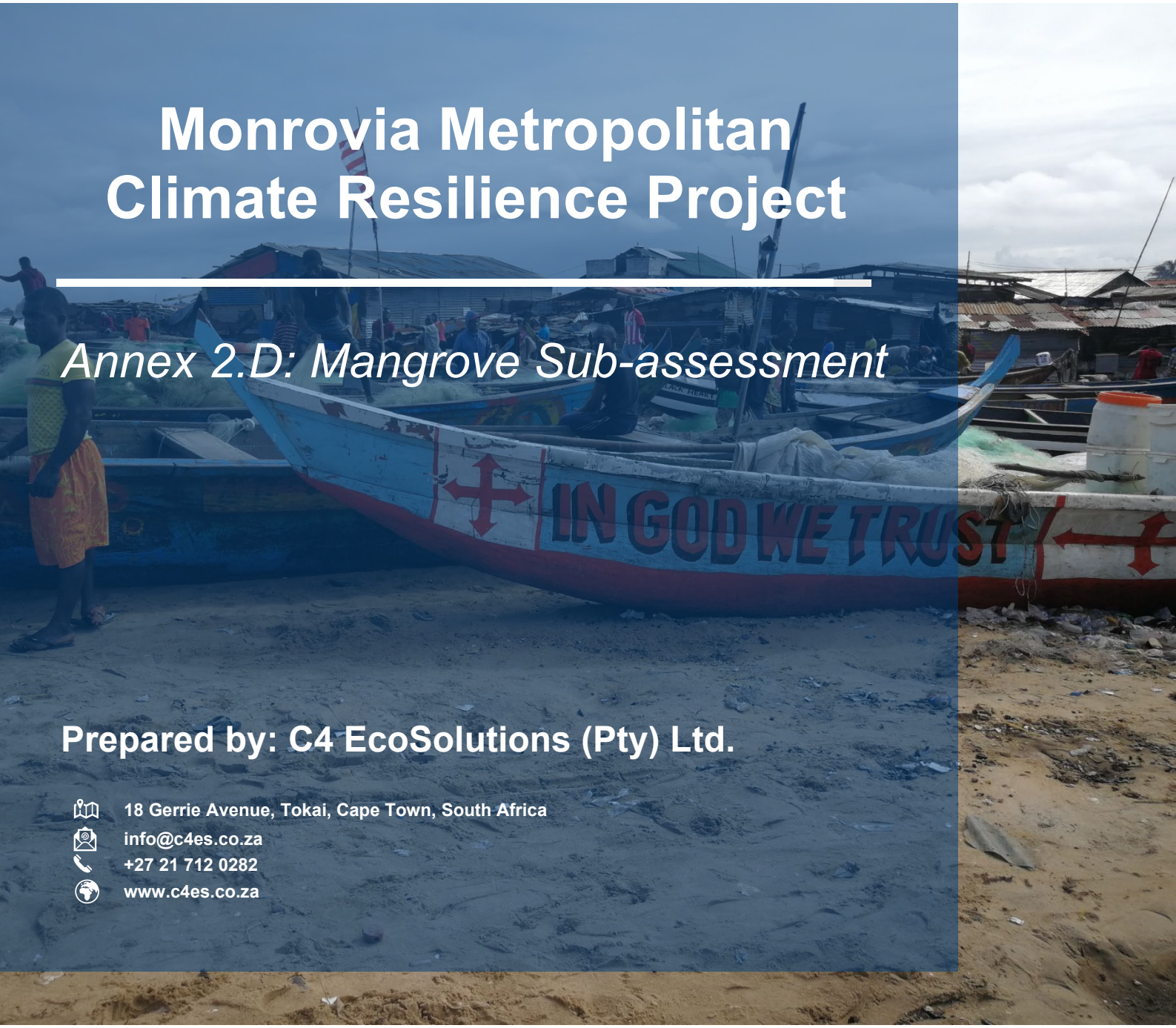
Monrovia Metropolitan Climate Resilience Project

Annex 2.D: Mangrove Sub-assessment



Prepared by: C4 EcoSolutions (Pty) Ltd.

18 Gerrie Avenue, Tokai, Cape Town, South Africa
info@c4es.co.za
+27 21 712 0282
www.c4es.co.za

C4 EcoSolutions
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Operating at the forefront of the world's climate change and biodiversity challenges

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1. EXECUTIVE SUMMARY

This report presents a spatial analysis and desktop study of the mangrove ecosystems in the Mesurado Wetland of Monrovia, Liberia, to inform the design of the proposed Green Climate Fund (GCF) project, the '*Monrovia Metropolitan Climate Resilience Project (MMCRP)'*. It includes an assessment of the degradation of and threats to these mangrove ecosystems as well as a summary of lessons learned from previous projects that have addressed mangrove and wetland conservation in Liberia.

Mangrove ecosystems

Mangrove forests occur in the intertidal zone along tropical and subtropical coastlines, occupying in excess of 80,000 km^2 in over 100 countries[1]. Globally, these forests are under threat, with the area covered by these valuable ecosystems having declined by ~50% since the turn of the century[2]. This global degradation of mangrove ecosystems is driven by *inter alia*: i) dredging and clearing of forests for aquaculture and other extractive land uses; ii) unsustainable exploitation of fuelwood and other raw materials; and iii) encroachment driven by urbanisation. Furthermore, sea-level rise (SLR) associated with climate change is projected by climate scientists to inundate mangroves in many parts of the world, exacerbating the above-mentioned anthropogenic degradation.

National context of mangroves in Liberia

Mangrove forests in Liberia are found along a 15 km-wide belt that extends along the length of the country's ~560 km long coastline, occurring behind barrier islands within estuaries or lagoons that run parallel to the coast[3]. Mangrove forests support the livelihoods of more than half of Liberia's ~4 million people. The resource-rich nature of Liberia's coastal zone has driven this reliance, with coastal communities depending on mangrove ecosystems for subsistence and commercial activities alike[4]. In general, communities residing along Liberia's coast have few alternative livelihood strategies and consequently rely heavily on mangroves for food, land, and other resources[5].

Local context of mangroves in Monrovia: the Mesurado Wetland

Located at the mouth of the Mesurado River and covering more than half of the city's total land area, the Mesurado Wetland[6] is a primary geographic feature and landmark of Monrovia[7]. Extensive mangrove forests occur within this estuary, especially in the sheltered tidal basin formed by the Mesurado River as it nears the Atlantic Ocean (Figure 1).

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[1] Extrapolated value for 2014. From: Hamilton, SE, & Casey, D. 2016. Creation of a high spatiotemporal resolution global database of continuous mangrove forest cover for the 21st Century (CGMFC-21). Available at: https://arxiv.org/abs/1412.0722

[2] WWF. 2020. Mangroves. Available at: https://www.worldwildlife.org/biomes/mangroves

[3] EarthTime Inc, CDR International, UNDP. 2019. Provision of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MAA) in Liberia. Part III - Environmental and Social Assessment Report (ESAR): United Nations Development Programme and Liberia Environmental Protection Agency.

[4] Hahn B, Barber J, Johnson D, Garbo HW (eds). 2014. *Liberia - Environmental threats & opportunities*. US Department of Agriculture Forest Service of International Programs. Washington.

[5] Republic of Liberia 2014a. *Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas*. Global Environment Facility (GEF) Request for CEO Approval. Monrovia: Environmental Protection Agency and Conservation International

[6] The term 'wetland' is misleading as it implies a purely freshwater ecosystem. The Mesurado Wetland is in fact primarily an estuarine or saline environment, although estuaries are considered part of the broader definition of wetlands in most national contexts. Whereas the terms 'Mesurado Wetland', 'estuary', and 'mangroves/mangrove forests' are used interchangeably in this report, the interrelationship between these biophysical aspects is important. A diagrammatic summary of these aspects is shown in Figure 6 on page 6 of this report.

[7] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.

Figure 1. Extent of mangrove forests within the Mesurado Wetland in Monrovia.

Mangrove forests in the Mesurado Wetland are highly productive ecosystems and provide vital spawning grounds and nurseries for many inshore and nearshore fish as well as shellfish species of commercial value. In addition to their high productivity, mangroves within the Mesurado Wetland are home to several endangered species of flora and fauna and are consequently of high conservation value. Indeed, the Mesurado Wetland's status as a Ramsar Convention Site recognises its international significance in this regard. Mangrove forest ecosystems in the Mesurado Wetland provide surrounding communities with essential ecosystem services such as raw materials for firewood, charcoal production, fish smoking, construction, and agricultural land.

Spatial and temporal analysis of mangrove degradation in the Mesurado Wetland

A global dataset developed by Global Mangrove Watch[8] (GMW) was used to assess the extent of mangrove degradation in the Mesurado Wetland. The extent of mangrove forests in the Mesurado Wetland is declining overall, with the GMW dataset showing a decadal loss of ~6.3% (~150 ha) of mangrove forest between 1996 and 2016. While mangrove coverage declined every year between 1996 and 2016, the largest annual loss — 120 ha, 5% of total mangrove area in 1996 — occurred between 2009 and 2010 (Figure 2 overleaf).

[8] Global Mangrove Watch. 2020. 2010 Baseline Released Version 1.2.[Online]. Available: https://www.globalmangrovewatch.org/. Accessed 6 May 2020.

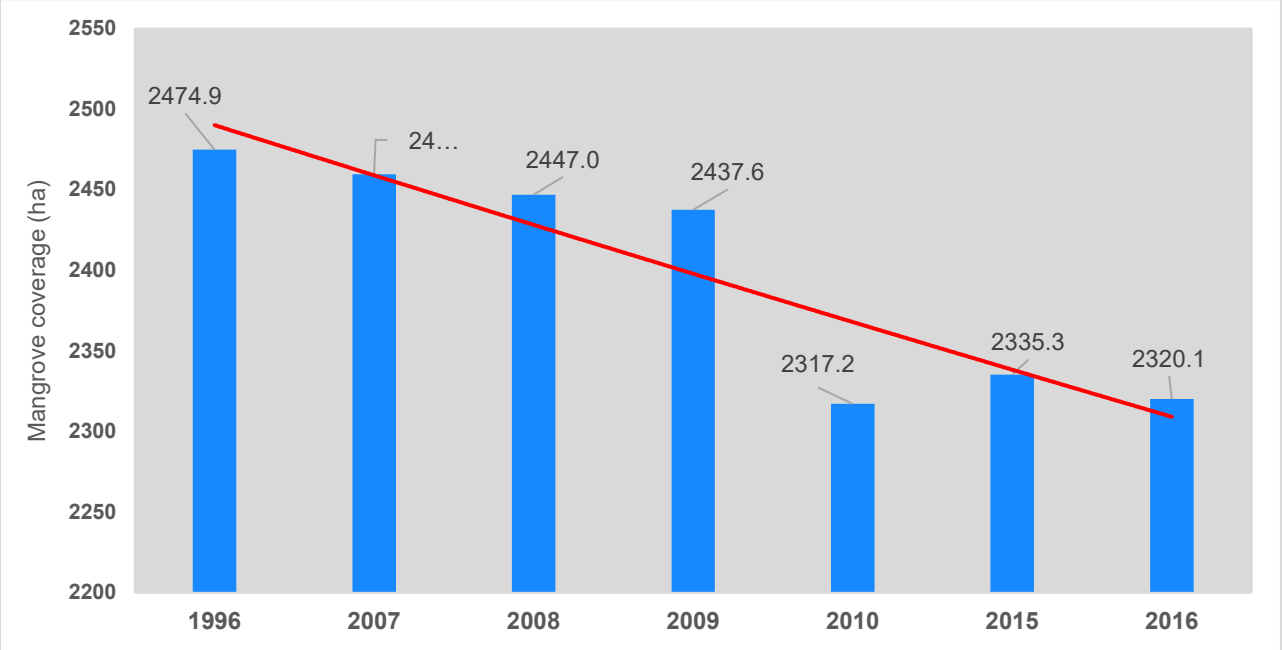

Figure 2. Change in absolute area (ha) of mangrove forests within the Mesurado Wetland between 1996 and 2016.

Anomalously, the GMW data showed a slight increase in the extent of mangrove coverage in the Mesurado Wetland of ~ 18 ha (0.7% of total mangrove area in 1996) in 2015 (Figure 3).

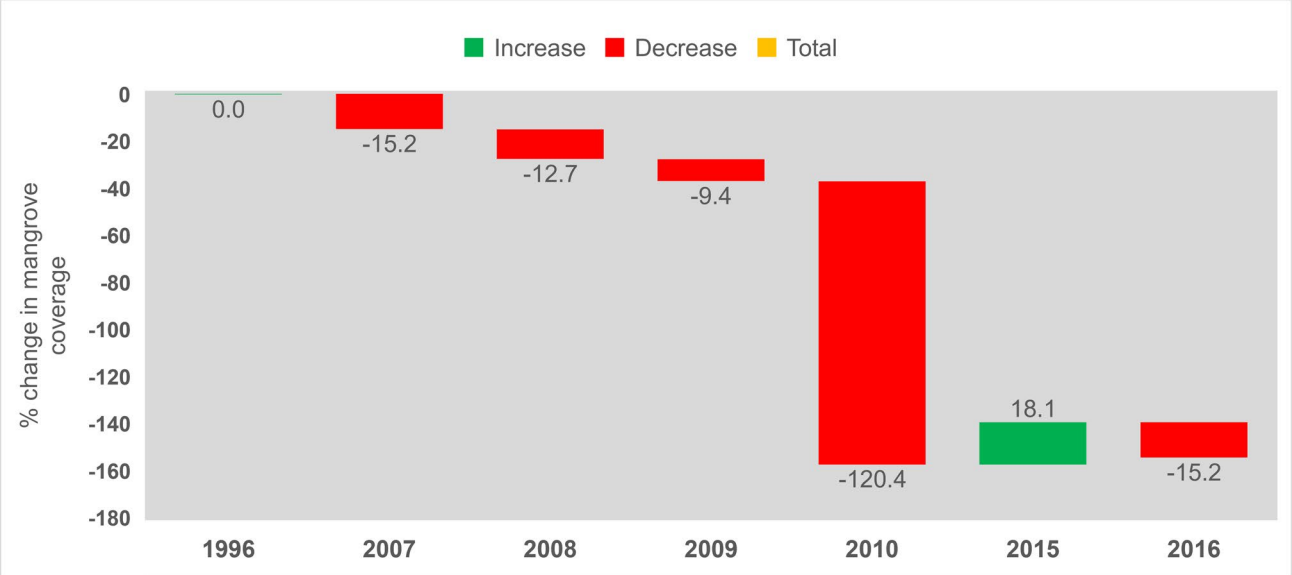

Figure 3. Percentage change in total mangrove coverage in the Mesurado Wetland between 1996 and 2016.

In general terms, the spatial decline in coverage of mangrove forests in the Mesurado Wetland is concentrated in three communities: i) Topoe Village; ii) Plonkor/Fiamah; and iii) Nipay Town/Jacobs Town (Figure 4 overleaf). While this spatial degradation trend implies that these communities may be solely responsible for the loss of mangrove forests in these focus areas, it is important to note that this is not necessarily the case. It is likely that the ecosystem services and livelihood opportunities (Section 2.3) provided by the mangroves attract subsistence and commercial harvesters and users from communities much further afield. For example, community members from West Point are known to travel upriver to access mangrove resources. Fuelwood and charcoal derived from clearing these

mangroves is then transported by boat to the lumber yards and fish market at West Point, where it is sold.

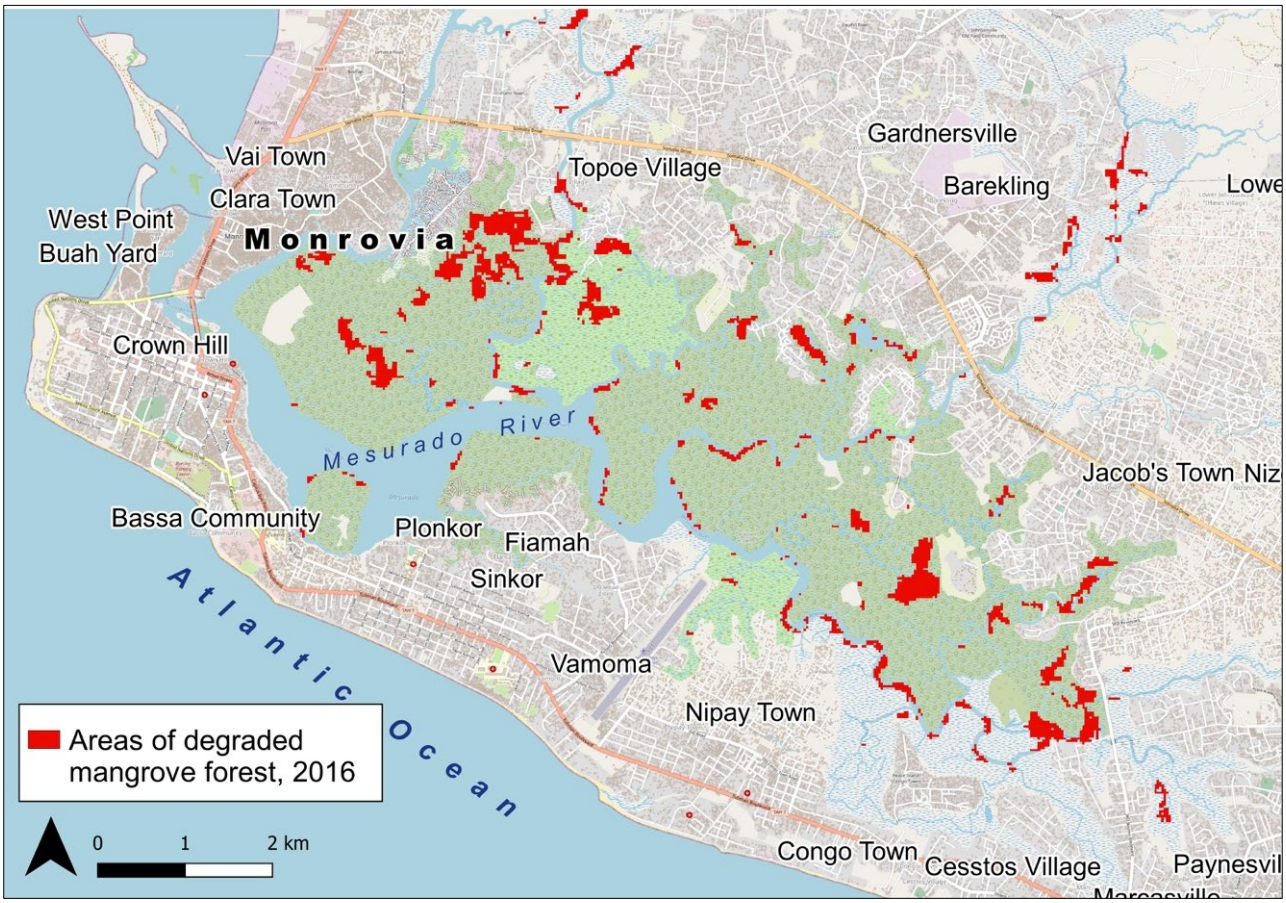

Figure 4. Spatial trend of mangrove loss in the Mesurado Wetland between 1996 and 2016.

Lessons and best practices learned from past and ongoing projects

Past and ongoing projects are a rich source of context-specific information, and best-practice examples. The lessons learned from a variety of relevant projects in Liberia and Monrovia have been assessed and incorporated into this report, the Feasibility Study (Annex 2.A), as well as the Funding Proposal. Section 6 of this report summarises the key lessons learned in this regard as follows:

- the tangible value of raising awareness on the importance and value of mangrove ecosystems;
- the need for, and benefit of, gender mainstreaming and gender equality in developing climate-resilient livelihood strategies;
- the potential of land-use planning to promote sustainability of coastal settlement and growth;
- the role and importance of partnering with local communities and users of ecosystem services via community-based natural resource management (CBNRM) and co-management agreements; and
- the proven financial and social benefits of creating an enabling environment for the uptake of alternate, climate-resilient livelihoods in coastal communities.

Recommended interventions

Over-exploitation and deforestation of mangrove forests in the Mesurado Wetland is driven primarily by unsustainable extraction of resources, encroachment into the mangrove forests for housing and limited legal protection of mangrove forests (Section 3.1). In Monrovia, smoking is the traditional and

dominant means of preserving fresh fish. The comparatively low level of technology of open, wood-fuelled smoking systems[9] means that the preservation process is inefficient and so large amounts of wood are consumed[10]. Preserving fish by smoking therefore exacerbates the deforestation of the Mesurado mangrove forests, degrading the mangrove ecosystems and further threatening local livelihoods. Preservation of fresh fish through smoking with energy-efficient cookstoves; or through cold storage are methods that could reduce the amount of fuelwood harvested and thus reduce mangrove degradation.

The proposed project therefore recommends energy-efficient cold storage facilities and cookstoves, respectively, as efficient and sustainable alternatives to current practices in the artisanal fishing industry that degrade the mangroves of the Mesurado Wetland. These proposed interventions are discussed in detail under Section 7.1 and 7.2, respectively.

[9] open fire-pits fuelled by mangrove wood
[10] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.

2. INTRODUCTION

This report presents a desktop evaluation of the ecological state of mangrove forests in Monrovia's Mesurado Wetland[11], highlighting the importance of mangrove ecosystems in supporting the livelihoods of surrounding communities (Section 3.1). The study includes a spatio-temporal analysis[12] that maps the threats to mangrove forests within the Mesurado Wetland, as well as trends in their degradation over the past three decades (Section 4.3). Based on the results of this analysis — as well as lessons learned from related projects and ongoing mangrove conservation initiatives (Sections 5 and 6) — several recommendations are made for project-level interventions. If implemented, these interventions will enhance the climate resilience of communities in Monrovia through the protection and conservation of mangrove forest ecosystems (Section 7).

2.1. Mangrove ecosystems

Mangrove forests occur in the intertidal zone along tropical and subtropical coastlines, covering ~81,000 km^2 across 105 countries[13]. These ecosystems include 60 species of trees in 12 genera that are adapted to high salinity and fluctuating water levels. Mangrove ecosystems are important for the food security and livelihoods of communities in surrounding areas as they provide essential ecosystem services such as: i) spawning grounds and nurseries for fish, crabs, shrimps and other forms of marine life; ii) protection against extreme weather events such as storm winds and marine and terrestrial floods; ii) preservation of coastlines by reducing erosion from storm surges, currents, waves, and tides; and iii) provision of food, medicine and wood and non-wood forest products. Mangrove ecosystems are however under threat globally, with their geographical area having declined by up to 50% during this century[14]. This global degradation of mangrove ecosystems has been driven by *inter alia*: i) clearing for aquaculture; ii) fuelwood harvesting; and iii) encroachment linked to urbanisation. Furthermore, sea-level rise (SLR) associated with climate change is projected by climate scientists to inundate mangroves in many parts of the world, exacerbating the degradation of these ecosystems.

2.2. National context of mangrove ecosystems in Liberia

Mangrove forests in Liberia cover ~0.5% (~127,900 ha) of the total land surface and occur along a 15 km-wide belt that extends along the length of its ~560 km long coastline (Figure 5). The forests mainly occur within estuaries or lagoons that run parallel to the beach behind barrier islands[15,16]. Although the area of mangrove forests that occur along Liberia's coast is not as large as some African countries, these forests support the livelihoods of a large proportion of Liberia's population. This is because ~58% of Liberia's ~4 million people live within 64 km of the coast and many of them depend on mangrove ecosystems for subsistence and commerce[17]. In general, communities residing along

[11] The Mesurado Wetland is a Ramsar Convention site. Wetlands listed under the aforementioned convention are considered to be of global significance and conservation importance.
[12] Spatiotemporal models arise when data are collected across time as well as space and have at least one spatial and one temporal property. An event in a spatiotemporal dataset describes a spatial and temporal phenomenon that exists at a certain time, 't' and location, 'x'.
[13] Extrapolated value for 2014. From: Hamilton, SE, & Casey, D. 2016. Creation of a high spatiotemporal resolution global database of continuous mangrove forest cover for the 21st Century (CGMFC-21). Available at: https://arxiv.org/abs/1412.0722
[14] WWF. 2020. Mangroves. Available at: https://www.worldwildlife.org/biomes/mangroves
[15]Earthtime Inc, CDR International, UNDP. 2019. Provision of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MAA) in Liberia. Part III - Environmental and Social Assessment Report (ESAR): United Nations Development Programme and Liberia Environmental Protection Agency.
[16] Ibid.
[17] Hahn B, Barber J, Johnson D, Garbo HW (eds). 2014. *Liberia - Environmental threats & opportunities*. US Department of Agriculture Forest Service of International Programs. Washington

Liberia's coast have few alternative livelihood strategies and rely heavily on mangroves for food, land, and other resources[18].

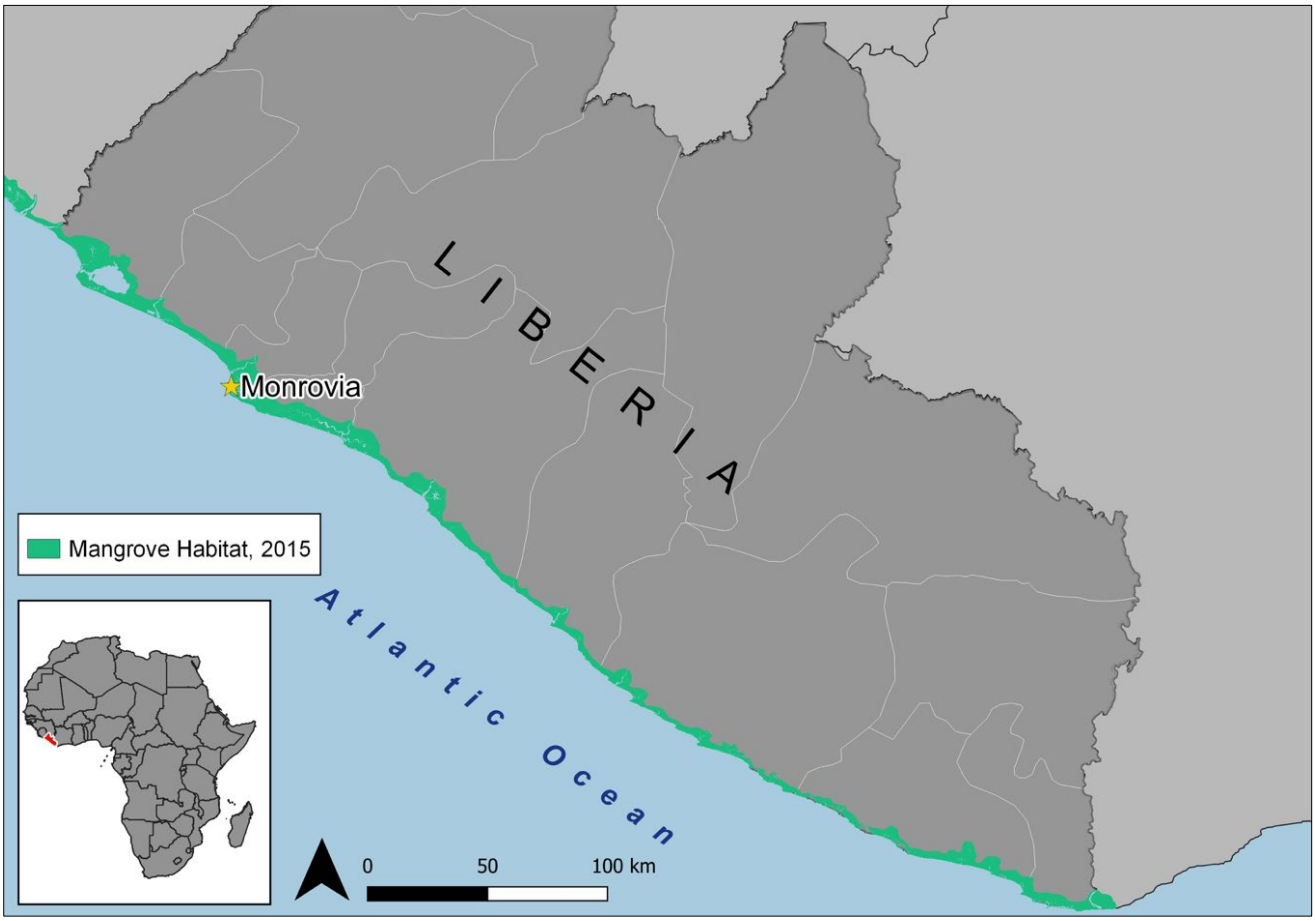

Figure 5. National extent of mangrove coverage in Liberia[19].

2.3. Local context of mangrove ecosystems in Monrovia: the Mesurado Wetland

In addition to its status as the national capital of Liberia, Monrovia is also the capital of the Montserrado County. The Mesurado Wetland[20] (06° 18'N 10° 45'W), within this county, is a primary feature of the Monrovian landscape and covers ~60% (~6,760 ha) of the city's total area[21]. Extensive mangrove forests occur within this estuary, particularly in the tidal basin formed by the Mesurado River as it nears the Atlantic Ocean. Figure 5 overleaf illustrates the interrelationships between the estuarine, wetland and mangrove components of the Mesurado Wetland.

[18] Republic of Liberia 2014a. *Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas*. Global Environment Facility (GEF) Request for CEO Approval. Monrovia: Environmental Protection Agency and Conservation International

[19] Source data: Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

[20] The term 'wetland' is misleading as it implies a purely freshwater ecosystem. The Mesurado Wetland is in fact primarily an estuarine or saline environment, although estuaries are considered part of the broader definition of wetlands in most national contexts. Whereas the terms 'Mesurado Wetland', 'estuary', and 'mangroves/mangrove forests' are used interchangeably in this report, the interrelationship between these biophysical aspects is important.

[21] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.

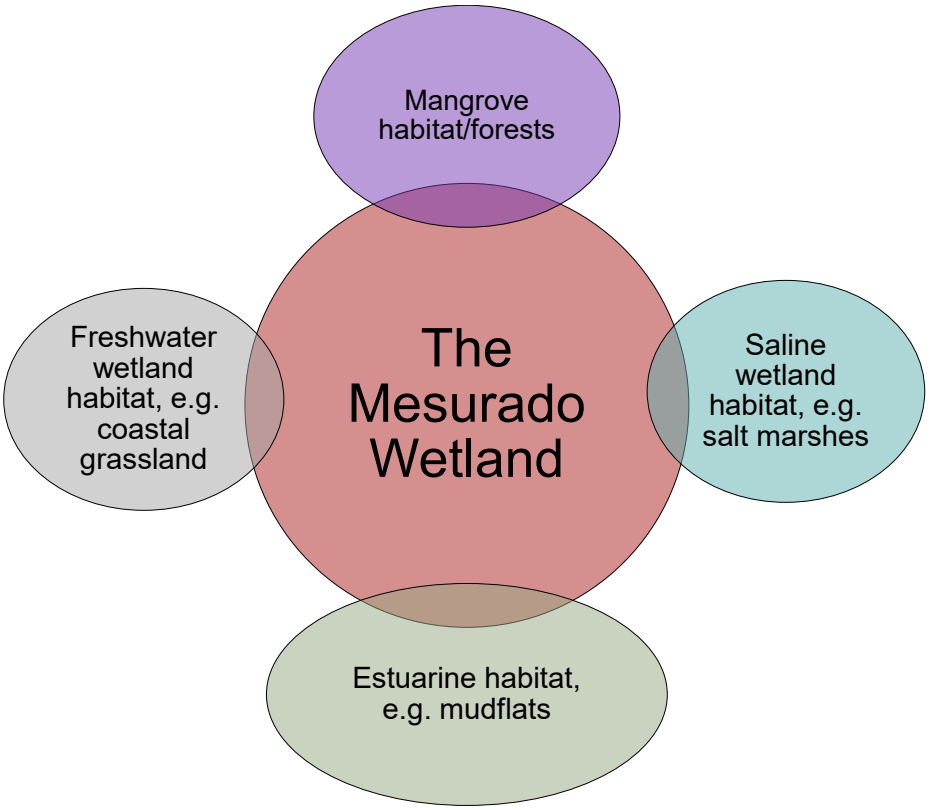

Figure 6. Visual summary of the relationship between the biophysical constituents of the Mesurado Wetland.

Monrovia has urbanised rapidly over the past 50 years to the detriment of its mangrove forests. Clearing and transformation of this habitat is primarily driven by high demand for dwellings and raw materials, as well as pollution from inadequate sanitation infrastructure and unsustainable waste management practices. Figure 6 overleaf emphasises this trend of transformation by showing that the Mesurado Wetland, as at 2016, is entirely surrounded by built-up or transformed landcover classes[22].

[22] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.

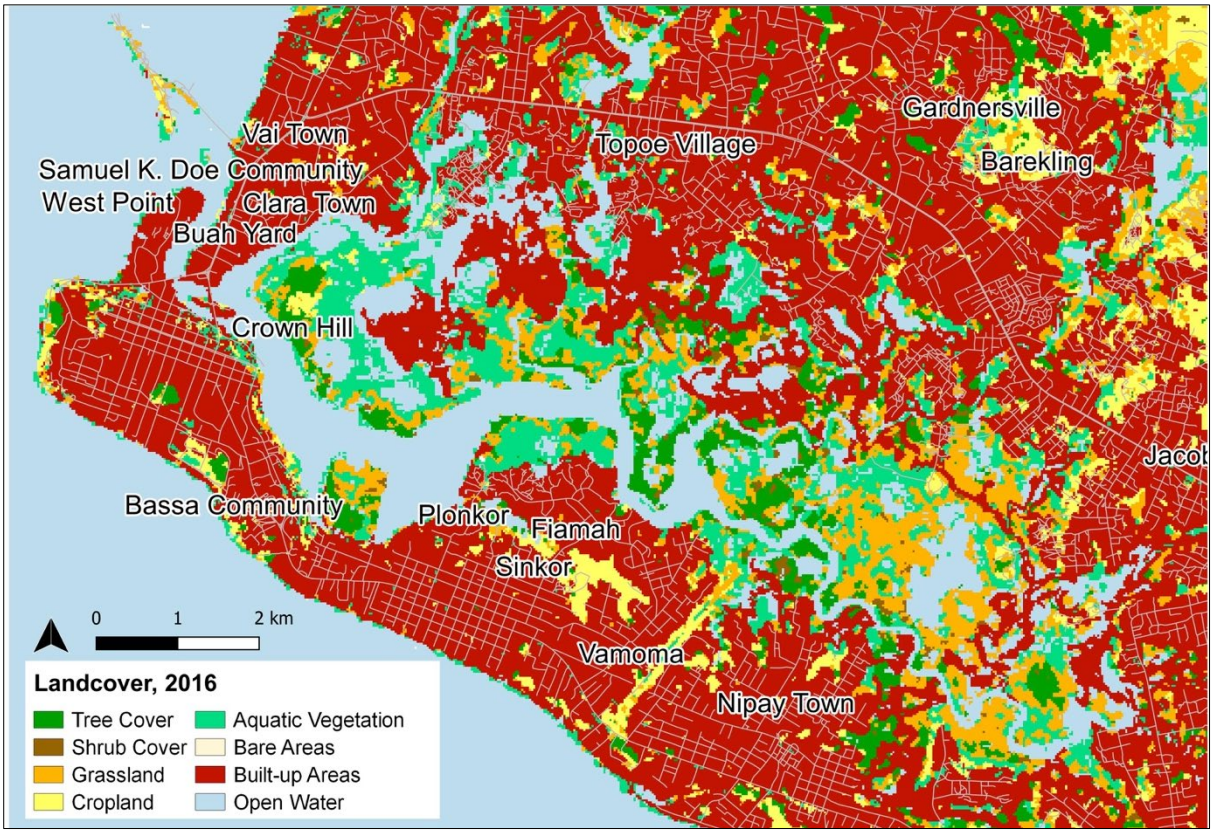

Figure 7. ESA 2016 landcover map of the Mesurado Wetland and the surrounding communities[23].

Mangrove forests are the dominant vegetation type in the Mesurado Wetland, covering more than 99% (~6,750 ha) of the wetland's area[24]. The forests contain important mangrove tree species such as French petit (*Rhizophora harrisonii),* red mangrove *(R. mangle)* and black mangrove (*Avicennia africana)* that are threatened by intensive charcoal burning and fuelwood collection. The red mangrove tree (*R. mangle*), which represents more than 80% of the forest area, is the most common tree species in the mangrove forests of the Mesurado Wetland. These forests provide a favourable habitat and feeding ground for several species of birds including the African spoonbill (*Platalea alba*), common pratincole (*Glareola nuchaltis*) and curlew (*Numenius arquata*). They also host the vulnerable African dwarf crocodile (*Osteolaemus tetraspis*), the Nile crocodile (*Crocodylus niloticus*), the critically endangered African sharp-nosed crocodile (*Mecistops* sp.), and the endangered Upper Guinea red colobus monkey (*Procolobus badius*), as well as many other ecologically important species. As a result, the Mesurado mangrove forests are considered to be of high conservation value and have been designated as one of five wetlands in the country of global significance under the Ramsar Convention[25].

In addition to being of high conservation value, mangrove forest ecosystems in the Mesurado Wetland also provide surrounding communities with essential ecosystem services such as: i) spawning grounds and nurseries for many inshore and nearshore fish and shellfish species of commercial value; ii) firewood for fuel, charcoal production and fish smoking; and iii) fertile soils for agricultural land. Notably, by providing nursery habitats, these mangrove forests support the tilapia (*Pelmatolapia*

[23] Data source: European Space Agency Sentinel-2A Prototype Land Cover 20 Meter Map of Africa 2016. [Online]. Available: http://2016africalandcover20m.esrin.esa.int/
[24] Kiazolu OG. 2019. *Assessment of level of public knowledge, attitudes, and perception towards mangrove forest conservation in Mesurado Wetland in Liberia*. Unpublished Master of Arts thesis, University of Nairobi, Nairobi.
[25] The Convention on Wetlands, known as the Ramsar Convention, is an intergovernmental environmental treaty established in 1971 by UNESCO, which came into force in 1975.

mariae) population, which is an important component of the fisheries in the lagoons and lower river courses of the greater Monrovia area. Consequently, the productivity of fisheries in the area is closely linked to the functioning and conservation of Mesurado mangrove ecosystems. Degradation of mangrove forests can have a devastating impact on fishery yields, with losses to coastal fisheries amounting to as much as 480 kg of fish per year for every hectare of forest lost[26].

Mangrove forests in the Mesurado Wetland are also used intensively as a source of firewood for fuel, charcoal production and fish smoking[27]. High demand for mangrove fuelwood within Liberia's coastal communities has created value chains based on fuelwood trading (Figure 8). These value chains provide economic and subsistence opportunities to woodcutters, wood retailers, and charcoal producers and retailers. Woodcutters harvest wood from the nearby mangrove forests which is split into smaller logs for firewood. Some of the bigger trees are harvested to produce planks for wood workshops and domestic construction. Offcuts are sold to firewood traders who use them to produce charcoal or split them into smaller pieces for sale. Charcoal is produced in large quantities by coastal communities and transported to nearby major urban centres such as Monrovia, Buchannan and Robertsport, where a 35 kg bag is sold for ~US$5[28]. The intensive extraction of firewood for fuel, charcoal production, and fish smoking linked to value chain has resulted in extensive deforestation and degradation of mangrove forest ecosystems in the Mesurado Wetland[29]. The degraded mangrove ecosystems, however, have the potential to recover through secondary regrowth if firewood harvesting is regulated and carried out sustainably.

[26]Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

[27] Republic of Liberia (ed). 2006. *First state of the environment report for Liberia - 2006*. Environmental Protection Agency and United Nations Development Programme. Monrovia.

[28] Tuagben DS. 2012. The vulnerability of the coast of Liberia to marine oil spills: Implications for biodiversity and renewable natural resource utilization. Unpublished MSc thesis, University of Cape Town, Cape Town.

[29]Republic of Liberia (ed). 2006. *First state of the environment report for Liberia - 2006*. Environmental Protection Agency and United Nations Development Programme. Monrovia.

Figure 8. One of the lumber yards at West Point where mangrove wood and charcoal are sold.

Local communities that reside in and around the Mesurado Wetland also use mangrove forest ecosystems for agriculture, although this practice is not widespread in this area. In other mangrove forests in Liberia, such as those in the Gbedin and Kpatawee and Lake Piso estuaries, agriculture is the dominant economic activity. A recent survey has shown that ~86% of residents of communities surrounding the Mesurado mangroves do not engage in agricultural cultivation within the forests[30]. This is because the highly urbanised communities that live in and around the Mesurado mangrove forests depend mainly on alternative livelihoods such as small-scale informal business and casual employment[31]. Indeed, approximately 49% of residents in communities around the Mesurado rely on Monrovia's small-scale, informal sector — dominated by small traders and service providers — for their primary livelihood activities[32]. Fishing is another less-prevalent livelihood activity among the communities in and around the Mesurado Wetland. Although fish yields in mangrove forest areas are significantly higher than in other shoreline habitats, only 1% of residents in these communities conduct fishing as a livelihood activity in the Mesurado Wetland itself, while many more Monrovians rely on nearby coastal fisheries for their livelihoods[33].

[30] Kiazolu OG. 2019. *Assessment of level of public knowledge, attitudes, and perception towards mangrove forest conservation in Mesurado Wetland in Liberia*. Unpublished Master of Arts thesis, University of Nairobi, Nairobi.
[31] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.
[32] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International
[33] Kiazolu OG. 2019. *Assessment of level of public knowledge, attitudes, and perception towards mangrove forest conservation in Mesurado Wetland in Liberia*. Unpublished Master of Arts thesis, University of Nairobi, Nairobi.

3. PROBLEMS AND ROOT CAUSES

3.1. Threats to mangrove-dependent livelihood activities

Approximately 1.12 million people living in Monrovia benefit directly or indirectly from the ecosystem services provided by mangrove forests in the Mesurado Wetland and from the associated waterways which are used for transportation, commercial and non-commercial fishing, and sand mining for construction[34]. Despite their substantial socio-economic importance, mangrove forests in the Mesurado Wetland are among the most threatened ecosystems in Liberia[35]. The ecological integrity of the forests and the ecosystem services they provide are threatened by *inter alia*: i) unplanned clearing for housing and infrastructure development by surrounding communities; ii) uncontrolled and unsustainable harvesting of firewood for fuel, charcoal production and fish smoking by communities residing within the forests and surrounding areas; iii) unsustainable sand mining; iv) illegal felling of mangrove trees for building poles and timber production; v) unregulated fishing; vi) uncontrolled waste disposal, especially of city garbage and sewage from residents within the mangroves and neighbouring homes; and vii) pollution from nearby industrial plants, including an oil refinery and paint factories[36,37]. As a result of these root causes, mangrove ecosystems in the Mesurado Wetland are severely degraded. Additional information on anthropogenic threats to mangrove forest ecosystems and mangrove-dependent livelihood activities in the Mesurado Wetland are provided below.

Sea-level rise (SLR) caused by climate change is expected to result in higher water levels in the Mesurado Wetland over the next few decades. Consequently, climate change will worsen the impact of the above-mentioned root causes of mangrove degradation by inundating or 'drowning' mangrove forests[38]. In many parts of the world, mangrove forests are expected to adapt to sea-level rise by migrating upslope or inland, i.e. horizontal migration. However, in Monrovia, mangrove forests are almost surrounded — and are being encroached — by the city and will not be able to adapt to sea-level rise through horizontal migration[39]. Therefore, unless appropriate action is taken to protect the mangroves in the Mesurado Wetland, climate change-related SLR will exacerbate pressure on the ecosystem and result in a reduction in the area suitable for mangrove habitat. This may be offset by a reduction in pressure on the mangroves as people become displaced by the effects of SLR, with flooding forcing them to relocate. If relocation is extensive, some expansion of mangroves may occur as the negative anthropogenic impacts are reduced.

Mangrove inundation in the Mesurado Wetland is however projected to occur over an extended period as high rates of sedimentation in the forests is expected to ameliorate the effects of climate change-related SLR. The Mesurado estuary — in which the mangrove forests of the Mesurado Wetland occur — has a low water outflow rate and receives substantial sediment input from upstream. As a result, mangrove soil surfaces are projected to rise in tandem with SLR, resulting in the forests maintaining their locations and extent into the foreseeable future. Measurements using the Surface-Elevation Table-Marker Horizon method in 2006 and 2011 showed that mangrove surfaces were rising at similar rates to SLR at several sites across the wetland[40]. Mangrove forest in the Mesurado Wetland,

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[34] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

[35] Republic of Liberia (ed). 2006. *First state of the environment report for Liberia - 2006*. Environmental Protection Agency and United Nations Development Programme. Monrovia

[36] Republic of Liberia (ed). 2010b. *The master plan study on urban facilities restoration and improvement in Monrovia in the Republic of Liberia. Environmental impact survey on the project for reconstruction of Somalia Drive in the Republic of Liberia*. Ministry of Public Works. Monrovia.

[37] Kiazolu OG. 2019. *Assessment of level of public knowledge, attitudes, and perception towards mangrove forest conservation in Mesurado Wetland in Liberia*. Unpublished Master of Arts thesis, University of Nairobi, Nairobi.

[38] CDR International. 2019. Consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia. Annex 2.C: Engineering Sub-assessment. Monrovia: United Nations Development Programme and Liberia Environmental Protection Agency.

[39] Ibid.

[40] Ibid.

therefore, have the potential to enhance vulnerable Monrovian communities' resilience towards climate change into the medium and long-term future by continuing to provide them with essential ecosystem services if they are protected and conserved.

3.1.1. *Clearing for housing and infrastructure development*

Large areas of the mangrove forests within the Mesurado Wetland have been cleared for residential housing and construction of industrial buildings (Figure 9), as well as for road construction, landfills and cemeteries[41]. Much of this clearing has occurred in the Paynesville, Caldwell, Johnsonville, and Barnesville areas of the capital[42]. The removal of mangrove forests for residential and business expansion began during Liberia's first civil conflict (1989–1997) when many displaced people — having minimal space to construct homes and business premises — established landfills and began building in the Mesurado wetlands. Urban sprawl into mangrove forests is projected to worsen as Liberia's rapidly growing post-conflict economy and increasing population overwhelm Monrovia's originally planned land area[43].

Figure 9. Expansion of residential housing and infrastructure into the Mesurado Wetland[44].

3.1.2. *Harvesting of firewood for fuel, charcoal production and fish smoking*

The high demand for firewood in greater Monrovia has resulted in considerable degradation of mangrove forest ecosystems[45]. The reliance of communities in Monrovia on wood for cooking, heating and fish smoking is driven by limited access to reliable electricity supplies. The high demand for firewood is influenced further by the current practice of cooking, heating and smoking fish using open wood fires. Open fires are energy inefficient as large amounts of heat energy escape during the process. This energy inefficiency increases the amount of firewood required. Mangrove wood is also used extensively in producing charcoal. While there is no official data available on the volume of mangrove wood used by coastal communities in charcoal production, and whether the amount is

[41]FAO (ed). 2005. *Liberia country profile*. Food and Agriculture Organization of the United Nations, Forestry Department. Rome.
[42] Edmond KP, Lloyd P, Bhat BV, Padhya HJ. 2016. *Urban land use planning scopes in post-war city of Monrovia, Republic of Liberia*. Paper presented at the International Conference on Engineering: Issues, Opportunities and Challenges for Development, S.N. Patel Institute of Technology & Research Centre, Umrakh, Bardoli.
[43] Ibid.
[44] Earthtime Inc, CDR International, UNDP. 2019. Provision of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MAA) in Liberia. Part III - Environmental and Social Assessment Report (ESAR): United Nations Development Programme and Liberia Environmental Protection Agency.
[45] Republic of Liberia (ed). 2006. *First state of the environment report for Liberia - 2006*. Environmental Protection Agency and United Nations Development Programme. Monrovia.

sustainable, the practice is widely considered to pose a severe threat to mangrove forests in the country[46].

The high demand for and use of mangrove wood for charcoal production and fish smoking by communities residing around mangrove forests does not entirely depend on access and availability, but also on the specific qualities of mangrove wood. Although most of the charcoal in Liberia is produced from wood collected from terrestrial ecosystems, mangrove wood is widely used in the process as it is considered to add strength and longevity to the product. As a result, charcoal made with a percentage of mangrove wood is more valuable on the market compared with charcoal produced entirely from wood from terrestrial ecosystems. Firewood from mangrove forests is also valued for smoking fish because, unlike wood from terrestrial ecosystems that turn fish black during smoking, mangrove wood imbues the fish with a distinctive brown colour that buyers find more appealing[47]. As a result, it is difficult to provide Liberia's coastal communities with a suitable substitute for mangrove wood in charcoal production.

3.1.3. *Sand mining*

Sand mining (Figure 10) is a threat to mangrove forests in the Mesurado Wetland. Although no data is available on the exact volumes mined, sandpits dug during sand mining cause depressions along the coast that enhance erosion along the shoreline. Increased coastal erosion, in turn, causes mangrove forest degradation by reducing the area of suitable habitat. The process is self-reinforcing as mangrove degradation causes further coastal erosion as the forests, with their complex root structures, play an essential role in preventing erosion.

Figure 10. Sand mining in mangrove forest areas in Liberia[48].

At present, however, sand mining is a marginal factor in causing loss of sediment and coastal retreat in the Monrovia area when compared with climate change-induced sea-level rise (SLR) and natural coastal erosion. The West Point area, for example, is currently experiencing the loss of ~50-60,000 m^3 of sand per annum due to natural causes and this figure is increasing exponentially because of climate change. Sand mining is, therefore, a negligible contributor to erosion in this context, i.e. to have a significant impact there would need to be movement of thousands of truckloads (12 m^3/truck)

[46] Earthtime Inc, CDR International, UNDP. 2019. Provision of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MAA) in Liberia. Part III - Environmental and Social Assessment Report (ESAR): United Nations Development Programme and Liberia Environmental Protection Agency.
[47] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International
[48] Ibid.

of sand per year. Furthermore, the beach at West Point is difficult for trucks to access, so any sand mining that occurs there would likely be via canoes or by hand (Figure 10). Nevertheless, there is a need for institutional and capacity building to ensure that sand mining conducted in the area is regulated.

3.1.4. *Felling of mangrove trees for building poles and timber production*

Although no primary data is available, the felling of trees for building poles and timber production has led to extensive deforestation and degradation of mangrove forests in the Mesurado Wetland. This is mainly because of inadequate regulation or monitoring of the domestic timber value chain in Liberia[49]. Nationally, ~20% of Liberia's mangroves have been lost to deforestation, with tree species such as *Rhizophora racemosa* and *Laguncularia racemosa* driven to extinction in some parts of the coast by unsustainable felling[50]. Much of this forest loss has been concentrated around the major coastal towns and cities, such as Monrovia, Buchanan, Greenville, Robertsport and Harper. Except for a few places in the central part of the country, primary mangrove forests in Liberia have been replaced by secondary forests, that is, successional forests that re-grow after clearing/destruction of the original forest but are composed of different plant species (Figure 11). These successional forests might offset some of the negative effects of timber harvesting but timber extraction in the Mesurado Wetlands is expected to increase in response to increasing demand for domestic timber driven by the growing population, high levels of construction, and rapid urbanisation in Monrovia. If these successional forests are exposed to harvesting before they facilitate the return of primary mangrove forest species, then the natural recovery process will be hindered.

Figure 11. A dense stand of *Rhizophora racemosa* and an area of cleared mangrove forest at an early stage of successional regrowth.

3.1.5. *Unregulated fishing*

Most communities living in, and next to, mangrove forests in Liberia capture fish from these ecosystems using lines, traps and nets (Figure 12). However, in some areas, such as the Marshall and Lake Piso Wetlands (both of which are among the five Ramsar wetlands in Liberia), community

[49] Bickel, Allison & Cerutti, Paolo, *Liberia: Domestic Timber Value Chain Analysis*, 2017. [Online].Available: https://www.researchgate.net/publication/312332213_Liberia_Domestic_Timber_Value_Chain_Analysis. Accessed 5 May 2020

[50] Hahn B, Barber J, Johnson D, Garbo HW (eds). 2014. *Liberia - Environmental threats & opportunities*. US Department of Agriculture Forest Service of International Programs. Washington.

members frequently use unsustainable and destructive fishing methods — such as a poison known locally as '*zama*', and dynamite — which lead to marked declines in fish populations. These unsustainable and wasteful fishing methods place the livelihoods of coastal communities that rely on the mangroves for their income at risk [51]. While some information about the system is available, the marine biology of the Mesurado mangrove forests has not been studied in detail and its sensitivity to over-fishing, as well as to pollution and the impacts of climate change, remain predominantly unknown[52].

Figure 12: Fishmongers plying their trade in central Monrovia (A). Beached fishing boats looking out towards the Mesurado Wetland from West Point (B).

3.1.6. *Waste disposal and pollution from nearby industrial plants*

The rapid expansion of Monrovia has outstripped the provision of infrastructure and services across the city[53]. The rapid development of Monrovia began during the presidencies of Tubman and Tolbert (1944 to 1980) and continued, though with less structure, through the years of civil war (1980 to 2003) and beyond[54]. One of the results of this unstructured development has been a breakdown in waste management in Monrovia, resulting in the ecological integrity of mangrove forests being threatened by marine debris and poor water quality (Figure 12 and Figure 14)[55]. In addition, the pollution has resulted in large areas of mangroves becoming degraded as they are used as dumpsites or for sewage disposal.

[51] Republic of Liberia (ed). 2006. *First state of the environment report for Liberia - 2006*. Environmental Protection Agency and United Nations Development Programme. Monrovia.
[52] CDR International. 2019. *Consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia*. Annex 2.C: Engineering Sub-assessment. Monrovia: United Nations Development Programme and Liberia Environmental Protection Agency.
[53] Ibid.
[54] Ibid.
[55] Ibid.

Figure 13: Informal homes built on cut mangroves in the Mesurado Wetland, viewed from West Point.

Figure 14. Mangrove root systems collecting and trapping debris in the Mesurado Wetland[56].

[56] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

4. SPATIO-TEMPORAL DEGRADATION ANALYSIS

4.1. Introduction

The Mesurado Wetland is a highly urbanised system, with built-up areas surrounding the estuary on all sides (Figure 15). Close to the estuary are the communities of West Point, Crown Hill, Tope Village, Vamom and Nipay Town. The mangrove forests of the Mesurado Wetland — categorised below according to their density and functional integrity as: i) sparse; ii) transitional; or iii) well-established — are predominantly surrounded by built-up areas. The encroachment of this densely-populated human settlement into the mangrove forests exposes the ecosystem to human activities and drives degradation (Section 3.1).

Figure 15. GTI 2015 landcover map of the Mesurado Wetland and the surrounding communities[57].

4.2. Methodology

The purpose of this spatio-temporal analysis[58] is to quantify and map changes in the extent of mangroves in the Mesurado Wetland, focusing on degradation hotspots and degradation trends, respectively. To achieve this, historical remote sensing satellite data was analysed to identify potential degradation trends and hotspots. A combination of two spatial data analysis methods was used as described below.

[57] GeoTerraImage (Pty) Ltd (GTI). 2015. Liberia Mangrove Classification Dataset, 2014-15.
[58] Spatiotemporal models are used to compare data across time as well as space and have at least one spatial and one temporal property. An event in a spatiotemporal dataset describes a spatial and temporal phenomenon that exists at a certain time, 't' and location, 'x'.

4.2.1. *Analysis of Global Mangrove Watch data*

A global dataset created by Global Mangrove Watch[59] (GMW) was used to assess the extent of mangrove degradation in the Mesurado Wetland. The GMW is an international coalition formed by the Japanese Aerospace Exploration Agency's (JAXA) Kyoto and Carbon Initiative, with the objective of producing geospatial information on changes to mangrove extent at a global and regional scale. Data collection for this project began in 1996, with the most recent available dataset being from 2016.

The GMW data was developed by first establishing a baseline map in 2010 of mangroves at a global level through a random forest classification of both Landsat sensor spectral composite data — all spectral wavebands — and Advanced Land Observing Satellite (ALOS) Phased Arrayed L-band Synthetic Aperture Radar (PALSAR). Using both optical and radar data types benefited the random forest classification as these are sensitive to the differences in species composition, cover and distribution of woody material. Changes away from and within this baseline were subsequently derived for 1996 (JERS-1[60]), 2007, 2008, 2009 (ALOS PALSAR[61]), 2015 and 2016 (ALOS-2 PALSAR-2[62]) using a thresholding histogram[63] approach. These data reflect losses or gains in mangrove wood volume or biomass and can accordingly be used to map changes relative to mangrove baseline data.

To assess the degradation of mangroves in Monrovia, the global dataset provided by GMW was overlaid with the area of the city. The loss of mangrove areas was spatially represented by stacking layers for each year, with the most recent years on top. Removing the most recent dataset (2016) spatially demonstrates the degradation of areas that were part of the historical mangrove extent. (Figure 16).

[59] Global Mangrove Watch. 2020. 2010 Baseline Released Version 1.2. [Online]. Available: https://www.globalmangrovewatch.org/. Accessed 5 May 2020
[60] Japanese Earth Resources Satellite 1 was a satellite launched in 1992 by the Japan Aerospace Exploration Agency.
[61] Advanced Land Observing Satellite-1 was a satellite launched in 2006 by the Japan Aerospace Exploration Agency, PALSAR was one of three instruments aboard.
[62] Advanced Land Observing Satellite 2 is a Japanese satellite launched in 2014, PALSAR-2 is an upgraded version of PALSAR was one of the instruments aboard.
[63] Method of image processing which uses peaks, valleys and curvatures of the smoothed histogram for analysis

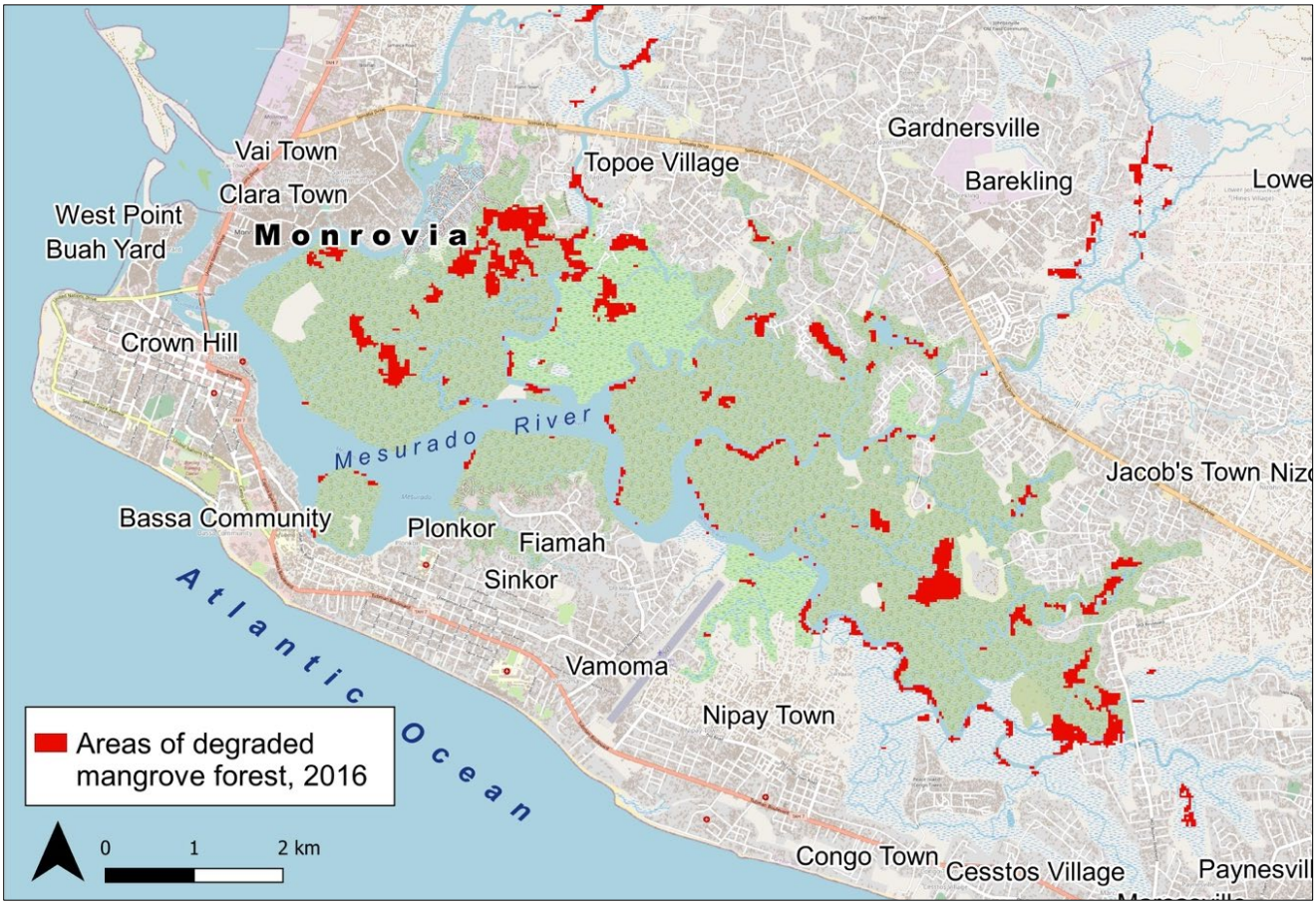


Figure 16. A map indicating areas of degraded mangrove forests in the Mesurado Wetland. These areas were historically part of the mangrove extent, but the 2016 GMW dataset[64] indicates that they have been completely transformed.

4.2.2. *Analysis using the Enhanced Vegetation Index*

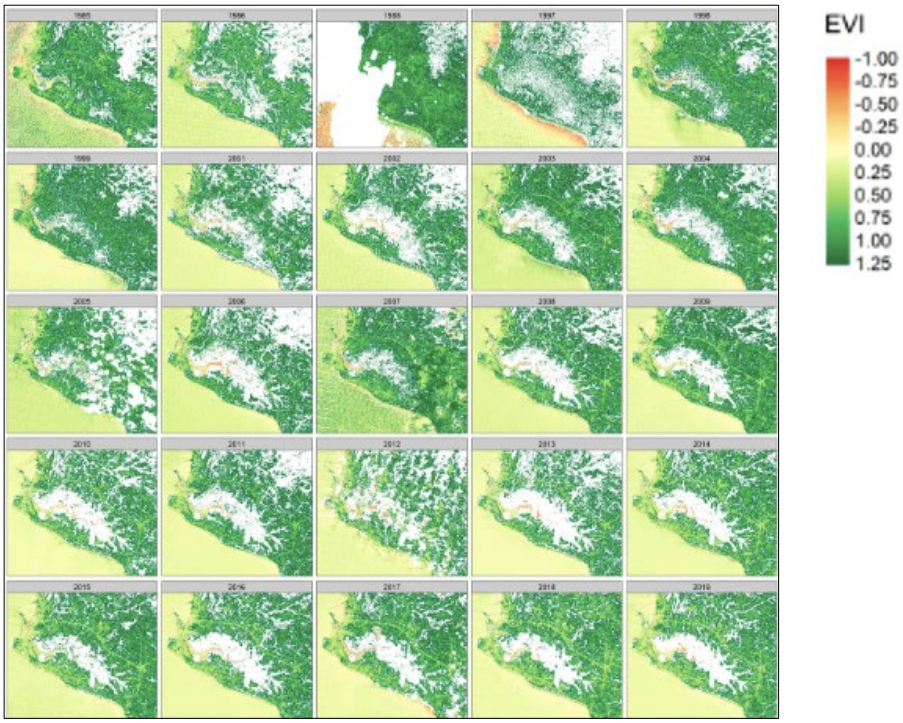
To address the limitations of available data from the GMW dataset, the analysis in this study was supplemented using Enhanced Vegetation Index (EVI) to complete the dataset. EVI is an optimised vegetation index designed to enhance vegetation cover identification with improved sensitivity and was developed as an alternative index to the more limited Normalised Difference Vegetation Index (NDVI). Improvements in the EVI include correcting for distortions in the reflected light caused by particles in the air, as well as the ground cover below the vegetation. Data from EVI also does not become saturated as easily as NDVI when viewing areas of the earth with large amounts of chlorophyll[65].

For EVI analysis of the Mesurado Wetland mangroves, United States Geological Survey (USGS)[66,67] for the period between 1985-2019 and the median EVI value for the dry season (December through March) was calculated using the following equation:

[64] Global Mangrove Watch. 2020. 2010 Baseline Released Version 1.2. [Online]. Available: https://www.globalmangrovewatch.org/. Accessed 5 May 2020
[65] NASA Earth Observatory. 2000. Measuring vegetation (NDVI & EVI). [Online]. Available: https://earthobservatory.nasa.gov/features/MeasuringVegetation. Accessed 6 May 2020.
[66] This dataset is the atmospherically corrected surface reflectance from the Landsat 7 ETM+ sensor.
[67] Available at https://earthengine.google.com

2.5 * ((NIR - RED) / (NIR + 6 * RED - 7.5 * BLUE + 1))[68]

A range of EVI values that approximate tree cover around Monrovia was determined as EVI > 1.5 by using satellite-based true colour image validation (Figure 17). Nine out of 34 total years in the dataset were excluded based on quality control or gaps in data. The total classified tree cover area for each year was extracted and the change in cover for the earliest (2002) and latest (2019) years included in the analysis were visualised for comparison (Figure 17).



[68]Calculation for EVI from Landsat 4-7 provided by USGS.[Online]. Available: https://www.usgs.gov/land-resources/nli/landsat/landsat-enhanced-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con . Accessed 6 May 2020.

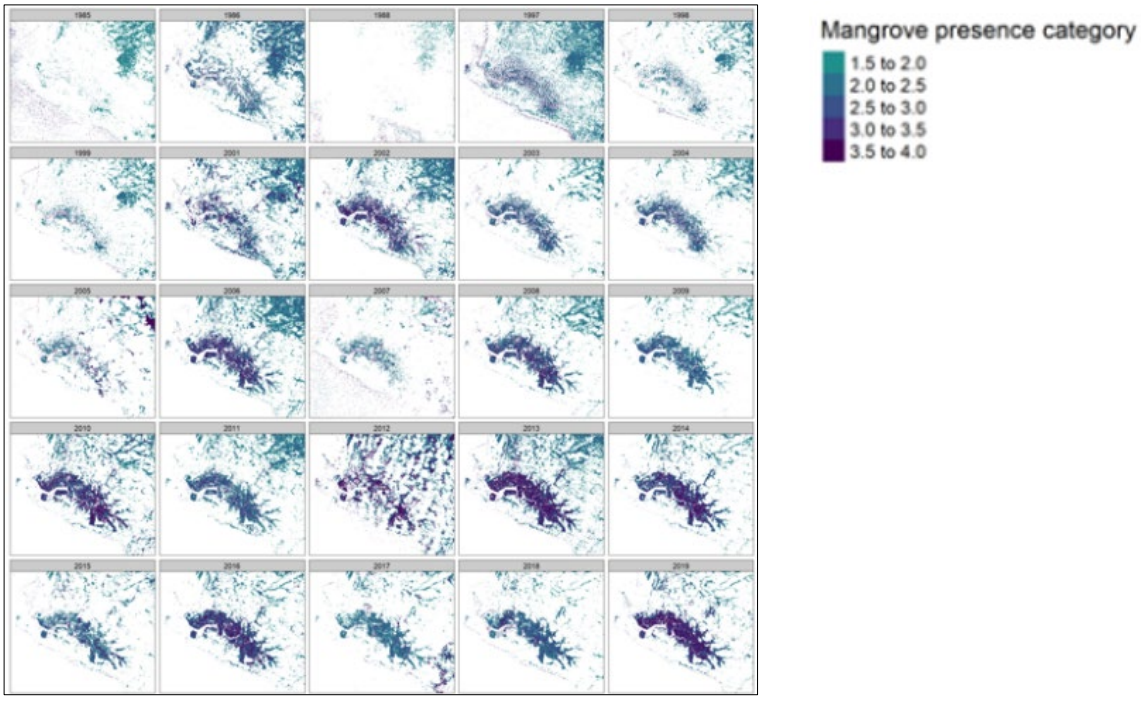


Figure 17. EVI values for the Mesurado Wetland and surrounding areas, before (TOP) and after (BOTTOM) extracting data from the identified EVI range (>1.5) in order to isolate mangrove vegetation[69].

[69] Calculation for EVI from Landsat 4-7 provided by USGS https://www.usgs.gov/land-resources/nli/landsat/landsat-enhanced-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con

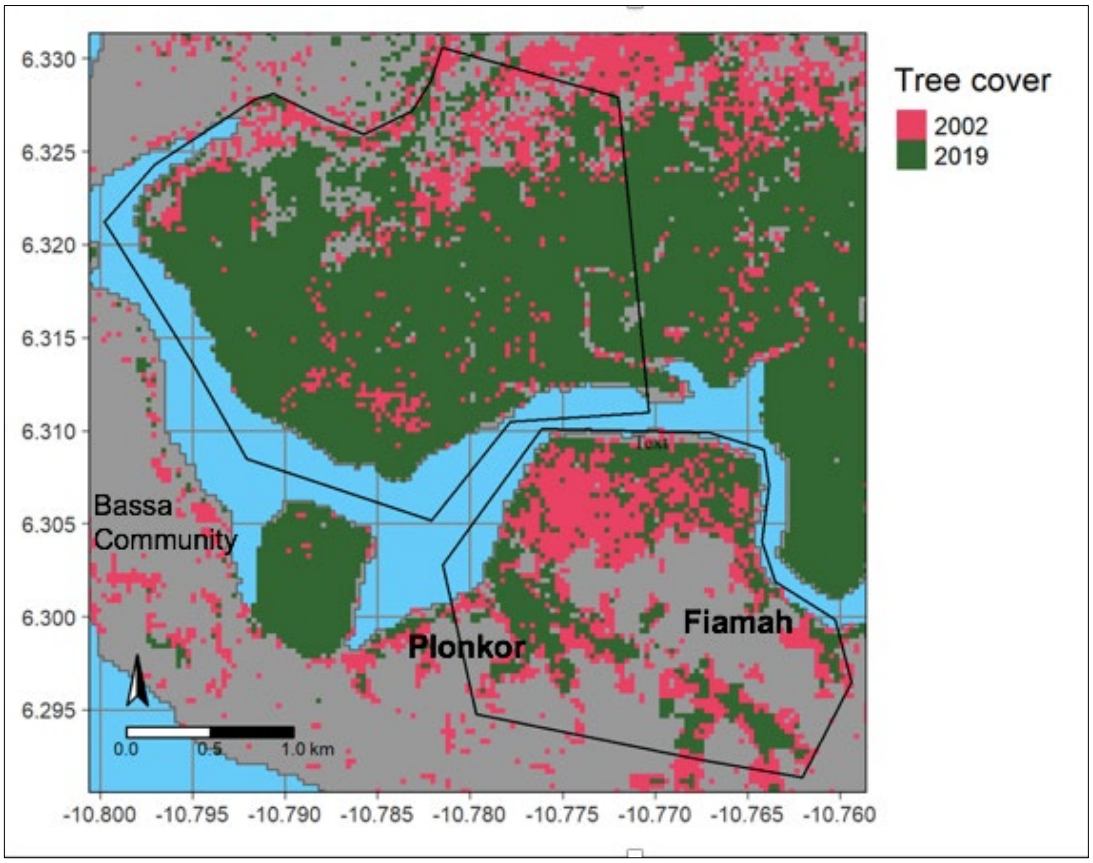


Figure 18. EVI analysis of the Mesurado Wetland to measure degradation. A comparison of mangrove forest coverage of 2002 and 2019 is presented[70].

4.3. Degradation trends and hotspots

The overall trend of mangrove forest area extent in Monrovia shows a decline. Every year in the GMW dataset recorded a loss of mangrove forest area (Figure 15), with the largest loss (from 2009 to 2010) accounting for ~5% of the total mangrove area.

[70] Ibid.

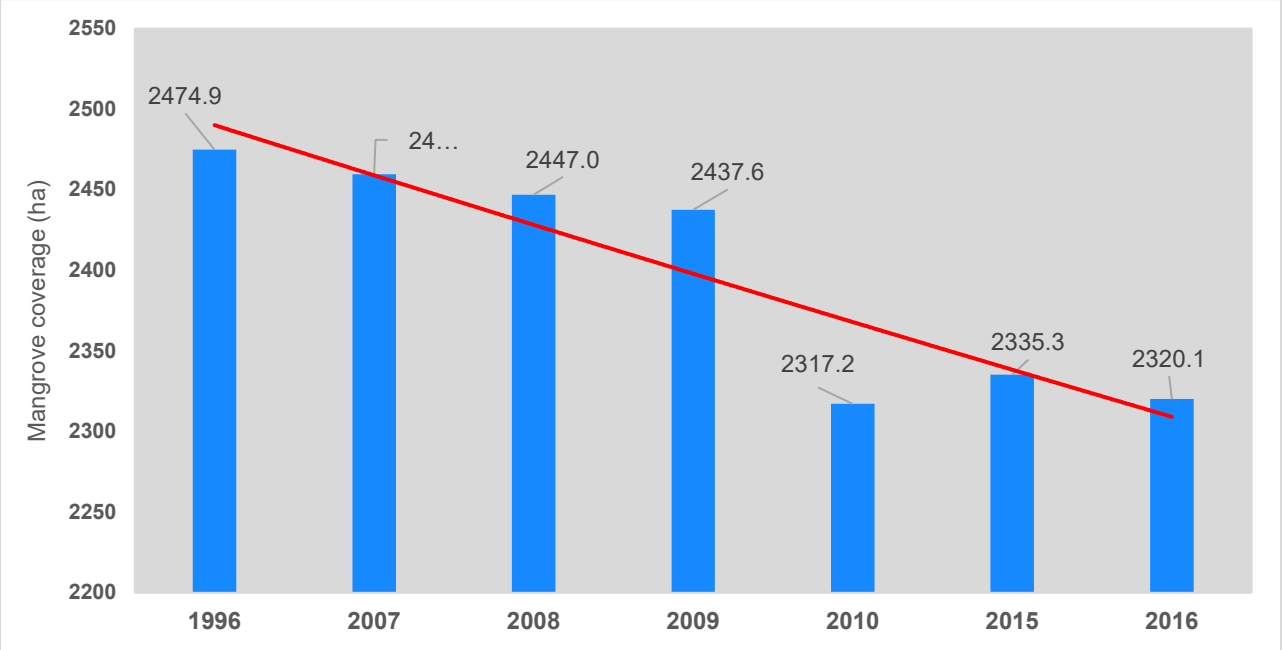


Figure 19. Extent of mangrove coverage within the Mesurado Wetland between 1996 and 2016. Data sourced from Global Mangrove Watch[71].

The potential future loss of mangrove forests was examined using EVI data (2002-2019) to identify if the previous trend shown in the GMW dataset would persist. The EVI data was used to extract the predicted tree cover extent at three levels: i) the entire Monrovia area of interest; ii) the northwest corner of the estuary; and iii) an area on the southwest bank of the estuary that includes the Plonkor and Fioma communities. The latter focus area is characterised by referred to informally as "*the Stilts*" (Figure 20 overleaf) due to the high levels of clearing for residential housing.

[71] Global Mangrove Watch. 2020. 2010 Baseline Released Version 1.2. [Online]. Available: https://www.globalmangrovewatch.org/. Accessed 5 May 2020

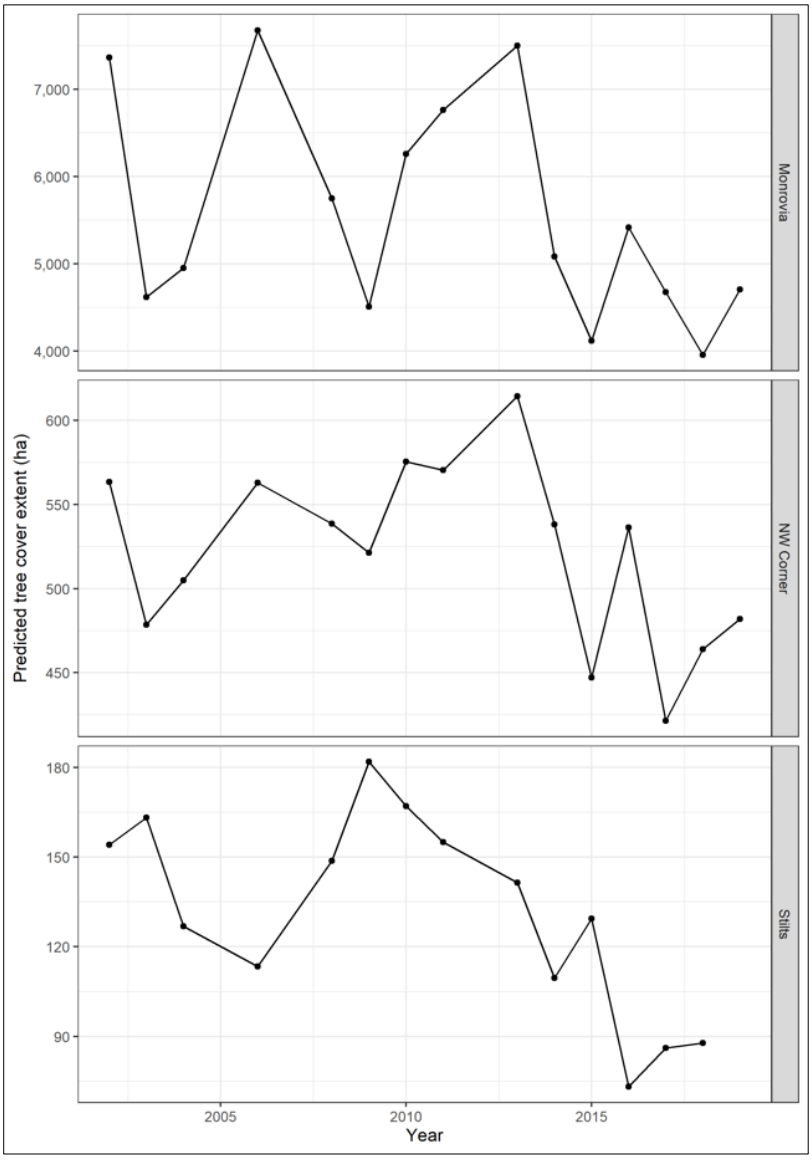


Figure 20. From the results of the EVI analysis, the predicted tree cover extent was extracted at three levels: the overall Monrovia area and two focused areas within the Mesurado Wetland[72].

A trend of decline in mangrove coverage at all three levels is visible. While earlier years see fluctuation between increases and decreases, a steady decline is visible from around 2012, after which the mangrove cover does not return to its previous peaks. The sharpest decline is experienced in the area termed “the Stilts”, located within the Plonkor and Fiama communities, where human settlement has encroached further into the wetlands (Figure 21).

[72] Calculation for EVI from Landsat 4-7 provided by USGS https://www.usgs.gov/land-resources/nli/landsat/landsat-enhanced-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con

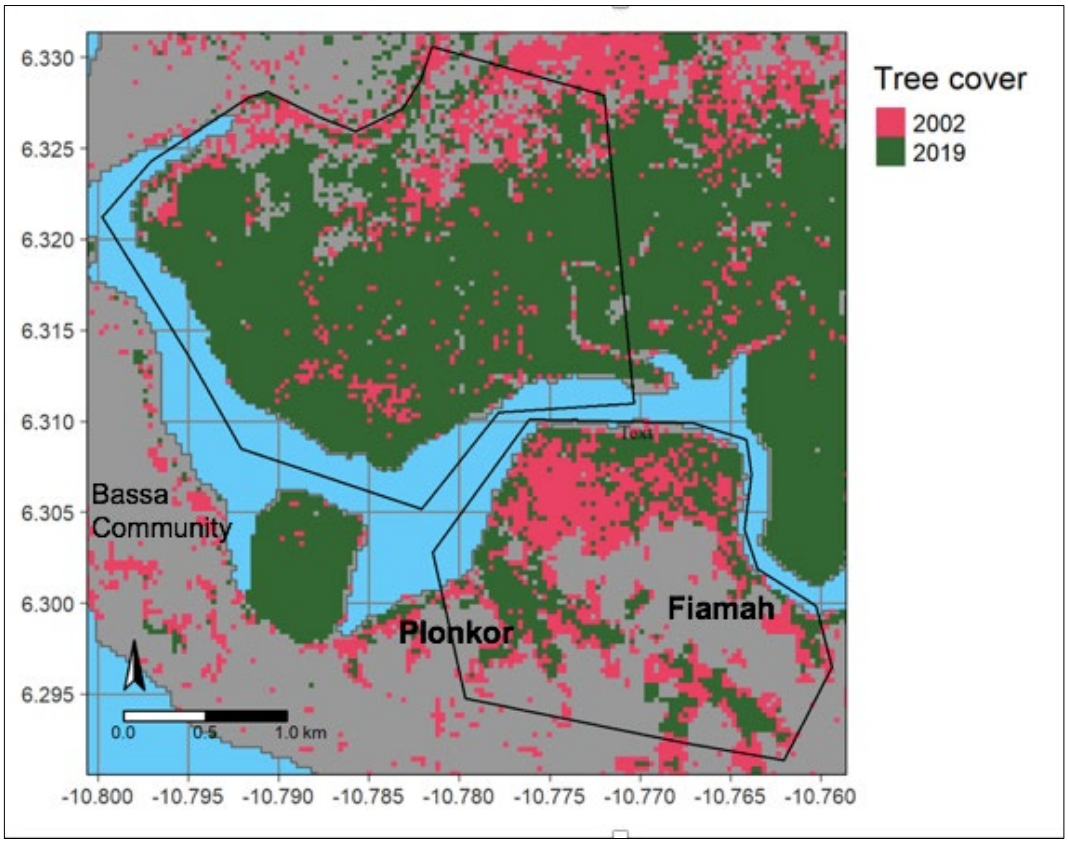


Figure 21. Focused map of the two smaller extents within the larger Monrovia area of interest. The upper polygon indicates the northwest corner of the Mesurado Wetland, and the lower polygon denotes the communities of Plonkor and Fiama[73].

As a general trend, degradation occurs predominantly in areas where human settlements about the mangroves, as well as on the banks of the Mesurado river and its smaller channels. There are also several degradation hotspots on small islands that occur within the wetlands. These islands are accessible via land-bridges which connect to nearby suburbs such as Jacobstown.

4.4. Conclusions

Overall, mangrove forest loss in the Mesurado Wetland occurs in the areas most accessible to humans, i.e. the spatial distribution of degradation shows an association between mangrove degradation and human settlements. As human settlement in the area expands, more of the mangrove forest will be surrounded by developed areas, and as a result, mangrove degradation can be expected to continue to increase.

[73] Calculation for EVI from Landsat 4-7 provided by USGS https://www.usgs.gov/land-resources/nli/landsat/landsat-enhanced-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con

5. BASELINE INTERVENTIONS AND PAST AND ONGOING PROJECTS

Relevant past and ongoing projects in Liberia are summarised in the following sections.

5.1. Reclaiming Liberia's beaches and waterways, 2011-2014

The Liberia Maritime Authority-run project "**Reclaiming Liberia's beaches and waterways, 2011-2014**."[74] This project — which was funded at ~US$1.5 million/year — was aimed at raising the awareness of local communities in Liberia about the importance of coastal and mangrove ecosystems. In addition, the project provided employment through beach clean-ups and supported small community developments such as latrines.

5.2. Enhancing resilience of vulnerable coastal areas to climate change risks in Liberia

The UNDP GEF-financed pilot project "**Enhancing resilience of Liberia Montserrado vulnerable coastal areas to climate change risks in Liberia, 2017-2018**."[75] This project piloted a series of strategies for reducing vulnerability and building the resilience of local communities and socio-economic sectors to the threats of climate change in Liberia's coastal Montserrado County. The project included the rehabilitation of degraded mangroves and training local communities in integrated coastal management. Through this project, the UNDP supported coastal communities in Montserrado County in conserving mangrove vegetation and in constructing energy-efficient ovens for drying fish. The project had a pilot site in Robertsport which focused on more efficient fish smoking to reduce the timber demand from nearby mangrove forests. The promotion of solar dryers and construction of energy-efficient ovens for drying fish have been the primary management interventions.
Specific outputs of the project included:

- enhanced awareness of coastal climate change impacts and available adaptation measures for senior country officials, decision-makers and stakeholders;
- establishment and equipping of a county coastal protection unit;
- development of a system for monitoring and maintaining coastal protection measures;
- formulation of a climate sensitive development agenda for Montserrado County under the lead of the National Climate Secretariat (NCCS); and
- protection of Hotel Africa and Kru Town communities from climate change impacts.

5.3. Protection, planning and livelihood security of mangrove forests in Liberia

The GEF project entitled "**Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as building blocks towards Liberia's marine and coastal protected areas, 2017-2019**."[76] The aim of this project was to secure protection for mangrove forest areas in Liberia by providing integrated land-use policies and tools for mainstreaming biodiversity conservation in these areas. Some of the achievements of the 2-year project include:

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[74] Republic of Liberia 2014a. *Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas*. Global Environment Facility (GEF) Request for CEO Approval. Monrovia: Environmental Protection Agency and Conservation International.
[75] Republic of Liberia (ed). 2014b. *Strengthening Liberia's capability to provide climate information and services to enhance climate resilient development and adaptation to climate change*. Environmental Protection Agency and United Nations Development Programme. Monrovia.
[76] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

- collection of baseline information on the distribution, extent, conservation status, value and critical threats to the fauna and flora of mangroves in Liberia;
- approval of a management plan for the Lake Piso Multiple-Use Reserve by Liberia's Forestry Development Authority;
- sourcing of funding from the Prince Albert II of Monaco Foundation and the Turing Foundation to establish the Marshall Proposed Protected Area as a protected area;
- establishment of co-management committees for Lake Piso Multiple-Use Reserve and the Marshall Proposed Protected Area;
- development of a participatory land-use planning tool kit which was then piloted in 10 communities distributed across 11,107 ha of priority mangrove areas across Liberia;
- development of 10 community participatory land-use plans covering a total surface area of 15,253 ha, of which 4,146 ha are mangroves;
- establishment of a GIS lab at Liberia's Environmental Protection Agency (EPA) and training of staff in GIS;
- training of 88 (2 women and 86 men) Frontline Conservationists to use mobile tablets to collect monitoring data via Survey 123 for ArcGIS. Additionally, a dashboard was set up at the EPA GIS Lab to analyse and report on the data collected; and
- the signing of 10 Community Conservation Agreements with the communities of Nyangba, Bleewein, Sarwein, Edina, Snafu-Dock, Ben's Town, Falie, Mandoe, Bomboja and Bendu, distributed across 4,146 ha of mangroves.

5.4. Conservation and sustainable use of Liberia's coastal natural capital

The Conservation International and Environmental Protection Agency-run project "**Conservation and sustainable use of Liberia's coastal natural capital, 2019-2024**." The aim of this project is to improve the conservation and sustainable use of Liberia's coastal natural capital by mainstreaming the value of ecosystems into the country's development trajectory. In particular, the aims of the project are to:

- establish an inter-ministerial Natural Capital Accounting (NCA) Steering Committee to guide and develop the implementation of natural capital accounting in Liberia;
- develop and execute a mangrove ecosystem account;
- enhance the capacity of Liberian government officials and other stakeholders on technical aspects of natural capital accounting;
- establish an operational framework for System of Environmental Economic Accounts[77] (SEEA)-compliant natural capital accounts;
- provide support to the Liberian government to incorporate natural capital accounting results into the national Aichi Targets, Sustainable Development Goals (SDG) and other international commitments and reporting mechanisms;
- develop a roadmap for prioritising and developing natural capital accounts for additional ecosystems, resources and sectors;
- identify and assess potential carbon-based financing mechanisms for coastal ecosystem conservation;
- develop at least one conservation-conscious enterprise that will transact with market participants in the project area to improve sustainable use of coastal and marine resources;
- establish a small grant mechanism to support coastal conservation;
- assess the potential scope, need and feasibility of a national financing mechanism to ensure long-term support for sustainable management of coastal ecosystems;

[77] The SEEA is a statistical standard and conceptual framework to define environmental statistics and bring them into an integrated system of environmental-economic information alongside the System of National Accounts.

- execute Conservation Agreements (CAs) with 10 communities along the south-eastern coast of Liberia; and
- design and set up a national conservation agreement program that offers economic incentives for coastal protection.

5.5. Management plans for the Lake Piso Wetlands[78]

There are various management plans that have been put in place since 2006 to maintain the ecological character of the Lake Piso Wetlands, near the Mesurado Wetland[79]**.** These plans were prepared during a field mission organised by Bird International in collaboration with other organisations such as the Farmers Associated to Conserve the Environment (FACE) and the United Nations Environment Programme (UNEP) in 2006[80]. FACE's mission in Liberia is to help empower local farmers to engage in practices that are sustainable, environmentally friendly, and have the potential to yield significant positive net income[81]. The organisation is also involved in seed rice reproduction and mangrove conservation[82] as well as promoting stable, modern farming systems to improve food production and preserve the natural environment[83]. The baseline management plans also include the restoration plan for mangroves as outlined in the five-year plan (2005-2009) of the Coastal and Marine Ecosystem Plan of Action.

5.6. Ongoing investments by the Liberian government in mangroves and coastal areas

The Liberian government invests significantly in the management and conservation of mangrove and coastal regions of the country through funding the activities of government agencies such as the Forestry Development Authority (FDA), Environmental Protection Agency (EPA) and Maritime Authority. The agencies' activities in mangrove and coastal areas are mainly directed at building awareness, improving livelihoods, monitoring intervention efforts, and planning sustainable ecosystem management planning. The FDA is the custodian of protected areas and provides employees to manage mangrove protected areas in Liberia. The EPA hosts several education and awareness-raising events related to conserving coastal regions and their biodiversity. These include hosting National Wetlands Day, Biodiversity Day, World Environment Day and Ozone/Climate Change Day. The total investment in these activities annually is ~US$75,000[84]. There is also ongoing collaboration between the EPA and the FDA in developing sustainable methods for using mangrove resources.

6. LESSONS LEARNED AND BEST PRACTICES

6.1. Awareness of the importance of mangroves

Although Liberia has a coastline that is dominated by mangrove forests, there is limited public knowledge on the ecological and socio-economic importance of these ecosystems in the country[85]. There is particularly limited understanding of mangroves' critical role in providing ecosystem services to local communities, including the maintenance of healthy fish stocks, coastal line protection, habitat

[78] Lake Piso is an open coastal lagoon ~100 km to the west of Monrovia. It is classified as a Ramsar site and its mangroves are important both as a nursery and spawning ground for fish and other animals like sea turtles.
[79] Republic of Liberia (ed). 2007. *Information Sheet on Ramsar Wetlands (RIS): Lake Piso*. Environmental Protection Agency. Monrovia.
[80] Ibid.
[81] Hahn B, Barber J, Johnson D, Garbo HW (eds). 2014. *Liberia - Environmental threats & opportunities*. US Department of Agriculture Forest Service of International Programs. Washington.
[82] Ibid.
[83] Ibid.
[84] Republic of Liberia 2014a. *Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas*. Global Environment Facility (GEF) Request for CEO Approval. Monrovia: Environmental Protection Agency and Conservation International.
[85] Tuagben DS. 2012. The vulnerability of the coast of Liberia to marine oil spills: Implications for biodiversity and renewable natural resource utilization. Unpublished MSc thesis, University of Cape Town, Cape Town.

provision to fish, carbon sequestration and provision of storm shelters. As a result, the importance of mangrove forest conservation is yet to be fully appreciated by most local communities living along Liberia's coastline. A recent survey conducted among the residents of Monrovia's Mesurado mangroves revealed that just over half of its residents are aware of mangroves' vital ecological functions[86].

Effective management and conservation of mangrove forests require an understanding of the ecological and economic value of mangrove ecosystems by local communities living in and around these forests to limit their degradation. Education on mangrove forest conservation that will further enlighten local communities on the sustainable management and conservation of these natural resources therefore needs to be implemented.

6.2. Conservation Agreements

The use of Conservation Agreements (CAs)[87] as part of ecosystem conservation projects in Liberia has been successful in improving the livelihood of communities and could therefore be useful in future projects. In Liberia, CAs have commonly been used to link conservation funders to resource owners or users whose decisions influence conservation outcomes. In many of the agreements, conservation investors (including governments, bilateral agencies, private sector companies, foundations, and individuals) have provided negotiated benefits packages in return for conservation actions by communities. The benefits packages in the CAs have typically included funding for provisioning of social services like health and education, as well as investment in livelihoods, often in agricultural or fisheries sectors. Examples of conservation commitments that have been included in CAs include: i) forgoing forest clearing; ii) adopting sustainable farming or fishing practices; and iii) participating in patrolling and other monitoring activities.

The use of CAs, however, requires careful consideration of local gender dynamics and customary decision-making mechanisms to be successful. As mentioned earlier, men and women interact with their environment in different ways and therefore have different needs, priorities, and interests in conservation. As a result, it is critical that projects design CAs with a clear understanding of the diverse needs, preferences and interests of men and women in the use of natural resources. For example, if harvesting mangrove wood for charcoal production is banned under a Conservation Agreement, this may only directly affect men who use the wood in charcoal production. However, if the ban includes harvesting mangrove wood for other purposes such as domestic fuel and fish drying, this will affect both men and women — with the latter disproportionately affected as they use fuelwood for these purposes. This also applies to activities and benefits included in CAs[88]. A previous project that employed CAs found that men in Liberia are more interested in patrol work and fishing, while women are interested in activities such as soap making and using eco-stoves for cooking and smoking fish. Gender mainstreaming is therefore critical in determining the kinds of benefits provided to communities in the implementation of project activities, which means CAs should contain negotiated appropriate alternatives.

Respecting customary decision-making mechanisms within a CA's targeted communities ensures that agreements are adapted to local contexts. However, some customary decision-making mechanisms restrict the disadvantaged or marginalised from having equal representation and voice. It is therefore

[86] Kiazolu OG. 2019. *Assessment of level of public knowledge, attitudes, and perception towards mangrove forest conservation in Mesurado Wetland in Liberia*. Unpublished Master of Arts thesis, University of Nairobi, Nairobi.
[87] An agreement where communities commit to implementing conservation actions, such as patrolling activities, forgoing logging and hunting and carrying out more sustainable resource extraction practices in exchange for a benefits package defined through participatory processes to address local development needs and priorities.
[88] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

necessary to find culturally appropriate ways to ensure that the interests of all stakeholders are considered in project decision-making processes[89].

6.3. Land-use planning

Partly because of Liberia's long civil wars[90], urban land-use planning and zoning regulations at the national or county level are limited in Liberia. Rapid urbanisation in Monrovia characterised by increased informal settlements contributes to constrained land-use planning in the city[91]. Activities such as unsanctioned urban sprawl and unplanned sand-mining have resulted in destruction of mangrove forest in the Mesurado Wetland[92]. Projects that seek to conserve mangrove ecosystems should, therefore, secure formal zoning of their targeted intervention sites. Without the development of detailed plans and legal zoning to guide land-use at project intervention sites, ensuring the sustainability of conservation initiatives is challenging[93]. The enforcement of both land utilisation and tenure at project sites will require the collaboration of the local communities to guarantee sustainability of project interventions beyond project implementation[94]. This requires awareness-raising and extensive consultations to secure community buy-in at project intervention sites[95].

6.4. Energy-efficient cookstoves

Historically, the people of Monrovia — and West Point in particular — have relied on mangrove forests as a source of fuelwood for cooking, heating and smoking purposes. This reliance is closely tied with the limited access to electricity in West Point, which coupled with the strong culture of fishery-based livelihoods and the specialised taste for smoked fish, promoted the practice of smoking fish for preservation. The increasing demand for fuelwood resources has led to deforestation of the mangrove forests, threatening the ecosystem services they provide. This problem is common in West Africa. An analysis of field interviews, literature and reported data on the state of mangrove forests across West African countries between 2000-2015 revealed that ~6% of the mangrove forests have been deforested[96]. In Liberia specifically, the decline in the mangrove forest area over this period was estimated at ~16.5km^2[97].

Given that the reliance of local communities on wood for cooking and smoking fish is one of several anthropogenic causes of degradation (as outlined in Section 3), there is opportunity to reduce mangrove degradation through the introduction of energy-efficient cookstoves. Such intervention will decrease the demand for fuelwood, thereby reducing pressure on natural forests. For the integration of alternative cookstoves to be effective as an intervention for energy-efficiency, it is necessary to consider the needs of the target community as well as the resources available to them.

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[89] Republic of Liberia (ed). 2016b. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Gender mainstreaming Strategy and Action Plan. Environmental Protection Agency and Conservation International Monrovia.
[90] 1989–1997 and 1999–2003
[91] Edmond KP, Lloyd P, Bhat BV, Padhya HJ. 2016. *Urban land use planning scopes in post-war city of Monrovia, Republic of Liberia*. Paper presented at the International Conference on Engineering: Issues, Opportunities and Challenges for Development, S.N. Patel Institute of Technology & Research Centre, Umrakh, Bardoli.
[92] USAID (ed). 2009. Liberia environmental threats and opportunities assessment (ETOA). USAID/Liberia, Office of Economic Growth. Monrovia.
[93] Ibid.
[94] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.
[95] Ibid.
[96] Feka, Z.N. and Morrison, I., 2017. Managing mangroves for coastal ecosystems change: a decade and beyond of conservation experiences and lessons for and from west-central Africa. *Journal of Ecology and The Natural Environment* 9:99-123.
[97] Ibid.

6.5. *Solar-powered cold storage solutions*

Another intervention as part of the proposed project is to implement cold storage units as a means of preserving fish and reducing pressure on fish populations (see section 7.1). The introduction of cold storage units will provide fishmongers with greater flexibility as to when to smoke fish without risking fish spoiling. The cold storage units will also provide fishmongers with the opportunities to access new markets — such as hotels, restaurants and fresh fish markets. In a recent project, the International Food Policy Research Institute (IFPRI) implemented a similar measure with ColdHubs[98] – walk-in, solar-powered food storage units – in rural Nigeria, where other forms of refrigeration have proved inadequate for food storage due to unreliable energy sources (Figure 22 overleaf). ColdHubs provide uninterrupted cold storage for produce which resulted in extending the shelf life of fresh foods from two to 21 days. ColdHubs operates a simple pay-as-you-store model. Farmers and retailers pay 100 Nigerian Naira (equivalent to USD 0.50) per day to store 20 kg of perishable food in a plastic crate inside the cold room[99]. ColdHub project managers in Nigeria identified some key challenges to implementation that serve as valuable lessons learned to integrate into future projects[100]. One challenge included educating farmers, retailers and wholesalers about the benefits of refrigeration compared with traditional methods. Overcoming this challenge required two phases: in the first phase project managers offered free trials to store produce in cold rooms. In the second phase, educational booklets in local languages were provided to potential customers on the best practices for post-harvesting and the financial benefits of cold storage.

6.6. *Gender mainstreaming*

Men and women in Liberia use mangroves differently and have unique perspectives about the value of mangroves and how they should be protected[101]. In general, men do the majority of fishing while women are responsible for smoking and selling the fish. Acknowledging these gendered differences is central to addressing the different drivers of mangrove loss and the principal beneficiaries of mangrove conservation[102]. Based on the critical differences in the use of mangrove and coastal resources by men and women in Liberia, a gendered perspective on mangrove conservation should be adopted by future projects.

Both women and men in Liberia are often included in decision-making bodies, but women tend to be offered nominal positions with little decision-making power or influence[103]. Therefore, despite women's statistical representation, their political and public voice remains underrepresented. In many cases, women find it difficult to contribute to the decision-making processes often as a result of the cultural taboo of women openly disagreeing with their male counterparts. Subsequently, efforts to increase gender equality in decision-making around coastal resources by combining men and women in public forums may not create an enabling environment for women's engagement, because the presence of men may serve as a limiting factor to women's participation[104].

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[98] International Food Policy Research Institute (IFPRI). 2020. ColdHubs: Addressing the crucial problem of food loss in Nigeria with solar-powered refrigeration. [Online]. Available: https://www.ifpri.org/blog/coldhubs-addressing-crucial-problem-food-loss-nigeria-solar-powered-refrigeration. Accessed 5 May 2020

[99] ColdHubs. 2020. https://www.caas-initiative.org/casestudies/caas-in-nigeria/

[100] International Food Policy Research Institute (IFPRI). 2020. ColdHubs: Addressing the crucial problem of food loss in Nigeria with solar-powered refrigeration. [Online]. Available: https://www.ifpri.org/blog/coldhubs-addressing-crucial-problem-food-loss-nigeria-solar-powered-refrigeration. Accessed 5 May 2020

[101] Republic of Liberia 2016a. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Global Environmental Facility (GEF) Project Document. Monrovia: Environmental Protection Agency and Conservation International

[102] Ibid.

[103] Republic of Liberia (ed). 2016b. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Gender mainstreaming Strategy and Action Plan. Environmental Protection Agency and Conservation International Monrovia.

[104] See Annex 8: Gender Assessment and Action Plan for further details

Projects that seek to ensure the equitable representation and participation in decision-making by both men and women should include the establishment of separate project decision-making bodies for men and women at targeted project sites[105]. These separate project decision-making bodies will then report directly to the main project management decision-making body[106]. Finally, efforts should aim to ensure that women's representation in mixed main project management decision-making bodies is not limited to nominal positions[107]. One way to achieve this is to ensure an equal number of positions and voting power for both men and women in such organisations.

Although women in Liberia tend to have limited access to positions of power and decision-making, the fishing industry supports the communities in a relatively equitable manner which appears to be rare[108]. The gendered distribution of labour in West Point – with men exclusively fishing while women are responsible for fish mongering – means that women occupy a powerful economic position as the receivers of revenue at the point of sale. The aforementioned ColdHub units (Figure 22 and Figure 23 overleaf) in Nigeria are run by women, who are employed as unit operation managers. They monitor the loading and unloading of crates, collect fees and build relationships with farm clusters and markets[109]. This upskills and empowers women. The proposed project might, in planning and implementing solar-powered cold storage units in Liberia, aim to learn from these practices to also capitalise on the need and opportunity to empower women in Liberia's fishing communities.

Further information and findings on gender conditions in the project area, as well as interventions to address gender-based vulnerability through project interventions is described in detail in the Gender Assessment and Action Plan in Annex 8.

[105] Republic of Liberia (ed). 2016b. Improve sustainability of mangrove forests and coastal mangrove areas in Liberia through protection, planning and livelihood creation – as a building block towards Liberia's marine and coastal protected areas. Gender mainstreaming Strategy and Action Plan. Environmental Protection Agency and Conservation International Monrovia.
[106] Ibid.
[107] Ibid.
[108] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.
[109] Deutschland.de. 2020. Solar-powered ColdHubs, Nigeria. [Online]. Available: https://www.deutschland.de/en/solar-powered-coldhubs-nigeria. Accessed 6 May 2020.

Figure 22. ColdHubs – walk-in solar-powered cold storage units – in rural Nigeria[110].

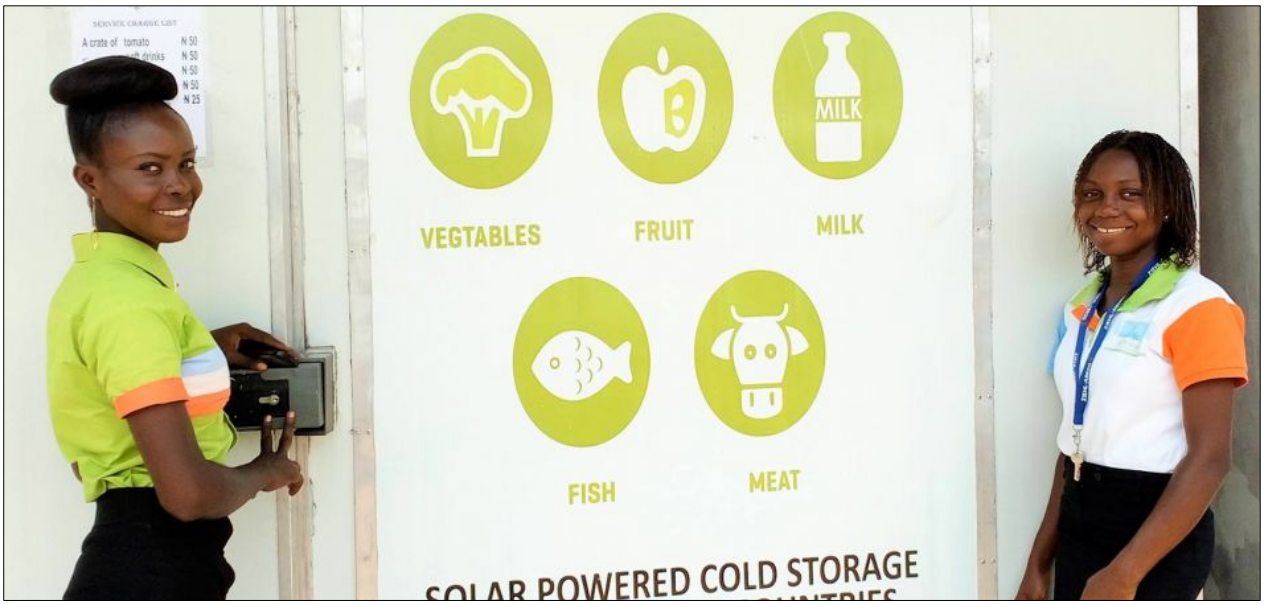

Figure 23. ColdHubs in Nigeria employ two women to manage the operations for each solar-powered cold storage unit[111].

[110] ColdHubs. 2020. The Solution: Walk-in, solar-powered cold stations for 24/7 storage and preservation. [Online]. Available: http://www.coldhubs.com/. Accessed 5 May 2020.
[111] ColdHubs. 2020. The Solution: Walk-in, solar-powered cold stations for 24/7 storage and preservation. [Online]. Available: http://www.coldhubs.com/. Accessed 5 May 2020.

7. RECOMMENDED INTERVENTIONS

Over-exploitation and deforestation of mangrove forests in the Mesurado Wetland is driven by primary factors such as unsustainable extraction and the expansion of informal settlements into the mangrove forests, as well as limited regulation on mangrove forests protection (Section 3.1). Felling and degradation of mangroves threatens the provision of important ecosystem services, consequently negatively impacting communities that are reliant on mangrove forests for their livelihoods (Section 2.3).

In Monrovia, smoking fish on an open fire is the traditional and dominant method of preserving fresh fish. The comparatively low-level technology characteristic of these wood-fuelled smoking systems requires an inefficient amount of wood consumption [112]. The high amount of wood for preserving fish through smoking therefore exacerbates the deforestation of the Mesurado mangrove forests, which further degrades the mangrove ecosystems and further threatens local livelihoods. Preserving fish in cold storage or smoking fish using energy-efficient cookstoves are two preservation methods that can reduce the wood harvesting and amount of fuelwood used by local communities in Monrovia, which can slow down the mangrove forest degradation.

The information presented in this annex indicates how both energy-efficient cold storage facilities and cookstoves would be appropriate as efficient and sustainable interventions to help alleviate degradation associated with current artisanal fishing industry practices — such as fish smoking — in the Mesurado Wetland. These proposed interventions are discussed in the following sections.

7.1. Energy-efficient cold storage to reduce fuelwood use and improve livelihoods

Cold storage is an effective fish preservation technique that does not require fuelwood. Cold storage solutions in close proximity to fish processing sites will enable communities to extend the shelf-life of fish catches, thereby reducing fish waste. Consequently, more fish per catch will be available to sell, which in turn may reduce the overall amount of fishing in a community, since effective preservation reduces loss to spoilage and helps stabilise fish supply. Pressure on fish populations will furthermore be reduced, which will improve ecosystem health and protect the livelihoods of fishing communities.

Long-term preservation of fish requires electricity to ensure fish stocks are frozen at -22°C at the start of the cold chain to prevent thawing until the fish is prepared for cooking. Monrovia's electricity supply is however unreliable, meaning cold storage systems might require alternative energy sources, such as solar energy. Solar panels are already successfully used in homes, businesses and schools in Liberia[113]. Solar energy technology should therefore be readily accessible to cold storage facilities and local knowledge regarding the maintenance of solar energy systems should already be established. Food storage facilities can be customised to include a diesel generator as a backup for solar energy where necessary, and additionally battery systems can be used on cloudy days.

UNDP recently procured five solar-powered cold storage containers for a Sierra Leone-based project that required fish storage facilities, and their use can be replicated in Monrovia. UNDP has provided specifications about the two cold container units, which have different sizes and manufacturers. Both include cold solar panels, an air cooler and a condensing unit and are insulated with polyurethane or polystyrene, both of which have a low thermal conductivity.

[112] UNDP in Liberia (ed). 2019. Provision of consultancy services for engineering and safeguards assessment of proposed interventions in the coastal areas of the Monrovia Metropolitan Area (MMA) in Liberia Environmental Protection Agency. Monrovia.
[113] Power Africa. 2020. Power Africa Off-grid Energy Grants Portfolio. [Online]. Available: https://static1.squarespace.com/static/564bee8de4b05dd815f0baa0/t/58d12fefe6f2e1c8a6b3dbc4/1490104305501/Power+Africa+External+Briefing+Sheet+1-1-2017.pdf. Accessed 5 May 2020

One of the solar-powered cold storage units procured by UNDP is produced by CSCPOWER in Fujian, China (Figure 24). This cold storage unit, used for storing fish, meat, vegetables and ice, is relatively compact at ~6 m in length, requiring power of 5kw. The unit comes with a one-year warranty, field installation, commissioning and training, field maintenance and repair services as well as video and online technical support. Its temperature range is also customisable from 0°C to 35°C. The unit comes with a one-year warranty, field installation, commissioning and training, field maintenance and repair services as well as video and online technical support.

Figure 24. Example of a small solar-powered cold storage unit [114].

The larger unit procured by UNDP (Figure 25) is a 12 m long solar-powered cold room container, used for fish and meat, and is manufactured by DACHANG in Guangdong, China. Its temperature range is from -40°C to +20°C but this depends on the selected insulation panel thickness. For example, a 50 mm insulation panel has a temperature range of 5°C and above whereas a 150 mm insulation panel has a range of -45°C and above. The container has a heavy-duty door hinge, lock and hydraulic door closer. It also has a one-year warranty and there are Chinese engineers linked to the manufacturing company available to service the machinery. However, an important dimension of the proposed project is to empower local people and give them agency over the proposed technological interventions, and there will therefore be a focus on training local people on the maintenance of cold storage units in their communities.

[114] Alibaba.com. 2020. 20ft solar power container cold room. [Online]. Available: https://www.alibaba.com/product-detail/20ft-solar-power-container-cold-room_62100180236.html?spm=a2700.galleryofferlist.0.0.5a796cc9LzH3n9&bypass=true . Accessed 5 May 2020.

Figure 25. Example of a large solar-powered cold storage unit[115].

7.2. Energy-efficient cookstoves to reduce fuelwood use and improve livelihoods

In open fires used for cooking, heating and smoking, heat energy is able to escape, which makes them energy inefficient and they therefore require relatively large amounts of fuelwood. Cookstoves, meanwhile, are more energy efficient because they trap heat energy, and they in turn require less fuel to provide the same result as an open fire. One study found that energy-efficient cookstoves required 13%-33% less fuelwood than an open fire set-up. The uncontained nature of open fires also poses health and safety risks, such as the danger of fire spreading and increased exposure of people to smoke inhalation. Despite these drawbacks only ~2% of Liberians have access to cooking technology which is energy-efficient and eco-friendly[116]. Because of the energy inefficiency of open fires, the introduction of energy-efficient cookstoves is outlined in Liberia's National Energy Efficiency Action Plan (NEEAP) which seeks to promote safe, sustainable and clean cooking as part of its actions for improving energy efficiency[117]. There have also been small workshops, such as the ones

[115] Alibaba.com. 2020. Solar power cold room wit hsolar panel and heat exchanger. [Online]. Available: https://www.alibaba.com/product-detail/solar-power-cold-room-with-solar_933474743.html?spm=a2700.details.deiletai6.10.7f78ATGOATGOkQ&bypass=true. Accessed 6 May 2020.
[116]Energypedia. 2020. Liberia energy situation. [Online]. Available: https://energypedia.info/wiki/Liberia_Energy_Situation#Firewood
[117] NEEAP. 2016. Liberia National Energy Efficiency Action Plan (NEEAP). Available at: https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANEE/Liberia_national_energy_efficiency_action_plan_neeap.pdf. Accessed 5 May 2020.

hosted by Renewables Liberia[118] and UNDP[119], aimed at training local communities about construction and utilisation of energy-efficient cookstoves in Liberia. These workshops have been focused on cookstoves made with clay and brick and have been implemented in rural areas. However, given the congested living conditions in West Point, portable cookstoves are better suited for cooking or smoking at different sites in the area, which will better enable fishmongers to sell cooked fish at markets.

Similar cookstove introduction projects have been implemented elsewhere in Africa. The "**Stoves for Life – Energy-Efficient Cook Stove Project in Kakamega**" project in Kenya has focused on the introduction of efficient cookstoves to reduce dependency on harvested wood for open fire heating and cooking (Figure 26)[120]. Much like the communities in West Point, the communities surrounding the Kakamega forest in Kenya relied on wood for cooking which led to considerable deforestation. The project involved the training of women and youth for manufacturing and selling the energy-efficient stoves. By 2014, the project had employed 340 people (68% women) and ~24,000 stoves had been constructed through the project, with each stove estimated to reduce CO_2 emissions by ~3.3 tonnes per year[121].

Figure 26. Energy efficient cook stoves in Kenya[122].

[118]Renewables Liberia. 2017. Improved Cookstoves Workshop Draws Technicians from Liberia and Sierra Leone. [Online]. Available: http://www.renewables-liberia.info/index.php/category-blog/archive-2016/159-improved-institutional-cook-stoves-workshop-at-endev. . Accessed 5 May 2020.
[119] UNDP. 2018. 51 vulnerable youth and women trained in the production of Energy Efficient Stoves. [Online]. Available at: https://www.lr.undp.org/content/liberia/en/home/presscenter/articles/2018/51-vulnerable-youth-and-women-from-7-counties-trained-in-the-pro.html. Accessed 5 May 2020.
[120] UNFCCC.2020. Stoves for Life – Energy-Efficient Cook Stove Project in Kakamega – Kenya. [Online]. Available:: https://unfccc.int/climate-action/momentum-for-change/activity-database/momentum-for-change-stoves-for-life-energy-efficient-cook-stove-project-in-kakamega_-kenya. Accessed 5 May 2020.
[121] Gold Standard. 2019. Stoves for Life: Energy Efficient Cook Stove Project in Kakamega, Kenya. [Online]. Available: https://www.goldstandard.org/projects/stoves-life-energy-efficient-cook-stove-project-kakamega-kenya. Accessed 5 May 2020.
[122] World Bank. 2016. Kenya Cooks with Improved Stoves. [Online]. Available: https://www.youtube.com/watch?v=TRXP8l4MKfc. Accessed 5 May 2020.

Similarly, in Liberia, an energy-efficient cookstove project has been established in Monrovia, with "Red Fire Pots" manufactured and sold as an alternative for cooking and heating over open fires in order to reduce fuel consumption[123]. These portable structures are designed with the principles of improved cookstoves and are made with steel (Figure 27). The stoves are available in different sizes and comprise a lower combustion chamber which holds wood and charcoal, and an upper base or "pot seat" with cylindrical walls in which a pot or cooking grid may sit[124]. Heat is captured in the lower chamber and transferred upwards into the walls of the upper base to surround the pot placed on the seat.

Figure 27. Red Fire Pots currently sold as an alternative cookstove in Liberia[125].

While Red Fire Pots are already available in Monrovia, cooking over open fires is still pervasive in West Point. This is likely because of ineffective marketing and a limited knowledge of the benefits of these cookstoves. The sale of these cookstoves is hindered by these factors, a problem that is exacerbated by the cookstoves having a short lifespan, with each pot lasting only ~1 year before needing replacement. Given these hindrances, there is potential to expand this market through the introduction of improved cookstoves combined with better marketing and awareness. Doing so would: i) improve economic viability for fishmongers through improved technology for smoking and preserving fish; ii) expand livelihood options available to the people of West Point through the

[123] Renewables Liberia. 2020. Where to find the red fire pot in Monrovia. [Online]. Available:: http://www.renewables-liberia.info/index.php/category-blog/192-where-to-find-the-red-fire-pot-in-monrovia. Accessed 5 May 2020.
[124] Ibid.
[125] Clean Cooking Catalogue. 2020. Red Fire Pot (RFP). [Online]. Available: http://catalog.cleancookstoves.org/stoves/472. Accessed 5 May 2020.

production and sale of energy-efficient cookstoves; iii) improve access to small scale economic enterprises through the introduction of technology which is not dependant on electricity; and iv) improve ecological conservation of mangroves through decreased reliance on fuelwood harvested for open fires for smoking and cooking purposes.

The introduction and promotion of improved cookstoves for the smoking of fish — which is primarily performed at the household level — will work towards strengthening small scale economic enterprises. However, the project will also introduce a larger scale improved fish smoking kiln system at the education and innovation centre as a demonstration and education tool, as well as an initial starting point, for collectives who wish to scale up their fish smoking operations. This improved fish smoking system will be modelled after the FAO-Thiaroye fish processing technique (FTT)[126]. The FTT system will be introduced as it is the result of extensive research by the FAO and offers several benefits over traditional fish smoking systems, including: i) protecting fish from the risk of contamination, as the smoking trays are covered; ii) the ability to be used in all weather situations; iii) reduced smoking time — between 3–5 hours depending on the fish species; iv) increased holding capacity — 0.5–3 tonnes/day; v) longer lifespan — up to 20 years, depending on the specific model; vi) reduced post-harvest losses; vii) reduces environmental impact through improved fuel efficiency and ability to be fuelled by biomass and agricultural wastes and residue; and viii) facilitating the structuring and organising of fish processors into cooperative societies.

7.3. Focus areas

Extractive practices by local communities within and around the Mesurado Wetland are the primary drivers of degradation and mangrove loss (Section 3.1). The spatial degradation trends and hotspots identified under Section 4 are consequently the logical focus areas for project interventions. The sections below show the spatial location of focus areas for proposed project interventions under Outputs 1 and 3 of the Funding Proposal. Demographic and socioeconomic summaries of each focus area can be found under Section 8 of Annex 2.A: Feasibility Study.

[126] Mindjimba, K., Rosenthal, I., Diei-Ouadi, Y., Bomfeh, K. and Randrianantoandro, A. 2019. FAO-Thiaroye processing technique: towards adopting improved fish smoking systems in the context of benefits, trade-offs and policy implications from selected developing countries. FAO Fisheries and Aquaculture Paper no. 634. Rome. FAO. 160 pp. Licence: CC BY-NC-SA 3.0 IGO.

7.3.1. *West Point*

Figure 28. The West Point focus area, highlighting its strategic position as a fishing community as well as its proximity to the mouth of the Mesurado Wetland and the Atlantic Ocean. Mangrove degradation in this area is also shown circa 2016[127].

[127] A significant gap in the Global Mangrove Watch (GMW) dataset (refer to Section 4.2.2) exists at the Fiamah Focus Area. Despite mass encroachment into the mangrove forests for housing being clearly visible, only a fraction of this degradation and loss of mangrove habitat is shown in red in the GMW analysis. Given the high rates of degradation at this location

7.3.2. *Topoe Village*

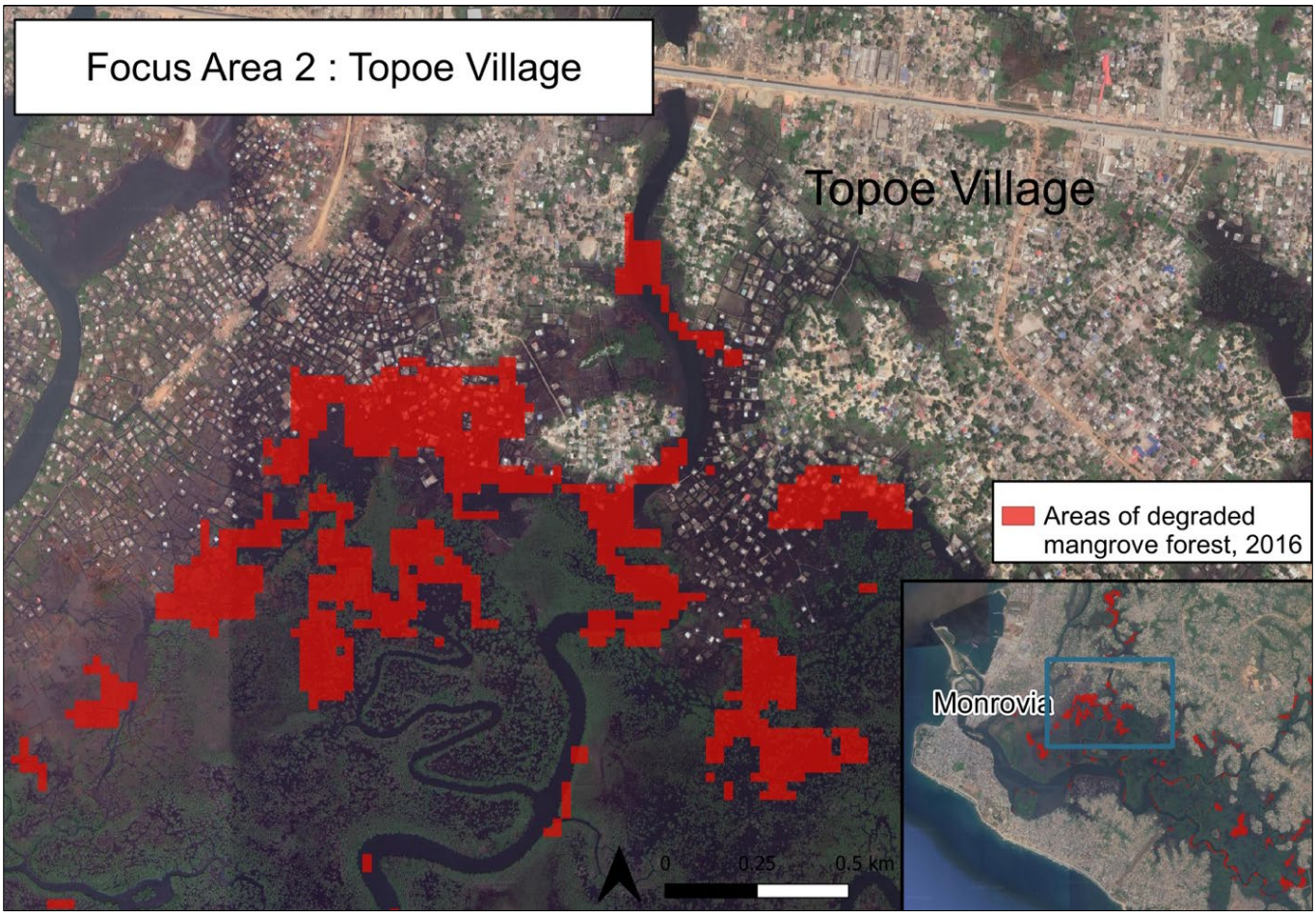

Figure 29. The Topoe Village focus area, showing mangrove degradation circa 2016[128].

[128] A significant gap in the Global Mangrove Watch (GMW) dataset (refer to Section 4.2.2) exists at the Fiamah Focus Area. Despite mass encroachment into the mangrove forests for housing being clearly visible, only a fraction of this degradation and loss of mangrove habitat is shown in red in the GMW analysis. Given the high rates of degradation at this location

7.3.3. *Plonkor & Fiama*

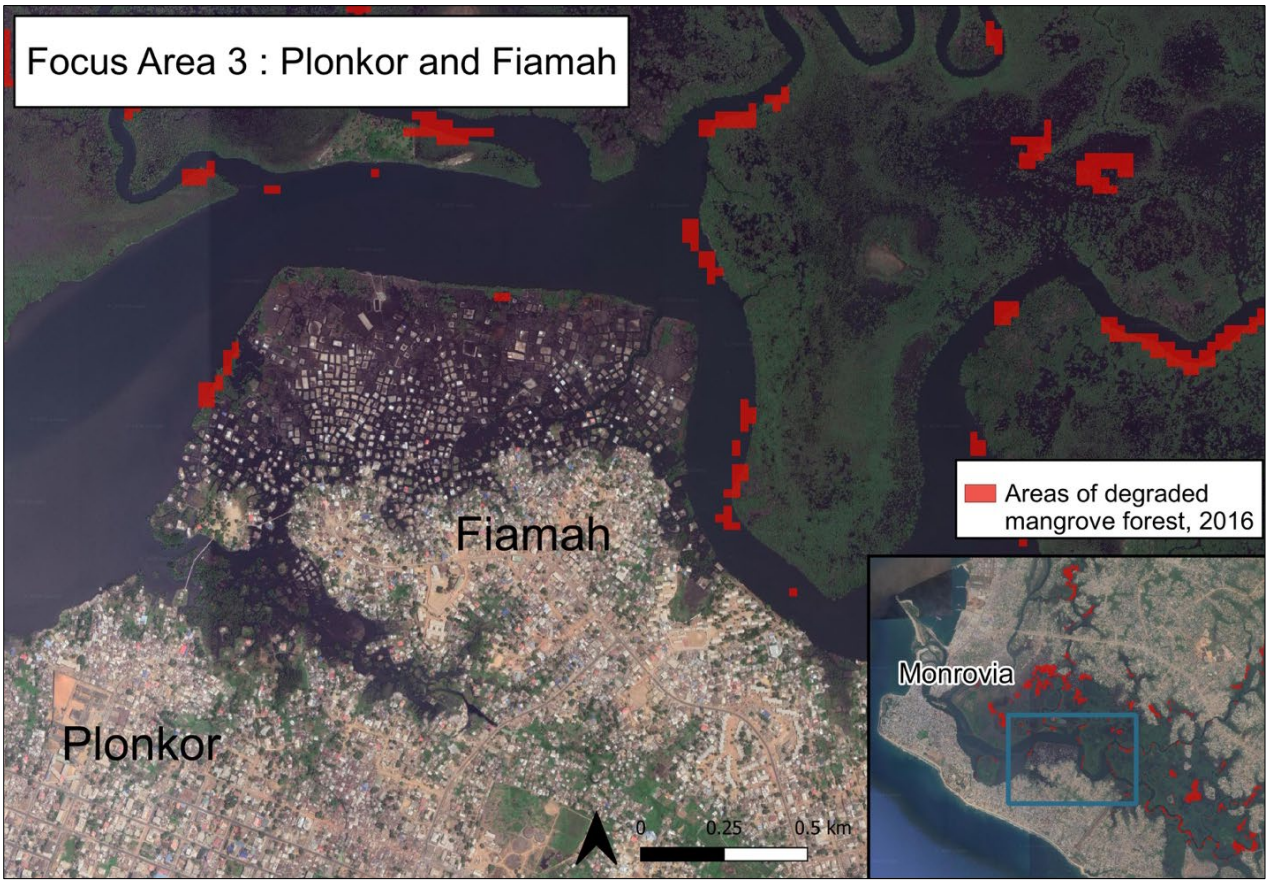

Figure 30. The Plonkor/Fiamah focus area, showing mangrove degradation circa 2016[129].

[129] A significant gap in the Global Mangrove Watch (GMW) dataset (refer to Section 4.2.2) exists at the Fiamah Focus Area. Despite mass encroachment into the mangrove forests for housing being clearly visible, only a fraction of this degradation and loss of mangrove habitat is shown in red in the GMW analysis. Given the high rates of degradation at this location

7.3.4. *Nipay Town & Jacobs Town*

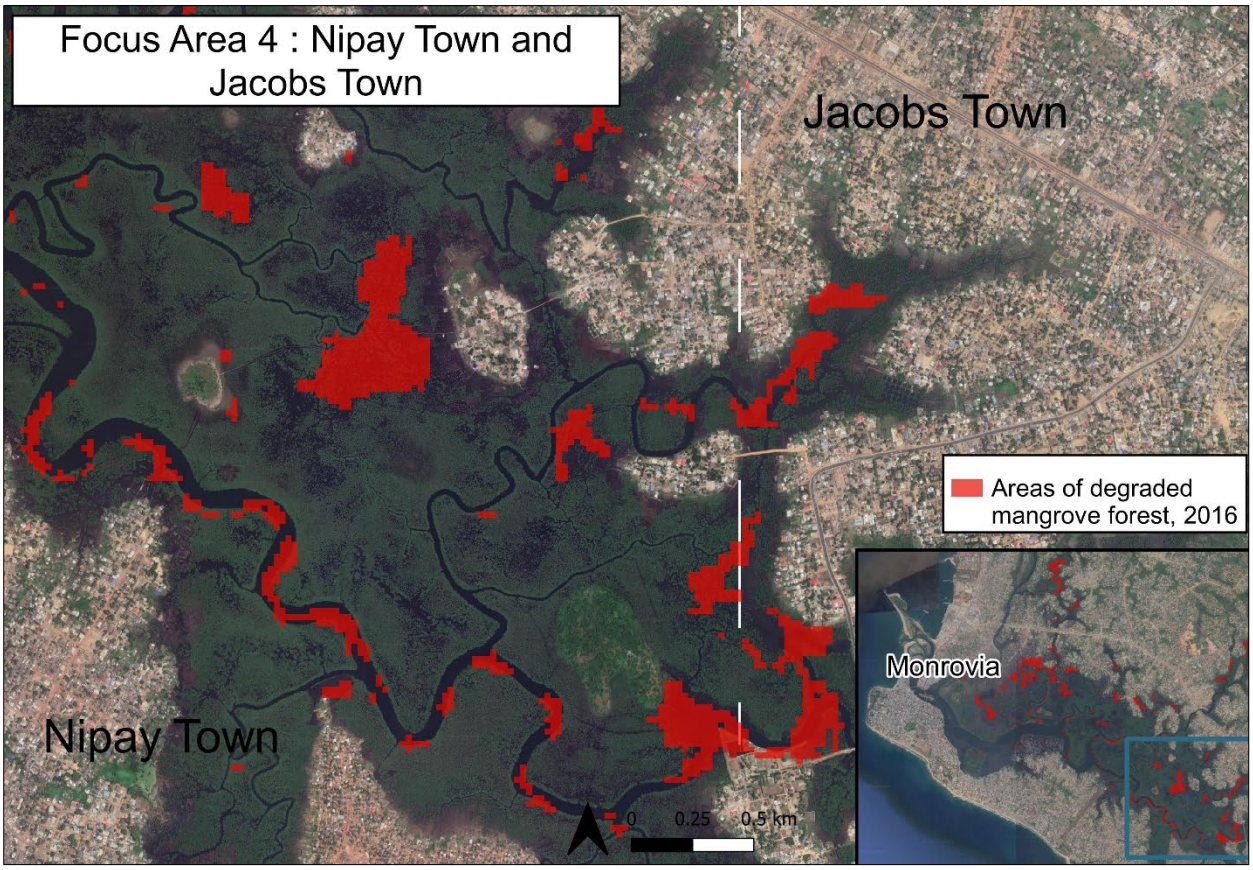

Figure 31. The Nipay and Jacobs Town focus area, showing mangrove degradation circa 2016[130].

[130] A significant gap in the Global Mangrove Watch (GMW) dataset (refer to Section 4.2.2) exists at the Fiamah Focus Area. Despite mass encroachment into the mangrove forests for housing being clearly visible, only a fraction of this degradation and loss of mangrove habitat is shown in red in the GMW analysis. Given the high rates of degradation at this location