



Forest Cover and Land Use Analysis

Technical Annex C

Final Report

Consulting Services Contract For the Development of A National REDD+ Strategy for Liberia

November 2016

Technical Annex A – Draft REDD+ Strategy

Technical Annex B – REDD+ Roadmap

Technical Annex C – Forest cover and land use analysis

Technical Annex D – REDD+ Strategy Options

Technical Annex E – Cost-benefit analysis

Technical Annex F – Policy, Legal and Institutional Framework

Technical Annex G – Consultation Report

This Technical Annex is part of a set of reports produced by LTS & NIRAS as part of the 'Consulting Services Contract For the Development of A National REDD+ Strategy for Liberia' commissioned by the Forestry Development Authority as part of its Readiness Preparation Proposal (R-PP) Implementation Grant from the Forest Carbon Partnership Facility.

The complete set of reports can be found here:

<http://www.ltsi.co.uk/projects/liberia-national-redd-strategy-consultation/>



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Executive Summary

A detailed analysis of the area and quality of forest that is to be found in land allocated to particular land uses was conducted. This was done to inform the development of a national REDD+ strategy for Liberia, in accordance with Forest Carbon Partnership Facility guidelines.

Up-to-date Land and forest cover data was obtained from the 2015 Metria & GeoVille land cover assessment commissioned by the FDA. Spatial data on land use in Liberia is largely limited to Government of Liberia concessions for forestry, agriculture and mining. Also available are data on the land area that the Government has designated for conservation, as Protected Areas. The land uses included in the analysis are:

- Forestry concession; Forest Management Contracts (FMCs), Timber Sales Contracts (TSCs) and Community Forest Management Agreements (CFMAs)
- Agricultural concessions, including oil palm plantations and rubber plantation concessions
- Mining, including large scale mineral development concessions and small-scale "artisanal" mining.
- Protected areas, where forest is to be used primarily or exclusively for biodiversity conservation
- A variety of smallholder, subsistence uses of land at community level, including shifting agriculture, chainsaw logging ("pit sawing") and charcoal production.

Approximately 50% of the forest land in Liberia is allocated for commercial concessions or is designated for conservation as Protected Area. Most of the concession land is yet to be developed and most of the Protected Areas are yet to be established, so the available land uses data is more of an indication of planned land use changes than a measure of current land use.

Community land uses, of which there are many types, affect the largest area of forest land. They are the principal land uses in the forest land that is not designated for commercial or conservation purposes. They also extend over the concession areas and proposed Protected Areas. The limited information available indicates that shifting agriculture, pit sawing and charcoal production are all significant drivers of deforestation and forest degradation:

- The area of forest land affected by shifting cultivation is estimated at over 30% of the >80% canopy cover forest and almost 70% of the 30-80% canopy cover forest.

- The pit sawing industry is estimated as affecting an area at least as large as the total area that is subject to logging concessions (25% of total forest).
- Charcoal production is estimated to affect at least a similar area of forest as pit sawing.

Forestry concessions are the largest "official" category of land use by area. If all existing and proposed concessions were exploited this would affect approximately 25% of the total forest area. FMCs account for 29% of the most dense forest (>80% canopy cover). Furthermore, the scale and positioning of FMCs, often between Protected Areas or Proposed Protected Areas and covering large blocks of high canopy cover forest, suggests that they have a vital role to play in the conservation of forest carbon stocks.

Palm oil is the largest of the industrial agriculture land uses, based on the maximum area that is permitted for development by concession agreements. It accounts for approximately 5% of the total forest area. The remaining land uses, in order of potential forest area affected, are Timber Sales Contracts (3% of total forest), Community Forestry Management Agreements (2%), Mining (2%) and then rubber and other plantations (1%).

The study enables a distinction to be made between those land uses that pose a short-term threat to forests, and those that have a longer-term impact. The major palm oil concession holding companies aim to clear land and establish plantations within the next 10-15 years. TSCs, although a relatively small area, allow forest to be completely cleared. Pit sawing and charcoal production are also immediate priorities for the REDD+ Strategy because they already have a significant impact and can be quickly scaled-up. They require relatively little capital investment and the activity is effectively un-regulated.

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Acronyms

ASM	Artisanal and Small-scale Mining
CFMA	Community Forestry Management Agreement
CI	Conservation International
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EPO	Equatorial Palm Oil
ESA	European Space Agency
ESIA	Environmental and Social Impact Assessment
FDA	Forestry Development Authority
FFI	Fauna and Flora International
FMC	Forest Management Contracts
GDEM	Global Digital Elevation Models
GFW	Global Forest Watch
GVL	Golden Veroleum
HCV	High Conservation Value
HCS	High Carbon Stock
LULC	Land Use / Land Cover
MDA	Mineral Development Agreement
MEL	Mineral Exploration Licenses
MOPP	Maryland Oil Palm Plantations
OSM	Open Street Map
PA	Protected Area
PUP	Private Use Permits
REDD+	Reducing Emission from Deforestation and Forest Degradation (with sustainable management of forests, conservation of forest carbon stocks and enhancement of forest carbon stocks)
R-PP	Readiness Preparation Proposal
RSPO	Roundtable on Sustainable Palm Oil
SESA	Strategic Environmental and Social Assessment
SRTM	Shuttle Radar Topography Mission
TSC	Timber Sale Contract

UN	United Nations
UNHIC	United Nations Humanitarian Information Centre
USAID	United States Agency for International Development
USGS	United States Geological Survey
WDPA	World Database on Protected Areas

1. Introduction

1.1 Purpose

The purpose of this study is to help identify and prioritize interventions for reducing emissions from deforestation and forest degradation (REDD+)¹ in Liberia, by analyzing land cover and land use suitability. The analysis uses land cover maps and modelling work to categorize and identify land use areas, based on the most up to date data available for 2016. In particular the study aims to clarify:

- a) Where the highest value (carbon and biodiversity) forest is;
- b) How it relates to existing land use patterns;
- c) What future land uses are likely to be and where will they be located.

1.2 Method

1.2.1 Data

Data were collected from numerous sources, with the majority obtained from the Forestry Development Authority (FDA). The preparation of these data included re-projecting all the data layers to standardize them for use in geospatial analysis, as well as completing and extrapolating any missing datasets or information, where possible. The projection used for all layers was standardized to the following:

WGS_1984_UTM_Zone_29N
Projection: Transverse Mercator
False Easting: 500000.000000
False Northing: 0.000000
Central Meridian: -9.000000Line
Scale Factor: 0.999600
Latitude of Origin: 0.000000
Linear Unit: Meter (1.000000)
Name: GCS_WGS_1984

¹ The '+' signifies "with sustainable management of forests, conservation of forest carbon stocks and enhancement of forest carbon stocks".

A number of new data layers were created by processing existing sets of data. For example, buffer zones around mining sites were created by extending out from selected layers.

Digital Elevation Model (DEM). A DEM was created by downloading and mosaicking 18 tiles of 1 Arc-second Shuttle Radar Photography Mission (SRTM) data (30m resolution) in GeoTIFF format, covering the whole of Liberia. These tiles were freely downloaded from United States Geological Survey's (USGS) Earth Explorer platform and then mosaicked and processed to fill in any missing elevation data gaps by programming a moving window that searches the DEM for Nodata values and fills them with an average of the surrounding pixels iteratively until all the Nodata pixels are removed.

Land Cover Map. The Metria & GeoVille land cover mapping, used Rapideye 5m resolution data acquired in 2014 to produce land cover maps and statistics for Liberia. Of the 11 classes of land-type that this provides (see Table 1, below), the **first** (Forest >80% canopy cover) corresponds to the highest tree canopy cover, typically high primary forest, that contains the highest carbon stock. The **second** class (Forest 30-80% canopy cover) is a wider category that includes a wider range of forest types, from open, fragmented, and logged forest to secondary forest with characteristics that are close to primary forest. The **third** class of forest of less than 30% canopy cover fall outside of the definition of "forest" that was adopted in Liberia in January 2016 and is therefore not used in the following analysis.

The purpose of the following analysis is to provide information on how much high canopy forest is contained within the 'allocated' and 'non-allocated' land use categories, and its suitability either for community, conservation or commercial forestry, taking into account population pressure and clan boundaries.

The land cover statistics and maps produced from 2014 Metria & GeoVille data can be seen in Table 1 and Figure 1.

Table 1. Area data for the 2015 Metria & GeoVille land cover layer

Land cover class	Hectares	% of mapped area
Forest > 80% canopy cover	4,389,270	45.5%
Forest 30 - 80 % canopy cover	2,186,495	22.6%
Forest < 30% canopy cover ²	1,529,949	15.8%
Mangrove & Swamps	37,158	0.4%
Settlements	44,595	0.5%
Surface Water Bodies	60,374	0.6%
Grassland	625,332	6.5%
Shrub	606,928	6.3%
Bare Soil	173,690	1.8%
Ecosystem complex (rocks & sand)	2,271	0.02%
Clouds (unmapped)	14,336	0.15%
Total mapped area (land and inland water)	9,656,062	100%



Figure 1. Metria & GeoVille land cover map for 2015

Population Data

Clan population data are important because they are the most relevant population grouping in Liberia, and data are available. Clan level population data were derived from the 2008 national census (the most recent) and extrapolated to 2015 using the

² This category falls outside of the newly agreed definition of forest in Liberia.

World Bank population growth rates³, applied to each year between 2008 and 2015. An estimated growth rate of 2.4% was used for 2014-2015 because data were not available for this year (Figure 2). The population estimate for 2015 was then used to calculate the population density for each clan area and these population density values were then applied to calculate subsequent population in the areas being examined.

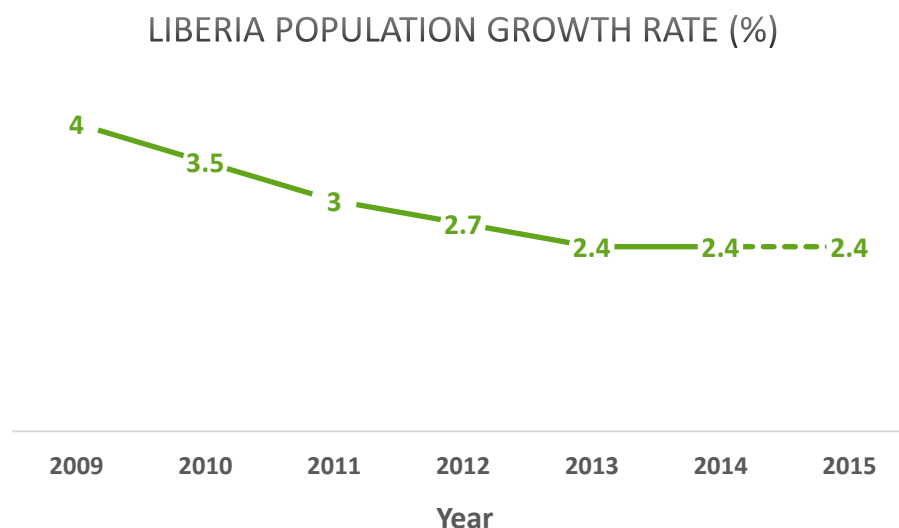


Figure 2. World Bank population growth rates for Liberia

1.2.2 Modelling Community, Commercial and Conservation land use suitability

An attempt to describe possible future land use was made by modelling the suitability of land for commercial, conservation or community use. The approach follows Nebel *et al.*, 2006⁴ but using contemporary data to allow for suitability to be described for 2015. For each of the three basic land use forms – commercial, conservation and community – the following process was carried out:

- 1) Define and quantify the various criteria or variables that make any given location more or less suitable for a particular land use category;

³ World Bank- Population growth (annual %) <http://data.worldbank.org/indicator/SP.POP.GROW/countries/LR?display=graph> Accessed- Dec. 2015.

⁴ Nebel M.L., Christie, W.T., Simpson, R.D., Woods, J.T. & Pierson, O.E. (2016). GIS for Land Use Planning in Liberia. Liberia Forest Initiative, USDA-Forest Service, Lassen National Forest.

- 2) Define weights (from least to most suitable) for the quantified values, or ranges of values, for each criterion within a land use category, and reclassify the values to a normalized scale. For this model, the scale 1-5 (1= least suitable, 5= most suitable) has been used;
- 3) Rank the multiple criteria within a land use category, so that the total for all variables equates to 100%.

Modelling Approach

ArcGIS 10.3 Model Builder was used to construct and run all of the suitability models. This tool provides documentation of the process used, and allows for multiple iterations of the model with changing variables. A spatial weighted overlay was used to carry out the work, allowing multiple characteristics that affect the appropriateness of any given location for a specific land use (one of the 3Cs⁵) to be identified and for those characteristics to be ranked according to their relative importance in identifying the suitability of the area within the model. The combination of these weighted layers will, in effect, calculate an overall suitability of the land for one of the three land uses.

The same basic process was used for all suitability models. Most GIS datasets were in vector file formats, and needed to be converted to raster data for the models. Many of the model parameters involved distance from specific features and this calculation was accomplished by creating distance rasters from vector features using a multiple buffer tool in ArcGIS. The distance rasters were then reclassified based on the values in Nebel *et al.*, 2006, to identify areas suitable for Community, Commercial and Conservation forestry. These values were used so that a comparison could be made with the layers produced by the Nebel study to the layers produced by this study using new information for 2015. The reclassified rasters were then combined using the Weighted Overlay function and the Relative Rank model Parameters of the ArcGIS tool. The Protected Areas were also included in this study and treated as always being suitable for Conservation/Preservation and always unsuitable for Commercial Forestry or Community Forestry.

To better understand the following sections, we have included definitions of key terms:

- 1) **Category:** this is the land use category (Conservation, Commercial, or Community) that is being modelled for suitability.
- 2) **Variable:** these are the specific criteria that influence the suitability of the land for the particular 3C category being modelled.

⁵ Based on work done by the Liberia Forest Initiative, the '3 Cs' refer to three forestry-related land use categories: Community, Conservation and Commercial.

- 3) **Relative rank (100%):** this is the relative rank/importance of each variable in the model, relative to all other variables within the model, expressed in this case as a percentage, with the total summation equating to 100%.
- 4) **Value class:** this is the quantified values/units/description for each specific criterion and the values classes used in the reclassification of the data to a normalized scale.
- 5) **Weighting (1-5):** this prescribes the weights from least to most suitable for the reclassified layers (1 being least suitable and 5 being most suitable), reclassifying a range of value classes to this normalized scale. Some areas were designated a value of "0" to signify unsuitability for the particular 3C classification.

2. Forest Cover and Land Use

2.1 Protected Areas and Proposed Protected Areas

There are three existing Protected Areas in Liberia: East Nimba Nature Reserve (ENNR), Sapo National Park and Lake Piso Multi-Use Protected Area. There are also 10 Proposed Protected Areas (PPA) around Liberia, two of which are coastal/wetland and the rest being terrestrial (Figure 3). The existing Protected Areas (PA) total approximately 263,215 hectares (ha) (Table 2), accounting for approximately 3% of the land area in Liberia.

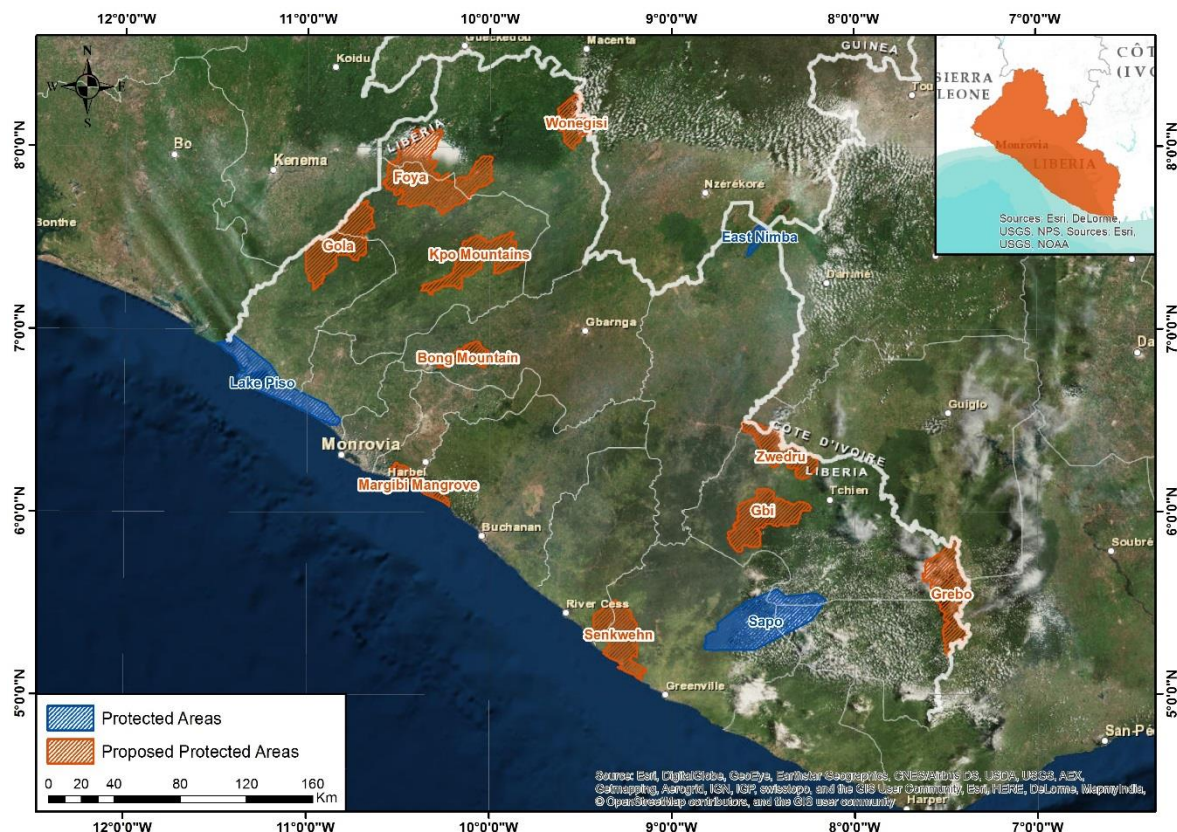


Figure 3. Location of existing and Proposed Protected Areas in Liberia

The largest PPA is Foya, in the Foya District – one of six Districts located in Lofa County, in the North-West of Liberia – is almost twice as large as Gola, the second largest Proposed Protected Area. These PPAs are located in the North-West and South-East of Liberia and are mainly intended as National Parks. The total proposed area would amount to an additional 756,431 ha of protected land, approximately 8% of the land area in Liberia.

Table 2. Areas coverage of A) Protected Areas and; B) Proposed Protected Areas (in ha)

A) Protected Areas		B) Proposed Protected Areas	
Name	Area (ha)	Name	Area (ha)
Sapo	154,966	Bong Mountain	24,821
East Nimba	12,154	Gbi	88,404
Lake Piso	96,094	Gola	97,975
TOTAL	263,215	Grebo	97,135
		Kpo Mountains	83,667
		Margibi Mangrove	23,813
		Senkwehn	80,347
		Wonegisi	37,978
		Zwedru	64,249
		Foya	164,628
		TOTAL	756,431

2.1.1 Land cover in Protected and Proposed Protected Areas

Lake Piso is located on the Western coast of Liberia, spanning over 18 Clan boundaries, located within the Grand Cape Mount, Bomi and Montseraddo Counties. It is approximately 95,921 ha in area and extends from the Mano River at Liberia's border with Sierra Leone to the Po River.

Sapo National Park is a National Park in Sinoe County in South-East Liberia. It is the country's largest Protected Area of rain forest, its only National Park, and contains the second largest area of primary tropical rain forest in West Africa after Tai National Park in neighboring Côte d'Ivoire at 154,966 ha. The land cover for the Sapo Nature Reserve is largely made up of high canopy forest that has a canopy density that is greater than 80%. Approximately 143,046 ha of the Sapo Nature Reserve comprises of high canopy cover forest, equating to 92% of the reserve area (Table 3, Figure 4).

On the Mount Nimba Mountain range, located in the North of Liberia, East Nimba Nature Reserve (ENNR) borders both Côte d'Ivoire and Guinea. It is located in an area that has a high density of iron ore, and includes mining concessions held by companies such as ArcelorMittal. The ENNR covers an area of approximately 12,153

ha and protects high closed canopy tropical forest and montane ecosystems. It is a stronghold for species endemic to the Nimba area and it extends over the boundaries of the Gbar, Lan-Kao and Zor Clans within Nimba County.

Table 3. Land cover in existing Protected Areas- A) Sapo Nature Reserve; B) East Nimba Nature Reserve; C) Lake Piso Ramsar Site

A) Sapo National Park		B) East Nimba Nature Reserve	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80% canopy cover	143,045	Forest cover > 80%	7,320
Forest cover 30% - 80%	7,757	Forest cover 30% - 80%	2,367
Forest cover < 30%	3,672	Forest cover < 30%	613
Shrub	461	Shrub	908
Grassland	2	Grassland	578
Bare soil	14	Bare soil	364
Surface water bodies	11	TOTAL	12,152
TOTAL	154,965		

C) Lake Piso Multi Use Protected Area	
Land Cover	Area (ha)
Forest cover > 80%	15,029
Forest cover 30% - 80%	33,091
Forest cover < 30%	2,863
Shrub	3,636
Grassland	15,471
Ecosystem Complex (Rock& Sand)	454
Mangrove & swamps	8,272
Settlements (urban & rural)	246
Bare soil	1,279
Surface water bodies	15,576
TOTAL	95,921

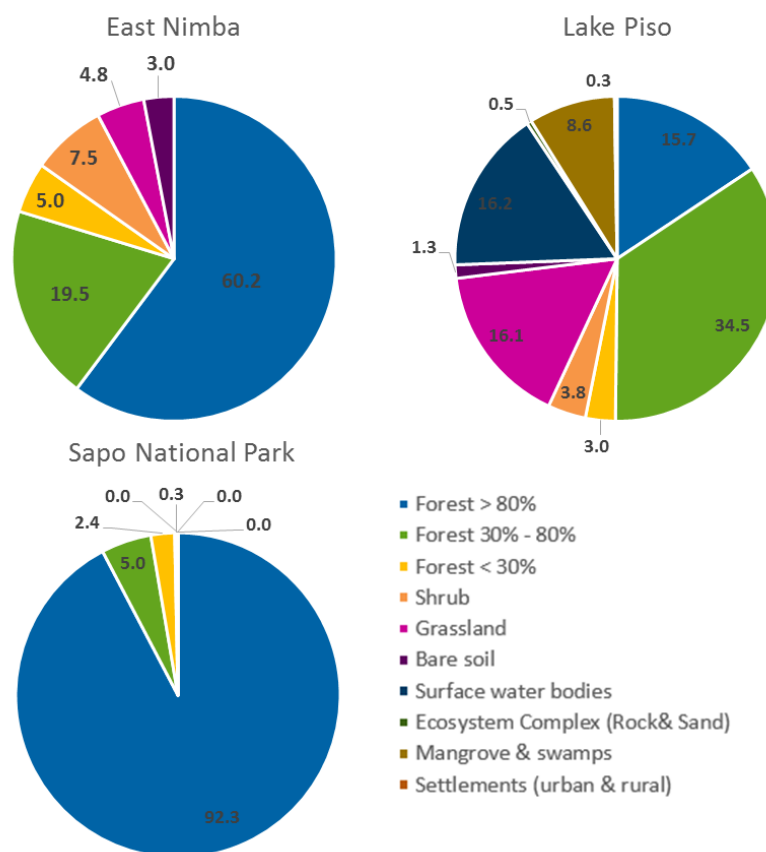


Figure 4. Percentage coverage of land cover in Protected Areas

The Proposed Protected Areas are largely in areas of high canopy cover forest, with an estimated 94% of the land cover being categorized >80% canopy cover and 71% in the >80% category. A total of 200 ha of urban and rural settlement areas were identified, representing 0.03% of the total proposed Protected Area (Table 4).

Table 4. 2015 Metria & GeoVille land cover in Proposed Protected Areas

Land Cover	Land use area (ha) in Proposed Protected Areas
Land Cover	Area (Ha)
Forest cover > 80%	541,487
Forest cover 30% - 80%	132,427
Forest cover < 30%	45,214
Shrub	10,140
Grassland	13,618
Mangrove & swamps	7,576
Bare soil	3,116
Ecosystem Complex (Rock& Sand)	238
Settlements (urban & rural)	201
Surface water bodies	4,397
Clouds	2,739
TOTAL	761,152

2.1.2 Populations in Protected and Proposed Protected Areas

Population estimates for the existing and Proposed Protected Areas were calculated in order to gain insight into potential threats to these areas and to identify where conflicts may arise with those who rely on them as resources and for their livelihoods. The population figures are based on an average density across the whole Clan area and will almost certainly mean that the estimated population within the Protected Areas boundaries is over-inflated. This is because most of the population in the Clan areas is likely to be concentrated in settlements that are outside the Protected Areas. The population estimates should not be interpreted as the number of people living within the boundaries of Protected and Proposed Protected Areas. Rather, they should be seen as an indication of the level of population in the vicinity of the Protected and Proposed Protected Areas and hence the level of pressure they are likely to be under from community uses of the forest.

Sapo Nature Reserve, accounts for the largest Protected Area in Liberia but is estimated as having a very small population, with a population density of roughly 0.05 people/ha. On the other hand, Lake Piso has a much larger population density at an estimated 0.38 people/ha and East Nimba has a moderate population density of approximately 0.26 people/ha. The total population of people who live in current Protected Areas is estimated at just over 47,000 (Table 5).

Table 5. Estimated population in Liberia's Protected Areas in 2015.

	Clan Name	Population/ha	Area (ha)	Estimated Population	Total Population
East Nimba	Gbar	0.38	6,957	2,672	3,194
	Lan-Kao	0.31	1,238	380	
	Zor	0.58	245	142	
Lake Piso	Deygbo	0.54	5,111	2,738	36,329
	Fahnbulleh	0.51	7,735	3,922	
	Gbavon	0.81	5,401	4,383	
	Gorblah	0.59	391	232	
	Kaidii	0.57	14	8	
	Kaihon	0.32	4,834	1,565	
	Kiazolu 1C	0.41	1,780	726	
	Kpatiah	0.56	4,154	2,318	
	Kpey	0.83	132	110	

	Clan Name	Population/ha	Area (ha)	Estimated Population	Total Population
	Kpor	3.18	22	70	
	Lower Tombey	0.28	5,120	1,453	
	Manobalah	0.70	3,879	2,718	
	Moifeh	0.22	5,272	1,184	
	RobertSPORT	3.51	1,186	4,161	
	Royesville	0.72	3,960	2,862	
	Sambola	0.28	13,651	3,767	
	Tallah	0.16	6,902	1,092	
	Tehr	0.60	626	378	
	Upper Tombey	0.17	6,055	1,036	
	Zogbou	0.29	5,494	1,607	
Sapo Nature Reserve	Bio Wiah	0.13	3,253	409	7,526
	Central Drepoh	0.03	739	25	
	Central Wedjah	0.07	121	9	
	Cheeseman	0.03	14,343	422	
	Gbalawein	0.02	14,988	323	
	Jehdubu	0.04	8,753	324	
	Korjahyee	0.04	6,337	226	
	Lower Drepoh	0.05	1,261	68	
	Motor Road	0.03	4,411	144	
	Mt. Seagboken	0.06	5,683	361	
	Ponnuh	0.04	4,864	208	
	Sarpo	0.05	25,542	1,186	
	Seamannah	0.07	21,346	1,587	
	Twinboe	0.06	19,816	1,183	
	Upper Drepoh	0.05	1,632	76	
	Upper Jebebo	0.35	60	21	
	Upper Tarweh	0.05	321	17	
	Wlufueh	0.02	18,073	322	
	Zeenonblogbo	0.18	3,423	614	
TOTAL:			245,123	245,123	47,048

The average population density for the combined area of proposed Protected Areas (approximately 756,400 ha) is estimated at 0.22 people/ha. The PPAs with the densest population are Margibi Mangrove and Bong Mountain. Margibi Mangrove has an estimated 18,720 people on 23,538 ha of land, resulting in the highest population density of all the Proposed Protected Areas at approximately 0.80 people/ha. Bong Mountain has the second largest population density at around half that of Margibi

Mangrove, approximately 0.46 people/ha. All other proposed Protected Areas have population densities < 0.20 people/ha, with Kpo Mountains, Foya, Gbi, Grebo and Senkwehn having population densities < 0.10 people/ha. The total population of people who live in the clan areas that overlap with the Protected Areas is estimated at just over 100,000 (Table 6).

Table 6. Estimated population in proximity to Liberia's Proposed Protected Areas in 2015.

	Clan Name	Population/Ha	Area (Ha)	Estimated Population	Total Population
Gola	Jawajeh	0.05	44,089	2,244	12,577
	Kposo	0.37	5,044	1,871	
	Laar	0.09	2,638	239	
	Mana	0.27	203	55	
	Sokpo	0.18	44,347	8,074	
	Zuie	0.06	1,540	94	
Kpo Mountains	Bade	0.06	58,524	3,381	7,430
	Koninga	0.04	9,140	407	
	Lower Bokomu	0.16	6,280	1,006	
	Nwolaila	0.13	71	9	
	Upper Bokomu	0.27	9,653	2,627	
Foya	Bade	0.06	40	2	15,513
	Buluyeama	0.04	639	24	
	Hassala	0.39	9,425	3,704	
	Hembeh	0.07	29,438	2,179	
	Jawajeh	0.05	76,455	3,891	
	Lobarsu	0.16	210	33	
	Lower Guma	0.30	823	245	
	Lukasus	0.15	3,362	506	
	Upper Guma	0.29	9,927	2,838	
	Zuie	0.06	34,309	2,090	
Wonegisi	Bondi	0.09	16	2	6,898
	Quardu	0.69	28	19	
	Zeayeama	0.18	37,732	6,877	
Bong Mountain	Bonkomu	0.32	3,041	986	11,352
	Giamusu	0.27	5,699	1,562	
	Konoyea	0.28	6,716	1,907	
	Nyaforquellie	0.77	5,456	4,207	
	Wiah	0.75	3,398	2,558	
	Yarbayon	0.26	512	134	
Marig	Charsville	4.07	1,505	6,123	18,720

	Clan Name	Population/Ha	Area (Ha)	Estimated Population	Total Population
	Doewein	0.41	5,379	2,195	
	Gahneo	0.35	103	36	
	Giah	0.53	4,754	2,518	
	Kiaffarh	0.24	1	0	
	Kpaye	1.33	1,671	2,220	
	Marshall City	0.81	3,132	2,533	
	Scheiffelin Township	1.30	1,853	2,400	
	Sonniewein	0.46	646	296	
	Whenzohn	0.09	4,493	397	
	Yeannah	0.63	2	1	
Gbi	Blawo	0.04	7,998	301	7,528
	Gorbo	0.08	505	42	
	Jaladaye	0.24	15,785	3,774	
	Marbo #2	0.06	21,847	1,381	
	Neezonnie #1	0.05	32,415	1,515	
	Voogbadee	0.19	0	0	
	Wromel	0.05	9,854	516	
Zwedru	B'Hai-Nicko	0.31	7,945	2,474	10,490
	Blawo	0.04	1,093	41	
	Duowoe	0.12	4,755	548	
	Gayea	0.36	3	1	
	Gblor	0.16	7	1	
	Gborbo	0.16	14,594	2,355	
	Jaladaye	0.24	2,959	707	
	Marbo #1	0.19	10,602	2,008	
	Tian-Duogee	0.19	8,675	1,651	
	Wromel	0.05	13,440	704	
Grebo	Chattan	0.18	8,896	1,575	5,069
	Dugbehbo	0.03	47,374	1,213	
	Gbarlahn	0.17	5,778	960	
	Karyellibo	0.05	923	44	
	Nenebo	0.12	483	60	
	Sackor	0.05	13,284	700	
	Salla	0.04	11,633	411	
	Youbor	0.03	3,180	106	
Senkwehn	Blonee/Negba	0.14	10,070	1,436	8,151
	Bour	0.05	919	49	
	Central Tarsue	0.23	6,535	1,533	

	Clan Name	Population/Ha	Area (Ha)	Estimated Population	Total Population
	Clan 1	0.06	10,529	597	
	Clan 2	0.13	2,187	276	
	Gbannoh	0.13	2,172	279	
	Jaquiakpo	0.07	2,954	199	
	Lower Duo	0.07	7,995	534	
	Lower Kao	0.05	508	24	
	Lower Sanquin	0.09	1,379	127	
	Neegba/Bar	0.10	8,695	902	
	Sueh	0.13	1,993	269	
	Trody	0.07	6,217	407	
	Tuo	0.24	2,771	675	
	Upper Duo	0.04	11,606	513	
	Upper Kao	0.17	13	2	
	Upper Tarsue	0.09	3,570	330	
	TOTAL:		756,432		103,729

The population density figures for the Protected and Proposed Protected Areas were taken and used to rank and identify those that are potentially most susceptible to anthropogenic impacts leading to deforestation and forest degradation. It is clear that Margibi Mangrove PPA has the highest indicative population density by a large margin, which draws out similarities with the existing Protected Area, Lake Piso, which also includes mangroves and fresh water (Table 7).

Table 7. Population density ranking for the Proposed Protected Areas

		Area (Ha)	Pop. Density/ha	Ranking
Proposed Protected Areas	Margibi Mangrove	23,813	0.79	1
	Bong Mountain	24,822	0.46	2
	Wonegisi	37,979	0.18	3
	Zwedru	64,249	0.16	4
	Gola	97,975	0.13	5
	Senkwehn	80,348	0.10	6
	Foya	164,628	0.09	7
	Kpo Mountains	83,667	0.09	8
	Gbi	88,405	0.09	9

	Grebo	97,136	0.05	10
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2.2 Forestry Concessions

Following the lifting of United Nations (UN) timber sanctions in 2006, there has been a strong push by the Liberian Government and some donors to grant logging concessions. By 2012, almost two million hectares of land – approximately 20% of the total land area of Liberia – had been allocated for forestry concessions of various kinds.

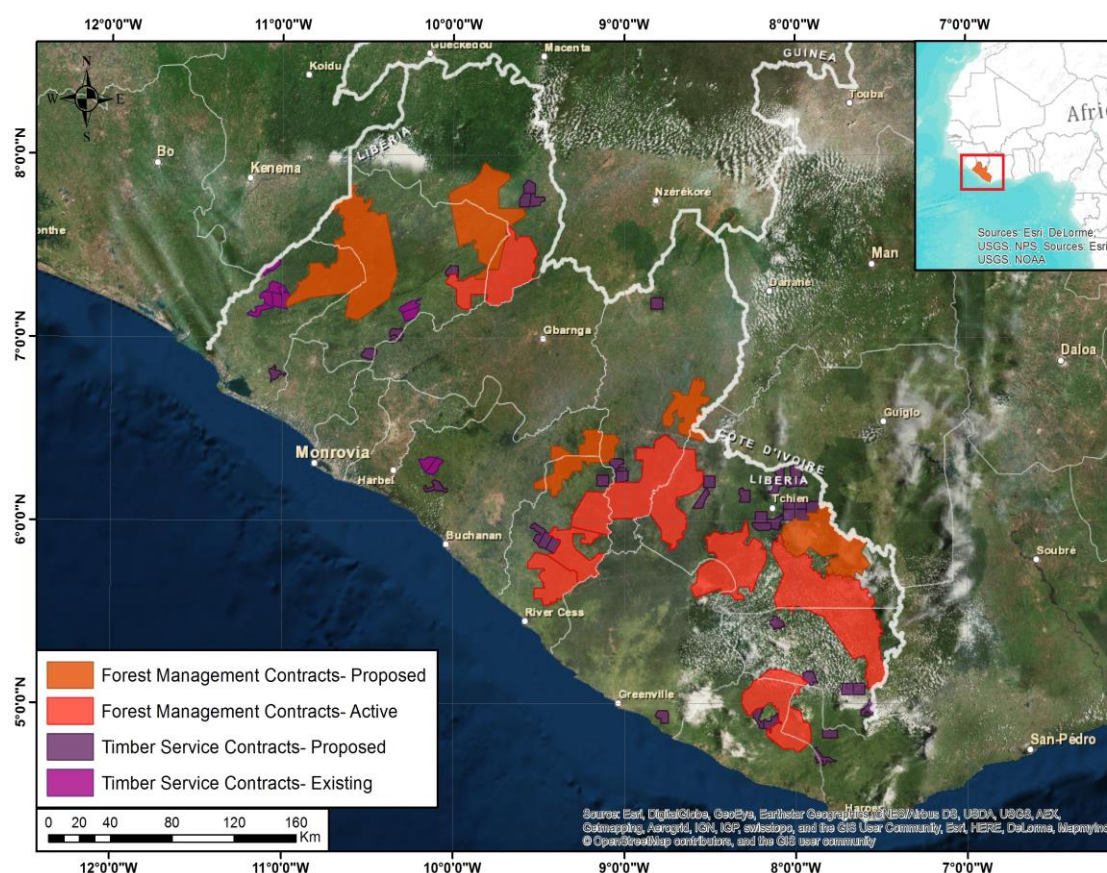


Figure 4 - Existing and proposed Forest Management Contracts and Timber Sale Contracts

2.2.1 Forest Management Contracts: Proposed and Active

A total of over one million hectares of land in Liberia is currently under an active Forest Management Contract (FMC). In addition, FMC concessions are proposed for a further area of over 700,000 ha, totaling a potential area of over 1.7 million ha for all

FMCs. This represents a significant proportion of the country: 11% conceded as FMC and a further 7% proposed for such use.

An FMC license is issued (under Section 5.3 of the National Forestry Reform Law) for exploitation of forest areas over 5,000 ha on state owned land. FMCs are meant to be managed on a sustainable basis, to conserve tree cover and ensure future supplies of timber.

Table 8 - Areas of A) FMC Proposed Concessions and B) FMC Active Concessions

A) FMC Proposed Concessions Areas		B) FMC Active Concessions Areas	
Location	Area (Ha)	Location	Area (Ha)
Gbarpolu & Grand Cape Mount	270,435	Lofa	119,240
Nimba	58,834	River Cess 1	57,262
Grand Gedeh	129,673	River Cess 2	59,373
River Cess	82,592	Grand Gedeh & River Gee	254,580
Gbarpolu	168,942	Grand Gedeh	131,450
TOTAL	710,477	Nimba	266,914
		Grand Kru	119,344
		TOTAL	1,008,164

The land cover under these active and proposed FMC concession is mostly high canopy cover forest; an estimated 71% of proposed FMCs and 76% of active FMCs are classified as Forest >80%. Further details of the land cover under active and proposed FMC concession areas can be seen below table 9.

Table 9 - 2015 Metria & GeoVille land cover on A) FMC Proposed and; B) FMC Active Concessions Area

A) Land Cover on FMC Proposed Concessions		B) Land Cover on FMC Active Concessions	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80% canopy cover	505,956	Forest cover > 80% canopy cover	766,015
Forest cover 30% - 80% canopy cover	142,591	Forest cover 30% - 80% canopy cover	144,640
Forest cover < 30%	43,052	Forest cover < 30%	68,038
Shrub	10,230	Shrub	19,375
Grassland	5,262	Grassland	4,009
Settlements (urban & rural)	156	Settlements (urban & rural)	202
Bare soil	2,195	Bare soil	3,921
Surface water bodies	734	Surface water bodies	1,807
TOTAL	710,179	TOTAL	1,008,010

FMCs account for approximately 24% of the total forested area in Liberia and 29% of the highest canopy cover (>80% canopy cover). Furthermore, the scale

and positioning of FMCs – often between Protected Areas or Proposed Protected Areas and covering large blocks of high canopy cover forest – suggests that they should be an important part of the REDD+ strategy. If managed appropriately they may link and maintain large contiguous blocks of the highest carbon and biodiversity value forest. Conversely, if forest degradation and eventual deforestation occurs in FMC areas, either directly through logging or through uses associated with roads and population growth, then a diminished and fragmented forest landscape will result.

The indirect impact of commercial logging on forest area is unknown but likely very significant. Most of the road network in Liberia, and all in some rural areas, was built by logging companies to extract timber. These play a vital role in opening up the land for pit sawing, agriculture, settlement expansion, charcoal production, hunting, artisanal mining and other activities that lead to deforestation and forest degradation.

2.2.2 Timber Sale Contracts

Timber Sale Contracts (TSC) allow for the complete clearance of an area of forest and the conversion of the land to agriculture or some other land use.

Although the area of land under TSCs is small compared to the area under FMCs, the impact of TSCs on Liberia's forest emissions – and hence, REDD+ performance – is potentially large because they could result in substantial deforestation in a short period.

Existing and proposed TSCs cover 3% of the total forest area in Liberia, the majority of which is high canopy cover (>80%) forest. Unlike FMCs, total clearance of forest from TSC land is permitted and expected, to make way for agricultural development. Existing TSCs are located in the west of Liberia, in the counties surrounding Monrovia (within 120 Km of Monrovia) including Grand Bassa, Gbarpolu, and Grand Cape Mount. Proposed TSC areas are located across Liberia and the forest area proposed is approximately four times larger than the existing forest area under TSCs, totaling just over 200,000 ha.

Table 10 - 2015 Metria & GeoVille land cover on A) Existing and; B) Proposes Timber Sale Areas

A) Timber Sale Contracts- Existing		B) Timber Sale Contracts- Proposed	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80%	32,646	Forest cover > 80%	94,981
Forest cover 30% - 80%	13,014	Forest cover 30% - 80%	52,432
Forest cover < 30%	3,301	Forest cover < 30%	36,692
Shrub	1,048	Shrub	10,059
Grassland	480	Grassland	3,435
Settlements (urban & rural)	20	Settlements (urban & rural)	227

Bare soil	457
Surface water bodies	78
TOTAL	51,048

Bare soil	2,802
Surface water bodies	174
Clouds	462
TOTAL	201,267

2.2.3 Community forestry concessions

Community Forestry Management Agreements (CFMA) are a form of government-granted concession that gives communities prescribed user rights to the forest. CFMA can have either a commercial or a conservation objective. The area of land designated for commercial CFMA is much larger than the area of land allocated to conservation CFMA; 183,000 ha and 21,000 ha, respectively.

The land cover under commercial CFMA consists mainly of forested area, with an estimated 60% of the total commercial CFMA area being classed as forest >80%. Similarly, conservation CFMA have an estimated 73.6% of the area classed as forest >80% (Table 11).

Table 11 - 2015 Metria & GeoVille land cover on A) Commercial CFA and; B) Conservation CFMA Area

A) Commercial CFMA		B) Conservation CFMA	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80%	109,959	Forest cover > 80%	15,366
Forest cover 30% - 80%	39,002	Forest cover 30% - 80%	3,412
Forest cover < 30%	25,829	Forest cover < 30%	860
Shrub	6,084	Shrub	714
Grassland	1,236	Grassland	504
Bare soil	1,119	Bare soil	2
Settlements (urban & rural)	76	Clouds	7
Surface water bodies	362	TOTAL	20,869
TOTAL	183,671		

Commercial forestry activity on land designated for community forestry is, in principle, subject to the same policy and regulations as commercial forestry on FMCs. In practice, this is untested. The number of applications for CFMAs received by FDA has increased considerably over the past few years and the Land Rights Act currently before the Liberian Parliament is expected to strengthen community rights to own and use land over which they previously had customary or traditional rights. It is possible that large areas of land currently allocated as FMC will be re-designated as

CFMA, if communities establish their rights to the land under the incoming legislation.

CFMAs can have either a commercial or a conservation objective. The area of land designated for commercial CFMA is much larger than the area of land allocated to conservation CFMA. The area of conservation CFMA totals approximately 21,000 ha and is located as clusters in two separate locations; the first near Greenville on the coast and the second around the Nimba Nature Reserve. The majority of the commercial CFMAs are located centrally around the FMC site located in Southern Nimba, with one location found North in Lofa County.

The land cover under commercial CFMA consists mainly of forested area, with the largest area dedicated to Forest > 80%, at of an estimated 60% of the total commercial CFMA area. Forest > 80% is also the largest land cover category for conservation CFMA, accounting for an estimated 73.6% of the area. Figures for all land cover in CFMA areas can be seen below to in Table 12.

Table 12. 2015 Metria & GeoVille land cover on- A) Commercial CFA and; B) Conservation CFMA Area

A) Commercial CFMA		B) Conservation CFMA	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80%	109,960	Forest cover > 80%	15,367
Forest cover 30% - 80%	39,002	Forest cover 30% - 80%	3,412
Forest cover < 30%	25,829	Forest cover < 30%	861
Shrub	6,085	Shrub	714
Grassland	1,236	Grassland	505
Bare soil	1,120	Bare soil	3
Settlements (urban & rural)	76	Clouds	7
Surface water bodies	363	TOTAL	20,869
TOTAL	183,671		

2.2.4 Private Use Permits

Private Use Permits (PUP) are a form of land concession by government that are intended to allow private owners or relatively small areas of land to carry out commercial forestry operations. PUPs were issued illegally during the period 2010-

2012 and all of these have subsequently been suspended or cancelled^{6,7}. The reason for including the former PUPs in this analysis is that they indicate the scale and location of land for which there is pressure to create commercial logging arrangements between companies and the land owning communities. Most of the illegal PUPs were on land that is customarily owned by communities, even if they tend not to hold land title deeds. They therefore indicate the extent to which CFMAs may expand if community ownership rights are established for all or most of this forest and if the CFMA process allows these to go forward for either commercial or conservation land use.

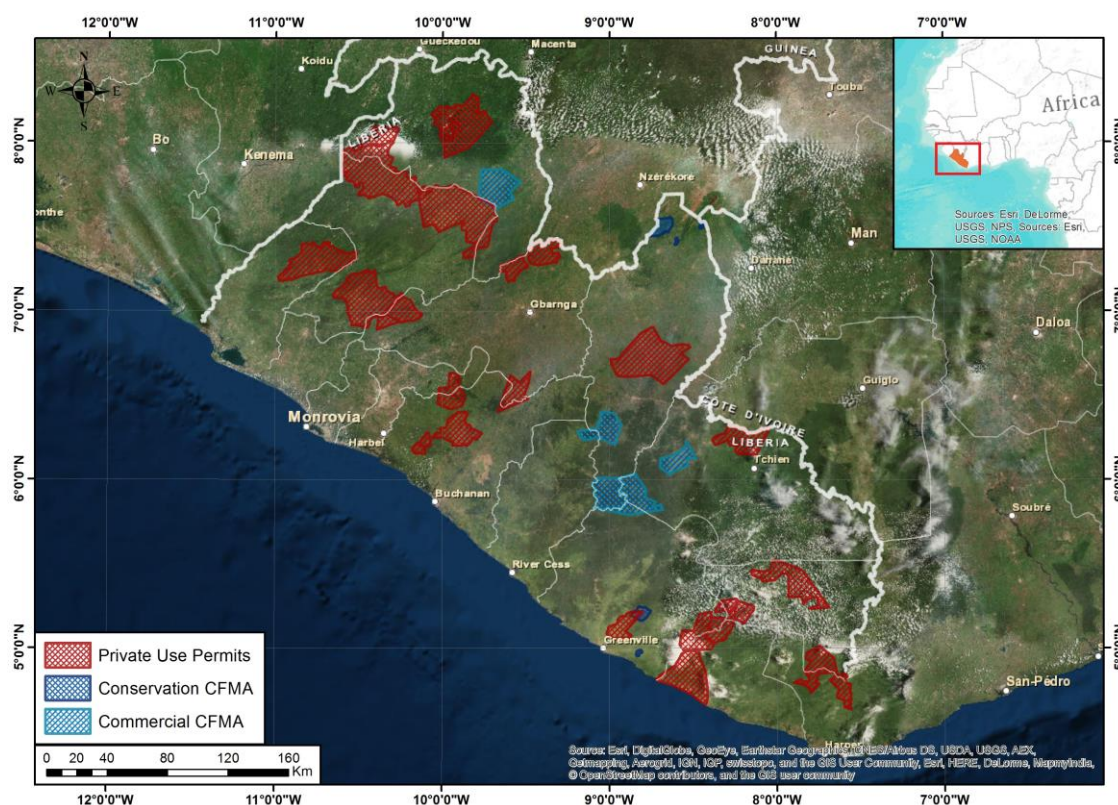


Figure 6 - Private Use Permits and CFMA areas in Liberia

The size and location of former PUPs can be seen in Figure 6 and a breakdown of the area by land cover class is given in Table 13. The land cover is varied but the majority (59%) of the area is Forest cover > 80%. 92% of the land area is Forest cover of >30% canopy cover **Error! Reference source not found.**

⁶ Yiah, J.W. (2012). Transforming Decision Making about Natural Resources in Liberia. Sustainable Development Institute.

⁷ De Wit, P. (2012). Land Rights, Private Use Permits and Forest Communities. Land Commission of Liberia, EU Project FED/2011/270957.

Table 13. 2015 Metria & GeoVille land cover on Private Use Permits

Land Cover on Private Use Permits	
Land Cover	Area (ha)
Forest cover > 80%	656,203
Forest cover 30% - 80%	221,472
Forest cover < 30%	141,863
Shrub	44,082
Grassland	26,940
Mangrove & swamps	857
Ecosystem Complex (Rock& Sand)	147
Bare soil	9,450
Settlements (urban & rural)	706
Clouds	2,649
Surface water bodies	2,209
TOTAL	1,106,584

2.3 Agricultural Concessions

Amongst Liberia's rich natural resources, palm oil production is considered by the Government of Liberia to be one of the most important industries for future economic development. Since 2009, four international palm oil companies have been granted concessions for palm oil production on 620,000 ha of land. After timber, this makes palm oil the second largest industrial land use in Liberia, and reflects ambitions for the country to become one of the main palm oil producers in the world.

Agricultural development is the key driver of deforestation globally. An estimated 80% of deforestation of tropical forest is due to agricultural expansion. More specifically, in Indonesia and Malaysia massive deforestation has occurred due to palm oil expansion. This has been driven by large estate development, and in recent years, by smallholders. In the West Africa region, Ghanaian and Ivorian forests have been rapidly converted into agricultural land due to smallholder expansion for cocoa, rubber and palm oil. Ghanaian forests are largely gone, and the Ivorian forests are severely encroached.

The key points from the following description of agriculture concessions are:

- **The area of land cleared for oil palm plantation in the next 10-15 years is estimated at a maximum of 530,000 ha and is likely to be nearer 250,000 ha based on current industry plans.** This includes a maximum of

approximately 352,000 ha of forest (30-80% and >80 Forest canopy cover classes) and a minimum of 160,000 ha⁸ of forest that will be cleared.

- **The area of rubber and other plantations is relatively small, covering 56,000 ha of forest** (30-80% and >80 Forest canopy cover classes).

Although the total land area covered by rubber or other plantations is around 180,000 ha, the majority of this is non-forest land, because clearance of natural forest took place in the past. This area of land cleared is unlikely to expand substantially in the next decade because investment will be directed into renovating the existing plantations.

2.3.1 Oil palm plantations

Approximately 545,000 ha of land in Liberia has been granted to concessions for oil palm plantations⁹. These concessions are operated by four oil palm companies: Sime Darby, Golden Veroleum (GVL), Equatorial Palm Oil (EPO), and Maryland Oil Palm Plantations (MOPP). The largest gross concession area for palm oil is owned by Golden Veroleum and is located on the South-East coast of Liberia extending to 350,000 ha. The next largest is owned by Sime Darby, with 311,000 ha, located North-West of Monrovia, in Gbapolu, Grand Cape Mount and Bomi Counties.

⁸ This estimate is based on an expected minimum of 250,000 ha of new plantation land, minus the 90,000 ha of 'non-forest' land that is available for development within the concession areas.

⁹ Based on concession agreements. The gross concession area is approximately 766,000 ha but the maximum permitted development area within this is less, approximately 545,000 ha.

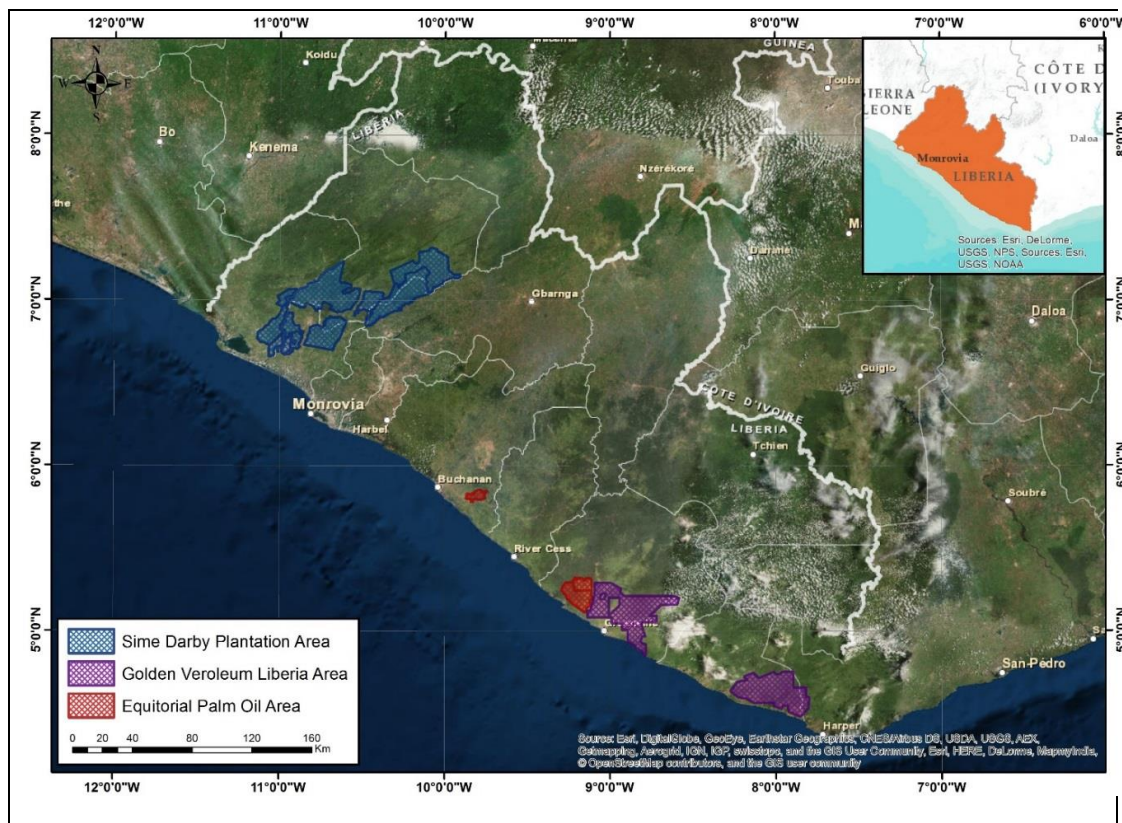


Figure 7 - Major oil palm concession areas in Liberia

Within these gross concession areas there is a smaller 'permitted development area' which is the maximum that can be cleared for plantations, within the terms of the concession agreements. Both GVL and Sime Darby have permitted development areas of 220,000 ha. They are also allowed to develop additional areas of approximately 40,000 ha each under out-grower schemes. The permitted area for EPO is less clear contractually, as they hold a gross concession of 89,000 ha and have agreed a further 80,000 ha 'expansion area' where they may develop plantations subject to agreement with local communities. EPO's planting target is 100,000 ha¹⁰.

Based on this target, this study estimates that the maximum permitted development area of the three main concession holders is 620,000 ha, although a smaller area of approximately 546,000 ha is identified from the digitized data available from the Government of Liberia (Table 14). The available data appear to show gross concession areas in some cases (e.g. Sime Darby) and permitted development areas or areas identified for development within this in the cases of EPO and GVL.

The concession areas identified on the available national datasets include the majority of the land with greater than 80% forest cover. Since clearance of High Conservation Value (HCV) forest and High Carbon Stock (HCS) forest is forbidden by

¹⁰ Equatorial Palm Oil (2013) African Sustainable Palm Oil Producer. Investor Presentation June 2013.

the operating principles of all Roundtable on Sustainable Palm Oil (RSPO) members, the palm oil companies should avoid clearing this area and much of the 30-80% forest. The companies will either have to develop substantially less than the maximum permitted area, or seek suitable land elsewhere. This is allowed within the terms of the concession agreements.

The threshold for what is defined as HCV and HCS forest in Liberia has not yet been defined but based on the area of >80% forest cover alone, around 43% of the Sime Darby concessions should not be cleared and 40% of the GVL concession. This leaves a large area of high canopy cover forest, over 200,000 ha for which the ownership and responsibility for management is very uncertain.

The 'business as usual' scenario in the oil palm sector in West Africa is that the companies will develop the degraded lands for palm oil, setting aside large areas of HCV and HCS forest. Local communities are then likely to use, degrade and ultimately remove this forest as demand for agricultural land and other natural resources increases and as the land available to communities diminishes.

Table 14 - 2015 Metria & GeoVille land cover on A) Equatorial Palm Oil; B) Sime Darby; and C) Golden Veroleum on oil palm plantations

A) Land Cover on Equatorial Palm Oil Area		B) Land Cover on Sime Darby Plantation	
Land Cover	Area (ha)	Land Cover	Area (ha)
Forest cover > 80%	21,169	Forest cover > 80%	134,238
Forest cover 30% - 80%	2,380	Forest cover 30% - 80%	102,084
Forest cover < 30%	2,369	Forest cover < 30%	32,700
Shrub	1,466	Shrub	11,061
Grassland	5,413	Grassland	20,585
Mangrove & swamps	5	Bare soil	8,898
Bare soil	1,243	Settlements (urban & rural)	393
Settlements (urban & rural)	49	Surface water bodies	182
Surface water bodies	1	TOTAL	310,144
Clouds	3,474		
TOTAL	37,573		

C) Land Cover on Golden Veroleum Liberia

Land Cover	Area (ha)
Forest cover > 80%	79,266
Forest cover 30% - 80%	13,547
Forest cover < 30%	58,298
Shrub	23,862
Grassland	17,985
Mangrove & swamps	1,218
Bare soil	1,797
Ecosystem Complex (Rock& Sand)	22
Settlements (urban & rural)	286
Surface water bodies	278
Clouds	1,683
TOTAL	198,247

The amount of land that will actually be cleared and developed for oil palm plantation is unclear. Only a minority of the land conceded for palm oil has been developed to date. GVL has started with 56,000 ha out of a maximum area permitted for planting of up to 260,000 ha. Sime Darby had planted only 1,190 ha of its 264,000 ha, permitted plantable area by 2012. EPO's 89,000 ha concession area includes former palm oil plantation and so already has 10,000 ha under production. The fourth company, MOPP, with a total concession of 15,000 ha, had rehabilitated 1,500 ha of former plantation and planted 500ha of new palm oil by 2012¹¹.

Looking longer term, the four palm oil concessions granted are very much the basis for the scale and location of the industry for the next 50-90 years. No major new concessions are expected, because rights to the majority of suitable land have already been sold. Nonetheless, questions remain about the precise location and timescale for expansion of the industry. Palm oil companies are putting significant efforts into finding enough hectares of land that is not HCV or HCS forest, or is not encumbered by Community use/ownership¹². The terms of the concessions agreements are that, if the agreed plantation land cannot be found within the initial Areas of Interest, the Government of Liberia will make other land available, although it is not yet known if this will be required.

¹¹ African Development Bank (2012) Maryland Oil Palm Plantation Project: Summary of the ESIA

¹² Personal communication. Based also on the documented difficulties EPO have had securing land in their 'expansion area' in River Cess County.

All four concessionaires are required by their concession agreements to develop sizeable out-growers schemes, with a total area of approximately 100,000 ha, however there has been little progress to date. The development of out-growers schemes is particularly challenging for the palm oil companies because responsibilities are not clearly defined with Government, and also because community relations, land use and land rights are difficult problems to solve. Most of the existing smallholder oil palm farmers are in other areas, particularly the central belt, so out-growers schemes linked to the large concessions may create a new population of small holder oil palm producers.

The pace and scale of land use change on palm oil plantations over the next 10-15 years is expected to be substantial, and largely driven by the three largest concessions. Existing smallholder palm oil production is unlikely to expand and clear forest rapidly because of its limited ability to invest. The maximum plantable area for the three large concessions, allowed by their concession agreements, is approximately 530,000 ha. In addition, Sime Darby and GVL are obliged by the terms of their concession agreement to develop a further area of 80,000 ha. The minimum area that is likely to be planted is approximately 250,000 ha¹³.

2.3.2 Small-scale oil palm production

In addition to the large and new palm oil concessions, there is an estimated 35,000 ha of oil palm worked by around 220,000 smallholders¹⁴. This is partly a legacy of industrial plantations of around 70,000 ha that were established in the 1970s by the government-owned Liberian Produce and Marketing Corporation. These ventures faltered during the wars and what remains is mostly under smallholder production¹⁵. There is also a substantial but unknown level of palm oil production from wild oil palms in forests.

2.3.3 Rubber and other plantations

Significant areas of land have been allocated as concessions for rubber and other plantations. Of these, the largest is the Firestone rubber concession, which dates back to a 405,000 ha concession granted in 1926. This is described by its owner (now Bridgestone Corporation) as the largest single natural rubber operation in the

¹³ Based on 100,000 ha for GVL and Sime Darby, 50,000 ha for EPO, based on the likely area of HCV/HCS and what is known about the plans of the companies

¹⁴ FFI (2014) Characterising smallholder oil palm production in Liberia

¹⁵ IDH 2014 landscape scoping study

world¹⁶. Current data indicate that the actual area developed as plantation is approximately 120,000 ha, much of which is overgrown and requiring re-planting¹⁷.

The second largest rubber concession is operated by the Liberia Agriculture Company, an estate that covers an area of 120,000 ha, out of which 17,000 ha has been developed as a rubber plantation¹⁸.

Other significant rubber plantations include Cavalla in Maryland County and Salala Rubber in Nimba County.

In total, the area allocated to Rubber or other plantations is approximately 178,200 ha (Figure 5). As with palm oil, the future land area dedicated to rubber and other industrial tree crops is uncertain. Companies such as Sime Darby have the option of growing either rubber or oil palm on their concession and their choice will be influenced by future commodity prices. Also, smaller private farms and community-owned plantations may expand in the future.

¹⁶ <https://www.bridgestoneamericas.com/en/corporation/subsidiaries-and-business-units/firestone-natural-rubber-co>

¹⁷ Based on shapefile for concession area supplied by FDA. This is judged by the author to be the most reliable source but other figures are cited in references: Global Witness (2015) "The new snake Oil" give a figure of 126,500 ha. The Bridgestone Corporation web site refers to concession size as 65,000 ha.

¹⁸ Based on data provided by FDA. Judged by the author to be the most reliable source but 10,500 ha is the area cited in 'IFC, Summary of Project Information: Liberian Agricultural company, 1999'. The Global Witness (2015) study cited above gives a figure of 18,400 ha.

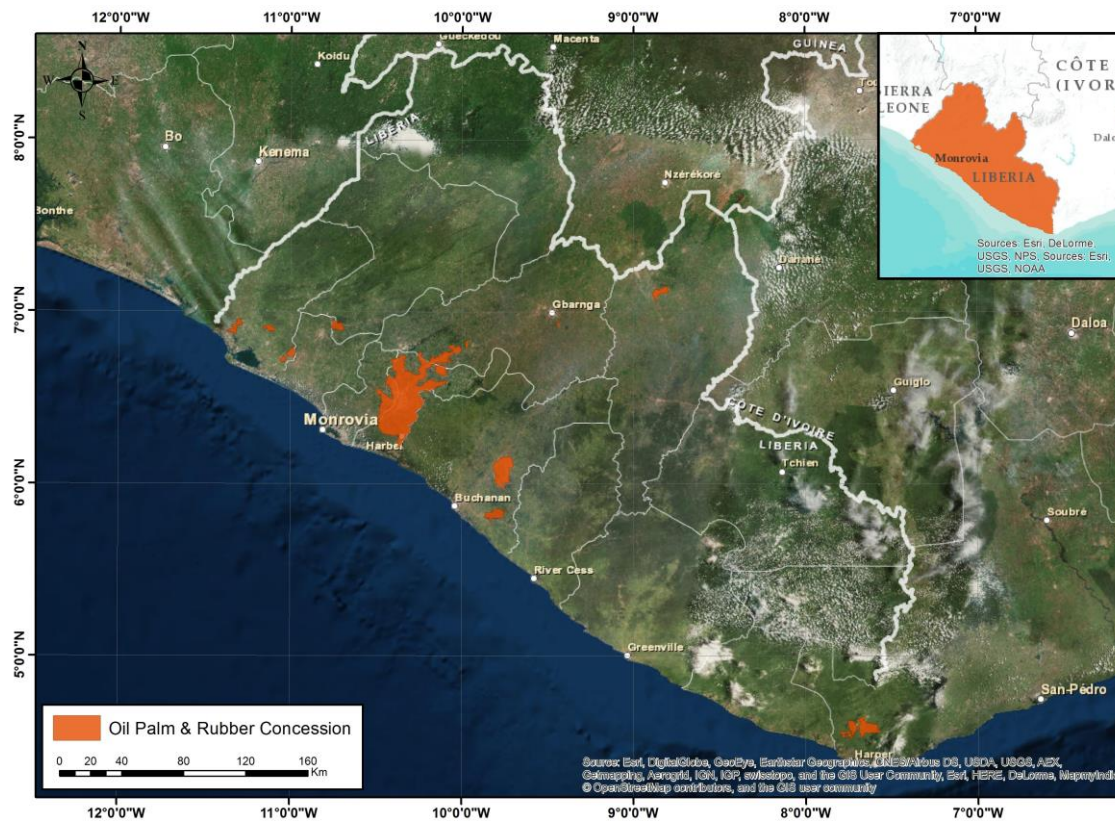


Figure 5 - Land cover categorized as Rubber Plantation from spatial data provided by FDA

Compared to the palm oil concessions, the rubber and other plantations have much lower forest cover. This reflects the fact that they are established plantations and so have already been substantially cleared of natural forest. Having been neglected during the war years, large areas of these plantations have recently been cleared for re-planting. Thus, approximately 65,816 ha, 37% of the total area, falls under the Grassland land cover class. The second largest area is Forest 30% - 80%, covering 24.1% of total area. This is followed by Bare Soil at 14.2% of the total area. Only 7% of the plantation land is classed as forest >80 canopy cover.

Table 15 - 2015 Metria & GeoVille land cover on rubber and oil palm areas

Rubber/Other plantation	
Land Cover	Area (ha)
Forest cover > 80%	12,853
Forest cover 30% - 80%	42,926
Forest cover < 30%	18,063
Shrub	10,135
Grassland	65,816
Bare soil	25,325
Mangrove & swamps	7
Settlements (urban & rural)	3,009
Surface water bodies	108
TOTAL	178,248

2.4 Mining Concessions

Large scale mining of iron ore was a major export earner for Liberia in the past and has become so again in the post-conflict period, with the re-starting of iron ore extraction in the Nimba Hills by ArcelorMittal in 2011. Liberia has rich mineral resources – including iron ore, gold, and diamonds – and mining is expected to become a major industry and driver of economic development. The country has sufficient reserves to join the top ten iron producers in the world. At least six iron ore concession agreements have been signed with a total estimated investment value of \$13 billion¹⁹.

Mining is identified as a potentially important cause of deforestation in various publications, including the Liberia Readiness Preparation Proposal (R-PP). This is largely based on the extent of Mineral Exploration Licenses (MEL) which have been granted over 4.6 million ha of land, near half the total land mass of the country. On this basis, mining has been described as amongst the greatest threats to forests and wildlife²⁰. Artisanal and small scale mining is also practiced extensively across Liberia, although the environmental impacts of informal mining at a national level are not well known.

¹⁹ Columbia University CICR (2010) Smell no taste: The social impact of foreign direct investment in Liberia.

²⁰ USAID (2013) Liberia climate change assessment

The scale of threat suggested by the extent of exploration is misleading because most of the prospecting and exploration licenses do not result in operating mines. There are few mines actually operating, currently around six operating in Liberia (large-scale commercial mines) and they have a relatively small footprint²¹.

The current area of actual mining operations is relatively small compared to agriculture and logging concessions. Immediate deforestation occurs only in the area actually being mined, which will typically be a smaller area than the actual concession. Also, the impact on forest can potentially be mitigated through the use of biodiversity offsets in which an area of forest equal or greater than that cleared for the mine is conserved elsewhere²²; although it is not clear how such a scheme would fit in a national REDD+ program.

For the purpose of estimating areas of likely change in forest cover, this report uses Class A licenses as the basis for estimating the forest area immediately threatened, and Mineral Development Agreements (MDA) as the basis for the likely scale of the industry in the next 10-15 years. It should be noted that the extent of mining in the future and the resulting forest clearance is unknown. Activity and investment depends largely upon commodity prices, which are currently relatively low.

Approximately 84,250 ha of land in Liberia is designated with Class A MELs which give companies the right to extract the minerals. The two commodities which are currently being mined are iron ore and gold. A larger area of 209,290 ha has been granted with MDAs which allows companies to carry out the pre-extraction development of a mining area.

²¹ The mining companies that are currently operating in the targeted landscapes include, Arcelor Mittal's Nimba iron ore project, Russia's Severstal Resources (which has acquired rights to develop the Putu iron ore project), Vedanta (developing the Western Cluster iron ore projects), China Union (developing the Bong project), Aureus Mining (constructing the New Liberty mine located within the Bea Mountain mining license), Hummingbird Resources (developing the Dugbe gold project) (Source: Johnson, 2014).

²² An aggregated offset approach is advocated for Liberia, through which mining companies would support conservation in the existing and proposed protected area network (Johnson, 2014) Aggregated biodiversity offsets: A roadmap for Liberia's mining sector, World Bank Group). However, existing offsetting initiatives have been focused on the landscapes surrounding the mines.

Table 16 - Class A and Mineral Development Agreement Licenses in Liberia

Label	License Holder	License Type	Date	Commodity	Area (ha)
1)	AcelorMittal	Class A Mining License	17/08/2005	Iron Ore	10,550
2)	BEA Mountain	Class A Mining License	29/07/2009	Gold	47,023
3)	China Union (Hong Kong) Mining Co.	Class A Mining License	13/09/2011	Iron Ore	7,847
4)	Putu Iron Ore Mining Inc.	Class A Mining License	02/07/2014	Iron Ore	18,825
5)	AcelorMittal	Mineral Development Agreement	-	Iron Ore	51,034
6)	AMLIB United Minerals Inc. -Klekle	Mineral Development Agreement	17/09/2010	Gold	4,950
7)	AMLIB United Minerals Inc. -Cestos	Mineral Development Agreement	17/09/2010	Gold	82,675
8)	AMLIB United Minerals Inc. -Zwedru	Mineral Development Agreement	17/09/2010	Gold	10,000
9)	China Union (Hong Kong) Mining Co.	Mineral Development Agreement	14/07/2011	Iron Ore	60,629
TOTAL					293,534

Source: Land use and land suitability analysis, a component of the REDD+ strategy contract.

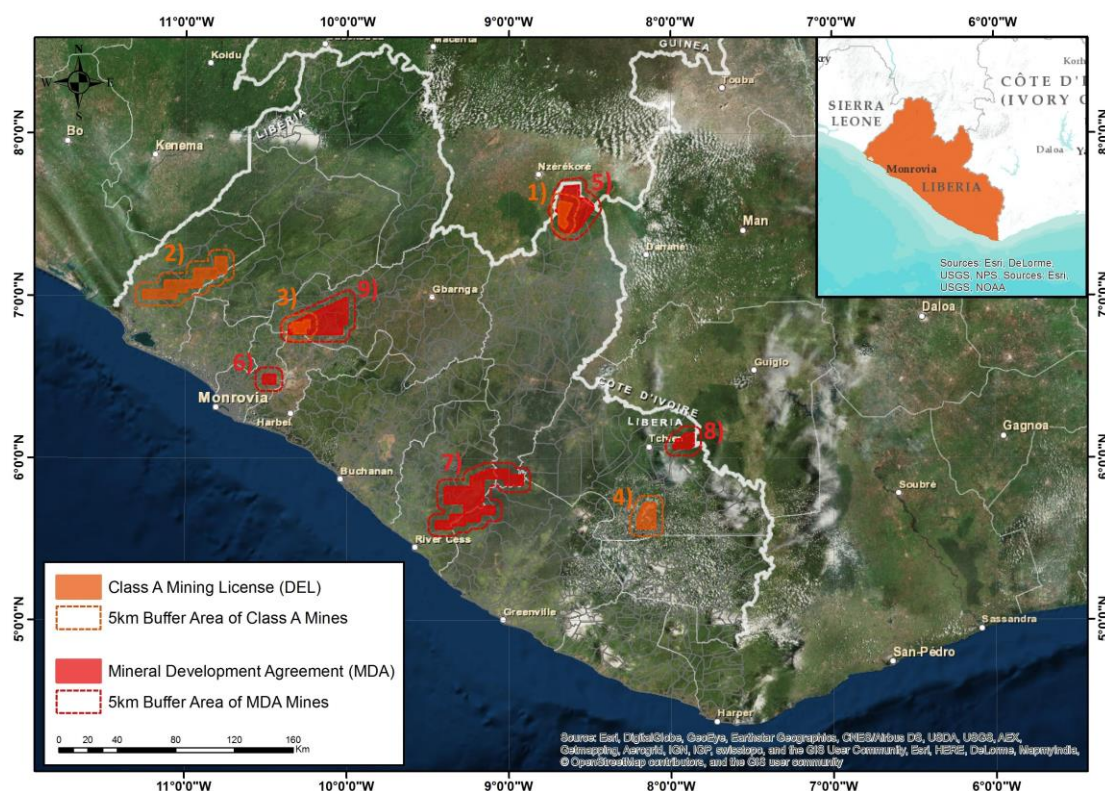


Figure 9 - Mining and Mineral Development Licenses in Liberia

2.4.1 Land cover around mining concessions

Although the area of forest directly cleared for mining is relatively small, the industry may result in deforestation and forest degradation of areas

surrounding the mine because of the economic activity and population growth that accumulates around these operations. For this reason, the REDD+ strategy is informed by analysis of the area within a five kilometer buffer of the mining concessions, on the assumption that land use within this area is heavily influenced by the mining business.

In the short-to-medium term it is likely that the indirect effect of mining is more significant in REDD+ terms; in other words, mines attract workers and raise local income and consumption levels which results in an enhanced level of degradation, caused by increased community use of the forest in the surrounding landscape²³.

The total area covered by the Class A Mining License areas with a five km buffer is estimated at 186,575 ha. This is over 100,000 ha larger than the mining concession area itself.

The total area within a five km buffer around MDA areas is 298,063 ha, which is approximately 90,000 ha larger than the MDA itself (Table 17).

Table 17 - Total area within 5 km buffer around mining concessions

License Holder	License Type	Area (ha)
AcelorMittal	Class A Mining License	32,505
Bea Mountain	Class A Mining License	89,136
China Union (Hong Kong) Mining Co.	Class A Mining License	28,514
Putu Iron Ore Mining Inc.	Class A Mining License	36,419
AcelorMital	Mineral Development Agreement	55,369
AMLIB United Minerals Inc.-Klekle	Mineral Development Agreement	22,103
AMLIB United Minerals Inc.-Cestos	Mineral Development Agreement	125,346
AMLIB United Minerals Inc.-Zwedru	Mineral Development Agreement	30,161
China Union (Hong Kong)	Mineral Development Agreement	65,083
TOTAL		484,639

A large proportion of the area within the five km buffer areas around mining concessions is high canopy forest cover. Approximately 78% of the MDA and 86% of the Class A license areas are covered by the 30-80% and the >80% forest canopy cover classes (Table 18).

²³ The evidence from Liberia on the indirect impact of mining operations is limited to specific cases; for example the iron ore mine of Arcelor Mittal Liberia in northern Nimba County will have a total footprint (forest clearance) of approximately 1,475 ha. The biodiversity conservation program funded as an offset scheme aims to reduce degradation across a much larger area; encompassing the East Nimba Nature Reserve (11,550 ha.) and a wider landscape of approximately 84,500 ha.

Table 18 - 2015 Metria & GeoVille data on land cover in 5 Km buffer area around A) MDA; and B) Class-A Mining Concession

A) Land Cover: MDA	Area (ha)	B) Land Cover: Class A	Area (ha)
Forest cover > 80%	134,042	Forest cover > 80%	81,596
Forest cover 30% - 80%	66,508	Forest cover 30% - 80%	55,649
Forest cover < 30%	31,404	Forest cover < 30%	22,263
Shrub	14,745	Shrub	9,110
Grassland	20,931	Grassland	11,193
Settlements (Urban & Rural)	604	Settlements (Urban & Rural)	357
Bare soil	5,920	Bare soil	3,416
Surface water bodies	821	Surface water bodies	286
Clouds	1,857	Clouds	0
TOTAL	298,049	TOTAL	186,564

The Class A license data indicates that approximately 137,200 ha of forest is threatened by mining (using 30-80% and >80% forest classes). An estimate of the future area affected by mining is given by the MDAs which amounts to an additional 200,800 ha of forest.

In addition to the formal mining sector, there are an estimated 100,000 artisanal miners operating in Liberia²⁴. The area affected by their operations is unknown, as is the impact on forest, although recent studies suggest that, individually, artisanal mines have a minor effect on biodiversity and tropical forests but a significant cumulative effect. Further information on artisanal mining is given in Section 2.5.

2.4.2 Population around mining concessions

The population in the areas surrounding the mining concessions are estimated at a total of 96,993 for the five km buffer area around MDA and a 66,526 for the five km buffer area around Class A Mining License. There are a number of Clan areas that overlap the five km buffer areas and account for these populations (Table 19, Table 20).

²⁴ WWF (2012) Artisanal and small-scale mining in and around protected areas and critical ecosystems: Liberia case study report. Report by Dr. Rob Small.

Table 19. Estimated population in five km buffer area around Mineral Development Agreements.

Clan Name	Area (ha)	Population in 2015
Bensonville City	1,684	1,493
Bloquiah	1,572	44
Boe	10,148	142
Boewein Toba	12	7
Bonkomu	5,680	1,841
Borbor	8,460	279
Bour	20,812	1,114
Boyeramah	81	22
Careyburg City	2,974	3,621
Crozierville Township	250	175
Dingmah	97	27
Dobli	764	235
Dowein	26,433	1,061
Fahn-Seh	7,006	7,932
Gbar	5,284	2,029
Gbeleyee	1,171	956
Gbeyi	3,086	1,485
Giamusu	3,822	1,047
Golorhama	3,202	1,547
Kannah	6,598	388
Kingsville Township	3,561	5,642
Konoquellah	19	17
Konowolola	1,400	799
Konoyea	8,803	2,500
Kpartolee	4,906	4,787
Kpoo	1,434	723
Lan-Kao	3,996	1,226
Mount Coffee Township	2,518	1,272
Neequiah	2,457	131
Neezonnie	12,658	395
Nyaforquellie	5,011	3,864
Nyehn	3,534	1,978
Pleemu	577	474
Sanoyea	7,007	3,601
Sehyi	12,134	9,293
Tchien Menyeya	11,746	10,662
Teekpeh	16,348	1,076
Telbawein	14,981	374
Trody	1,027	67
Upper Gbardru	8,339	586
Vayee	3,569	3,083
Weh	1,179	246
Wiah	4,852	3,652
Yarbayon	11,653	3,046
Zaweakomu	5,086	8,887

Zialu	9,259	609
Zor	3,904	2,268
Zulo	1,268	289
TOTAL	272,358	96,993

Table 20. Estimated population in 5 km buffer area around Class-A Mining License (MEL)

Clan Name	Area (ha)	Population in 2015
Bio Wiah	12,010	1,508
Darblo	22,416	3,340
Dobli	520	160
Fahnbulleh	386	196
Gbar	10,017	3,847
Gbarma	3,839	1,867
Gbeleyee	4,801	3,921
Gbeyi	3,167	1,524
Giamusu	7,070	1,937
Gion	1,045	412
Golorhama	3,525	1,703
Kiazolu	3,630	1,067
Kpoo	83	42
Laar	13,014	1,178
Lower Gbillibo	13	1
Lower Jebebo	15,061	2,409
Mana	21,695	5,865
Mt. Pennah	1,559	55
Mt. Seagboken	3,287	209
Passawe	13,935	9,459
Sehyi	11,121	8,517
Seimavula	51	52
Upper Jebebo	4,491	1,573
Wiah	4,533	3,412
Yangaya	9,125	1,264
Yarbayon	7,624	1,993
Zaweakomu	5,160	9,017
TOTAL	18,3177	66,526

2.5 Non-Designated Areas

Although a large area of land and forest has been designated or conceded for forestry, agriculture, mining or Protected Areas cover, approximately 43% of

Liberia's forest land remains un-designated for any specific land use²⁵. The largest block of this non-designated land lies in the central belt of Liberia, stretching from the capital Monrovia northwards to the counties of Bong and Nimba, and to the borders with Guinea and Ivory Coast. This is the most heavily populated and least forested part of the country and it serves the role of a 'Growth Corridor' in Liberia's economic development strategy (Figure 6).

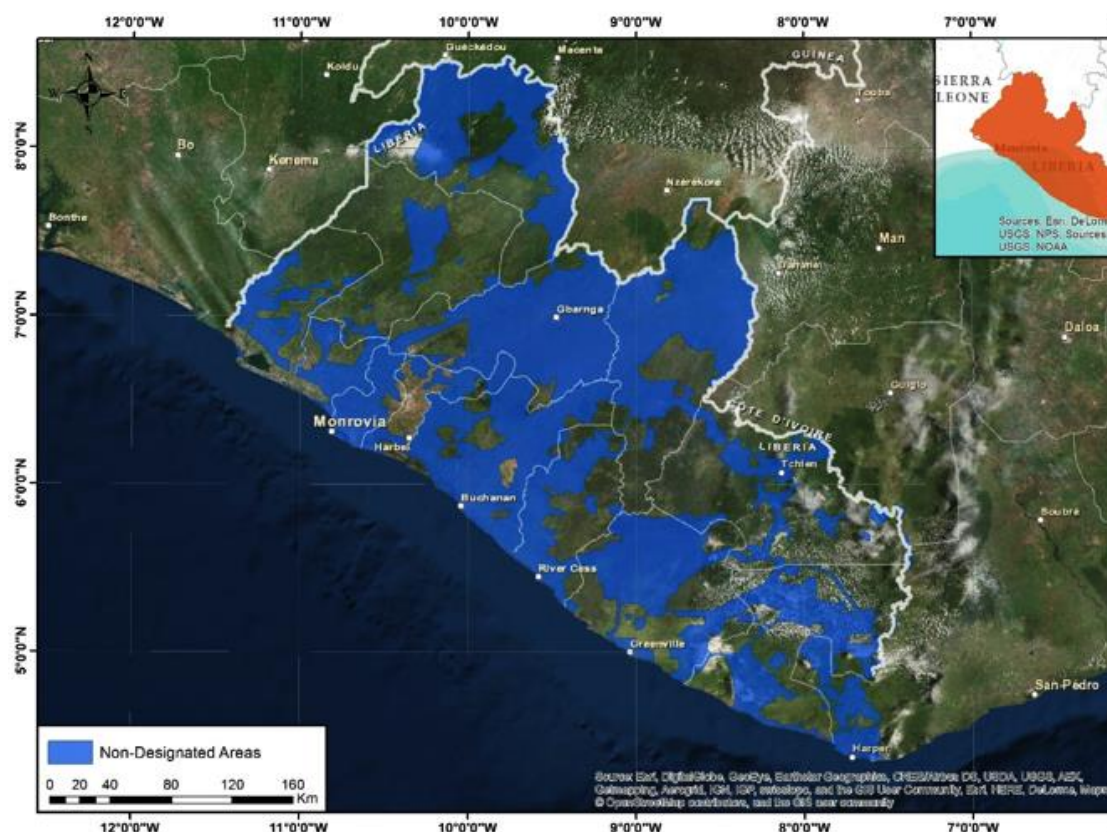


Figure 6 - Areas outside of government concessions

Overall, the land outside of concessions is less densely forested than the concession lands. It contains approximately 31% of >80% Forest compared to the total national figure of 45% of land covered by >80% Forest.

Nonetheless, the area outside of government concessions contains large blocks of high canopy forest cover in the South-East, West and North-West of the country and, considering all forested land, contains approximately 57% forested (30-80% and >80% Forest canopy cover classes).

²⁵ The 43% figure is derived from the following estimates: Total forest = 6,575,765 ha. Total forest in non-concession areas = 2,849,140 ha.

Table 21. 2015 Metria & GeoVille land cover on Non-Designated Areas

Land Cover in Non-Designated Areas	
Land Cover	Area (ha)
Forest cover > 80%	1,556,484
Forest cover 30% - 80%	1,292,656
Forest cover < 30%	1,057,028
Shrub	448,521
Grassland	438,549
Ecosystem Complex (Rock& Sand)	939
Bare soil	110,814
Mangrove & swamps	19,063
Settlements (urban & rural)	38,576
Surface water bodies	14,703
Clouds	5,162
TOTAL	4,982,495

Although not designated for a particular land use, the 'non-concession land' is used in a variety of ways by communities, smallholders and transitory people.

The scale and location of these various uses is not known. There is no national land use plan or land use inventory covering the non-concessions land uses, so by default it is land allocated for development. Work has started under the Land Commission to prepare a land use and land ownership inventory for Monrovia and for some of the other major towns, but this has yet to extend to rural areas.

The fact that there is less forest remaining in the non-concession area suggests that the level of use and pressure on remaining forest is relatively high. This pressure and the variety of land uses evident at community level is not confined to 'non-concession' areas. Communities also live in all the concessions and use the forest for shifting agriculture, hunting, artisanal mining, charcoal production and numerous other activities. Communities are also using land within the Protected Area Network.

It is therefore simplistic to relate the extent of smallholder land uses to the area of forest that in 'non-concession' but, it gives a practical starting point for estimating the relative importance of community-level drivers of deforestation and forest degradation. The analysis can be improved further by examining the distribution of settlements and roads across non-concession and concession areas.

The majority of the forested land in Liberia is vulnerable to use by communities and smallholders, based on the area that is in close proximity to settlements.

Using a buffer zone of two km around small settlements and five km around larger (>1,000 inhabitants) as a guide to where land is subject to use by smallholders, an

estimated 34% of the >80% forest canopy cover class is covered by this area and approximately 67% of all the 30-80% canopy cover forest in the country (Figure 11).

A second indicator of land use by communities and smallholders is proximity to roads. If a two km buffer is included either side of marked roads, an estimated 42% of the >80% canopy cover forest is included in this area and 55% of the 30-80% canopy cover forest.

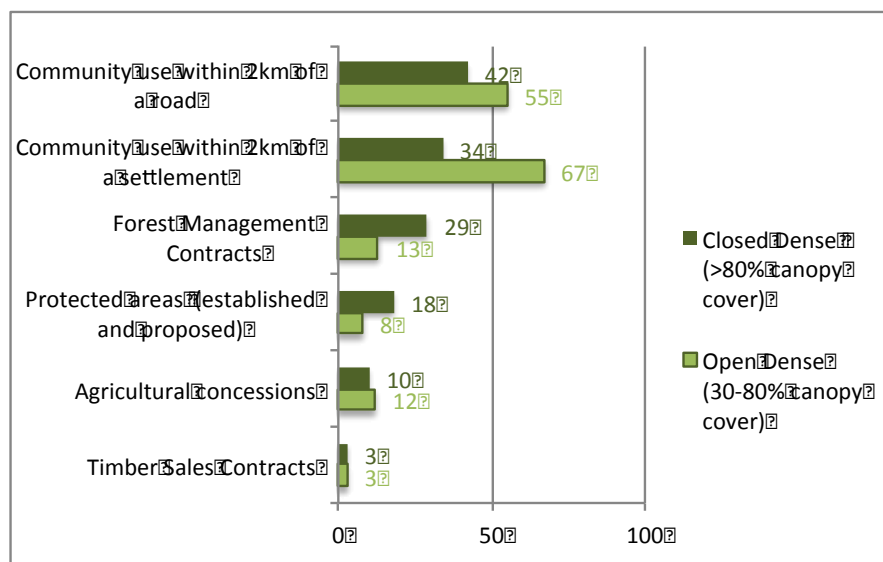


Figure 11 - Percentage of Liberia forest associated with land uses

Source: Rothe D, Golombok R, Lorenz K (2015) *Geographical analysis of targeted landscapes: Liberia* (Land Cover data from Metria Geoville land cover assessment, 2015).

Based on these two indicators – proximity to settlements and proximity to roads – land use by communities and smallholders accounts for the largest proportion of forested land in Liberia. The overall pattern of remaining forest cover in Liberia supports this finding: the blocks of high canopy forest cover that remain are furthest from roads and settlements. The degradation of forest that has occurred previously can be considered largely a result of this smallholder activity, given that large-scale use of land for logging, palm oil and other concessions started only recently in this period and on a minority of the land area that is permitted for development.

2.5.1 Shifting cultivation and other community-level uses of the forest

National datasets reveal the general pattern of land use and impact on forest described above, but there is no national level or comprehensive data on the location or scale of the different land uses that are included in the ‘non-concession’ category. Despite the lack of national data on community level land

uses, activities such as shifting agriculture, chainsaw logging, charcoal production and firewood collection are commonly understood by professionals working in the forestry and environmental sectors to be significant drivers of degradation and deforestation, perhaps the most significant drivers. They were recognized as such in the 2012 R-PP and need to be considered within a REDD+ strategy.

Over 50% of the total land in Liberia is used for shifting cultivation, according to figures cited in the R-PP and based on a previous (2004) land classification study. This included extensive and intensive shifting agriculture as two distinct land use categories and associated them with 19% and 33% of total land use, respectively. The accuracy of these figures is likely to be low because of the inherent difficulties of identifying specific land uses from satellite imagery. Furthermore, shifting agriculture involves a rotation of clearance, cropping and then abandonment and regrowth. The measurement of the area of forest affected, and how it is affected, is therefore very complex.

But broadly speaking, the 2004 estimate is in line with proportion of land that is accessible for community use, although only a small proportion of that land will be cleared and actively farmed at any one point in time. It also fits with the understanding that most farming in Liberia takes place in and around forests and is 'slash and burn' shifting cultivation²⁶. Although around 30-40% of the population live in Monrovia and smaller regional centers, most of the population is rural and producing all or most of their food from forest areas²⁷.

The national policy is to move towards settled agriculture, particularly in the low lying coastal belt. There has been a particular emphasis on lowland swamp rice production and this has captured a large proportion of international donor support to the food and farming sector. Commercial farming of rice and other cash crops (cocoa, rubber and coffee) was all but abandoned during the conflict, it being estimated that less than 10% of agricultural land was being cultivated by 2003²⁸. Liberia is therefore heavily dependent upon food imports, although no longer on food aid. Structural change in the farming sector is however likely to result in changes to land use and impacts on forest only in the medium-to-long term.

²⁶ Government of Liberia (2008) Food and Agricultural Policy and Strategy.

²⁷ Government of Liberia. 2008 National Population and Housing Census. Liberian Institute for Statistics and Geographical Information Services, Monrovia

²⁸ EPA (2012) Initial National Communication of Liberia – citing figures from a UNFFAO study in 2003.

2.5.2 Chainsaw milling (pit sawing)

The domestic industry of felling and milling logs by chainsaw (known as pit sawing) expanded in the post-conflict period. Prior to that, it was a marginal industry largely based on the use of forest residues from the large scale, concession-based operators. The ending of the export-logging industry with the 2003 UN Security ban on timber exports (lifted in 2006) – and the cancelling of historic logging concessions in that same year – created a vacuum which was rapidly filled by the informal chainsaw milling industry. In effect, all domestic timber comes from chainsaw milling; an illegal and largely ungoverned activity, hence data on the scale and impact of the industry are scarce.

A study of chainsaw milling commissioned by the FDA in 2009 described how logs are felled and planked on site, usually within five km of a roadside, before being carried to the road for transport to market, mostly in Monrovia²⁹. Chainsaw milling was found to normally take place in community-owned forests, often as part of the process of clearing forest for agriculture, or in forestry concessions that had already been selectively logged by the main operator.

The same 2009 study estimated an annual harvesting rate of 280,000 to 650,000 m³ of timber. No estimates are given on the area of forest affected or the extent of forest degradation or deforestation that results from chainsaw milling, but the total annual allowable cut – the FDA's estimate of what can be removed sustainably – for Liberia's forests at the time of the study was 750,000 m³. **Thus, in 2009, the informal chainsaw milling industry was possibly as large as the entire potential formal forestry sector.** A 2009 study of the seven forestry concessions allocated at that time estimated that the maximum annual cut to allow a sustainable 25-year rotation would be around 220,000 m³. In other words, **pit sawing production is up to three times greater than the maximum potential output of the existing forestry concessions**³⁰.

Based on these estimates, and recognizing that pit sawing is effectively unregulated, **it is reasonable to estimate that pit sawing is a more significant cause of forest degradation and deforestation than logging on forestry concessions.**

²⁹ Blackett, Lebbie, Marfo (2009) Chainsaw logging in Liberia. Forestry Development Authority, Monrovia 11 August 2009

³⁰ Shearman (2009) Liberian forest cover and timber projections. Report commissioned by Green Advocates, Monrovia.

2.5.3 Charcoal production

Charcoal use in Monrovia was estimated to be around 4.1 million bags of 25 kg in 2010³¹. This quantity is estimated to be equivalent to 1.1 million m³ of wood. This is four to five times greater than the maximum annual sustainable harvest from the formal forestry sector. **Like pit sawing, charcoal production probably represents a greater driver of forest degradation and deforestation than the formal forestry sector, but its informal nature makes it difficult to accurately estimate.** Despite the value of the charcoal industry, production, trading and consumption are almost entirely unregulated. The FDA operates a rudimentary licensing system for transporters but recognizes that they do not have effective control or monitoring at present³².

Most wood for charcoal production is currently thought to come from old rubber trees felled as part of the restoration of plantations after neglect in the war. The clearance of land for palm oil and other agriculture is also likely to be another source of wood for charcoal production. Charcoal is therefore a by-product of other forest conversion activities, but where and when supply is low, additional fuelwood collection acts as a driver of deforestation and/or forest degradation to meet the demand. It is closely linked to shifting agriculture; when land is cleared for cropping, the sale of timber for fuel provides cash for seeds and planting.

As alternative energy sources are slow to develop and urban populations grow, it is likely that charcoal consumption will increase or at least continue at its current level. Substantial international assistance is going into Liberia's energy sector, which was entirely destroyed during the war. It is one of the major sectors for international donor support and there is an ambition to provide electricity to approximately 35-40% of Liberia's population in the next decade, through a combination of indigenous heavy fuel oil, hydro-electric generation and connection to the West African Power Pool – a cross-border grid system. Decentralized power generation and mini-grid systems are also being piloted.

However, by 2010 less than 1% of Monrovia's population was connected to a public electricity grid and practically none of the rural population³³. Electricity tariffs are 0.43

³¹ Van der Plas (2011) Liberia: Project Identification. Sustainable Charcoal Supply Chain.

³² Rothe (2012) Improving access to sustainable wood energy in Liberia. Project Identification Fiche for EU.

³³ World Bank (2011) Options for the development of Liberia's energy sector

US\$ kWh on average, three times higher than the Sub-Saharan African average³⁴. It is therefore expected that most of the population will remain dependent upon wood and charcoal for energy in the near future. The National Energy Policy³⁵ prioritizes universal energy access and protection of the most vulnerable households, and it recognizes the importance of woodfuel by promoting greater efficiency of use.

2.5.4 Artisanal mining

A study of artisanal and small-scale mining (ASM) in 2009 estimated that 100,000 people were engaged in the activity nationally, but gave no indication of the area of forest affected. This study included a review of previous work on ASM, which is very limited.

ASM was found to be occurring in and around Sapo National Park – the flagship Protected Area in Liberia – and other Proposed Protected Areas. The case of Sapo provides an indication of the scale and impact of ASM in Liberia. Gold was discovered in the 1990s and the number of ASMs increased after 2013 when the park was overrun by militia opposed to the Taylor government. The names of the two main mining camps in Sapo; 'Iraq' and 'Afghanistan' reflect the association with conflict. By 2005, approximately 3,000 to 5,000 illegal miners in the National Park were reported. That year the Government, with troops, cleared the Park of miners, and a second similar evacuation took place in 2010. Clearance of the forest occurred in the immediate mining areas, which are relatively small. Hunting pressure was found to have greatly increased in the surrounding area. No use of mercury and consequent poisoning of water courses were reported, although this was expected to change as Liberian miners adopted practices used in neighboring countries.

ASM can be legal with licenses issued by the Ministry of Land, Mines and Energy but the cost of the license is high for small operators. At the time of the 2009 study there were 48 licensed ASM operators. The national minerals policy is firmly in favor of large scale industrial mining.

The impacts of ASM on forest at a national scale is unknown and will be sporadic and mobile, according to where the next 'gold rush' of diamond finds occurs. The available evidence suggests it is not a major driver of deforestation and forest degradation.

³⁴ PRSII (2012)

³⁵ National Energy Policy: an agenda for action and social and economic development. Ministry of Land, Mines & Energy, May 2009

2.5.5 Population in Non-Designated Areas

Areas that are outside of designated areas are extremely vulnerable to land use change as there is comparatively little control or enforcement on land use, particularly when it comes to extracting timber and other forest commodities.

Most of Liberia's rural population is dependent on these forests and their various products and ecosystem services as they play an important role as a safety net for vulnerable and marginalized people. The forest areas in close proximity to large populations and roads are especially threatened by clearance and forest degradation from agriculture, pit sawing, charcoal production and other forest uses.

The total population of lands outside of the designated areas equates to an estimated 3.3 million people. This amounts to about 78% of the total estimated population of Liberia for 2015, over 4.2 million people. There is a large area of high canopy forest cover that is either close to a settlement area or is relative close to Primary/Paved roads and hence is more vulnerable (Figure 7).

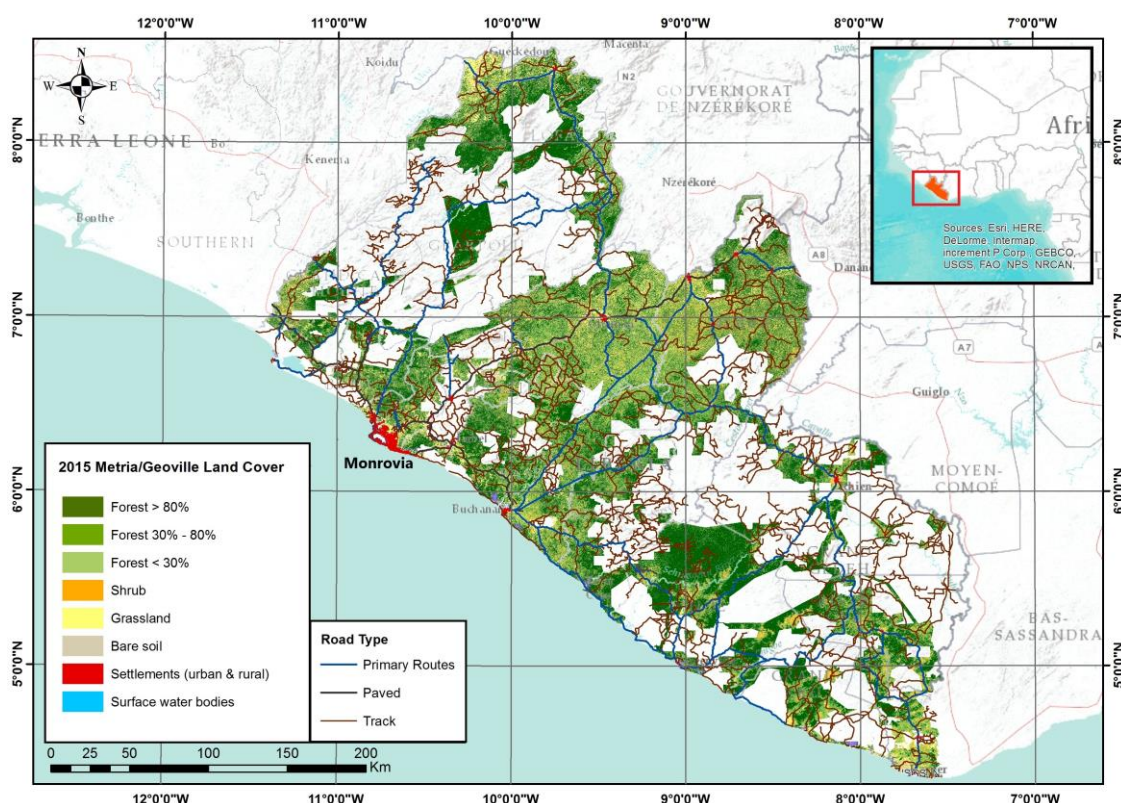


Figure 7 - Infrastructure on 2015 Metria & GeoVille land cover in Non-Designated Areas

Community-level use of forested land as described above is likely to increase significantly as the population increases and as levels of productivity and

consumption increase during the time period that Liberia moves from a post-conflict nation to an aspiring middle-income country. At the same time, the land available to communities and smallholders for subsistence and commercial uses is diminishing substantially. Although the large area of forest land under concession for forestry, agriculture or mining currently accommodates community use, this will decrease as the concessions become more developed and more strictly controlled by the main operators. The resulting 'squeeze' of increasing forest use into a decreasing area is likely to accelerate the community-level drivers of deforestation and forest degradation.

3. Land Use Suitability

In the previous chapter, current and potential land use were considered in terms of the areas designated by government for specific land uses and how this relates to forest cover. Because the commercial concessions and the Protected Areas are mostly undeveloped they give an indication of future land use pattern.

This chapter presents an alternative way of predicting future land uses based on underlying factors such as population, distance from roads and topography. It updates a 2006 land use suitability modelling exercise which was done as a contribution to land use planning in Liberia.

The lack of detailed national biophysical data means that only a limited number of suitability factors can be modelled. The results are therefore "high-level" and should be seen as no more than indicative.

3.1 Forest conservation suitability

The Nebel *et al.* (2006) study considered distance from roads, within or near high canopy forests and near the Atlantic Ocean the most important factors in defining areas that are most suitable for conservation. The existing Protected Areas were also considered always suitable for conservation. The weights and relative ranks for the layers were developed by Conservation International, through regression analysis, correlated to biological diversity data from Fauna and Flora International (Table 22, Figure 8).

Table 22 - Forest conservation suitability relative weightings and rankings in percentage.

	Variable	Relative Ranks	Value Class	Weight (1-5)
CONSERVATION			Population/Km²	
	Population Density	0%	0-10	5
			10.01-30	4
			30.01-100	3
			100.01-200	2
			200.01 +	1
			Metres	
	Distance From Roads	8%	0-1000	2
			1000.01-3000	3
			3000.01-5000	4
			5000+	5
	Distance from Edge	78%	Metres	
			0-1000	5
			1000.01-3000	4
			3000.01-5000	3
			5000+	2
	Proximity to Ocean	14%	Metres	
			0-1000	5
			1000.01-3000	4
			3000.01-5000	3
			5000+	2
	Protected Areas	YES	Designation Protected	YES

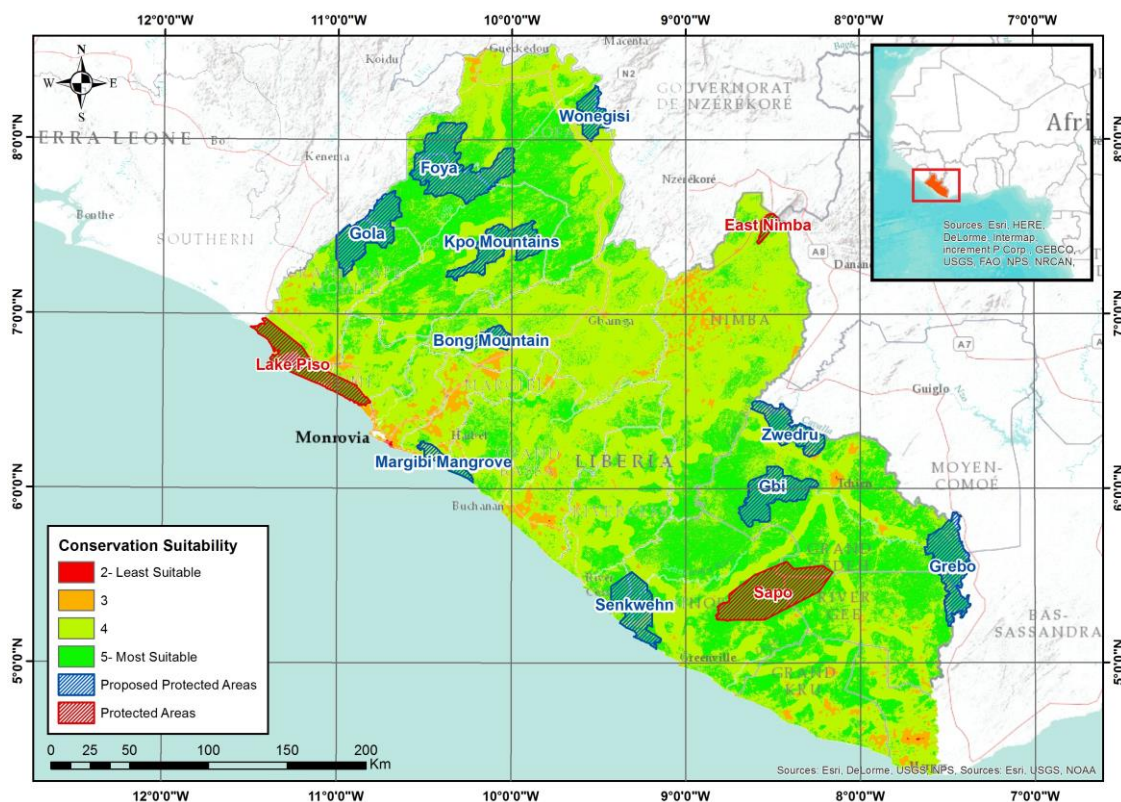


Figure 8 - Conservation suitability model output (1- Most suitable; 5- Least suitable)

3.2 Commercial forestry suitability

The areas that were considered most suitable for commercial forestry are low in population, have a high canopy forest cover and have good road access. Existing Protected Areas and areas that have a slope greater than 30% were designated as always unsuitable for commercial forestry. Other parameters were considered in the study as model variables but not used in the final outputs. Weights and relative ranks were developed by the LFI Commercial Forestry stakeholder group for the work carried out (Table 23, Figure 9).

Table 23 – Commercial forestry suitability relative weightings and rankings in percentage.

	Variable	Relative Ranks	Value Class	Weight (1-5)
COMMERCIAL			Population/Km²	
	Population Density	20%	0-10	5
			10.01-30	5
			30.01-100	4
			100.01-200	2
			200.01 +	1
			Class	
	Land Cover Type	60%	Forest < 30%	2
			Forest 30% - 80%	3
			Forest > 80%	4
			Other	1
			Metres	
	Distance from Road	20%	0-3000	5
			3000.01-8000	4
			8000+	3
			Designation	
	Protected Area	NO	Protected	0
			Percent	
	Slope	NO	Above 30	0

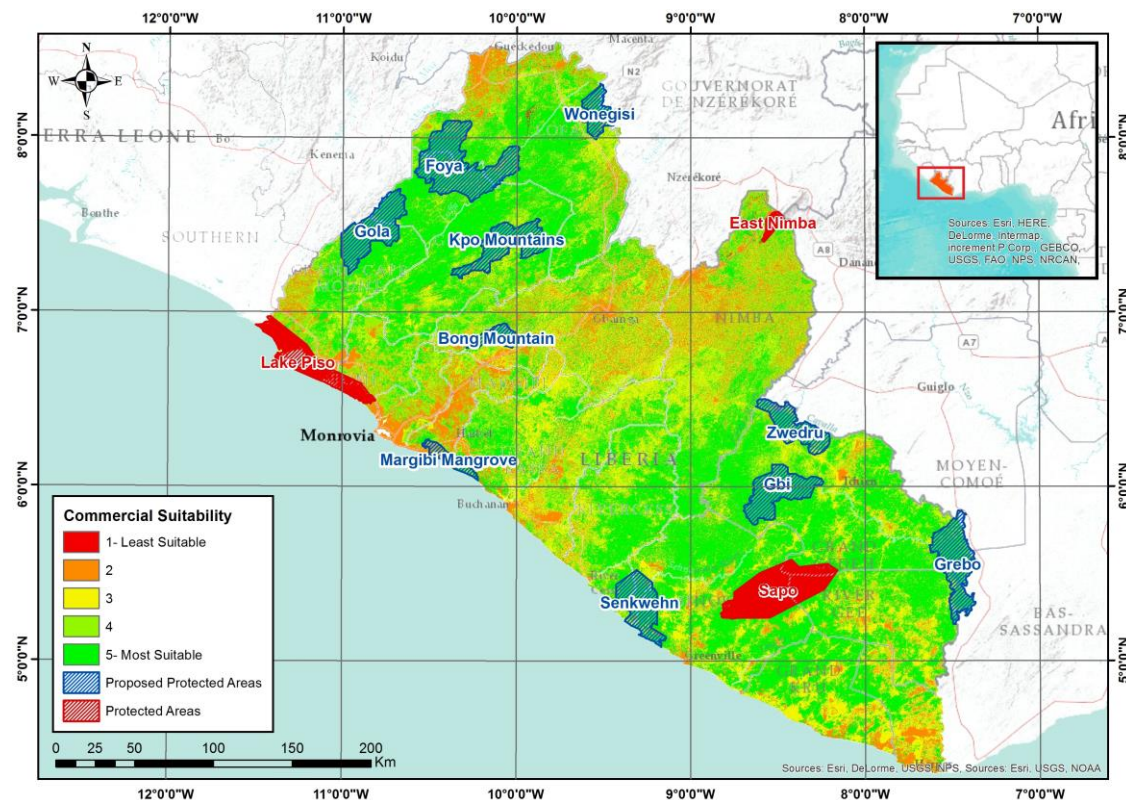


Figure 9 - Commercial suitability model output (1- Most suitable; 5- Least suitable)

3.3 Community forestry suitability

The areas that were deemed most suitable for community forestry were those that have a moderate population, a mixed forest and agriculture land cover and are near roads and settlements. The Protected Areas were also designated as always unsuitable for community forestry. The layers used and the weighting allocated to them was developed and decided upon by the Liberia Forest Initiative's Community Forestry stakeholder group, the layers used were allocated equal weighting and considered of equal importance (Table 24, Figure 10).

Table 24 - Community forestry suitability relative weightings and rankings in percentage.

	Variable	Relative Ranks	Value Class	Weight (1-5)
COMMUNITY	Population Density	25%	Population/Km²	
			0-10	5
			10.01-30	5
			30.01-100	4
			100.01-200	2
			200.01 +	1
	Distance from Roads	25%	Metres	
			0-1500	5
			1500.01-3000	4
			3000.01-5000	3
			5000.01-10000	2
			10000 +	1
	Land Cover Type	25%	Class	
			Other	1
			Grassland	3
			Shrub	4
			Forest < 30%	5
			Forest 30% - 80%	3
			Forest > 80%	3
	Distance from Settlements	25%	Metres	
			0-3000	5
			3000.01-5000	4
			5000.01-7000	3
			7000.01-10000	2
			10000 +	1
	Protected Areas	NO	Designation	
			Within Protected	0

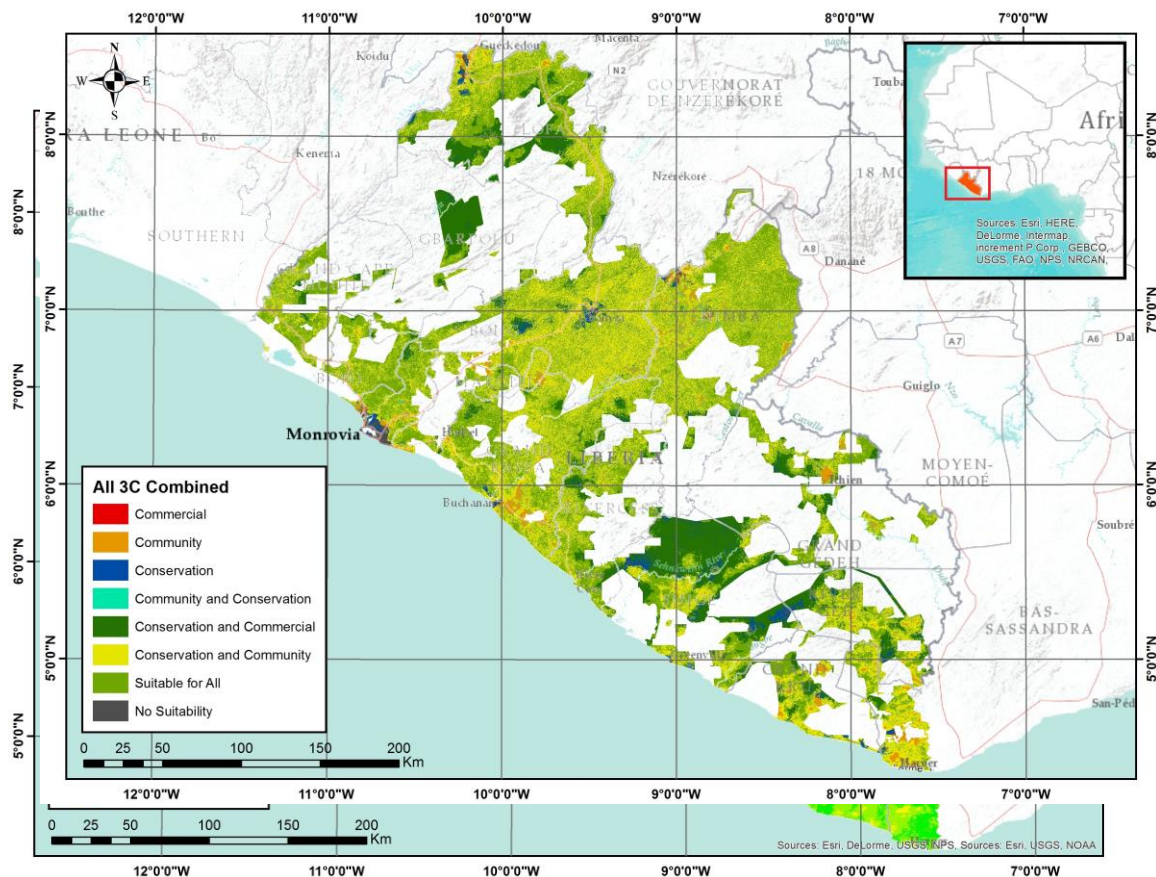


Figure 10 - Community forestry suitability model output (1- Most suitable; 5- Least suitable)

3.3.1 Non-Designated Areas on Community, Commercial and Conservation Areas

It is clear from Figure 11 that the largest areas within the Non-Designated area fall under 'Conservation and Community' and 'Suitable for All' and that there are also large blocks of area that are dedicated to 'Conservation and Conservation'. It should also be noted that there are some areas, particularly towards the South-East, in Sinoe County, and in Central Gbarpolu that are suitable for conservation and community use.

3.4 Combining the 3C model outputs

The three model outputs for Community, Commercial and Conservation areas were combined to create a layer displaying the combined suitability for Liberia land use (Figure 11). To combine these, the raster calculator was used to prepare the outputs for combining, by giving the suitability unique values to identify the layer properties when combined. The layers were then combined by adding the layers together and producing a layer that has unique codes that would identify and categorize particular areas based on the combined 3Cs. These uniquely coded areas were then defined by

the areas of highest suitability for each of the 3C categories (resulting rank ≥ 4), defining that area based on what it was considered most suitable for.

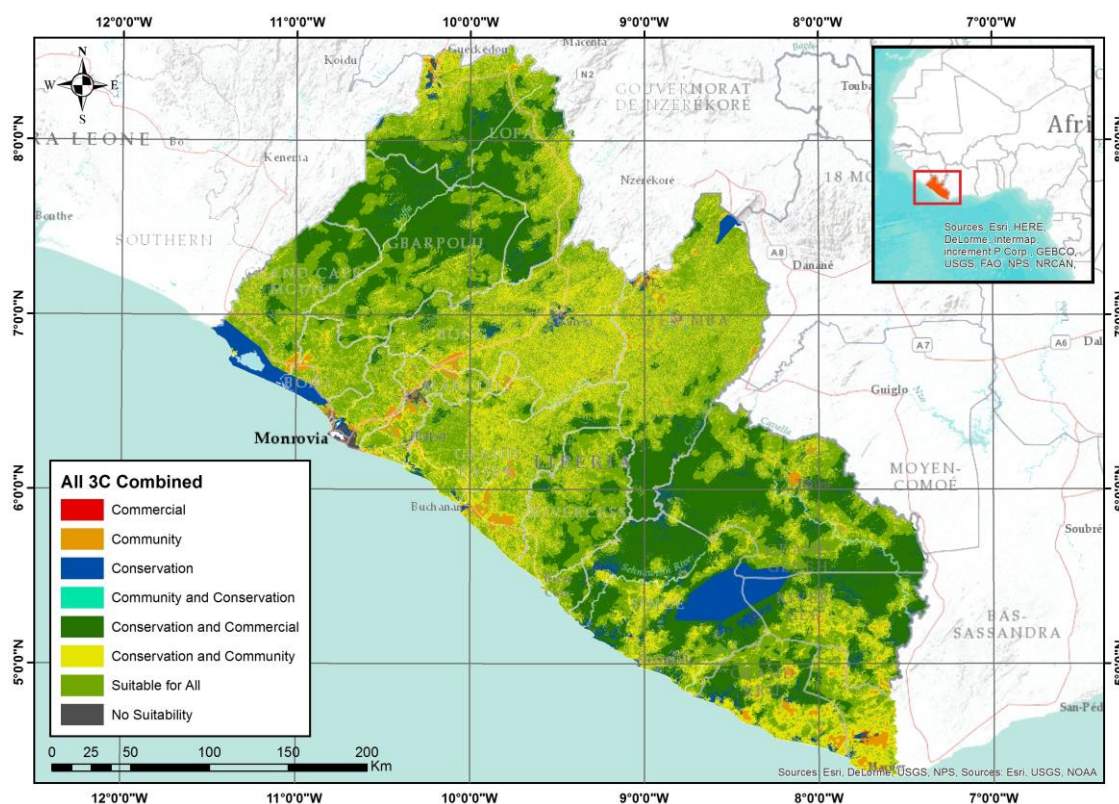


Figure 11 - Combined output for the 3C suitability layers

3.5 3C model results

It is clear from the results that there is a large amount of overlap in suitability of land uses, particularly in those areas that are both designated for **Conservation and Commercial**, as well as **Conservation and Community** uses; both have an estimated overlap of over 2.4 million ha (Table 25). The areas that indicate suitability for all three of land uses – Community, Commercial and Conservation – accounts for the largest overlapping area, totaling over 3.6 million ha of the total area within Liberia.

Table 25. Area data for combined suitability of 3C areas

Classification	Area (ha)
Conservation	553,938
Community	235,494
Commercial	1,475
Community and Conservation	40,919
Conservation and Commercial	2,624,885
Conservation and Community	2,449,566
Suitable for All	3,653,320
No Suitability	33,031
TOTAL	9,592,628

When looking at the areas that fall under high suitability of the individual 3Cs, the areas that are noted as only being classified as one of the 3Cs from each of the model outputs – e.g. areas that are only suitable for Community, Conservation or Commercial use – can also be noted from Table 25.

Conservation Areas

An estimated 552,938 ha of area within Liberia are defined as suitable only to conservation, although this figure also includes Protected Areas. The total area of conservation suitable land outside of these Protected Areas equals 290,898 ha. These resulting areas are spread widely across Liberia in fragmented patches. The wide spread is primarily the result of such large areas being classified under “Forest > 80%” in the 2015 Metria & GeoVille land cover layer.

Commercial forestry areas

The areas that have been determined as suitable for commercial forestry totals a very small area of Liberia, at an estimated 1,475 ha. These areas are located around the areas that are highly suitable for community forestry. The majority of this land is located in the East of Nimba County.

Community forestry areas

It is clear from the combined model outputs that the areas of community forestry account for an estimated 235,494 ha of the surface area of Liberia. The areas should be noted as being primarily in central Liberia. Notable high community forestry suitability areas include Nimba, Grand Bassa, Bong and Margibi Counties.

4. Conclusions

The land cover analysis carried out under this study provides insight into sectors that have been identified as the main drivers of deforestation and degradation in Liberia, namely:

- **Forestry:** commercial logging and chainsaw logging;
- **Agriculture:** shifting cultivation and plantations/permanent agriculture;
- **Energy:** charcoal production
- **Mining:** mineral extraction.

Community land uses affect the largest area of forest land. They are the principal land uses in the 43% of the total forest land that is not formally designated by the Government of Liberia for commercial or conservation purposes. Community land uses, of which there are many types, extend also over the concession areas (most of which are to be developed) and even intrude into Protected Areas (most of which are yet to be established).

There are no robust data with which to quantify the different community land uses. The information that is available does however indicate that shifting agriculture, pit sawing and charcoal production are all drivers of deforestation and forest degradation that threaten a larger area of forest.

- Based on the area of land that is easily accessible to settlements, a rough estimate of the area of forest land affected by shifting cultivation is 34% of the >80% canopy forest and 67% of the 30-80% canopy forest.
- Based on the volume of timber that is thought to be consumed by the pit sawing industry, it can be estimated that this affects an area at least as large as the total area that is subject to FMC logging concessions (24% of total forest).
- The volume of timber consumed for charcoal production is estimated at around double that by pit sawing, but a significant (if unknown) proportion of this comes from by-product timber cleared from rubber plantations that are being replanted, or new agriculture plantations that are being cleared. A rough and possibly conservative estimate of the area of forest affected by charcoal production is therefore the same as that for pit sawing; in other words, it is greater than the area affected by all existing and proposed logging concessions.

Forestry concessions are the second largest category of land use by area. If all existing and proposed FMCs were exploited this would affect 24% of the total forest area. FMCs account for 29% of the most high canopy forest cover (>80% canopy cover). Furthermore, the scale and positioning of FMCs, often between Protected Areas or Proposed Protected Areas and covering large blocks of high canopy forest cover, suggests that they should be an important part of a REDD+ strategy.

Palm oil is the third largest land use, based on the maximum area that is permitted for development by concession agreements. It accounts for 5% of the total forest area.

The remaining land uses, in order of potential forest area affected, are Timber Sales Contracts (3% of total forest), Community forestry agreements (2%), Mining (2%) and then rubber and other plantations (1%) (Figure 12).

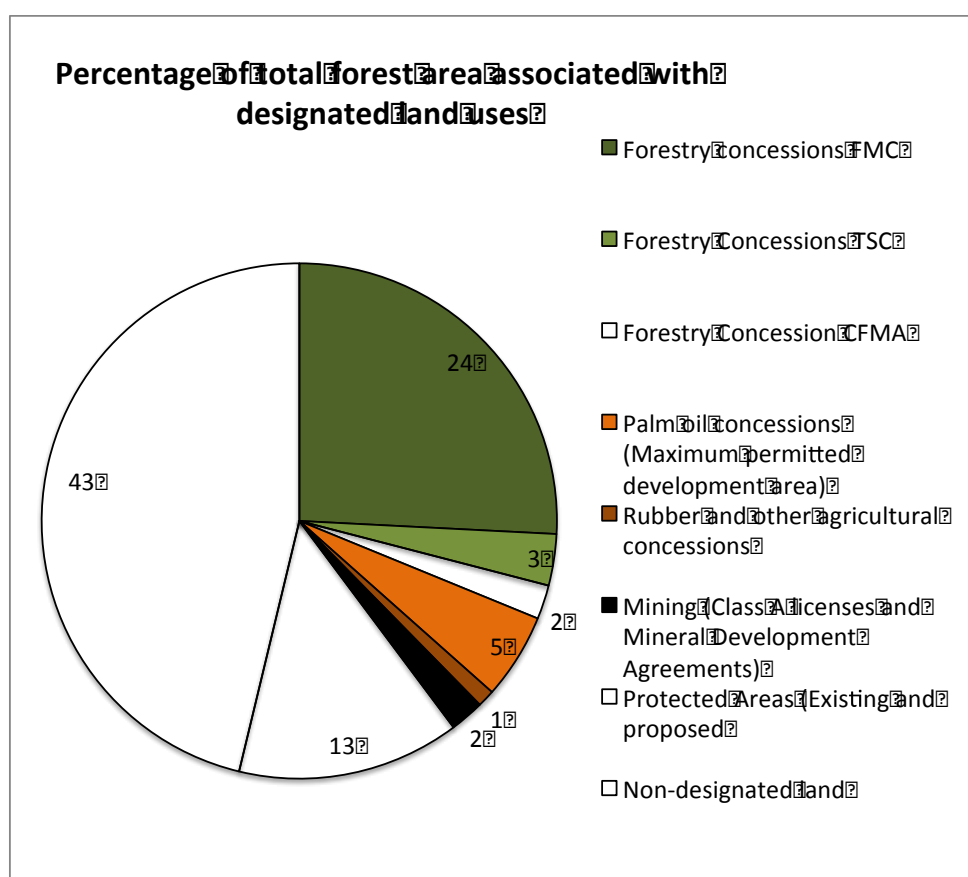


Figure 12 - Percentage of the total forest area in Liberia associated with designated land uses

There is particular need to look closely at the areas that fall outside of private, Governmental and designated use as these are the areas that could be considered most likely to be impacted by unregulated activities that cause deforestation and forest degradation. The "Non-Designated" include an estimated 78% of the population of Liberia and, although it does not account for the majority of high canopy forest cover

(Forest >80%), approximately 3,906,168 ha in these Non-Designated areas are still categorized as forested land (>30% canopy cover)

Areas of particular note, identified through the work carried out in this study, should be the north of Sinoe county and central Gbarpolu county. There are large areas in both that are Non-Designed and are covered primarily by high density forest. These areas in Sinoe and Gbarpolu are identified as being suitable for both conservation and commercial forestry, leading to potential competition between these two land uses and potential conflict if either expand at the expense of communities who rely on forest resources.

Mineral extraction is a growing industry in Liberia with increased exploratory work, particularly for gold and iron ore. It is clear from the analysis work that significant areas of high canopy forest cover fall within the surrounding areas of mining localities.

The population analysis work in the areas that are under Proposed Protected Areas status indicated that some – such as Margibi Mangrove and Bong Mountain – are surrounded by large populations and are therefore more vulnerable to encroachment and deforestation and forest degradation.

Annex 1: Review of Availability and Quality of Data

GIS Data

There are multiple data sources compiled for this work; the main sources include Liberia Forestry Initiative, the FDA, the World Bank and the United Nations Humanitarian Information Centre for Liberia (UNHIC), Conservation International (CI), Global Forest Watch (GFW), Fauna and Flora International (FFI), Open Street Map (OSM), European Space Agency (ESA), USAID, Tetra Tech, Metria & GeoVille as well as various individual data producers and are specific project work carried out around Liberia. There is a clear lack of metadata (content, quality, condition, origin, and other characteristics of the data layers) of the data obtained, but the SESA team has worked to the best of its ability to determine completeness, correctness, and currency of the data that it has obtained so that such considerations are taken into account in its data selection.

Several recent studies deal with identification of Liberia's forest land use suitability using GIS methods to identify, prioritize and make land use recommendations based on the available data. Of these, the SESA scoping report work accumulated a large amount of GIS data, although some of this, notably forest concessions and Protected Areas, is out of date and updated by newer versions³⁶. Mapping procedures in the SESA report identified priority areas of environmental and socioeconomic importance ('Hotspots'). Environmental hotspots were ranked by overlaying forest cover from the Metria & GeoVille land cover survey with designated PA areas, biodiversity KBAs and the Junker priority sites³⁷. Socioeconomic factors representing pressure from mineral exploration licenses, estate crops and forest industry, i.e. Forest Management Contracts (FMC) and Timber Sale Contracts (TSC). Both methods are valid as indicators of forest significance and the economic pressure (or threat in forest conservation terms) but make no use of population density in terms of pressure or

³⁶ Tetra Tech. (2015). Strategic Environmental and Social Assessment for the REDD-Readiness Preparation Activities of the Liberian Environmental Protection Agency.

³⁷ Junker, J., Boesch, C., Freeman, T., Mundry, R., Stephens, C., and Kühl, H. S. (2015). Integrating Wildlife Conservation with Conflicting Economic Land-Use Goals in a West African Biodiversity Hotspot. *Basic and Applied Ecology*. Volume 16, Issue 8, December 2015, Pages 690–702.

prospective future function - i.e. in terms of potential land use options for agriculture, commercial / community forestry or conservation / protection.

The World Bank-commissioned 'Targeted Landscapes' paper reports a broad spatial analysis in which national regions and districts are prioritized in terms of conservation value (for REDD+ conservation)³⁸. Vulnerability estimates were based solely on physical criteria and the authors acknowledged the significance of lacking socio demographic information in their analysis. The two main forested regions in the North-West and South-East) were identified as priority intervention sites plus the North Nimba landscape.

Data Used in the Analysis Work

Land Use and Land Cover Maps

Land Use and Land Cover (LULC) maps are fundamental to REDD+. Without a series of scientifically defensible LULC maps, a REDD+ program would lack a number of fundamental inputs, including a baseline assessment of various LULC metrics (e.g., forest cover, deforestation, and forest degradation), an underlying methodology for MRV, and analysis of the impact of drivers (i.e., change in forest cover and attendant forest carbon emissions attributable to each driver). There are very few land use layers available for Liberia but a 2015 land cover layer has been developed through efforts by the Metria & GeoVille contract with the FDA's REDD+ readiness program.

The Metria & GeoVille land cover mapping, used Rapideye five m resolution data acquired in 2014 to produce land cover maps and statistics for Liberia composed of 11 classes (Table 26). The first of these corresponds to the highest value: high canopy forest cover. The second is a wider class that includes a wider range of forest, from open, fragmented, and logged forest to nearly intact primary forest. As the third class of forest of less than 30% cover will include mainly non-permanent forest, shifting cultivation and secondary forest this is not used in the following analysis. The purpose of the following is to provide information on how much high value forest is contained within the 'allocated' and 'non-allocated' use categories, and its suitability either for community, conservation or commercial forestry, taking into account population pressure and clan boundaries.

³⁸ Nketia, S.K., Larmie, S.A., Ansah, N.Y.O. (2016). Environmental and Social Management Framework (ESMF) (Final draft report). Liberia Forest Sector Project. Government of the Republic of Liberia.

Table 26. Area data for the 2015 Metria & GeoVille land cover layer

Land cover class	Hectares	% of mapped area
Forest cover > 80%	4,389,270	45.50%
Forest cover 30 - 80 %	2,186,495	22.60%
Forest cover < 30%	1,529,949	15.80%
Mangrove & Swamps	37,158	0.40%
Settlements	44,595	0.50%
Surface Water Bodies	60,374	0.60%
Grassland	625,332	6.50%
Shrub	606,928	6.30%
Bare Soil	173,690	1.80%
Ecosystem complex (rocks & sand)	2,271	0.02%
Clouds (unmapped)	14,336	0.15%
Total mapped area (land and inland water)	9,656,062	100%

Topography

Topography, or elevation, is a fundamental variable for nearly all ecological analyses and modelling approaches related to REDD+ priorities. Elevation largely defines the distribution and variation of numerous natural phenomena, including vegetation zones, land systems, habitats, and hydrologic networks (or, rivers and streams). Shifts in elevation not only correlate with particular land cover types, but also with potential for land cover change; slope, a derivative of elevation, has an inverse relationship with the incidence of deforestation (the greater or steeper the slope, the less likelihood for land cover change). The principle sources for accurate elevation data are the free, publicly available SRTM and Global Digital Elevation Models (GDEM)³⁹. Subsets of these covering Liberia exist online and through various data sources.

The topological data sets, both DEM and DTM, have been created for the whole of Liberia using freely available and reliable datasets, at varying degrees of resolution and for a few different scales of extent. In terms of national datasets, SRTM data allows for a 1 arc second resolution (30m) DEM and is freely available for the whole of Liberia⁴⁰.

³⁹ For more information on SRTM, visit <https://lta.cr.usgs.gov/SRTM>. For more information on GDEM, visit <http://gdem.ersdac.jspacesystems.or.jp/>

⁴⁰ A possible next step would be that a DEM could be derived from freely available Sentinel-1 radar data at 10m resolution and next steps would be to carry out such a task at a national level, if needed and not already done.

Protected Areas

Proposed and existing Protected Areas in Liberia are mapped using data obtained from the FDA in 2015. In addition there are a number of sources that cover global protected and Proposed Protected Areas that can be accessed. This includes ProtectedPlanet.net, an online interface for the World Database on Protected Areas (WDPA), a joint project of IUCN and UNEP, and a comprehensive global database on terrestrial and marine protected areas.

Inconsistencies in the boundaries of Protected Areas and Proposed Protected Areas exist within the national and international data sources so it is recommended that an exercise be undertaken to standardize the boundaries as well as attribute information and metadata of these Protected Areas with the Liberian government. This would be carried out by combining and drawing together all information and data sets for the Protected Areas and drawing on expert opinions on the Protected Areas from relevant stakeholders, with particular emphasis on forest reserves. This would help in creating an agreed-upon and standardized set of data that can be built on and used for REDD+ activities that does not rely on Liberian data being sources from global data sets.

Biodiversity

The Metria & GeoVille land cover data which identifies general land cover categories based on estimated tree cover or lack thereof can be used to identify areas of high and low potential plant biodiversity. One study used Liberia's chimpanzee population as a proxy for total biodiversity and related field observations with Marxan software⁴¹. The relationship between biodiversity and forest fragmentation demonstrated with Marxan software concludes a high amount of terrestrial biodiversity is not adequately included in the Government's existing network of PPAs.

The IUCN Red List of Threatened Species contains assessments for just over 76,000 species, of which about two-thirds have spatial data. These data sets include Amphibian, Marine & Terrestrial Mammal, Reptiles, Birds as well as a number of marine and freshwater groups covering Liberia. The data is available as ESRI shapefiles format and contains the known range of each species. Ranges are depicted as polygons, except for the freshwater HydroSHED tables. The shapefiles contain taxonomic information, distribution status, IUCN Red List category, sources and other details about the maps.

⁴¹ Junker, J., C. Boesch, T. Freeman, R. Mundry, C. Stephens, and H. S. Kühl. (2015). Integrating Wildlife Conservation with Conflicting Economic Land-Use Goals in a West African Biodiversity Hotspot. *Basic and Applied Ecology*. Volume 16, Issue 8, December 2015, Pages 690–702.

Infrastructure

Roads

Road network data are relevant to REDD+, especially as key input into the analysis of drivers of deforestation and forest degradation. Roads correlate strongly with the exploitation and degradation of forest resources, acting as both an enabling mechanism that increases accessibility to markets and urban centers, and an indicator of land use conversion from forest to infrastructure when new roads are built. A comprehensive road network data set is necessary allows for more informed land use change modelling. With that in mind, the more detailed and comprehensive the road network data set is the better. Such a data set should include multiple tiers and attributes (i.e., major, minor, tracks, paved, and unpaved).

A considerable amount of information exists on roads that would be of great use for modeling potential rates of deforestation and forest degradation as well as accessibility to natural resources. Attribute data for roads should include the general road quality, speed limits, year of build as well as road upgrades and future development plans, amongst others. Metadata and the methodology behind the road layer creation are also not clear for all datasets. It is recommended that all road data layers and attribute information be combined to create a complete road data layer and any outstanding information be derived from stakeholder expertise and community mapping activities with the inclusion of digitized roads that are planned in future infrastructure development plans. Cleaning and processing of the data would also include standardizing the attribute data and particular effort should be undertaken, perhaps drawing on voluntary work in community mapping exercises, to agree and attribute names of all roads, where this information is missing. Additionally, roads can be derived from high resolution optical data that can be used to fill in any remaining data gaps. Better road data would increase the accuracy of the buffer layers used in the 3C model to describe the areas at different proximities from the road network.

Settlements

The data available on village areas and urban centers is quite comprehensive and covered under many studies, particularly through community mapping exercises. Data from the Metria & GeoVille land cover map can also be used as it identifies area and extent of settlement areas, but does not provide an attribute data to them. These data need to be updated regularly because village populations and boundary changes will impact their respective attribute data (e.g. weighting of each variable in a LULC model). The expansion of village and urban areas is an important indicator of current and future potential resource demands based on population growth. It would

be suggested that activities of monitoring and digitizing of these areas should be carried out, providing information on the rate and direction of expansion.

Socio-Economic Data

The main population data source for Liberia comes from a 2008 household census. These data are available in the data repository as a map layer with population organized on a Clan boundary level, which are nested within County level sets, the dataset provides total population, gender (total males and total females) and another of other social attribute data.

Although there are a number of comprehensive data sets collected for socio-economic data, there are also a number of projects, ranging in scale, that have collected household survey and socio-economic data and that are extensive, covering a wide range of aspects and approaches. A good number of these projects have geospatially allocated information but have been conducted using pen- and paper-based approaches, without being digitized or being made widely available. As the work carried out focuses modelling at a national scale, these smaller scale projects were not used for this work as it would skewer the accuracies for each region. A modified version of the census data was use, predicting population values for 2015.

Next steps for this would be to look to digitize as much of this geospatially attributed information as is possible to make the data and its analysis more assessable digitally. A number of the socio-economic data layers available need to be updated, particularly for basic information such as population and their location, as this information can convey areas highest risk of deforestation and degradation (through identifying areas of highest resource needs, with the latest data identified for 2008 and out of date).

Agriculture

Global Forest Watch⁴² data were used to collect the "Oil palm concession" data, which refers to an area allocated by a government or other body for industrial-scale oil palm plantations. These data may come from government agencies, NGOs, or other organizations and, because of these multiple sources, there are many anomalies in the available spatial records of land allocated for development as oil palm concessions. This includes concession areas containing multiple areas overlapping with areas already flagged for use as Timber Sale Contract, Protected Areas or other uses. These uncertainties cannot be effectively investigated within the scope of this report. However, we assumed that, given serious anomalies, these 25 sites may

⁴² <http://www.globalforestwatch.org/> Accessed- February 2016.

potentially be – or have a strong likelihood of being – assigned for use as oil palm plantations in the future.