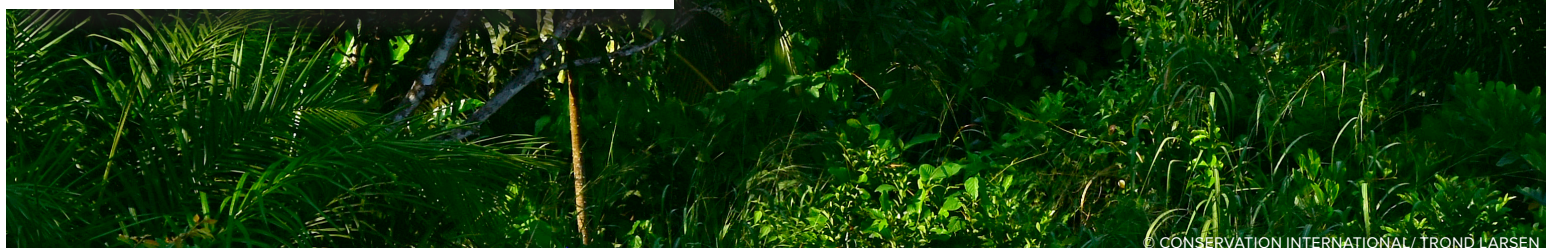




ECOSYSTEM ACCOUNTS FOR COASTAL AREAS OF LIBERIA:

Technical Brief



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TABLE OF CONTENTS

Key Results	1
1. Introduction	2
1.1. Background	2
1.2. The System of Environmental-Economic Accounts (SEEA)	2
1.2.1. The SEEA Ecosystem Accounting (SEEA EA)	3
2. Implementing SEEA EA in Liberia	4
2.1. Ecosystem Extent Account	4
2.2. Ecosystem Condition Account	6
2.3. Ecosystem Services Flow Account	7
2.3.1. Crop Provisioning Services	7
2.3.2. Wood Provisioning Services (Firewood)	8
2.3.3. Wild Fish Biomass Provisioning Services (Marine Fisheries)	9
2.3.4. Coastal Protection Services	10
2.3.5. Global Climate Regulation Services	11
2.4. Thematic Account	12
3. Applications in Policy and Decision-making	13
3.1. Using SEEA EA Indicators	14
References	15



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KEY RESULTS

- Since 2000, Liberia lost its **26%** mangrove areas, as a result of expansion of built-up areas and conversion to other land use.
- In recent years, the *number of ecosystem patches of ecosystems* is **increasing** while *their average size* **decreasing** – an indication that deforestation is accelerating.
- In 2017, *the estimated value of crop production* in coastal areas is **USD \$80 million** from 150 thousand ha areas.
- In 2020, *total fisheries production* was about 15,000 metric tons, earning **>USD \$20 million** revenue; aquaculture is insignificant.
- In 2008, *total firewood supply* was 0.5 million m³/year equivalent to **USD \$4 million** market price.
- **Mangroves** provide significant coastal protection – worth **USD \$95 million** of physical capital alone in 2018 estimates.
- In the past two decades, more than **3 million Mg CO₂e emissions** resulted from mangrove conversion alone.

INTRODUCTION

1.1 BACKGROUND

In February of 2020, the Liberia Environmental Protection Agency, in partnership with many governmental agencies, and with support from Conservation International, started implementing the GEF-funding project *Conservation and sustainable use of Liberia's coastal natural capital* (the GEF-NCA project). The project objective is to improve conservation and sustainable use of Liberia's coastal natural capital by mainstreaming the value of nature into Liberia's development trajectory. A core part of this project is the implementation of System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting (EA) to demonstrate the value that coastal ecosystems deliver to societal benefits and economic development in Liberia, and ultimately to further momentum for adoption of environmental economic accounting in the country.

This technical brief provides a synthesis of key outputs from measurements and modeling of accounts associated with SEEA EA, as implemented by the GEF NCA project. These include: i. ecosystem extent account; ii. ecosystem condition account; iii. ecosystem services flows account and thematic account (biodiversity). Note that the underlying analysis required for the accounts are derived from currently available data and measurements, and thus these preliminary results are subject to change in future iterations with improved data and modeling capability.

1.2 THE SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTS (SEEA)

The United Nations' [System of Environmental-Economic Accounts \(SEEA\)](#) is an internationally accepted framework for incorporating nature into national accounting systems. SEEA includes the [Central Framework \(CF\)](#) and [Ecosystem Accounting \(EA\)](#). The CF focuses primarily on the environmental flows (i.e., provision of nature's goods to the economy, their uses within the economy and return to the environment), stocks of environmental assets (e.g., water, energy, etc.), economic activity related to the environment (e.g., spending on environmental protection and resource management). The SEEA EA expands SEEA's CF measurements to assess ecosystems assets, tracking their changes over time, as well as ecosystem provisions of numerous benefits, including regulating and cultural functions of ecosystems, other flows of benefits to the economy often overlooked. Ecosystem accounting involves more comprehensive spatial identification and mapping, resulting in a more holistic picture of ecosystems and the benefits they provide to various parts of an economy.



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1.2.1 The SEEA Ecosystem Accounting (SEEA EA)

The SEEA Ecosystem Accounting (SEEA EA), adopted as the international statistical standard for accounting for ecosystem and their benefits in 2021, is composed of five core accounts with spatially-explicit information on [ecosystem assets](#) and the [services](#) they produce as follows:

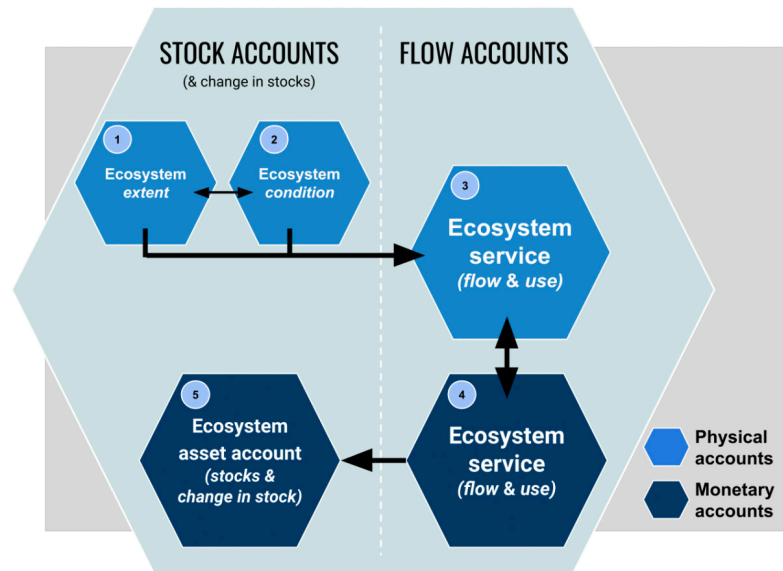


Figure 1. Sequence of the full set of ecosystem accounts (Source: United Nations et al. (2021)).

- **Ecosystem Extent Account** summarizes information on the extent of different ecosystem types within an ecosystem accounting area and its change over an accounting period. This provides the basis for measurements of stocks and changes and provision of important services.
- **Ecosystem Condition Account** synthesizes information on the condition of ecosystem assets and their change over time relative to a baseline, (e.g., pollution), providing valuable insights into the health (or degradation) of ecosystems.
- **Ecosystem Services Flow Account** records ecosystem services flows (physical and monetary) as contributions from ecosystem assets that benefit humans and the economy. The measurement of ecosystem services (e.g., coastal protection) can support the assessment of the costs and benefits of interventions and coastal and marine areas, helping the design of conservation and adaptive management plans.
- **Monetary Asset Account** records information on stocks and changes in stocks of ecosystem assets in monetary terms, with consideration of degradation/enhancement.
- **Thematic Account** serves as a complementary account to those described above and is designed for specific policy-relevant environmental interests, e.g., biodiversity, climate change, oceans, urban areas.

IMPLEMENTING SEEA EA IN LIBERIA

2.1 ECOSYSTEM EXTENT ACCOUNT

The SEEA Ecosystem Extent Account represents a starting point for ecosystem accounting by providing information about the area, composition of, and changes in, ecosystem assets within an ecosystem accounting area (EAA).

Ecosystem Extent Account consists of two complementary tables that record extent of ecosystem assets, and their change over time, measured in units of area (e.g., km²). The two tables record the following information: 1) the areas and changes in areas of ecosystem assets (collectively referred to as ecosystem conversions), and 2) the area of transition between ecosystem types (also referred to as ecosystem type change matrix) that occurred between two or more measuring periods (e.g., between 2020 and 2021).

In order to compile Ecosystem Extent Account in Liberia, we generated ecosystem extent maps following the methodology developed by Conservation International in a partnership with NASA (NASA, 2018). Broadly, the methodology for mapping the ecosystem extent consisted of the following steps: 1) generate a base land cover map from remote sensing and other auxiliary data (de Sousa et al. 2020); 2) produce an annual time series of land cover maps for 2000-2021 using the LandTrendr methodology (de Sousa et al., 2022); 3) model terrestrial plant biotic dissimilarity using plant data and environmental variables (Honzák et al., in draft); 4) combine the land cover and the plant biotic dissimilarity maps to produce an annual time series of ecosystem extent maps for 2000-2021. As an example, Figure 2 depicts two ecosystem extent maps produced at the national scale.

Using the annual time series of the ecosystem extent maps we compiled the two ecosystem extent tables. An example of preliminary results showing ecosystem conversions in 5-year increments is in Table 1. Figure 3 shows a summary graph of transitions of mangrove ecosystems that occurred between 2000 and 2018. As an example, the results show that between 2000 and 2018, Liberia lost about 20% of its mangrove ecosystems. Height proportion of transitions that occurred in mangrove ecosystems could be attributed to conversion of mangroves to barren land and forest-agriculture mosaic by humans.

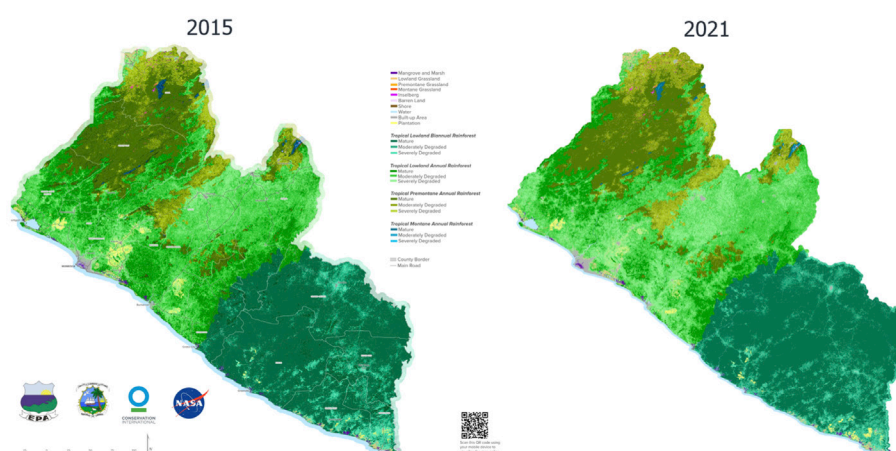


Figure 2. Ecosystem extent maps produced at the national scale for years 2015 and 2021. The maps show 22 classes of terrestrial ecosystems that were identified in Liberia to match the International Union for Conservation of Nature (IUCN) Ecosystem Typology classification scheme (Keith et al., 2020).

ECOSYSTEM CLASS		2000/2005	2005/2010	2010/2015	2015/2018
River and Lake	Opening Stock	3788	3818	2833	2444
	Addition to stock	30	0	0	11
	Reduction to stock	0	985	389	0
	Closing Stock	3818	2833	2444	2455
Mangrove and Marsh	Opening Stock	27443	27480	26328	24192
	Addition to stock	37	0	0	0
	Reduction to stock	0	1152	2136	2272
	Closing Stock	27480	26328	24192	21920
Built-up Area	Opening Stock	14021	15983	19148	24431
	Addition to stock	1962	3165	5283	4055
	Reduction to stock	0	0	0	0
	Closing Stock	15983	19148	24431	28486
Barren Land	Opening Stock	9515	8778	11415	11655
	Addition to stock	0	2637	240	5815
	Reduction to stock	737	0	0	0
	Closing Stock	8778	11415	11655	17470
Shore	Opening Stock	1183	1191	1201	1202
	Addition to stock	8	10	1	3
	Reduction to stock	0	0	0	0
	Closing Stock	1191	1201	1202	1205
Plantation	Opening Stock	30979	33085	34765	33945
	Addition to stock	2106	1680	0	0
	Reduction to stock	0	0	820	10200
	Closing Stock	33085	34765	33945	23745
Grassland	Opening Stock	74521	71360	65969	47404
	Addition to stock	0	0	0	0
	Reduction to stock	3161	5391	18565	2978
	Closing Stock	71360	65969	47404	44426
Mature Tropical Lowland Annual Rainforest	Opening Stock	264638	270350	229066	160746
	Addition to stock	5712	0	0	0
	Reduction to stock	0	41284	68320	44041
	Closing Stock	270350	229066	160746	116705
Mature Tropical Lowland Biannual Rainforest	Opening Stock	514878	514548	489378	433486
	Addition to stock	0	0	0	0
	Reduction to stock	330	25170	55892	83636
	Closing Stock	514548	489378	433486	349850
Degraded Mature Tropical Lowland Annual Rainforest	Opening Stock	280915	319527	385158	430329
	Addition to stock	38612	65631	45171	0
	Reduction to stock	0	0	0	14668
	Closing Stock	319527	385158	430329	415661
Degraded Mature Tropical Lowland Biannual Rainforest	Opening Stock	135082	169119	204791	233823
	Addition to stock	34037	35672	29032	34449
	Reduction to stock	0	0	0	0
	Closing Stock	169119	204791	233823	268272
Forest-agriculture Mosaic	Opening Stock	357542	279503	246051	313460
	Addition to stock	0	0	67409	113780
	Reduction to stock	78039	33452	0	0
	Closing Stock	279503	246051	313460	427240
Estuary and Lagoon	Opening Stock	27743	27436	26025	24885
	Addition to stock	0	0	0	0
	Reduction to stock	307	1411	1140	267
	Closing Stock	27436	26025	24885	24618
Sea	Opening Stock	242403	242474	242524	242650
	Addition to stock	71	50	126	0
	Reduction to stock	0	0	0	47
	Closing Stock	242474	242524	242650	242603

Table 1. Preliminary Ecosystem Extent Account (ha) for the coastal zone of Liberia developed from the annual time series of ecosystem extent maps.

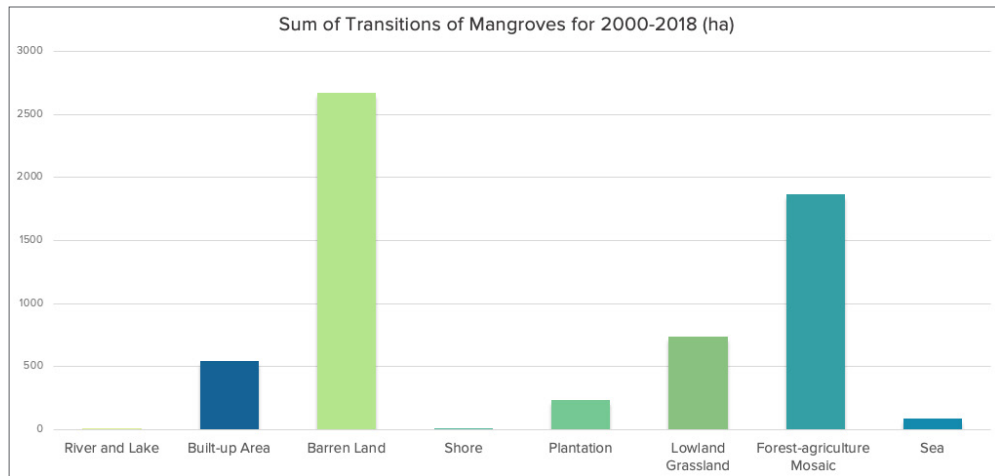


Figure 3. Sum of transitions of mangrove ecosystems that occurred between 2000 and 2018. Height proportion of transitions can be attributed to conversion of mangroves to barren land and forest-agriculture mosaic by humans.

2.2 ECOSYSTEM CONDITION ACCOUNT

The SEEA EA Ecosystem Condition Account uses indicators and indices to measure the ecological integrity of ecosystem and their ability to deliver ecosystem services. Condition indicators include biotic, abiotic, as well as landscape attributes meant to represent a comprehensive set of relevant criteria to determine the overall ecosystem health relative to a reference condition, allowing for changes in ecosystem condition to be tracked over time.

Our initial efforts to generate condition indicators involved an analysis of forest fragmentation using the annual time series of the ecosystem extent maps described in the previous section (de Sousa et al., 2022). We developed two metrics of fragmentation: 1) number of forest fragments, and 2) size of forest fragments. Figure 4 shows change in those two metrics relative to the baseline (2000). Results show that starting approximately in 2015, not only was there an exponential increase in the number of patches, but the average size of such patches decreased exponentially. This is an indication that conversion/deforestation of the remaining mature forest has been accelerating in recent years.

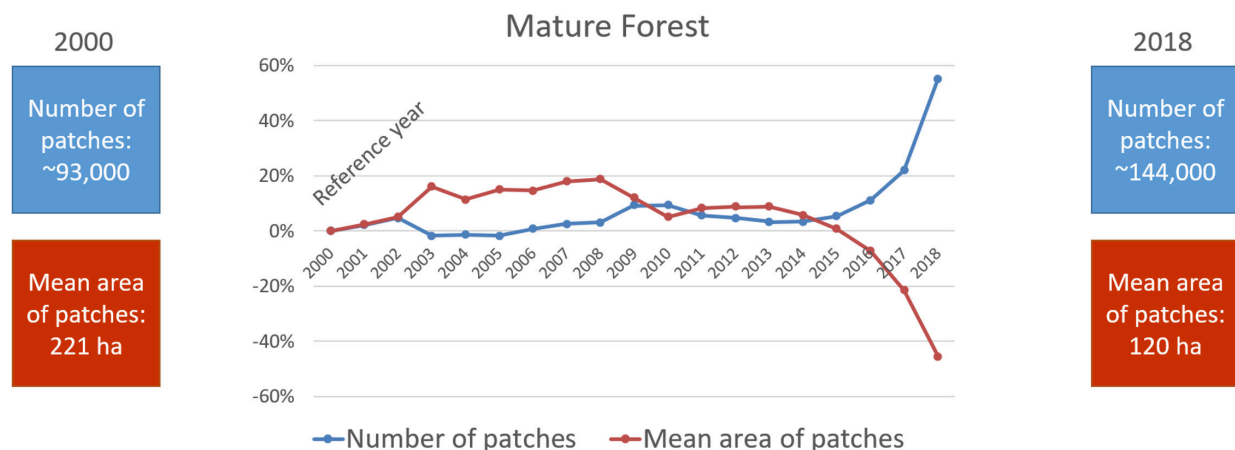


Figure 4. The graph shows a trend in fragmentation of mature forest in Liberia between 2000-2018 using two metrics: 1) number of forest fragments, and 2) size of forest fragments. The metrics are displayed as relative values to the reference year 2000 which was set to zero value.

2.3 ECOSYSTEM SERVICES FLOW ACCOUNT

Ecosystem services flow account constitutes a central part in ecosystem accounting, connecting ecosystem assets with beneficiaries/end users. The primary purpose of this account is to measure the role of ecosystems in producing a flow of benefits through ecological production functions and to record the contributions to people and economy. We selected 6 ecosystem services based on their significance, data availability and modeling feasibility. Here we provide preliminary results of 5 services, noting that these preliminary results are subject to change in next iteration with improved data availability.

2.3.1 Crop Provisioning Services

Accounting for crop provisioning services account required the i. identification of locations and spatial distribution of major crop production areas within coastal ecosystems; ii. the measurement of the total production; and iii. the estimate of the monetary value associated with such benefit. In order to do that, we extracted data from Spatial Production Allocation Model (SPAM) developed by International Food Policy Research Institute (IFPRI) and other organizations (www.mapspam.info). Among other inputs, the SPAM model uses crop production statistics, administrative boundaries and landcover data and combined them in a “cross-entropy” methodological approach outlined in You et al. (2014). The results in Figure 5 show that about an area estimated at 146 thousand hectares is under cultivation within the coastal boundary (red demarcated area on the maps). The production of 8 major crops (cassava, rice, sugarcane, oil palm, banana, vegetables, cocoa, coffee) amounts to 0.5 million metric tons per year and worth USD \$80 million in market value (2017 estimates). The analysis is based on global models; therefore, availability of local geospatial data and production estimates will greatly enhance the accuracy of these estimates.

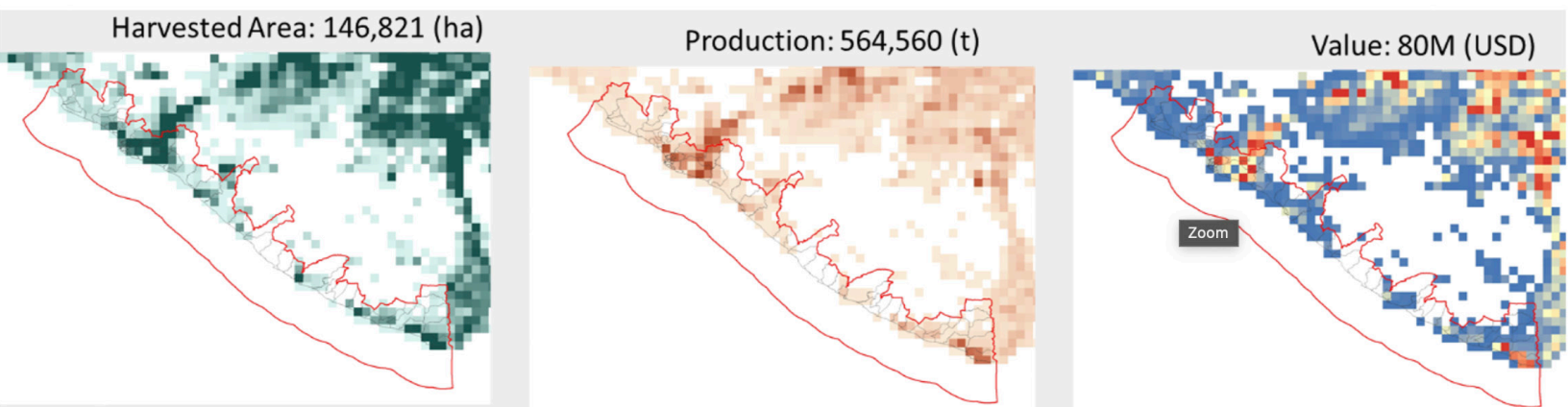


Figure 5. Distribution of harvested area, production, and monetary value of 8 major crops grown in coastal areas of Liberia.



2.3.2 Wood Provisioning Services (Firewood)

Analysis of wood provisioning services focused on firewood use by local communities and their supply from coastal ecosystems. We first calculated total demand of firewood based on spatial distribution of communities from Liberia 2008 Population Census. We then developed a spatial allocation model to distribute this demand to surrounding ecosystems based on criteria such as proximity of communities and presence of eligible ecosystem types using spatial data from the extent account. We also developed kernel density maps to identify hotspots of firewood demand and to examine correlation between deforestation/degradation and firewood collection (Figure 5).

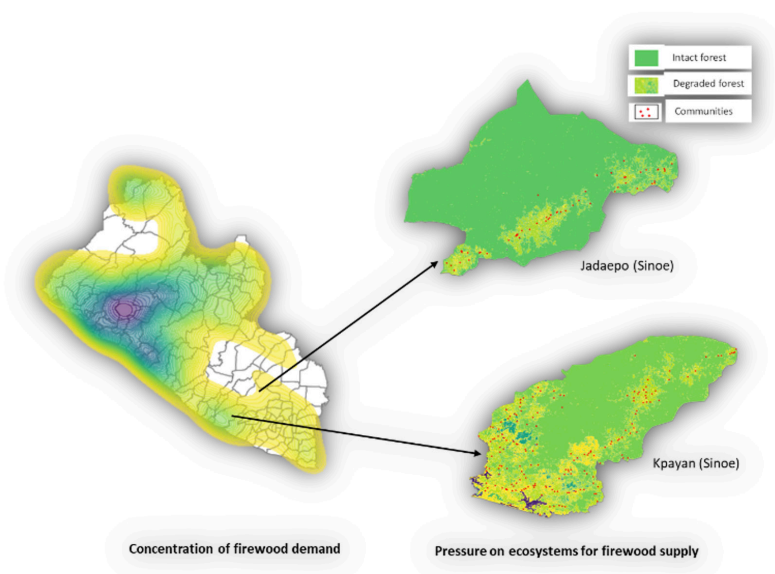


Figure 6. Kernel density of firewood demand hotspots (left) and corresponding pressure on nearby ecosystems prevalent in Jadepe and Kpyan districts (right).

In this analysis we estimated that total firewood demand in the coastal zone of Liberia is about 0.5 million m³ per year. The total monetary value of firewood supply by ecosystems is worth more than USD \$4 million per year (Table 2). This estimate is based on 2008 population census data, and is also a conservative estimate since mangrove's wood contribution to smoking fish was not accounted for due to the lack of data. Not surprisingly, much of the firewood demand is met by degraded forests and forest-agriculture mosaics. In fact, firewood may be, among other factors, a major driver of this degradation, and we observe a strong correlation between communities' locations and forest degradation in many places (Figure 6, right).

Physical/ monetary supply	Unit	Ecosystem type											Total
		Water Body	Mangrove / Wetland	Built-up Area	Barren Land	Inselberg	Shore	Plantation	Grassland	Mature Tropical Lowland Rainforest	Degraded Tropical Lowland Rainforest	Forest-Agriculture Mosaic	
Physical	m ³ /year	-	-	-	-	-	-	-	150,638	5,989	103,151	186,595	446,374
Monetary	USD/year	-	-	-	-	-	-	-	1,355,746	53,903	928,357	1,679,357	4,017,362

Table 2. Physical supply (m³/year) and monetary value (USD/year) of firewood supply by coastal ecosystems.

2.3.3 Wild Fish Biomass Provisioning Services (Marine Fisheries)

The fisheries sector in Liberia makes a large contribution to GDP, going up to 10% in some years, alongside its contribution to food and nutritional security and the livelihoods of hundreds of thousands of people living on the coast and further inland. However, a systematic and consistent approach to measurements and accounting of fisheries resources is lacking. The fisheries flow accounts developed in this project aim to fill that gap by generating information, statistics and indicators using most recent data obtained through a number of sources, primarily, Global Fishing Watch (www.globalfishingwatch.org) (Kroodsma et al 2018) and National Fisheries and Aquaculture Authority (NaFAA).

The daily fishing efforts (number of hours/day) by all fishing vessels combined is presented in Figure 7. The data shows that total fishing efforts have been relatively low up until mid-2019 with a daily average of around 30 hours (by all vessels combined), and since then it's been steadily increasing, fluctuating around 80-100 hours/day. A clear seasonal pattern can also be identified in this time series, especially over the last 3 years.

Table 3 below synthesizes annual catch and their monetary values for the last 5 years. In 2016, total catch was only 250 metric tons, increasing by a factor of 20 in 2020. The market value of industrial fishing efforts in 2020 and 2021 was around US \$7 million. Note that, in all likelihood, these estimates will vary depending on how the catch per unit efforts (CPUE) is calculated and the market price used – an important area of future research for increasing precisions in estimates.

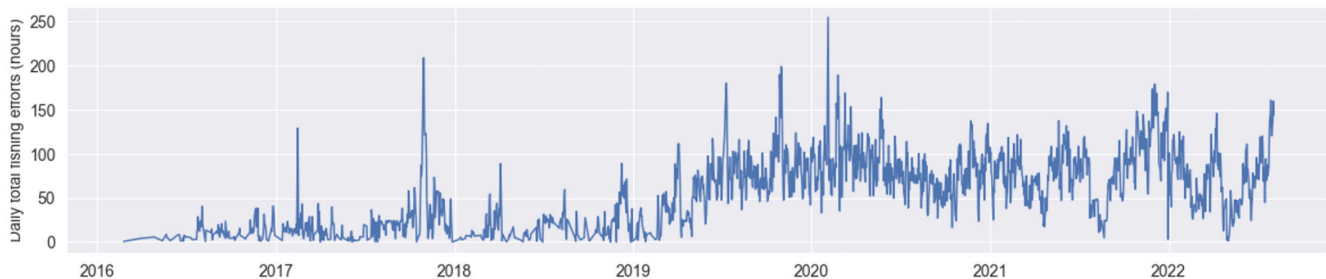


Figure 7. Industrial fishing efforts off the coast of Liberia (2016-2022).

	2016	2017	2018	2019	2020	2021
Catch (10 ³ kg)	249	1215	774	3981	5377	5234
Value (USD)	323661	1579972	1006677	5175442	6990293	6804850

Table 3. Annual industrial catch and monetary value (USD) between 2016-2021.



MANGROVES PROVIDE US \$95 MILLION/YEAR IN COASTAL PROTECTION SERVICES

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2.3.4 Coastal Protection Services

A significant proportion of Liberia's population live in coastal districts, making them vulnerable to storm surge, flooding and coastal erosion. We developed ecosystem services flows account for coastal protection services to measure/track how different ecosystem types in the coastal zones contribute to mitigating coastal vulnerability – saving livelihoods and valuable coastal infrastructure. We implemented InVEST coastal protection model (Tallis and Polasky 2011) to measure coastal vulnerability and exposure by running the model both with and without ecosystems (mangroves in this case). We then attributed the difference to the ecosystems as their service. We also developed an opportunity cost of land based on the value of physical capital present in the vulnerable areas using data from Changing Wealth of Nations (World Bank, 2021). By combining the biophysical data with opportunity cost we find that the total monetary value of coastal protection (physical capital) by mangrove ecosystem is worth USD \$95 million/year (2018 estimates).

The analysis is based on coarse global input datasets; therefore, improved resolutions will also improve estimated coastal protection value. Other potential improvements include incorporating more ecosystem types besides mangroves, using distance gradient of exposure instead of uniform values, and by incorporating forgone benefits of losses from crop production etc.



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2.3.5 Global Climate Regulation Services

Ecosystem accounting of climate regulation services focuses primarily on the role of ecosystems in mitigating climate change through their ability to remove carbon from the atmosphere and to store carbon. This complements measurements of the emission of greenhouse gases (GHG) because of economic and human activity and the associated changes in concentration of these gases in the atmosphere.

In our initial analysis we utilized the time series of annual ecosystem extent maps for 2000-2021 (see section above on ecosystem extent) and globally available measurements of carbon stocks (e.g., Noon et al., 2022), to estimate carbon stocks and their change over time for 22 terrestrial ecosystems. As an example, Figure 8 shows the change in the area and carbon stocks of mangrove ecosystems in Liberia. The results show that between 2000 and 2021 Liberia lost 26% of its mangrove ecosystems through conversion to other land uses. The carbon stock in mangrove ecosystems also declined from 12 to 8.9 Mt C in the same period. However, in recent years starting around 2015, we can observe a slight slowdown in the loss of mangrove ecosystems in Liberia.

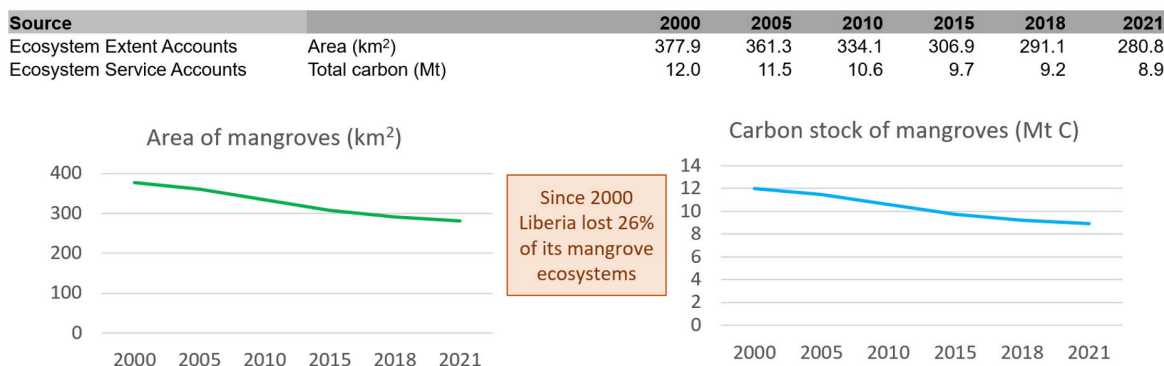


Figure 8. The area and carbon stocks of mangrove ecosystems between 2000 and 2021. Starting around 2015, we can observe a slight slowdown in the loss of mangrove ecosystems in Liberia.



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2.4 THEMATIC ACCOUNT (BIODIVERSITY)

While core ecosystem accounts provide information to describe the relationships between ecosystems, economic activity and human well-being, the thematic biodiversity account seeks to mainstream the use of data on biodiversity into decision-making for conservation, enhancement of biodiversity and continued provision of ecosystem services. Some of the data from the ecosystem extent, condition and services accounts can also provide input into the biodiversity accounts. The primary type of biodiversity account we plan on developing in Liberia is species accounts, which report opening and closing values for species or groups of species based on their conservation status, stocks (abundance or presence) or distribution. Another type of biodiversity account we propose to develop are analyses of changes in the extent and condition of ecosystems across the distributional range of priority threatened species, which serve as habitat-based proxies for the status of those species.

Upcoming fieldwork will assess birds, mammals, reptiles, amphibians, fishes, mollusks, crustaceans and plants. We will also conduct aquatic eDNA sampling to identify the presence of vertebrate species which may not be detected with traditional methods. Multiple species accounts will be developed based on these surveys, which will include accounts for mangrove species and possibly sea turtles (existing monitoring projects in Liberia can provide sea turtle data). For some taxa, such as birds, we will analyze changes in species richness and relative abundance as a single species group, rather than developing accounts for each individual species.

APPLICATIONS IN POLICY & DECISION-MAKING

The coherent, integrated and organized accounting approach enables measurement and better understanding natural resources, with consideration of the connection among ecosystems, economy and biodiversity. SEEA EA-derived statistics (e.g., changes in ecosystems area, their condition and related ability to provide ecosystem services), combined with other socio-economic data can help to identify more sustainable, cross-sectoral economic policy and planning.

Generation of ecosystem accounts, following standardized SEEA EA approaches and repeatedly in a regular time interval, is an important outcome in and of itself towards transforming Liberia's statistical systems, but EA can benefit Liberia's environmental policy and decision-making in numerous other ways, including:

- **Planning and measurement of nature-based indicators**, including measurements and trends in ecosystems extent and health, as well as of provision of ecosystem services and their benefits to livelihoods and economies (e.g., global climate regulation, coastal protection, flood regulation, crop production). For example, the information on the SEEA Ecosystem extent and condition accounts, respectively on extent of the losses of mangroves over the last two decades, and their deteriorated condition – as measured by fragmentation indicators are critically important to support policies to curb drivers of deforestation and for the pressing need for mechanisms/interventions for their conservation.
- **Integrated identification/assessment/delivery of nature-based solutions (NBS)**, including Identification of cost-effective, more sustainable interventions (e.g., for climate mitigation and adaptation, agriculture, fisheries, infrastructure, etc.), as well as resource mobilization/investments with consideration of biodiversity and ecosystem added benefits. For example, indicators derived from the coastal accounting in Liberia (i.e., extent, condition, and ecosystem services) can be used with other information (e.g., cost of restoration) to determine the siting and viability of restoring mangrove ecosystems, thereby supporting blue carbon interventions that consider biodiversity and provision of other important mangrove benefits (e.g., water purification, fisheries, etc.), in addition to climate mitigation and adaptation.
- **Monitoring and reporting of policies**, including indicators in support of development plans, state of the environment report, Multilateral Environmental Agreements (NDCs, SGDs, CBD post-2020 GBF, etc.). For example, information derived from the SEEA Ecosystem Extent Accounts in Liberia has already been used as input to updating country's Nationally Determined Contribution (NDC) to the Paris Agreement, which sets Liberia's commitment to reducing its greenhouse gas emissions. The maps helped with the measurement of sectoral contributions of CO2 emissions (e.g., coastal, forestry, agriculture sectors) thus providing statistical information in design, planning, and monitoring of NDC targets, activities, and indicators.

The GEF-NCA project team is committed to engage with stakeholders in the coming months to i. improve results of the set of accounts currently implemented; ii. identify other accounts for further development; iii. discuss priority policies that could benefit from accounting-generated data; and iv. identify a set of feasible post-accounting analytical work based on agreed priority policies.



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3.1 USING SEEA EA INDICATORS: THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK OF THE CONVENTION OF BIOLOGICAL DIVERSITY (CBD)

The upcoming fifteenth meeting of the Conference of the Parties to the CBD is expected to adopt a post-2020 global biodiversity framework (GBF), an important monitoring tool towards the 2050 Vision of “Living in harmony with nature”. SEEA is being proposed as one of the methodological approaches for various headline indicators in the [provisional monitoring framework](#) for measurable goals and targets.

The headline indicators for goals and targets currently proposed focus on measurement of ecosystem extent (Goal A), as well as the flow of ecosystem services from such ecosystems (Goal B).

As demonstrated in this report, the SEEA EA indicators generated for coastal accounting in Liberia can help to track progress toward achieving the 2050 Vision. For example, for [Goal B. Target 10](#). *Ensure all areas under agriculture, aquaculture and forestry are managed sustainably, in particular through the conservation and sustainable use of biodiversity, increasing the productivity and resilience of these production systems*, SEEA EA accounts can inform:

1. measurement of state and trends in extent (in km²) and condition of food provisioning ecosystems (crops, pasture, water ponds, marine ecosystems, etc.)
2. measurement of flows of ecosystem services that provide food security and nutrition including crop provisioning, fisheries, firewood, etc. can be measured in biophysical or cultivated biomass (e.g., tonnes of m³/yr) and associated monetary value (USD/yr).

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