TECHNICAL REPORT

WEST AFRICA COASTAL AREAS HIGH-LEVEL PLATFORM

BENEFITS OF MANGROVE AFFORESTATION AND RESTORATION PROGRAMS IN GHANA

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ACRONYMS AND ABBREVIATIONS

BCR	Benefit-cost ratio
CM	Carbon material
DBH	Diameter at breast-high
GWS	Ghana Wildlife Society
ha	hectare
IRR	Internal rate of return
NPV	Net present value
PPP$	Purchasing Power Parity Dollar
TEV	Total economic value
WTP	Willingness to pay

All amounts in US dollars ($) unless otherwise stated

EXECUTIVE SUMMARY

Ghana's mangrove ecosystems constitute a very important natural resource in the country's coastal region, where more than a quarter of the population resides. These areas not only support the gathering of timber and nontimber forest products; they also provide a myriad of ecosystem services, from carbon sequestration to 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.

However, between 1980 and 2014, the mangrove area in Ghana has been reduced from 181 to 114 square kilometers (sq km). This represents a loss of nearly 33 percent, and is mainly due to the unsustainable harvesting of mangroves. The harvesting of mangroves for their direct benefits can result in the loss of whole mangrove areas, as well as the associated ecosystem benefits they provide, which often exceed the direct benefits.

Understanding the full benefits that mangroves provide can help raise awareness of the need to preserve them for the overall betterment of society. Full accounting of the benefits that can be realized from mangroves them can also help to justify redevelopment of mangroves in areas where such planting is feasible. **The objective of the current study is to estimate the total economic value (TEV) of current mangrove areas in Ghana by considering the whole range of benefits they provide, and to use those estimated values in economic cost-benefit analyses**.

This study focuses on the respective values of private direct and indirect use; social use; and social option/nonuse of mangroves in Ghana. A survey of the literature was conducted to find studies that arrived at the values from all of these uses. These studies were from a number of locations in the Western Coast and Volta regions, where almost all of the mangroves in Ghana are currently found. If there were no studies available for a particular use of mangroves in Ghana, the values were arrived at by using data obtained from similar locations elsewhere. Since these studies were done in different years, all of the values were adjusted to 2020 PPP$, using inflation data in Ghana and the PPP$ conversion factor in order to compare these values on a similar basis. The results were reported as a mean value per hectare, along with the range of values found in those studies.

The mean value of private direct use of mangroves, mainly for timber and fuelwood, was calculated by using the quantity of mangroves harvested and their market price. The mean value was found to be $2,498 per hectare (ha), ranging from $811–$5,568. Private indirect use arose mainly from fisheries, the hunting of animals, and tourism. Using the quantity of fish harvested and their market price, the mean value of fisheries amounted to $719 per hectare ($402–$940). The hunting value was $82 per hectare, derived from only one study, based on the quantity of wildlife and its market price. The mean value for tourism was $46 per hectare ($45–$46), based on actual revenue generated.

Three social-use values of mangroves were assessed: carbon sequestration, flood protection, and water purification. The mean carbon sequestration value of $480 per hectare ($380–$500) was based on allometric studies to assess the carbon content in mangroves and the price of carbon. However, since no studies could be found in Ghana for flood protection and water purification, the mean flood protection value of $1,120 per hectare ($1,120–$1,370), and the mean water purification value of $327 ($151–$504) were based on studies done at locations outside of Ghana. **Biodiversity benefits were estimated as a social option**, and **nonuse value based on a willingness to pay approach**. The mean value found for nonuse was $1,281 ($911–$$1,651).

The cost of planting was based on 2 x 2-meter spacing for mangrove plantings. The mean cost of planting was found to be $2,528 ($1,760–$3,825), 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 $15,860, with a benefit cost ratio (BCR) of 5.7. With the inclusion of **indirect private benefits** from fisheries, the NPV per hectare increases to $21,398, with a BCR of 7.7. Once all of the **social-use values** are factored in, the NPV increases to $33,996, with a BCR of 12.2.

Two 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 occurs mainly for direct use would lead to net social benefits. **Second, the large NPVs and BCRs that could be realized from planting mangroves makes a clear case for launching an immediate drive to plant mangroves on a war footing in all of the lands that are now barren, but are suitable for growing mangroves.**

CHAPTER 1.
INTRODUCTION

A significant share of Ghana's economy is dependent on its coastal zone; more than a quarter of the population resides there, and it accounts for nearly 80 percent of the country's industrial establishment (WEF 2015). Oil and gas production, port operations, and the generation of hydro and thermal electricity are some of the important industrial activities found in this area. This area also contributes to the overall economic activity of the country through coastal agriculture and fisheries. **The health of the coastal areas is therefore of vital importance for the country's economy.**

In recent times, increased pressure on the ecosystem of the coastal areas is posing a major threat to the population as well as the economy of Ghana. However, the extent of the problem differs depending on the location. The coastal zone in Ghana can be divided into three broad sections: the western, central, and eastern zones. All three sections have been facing the threat of erosion to varying degrees. The eastern section, which is influenced by the Volta Delta system, has been identified as the most vulnerable (WEF 2015).

Oil and gas production in the western section of the country has resulted in increased migration of people to that area, which has created increased stress on the coastal environment, along with changes in the coastal ecology systems. One major impact has been the destruction of vegetation like mangrove swamps, which exacerbates damage to the ecosystem. The mining of precious minerals along portions of the coast is also destroying the equilibrium of the beach system, and either initiating or intensifying erosion. Sand mining, which is banned but is still practiced along the entire coast for construction purposes, is also having a negative effect (WEF 2015).

The vulnerability of the coastal zone is expected to increase significantly as a result of climate change and the associated sea-level rise. Sea-level rise increases the direct inundation of low-lying areas, facilitates the rapid erosion of soft shores, and increases offshore loss of sediment as well as flooding. It is estimated that a one-meter increase in sea level will inundate a significant portion of the Volta Delta system in the eastern section of the country.

Management of the coastal ecosystem in Ghana, including the prevention of coastal erosion, is mostly reactive, site-specific, and usually involves using difficult engineering approaches (WEF 2015). These projects involve a combination of groynes and revetment. Groynes is a form of coastal protection in which barriers are built into the sea to prevent erosion. They essentially trap the sand and stop it from moving too far from the coast. Concrete or wooden structures known as revetments have also been built to act as a barrier against the waves in an attempt to stop the effects of coastal erosion. The revetments absorb the energy of the waves, and prevent the cliffs from eroding. While they stabilize the shoreline at the protected section, they may increase erosion elsewhere.

The current approaches adopted by the government for protecting its coastal ecosystems are unsustainable, and environmentally unfriendly. Future projections of erosion along the coast of Ghana indicate that the present coastal buffer zones may be completely eroded by 2100. Also, between 2052 and 2082, it is projected that coastal erosion will affect important landmarks such as the Christiansburg Castle, Ghana's Independence Square, and the Densu Ramser site in Accra – all of which are all located within the coastal zone (WEF 2015). In addition, site-specific interventions are having knock-on effects in most cases. Thus the construction of the Keta sea defense, using a combination of groynes and revetments, has led to increased coastal erosion on the downdrift coast, toward the Ghana–Togo border, by over 50 percent (World Bank 2017).

There is an urgent need to develop a comprehensive coastal policy for managing the coastal ecosystem; and mangroves present a cost-effective solution to the problem. They can provide the opportunity to create policy that incorporates strategies for tackling coastal management problems using the "green" concept of working ***with*** nature, not against it. Protecting the sustainability of the existing mangrove forests, and developing new mangrove swamps in suitable areas could be an important part of a green strategy. However, the use of mangroves as a policy intervention will have to be cost-effective; a detailed cost-benefit analysis can help in creating one.

Ghana's mangrove ecosystems are tremendously valuable; they provide carbon sequestration; protection from storms, floods, and erosion; timber and nontimber forest products; the processing of waste and nutrient pollution; support for aquaculture and agriculture; and habitats for both aquatic and terrestrial species. A thorough estimation of the potential benefits of mangroves can help determine the total overall net benefits that could be realized in Ghana, and can also help to identify the best areas to plant and maintain mangrove plantations.

The objectives of the current study are to:

1. Estimate the total economic value (TEV) of current mangrove plantations in Ghana by considering the whole range of potential benefits from mangroves;
2. Use those estimated values in economic cost-benefit analyses in order to determine the possible effects of replanting and/or creating additional mangrove plantations in suitable locations.

Section 2 of this report discusses the location, extent, and type of mangrove cover in Ghana. **Section 3** explains the methodology used, and the actual valuation of the various benefits that mangroves provide. **Section 4** discusses the costs that would be 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 under mangroves.

CHAPTER 2.
MANGROVES IN GHANA

Mangrove swamps are structurally and functionally unique habitats restricted to intertidal and adjacent communities in tropical and subtropical regions. Mangrove species possess unique adaptations, including stilt roots and pneumatophores that allow the exchange of gases for their root tissues (Kauffman and Donato 2012). Their aerial root systems extend into intertidal and subtidal areas, where they provide stability for the otherwise soft sediment environment (Ellison and Farnsworth 1992). Indeed, mangroves are important habitats for many terrestrial and marine fauna, including several important commercial fish species (Aheto et al. 2014). Within the water column, mangrove roots are overgrown by epibionts such as tunicates, sponges, algae, and bivalves, with the spaces between their roots serving as shelter and food for motile fauna such as prawns, crabs, and fishes (Nagelkerken et al. 2008). Mangrove trees and canopies provide an important habitat for a wide range of species of birds, insects, mammals, and reptiles (Nagelkerken et al. 2008). Though they are restricted to coastlines, mangroves are one of the most productive coastal ecosystems, supporting a wide range of goods and services (Field et al. 1998). Humans have traditionally relied on mangrove-related products such as finfish, shellfish, firewood, timber, tannins, dyes, and medicinal products for their basic subsistence (Robertson 1988; Barbosa et al. 2001; Aheto 2011), which has probably contributed to the high level of degradation of mangrove ecosystems worldwide. It is noteworthy that among the major terrestrial land covers, the carbon storage potential of mangroves is the highest; yet mangrove ecosystem services are among the least investigated (Kauffman and Donato 2012).

In Ghana, mangroves are mainly limited to the beaches around lagoons on the west coast of the country, and bordering the lower reaches and delta of the Volta River. They are most developed on the west coast between Cote d'Ivoire and Cape Three Points. Six species of true mangrove are found in Ghana: *Acrostichum aureum; Avicennia germinans; Conocarpus erectus; Laguncularia racemose; Rhizophora harrisonii;* and *Rhizophora racemose*. Open lagoons are often dominated by *Rhizophora*, while closed lagoons, which have elevated salinity, contain *Avicennia germinans, Conocarpus erectus, Laguncularia racemose,* and *Acrostichum aureum*. The mangrove swamps in Ghana are very restricted in area and distribution, and they rarely develop beyond the thicket stage. *Laguncularia racemosa* and *Rhizophora racemosa* are found on the seaward side of lagoons in saline conditions. *Avicennia germinans* (syn *A. nitida*) occurs on the landward side of the swamps.

The mangrove stands in most areas are secondary growth, with degraded faunal composition due to intensive use of the mangrove for fuelwood to smoke fish and extract salt. *Avicennia germinans* is exploited for its bark, which is used for tanning fishing nets, and as firewood for local use. Mangrove wood is also used for construction. Mangrove lands have been reclaimed for both agricultural uses and urbanization, and they are threatened by oil pollution. As in many other parts of the world, short-term development needs are undermining long-term mangrove health and survival.

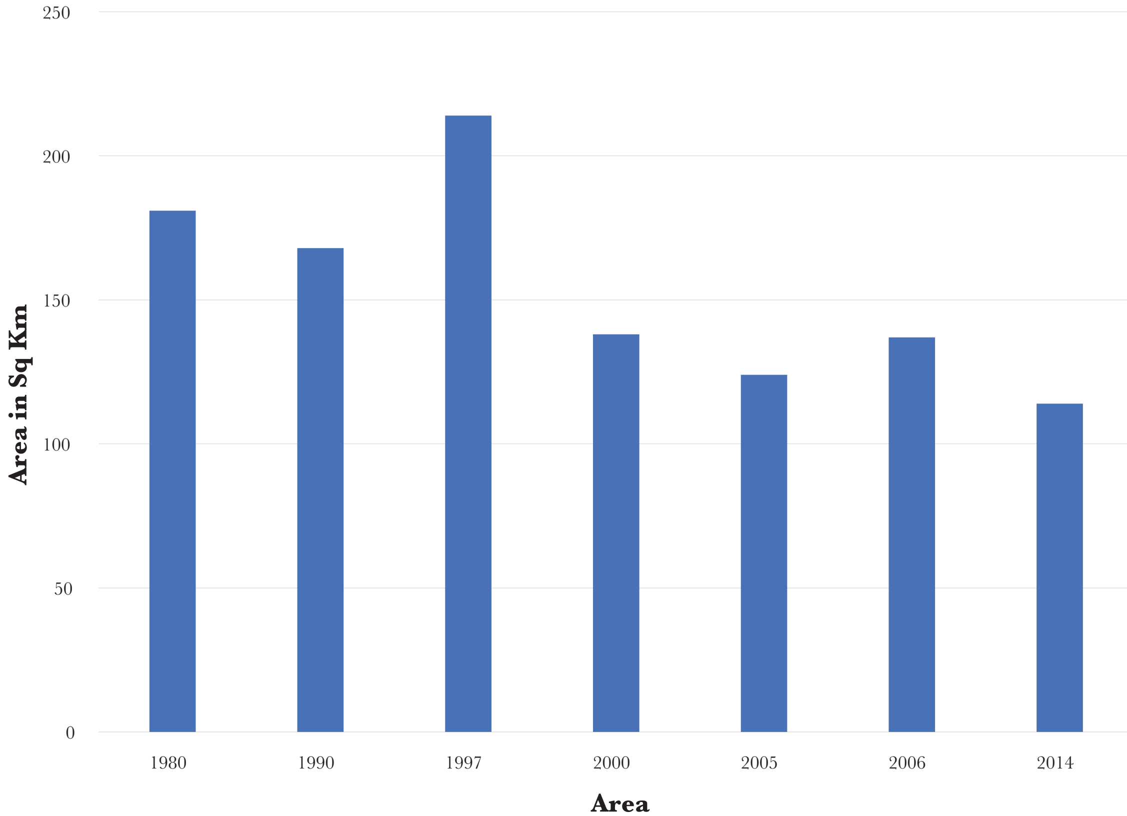
A number of local studies in Ghana have examined changes in the mangrove area coverage in specific small habitats; but only one large study has looked at changes in the overall Volta region. Most studies show a decline in mangrove areas, with only one study showing an increase, where extensive mangrove restoration had taken place (Yevugah 2017). The study encompassing the Volta region has shown a steady decrease in mangrove area, from 93.9 sq km in 1991 to 87.7 in 2002, and 63.7 in 2014 (Myers 2016).

A few local studies have also attempted to determine the quality of the mangrove cover in specific habitats by identifying the areas as intact, partially degraded, or fully degraded (Asante and Jengre 2012; Yevugah 2017). Some studies have also examined the types of mangrove species found in areas with mangroves (Dali 2020; Nortey et al. 2011). However, comprehensive, reliable, and detailed data for the whole country is lacking. The current complete country data for Ghana only provides an overall estimate of mangrove cover, with little detail. These data are mostly based on satellite images, with little ground validation of the data. The regional study in the Volta region using satellite images demonstrated the difficulty of correctly differentiating mangroves from other mangrove-related species, which often replace mangroves after the mangroves have been cut for timber and fuelwood (Myers 2016).

Based on the best available data, between 1980 and 2006 the mangrove area in Ghana fell from 181 to 137 sq km, a loss of 24 percent (UNEP 2007; Ajonina et al. 2008). Accounting for the further loss of mangrove areas in the Volta region between 2002 and 2014, these areas have been reduced even further, to 114 sq $3 km in 2014, a loss of 33 percent from 1980 (Myers 2016). Going by these trends, it is probable that the current area under mangroves may even be lower (Figure 1). While the decrease in mangrove cover in such data generally matches the ground realities of increasing the unsustainable harvesting of mangroves, the actual numbers require greater validation. The available data also does not distinguish between the various mangrove species on the ground; this is an important requirement when estimating the biomass in mangroves, since it can differ from species to species. With advances in satellite imagery that can provide more granularity of data concerning vegetation coverage on the ground, and other improved technical capabilities for differentiating each species, it is becoming increasingly feasible to develop such detailed data. Some recent studies conducted in other countries have been able to determine the composition of mangrove forests using red-edge spectral bands and chlorophyll absorption information from AVIRIS-NG and Sentinel-2 data.[1] The use of such techniques in the analysis of mangrove cover in Ghana can increase the accuracy and usefulness of these area estimations.

1 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

FIGURE 1: AREA OF MANGROVES IN GHANA (IN SQ KM)



2.1. COMMON MANGROVE SPECIES FOUND IN GHANA

Six true mangrove species are found in Ghana (Tomlinson 1986). These are *Avicennia germinans* (Black Mangrove); *Laguncularia racemosa* (White Mangrove); *Conocarpus erectus* (Buttonwood); *Acrostichum aureum* (Golden Leather Fern); *Rhizophora racemosa* (Red Mangrove); and *Rhizophora harrisonii* (Red Mangrove). The characteristics, occurrence, and method of propagation for each of them is described in Table 1.

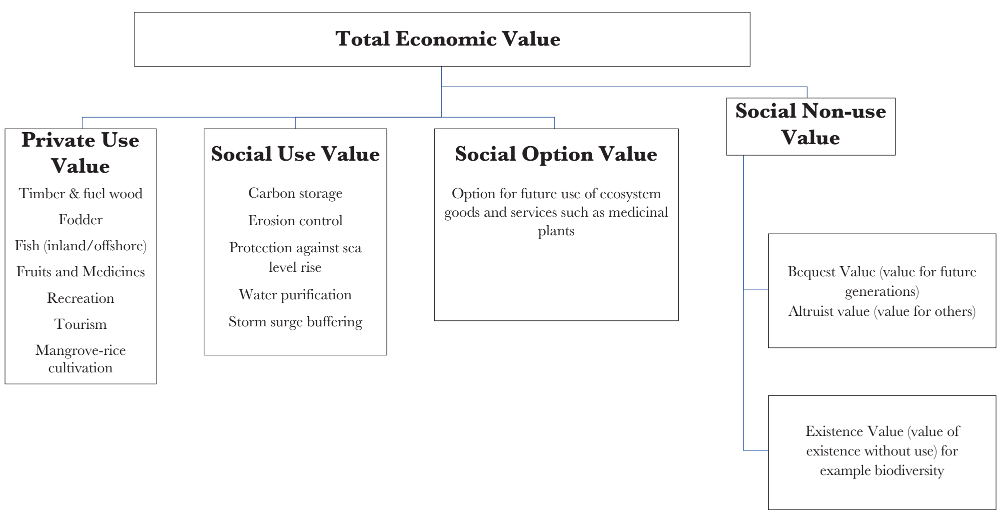
TABLE 1: COMMON MANGROVE SPECIES IN GHANA

Mangrove Species	Characteristic	Occurrence	Propagation
Avicennia germinans (Black Mangrove)	Develops finger-like projections, called pneumatophores, which protrude from the soil around the trunk (Tan 2001).	This species occurs at higher inland elevations 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 tixdes to other suitable locations (Florida Keys NMS 2006).
Lagunculari racemosa (White Mangrove)	Does not develop visible aerial roots; has elliptical light yellow-green leaves.	Occurs at even higher elevations farther upland than either the red or black mangroves.	Sprouting seeds 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, and thrives in the broken shade and wet soils of hammocks.	The seed heads burst when they are ripe, and the seeds are dispersed by water.
Acrostichum aureum (Golden Leather Fern)	Does not have any aerial roots; instead it has fibrous, fern-like 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, and 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 (Kathiresan 2010).
Rhizophora harrisonii (Red Mangrove)	A hybrid of *R. mangle* and *R. racemosa*, it 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 (Duke 2006).	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 racemosa (Red Mangrove)	Grows up to 30 meters (100 ft) tall, often with aerial stilt roots; in more marginal habitats this species 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 (Duke 2006; WWF 2001).	The fruit produces propagules which may fall into the water and be dispersed by wind and currents.

CHAPTER 3.
ECONOMIC BENEFITS FROM MANGROVES

Mangroves provide many direct-use benefits in the form of timber, fuelwood, animal fodder, fuel for smoking (curing) fish, medicines, etc. A number of other indirect benefits, including fisheries, recreational uses, and tourism are also made possible by the existence of mangroves. However, most of these constitute **private benefits** for the people who live in the immediate proximity of the mangrove plantations; this does not fully reflect the total economic value (TEV) of mangroves. To arrive at the TEV, we need to account for the **social benefits** arising from mangroves: for example, carbon storage, coastal erosion control, protection against sea-level rise, water purification, and storm surge and swell buffering; as well as **social option values** and **social nonuse values** (Figure 2).

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



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

The benefits derived from mangrove plantations and/or the costs of planting and maintaining them are often location- as well as context-specific. The present study developed a methodology for estimating the full benefits that could be received from mangrove plantations in Ghana and used that to determine the economic value from such activity. These data, along with the costs required for planting mangroves, were then used to determine whether mangrove afforestation projects are economically justifiable. This method can help demonstrate how these procedures can be applied in general, when establishing priorities among various adaptation projects that all have significant benefits.

3.1. PRIVATE-USE VALUE

3.1.1. DIRECT PRODUCTS

Mangrove forests provide a number of useful products—fuelwood, charcoal, timber, poles, honey, wax, fruits, medicinal plants, *akpeteshi* distilling, etc. The benefits from each species of mangrove present in Ghana, as found in the literature, for direct use and for medicinal use are listed in Table 2.

However, not of all of these uses can be realized from the types of mangroves found in Ghana. The most common uses of mangroves in Ghana are timber and fuelwood for smoking fish, and domestic fuel: a number of studies in various locations in Ghana have tried to determine the monetary value of these uses (studies referenced under table 3). There is some anecdotal evidence about its medicinal use, but there is no actual available data. Moreover, medicinal use may be declining over time, with the greater availability of conventional modern medicine in the country. There is also some reported use as tannin for staining, but there is very little accurate data about the quantity of such use.

Table 3 lists the direct private-use value per hectare in a number of locations in Ghana in the Western Coast and Volta regions, where currently almost all of the mangroves in Ghana are found. Since these studies were done in different time periods, and the rate of inflation has been quite high in Ghana for the last few years, all of the reported results are converted to 2020 valuations using the annual inflation rate in Ghana during this period. These results were then converted into PPP$ using the purchasing power parity for Ghana in 2020. The valuation of total use as wood per hectare ranged between $811 and $5,568, with fuelwood being the largest share in such use. The valuation also shows an increasing trend over the years, mainly from the likely increase in prices for mangrove wood over time, which exceeded the average inflation rate in the overall economy.

TABLE 2: PRIVATE DIRECT-USE VALUE OF MANGROVES PER HECTARE IN 2020 PPP$

	West Coast Y2004	Volta: Y2009	West Coast: Y2011	Volta: Y2013
Timber	$ 94	$ 207	N/A	Only combined total use data
Fuelwood (Domestic Use and Fish- Smoking)	$ 717	$ 621	$ 5,568	Only combined total use data
Total Use as Wood	$ 811	$ 828	$ 5,568	$ 2,783

Sources: For West Coast 2004 (Aheto 2011); for Volta 2009 (Gordon et al. 2009); for West Coast 2011 (Ajonina 2011); and for Volta 2013 (Aheto 2011).

3.1.2. INDIRECT VALUE OBTAINED FROM MANGROVE PLANTATIONS

Mangroves make possible a number of benefits, such as fisheries and the hunting of animals and birds; they also provide opportunities for developing tourism. The biggest economic benefits arise from the fishery sector. The water bodies of mangroves are used as spawning, hatching, nursery, and foraging grounds by a variety of fish, crab, shrimp, mollusks, and other aquatic creatures. They spend a portion of their lifecycles in the mangrove forests and later move on to the sea. It has been found that when mangrove forests are added to the coast, the fish population of nearby areas tends to increase.

A number of crab, fish, and black snail species are found in the mangroves in Ghana. One study of the Lower Volta mangrove swamps encountered 38 finfish and 14 shellfish species (Dankwa and Gordon, 2002).[2] Areas with more extensive mangrove cover were found to have greater species diversity than areas with sparse or no mangrove vegetation. The size and frequency distribution of all the species considered indicated a higher proportion of juveniles in the catch, emphasizing the nursery role of the study area.

[2] The most abundant finfish species were *Gerres melanopterus* (20.2 percent); *Clarias anguillaris* (18.7 percent); *Liza falcipinnis* (9.7 percent); *Mugil curema* (9.6 percent); and *Sarotherodon melanothero* (8.5 percent) of the total catch.

TABLE 3: COMMON DIRECT USES OF MANGROVES

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 can be mixed with palm oil for treatment of lice, ringworm, and mange; or 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 throats. Roots: Used as an aphrodisiac, or 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 for 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. It is also attributed some antitumor activity.
Conocarpus erectus (Buttonwood)	The heavy wood (specific gravity 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 can be used for piling and firewood. The 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, 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 because it can be grown in pots.	Rhizomes are used for the healing of stubborn ulcers. Leaves are used topically as emollient. Medicinally, the pounded or grated leaves and rhizomes are applied as a paste to wounds, ulcers, and boils, and are used against worms.
Rhizophora harrisonii (Red Mangrove)	Similar to other Rhizophora species.	Similar to other Rhizophora species.
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 is used for fungal infections of the skin; treatment of diarrhea and dysentery in children; leprosy, and sore throat.

Many animals, including monkeys, antelopes, rats, and grasscutters constitute important wildlife species found in mangroves. The mangroves also provide a habitat for a number of bird species. These animals and birds are caught by local inhabitants and are used as a source of food. The presence of these animals and birds, as well as the vegetation, also help tourism, since they attract visitors to these locations.

The ecosystem of a mangrove forest is completely different from the ecosystems in other areas of Ghana, and is therefore attractive to visitors. There are opportunities for recreational fishing, bird watching, and boating, or simply touring the area on boardwalks. The Ghana Wildlife Society (GWS) has been playing a critical conservation role in the area by promoting small-scale development projects that protect biodiversity while enhancing the economy around the Amanzule wetlands, which are covered with mangroves. To promote tourism, they have built walkways and provided boats to facilitate viewing the plant and animal species in the reserve.

The recreational benefits of mangroves are very little exploited in Ghana at present. However, such potential can be estimated using a travel cost method based on the estimation of transport costs to and from the recreational area as well as all additional expenses (food, lodging, transport, tickets, etc.), plus the opportunity cost of total time spent by the visitors for the whole trip.

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

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

Where:

T = travel time (in hours)

w = average wage rate (SAR/hour)

D = distance (in km)

v = marginal vehicle operating costs

Ca = cost of admission to asset

Va = average number of visits per year

Table 4 lists the current valuation of these indirect benefits in a number of locations in Ghana based on several studies. Since these studies were done in different years, all of the values have been adjusted to 2020 PPP$ using inflation data in Ghana and the PPP$ conversion factor. The fishery benefits per hectare ranged from $402 to $940, with benefits on the West Coast being greater than in the Volta region. Only one study on the West Coast computed the benefits from hunting animals and birds, while two studies, both on the West Coast, found benefits from tourism. However, the tourism data revealed wide variations from year to year, with decreasing revenue possibly due to inadequate infrastructure. To determine potential tourism revenue, the highest revenue figure was used in the benefit determination from both studies.

TABLE 4: PRIVATE INDIRECT-USE VALUE OF MANGROVES PER HECTARE IN PPP$ IN 2020

	West Coast: Y2004	Volta: Y2009	West Coast: Y2011	West Coast: Y2018
Fisheries	$ 940	$ 402		$ 814
Hunting	$ 82	NA	NA	NA
Tourism	NA	NA	$ 45	$46

Sources: For West Coast 2004 (Aheto 2011); for Volta 2009 (Gordon 2009); for West Coast 2011 (Ajonina 2011); for West Coast 2018 (Jonah 2020)

Mangroves also enable a large share of the fish catch in the coastal areas and the ocean by providing vital nursery facilities. Without the presence of mangroves these fishes would no longer be able to reproduce, and wouldn't be sustained. The annual fish catch in Ghana was 327,457 tons in 2016, of which inland catch was 87,816 tons; the remaining was in coastal areas and the ocean. Large pelagics (tuna, skipjacks, etc.) do not use mangroves as nurseries. It is estimated that nearly 70 percent of the rest—small pelagics like sardinellas, anchovies, chub mackerels, etc.; demersal fish (breams, carangids, snappers, groupers, etc.); and shellfish (shrimps and lobsters) use mangroves for spawning, hatching, nurseries, and foraging grounds.

The economic valuation of the annual nursery services for fish that mangroves provide is based on the net valuation of the fishery output after subtracting the production, transportation, and handling costs. A survey of small pelagic fish prices in 2018 showed an average price of 2.74 cedi/kilogram, of which equipment, transportation, and handling costs accounted for around 40 percent of the price (Jonah 2020). Based on the fish catch that is dependent upon mangroves and the average price, the total net value of the annual fish catch was found to be $203.7 million (in 2020 PPP$). Based on the mangrove cover of 11,400 hectares (the latest data available), the annual value addition from nursey services for fish was found to be 10,719 PPP$ per hectare.

3.1.3. INDIRECT ECONOMIC BENEFITS

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

Benefits of Carbon Sequestration

Mangroves are very good for carbon sequestration since they store carbon material (CM) not only in the above-ground biomass (trunks, branches, trees, twigs, etc.) but also in the roots and soil. In fact, with mangroves a larger share of carbon is stored underground than above-ground (Alongi 2014). The soil in the mangroves is also rich in CM, since the anoxic condition of the mangrove floor prevents carbon (C) combining with oxygen (O_2) in the air to form carbon dioxide (CO_2) and then being released into the atmosphere.

There are five areas where carbon materials are stored in mangroves:

1. Above-ground biomass (trunk, branches, leaves, etc.)
2. Underground biomass (living roots)
3. Aerial roots
4. Fallen leaves, branches, twigs, etc.
5. Dead roots

A number of studies in Ghana have made use of the standard procedure of using an allometric function to estimate the above-ground biomass stored in the trunks, branches, and leaves in plants that express it as a function of the plant's height and diameter at breast height (DBH) (Abohassan et al. 2012). The following allometric function is usually used for such analysis:

$$\text{Biomass} = \alpha + \beta_1 \text{Ht} + \beta_2 \text{DBH} + \varepsilon$$

Where α is the intercept, β_1 and β_2 represent regression coefficients for height (Ht) and DBH for respectively, and ε stands for the residual.

Such surveys are based on data from selected plots from the survey area, and then extrapolating the results to the whole area. Typically, the mangrove forest inventory would use three subplots in each location, with each subplot having either a 2- or 3-meter radius. The plots would be randomly laid out using a stratified random sampling. In the first stage, the area under mangroves is divided into strata of equal size, covering the whole area. In the second stage, a representative number of sample plots would be picked randomly from each stratum.

The survey sample size is determined based on the variability of biomass within the samples and the precision level required by the methodology (an allowed 10 percent error). In other words, the sampling strategy aims to achieve an error with a mean value of 10 percent or less, thus with a 90 percent level of statistical confidence that the claimed amount of carbon sequestered is the true amount.

During data collection, the following parameters are assessed and/or measured:

- Species code
- Size: Classification between trees and saplings.
- DBH: Diameter at breast height (1.3). (Only measured in trees.)
- D_{30}: Diameter of stem at 30 centimeters above ground level. (Only measured in saplings.)
- Total Height: Total height of the tree or sapling.

Once the total ground biomass per unit of land is determined, the carbon sequestration can be computed using information about the carbon content of the biomass. Since the amount of sequestration differs among various species of mangroves, the carbon content in the biomass per unit of the species encountered has to be separately estimated. This factor is then applied to determine the carbon content of the biomass found in the study.

The calculation method is as follows:

$$BM/Hectare = (a + \beta_1 Ht + \beta_2 DBH) * (1+BGF) * TD$$

Where:

BM/Hectare = Biomass per hectare

BGF = Below ground biomass factor as a share of above ground biomass

TD = Mangrove tree density per hectare

CC = Carbon content per unit of biomass

A number of studies have determined the biomass in various locations in Ghana in recent years using the procedure described. However, most of these studies were done on the West Coast, with only one study being done in the Volta region. Since *R. mangle*, *A. germinas*, and *L. racemose* are the predominant mangrove species found in Ghana, most studies report data on DBH and height for these three species of mangroves separately (Table 5). The DBH data for all three species generally ranged between 2.3–4.1 cm; only one study reported a much higher number (8–11 cm), presumably because of the presence of very old trees in that location. It may therefore be treated as an outlier. Among the three species, on average the *R. mangle* trees were the tallest in height (2.9–5.2 meters) and the *L. racemose* the shortest (2.3–3.8 m) with the height of *A. germinus* (2.7–4.4 m) lying in between.

TABLE 5: AVERAGE DBH AND HEIGHT OF MANGROVES FOUND IN VARIOUS GHANAIAN HABITATS

R. mangle		***A. germinas***		***L. racemosa***		
DBH cm	**Height m**	**DBH cm**	**Height m**	**DBH cm**	**Height m**	**Year**
3.5	4.5	3.2	3.2	2.9	2.9	2018
2.9	4.3	4.1	4.4	3.3	3.8	2018
3	3	1.3	1.7	2.5	2.5	2011
2.8	2.8	3.1	3.1	3	3	2011
2.9	2.9	3	2.7	2.7	2.3	2015
11	8.2	8	5.8	4.1	3.7	2015
3	5.2	2.9	3.1	2.3	2.3	2010

Sources: Dali 2020; Nortey et al. 2016 ; Adotey 2015 ; Aheto et al. 2011.

TABLE 6: AVERAGE CARBON STORAGE (TON PER HECTARE) IN MANGROVES FOUND IN VARIOUS GHANAIAN HABITATS

Above ground Carbon	Below ground Carbon	Soil Carbons	Total	Year	Region
184			184	2011	WC
114	23		137	2012	WC
1467	189		1656	2016	WC
107	48	311	466	2015	WC
3771	1193	352	5316	2015	WC
100			100	2014	Volta
93[3]		3872	3962	2018	WC

Sources: Ajonina 2011; Asante and Jengre 2012; Yevugah 2017; Adotey 2015; Myers 2016; Jonah 2020.

The carbon content found in mangroves per hectare in the chosen study locations showed large variations mainly because of the condition of the plantations (Table 6). All of the studies reported on the above-ground carbon, and a majority of them also reported on the underground carbon stored in roots. However, only three of the studies reported on the carbon trapped in the soil. Inclusion of soil carbon in the estimation for carbon storage in mangroves is important, since unlike normal soil, the decomposition of such carbon is much slower in mangrove plantations; this is because the soil remains submerged most of the time. As a result, the carbon stored in such soil over time can often exceed the carbon stored in the mangrove plants.

The above-ground carbon storage of 93–184 tons per hectare found in these studies mostly represents younger mangroves (less than 10 years old), while the greater amounts of carbon storage were found in areas with pristine, very old mangroves. Assuming an average growth period of 10 years, these data reveal that mangrove plantations can sequester between 9 and 18 tons of carbon per hectare per year, with an average of 14 tons. Additional carbon storage occurs as litter falls from the plants that remain in the soil. A study in two locations in Ghana found the annual carbon addition from litter fall to be around 10 tons per hectare. The estimates indicate an average total annual carbon sequestration from existing mangroves found in a typical mangrove cover in Ghana to be around 24 tons per hectare.

The annual economic value addition from carbon sequestration from each hectare of mangroves in Ghana is monetized using the shadow price of carbon. The social cost of carbon is highly country-specific; current estimates for Ghana suggest a price of $1 per ton.[4] However, as the international trading of such carbon is becoming increasingly feasible, the social cost of carbon in Ghana is based on the price it can command in that market if the carbon reduction is traded. The global weighted average price of carbon has been variously estimated to be around $20 per ton in 2020.[5] This suggests an annual economic value addition of $480 from the 24 tons of carbon sequestered in each hectare of mangroves in Ghana.

In other words:

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

[3] Combined above and below ground biomass
[4] https://www.nature.com/articles/s41558-018-0282-y
[5] https://carboncreditcapital.com/value-of-carbon-market-update-2020/

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

The presence of mangroves along the coasts plays an important role in minimizing the damages from coastal erosion and flooding 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 infrastructure. Mangroves also reduce the movement of debris during extreme events.

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

Studies have found that with each kilometer of mangroves, swell height could be reduced by 5 to 50 centimeters (McIvor et al. 2012). The effectiveness depends on the geomorphological conditions of the sites, the plant species, and the density of the forests. Mangroves on their own cannot completely protect vulnerable communities from flooding caused by storm-induced swells. However, they can work in conjunction with complementary engineering infrastructure. Swell attenuation by mangroves should allow for a lower level of the investment needed in protective engineering infrastructure by allowing embankments of lower height and width to be built, saving a substantial amount in construction costs. In addition, the presence of mangroves in front of the infrastructure can reduce the maintenance cost of the infrastructure.

A separate project to estimate the physical benefits of the decreased coastal erosion, and reduction of flooding that is provided by mangroves at select coastal locations in Ghana is underway at present. However, the actual data from the project will take some time and may not be available by the time this report is finalized. The current estimation will therefore use data extrapolated from studies done elsewhere, making allowances for local characteristics of the Ghanaian coast. These estimates can be updated later with actual data for the Ghanaian coast once these become available.

Valuation of the protective services provided by mangroves can be done in two ways: by the replacement method, and by the avoided damage cost method. If the protective service of the mangrove forests can be replaced by installing breakwaters or any other engineering structure, the cost of installing that engineering structure is treated as the economic value of the erosion protection service of the mangroves. The other way is to calculate the economic damages that might have occurred in the absence of the mangrove forests.

Valuation of the protection provided by mangroves based on avoidance of damage has been estimated in a number of countries around the world. These estimates range between $ 1,120 – 1,369 per hectare (Barbier 2007; Estoque et al. 2018). The lower end of these estimates may be more appropriate for use in benefits estimation in Ghana, given the average income levels of the countries included in the studies.

Biodiversity Benefits

Mangrove ecosystems and their associated wetlands support a wide array of biodiversity in Ghana 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 Ghana depends on the input of organic matter and detritus from the coastal mangroves (Shalovenkov 2000). A great number of seabirds use the mangrove forests for feeding, reproduction, and shelter (Sagno 2005). A number of endangered species also depend on these wetland ecosystems for their survival. The preservation of these mangrove ecosystems through the sustainable use of resources is therefore vital for protecting the biodiversity found in Ghana.

Only a limited share of the area identified as mangrove forests in Ghana falls within designated protected areas. Designating wetlands as protected areas based on the principles laid down under the Ramsar Convention, and implementing them fully is important for preserving the unique character that supports biodiversity around such areas. This would involve following the established rules for preventing unsustainable use of wetlands that puts pressure on the survival of the ecosystem. However, since the designation as a protected area would curb some of the practices currently followed in harvesting 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 Ghana can be determined indirectly by using the Willingness to Pay (WTP) approach. The WTP would be 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 would be a way of determining how much value these communities assign to protecting the biodiversity associated with mangrove areas that would be a proxy of the benefits provided to these areas by preserving biodiversity.

In other words:

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

The WTP approach, based on a survey, was used to determine the biodiversity benefits in two habitats in Ghana, both on the Western coast. One study, conducted in 2004, revealed an average per-hectare valuation of $911 when valued in 2000 PPP$ (Aheto 2011). The other study, completed in 2018, when valued in 2020 PPP$ revealed a valuation of $1,651 per hectare (Jonah 2020). However these values, based on WTP, often underestimate their true value, since all of the relevant information about the benefits that biodiversity can provide may not be available to the survey respondents.

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 (Shimoda et al. 2009) in a mangrove environment. Mangroves are also known for removing harmful materials from wastewater and transforming toxic pollutants to less harmful materials.

The benefits of the water purification service of mangroves in Ghana was estimated using an alternative cost approach found in water purification studies done elsewhere. Essentially, the 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 the water purification services of mangroves is equivalent to $5,820 hectares/year. However, with technological improvements, the cost of such filtering services in treatment plants have come down over the past 30 years; therefore, current values are likely to be much lower.

Another way of valuing the benefits of water purification performed by mangroves is based on the property of removal of salinity from sea water. Mangroves are facultative halophytes and are known for their special ultrafiltration system, which can filter approximately 90 percent of sodium ions from the surrounding seawater through the roots.[6] 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.

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

In other words:

The 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 the desalinization of sea water is around $3 per 1,000 gallons, while that of brackish water is $1.09. The volume of water purified by mangroves per hectare annually was estimated using an average root height of 50 centimeters, and a conservative 6 to 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 from $151 to $504.

Total Benefits from Mangroves

The valuation of benefits derived from mangroves in Ghana clearly reveals that the private-use direct benefits are only a small fraction of the total economic benefits mangroves provide (Table 7). The total private direct benefits are also much smaller than the private indirect benefit from the fisheries sector.

Once the social-use benefit from mangroves is included in the overall benefits, a much stronger case can be made for the preservation and 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 7: TOTAL BENEFITS FROM MANGROVES IN GHANA PER HECTARE IN 2020 PPP$

Annual Total Benefits	Mean Value	Range: Min-Max
Private Direct Use		
Timber	$ 151	$94 – $207
Fuelwood (Domestic and Fish-Smoking	$ 2,422	$621 – $5,568
Total Wood	$ 2,498	$811 – $5,568
Private Indirect Use		
Fisheries	$719	$402 – $940
Hunting	$82	Only one value
Tourism	$46	$45 – $46
Social Use		
Carbon Sequestration	$480	$380 – $500
Flood Protection	$1,120	$1,120 – $1,370
Water Purification	$327	$151 – $504
Social Option and Nonuse		
Biodiversity	$1,281	$911 – $1,651

CHAPTER 4.
ECONOMIC COST ESTIMATIONS OF THE AFFORESTATION PROGRAM

The total cost of mangrove plantation in Ghana will involve an initial one-time 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 to plant mangroves, assuming that the plantations will be done on public land and no land acquisition costs would be incurred.

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

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

The cost of planting will be based on 2 x 2-meter spacing for the plantings. Three data sources for the cost of planting were found in Ghana: one on the West Coast, and the other two in the Volta region. The cost of initial planting in the first year (2013) was found to be $1,760 per hectare after extrapolation to 2020 PPP$ (Aheto et al 2016). The second cost, from 2018, was found to be $3,825 per hectare after extrapolation to 2020 PPP$ (Denis Aheto (Personal communication) March 14, 2020). A recent cost estimate of $2,000 per hectare was also reported for the Songar Ramsar site.[7] To ensure that the plants are protected and continue to grow, annual maintenance costs, mostly in terms of labor costs, was found to be $72 per hectare in 2020 PPP$.

[7] C. Gordon, personal communication, November 4, 2021

The NPV from each hectare of new plantation is estimated using the following formula over a 20 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 a ratio of NPV of benefits and the cost based on these values

Assuming that the annual benefits start accruing ten years after planting, over a 20 year period, the private direct benefits show a positive NPV per hectare of $15,860, with a BCR of 5.7. Using the minimum and maximum values the NPV per hectare ranges between $4,831 and $35,931, with a BCR between 1.7 and 12.9. With inclusion of private indirect benefits from fisheries, the NPV per hectare increases to $21,398, with a BCR of 7.7. Once the social use values are factored in, the NPV increases to $33,996 with a BCR of 12.2. These reveal the large benefits that can occur with investment in planting mangroves in Ghana.

CHAPTER 5.
CONCLUSION

The findings from this study can help formulate policies that will enhance social welfare through not only preserving the existing mangrove areas, but also developing new mangroves in lands that are now barren but are suitable for growing mangroves. Preserving the current mangrove areas will be welfare-enhancing, since the sum of benefits from private indirect use, social use, and social option/nonuse that mangroves provide far outweighs the private direct-use benefits. This suggests that policies that provide incentives and disincentives to discourage the unsustainable exploitation of mangroves would lead to net social benefits. These incentives and disincentives can take many forms, from the use of regulations to ban the unsustainable cutting of mangroves to economic interventions like imposing taxes on mangrove products, or providing subsidies to encourage the use of substitutes for them.

Mangroves in Ghana provide many monetary benefits; even the direct private benefits clearly outweigh the costs of creating and maintaining them in most areas that are now barren but suitable for mangroves. In areas that have been cleared of mangroves for alternative uses like salt production or urban use, where mangrove restoration may not be feasible , the benefits from planting new mangroves can often be comparable to the benefits from the other uses once we monetize the private indirect and social use benefits. Identifying the locations that will provide the best prospects for the biggest return on investment calls for a detailed analysis of the benefits to be gained from investing in mangroves, using the methodology proposed for each type of benefit. However, an accurate, region-specific analysis of the net benefits in each area will require the collection of data specific to each region in Ghana, since the types of mangroves, and their spread, often differ across regions.

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