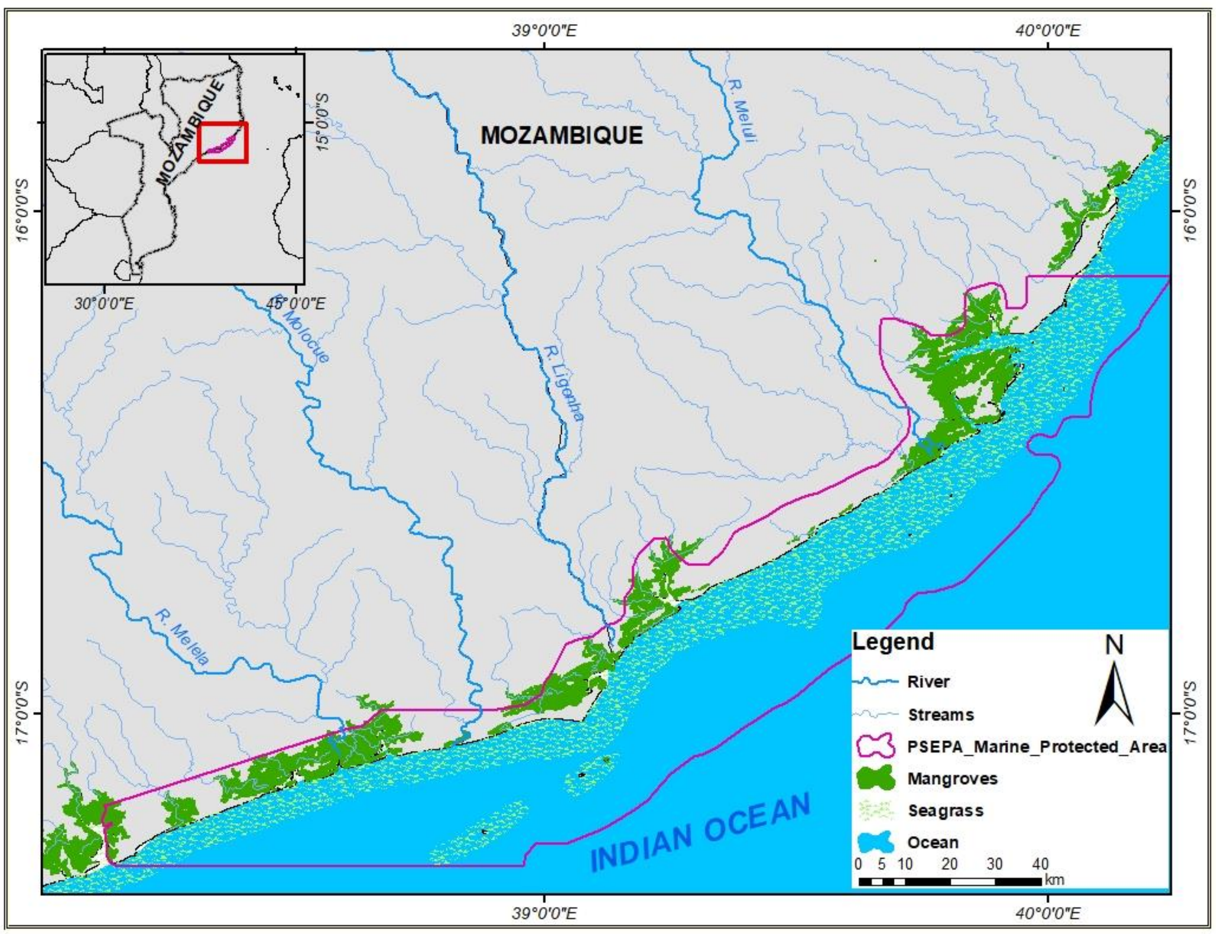

Figure 4: The Hydrology of PSEPA region of northern Mozambique

3.0 SITUATIONAL ANALYSIS OF MANGROVES IN PSEPA

There are 53,582ha of mangroves in PSEPA; distributed in Angoche, Larde, Moma and Pebane districts. This is 17.35% lower than the 1998 estimates that established coverage of 64,826.2 ha; translating to a a loss of 11,244.5 ha (Table 1). The degradation hotspots were identified close to human settlements at Angoche and Pebane.

Table 1: Mangrove Cover area dynamics in PSEPA

Year	Site				Total (ha)
	Angoche	Larde	Moma	Pebane	
1998	19,796.9	2,984.9	4,735.1	37,309.3	64,826.2
2018	15,905.3	1,815.1	4,792.7	31,068.6	53,581.7
Change	-3,891.6	-1,169.8	+57.6	-6,240.7	-11,244.5

3.1 Species composition

There are eight mangrove species within PSEPA, namely: *Avicennia marina, Bruguiera gymnorrhiza, Ceriops tagal, Rhizophora mucronata, Sonneratia alba, Lumnitzera racemosa, Heritiera littoralis* and *Xylocarpus granatum*. *Sonneratia alba* was only encountered in Angoche and *Avicennia marina* was not found in Pebane (Table 2). Missing species could mostly be associated with sampling intensity. There is a high probability that eight mangrove species occur in Pebane as well.

Table 2: Mangroves in PSEPA and their uses

Botanic Name	Mozambican Name	Use
Avicennia marina	Musso, N'tsQWQzi, Txamahati, Invede,Mpedge, Mangal branco	Firewood, fishing poles, dugout canoes, animal fodder, materials used in the construction of beehives
Bruguiera gymnorrhiza	Ikapa, Nkandala, M'Piria, N'kandaia, M'fumansL Setaka or Xitaka, M 'rinse	Firewood, fishing stakes, materials used in the construction of houses
Ceriops tagal	Ikapa, Nsangi. NkandaJa, Mucandala, Nhakandala, Hlohlotxwani, Hlohlodjani, Mangal Indiana	Firewood, charcoal, fishing stakes, materials used in house and for boat building,
Lumnitzera racemosa	Piripita, Mpiripito, Mangal prelo	Firewood, poles for building
Rhizophora mucronata	Nhantanzira, Mtanganda, Sinkaha, Ikapa, Mangal vermelho	Firewood, fishing stakes, fish traps, poles used in house construction, bark used for dying nets
Sonneratia alba	Mpiria, Tjindiri, Mangal maa	Poles, firewood

Xylocarpus granatum	Murrubo, Marrubo, Nseli, Shukuliha, Mangal boJa-de-canhao	Firewood, fish smoking, materials for boat building, medicine for stomach ache

Vegetation attributes of mangroves in PSEPA are given in Table 3 and Figure 5. Based on species Importance Value (IV), the most dominant mangroves species are *Rhizophora mucronata* and *Ceriops tagal* that occur as either single or mixed stands. Mangroves in PSEPA can be regarded as dwarf forest with median height and dbh of 5.0 m and 8 cm respectively (Figure 5), Pebane has relatively taller trees compared to Angoche; with 50% of the trees ranging between 5 m and 9 m in height. In Angoche, 50% of mangrove tree had a height range between 3 m and 5 m.

Table 3: Structural attributes of mangroves in PSEPA

Site	Species	Relative values (%)			IV
		Density	Frequency	Dominance	
Angoche	*Avicennia marina*	10.64	18.92	20.16	49.72
	Bruguiera gymnorrhiza	6.17	10.81	6.22	23.20
	Ceriops tagal	15.96	25.68	11.07	52.70
	Rhizophora mucronata	41.70	24.32	27.90	93.92
	Sonneratia alba	20.85	10.81	29.77	61.44
	Xylocarpus granatum	4.68	9.46	4.88	19.02
Moma	*Avicennia marina*	11.70	14.29	26.54	52.52
	Bruguiera gymnorrhiza	4.15	10.20	9.32	23.67
	Ceriops tagal	29.81	22.45	16.76	69.02
	Rhizophora mucronata	44.15	36.73	38.37	119.25
	Sonneratia alba	-	-	-	-
	Xylocarpus granatum	10.19	16.33	9.02	35.53
Pebane	*Avicennia marina*	-	-	-	-
	Bruguiera gymnorrhiza	7.29	13.73	4.41	25.43
	Ceriops tagal	61.88	45.10	79.46	186.44
	Rhizophora mucronata	30.59	39.22	15.98	85.79
	Sonneratia alba	-	-	-	-
	Xylocarpus granatum	0.24	1.96	0.15	2.34

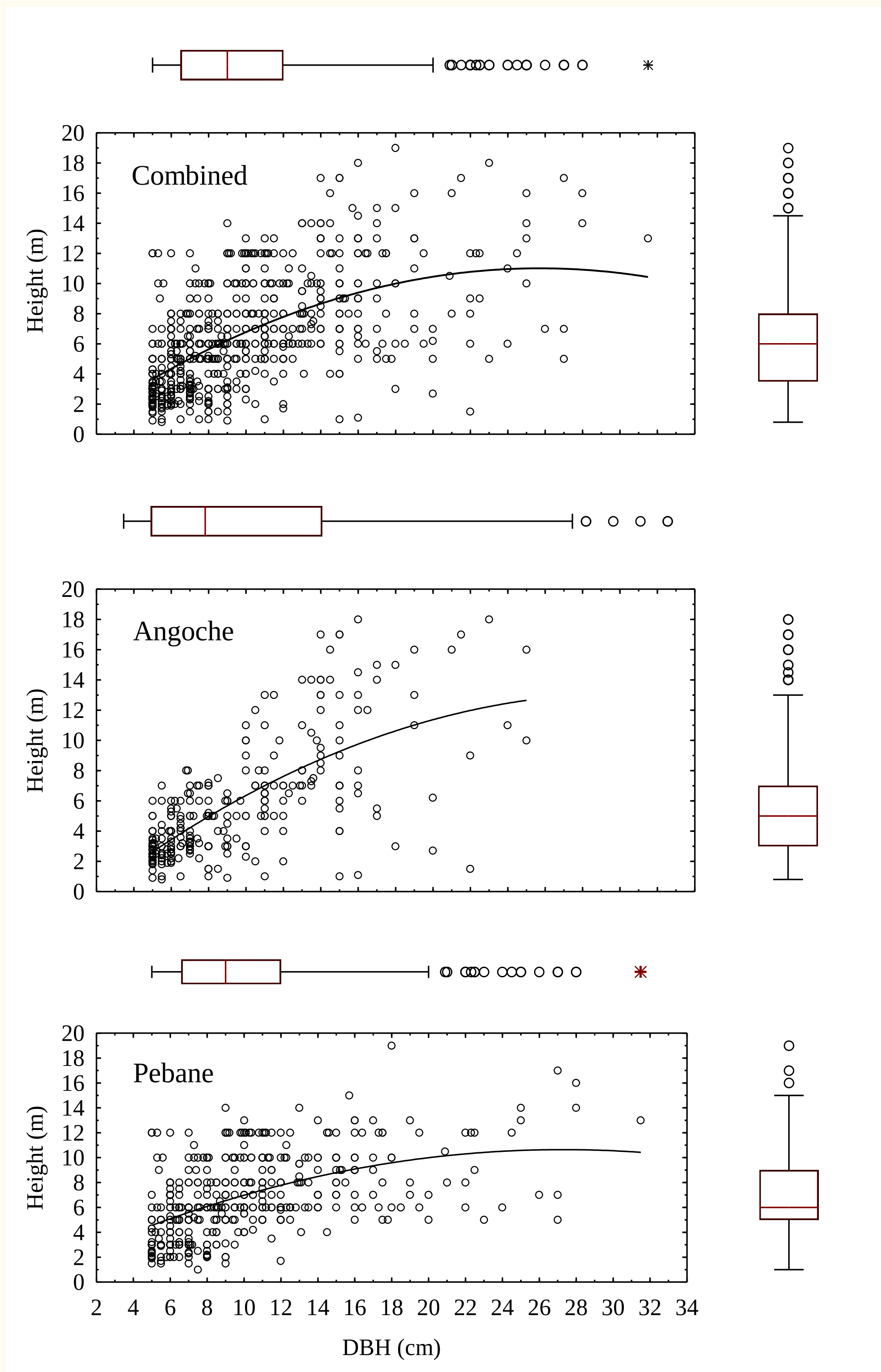

Figure 5: Height - diameter scattergrams for mangroves in PSEPA

3.2 Stocking rates and biomass

The stocking rates of mangroves in PSEPA are given in Table 4. The total stand density is estimated at 946 ± 128 stems ha^{-1}. Overall, small sized poles of DBH <16 cm dominate the forest; which is expected for non-even aged forests undergoing natural regeneration (FAO, 1994).

Table 4: Stand table data for mangroves in PSEPA (mean ± s.d)

Site	Diameter class (cm)							Density (Stems ha^{-1})	Biomass (t ha^{-1})
	<8.0	8.1-12.0	12.1-16	16.1-20	20.1-24	24.1-28	>28		
Angoche	445	236	128	39	15	6	4	873	113.46
Moma	409	218	136	49	26	19	3	860	-
Pebane	455	353	151	60	29	29	29	1,104	213.12
PSEPA combined	**436±24**	**269±73**	**138±12**	**49±11**	**23±7**	**18±12**	**12±15**	**946±128**	**163.29**

In terms of tree height, stand density and basal area mangroves in PSEPA are structurally less complex than those in Zambezi delta and other areas (Table 5). This could be due to human disturbance, but also because of physical drivers, particularly, fresh water influence. Zambezi mangroves are river-mediated and receive copious volume of freshwater and sediments that promote luxuriant growth of the forest.

Table 5: Structural attributes of mangroves in PSEPA compared to other sites in Mozambique

Site	Attribute						Source
	No. Species	Stem density (stems ha^{-1})	Mean height (m)	Mean DBH (cm)	Basal Area (m^2 ha^{-1})	Regeneration (juveniles/ha)	
PSEPA	**8**	**946**	**5.25**	**8.7**	**7.85**	**605**	**This study**
Zambezi Delta	8	2,036	9.4	10.4	26.58	3,712	Trittin *et al.,* 2015
Pemba	5	2,753	3.41	11.76	23.03	2,007	Bandeira *et al.,* 2009
Cabo Delgado	7	3,375	3.3	8.6	2.62	11,925	Macamo *et al.,* 2018
Quirimbas National Park	6	572	5.96	7.69	-	36,733 to 126,133	Nicolau *et al.,* 2017
PSEPA (Zambezia & Nampula provinces)	-	-	5.25	-	-	-	Fatoyinbo *et al.,* 2008
Maputo Bay	6	4,024	2.6	7.5	3.75	181	Macamo *et al.,* 2015
Zambezi delta	-	-	9.935	11.15	22.25	-	Stringer *et al.,* 2015

Standing biomass of mangroves in PSEPA were estimated at 116.56 Mg ha^{-1} and 46.76 Mg ha^{-1} for above- and belowground components respectively (Table 6). Data used to estimate soil organic carbon in PSEPA is derived from Zambezi delta (Stringer *et al.,* 2015). This could have over-estimated our value for PSEPA as mangroves of Zambezi delta are river-mediated. SOC estimates for PSEPA are however lower than the IPCC's 386 Mg C ha^{-1} for aggregated organic and mineral soils (IPCC, 2014).

Table 6: Total Ecosystem Carbon stocks of mangroves in PSEPA

AGB (t ha^{-1})	BGB (t ha^{-1})	TB (t ha^{-1})	AGBC (Mg C ha^{-1})	BGBC (Mg C ha^{-1})	TBC (Mg C ha^{-1})	SOC (Mg C ha^{-1})	TEC (Mg C ha^{-1})
116.56	46.76	**163.32**	58.28	18.23	**76.51**	**286.06**[a]	**362.57**
a=SOC is based on average value of reviewed data from Central Mozambique							

3.3 Natural regeneration

Mangrove juvenile density within PSEPA was estimated at 605 ± 416 juveniles ha^{-1}. Majority of juveniles were of regeneration class I (RCI) (63.47%) followed by regeneration class II (RCII) (20.33%) and regeneration class III (RCIII) (16.2) (Table 7). The regeneration ratio of mangroves in PSEPA (RCI: RCII: RCIII) was 4:2:1 which can be considered inadequate to support forest recovery (FAO, 1994; Saenger, 2003).

Table 7: Natural regeneration of mangroves in PSEPA (values in parentheses indicate percentage)

Site	Regeneration classes			Total density (Juveniles ha^{-1})
	RCI	RCII	RCIII	
Angoche	139 (37.07)	93 (24.8)	143(38.24)	375
Moma	94 (26.56)	114 (32.20)	146 (41.24)	354
Pebane	919 (84.7)	161 (14.84)	5 (0.46)	1,085
PSEPA combined	**384±464 (63.47)**	**123±35 (20.33)**	**98±81 (16.2)**	**605±416**

3.4 Carbon storage

Based on IPCC's guidelines for national greenhouse gas inventory (IPCC, 2014), some 50% of above ground vegetation biomass and 39% of below ground root biomass is carbon. On this basis, the vegetation carbon of mangroves in PSEPA is 76.51 Mg C ha^{-1}. Together with soil organic pool, the carbon density in mangroves of PSEPA is estimated at 362.57 Mg C ha^{-1} (Table 6); giving a total carbon stock of 19.4 Tg C.

3.5 Carbon emission from PSEPA

Over the 1998-2018 period, mangroves in PSEPA experienced a net loss of 11,244.5 ha, translating to a loss of 562.23 ha yr^{-1} (Table 5). This results in CO_2 emissions from the top 1m of sediments as well as lost vegetation cover. IPCC and other studies provide a range of possible fates of 'near-surface carbon' upon conversion from 25% to 100% emissions to the atmosphere depending on land use types (Pendleton *et al.*, 2012; IPCC, 2014). Using the low end of 25% emissions, potential carbon loss from mangroves in PSEPA was calculated as 90.64 Mg C ha^{-1}. To enable comparison with other assessments, the values were expressed in terms of CO_2 equivalent, by multiplying C stocks by 3.67, the molecular weight of C to CO_2. Therefore, potential carbon emissions from mangroves in PSEPA is estimated at 332.6 Mg CO_2e ha^{-1}; giving total emissions of 186,999.7 Mg CO_2e yr^{-1}.

Globally, C emissions due to land-use change have been estimated to range from 90 to 450 million tCO_2 yr^{-1} over a global mangrove area of 13.8 to 15.2 million ha; which translates to 6.55 to 29.61 tCO_2 ha^{-1} yr^{-1} (Murray, 2012; Pendleton *et al.*, 2012). Reforestation of degraded mangrove areas, avoided deforestation, and sustainable mangrove forest management would easily increase carbon stocks in the project area. Payment of Ecosystem Services such as the UN's REDD+ is a potential avenue for rewarding those involved in mangrove conservation activities. Assuming an offset value of US$10 per ton of CO_2 in the international market, the estimated value of sequestered carbon from PSEPA would be US$ 1,869,997 per year, plus other co-benefits such as fishery functions and shoreline protection. This justifies our pursuit for a carbon offset project in PSEPA.

4.0 SOCIAL-ECONOMIC CHARACTERISTICS OF PSEPA

According to Mozambique general population census, approximately 991,626 people reside in the four districts within PSEPA region (INE, 2017) – Table 8. The population density is around 100 inhabitants/km^2 with a growth rate of 2.8% per year; which is among the highest in the country (INE, 2017). The female population is slightly larger than male; representing 50.7% of the total population in PSEPA (INE, 2017).

Social amenities and infrastructure (education, health, water and sanitation, energy, road transport and financial services) are underdeveloped. Illiteracy rate stands at 43- 56%; which is highest in the country. Average illiteracy rates in Angoche, Moma and Pebane districts are about 68.2%, 68.8% and 64.4% respectively (WWF, 2019). Illiteracy among women is higher (84%) than that of men (48.4%) (INE, 2014). Some 53.1% of household heads in Angoche and Moma had at least a basic level of education, 11.5% had a secondary level education or higher; while 35.4% of the household heads had no education at all (Skinner *et al.*, 2019). At least 40% of the population in Angoche and Moma communicate in Portuguese language (the national language of Mozambique). Of all the household heads in the study, 89% were male. The predominant religion is Muslim at 67% in both Angoche and Moma (INE, 2014).

Access to clean and safe water is a major challenge in PSEPA. Some 99.3% of population in Pebane have no direct access to clean water; same with Angoche (94%) and Moma (99.3%) (INE, 2013). Of these populations, 76.4%, 77.4% and 79.9% rely on water from open traditional wells or boreholes in Angoche, Moma, Pebane respectively (INE, 2013). Regarding sanitation, more than 80% of the population have no latrines; 82% in Angoche, 93.6% in Moma and 90.8% in Pebane (INE, 2014). Revenue generated from the sale of mangrove carbon credits and other sources could be used to accelerate priority local development and conservation programs in the area.

Table 8: Human Population Change in PSEPA (1997-2017)

District	1997	2007	2017
Angoche	228 526	276 471	399 092
Larde	n/a	n/a	85 971
Moma	286, 522	360, 690	310,706
Pebane	168, 602	185, 333	195, 857
Total	**683, 650**	**772, 494**	**991 626**

The major sources of livelihood activities in PSEPA include agriculture, fishing, and harvesting of mangrove forest products (WWF, 2019). In Angoche and Moma, 45% of the population relies on agriculture (subsistence and cash crops), while 24% are into fisheries (local and external fish sales) for income generation (Skinner *et al.,* 2019, Macamo *et al.,* 2016).

5.0 POLICY AND LEGAL FRAMEWORK FOR BLUE CARBON PROJECTS IN MOZAMBIQUE

This section reviews relevant national and international legal and policy frameworks relevant to sustainable management of mangroves in Mozambique. These laws and policies may be used to promote establishment of blue carbon projects in Mozambique.

5.1 Institutional framework

The management of mangroves in Mozambique falls under the Ministry of Land, Environment and Rural Development (MITADER). Below the ministerial level, the National Administration of Conservation Areas (ANAC) plays a coordination role with regard to all protected areas in the country. At the local management scale of Marine Protected Areas (such as PSEPA), there are Natural Resource Management Committees (CGRN) and Community Fisheries Councils (CCP). As a complementary institution, the government set a Foundation for the Conservation of Biodiversity (BIOFUND) with the specific mandate to raise funds to support the long-term management of Mozambique's conservation areas while the Ministry of Fisheries is responsible for the sea-side management of the coastal environments. It is mandatory to have a joined management plan**,** where all stakeholders are involved, including the local communities. A participatory management plan for PSEPA already exist (see section:

5.2 National and legal framework

i. National Policy Environment of 1995

Resolution No. 5/1995 of this policy outlines the goals and objectives of ecosystem protection and their sustainable management. Resolution No. 10/1995 on National Land Policy and its Implementation Strategies classifies the land use areas as type A, B, C, D, with type C areas (where PSEPA falls under), consists of resources protected or to be protected. Here, the exploitation of the resources in these areas is in principle forbidden, except in cases of projects foreseen in the government plans. Any transfer of titles will be forbidden in these areas except where projects foreseen in the governments master plans may be implemented.

ii. The Land Law of 1997

The Land Law of 1997 (No. 19/1997) defines "Total Protection Areas" and "Partial Protection Areas." Partial Protection Areas include, among others, the strip of maritime coastline, including the area around islands, bays and estuaries, which is measured from the high tide line to 100 m inland. Hence, most mangroves in Mozambique fall within areas of partial protection except those within National parks, reserves and Marine Protected Areas, that have total protection.

iii. The Environment law (Law No. 20/1997)

This law gives a legal overview on management of the environment and its natural resources in Mozambique. The law is important for identifying misconduct and offences related to protected ecosystems, habitats and species thus advocates for their management and sustainable use. As such, it has direct implication to the management and use of mangrove forests within the PSEPA region as one of the country's protected spaces.

iv. Forestry and Wildlife Act of 2006

The Forestry and Wildlife Act, enacted in 2006, establishes the principles and rules that govern sustainable use, protection and conservation of forest resources and wildlife. It goes further to define mangrove ecosystems as fragile ecosystems that need to be sustainably managed. The law further demands that sustainable mangrove management be done also at the local level through local councils for the management of forest resources and wildlife. By restoring and protecting mangroves of PSEPA through carbon financing, we shall directly be responding to the objectives of this law.

v. The Conservation Law (Nr. 16/2014)

This law stipulates the governing principles of the "national system of conservation areas". It specifies that, "The public or private entity, exploiting natural resources in the conservation area or its buffer zone, which benefits from the protection provided by a conservation area, must contribute financially to the protection of biodiversity in the respective conservation area as well as compensation for any activity that impact or lead to loss of biodiversity. The blue carbon project proposed for PSEPA will increase the productivity and resilience of mangroves and at the same time generate income for community involved in mangrove conservation.

vi. **The Fisheries Law 2013 (No. 22/2013)**

This law has a provision on conservation and protection of mangrove areas in the country given that mangroves play key role in supporting coastal fisheries. Under article 101 of the Fisheries Law, it is prohibited to cut mangroves without their replacement. This attracts an imprisonment or the imposing of financial penalties. It further violates conversion of mangrove areas for other land uses. Development of a blue carbon project in PSEPA will enhance fishery productivity, improve community income as well as protect the fragile mangrove forests in the area.

5.3 Multilateral Environment Agreements (MEAs)

i. United Nations Framework Convention on Climate Change (UNFCCC)

Mozambique is a signatory to the UNFCCC; ratified in 1994 and entered into force the same year. In its second national communication under the UNFCCC (2012), Mozambique identifies various adaptation and mitigation measures in forestry and coastal zone areas in the National Climate Change Adaptation and Mitigation Strategy (NCCAMS) (MICOA, 2012). The national priority is defined in its mission "to increase resilience in the communities and the national economy including the reduction of climate risks, and promote a low carbon development and the green economy through the integration of adaptation and mitigation in various sectors including forests. Mangrove forests play a key role in mitigation of climate change through capturing of emitted carbon from the atmosphere.

ii. Paris Agreement

Mozambique became a signatory to Paris Agreement on Climate Change in 2018; and is therefore obliged to reduce GHG emissions into the atmosphere, or engaging in emissions trading if they maintain or increase emissions of these GHGs. As a non-Annex I country, Mozambique can engage in sale of carbon credits from Agriculture, Forestry and other Land Use (AFOLU) sector. As a carbon rich ecosystem, mangroves of the Mozambique could be used to offset carbon emissions and also earn funds through carbon trading under the voluntary and compliant carbon markets.

iii. Convention on Biological Diversity (CBD)

As a signatory to CBD, it is the responsibility of Mozambique to conserve and protect their biological diversity and to use their biological resources in a sustainable manner. Mangrove forests are among the most productive and biodiverse ecosystems on earth thus requires stringent measures to protect the biological resources for the benefit of present and future generations. As such It is necessary to anticipate and prevent causes of significant reduction or loss of biological diversity at source, in situ conservation of ecosystems and natural habitats is essential for conservation of biological diversity.

iv. Nairobi Convention

The Nairobi Convention is a partnership between governments, civil society and the private sector, working towards a prosperous Western Indian Ocean with healthy rivers, coasts and oceans. It mandates the states to plan and develop programmes that strengthen their capacity to protect, manage and develop their coastal and marine environment. This includes establishment of Marine Protected Areas (MPAs) to conserve marine resources (mangroves, seagrass, coral reefs, fisheries) against exploitation.

6.0 OPPORTUNTIES FOR MANGROVE CARBON PROJECT in PSEPA

Establishing a mangrove carbon project for PSEPA, will not only restore the lost mangrove forests but also provide many benefits, classified herein as either; climate, community, or biodiversity benefits.

6.1 Climate benefits

Implementation of a blue carbon project in PSEPA will have far reaching climate benefits. As discussed above, 11,244.5 ha of mangroves within PSEPA were lost between 1998 and 2018 (Table 1). This could have activated an emission of 186,999.7 Mg CO_2e yr^{-1} from the lost vegetation cover as well as from the top 1.0 m of sediments. Carbon emissions from PSEPA mangroves are huge, especially when compared to terrestrial ecosystems (Donato *et al.,* 2012). Reforestation of degraded mangroves areas, avoided deforestation, as well as carbon enhancement will enhance the carbon stocks and increase carbon sequestration in the area. If we were to set aside 10% of PSEPA mangroves for carbon offset the climate benefits can be estimated as in Table 9.

Table 9: Climate benefits of mangrove carbon project in PSEPA

Activity	Description	Mangrove Area	Annual Carbon Benefit			
			tC ha^{-1} yr^{-1}	tC yr^{-1}	tCO_2e yr^{-1}	US$
Afforestation/ Reforestation	Afforestation/ reforestation will be done in degraded areas created through sedimentation and shoreline change	867.28 ha	3	2601.84	9,548.75	95,487.5
Avoided Deforestation	Strengthening of community monitoring and control in the natural forests	3,632.72 ha	11	39,959.92	146,652.9	1,466,529
Carbon enhancement	This will include at least 10% of the area.	500 ha	5	2,500	9175	91,750
Total		**5,000 ha**		**45,061.76**	**165,376.7**	**US$ 1,653,766.5**

IPCC default values for carbon sequestration apply.

6.2 Community benefits

Local communities in PSEPA have utilised mangrove as a source of livelihood for a long time. Mangrove wood has majorly been used for building and firewood, boat construction, and charcoal production. At least 30% of the population within PSEPA depends on mangroves for firewood and building (WWF, 2019). Further, mangroves serve as a source of non- timber forest products such as honey, fodder, traditional medicine, and fisheries production. Within PSEPA fisheries is a major economic activity supporting approximately 30,000 fisher families, and contributing 90% of the protein to the households (Skinner *et al.,* 2019). Annual landing from PSEPA is about 30,000 tons of mostly *Penaeidae* and *Sergestidae* and fish species of *Sciaenidae* (Hoguane *et al.,* 2018) that are consumed locally or sold in urban centres including

Nampula and Maputo. A blue carbon project will contribute immensely to income generation and community wellbeing through sale of carbon credits, job creation, and capacity building. Revenue from sales of carbon credits estimated at (US$ 1.7 million) (Table 9) would be ploughed back and support local development projects in water and sanitation, education, and environmental conservation. Without blue carbon project, loss and degradation of mangrove in PSEPA will continue leading to habitat loss, reduction in fisheries, and increased suffering to the people already affected by degraded system.

6.3 Biodiversity benefits

Implementation of a blue carbon project will enhance mangrove functions not only within PSEPA but also the entire marine eco-region. PSEPA was designated as a protected area due to the marine wealth and also to the uniqueness of coastal habitats including mangrove forests, seagrasses and vibrant coral reefs. These habitats support life forms with great richness in biological diversity and are among the most important biodiversity hotspot in WIO (CBD, 2013). Biodiversity richness within PSEPA include 233 species of demersal fish, 113 species of pelagic fish and 22 species of crustaceans (Pereira *et al.,* 2007, 2014). Further, there are six species of seagrass (another blue carbon ecosystem), including: *Zostera capensis, Cymodocea serrulata, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium and Halodule wrightii.* PSEPA biodiversity is of regional and international significance as it is a home to unique and endangered species, such as dugongs, marine turtles, whales and dolphins. Due to poor fishing practices and destruction of habitat, some mangrove dependent shrimp (family: *Penaeidae* and *Sergestidae),* and fish species (Family: *Sciaenidae, Acanthuridae* (surgeons), *Caesionidae* (marines), Kyphosidae (lazy) have been on decline. A blue carbon project would reverse this, and lead to increased species richness due to improved mangrove management; while simultaneously enhancing the sustainability of ecosystem services for livelihoods as more communities take part in mangrove conservation and restoration.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The strong recognition by government on mangroves being critical ecosystem gives encouragement to the local communities and other stakeholders to take up efforts in the rehabilitation, conservation, and sustainable utilization of mangrove resources. Mangroves provide harvestable wood and non-wood products to communities within and outside PSEPA; this is in addition to ecosystem services they provide like carbon sequestration, shoreline protection, and biodiversity conservation Carbon sequestration in mangroves is higher than that in their terrestrial counterparts despite their limited spatial occurrence.

The sequestered carbon can be traded in the voluntary and compliant market thus earning the communities much needed revenue to drive local economies.

Establishing a blue carbon project for PSEPA would provide climate, community, and biodiversity benefits. For instance, setting aside only 10% of PSEPA mangroves for blue carbon project would abate emissions of 165,376.7 CO_2e yr^{-1} thus generating an income of US$ 1,653,766.5 yr^{-1} (Table 9); plus other benefits such as shoreline protection and biodiversity conservation.

While this scoping report provides positive signs for establishing a blue carbon project in PSEPA there are few steps to consider during its development. Stakeholder consultation is key in assessing community readiness for carbon-offset project. A Project Idea Note (PIN) detailing institutional, policy and legal capacity to support a blue carbon project then follows. Upon approval, PIN is upgraded to Project Design Document (PDD) detailing benefit-sharing scheme among other elements. Independent verification of the submitted PDD is conducted prior to trading carbon credits. Considering technical aspects of blue carbon projects, most clients would normally hire a project developer to prepare PIN and PDD. The cost of developing a project is about US$200,000.

Protocols and guidelines exist to guide development of blue carbon projects. Procedures for assessing, carbon stocks in mangroves and associated ecosystems are elaborated by Howard *et al.* (2014). These methodologies are further enhanced by (IPCC, 2014), "Guidelines for national greenhouse gas inventories for wetlands" and Wetlands Restoration and Conservation (WRC), which is a framework for accounting emissions reductions in Mangroves, seagrasses and their associated ecosystems. A blue carbon primer (Windham-Myers *et al.,* 2018) provides a one top-shop of developing and implementing a blue carbon project.

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9.0 ANNEXES

ANNEX 1: METHODOLOGY USED IN THE FEASIBILITY ASSESSEMENT

i. Mangrove cover change analysis

In order to develop information of mangrove extent over time within PSEPA, Landsat 5, 7 and 8 images were used to create mangrove maps at a spatial resolution of 30 m. Landsat scenes with cloud cover less than 95% were composited into a single cloud-free image and processed to surface reflectance. Vegetation indices were calculated and the water areas masked using an automated threshold of the near infra-red band. This information served as training data for the classification. Samples of mangrove and non-mangrove land cover classes were then digitized into the Google Earth Engine interface, and a random forest supervised classification algorithm was used in a second stage classification process resulting in a mangrove vegetation cover maps and changes.

ii. Measurements of mangrove forest structure, biomass and carbon stocks

Considering the robustness of mangroves in Mozambique as well as the time constraints, desktop review of underlying root causes of losses and degradation of mangroves within PSEPA was conducted; followed by a visit to the area to ascertain their status and conditions. This was complemented by data and information on structure and regeneration of mangroves in central and northern Mozambique generated by WWF (2018, 2019) and University of Edwardo Mondlane (Macamo *et al.,* 2018). The data included species composition, tree height, stem diameter (Dbh), stand density, vegetation biomass and subsequent carbon. In the AFOLU sector, emissions and removal of CO_2 are accounted in five broad carbon pools, including; above ground biomass, below ground biomass, dead wood, litter and soil organic matter (IPCC, 2006). In mangrove forestry, however, only three carbon pools are considered significant, including; aboveground living biomass (trees, scrub trees, lianas, palms, pneumatophores); belowground living biomass (roots and rhizomes); and soil carbon that include the dead belowground biomass (IPCC, 2014).

iii. Measurement of mangrove forest structure

Structural data (tree height, DBH, crown cover etc.) are easily estimated using modified forest mensuration procedures for mangroves (Kauffman & Donato, 2012; Howard *et al.,* 2014). From the structural data, the following stand parameters are calculated and expressed per hectare basis:

a) **Basal area (g)** or the cross-sectional area of the stem at breast height: $g = \frac{\pi DBH2}{4} (cm2)$ The total g for all species is the sum of basal areas for each tree in the plot ∑gcm^2.

Stand g = ∑g/area of plot) m^{2}ha^{-1}.

b) **Stand density** denotes number of individuals per unit area: Density (per ha) = (No. of stems in plots x 10,000)/Area of the plot

c) **Relative density, dominance, frequency, and Importance Value of species**

In the current study, relative vegetation parameters were derived using data collected by WWF for Angoshe, Moma and Pebane as follows (WWF, 2018):

Relative density = (Number of individuals of a species/total number of individuals) × 100

Relative dominance = (Total basal area of a species/Basal area of all species) × 100

Relative frequency = Frequency of a species/sum frequency of all species) × 100.

The importance value (IV) of each species was calculated by summing its relative density, relative frequency, and relative dominance (Cintron & Schaeffer-Novelli, 1984; Kauffman & Donato, 2013; Howard *et al.,* 2014).

Importance value (IV) = Relative density + relative frequency + relative dominance

iv. Above and below-ground biomass

High variability of mangrove biomass data exists in Mozambique (Table 4). Such differences could arise from sampling intensity and methodology used. For instance, using elevation data from SRTM (Shuttle Radar Topography Mission) Fatoyinbo *et al*. (2008) derived mangrove biomass value in PSEPA region as 90.5 Mg ha^{-1}. This value is considered rather low for the type of mangrove in PSEPA. In the current study we used structural data generated by WWF team for the area to determine above-and below-ground vegetation carbon. We aimed at using local equations for estimating biomass carbon of mangroves in PSEPA. However, this was not possible, as there are no robust biomass equations that have been developed for principal mangrove tree species in Mozambique. Instead, we used the generalized biomass equations for mangroves using stem diameter as the dependent variable (Komiyama *et al.,* 2005; 2008) and species-wood densities for mangrove trees in WIO region (Bosire *et al.,* 2012). The total vegetation was then computed as sum of below-and aboveground living biomass (Komiyama *et al.,* 2005; 2008)

$$AGB=0.251\rho D^{2.46} \quad (1)$$

$$BGB=0.199\rho^{0.899}D^{2.22} \quad (2)$$

Where, AGB = aboveground biomass (kg), BGB = belowground root biomass (Kg), p = wood density (g cm^{-3}), D = diameter at breast height, dbh (cm).

Biomass values were converted to carbon equivalents by multiplying them with conversion factors of 0.50 and 0.39 for AGB and BGB, respectively following Kauffman and Donato (2012). Subsequent vegetation carbon was estimated using carbon concentration factor of 0.5 and 0.39 for AGB and BGB, respectively according to Kauffman and Donato (2012).

v. Soil carbon pool

Carbon sequestration in mangrove ecosystem is significantly higher in soils; accounting for 50% to 90% of the total carbon stocks (Donato *et al.,* 2011; Pendleton *et al.,* 2012). To estimate mangrove soil carbon in PSEPA, we reviewed published data on mangrove soil carbon across the country (Stringer *et al.,* 2015; Shapiro *et al.,* 2015). An estimate of 286.06 Mg C ha^{-1} was derived which is slightly lower than the default SOC data (386 Mg C ha^{-1}) for mangroves in aggregated organic & mineral soils recommended by IPCC (2014).

ANNEX 2: ITINERARY (DEC 13 – 23, 2020)

Dec. 13: Mangrove expert in Nampula

Dec. 14: Arrival in Angoche and held consultative meeting and discussion with WWF project personnels, Dalila Sequeira, (Senior Marine Officer**) and Milton Jose Xavier (GIS/M&U expert). Later a courtesy call to the District Administrator in Angoche, Mr Alberto Daniel.**

Dec. 15: Consultative meetings with the communities at Mussuceia, Inguri, Thamole. Community moved to Mussiceia due to floods associated with cyclones that frequent the area. Inguri is a city suburb that is adjacent to mangroves. In Thamole mangrove area have been converted for salina.

Dec. 16: Further consultations with communities at Quelelene, Quilua, Pulizica, and Mitupeni. In most of this villages the Project had established community level Natural Resources Management Committee (CGRN) or Fisheries Community Councils (CCP) or both. In Pulizica the project had in addition established a NO Take community conservation area

Dec. 17: Travel day to the mangroves of Moma

Dec. 18: Visited mangroves and had consultations with communities at Mingurine, Maminhuco Campo and Ecucuho. At Mingurine we visited a mangrove restoration site but the trees had been choped again. At Maminhuco there were trials crab fattening initiative as well as mangrove replanting. The common mistake of poor species-site matching was evident in most of the restoration sites.

Dec. 19 A boat tour to the mangroves of Thapua and Corane. In the afternoon we visited Mecucune community. Community conservation areas have been established in both Thapua and Corane. Adjacent Titanium mining in Thapua pose a risk to the mangroves here. At Corane we came across Lumnitzera racemosa and Heritiera racemosa. These species had not been reported before in PSEPA.

Dec. 20-22 Remained in Nampula finalising debriefing report.

ANNEX 3: LIST OF PERSONS CONTACTED

District Administrator

Mr. Alberto Daniel

Angoche District

Permanent Secretary

Carolina Bande

Mona District

National Administration of Conservation Areas

Ricardina Matusse

Senior Warden, PSEPA

Community Groups

District	Names	Affliation community	Responsibilities
Angoche	Momade Silverio	Mussuceia	president
	Antonio Jacinto	Inguri	President (CCP)
	Momade Jamal Motovere	Inguri	president
	Carlos Ussene Alide	Quelelene	CGRN
	Mohamed Lipuro	Quelelene	Deputy president
	Seleimane Amisse	Quelelene	CCP- secretary
	Saide Jahaia	Mitupeni	Village president
	Muirazai Bomba	Mitupeni	CCP
	Abacar Momade Issufo	Pulizica	Secretary, CGRN
	Edwardo Saide	Pulizica	CGRR
	Momade Ussane	Pulizica	Member, CCP
Moma	Ermelinda Ali Mamugi	Mingurine A	President
	Ossufo Alide	Mingurine A	Secretary
	Isasela Disoureina	Mingurine A	Treasurer
	Arsenio Emilio	Mingurine A	District Secretary, CGRN
	Antonnio Suale	Naminhuco Campo	Secretary and vice president CGRN
	Alfonso Manuel Naharima	Ecucuho	President
	Mussapaha Edrica	Mucucune	President CGRN
	Esmail Omar Amade	Corane	CCP member