TECHNICAL REPORT

WEST AFRICA COASTAL AREAS HIGH-LEVEL PLATFORM

BENEFITS OF MANGROVE AFFORESTATION AND RESTORATION PROGRAMS IN GUINEA-CONAKRY

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TABLE OF CONTENTS

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ACRONYMS AND ABBREVIATIONS

AGB	Above-Ground Biomass
BCR	Benefit-Cost Ratio
BGB	Below-Ground Biomass
CM	Carbon Material
CNSHB	National Center of Fishery Sciences of Boussoura
DBH	Diameter at Breast-High
DEM	Digital Elevation Model
GBD	Global Burden of Disease
GF	Guinean franc
GLAS	Geoscience Laser Altimeter System
LAI	Leaf Area Index
LSMS	Living Standard Measurement Survey
NPV	Net Present Value
PPP$	Purchasing Power Parity $
SRTM	Shuttle Radar Topography Mission
TEV	Total Economic Value
WTP	Willingness to Pay

All amounts in US dollars ($) unless otherwise stated

EXECUTIVE SUMMARY

Guinea's 300-kilometer coastline has extensive mangrove forest coverage that extends for more than 10 kilometers inland and the mangroves situated on the widest rivers can be found up to 40 kilometers inland from the coast. These mangrove areas not only support the gathering of timber and nontimber forest products; they also provide a myriad of ecosystem services such as carbon sequestration; protection from storms, floods, and erosion; the processing of waste and nutrient pollution; support for aquaculture and agriculture; and habitats for both aquatic and terrestrial species.

Recent estimates show that Guinea currently has a little over 2,000 square kilometers (sq km) of mangrove forests, down from 2,992 in 1980; this represents a loss of 32 percent, mainly due to the unsustainable harvesting of mangroves.[1] Such harvesting of mangroves for their direct benefits can result in the loss of mangrove areas and the associated ecosystem benefits, which can often exceed the direct benefits.

Understanding the full benefits that mangroves provide can help raise awareness of the need to preserve them for society. The full accounting of benefits from mangroves can also help to justify redeveloping mangroves in areas where such planting may be feasible. **The objectives of the current study are to estimate the total economic value (TEV) of current mangrove areas in Guinea, considering the whole range of benefits from mangroves; and to use those estimated values in economic cost-benefit analyses.**

This study focuses on private direct use, private indirect use, social use, social option and/or nonuse values, and private alternate use of mangroves. A survey of the literature was done to find studies conducted in Guinea that arrived at the estimated values from all of these uses. If no study was found for a particular use in Guinea, the values were arrived at using data obtained from similar locations elsewhere after making allowances for local characteristics of the Ghanaian coast. Since these studies were not all done in the same year, in order to compare the values on a similar basis, all values were adjusted to 2020 PPP$ using inflation data in Guinea and the PPP$ conversion factor. The results were reported as total value per year, as well as a mean value per hectare of mangroves.

The mean value of all of these uses were determined as follows:

» **Private direct use of mangroves, mainly as timber and fuelwood for domestic use and for salt production and the smoking of fish,** was determined using the quantity of mangroves harvested and their market price. The annual mean value was found to be $248 per hectare, with a total annual value of $52 million.

[1] Some of it is also due to increased urbanization, including the building of ports.

- **Private indirect use arises mainly from fisheries made possible by mangroves**. Using the quantity of fish harvested and their market price, the annual mean value of fisheries amounted to $1,119 per hectare, with a total annual value of $232 million.
- **Three social-use values of mangroves were assessed:** carbon sequestration, flood protection, and water purification. The mean **carbon sequestration** annual value of $221 per hectare, with a total value of $49 million was based on allometric studies to assess the carbon content in mangroves and the price of carbon. The mean **flood protection** value of $1,120 per hectare, with a total annual value of $232 million, was based on studies conducted in mangroves in other similar locations after making allowances for local characteristics of the Guinean coast, since no studies could be found in Guinea for flood protection. The annual mean **water purification** value, estimated as $151–$504, with a total annual value of $31–$105 million was also based on studies done at locations outside Guinea.
- **Biodiversity benefits** were estimated as a social option, and nonuse value was based on the willingness to pay (WTP) approach. The mean annual value was found to range between $911–$1651, with total annual value ranging between $189–$343 million.
- **The primary alternative use of land with mangroves over the years has been growing rice**. Using the market price of such rice and the quantity produced, the mean annual value was found to be $7,896 per hectare, with a total annual value of $616 million.

The cost of planting was based on 2 × 2-meter spacing for the mangroves. The mean cost was found to be $968 per hectare, with an annual maintenance cost of $72 per hectare. Using these costs, the **private direct benefits show a positive net present value (NPV) per hectare of $1,357, with a benefit-cost ratio (BCR) of 1.4**. With the inclusion of **private indirect benefits from fisheries, the NPV per hectare increases to $18,503, with a BCR of 19**. With the **social use values factored in, the NPV increases to $38,333, with a BCR of 39.**

Three important findings emerge from this study. First, the sum of the benefits from private indirect use, social use, and social option/nonuse that occurs from the presence of mangroves far outweighs the private direct-use benefits. This suggests that the use of incentives and disincentives to discourage the unsustainable exploitation of mangroves that mainly occurs for their direct use would lead to net social benefits. **Second, the large NPVs and BCRs from planting mangroves make a clear case for launching an immediate drive to plant mangroves on a war footing in all lands that are now barren but are suitable for growing mangroves**. Finally, the economic return from land that has been converted to grow rice is greater than all of the benefits listed from its use as mangroves; **restoring mangroves to such land would require a high level of subsidy on an annual basis, and may not be an economically feasible option.**

CHAPTER 1.
INTRODUCTION

The coast of Guinea is approximately 300 kilometers long and is home to 2 million people which is nearly 20 percent of the Guinean population. The coast is indented, with rias (drowned river valleys) that form inlets, tidal marshes, mangrove forests, and estuaries; and there are numerous offshore islands. The continental shelf of Guinea extends 300 kilometers along the coast, and covers an area of 47,400 square kilometers (sq km), making it the largest continental shelf in West Africa (UNEP 2007). Guinea's coastal and marine areas are characterized by the presence of still-preserved ecosystems, including large mangrove zones and rich natural-resource waters that are habitats for important plant and animal species, including the endangered West African manatee, pygmy hippos, a variety of Cetacea, and critically endangered migratory birds.

The country's coastal areas are subject to a number of environmental impacts arising from population growth and development within the country's key economic sectors (agriculture, fisheries, mining, and infrastructure). Rapid population growth has resulted in increased exploitation of coastal resources like mangroves and fisheries, many of which raise issues of sustainability. The clearing of mangroves for fuelwood and charcoal, timber, and salt extraction has resulted in mangrove degradation, and expansion of the port of Kamsar in the Bay of Sangaréya has resulted in the loss of 700,000 square meters (sq m) of mangroves. Fortunately, reforestation of the same area using the Rhizophora and Avicennia species was undertaken between 1993 and 1998 to help mitigate these effects (UNEP 2007). The processing and transport of bauxite[2] that takes place in the coastal zone has also affected the coastal ecosystem, although the extent of the impact has not been studied extensively.

The vulnerability of the coastal zone is also expected to increase significantly as a result of climate change and the associated sea-level rise. Sea-level rise will increase the direct inundation of low-lying areas, facilitate rapid erosion of the soft shores, and increase offshore loss of sediment as well as flooding. It is estimated that a 1-meter increase in sea level will inundate a significant portion of the coastal areas, causing major problems for mangrove rice cultivation.

[2] Guinea possesses between 25 and 30 percent of the world's reserves of bauxite. The three bauxite mines in Guinea produce 80 per cent of the country's export revenue.

Management of the coastal ecosystem in Guinea, including the prevention of coastal erosion, thus far has been mostly reactive, site-specific, and usually involves using hard engineering approaches. The engineering infrastructure currently in use in Guinea that is used to protect the shoreline and minimize flooding involves a combination of dikes, fixed protection spikes (stone or concrete), and bunds as well as soft engineering (beach-fill) methods. These gray infrastructures provide coastal protection by (i) decreasing the kinetic energy and destructive force of ocean waves; (ii) protecting against coastline erosion; (iii) protecting the socioeconomic infrastructure against destruction by water torrents; and (iv) protecting agricultural and residential areas from floods.

One area where a unique green solution has been practiced in Guinea is in the creation of mangrove bunds to protect rice cultivation. Currently more than 400 kilometers of mangrove rice bunds have been created to protect agricultural fields, mainly for rice cultivation. However, overexploitation of mangroves is posing a danger to these protective infrastructures; there is a need for proper planning in order to arrest the degradation of the mangrove cover.

There is an urgent need to develop a comprehensive coastal management policy for managing the coastal ecosystem; this policy should include the protection and rehabilitation of mangroves as an important component. Mangroves can help in creating policy that incorporates strategies to tackle problems in coastal management using the green concept of managing with nature and not against it. Sustainability of the existing mangrove forests, and developing new mangroves in areas suitable for them would be an important part in this green strategy. However, the use of mangroves as a policy intervention has to be cost-effective; a detailed cost-benefit analysis can help in creating such policy.

In addition to coastal protection from soil erosion, storms, and floods, Guinea's mangroves also provide a number of cobenefits, from the provision of timber and nontimber forest products to ecosystem services like carbon sequestration, the processing of waste and nutrient pollution, support for aquaculture, and habit ats for both aquatic and terrestrial species.

Another unique feature of mangrove areas in Guinea is mangrove rice cultivation, which is made possible by mangrove bunds that protect the land from flooding. A full estimation of these benefits can help in determining the net benefits that mangroves can provide. Quantifying the total benefits can also help identify prospective areas where the planting and maintenance of mangrove plantations can provide overall net benefits.

The objectives of the current study are to:

- » **Estimate the total economic value of current mangrove plantations** in Guinea by considering the whole range of benefits that can be derived from mangroves; and
- » **Use these estimated values in economic cost-benefit analyses to determine possible areas for replanting** and/or for the creation of additional mangrove plantations in suitable locations.

Section 2 of this report discusses the location, extent, and type of mangrove cover in Guinea. **Section 3** examines the various benefits that mangroves provide, and discusses the methodology that can be used to quantify each type of benefit. **Section 4** determines the cost involved in the creation of new mangrove areas. **Section 5** concludes the report and proposes a way forward for the creation of new mangroves, as well as ways to sustain the current area of land under mangroves.

CHAPTER 2.
MANGROVES IN GUINEA CONAKRY

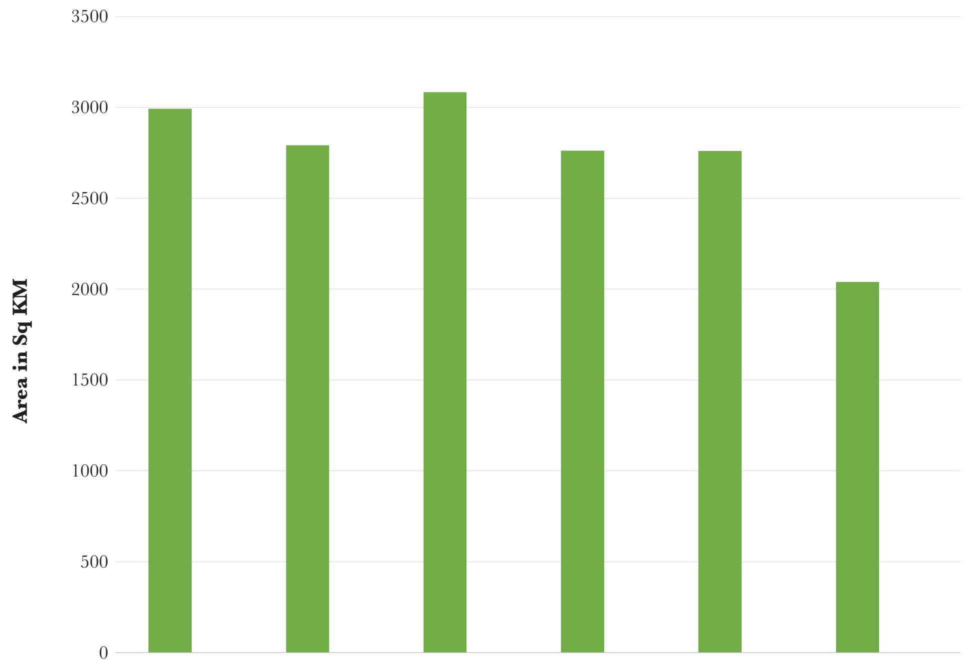
Mangroves are found along the length of the Guinean coast except for Cape Verga and Kaloum Island. The topography of the coastal area facilitates the deposition of sediment and submersion of the mouths of the rivers. There is a long tidal reach up the estuaries, which causes flooding of the rivers, leaving raised bars. It is here that mangroves can develop, within the bay of the estuary. Mangroves extend more than 10 kilometers inland and, along the widest rivers, they can be found up to 40 kilometers inland from the coast (Profile 2005).

The maximum possible area suitable for mangroves in Guinea, based on geomorphology, is estimated to be around 4,000 square kilometers (sq km).[3] Of these, approximately 1,300 square meters of land currently do not have any mangrove cover because these areas have been cleared for agriculture, for salt pans, or for increased urbanization, including the building of ports. Others are simply lying abandoned. The remaining 2,700 sq km currently under mangrove cover also faces various levels of degradation. A detailed analysis of the actual area of mangroves in Guinea over time, as found in the current literature, is presented in Appendix A.[4]

Estimates show that Guinea currently has a little over 2,000 sq km of mangrove forests, down from 4,000 in 1957.[5,6] Wide areas of mangroves have been cleared for agricultural use, salt pans, and for increased urbanization, including the building of ports. Between 1980 and 2006, it is estimated that the mangrove area in Guinea fell from 2,992 to 2,039 sq km, representing a loss of 32 percent, as shown in Figure 1 (UNEP 2007; Ajonina et al. 2008). A 2019 survey by NASA estimated the mangrove area to be 2,076 sq km. Estimates reveal that at present only about 1,000 sq km of this total area is in a good enough state that it could allow for commercial exploitation of mangroves if done on a sustainable basis.[7]

[3] Based on the conversion of an estimated 1,400 sq km of mangrove swamp being converted to rice fields, of which 620 sq km lay abandoned in 1993. (Spaulding 1997)
[4] The analysis is based on a report prepared by Dr. Oliver Ruë for the World Bank in 2020.
[5] Rouanet 1957, cited in Kaba, B. 2001.
[6] Diallo M. et al. 2019
[7] Ruë 1998

FIGURE 1: AREA OF MANGROVES IN GUINEA-CONAKRY (IN SQUARE KILOMETERS)



Source: (UNEP 2007; Ajonina et al. 2008; Sanderman et al. 2018)

In addition to mangroves being cut to support subsistence rural livelihoods and conversion to rice fields, sea-level rise and other climatic phenomena are also contributing toward mangrove degradation in Guinea. These occur through the loss of coastal and intertidal habitats, including changes in geomorphological processes, and the increased vulnerability of woody formations (UNDP 2019). Studies also reveal that sea-level rise is a major potential threat to mangrove ecosystems due to their sensitivity to the duration and frequency of flooding, and salinity levels that may exceed the physiological threshold of mangrove-specific tolerance. Additionally, the failure to maintain dikes built in previous decades, and the lack of planning and integration of climate risks in construction activities on the coast have contributed to the coastal zone's vulnerability to erosion, and have affected the mangroves.

Increases in the population and the development of urban centers, industry, and ports have also led to the conversion of lands; this changes drainage patterns, leads to conflicts over land use, and causes pollution. The discharge of domestic and industrial waste from land, ships, and aircraft threatens mangrove sustainability. Losses of mangrove areas have also been caused by the reclamation of land for agriculture, urbanization, and salt ponds. Currently the conversion of mangrove wetlands for solar salt production, and the expansion of towns and villages are major destructive threats to mangroves in Guinea (Armah 2006).

The estimation of the current economic benefit from mangroves in Guinea is based on the understanding that the 1,300 sq km of land cleared or converted, part of which is also currently lying abandoned, is unlikely to be brought back to mangrove cover in the near future. Therefore this valuation will focus on the remaining 2,700 sq km, and the actual estimation will include two approaches. The first will be based on the current state of the mangroves, assuming there is no further degradation. The other will examine what would happen if all of the current mangrove areas could be restored to normal health, since this would provide an idea of the true maximum natural capital potential of mangroves in Guinea.

2.1. COMMON MANGROVE SPECIES FOUND IN GUINEA

Seven species of true mangrove are found in Guinea: *Acrostichum aureum*, *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemose*, *Rhizophora harrisonii*, *Rhizophora mangle*, and *Rhizophora racemose*. The species distribution of woody mangroves varies by location. *Avicennia* needs greater substrate stability, and is generally found in the shallows along the channels going inland, whereas *Rhizophora*, *Avicennia*, and *Laguncularia* prefer convex banks prone to high sedimentation. According to UNEP (2007) the nonwoody mangroves of Guinea tend to be located in degraded areas. In denuded areas, *Avicennia* and *Rhizophora* are found in mixed settlements along the banks of the channels. More developed "forest cathedrals" are found along the Konkouré River where there is fresh water from inland. *Avicennia germinans* and grassy species often colonize the deforested areas intended for rice growing. *Rhizophora racemosa* can reach 25 meters in height in Kakounsou and in the Bay of Sangaréya, but in other areas the trees seldom exceed 8 meters and are often much smaller. In the same zone, *Avicennia germinans* grows up to 15 meters, and Conocarpus erectus can also be found here (Profile 2005).

TABLE 1: COMMON MANGROVE SPECIES IN GUINEA

Mangrove species	**Characteristic**	**Occurrence**	**Propagation**
Avicennia germinans (Black Mangrove)	Develops finger-like projections, called pneumatophores, which protrude from the soil around the tree's trunk.	This species occurs at higher elevations inland than the red mangrove.	Reproduces by vivipary, with sprouting seeds that drop into the soft bottom around the base of the trees. The seeds can also be transported by currents and tides to other suitable locations.
Laguncularia racemosa (White Mangrove)	Does not develop visible aerial roots, and has elliptical light yellow-green leaves.	Occurs at even higher elevations farther upland than either the red or black mangroves.	Sprouting seeds that drop into the soft bottom around the base of the trees. The seeds can also be transported by currents and tides to other suitable locations.
Conocarpus erectus (Buttonwood)	Belongs to the same family as the white mangrove, but has a different appearance, with dense, rounded flowerheads that grow in a branched cluster, and purplish-green, round, conelike fruit.	Grows in brackish areas and alkaline soils, thriving in the broken shade and wet soils of hammocks.	The seed heads burst when ripe, and the seeds are dispersed by water.
Acrostichum aureum (Golden Leather Fern)	Does not have any aerial roots; instead has fibrous, fernlike roots. It can grow up to 1.5 meters high and have leaves that can be up to 1 meter long and 4 centimeters wide.	Grows in swamps and mangrove forests, salt marshes, and on river banks; is tolerant of raised salinity levels.	Mature fronds become sporophyllous, diffuse spoprangia at the abaxial surface, mixed sporangia on both sides of the mid-vein, brown sporangia stalked, upper globose.

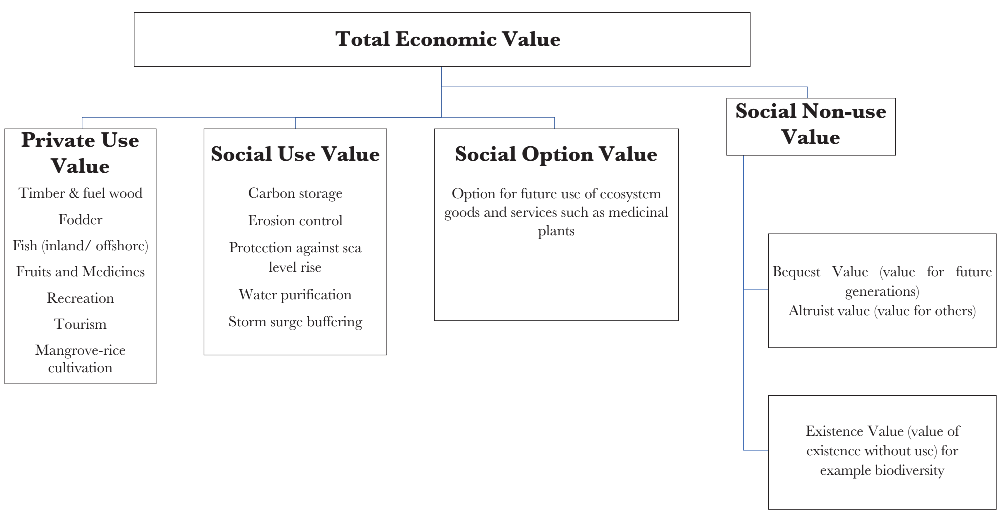
Mangrove species	Characteristic	Occurrence	Propagation
Rhizophora harrisonii (Red Mangrove)	A hybrid of *R. mangle* and *R. racemosa*; shares morphological characteristics with both species and is recognized by FAO as a distinct species.	Mostly found in the estuaries of river systems with more continuous freshwater flows.	Creates a propagule that is in reality a living tree; a fully-grown propagule on the mangrove is capable of rooting and producing a new tree.
Rhizophora mangle (Red Mangrove)	Usually grows to 10–20 meters in height and has a 10–30 centimeter diameter at breast height (DBH); in some sites has been observed to exceed 40 meters in height and 70 centimeters DBH (Jimenez 1985).	Generally found growing along the water's edge.	Sprouting seeds that drop into the soft bottom around the base of the trees. The seeds can also be transported by currents and tides to other suitable locations. (Florida Keys NMS 2006; Law FRC-43).
Rhizophora racemosa (Red Mangrove)	Grows up to 30 meters (100 ft) tall, often with aerial stilt roots; in more marginal habitats is shorter, more branched, and scrubby. The leaves grow in opposite pairs, each pair with two interlocking stipules. The leaves are simple and entire, with elliptical hairless blades and slightly down-rolled margins.	When new mudflats are formed, seagrasses are the first plants that grow on the mud, with *Rhizophora racemosa*, a pioneering species, being the first mangrove to appear. It primarily occurs in the open lagoon systems in areas along the coastlines.	The fruit produces propagules that may fall into the water and be dispersed by wind and currents.

CHAPTER 3.

ESTIMATION OF THE ECONOMIC BENEFITS FROM MANGROVES

Mangroves provide many direct-use benefits in the form of timber, fuelwood, animal fodder, salt manufacturing, fish-smoking, medicines and so on. A number of other indirect benefits including fisheries, mangrove rice cultivation, recreational opportunities, and tourism are also made possible by the existence of mangroves. However, most of these constitute benefits only for the people who live in the immediate proximity of the mangrove plantations; they do not fully reflect the total economic value (TEV) of mangroves. In order to arrive at the TEV, we need to account for the social benefits arising from mangroves as well: carbon storage, coastal erosion control, protection against sea-level rise, water purification, storm surge and swell buffering. There are also social-option and social nonuse values (Figure 2).

FIGURE 2: TOTAL ECONOMIC VALUE (TEV) ESTIMATION PROCESS OVERVIEW



The overall social benefits from mangroves can exceed the total private benefits; and some of which (like carbon sequestration) can also lead to global benefits. To determine the true economic benefits from mangrove plantations, all such private and social benefits have to be evaluated and accounted for. However, since many of the outcomes under social benefits cannot be traded in a market, there is often no ready market price that can be used to monetize these benefits. Therefore, alternative valuation methods have to be employed in order to arrive at a complete estimation of all of the economic benefits.

The benefits from mangrove plantations and/or the costs of planting and maintaining them are often location- and context-specific. The present study has developed a methodology for estimating the full benefits from mangrove plantations in Guinea Conakry, and uses that methodology to determine which mangrove afforestation projects have economic justification based on the costs involved. This can help demonstrate how these procedures can be applied in general, while prioritizing among various adaptation projects, all of which have significant benefits. The type of benefits to be included in computing the total benefit of mangroves in Guinea, and the methodology to be used in the actual computation exercise of these benefits are explained in the following sections.

3.1. PRIVATE-USE VALUE

3.1.1. DIRECT BENEFITS

Mangrove forests can provide a number of useful products: fuelwood, charcoal, timber wood, honey, wax, fruits, medicinal plants, animal fodder, and *akpeteshi* distilling, among other things. The benefits from each species of mangrove present in Guinea, as found in the literature, are listed in Table 2.

TABLE 2: COMMON DIRECT USE OF MANGROVE SPECIES

Mangrove species	Overall Direct Use	Medicinal Use
Avicennia germinans (Black Mangrove)	The cotyledons of the seed are eaten during famines, but only after careful preparation to remove toxic compounds. The leaves and roots are used to prepare a vegetable salt.	**Leaves:** Applied as an enema to treat piles. An extract of leafy twigs showed cytotoxic activity in several human cancer cell lines. The stems and leaves are combined with a smaller amount of *Rhabdadenia biflora* and *Nicotiana tabacum* to make a soothing remedy for stingray wounds. **Bark:** Powdered bark mixed with palm oil for treatment of lice, ringworm, and mange; added to a bath in order to promote childbirth. The bark resin is used in traditional medicine to treat tumors, diarrhea, hemorrhage, hemorrhoids, rheumatism, swelling, wounds, and sore throat. **Roots:** Used as an aphrodisiac, and as a decoction to treat intestinal problems.
Laguncularia racemosa (White Mangrove)	The bark and leaves produce a tannin and a brown dye of good quality, but not in quantities that are economically interesting. The bark is used to treat fishing nets for longer preservation. Sometimes used as animal fodder. The flowers are said to be useful in honey production, and in Guinea Bissau the fruits are eaten. The wood is heavy, hard, strong, and close-grained; it is mainly used as firewood, rarely for construction or wooden utensils.	Historically the high tannin content in the bark was used as a tonic to treat fevers, skin wounds, ulcers, dysentery, and scurvy, and to prevent tumors. A bark infusion is used as an astringent, tonic, and folk remedy for dysentery, aphthae, fever, and scurvy. Some antitumor activity is also attributed to it.

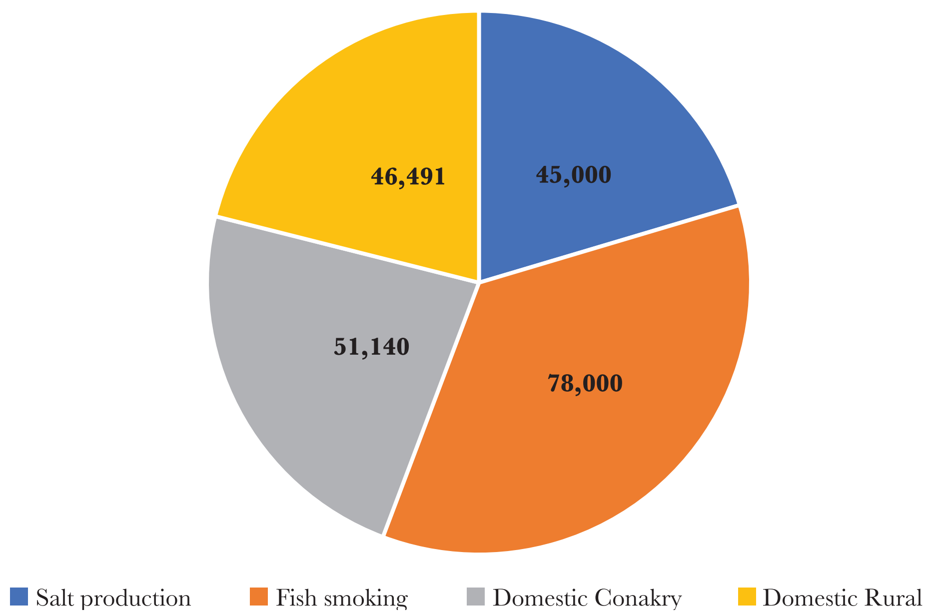
Mangrove species	Overall Direct Use	Medicinal Use
Conocarpus erectus (Buttonwood)	The heavy wood (sp. grav. 1-0) is durable and takes a fine polish. Durable in water, it is used for barges, boats, and maritime construction. Though susceptible to dry-wood termites, it is also used for crossties, fences, and turnery. Describing it as keeping well underground and in salt water, Irvine (1961) notes that it is used for piling and firewood. Bark has been used for tanning leather. Sometimes introduced as an ornamental evergreen.	**Leaves:** Decoction used as a febrifuge. Latex: Applied to cuts to stop bleeding. Roots**:** Ground and boiled as a cure for catarrh. Bark**:** Used in the treatment of gonorrhea. A folk remedy for anemia, catarrh, conjunctivitis, diabetes, diarrhea, fever, gonorrhea, headache, hemorrhage, orchitis, prickly heat, swelling, and syphilis.
Acrostichum aureum (Golden Leather Fern)	Young shoots are eaten as a vegetable. The firm, dried, parchment-like leaves are stitched together and used as thatching material in the place of straw-thatch, as the roof lasts longer with much less risk of fire. It has potential as an ornamental plant because of its handsome leathery leaves; and the plant can be grown in pots.	Rhizomes are used for the healing of stubborn ulcers. Leaves are used topically as an emollient. Medicinally, the pounded or grated leaves and rhizomes are applied as a paste to wounds, ulcers, and boils, and can be used against worms.
Rhizophora harrisonii (Red Mangrove)	Similar to other *Rhizophora* species.	Similar to other *Rhizophora* species.
Rhizophora mangle (Red Mangrove)	Used primarily for timber, building materials, fencing, firewood, charcoal, medicines, tannins for staining and leather-making, hunting, salt extraction, and as a habitat for commercial fisheries and aquaculture.	A folk remedy for angina, asthma, backache, boils, ciguatera, convulsions, diarrhea, dysentery, dyspepsia, and a host of other diseases. Bark extract can reduce gastric ulcers; it has antimicrobial and antioxidant properties.
Rhizophora racemosa (Red Mangrove)	Used for construction poles and firewood on a limited scale. The smoke has antimicrobial properties and is also used for smoking meat.	**Roots:** Used with palm oil as an ointment for boils. **Bark:** Extract used for fungal infections of the skin; treatment of diarrhea and dysentery in children; leprosy, sore throat.

However, only a few of these purposes are actually being used in Guinea; the rest of them can be considered as potential future uses. The most common use of mangroves in Guinea is as fuelwood and charcoal, especially for fish-smoking, since it imparts a unique color and flavor to the fish; and it is also used for salt production. Mangrove wood is also used for construction purposes, including the roofing of houses. The harvesting of wood from mangrove forests provides a major source of energy. Household consumption of firewood and charcoal in Guinea totalled more than 4.7 milliont in 1998, while the informal sector consumed nearly 0.18 million MT in 1996 (Samoura and Diallo 2003). A significant part of that use came from mangrove wood.

Current estimates indicate that approximately 220,000 MT of mangrove cuttings is in direct use each year for salt manufacturing, fish curing,

and as fuelwood and timber in Conakry and in rural areas of the country.[8] (Figure 3) However, the annual natural mangrove wood growth per year in the 1,000 sq km of commercially suitable area is only 80,000–150,000 MT, depending on the type of mangroves. This clearly demonstrates a reason for the loss of mangrove cover from overexploitation. However, it also shows that if all 2,700 sq km can be made commercially suitable, the annual sustainable yield would range from 210,000–410,000 MT, and could help to arrest the degradation of mangrove areas.

FIGURE 3: DIRECT USE OF MANGROVE (IN MT/YEAR) IN GUINEA



The valuation of the direct use of mangroves, using the local price of the end products when converted (using PPP adjusted $) is shown in Table 3.[9]

TABLE 3: TOTAL DIRECT USE VALUE

	Value PPP$M
Salt production	11.5
Fish-Smoking	19.9
Domestic, Conakry	8.3
Domestic, rural	11.8
Total	51.5

[8] The details of these uses are provided in Appendix B.
[9] Details in Appendix B.

Mangroves are known to provide medicinal uses for the population in a number of countries, but there is no substantive information about any such use in Guinea. Typically, these health benefits are estimated based on the reduction in mortality/morbidity either using the Global Burden of Disease (GBD) estimates within a country, or indirectly by the cost of medication saved. Future research is required to determine the amount of current use, as well as any future potential uses.

Annual Economic Value = Savings in traditional medicine costs, or the valuation of saved mortality/morbidity

3.1.2. INDIRECT BENEFITS

Inshore and Offshore Fisheries

The water bodies of mangroves are used as spawning, hatching, nursery, and foraging grounds by a number of fish, crab, shrimp, mollusks, and other aquatic creatures. They spend a portion of their lifecycle in the mangrove forests, and later move on to the sea. All of these marine creatures benefit from the presence of mangrove forests; it has been found that when mangrove forests are added to the coast, the fish population of the nearby areas tends to increase. Mangroves are estimated to provide habitats for the development of 70 percent of the fish caught in tropical and subtropical areas.[10] The loss of mangroves, therefore, also affects the livelihoods of local fisherfolk.

Guinea's waters contain significant resources associated with marine environments (shrimps, whitefish, small pelagics) that are relatively conducive to fisheries development(in terms of seasonal upwelling, river flow, and the like. Demersal resources include ground fish (sea bass, flounder, catfish, sea bream), cephalopods (mainly cuttle-fish), and shrimps. Pelagic resources (ethmalosa, sardinella, horse mackerel) also have considerable potential, and are mainly exploited by national operators in the artisanal subsector.

In the absence of mangroves, most of the marine fisheries in Guinea will not be sustainable. The contribution of mangroves to the fishery sector can be estimated using the value added by mangroves in the annual production of the sector. The total annual output in monetary terms can be calculated by taking into account the physical output and the price paid. The value added would be the net monetary value after subtracting the cost of fishing. The annual cost estimation includes both annualized fixed costs (vessels and other fishing gear) and variable costs (fuel, salaries for crew, repair and maintenance costs of vessels and gear, the cost of selling fish via auction, and fish handling and processing, for example, the purchase of ice).

Annual Economic Value Added = (Fish Yield/Year) × (Average price of fish/MT) − Cost of fishing/MT

The annual fishery output in Guinea in 2019 was a little over 350,000 tons, of which marine fisheries accounted for 289,544 tons (Fisheries Statistical Bulletin 2019). Of this amount**,** the annual coastal fish production was around 128,000 tons in 2019.[11] This consists mainly of demersal and pelagics; the output of cephalopods and shrimps are relatively lower. Among various types of fish, ethmalosis, captain royal, and various sardinellas account for nearly half of all of the fish captured.

The estimated annual value added by mangroves in the fishery sector is $232 million. This is based on a weighted average price of fish of $3,832 per ton. (The price of fish varies widely depending upon the type of fish, with a range of $1,121–$6,729 per ton).[12] The cost is based on the average cost of $1240 estimated for Africa, including all fixed and variable costs.

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[10] https://www.greenclimate.fund/sites/default/files/document/21890-enhancing-resilience-guinea-s-coastal-rural-communities-coastal-erosion-due-climate-change.pdf
[11] See Appendix B for details.
[12] All values are PPP-adjusted.

Tourism and Recreational Benefits

The ecosystem of a mangrove forest is completely different from the ecosystems in other areas of Guinea, and therefore would be attractive to visitors. There are opportunities for recreational fishing, bird watching, boating to explore the forests, or simply touring the area on boardwalks. Experience from other countries that have benefitted from mangrove-based tourism can provide guidance about the types of possibilities that may exist.

The actual tourism potential in mangrove areas has not been explored very much in Guinea so far. The tourism sector overall is underdeveloped; building proper infrastructure and making suitable investments in facilities would be required in order to attract tourists. Any future plan for developing the tourist industry should include mangrove-based tourism. Anecdotal evidence reveals hidden potential that could be better exploited with proper planning and investment; this would also involve encouraging the private sector to enter into this economic activity (ECOREX 2012). We can see the potential in Guinea from what is already occurring in Ghana, which has a much smaller extent of wetlands, and less than a tenth of the area in mangrove forests compared to Guinea. In Ghana, to promote tourism with minimal impacts to the wetlands, walkways have been built, and boats provided from which visitors can view the plant and animal species in the reserves. As a result, the number of tourists has been increasing in Ghana since 2006, and it is more than 10,000 annually at present.

The potential recreational benefits of mangroves, once they are developed, can be estimated using a travel cost method based on all expenses to be spent in the recreational area (food, lodging, transport, tickets, etc.), plus the opportunity cost of total time spent by the visitors for the whole trip. Current market data for these costs will be used, along with the projected number of visitors based on sample surveys, to compute the total benefit.

The value of the increased recreational opportunities (V) for a single visitor is given by:

$$V = ((T \times w) + (D \times v) + F\&L + Ca) \times Va$$

Where:

T = travel time (in hours)
w = average wage rate (Guinea franc/hour)
D = distance (in km)
v = marginal vehicle operating costs
F&L = Food and Lodging expenses
Ca = cost of admission to asset
Va = average number of visits per year

Mangrove-Rice Cultivation

Rice farming on the coastal plains adjacent to the mangrove forests is a unique feature in Guinea, and in a few other neighboring countries in West Africa. Although rice farming on the coastal plains is made possible only due to the presence of adjacent mangrove bunds**,** it can't be strictly included in indirect benefits from mangroves since most of the land used for rice cultivation has been obtained over time by clearing erstwhile mangrove plantations. Therefore, it is treated as an alternative use value made possible by the crucial contribution that nearby mangrove areas provide.

Twenty-three percent of the national rice production in Guinea is from mangrove areas, and it provides livelihoods for more than 50,000 rice farmers, the majority of whom are women. Shifting to agriculture also occurs where salt inundation is low. Mangrove rice is a flood-fed crop requiring two flooding cycles, one with freshwater and one with saltwater.[13] (The saltwater is needed to eliminate weeds, regulate soil pH, and deposit organic matter and nutrients. Freshwater is necessary for soil desalination prior to cultivation, and maintenance of the water table throughout the cycle.)

In ideal conditions, mangrove rice farming produces higher yields than other rice farming techniques used in the interior of the

[13] https://www.greenclimate.fund/sites/default/files/document/21890-enhancing-resilience-guinea-s-coastal-rural-communities-coastal-erosion-due-climate-change.pdf

country. Annual mangrove rice production averages around 376,000 tonnes; it represents 16 percent of rice farmland in the country, and 23 percent of national production (Agence Française de Développement 2016). The value added in rice farming can be determined by accounting for the cost of such cultivation, including labor, fertilizer, seeds, and depreciation.

Annual Economic Value Added = (Rice Yield/Year) × (Average price of rice/MT) = Cultivation Cost

The estimated net annual value added from rice grown in 70,000 hectares of land devoted to mangrove rice cultivation is estimated to be $824 million.[14] This is based on a net annual mangrove rice production of 300,481 tons, and a price of $3,462 per ton,[15] after subtracting the average cost of rice cultivation.

3.1.3. SOCIAL BENEFITS

Mangrove forests can provide a number of social benefits: carbon sequestration, protecting the coasts from erosion and flooding from storm-induced swells, and problems arising from prospective sea-level rise. A number of other benefits, such as increased biodiversity, and purification of contaminated water are also often associated with mangroves. Each of these benefits are estimated based on local data.

Benefits from Carbon Sequestration

Mangroves are very good for carbon sequestration because they store carbon material (CM) not only in the above-ground biomass (trunks, branches, trees, twigs) but also in the roots and soils. In fact, in mangroves a larger share of carbon is stored below ground than above ground (Alongi 2015). The soil in the mangroves is also rich in CM because the anoxic condition of the mangrove floors retards carbon (C) from combining with oxygen (O_2) in the air to form carbon dioxide (CO_2); and then being released into the atmosphere.

While a few studies have estimated the extent of carbon sequestration in mangroves, using both above-ground and below-ground biomass in locations in neighbouring West African countries, such studies in Guinea are rare. The estimation for Guinea is therefore based on satellite-generated digital elevation model (DEM) data that has been validated using in situ field measurements in some countries in West Africa.

This study has calculated the economic valuation arising from carbon sequestration using the total mangrove coverage in Guinea. The valuation procedure involved a three-step process. The first step estimated biomass using an allometric function. In the second step, the carbon sequestration estimation was calculated using the carbon content per unit of biomass that is appropriate for the mangrove species involved. The economic value was then determined in the final valuation procedure, using the shadow price of carbon per MT applied to the carbon content in MT.

The biomass estimation takes into account the five following carbon storage areas in mangroves, along with carbon trapped in the soils around mangroves:

1. Above-ground biomass (trunk, branches, leaves, etc.)
2. Below-ground biomass (roots)
3. Aerial roots
4. Litter falls (leaves, branches, twigs, etc.)
5. Dead roots

The above-ground biomass (AGB) estimation for the whole of Guinea uses remotely-sensed satellite data that has been validated with in situ field measurements. This assessment is based on the mangrove dataset created by NASA for Guinea that includes distribution, biomass, and the canopy height of mangrove-forested wetlands. The data includes

[14] Details provided in Appendix D.
[15] All values are PPP-adjusted to 2020.

information about the total mangrove carbon stock (above- and below-ground biomass (BGB), and soil), based on the extent of mangrove coverage (Simrad et al. 2019).

The extent of biomass sequestered in mangroves varies with the mangrove species, but current satellite-derived data generally do not take this into account. The data developed by NASA that is used in the current study also does not distinguish the mangrove species in estimating the biomass. However, recent studies have been able to determine the species composition of a mangrove forest by using the red-edge spectral bands and chlorophyll absorption information from AVIRIS-NG and Sentinel-2 data.[16] The use of this technique in the estimation of mangrove biomass can in the future increase the accuracy of these estimations.

The mangrove dataset created by NASA was based on NASA's Shuttle Radar Topography Mission (SRTM) in 2000 digital elevation model (DEM) data, which was released globally in 2015. To identify mangrove ecotype areas and mask non-mangrove regions in the SRTM elevation dataset, a global mangrove extent map from Giri et al. (2011) was used. The canopy-height maps were generated using SRTM DEM data collected in February 2000, and lidar heights from the ICESat/GLAS Spaceborne Lidar mission. GLAS lidar altimetry data were collected globally from 2003 to 2009. A regression model was applied relating GLAS RH100 to SRTM elevation measurements to obtain a global map of maximum canopy height:

$$SRTMH_{max} = 1.697 \times HSRTM$$

where HSRTM represents the original SRTM DEM, and $SRTMH_{max}$ is the new maximum canopy height data set.

Field data was used by NASA to estimate forest structure attributes, basal area-weighted canopy height (H_{ba}), the height of the tallest tree (H_{max}), and above-ground biomass (AGB). The data was collected in field plots, using fixed or variable plot sizes. Within variable plots, trees were selected using a fixed-angle gauge. For each selected tree, the species was identified, and the diameter at breast height (DBH) and height were measured using a laser rangefinder or clinometer. Tree density (that is, the number of stems) was estimated for each plot, and expressed per unit area (in hectares).

For all sites, H_{ba} was calculated as:

$$H_{ba} = \sum_i(\pi r^2_i \times H_i) / \sum_i(\pi r^{2i})$$

where H_i and r_i are the height and radius at breast height of tree i, respectively, in meters.

In situ field data were used to derive stand-level allometry between AGB, H_{ba} and H_{max}. Models were generated between plot-level canopy height and plot-level AGB density, where height and AGB relationships were fitted to the regression model:

$$AGB = a \times H_x^{\,b}$$

where Hx can represent either Hba or Hmax.

Total above- and below-ground biomass, and carbon stock estimates for Guinea were generated by summing all of the corresponding pixels, while accounting for below-ground biomass and soil carbon. The total above-ground carbon stocks were calculated assuming a stoichiometric factor of 0.475 as the AGB conversion factor. Total root biomass was estimated as 27 percent of the AGB. (See Simrad et al. 2019 for more detail on the procedure followed by NASA.) A greater amount of carbon is stored in the soil in mangrove plantations since carbon remains trapped much longer in such submerged soil. However, the carbon trapped in the soil is not included in the analysis, since it is more difficult to estimate the extra carbon that is added to the soil as degraded land is restored.

Based on the carbon content found in the NASA study, the value of the carbon that would be sequestered in mangroves in Guinea if the 700 square kilometers of degraded land were restored would amount to $49 million, with an

[16] https://www.researchgate.net/publication/351749539_Species-Level_Classification_and_Mapping_of_a_Mangrove_Forest_Using_Random_Forest-Utilisation_of_AVIRIS-NG_and_Sentinel_Data

annual value addition of nearly $1.6 million from the natural growth in the existing mangrove plantations.[17] This is assuming that the carbon offset could be traded on the international market, and is based on the global weighted average price of carbon, which was variously estimated at around $20 per ton in 2020.[18] However, if the carbon offset were not traded, the valuation would be much lower, as current estimates for Guinea suggest a price of only $1 per ton for carbon.[19]

In other words:

> *Economic Value of Carbon Sequestration from Mangrove = Carbon Stock Trapped in Mangrove x Shadow Price of Carbon*

Protection from Coastal Erosion, Coastal Floods, and Sea-Level Rise

The vulnerability of the Guinean coast is mainly due to the fact that the West African coast has a strong sensitivity to erosion and coastal aggression caused by: **(i) the nature of the materials** (mobile sandy sediment, or highly altered and fractured rocks); **and (ii) sediment flows that remain limited** due to their capture at the river-mouth level, or their dispersal, which can be observed on coasts that are more predominantly structured in cape and creeks. This strong sensitivity to erosion is reinforced by climate-induced and human-driven mangrove forest degradation in the shoreline area (for example, the construction of port infrastructure by the mining industry).

The presence of mangroves along the coasts plays an important role in arresting coastal erosion and minimizing damages from coastal flooding, especially those caused by storm swells. When waves and water navigate through the forests during a storm-induced swell event, the dense forests of mangroves, with their trunks, aerial roots, and low-hanging branches produce friction with the incoming water. The result is wave attenuation and reduced water velocity, which limits inland water intrusion and damage to coastal infrastructure.

Mangrove forests also provide better protection from sea-level rise resulting from climate change, since unlike manmade fixed engineering structures that are meant to protect the shoreline, mangrove forests will naturally experience vertical accretion over time. Thus, over time manmade engineering structures will be progressively less effective, while mangrove forests should be able to maintain their relative position in relation to the sea level provided that sufficient sediment is available. Recent evidence suggests that mangrove surfaces are keeping pace with rising sea levels in a number of locations (McIvor et al. 2013).

Direct valuation of the erosion protection, flood mitigation, and impact reduction from sea-level rise that is made possible by mangroves can be calculated using the value of damage avoided. However, this valuation method requires detailed data about current coastal communities and coastal infrastructure near mangrove plantations, which is not readily available at present in Guinea. A separate project to estimate the physical damage protection provided by mangroves at select coastal locations in Guinea is currently underway. However, since the data from the project is not available yet, an indirect method of valuation using the replacement method was employed. Once the data from this project become available the indirect estimates of mangrove benefits can be updated with direct estimates .

Studies have found that with each kilometer of mangroves, ocean swell height could be reduced by 5 to 50 centimeters (McIvor et al. 2012). The effectiveness depends on the specific geomorphological conditions of the sites, the plant species, and the density of the mangrove forests. Mangroves cannot completely protect vulnerable communities from flooding caused by storm-induced swells. However, they can work in conjunction with, and can complement hard engineering infrastructure. Swell attenuation by mangroves should allow for a lower level of investment in protective

[17] See details in Appendix C.
[18] https://carboncreditcapital.com/value-of-carbon-market-update-2020/
[19] https://www.nature.com/articles/s41558-018-0282-y

engineering infrastructure by allowing barriers of lower height and width to be built, saving a substantial amount in construction costs. In addition, the presence of mangroves placed in front of the hard infrastructure can reduce the maintenance cost of the infrastructure.

More than 400 kilometers of mangrove rice protection bunds have been created in Guinea for the protection of agricultural and residential areas from floods. The presence of mangroves in these bunds have helped to not only minimize the use of other gray infrastructure, but also to reduce the height and width of the bunds needed to protect the rice fields. These mangrove bunds also protect the shoreline from erosion and have helped to minimize the need to reinforce and/or rehabilitate dikes and spikes designed to minimize impact on the shoreline from sea-level rise.

In the indirect computation of mangrove valuation, any reduction in the current costs of building/rehabilitating dikes, spikes, and bunds in Guinea can be considered as the economic value of the erosion protection, flood mitigation, and impact reduction from sea-level rise that mangroves provide. However, the cost of building infrastructure that could be reduced in order to determine the savings that can arise when mangroves partially or fully replace it is not readily available in Guinea. Therefore, we have used estimates done elsewhere to determine the economic value of mangroves in Guinea after making allowances for local characteristics of the Guinean coast.

In other words:

> *the Economic Value of Protection from Coastal Erosion, Coastal Floods, and Sea Level Rise provided from Mangrove = Savings in Hard Gray Infrastructure (mainly, dikes and spikes, and a reduction in bund height and width).*

The valuation of the protection provided by mangroves based on avoided expenditure on physical reclamation and replenishment approach has been estimated in a number of countries around the world: these estimates range from $1,120–1,369 per hectare (Barbier et al. 2011, Estoque et al. 2018). The lower end of these estimates may be more appropriate for use in estimating the benefits in Guinea, given the average income levels of the countries included in the studies. Accordingly, the annual value of protection from coastal erosion, coastal floods, and sea-level rise with an estimated mangrove cover of 207,600 hectares in Guinea amounts to $232.5 million.

Biodiversity Benefits

Mangrove ecosystems and their associated wetlands support a wide array of biodiversity in Guinea by serving as a habitat for high concentrations of birds, mammals, reptiles, amphibians, fish, and invertebrate species. The biological diversity on the coastal shelf of Guinea depends on the input of organic matter and detritus from the coastal mangroves (UNEP 2007). A great number of seabirds use the mangrove forests for feeding, reproduction, and shelter (UNEP 2007). A number of endangered species also depend for their survival on these wetland ecosystems. **Preservation of these mangrove ecosystems through the sustainable use of resources is therefore vital for protecting the country's biodiversity.**

Only a limited share of the area identified as mangrove forest in Guinea falls within designated protected areas. Guinea has four Ramsar sites that contain mangroves that were designated in 1992. These are: Iles Tristao, covering 850 square kilometers (sq km); Rio Kapatchez (200 sq km); Rio Pongo (300 sq km); and Konkouré (900 sq km). Designating wetlands as protected areas based on the principles laid down under the Ramsar Convention, and implementing them fully is important for preserving their unique character, which supports the biodiversity around these areas. This means following the rules laid down to prevent unsustainable use that puts pressure on the survival of the ecosystem. However, since designation as a protected area would curb some of the practices currently followed to harvest resources, the communities around the protected areas may face reduction in their income-generating activities from these areas.

The economic benefit from preservation of the mangrove ecosystem in Guinea can be determined indirectly using the Willingness to Pay (WTP) approach. The WTP is based on how much reduction in income the communities around the mangrove areas are willing to accept if the area is designated as a protected area. This provides a measure of how much value these communities assign to protecting the biodiversity associated with the mangrove areas that would be a proxy of the benefits provided these areas by preserving biodiversity.

This study had planned to conduct focus groups in the communities around the mangrove areas, followed by the distribution of a questionnaire aimed to measure local willingness to accept a loss in income if the area were to be designated as a protected area. However, due to COVID 19-related restrictions, the survey could not be conducted. The estimation is therefore based on the results from a similar study of two separate locations done in the neighboring country of Ghana, in the Cape Coast area.

In otherwords:

> *Economic Value of Protection of Biodiversity Resulting from Mangrove = Willingness to Accept Income Reduction if the Area is Designated as Protected Area.*

The WTP approach is based on a survey that was used to determine the biodiversity benefits in two habitats in Ghana, both on the western coast. One study, which was done in 2004, revealed an average per hectare valuation of $911 when valued at 2000 PPP$ (Aheto 2011). The other study, completed in 2018, when valued in 2020 PPP$ revealed a valuation of $1,651 per hectare (Jonah 2020). However, values based on WTP are often underestimated, since all of the relevant information concerning the benefits that biodiversity can provide may not be available to the survey respondents. Based on these numbers, the annual WTP to preserve the mangrove areas as a protected natural reserve with an estimated mangrove cover of 207,600 hectares in Guinea ranges from $189–$343 million.

Water Purification Benefits

Mangroves provide natural water purification services. Excess nutrients present in the water are removed and broken down, which results in better-quality water. Laboratory experiments also show high removal rates of nitrogen and phosphorus from both organic and inorganic nutrient-rich wastewater in a mangrove environment (Shimoda et al. 2009). Mangroves are also known for removing harmful materials from wastewater and transforming toxic pollutants to less harmful materials.

The benefits of water purification from mangroves in Guinea was estimated using an alternative cost approach. Essentially, these estimates are based on the cost incurred for performing similar filtering services in a typical treatment plant. Using this method, Lal (1990) found that the monetary value of water purification from mangroves is equivalent to $5,820/hectare/year. (However, with technological improvements, the cost of such filtering services in treatment plants has come down.)

Another way of valuing the benefits from water purification performed by mangroves is based on its property of removing salinity from sea water. Mangroves are facultative halophytes and are known for their special ultrafiltration system, which can filter approximately 90 percent of the sodium ions from the surrounding seawater through their roots.[20] However, the efficiency found in these studies is based on a laboratory setting; in natural conditions the actual performance may be much lower. The cost of similar salt filtration in desalinization plants can be used to determine the monetary benefits arising from water purification by mangroves.

[20] https://www.nature.com/articles/srep20426

In other words:

Economic Value of Water Purification from Mangrove = Cost of Performing Similar Filtering Services in a Typical Treatment plant.

The cost of converting sea water into brackish water is used to determine the water purification benefits from mangroves. The current cost of desalinization of sea water is around $3 per 1000 gallons, while that of brackish water is $1.09 per 1,000 gallons.[21] The amount of water purified by mangroves per hectare annually was estimated using an average root height of 50 centimeters, and a conservative 6–20 percent efficiency based on location, because of the constant flow of sea water around mangroves. Based on these assumptions, the water purification benefits from each hectare of mangroves ranges between $151 and $504. Thus the annual water purification benefits from mangrove areas in Guinea, with its estimated mangrove cover of 207,600 hectares, ranges from $31,404,067 to $104,228,604.

Total Benefits from Mangroves

The valuation of benefits derived from mangroves in Guinea clearly reveals that the private-use direct benefits are only a small fraction of the total economic benefits mangroves can provide (Table 4). The total private direct benefits are also much smaller than the private indirect benefit from the fisheries sector. This study also shows why mangrove rice production is an attractive private benefit for farmers, since the benefits per hectare far exceed the private direct-use benefit they would otherwise get from mangroves in the same location.

Once the social-use benefit from mangroves is included in the overall benefits, a much stronger case can be made for preservation, and the creation of new mangroves in areas suitable for such growth. The social-use values presented are generally on the conservative side and do not fully account for all possible values. Even with these limitations, the overall value, including social values, far exceeds the private-use benefits.

TABLE 4: TOTAL BENEFITS FROM MANGROVES IN GUINEA

Annual Total Benefits	Value $M	Value $/Hectare
Private Direct Use		
Salt production	$12	$55
Fish smoking	$20	$96
Domestic, Conakry	$8	$40
Domestic, rural	$12	$57
Total Direct Use	$52	$248
Private Indirect Use		
Fisheries	$232	$1,119
Social Use		
Carbon Sequestration	$49	$221
Flood Protection	$232	$1,120
Water Purification	$31 - $105	$151 - $504
Social Option and Nonuse		
Biodiversity	$189 - $343	$911 - $1,651
Private Alternate Use		
Mangrove Rice	$616	$7,896

[21] https://www.advisian.com/en/global-perspectives/the-cost-of-desalination

CHAPTER 4.
ECONOMIC COST ESTIMATIONS OF THE AFFORESTATION PROGRAM

The total cost of mangrove plantation in Guinea will involve a one-time initial cost of planting plus the cost of maintenance, which will be estimated on an annual basis. The planting cost of mangroves per unit of land will differ depending upon whether these are plantations in new areas (including totally degraded land), or rehabilitation measures in existing partially-degraded mangrove forests. However, in both cases the cost will consist of the labor and materials needed for planting mangroves, assuming that the plantations will be done on public land, and that no land acquisition costs would be incurred.

The annual maintenance costs of mangroves, including rotational thinning and selective final felling, will involve both labor and material costs. These estimates are based on the typical amount of manpower needed in Guinea for forest maintenance per unit of land, and the prevailing wage rates. The material costs for annual maintenance is estimated as a percentage of the labor cost, as these costs are likely to be minimal.

The cost of planting with 2 x 2-meter spacing is estimated at $968 per hectare; and $1,815 with a 1x 1-meter spacing. This includes both the material and labor costs involved in the first year of the plantation. To ensure that the plants are protected and continue to grow, annual maintenance costs, mostly in terms of labor, are estimated at $72 per hectare. In the cost- benefit estimation for this study, we used the cost for 2 x 2-meter spacing.

4.1. COST-BENEFIT ANALYSIS AND ESTIMATION OF NET PRESENT VALUE AND INTERNAL RATE OF RETURN

The net present value (NPV) from each hectare of new plantations is estimated using the following formula over a twenty-year period:

$$NPV = \sum_{t=1}^{T} \frac{NPt}{(1+r)^t}$$

where NPV is the net present value; NPt is the net profit at time t; r is the discount rate; and T is the project lifespan. In addition, a benefit-cost ratio (BCR) is estimated based on the ratio of the NPV of benefits and the cost based on these values.

Assuming that the annual benefits start accruing ten years after planting, the private direct benefits show a positive NPV per hectare of $1,357, with a BCR of 1.4 over a twenty-year period, with a 3 percent discount rate. With inclusion of the private indirect benefits from fisheries, the NPV per hectare increases to $18,503, with a BCR of 19. Once the social-use values are factored in, the NPV increases to $38,333, with a BCR of 39. These reveal the large benefits that come with investment in planting mangroves in Guinea.

An additional NPV of $950 million can be created based on only private-direct use over a twenty- year period, with a 3 percent discount rate, by bringing the nearly 700 square kilometers of mangrove-suitable land that is currently barren or degraded back as pristine mangrove areas. If all of the other social benefits are also included, the NPV from such investment could be as high as $26.8 billion.

TABLE 5: NPV PER HECTARE, AND BCR FROM EXISTING MANGROVES

	NPV $/Hectare	BCR
Private Direct Benefit	$1357	1.4
All Private Benefits	$18,503	19
Private and Social Benefits	$38,333	39

CHAPTER 5.
CONCLUSION

Mangroves in Guinea provide many monetary benefits, and even the direct private benefits they provide clearly outweigh the costs of creating and maintaining them in most of the areas that are now barren but suitable for mangroves. In areas that have been cleared of mangroves for alternative uses like rice farming or urban use and may not be feasible for mangrove restoration, the benefits from mangroves can often be comparable to the benefits from other such uses once we monetize their private indirect and social-use benefits. To identify the locations that would provide the best return on investment in creating new mangroves, a detailed analysis of the benefits from mangroves, using the methodology proposed for each type of benefits, is needed. However, an accurate region-specific analysis of the net benefits in each area would require collecting data specific to each region in Guinea, since the types of mangroves and their spread often differ from region to region.

The benefit estimation in this study is based on the best local data available in Guinea and reveals a number of gaps in local data availability that may provide good areas for future research. First, the area estimates for mangroves currently do not clearly include species specific area coverage. With improvements in satellite technology, it is becoming increasingly feasible to determine these based on the satellite imagery data. Creating this mangrove species based coverage will help to more accurately determine the benefits from mangroves as the height and canopy cover differ across mangrove species. Second, some of the direct benefits like medicinal use are anecdotal and require more research to get a more accurate data estimates. Some other direct benefits like honey and tourism point towards possible future benefits that may still be untapped.

The biggest data gaps were found while estimating social benefits and option value benefits. One such area is carbon sequestration where, unlike in some of Guinea's neighboring countries, very few local on-the-ground estimates have been done. Regarding coastal protection, it is hoped that one current project in place in Guinea will help to collect suitable data for a location-specific estimate of benefits. There is also a need to carry out suitably structured surveys to determine the Willingness to Pay for mangrove preservation in order to more accurately determine such option value benefits.

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APPENDIX A.
ESTIMATION OF MANGROVE AREA IN GUINEA CONAKRY[22]

A survey of the current literature about the area coverage of mangroves in Guinea since 1951 reveals a number of issues. For example:

» The values provided are not, for the most part, accompanied by descriptions of the methodologies used (no calculation methods are provided), and rarely are there references provided from iconographic sources (topographic maps, aerial photographs, satellite images) or geomatics.

» The rounding nature of a number of the values supplied testifies to their imprecision.

» There is a repetition of values over time (from report to report), without citation of references, and without critical analysis of previous results.

In addition, what we have observed on reading various reports (mainly gray literature), which may be the source of some of the surface differences, are differences in the definition of the mangrove. Some of the definitions are:

» The tree formation seen in *Rhizophora* (the original Anglo-Saxon definition from the name of this tree),

» The entire tree layer (*Rhizophora, Avicennia, Laguncularia, Conocarpus*),

» All halophilic vegetation (vegetation that likes salt): tree, shrub, and herbaceous material

» All marshy surfaces that are liable to flooding by the sea (salt marshes);

The whole ecosystem integrating the hydrographic network, mud flats (*slikkes*), vegetated areas (*schorres*), and areas developed for growing rice or salt farming on salty substrate. Or 400,000 hectares (1951, 1974 ... 2018). Thus, estimates of mangrove areas and therefore deforestation rates may have been based on different spatial sets based on what the author of the calculation considers a reference area (for what he or she calls "mangrove"). These often do not distinguish between the types of mangrove plains taken into consideration.

One of the specificities of the mangrove areas of Guinea is the existence of three specific types of plains:

» **Estuarine plains.** These border the estuaries of the mouths of coastal rivers. They are very submersible, and are naturally occupied by *Rhizophora* mudflats (which are dominant).

[22] The contents in this Appendix is based on a report prepared by Olivier RUË in 2020 for the World Bank.

- **The seafront plains.** These are located in sectors further from the mouths of rivers. They are much less submersible than the estuarine plains, but with salty soils. They were originally occupied by *Avicennia*; since the 1950s they have been used for rice cultivation (the largest perimeters).
- **The back mangrove plains.** These are floodable (especially during winter). They are found in the transition between continental (non-salty) brackish and salty environments, and are partially colonized by hydrophytes with drainage constraints.

Some authors consider all of these plains in their calculation; others only consider estuarine areas with dominant *Rhizophora* (which are similar to the mangroves of Central Africa) because they are, in their natural state, submerged 50–70 percent of the time. Others include the dominant seafront plains or the rear mangrove plains in *Avicennia*, which are naturally submerged between 3 and 40 percent of the time. (Ruë 1998).

Considering these limitations, the following estimates can be found across time about the area coverage for mangroves in Guinea:

- IGN France Internationale, CIRAD, AFD ANASA: Agro-ecological zoning of the Republic of Guinea (2018–2020)[23]
  - 241,359 ha of maritime marshes (2015) including:
  - 141,953 ha of mangrove (2015)
  - 144,639 ha of mangrove (2005)
  - 99,406 ha (2015) and 99,677 ha (2005) of maritime wetlands
  - Loss of 2,686 ha of mangrove in 10 years between 2005 and 2015: either -1.9%/10 years, or 0.19%/year

- Diallo et al (2019)[24] use data from Rio Tinto (2012)
  - 279,100 ha of which
  - 203,600 ha of mangrove forest and 75,500 ha of brackish coastal marshes
  - 60,500 ha of floodplain rice fields
  - 30,500 ha of bare mud flats (slikkes) uses data from 2001 and from Altenburg (1989)

- Dolinguez F.[25] et al. (2018) after RUË (1995, 1998)
  - 270,000 ha of mangrove including 100,000 (almost a third) exploitable (wood)

- Green Climate Fund (2018)[26]:
  - 385,000 ha of mangrove (taken from Traoré et al. 2002).But according to the author “there is currently no official data that can accurately assess this area”. About twenty cartographic estimates and measurements were carried out between 1950 and 2000, varying from single to double depending on the year and the study.

- Heral A.[27] (2016):
  - 385,000 ha of mangrove swamps (10% of mangrove swamp areas in West Africa from Senegal to Sierra Leone)
  - Of which 250,000 ha of forest areas and 120,000 to 140,000 ha cleared and developed into rice fields, saltworks, areas for smoking fish and oysters or others

- Ministry of the Environment, Water and Forests (2015)
  - Decrease in mangrove area -4.2% (without source or calculation method)

[23] https://www.ignfi.fr/fr/portfolio-item/zonage-agro-ecologique-guinee/
[24] Diallo M. et al (2019): model of criteria taking into account halieutic biodiversity in strategic port planning in Guinea - Vertigo - the electronic journal in environmental sciences, vol.19 n ° 3 - posted online on 30 dec . 2019.
[25] Dolinguez F. et al (2018): Twenty years of rice development in mangrove areas in Maritime Guinea - Technical note n ° 44 from Agence Francaise de Développement
[26] Green Climate Change (2018): Strengthening the resilience and adaptation to climate change of the coastline of Guinea - feasibility study
[27] Heral A. (2016): The traditional salt production activity in Guinean mangroves and the alternative by solar production - capitalization of the establishment and innovation (1992–2016)

- State of the environment report (2012) cited in Afrikimpact of 21/01/20
    - 250,000 ha of mangrove
    - Annual regression rate of 4.2%/year (secondary reference)

- National Environmental Policy (2011)
    - 250,000 ha of mangrove forests

- IUCN (2010)[28] :
    - 250,000 ha of mangrove forests (possibly from FAO 1998); the author indicates that in 2000 the area was about 330,000 ha but without indicating its source.
    - Reduction 1000 ha/year (-4% without calculation basis)

- IUCN (2007) MAOI
    - 437,000 ha so-called mangrove zone (in deep salty alluvial soils)
    - 250,000 ha of mangrove (350,000 ha in 1956 - without source)
    - Mangrove reduction 450 ha/year (-4% - without calculation basis)

- Bangoura I. (2004)[29] Information presented as part of the study for the assessment of global forest resources (FAO 2005)
    - 299,200 ha of mangrove area:
    - GTZ (2002)
    - 356,342ha of mangrove area
    - Water and paddy fields are not taken into account

- National Strategy and Action Plan on Biological Biodiversity (2001)
    - 250,000 ha of mangrove forests (reminder 400,000 ha in 1957 but probably reproduced from 1951 (ref. Known) but is it the only tree formation or the whole ecosystem?
    - 30,500 ha of bare mud flats (*slikkes*)
    - Mangrove reduction of 375 ha/year or 1%/year

- UNEP WCMC (2000): Landsat image interpretation as part of the World Mangrove Atlas initiative
    - 187,800 ha of mangrove

- RUË O[30]. (1995, 1998)
    - 270,000 ha of mangrove forests (ref. SDAM 1989) including
    - 100,000 ha of exploitable forest and exploited mixed areas with dominant Rhizophora
    - Decrease - 6000 ha/year in 1998, ie - 6%/year (compared to 100,000 ha of still exploitable forest); -12,000 ha/year in 2020 or 12%/year

- IUCN Hughes (1992)
    - 285,000 ha
    -

- SDAM (1989) Cartographic analysis at a scale of 1:700,000. The data come from aerial photographs from 1979–80 updated with Landsat MSS images 1984–1985–1986. CTFT/BDPA-SCET AGRI. 1989. Potentialities and Possibilities of Relaunching Forestry Activity: Regional and National Synthesis. 1:700,000. CTFT/BDPA-SCET AGRI
    - 385,000 ha of ecoystemic mangrove area (maritime marsh including channels, mud flats, tannes) including
    - 270,000 ha of mangrove forests
    - 120,000 ha cleared and/or converted into rice fields, saltworks, smoking area or other, including 70,000 ha abandoned, including 35,000 sterilized

- FAO[31] (1987)
    - 280,000 ha of mangrove forests

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[28] IUCN (2010) Coastal Governance and Heritage
[29] FAO (2005) Global Forest Resources Assessment - Thematic Study on Mangroves in Guinea-
[30] RUË O. (1998): The development of the coast of Guinea - Memories of mangroves - ed. The Harmattan
[31] FAO (1987) Journal of the Forest Sector of Guinea

- » Decrease - 6,000 ha/year exploited i.e. - 2%/year (compared to 280,000 ha)

» Bangoura I. (1980?) Reported in 2004
- » 299,200 ha of mangrove forest

» Republic of Guinea (Diallo K, 1974)
- » 400,000 ha of marshes including
- » 262,000 mangrove forest
- » 110,000 ha of plains suitable for rice cultivation

» Rouanet (1957)
- » 400,000 ha of mangrove (- without indication of measurement method) cited by Kaba (2001)

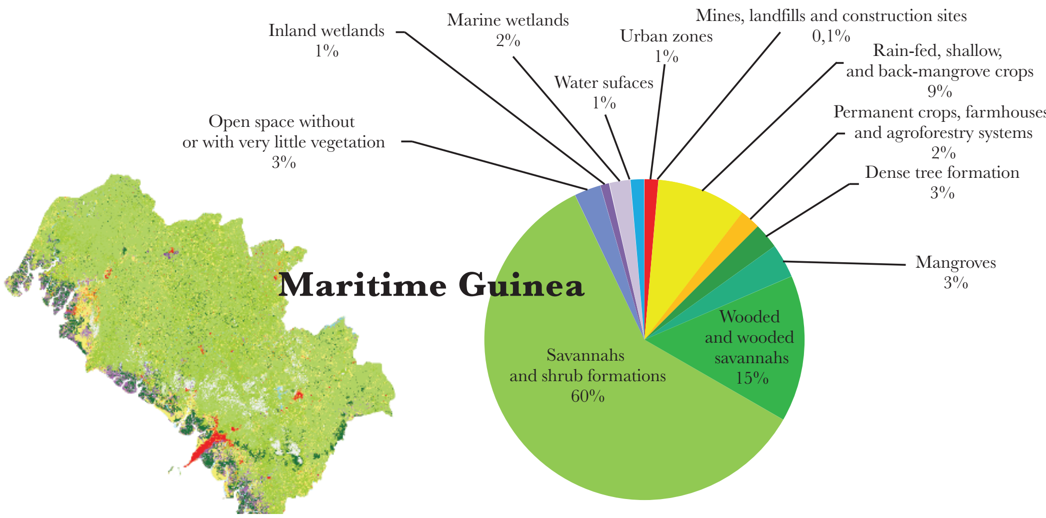
» Pre. R (1951) in The future of French Guinea
- » 400,000 ha of maritime marshes (this value includes the entire partially or totally submersible ecosystem, channels, mud flats, tannes, forest, coppice. In addition R.Pré, Governor of French Guinea dreamed of destroying the mangroves to replace them entirely in rice fields.) This measurement will often be repeated without planimetric verification.

TABLE A.1: AREA OF AGRO-ECOLOGICAL ZONES IN THE REPUBLIC FOUND BY GEOMATIC MEASUREMENT IN 2005 AND 2015

	S (ha) 2005	S (ha) 2015	2015 (%)	ΔCH	ΔCH (%)
Urban Zones	45,197	54,710	1.25%	9512.4	21.0
Mines, landfills and construction sites	3,947	5,117	0.12%	1170.8	29.7
Rain-fed, shallow, and back-mangrove crops	344,770	402,771	9.18%	58,001.0	16.8
Permanent crops, farmhouses and agroforestry systems	85,389	87,849	2.00%	2,459.5	2.9
Dense tree formation	118,744	117,656	2.68%	-1,087.6	-0.9
Mangroves	144,639	141,953	3.24%	-2,685.8	-1.9
Wooded and wooded savannahs	655,038	652,678	14.88%	-2,359.7	-0.4
Savannahs and shrub formations	2,676,488	2,611,352	59.52%	-65,136.0	-2.4
Open space without or with very little vegetation	119,598	119,603	2.73%	5.2	0.0
Inland Wetlands	34,695	34,517	0.79%	-178.4	-0.5
Marine wetlands	99,677	99,406	2.27%	-271.3	-0.3
Water surfaces	59,018	59,588	1.36%	569.9	1.0

Source:

FIGURE A.1: PERCENTAGE CHANGE OF AGRO-ECOLOGICAL ZONES IN THE REPUBLIC FOUND BY GEOMATIC MEASUREMENT BEWEEN 2005 AND 2015



Source:

The agroecological zoning work of the Republic of Guinea carried out by IGN F international, CIRAD and ANASA with *Agence France de Développement* funding over the past two years, on images from 2015 and 2005 constitutes the first rational geomatics work that distinguishes between mangroves and wetlands; but it is not differentiated by species. The results for the three regions, or three zones, as measured by Didier Bazzo on November 24, 2020 reveals the following data, which adds up to 200,000 hectares or 2,000 square kilometers.

TABLE A.2: AREA OF MANGROVES IN THREE ZONES IN GUINEA IN 2015

GB - Cap Verga border	Cap Verga - Kaloum	Kaloum - Frontière SL
90,000	74,000	36,000

MANGROVE EXPLOITATION AREA

A precise mapping (one of the few), at 1/20,000 scale, of natural formations, land use, development constraints, and the various levels of traditional interventions in the sector in Konkouré was carried out by the Mangrove Management pilot project in Sangaréah Bay (52,400 ha) between 1992 and 1995. It enabled a large-scale (detailed) inventory, but without differentiation of species, the proportions of specific forest and plant cover in one of the most beautiful mangrove massifs in Guinea. The results for area distributions were as follows:

- » Productive woodlands 37.5 percent
- » Rear mangrove 34.1 percent
- » Unproductive woodlands 22.9 percent
- » Rice and salt fields 2.8 percent
- » Wasteland and tannin 2.4 percent

This distribution showed that, in a sector considered to be one of the most beautiful and dynamic forested mangrove reserves in the country (the Konkouré Delta), only 37.5 percent of the surface was occupied by a productive formation and therefore can be used rationally for commercial exploitation. **We can therefore deduce,** by applying this proportion to all of the main mangrove areas of Guinea in *Rhizophora,* **that of the 270,000 hectares of natural mangrove plant formations, we can only count on about 100,000 hectares (37.5 percent) for this type of commercial exploitation.**[32]

[32] Rio Nunez, Rio Pongo, Konkouré; Forécariah, Mellacorée (5 estuarine mangrove sectors with beautiful *Rhizophora*).

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APPENDIX B.
BENEFITS FROM PRODUCTS OBTAINED FROM MANGROVE PLANTATIONS

DIRECT BENEFITS

The overall direct use of mangrove wood is based on the following:

- The production of mangrove salt by cooking (ignigenic) varies between 10,000 and 20,000 tonnes/year. Guinea's needs are 78,000 tonnes/year at a rate of 6 kilograms (kg) per person per year. At the rate of 3 kg of *Avicennia* to produce 1 kg of salt,[33] the consumption of wood (*Avicennia*) amounts to an average of 45,000 tonnes/year.
- It takes 3 kg of *Rhizophora* to to smoke 1 kg of fish. Based on 26,000 tonnes of fish per year, the consumption of *Rhizophora* wood amounts to 78,000 tonnes/year.
- The consumption of mangrove wood in Conakry was estimated at 800,000 cubic meters (m^3) at a rate of 0.8 m^3 per inhabitant per year × 1,000,000 inhabitants) at the end of the 1980s and at 1,200,000 m^3 at the rate of 1,500,000 inhabitants at the end of the 1990s. In 2020, the population of Conakry stood at 1,938,000 inhabitants. Knowing that the individual consumption of wood energy amounts to approximately 0.8 m^3/year, the demand for wood (wooded savannah, shrub savannah, and mangrove) just for Conakry amounts to 1,550,400 m^3. This is converted to 51,140 tonnes using the average density of 0.032985 tonnes/m^3.

The SDAM (1989) provides the first estimate of the distribution of the different uses of mangrove wood over the whole of Lower Guinea. The usage breakdown is as follows:

- **Production of salt 22 percent**
- **Smoking fish 36 percent**
- **Domestic needs of Conakry 22 percent**
- **Rural domestic needs 20 percent**

The consumption of 45,000 tonnes for salt, 78,000 tonnes for smoking fish, and 51,140 for wood is very close to the proportion found earlier. We used that same proportion to estimate the consumption for rural domestic as 6,490 tonnes for total use of 220,630 tonnes per year (Table A.2).

[33] On the other hand, the production of solar mangrove salt (which does not consume wood) amounts to an average of 1,600 tonnes/year (over 15 years), although this technique has been introduced and popularized for almost 40 years.

Salt production and fish smoking uses mangrove as fuel wood. The use in Conakry and the rural areas is based on a comparison of wood harvesting in rural areas (Douprou) and in peri-urban areas (Dubréka) in 1994 (Ruë 1998). The comparison of the use of wood between Dubréka and the towns of Douprou showed that in 1994:

» The sale of wood represented 0 percent of revenue in Douprou against 73 percent in Dubréka.
» Smoking represented 47 percent of revenue in Douprou against 1 percent in Dubréka.
» Salt represented 38 percent of revenue in Douprou against 18 percent in Dubréka;
» Other mangrove activities represented 15 percent of revenue in Douprou against 8 percent in Dubréka.

It was assumed that rural areas mostly use mangrove for fuelwood; the proportion of wood used for Conakry was based on the ratio of use found in the town of Dubréka, a similar but smaller urban area for which survey data was available. The use of fuelwood as charcoal, was based on assuming a 40 percent reduction in volume when converting wood to charcoal.

We use this consumption data in tonnes, and the price per tonne, to determine the monetary value of mangrove use. The price data included both the average wholesale price and the retail price of wood and charcoal in local currency in 2000 in Guinea (Table B.1). However, we used the wholesale price in calculating the value of mangrove wood, since the retail value includes costs like handling and transportation as well. To arrive at the value in 2020, we applied the inflation rate between 2000 and 2020 in Guinea and finally expressed the value in PPP$, using the 2020 PPP conversion factor.[34] The valuation of each use is shown in Table B.2.

TABLE B.1:PRICE OF MANGROVE

Trade	Wood (gf/kg)	Charcoal (gf/kg)
Wholesale	20	65
Retail	40	130

From Wood Energy, Guinea 2000

TABLE B.2:TABLE B.2 MANGROVE USE

	Tonnes	Value in PPP$M
Salt production	45,000	11.5
Fish smoking	78,000	19.9
Domestic, Conakry	51,140	8.3
Domestic, rural	46,490	11.8
Total	220,630	51.5

[34] https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=GN

INDIRECT PRIVATE BENEFITS FROM FISHERIES

The information about fisheries in Guinea reveals the following:

» Species that are subservient to shallow water (up to 15–20 meters) are mainly coastal *scianidaes* such as *pseudotolithus sp* (boboe) and *ariidae* (jawbones), etc.

» The *ethmaloses* and flat *sardinellae*, which are pelagics that move in schools, make up nearly 50 percent of artisanal fishing.

» The *ethmaloses* are coastal and are fished all year round, while the sardinella is more related to upwelling (seasonal). Both reproduce under the mangrove and are therefore subject to the sedimented mangrove hydrosystem.They also represent a good proportion of the stomach contents of other coastal species.

"These fish are of paramount importance for the food security of Guinea because they are the most numerous ichthyological communities (*scianids*). Unlike in Senegal and Mauritania, where the biomass increases offshore due to oceanic upwelling, in Guinea the biomass increases toward the coast due to nutrients provided by coastal rivers and the productivity of mangroves. In Lower Guinea 80 percent of the fishery and forest resources are dependent on each other, and are ecologically associated.

A number of reports on annual fishery output exist. Our analysis is based on the report published by the National Center of Fishery Sciences of Boussoura (CNSHB), Ministry of Fisheries, Aquaculture, and Maritime Economy, Republic of Guinea. The total annual marine fish production in Guinea totalled 289,544 tonnes in 2019, of which pelagics accounted for 135,971 tonnes, and demersals for 152,395 tonnes.[35] A survey carried out at a number of important fishing locations found that the fishing was mainly at sea in Bongolon (88 percent) and Matakang (78 percent). In Koukoudé, on the other hand, there is a significant percentage of fishing activities on the coast (38.57 percent) and on the inlet (17 percent).[36] Based on these findings, we arrive at an annual coastal fishery output of 128,000 tonnes in Guinea. Of this, 70–80 percent of coastal fishing sustenance is dependent on the presence of mangroves.

The price of fish depends on the type of fish: this varies widely—from 5,000 GF/kg to more than 100,000 GF/kg—during 2019.[37] We use a weighted average price of 10,250 GF/kg in valuing the output. In PPP$ in 2020, this price translated to $3,832 per ton. However, this price includes the cost of fishing gear, and storage and transportation costs. To arrive at the net value of fish made possible by the presence of mangroves we subtracted $1,240 per ton in 2020 PPP$ based on the average cost of fishing in Guinea.[38] Assuming that 70 percent of the annual coastal catch of 128,000 tons is arising from the presence of mangroves, the value added from fisheries amounts to $232 million in 2020 PPP$.

[35] Fisheries Statistical Bulletin, 2019. Republic of Guinea. Ministry of Fisheries, Aquaculture, and Maritime Economy. National Center of Fishery Sciences of Boussoura (CNSHB)

[36] Living Standard Measurement Survey (LSMS) and fishing community study of fisheries comanagement sites, 2019. Ministry of Fisheries, Aquaculture, and Maritime Economy, Republic of Guinea..

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[38] https://academic.oup.com/icesjms/article/68/9/1996/668065

APPENDIX C.
SOCIAL BENEFITS FROM CARBON SEQUESTRATION

To arrive at the estimation of carbon sequestered in mangroves, the usual approach is to use an allometric function that requires estimating the height of the plants and the average diameter at breast height (DBH). Some functions also include leaf area index (LAI) as another parameter. However, such estimations in Guinea are not very common. A survey of the literature revealed only one study carried out in 2010 (Kovacs et al). In that study of the 10,442 hectares (ha) of mangroves in the country that have been mapped, approximately 30 percent were classified as riverine, dominated by tall *R. racemosa*. The remaining mangrove areas were dominated by dwarf mangroves, either *Rhizophora* or *A. germinans*. Biophysical parameter data collected from 56 transects varied considerably among the classes. For the tallest mangrove class, the mean values of height, DBH, estimated LAI, stem density, and basal area recorded were 13 meters, 15.1 centimeters, 4.3/838 stems/hectare (ha), and 25.9 m^2/ha, respectively. In contrast, for *A. germinans,* values of 3 meters, 4.6 centimeters, 1.5/2,877 stems/ha, and 6.0 m^2/ha were calculated.

In the absence of adequate ground-level data for various areas of the country, the only other alternative is to base such estimations on data derived from satellite imagery. However, only a few studies can be found that have computed the biomass in mangroves in Guinea. One study estimated the mangrove biomass in a number of countries in West Africa, including Guinea (Tang et al. 2019). It found an average canopy height of 7.8 meters, with an above-ground carbon density of 54.0–59.6 ton/hectare and below-ground carbon density of 20.5–22.7 ton/hectare.

A study done by NASA in 2020 specifically using satellite data for Guinea estimated the carbon biomass in mangroves in Guinea (see Table C.1). These findings indicated a slightly lower carbon density than that estimated by Tang et al. It also revealed the large amount of carbon sequestered in the soil of mangrove plantations.

TABLE C.1: TOTAL BIOMASS IN MANGROVE IN GUINEA

	2016	2017	2018	2019	2020
Total Above-Ground Biomass (Tg)	11.7	10.5	10.8	11.0	11.0
Total Below-Ground Biomass (Tg)	3.18	2.81	2.93	2.94	2.94
Total (Tg)	14.9	13.3	13.8	14.0	13.9
Total Biomass Carbon (Tg of C)	7.08	6.31	6.54	6.64	6.62
Area (sq km)	2,001	2,021	1,877	2,013	2,076
Biomass Carbon (Ton/Hectare)	35.38	31.21	34.82	32.97	31.88
Total Soil Organic Carbon (Tg of C)	48.56	48.29	46.24	49.34	48.83
Carbon Biomass in soil (Ton/Hectare)	242.66	238.96	246.36	245.09	235.22

Source: NASA 2020[39]

These show that each hectare of mangrove sequesters 31–35 tons of carbon in Guinea. If the 700 square kilometers of degraded mangrove is restored it would result in around 2.45 M ton of carbon sequestration. In addition, in each existing hectare of mangrove, each year an average of 2.4 Cum of biomass is added. So, given the current estimated mangrove cover in Guinea of a little over 2000 sq km, the natural growth of mangroves is helping to sequester 164.420 Ton of biomass (or 78,000 ton of carbon) per year.

The shadow price of carbon is based on estimates of the social cost of carbon in Guinea. This can be used in two ways. We can use the country-specific social cost of carbon as the shadow price. The other option is to base it on the price it could command in the international carbon market if that carbon reduction were to be traded.

The social cost of carbon is highly country-specific, and current estimates for Guinea suggest a price of $1 per ton.[40] On the contrary, the global weighted average price of carbon is much higher, and has been variously estimated to be around $20 per ton in 2020.[41]

Since international carbon trading is becoming quite easy, we have based our valuation of carbon sequestration in mangroves using the global weighted average price of carbon of $20 per ton. Using this figure, the economic value of restoring mangroves in the 700 sq km of degraded land would amount to $49 million. In addition, the economic value added from the annual natural increase in carbon sequestration in mangroves would add nearly $1.6 million every year.

[39] Simard, M., T. Fatoyinbo, C. Smetanka, V.H. Rivera-monroy, E. Castaneda-mova, N. Thomas, and T. Van der stocken. 2019. Global Mangrove Distribution, Aboveground Biomass, and Canopy Height. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1665 https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1665
[40] https://www.nature.com/articles/s41558-018-0282-y
[41] https://carboncreditcapital.com/value-of-carbon-market-update-2020/

APPENDIX D.

MANGROVE RICE

Mangrove rice is currently grown in about 78,000 hectares of land in Guinea, as discussed in Appendix A. In 2019, the annual gross rice production was 353,946 tons, and there was a net annual mangrove rice production of 300,481 tons.[42] The average price realization for mangrove rice was 9262 GF per kg in 2019. Using inflation in Guinea terms of the 2020 PPP$, the price amounted to $3,462 per ton**.** However, to get the value added in rice production we have to subtract the cost of rice production.

The average input cost of rice cultivation is estimated to be 20.8 percent of total rice value on average, derived from a survey about the cultivation of mangrove rice.[43] An additional 20 percent was incurred as labor costs. Based on these, the annual value added in mangrove rice cultivation was estimated to be $616 million. Since rice is grown on around 78,000 hectares in Guinea, this translates to $7,896 per hectare.

[42] Agricultural Statistics Director, 2019. National Institute of Statistics, Republic of Guinea.
[43] General Report of the Agricultural Investigation. Agricultural Campaign 2014-15. Ministry of Agriculture, Republic of Guinea.

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